AN INVESTIGATION ON LEAN GREEN MANUFACTURING STRATEGIES IN INDIAN TRACTOR INDUSTRY

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Mechanical Engineering

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LOVELY PROFESSIONAL UNIVERSITY, PUNJAB
2024

DECLARATION

I, hereby declared that the presented work in the thesis entitled "An Investigation on lean Green manufacturing Strategies in Indian tractor industry" in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of Dr. Mahipal, Associate Professor, in the School of Mechanical Engineering of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of another investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled " An Investigation on lean Green manufacturing Strategies in Indian tractor industry" submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the school of Mechanical Engineering , is a research work carried out by Arun Arora, Registration No. 41900379 , is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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ABSTRACT

In today's era of intense competition globally, the primary objectives for an organization are to be successful in obtaining huge profit, remain competitive and increase market share. Further, strict environmental regulations have put additionally pressure to focus on operational excellence with environmental measures. Therefore, organizations must explore creative and innovative cost-effective methods and practices to meet the market demand on-time along with meeting environmental norms. Lean Green (LG) manufacturing strategies is one of the comprehensive approaches, that reduces wastes and variations in the operational system and simultaneously decreases the adverse impacts of environment. Therefore, for achieving primary goals, it is imperative for an organization to execute LG approach in their manufacturing processes. To execute LG approach, it is essential to look at critical success factors that consequently lead to attainment of this strategic approach. For an economic development of country and to achieve $ 5 trillion economy by 2025, Govt of India is focusing on agricultural sectors by enhancing productivity and efficiency of this sector. Apart from lucrative policies and scheme to enhance the liveliness of farmers community, there is need to provide ready-made farming solutions and featured technology to farmers which are cost effective and environmentally friendly by industry. So, the purpose of current study is to check the efficacy of LG approach in Tractor Manufacturing Industry. The LG approach is likely to get unsuccessful, if not focused on success factors and barriers at the initial stage of its execution. In this study, 26 Lean Green Success Factors (LGSFs) are identified through literature reviews and input from industrial and academic experts. Moreover, 22 LGSFs were screened through statistically and validated them via reliability test. The outcome of reliability test reveals that the Cronbach's alpha value of 0.802, which indicates good consistency. The standard error of mean was computed, resulted 2.6 %, Which further affirms good consistency and reliability. The finalized LGSFs were modelled and categorized using ISM and MICMAC approach, validated through SEM model for model fit. On the other side, 19 Lean Green Barriers (LGBs) were extracted through the inputs from experts and extensive literature reviews. The identified barriers were screened through statistical analysis and found that out of 19, only 15 LGBs are significant with Cronbach's alpha value of 0.810. Apart from this, 11 Lean Green Sustainable Parameters (LGSPs) were identified and statistical analysis were conducted for screening the parameters. Out of 11, only 9 were significant with Cronbach's alpha 0. 804. The standard error of mean was computed, resulted 3.1 % for barriers and 2.97% for sustainable parameters, which shows good consistency and reliability. Finally, weights of each sustainable parameter were calculated using Analytical Hierarchy Process (AHP) and further using weights, outranking of LGBs was done using Elimination and Choice Expressing Reality (ELECTRE) approach to enable management to take appropriate actions. The result reveals that 'Inadequacy of practiced manpower', is identified the most significant LGB. For an execution of LG approach at first level successfully, skilled manpower is required. Subsequently, organizations managers need to focus on next LGBs with clear mind-set according to their ranking obtained during study.

Further, a 5 phased integrated LG frame work was developed, which consists of clear road map for LG execution. This framework systematically guides for successfully executions of LG projects. The step-by-step framework augmented with LG tools that enable and encourage the industrial managers to implement this sustainable approach in their industry. The developed frame work was tested in Tractor industry in India through a case study. After successful completion of case study, the significant improvement was observed in KPIs, such as TAKT Time (TT), Lead Time (LT), water consumption, power consumption etc. The results of case study revealed that TT, LT and the unnecessary movement of man and material was reduced by 11.20 %, 45.75%, and 63%, respectively. Other side, in context of environmental and social scenario, the water consumption, power consumption and ecological impact reduced by 21%, 19.76%, and 66%, respectively. Overall, the net production/day is increased by 5.26% with respect to gross output along with tangible benefits of $64320. The effective execution of the LG framework facilitates many non-tangible benefits, such as cultural change, increase in employee's participation, positive outlook in employee's behavior and attitude, customer delight, etc. in the selected case plant. The current study will enable the organizations to have preparedness for the execution of a sustainable LG approach by a comprehensive understanding of Success Factors, Barriers, Integration and framework of LG including societal aspects. The existing study also furnishes a guiding reference for professionals and academicians to take forward similar improvement projects and identified opportunities to enlarge this research on integrated LG methodology into other industrial sectors.

ACKNOWLEDGEMENT

First and foremost, I am thankful to almighty for making things possible at the right time. I owe my success to my supervisor, co-supervisors and would like to sincerely thank to Dr. Mahipal Singh, Dr. Jai Inder Preet Singh and Dr. Vijay Kumar Singh for their guidance. I greatly appreciate their support, positive attitude, and his vast knowledge in a wide range of topics. Their guidance not only in terms of giving ideas and solving research problems, but also in terms of giving freedom to do research in my own ways has proved to be useful and invaluable. I am deeply influenced by my supervisor's and co-supervisor's way of guidance and sincerely thankful for standing by my side in tough times.

I would like to thank my wife Mrs. Vandana Arora, for her unconditional love, support and encouragement. I am grateful to my friends and researchers, particularly Dr. Hitesh Vasudev for his suggestions and extended support.

I would like to show my gratitude to the entire family of Lovely Professional University, Mittal School of Management, School of Mechanical Engineering and ABC Tractor Company, India for providing me a suitable research atmosphere to carry out my work in proper tie under the guidance of Mr. Kishor Naik. I am very much grateful to my loving mother-in law, father-in-law, my daughter Miss Muskaan Arora and my son Mr. Varun Arora for their moral support and care that they exhibited towards me during the period of this work.

Finally, I thank God for sailing me through all the rough and tough times during this research work.

Date: August 29, 2024 Arun Arora

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Abbreviations	Descriptions
AVE	Average Value Extracted
AHP	Analytical Hierarchy Process
ANNs	Artificial Neural Networks
AMOS	Analysis of Moment Structures
ANP	Analytic Network Process
ANOVA	Analysis of Variance
ANFIS	Adaptive Network-Based Fuzzy Inference System
AI	Artificial Intelligence
ABC	Activity Based Costing
BRT	Behavioral Reasoning Theory
BWM	Best Worst Method
BCT	Block Chain Technology
BOM	Bill of Materials
CSR	Corporate Social Responsibility
CA	Content Analysis
CFA	Confirmatory Factor Analysis
CR	Consistency Ratio
CSFs	Critical Success Factors
CFs	Critical Factors
CM	Cellular Manufacturing
CS	Circular Sustainability
CIPs	Continuous Improvement Projects
CC	Crank Case
CIs	Continuous Improvements
CI	Consistency Index
CFA	Confirmatory Factor Analysis
CR	Composite Reliability
C&E	Cause and Effect

CII	Corelative Importance Index
CH	Cylinder Head
CFT	Cross Functional Team
CIMTC	Corrected Item-Minus Total Correlation
D-f-E	Design of Environment
DOE	Design of Experiments
DOF	Degree of Freedom
DM WATER	Demineralized Water
DEA	Data Envelopment Analysis
DEMATEL	Decision Making Trial and Evaluation Laboratory
ECM	Environmental Conscious Manufacturing
EVSM	Environmental Value Stream Mapping
ELECTRE	Elimination and Choice Translating Reality
EFA	Exploratory Factor Analysis
EMS	Environmental Management System
GDP	Gross Domestic Product
GHG	Green House Gases
GRA	Grey Rational Analysis
GM	Green Manufacturing
GMM	Geometric Mean Methods
GLPs	Green Lean Practices
GMS	Green Manufacturing System
GFI	Goodness of Fit Index
GMT	Green Manufacturing Technology
HRM	Human Resource Management
HW	Hot Water
ISM	Interpretive Structural Modelling
ISO	International Organization for Standardization
IPR	Interpretive Ranking Process
JIT	Just-in-Time
KPIs	Key Performance Indicators
KRAs	Key Result Areas
KOPs	Key output Parameters
kWh	Kilo watt hour

KSFs	Key Success Factors
LGSFs	Lean Green Success Factors
LGBs	Lean Green Barriers
LPD	Lean Product Development
LM	Lean Manufacturing
LGCVSM	Lean Green Current state of Value Stream Mapping
LIBs	Lean Implementation Barriers
LGFVSM	Lean Green Future state of Value Stream Mapping
LPI	Lean Production Implementation
LG	Lean Green
LF	Lean Green Success Factors
LGSPs	Lean Green Sustainable Parameters
LMPs	Lean Manufacturing Practices
LCA	Life Cycle Assessement
LGVSM	Lean Green Value Steam Mapping
MSMEs	Micro, Small and Medium Enterprises
MCB	Miniature Circuits Breaker
MAXQDA	Max Qualitative Data Analysis
MICMAC	Cross-Impact Matrix Multiplication Applied to Classification
MCDM	Multi Criteria Decision Making
MIP	Mix Integer Programming
MLE	Maximum Likelihood Estimates
NVA	Non-Value Added
NFI	Normed Fit Index
NA	Not Applicable
PSS	Product-Service Systems
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PFMEA	Process Failure Mode and Effect Analysis
PDI	Pre delivery Inspection
PT	Pre-Treatment
PFD	Process Flow Diagram
PM	Particulate Matter

PH	Potential of Hydrogen
PCA	Principal Component Analysis
QC	Quality Control
QMS	Quality Management System
RF	Reason For
RA	Reason Against
RPH	Repair per hundred
RM	Research Methodology
RI	Random Index
RMSEA	Root Mean Square Error of Approximation
SCM	Supply Chain Management
SLR	Systematic Literature Review
SLM	Sustainable Lean Manufacturing
SCPC	Supply Chain and Production Control
SMED	Single-Minute Exchange of die
SMEs	Small and Medium Enterprises
SAP-LAP	Situation-Actor-Process and Learning-Action-Performance
SOP	Standard Operating Procedure
SFs	Success Factors
SPS	Sustainable Production System
SD	Standard Deviation
SSIG	Systemic Self-Interlinkage Grid
SPs	Sustainable Parameters
SEM	Structural Equation Modelling
SIPOC	Supplier Input Process Output Customer
SHE	Safety Health & Environment
SEM	Structural Equation Modelling
TBL	Tripple Bottom Line
TPS	Toyota Production System
TA	Total Acids
TOC	Theory of Constraints
TQM	Total Quality Maintenance
TLI	Tucker- Lewis Index

TREM	Tractor Emission Norms
TOPSIS	Technique for Order Performance by Similarity to Ideal Solution
TTR	Total Thickness Range
TT	TAKT Time
VSM	Value Stream Mapping
VAR	Value Added Ratio
VAT	Value Added Time
VOB	Voice of Business
VOC	Voice of Customer
VTU	Vehicle Testing Unit
WIP	Work in process
3D	Three Dimensional
5'R	Refuse, Reduce, Reuse, Repurpose and Recycle
3'R	Reduce Reuse Recycle

CHAPTER-1
INTRODUCTION

1.1 Pre-Text

The development of any country mostly relies on the up-gradation in functional and advancement of cutting-edge technology of manufacturing operational areas [1-2]. The manufacturing operational sectors' progress is straight way or consequentially linked with the transformation of farming, scientific and technological knowledge, modernization, employability, high-quality of life, changes in social and economic adaptation [3]. The above-mentioned area will prosper, if the manufacturing operational sectors acquire and exhibit more productive, creative and innovative for an improvement and growth, with efficiently and effectively [4]. Apart from, high quality of life of people and their prosperous positions will also get improved with the growth of manufacturing operational sectors [5]. The efficacy and quality standard of manufacturing operational sectors can be enhanced, if manufacturing units increases current utilization or adopt advance tools, procedures and methodology in their main business, but such transformation directly increases cost per unit [6]. To enhance productivity and gain high quality standards with lowest per unit cost, an alternative way to utilize the available resources in optimum way or reduce the operational waste in manufacturing unit [7]. Besides, it becomes known that median temperature of earth surface has increased in past century by 0.85 °C [8]. The magnitude of increase in temperature on earth surface could be recognized as, to change in style of living, economic progression and the industrial transformation. The dispersion of non-renewable fuel material by manufacturing operational organizations has evolved as rise in the magnitude of carbon footprints, which leads to an adverse impact on an environment [9-10]. Manufacturing organizations consume natural available resources in un-controlled way and dispense a significant amount of contamination into surroundings and ambience [11]. In addition, manufacturing organizations are not following appropriate waste disposing system and procedure, which again accounted for the degradation of environment [12]. As a result, an increase in carbon emission and other associated contamination have caused acute health concerns amongst the human being [13]. This has been revealed from previous research work associated to manufacturing operations, is only confined to the ecological and business-oriented aspects of being sustained, but neglected societal aspects [14]. This way of thinking is only to gain temporary benefits for short period of time and fix continued advantages for being sustainable. So, there is need to focus on healthy working environment, best business and employment practices, and incorporation of social perspectives in manufacturing practices. Further, the pressure for being sustainably focused, cutting-edge competition world-wide, changing and stringent government policies and regulations on environment protection, have compelled manufacturing organizations to adopt sustainability in reality [15]. Thereby, current research work presents a novel approach for sustainable growth called, Lean Green (LG) manufacturing strategies. The present research study provides different calculations, characteristics, framework of LG strategies, and validates the effectiveness of LG framework practically in manufacturing set-up for an improvement in all facet of Integrated Lean and Green with increased resource utilization.

1.2 Challenges to Manufacturing: From the Perspective of India

Manufacturing organizations are the key architect for an economic development of any country [16]. This sector performs a remarkable endeavour to create an employability, reduces variabilities in distribution of wealth that further lead to economic development of nation [17]. The literature study discovers the fact that if Gross Domestic Product (GDP) growth enhances by 1%, a reduction in poverty level has been noticed by 0.8%, whereas, in county like India, 1% enhancement in GDP has delivered only very amount of reduction in poverty by only 0.3% [2]. Therefore, it is vitally important to explore creative solutions that accelerate operational progression of the manufacturing organisations.

Manufacturing is gradually developing and evolving itself as one of the highest growing sectors in India. Government of India had launched “Make in India” program to develop country as manufacturing hub for glowing and shining India on world map and crown with global recognition to Indian economy. India is gradually transforming as one of the major Automotive and Farm Equipment manufacturing hub in the world and many of world–class organizations are looking for settling their business growth in India.

At present, Indian manufacturing growth at 17% contribution in GDP, and Govt. of India has set a target of manufacturing sector contribution to 25 % by 2025 [18]. Apart from this, Govt of India is putting extensive focus on agriculture growth in country. Various initiatives have been launched including subsidy on Farm agriculture equipment by Govt. of India for enhancing the life of farmers and shaping the growth of an agriculture for an achievement of India's GDP by $5 trillion by 2025[19].

Today's era of manufacturing is demanded by customized products & services. For fulfilling the demand of customized products and services, mass production of products in today's complex environment has become more challenging. Due to global market competition, retaining and attracting new customer has become much challenging task for industries. Need is felt before the organization to explore new tools and methods to move up the ladder in changed market scenario and overcome big challenge to stay in competition and long- term survival [20].

During the first decade of 21st century, in 2016, India GDP growth was noticed with a growth rate of 8.26%. With the recession world-wide, poor economic and social condition of our farmers, uncertainty in monsoon and jumping of pandemic COVID situation, Indian economy has jumped down to 4.04 % in 2019 [21]. Also, there is need to design product, which should have inbuilt eco- friendly attributes till use by customer [22]. Current scenario is pressing the finger to reduce cost and exhibit quick response towards customer [23].

Due to intense competition globally, Indian Farm Equipment manufacturing organizations (Tractors) are also facing tremendous pressure to produce world class technological quality product. Additionally, have to provide Agri-mechanization farming solutions to farmers with minimum cost for attracting & retaining customers to increase in market share and gain competitive edge over competitors [24]. Government Policies like various loan schemes, low interest rate plans, credit card facilities, minimum support price rates, collaborative farming, and advanced technological mechanization have been instrumenting the growth of farming sector [25]. These policies are favourable, but credit availability and monsoon dependence are the biggest challenges being faced by farm equipment sector. Present status of farm equipment industries owes some support from Government of India, but there is need to step back, understanding the vast opportunities available that requires to untapped by Tractor Manufacturing Industries. Therefore, need is to focus on their manufacturing value chain to support Government policies in order to enhance the productivity of Farm industries without neglecting existing boundaries.

Further, the growth of Industrial production has accompanied by increasing pressure on environment [26]. India's rapid economic and industrial growth, has come at the high cost of increasing GHG emissions, rising demand for scarce resources like water and increasing waste generation, particularly from urban centres. Today, India is the fourth largest economy in PPP terms and the fifth largest GHG emitter in the world [27]. During the 18 years period between 1990 and 2008, India's CO2 emissions increased more than 150%, placing it just behind China [28]. According to CII-BCG report, India generates close to 4 million tons of hazardous waste from industrial and biomedical sources [29]. Apart from hazardous industrial waste and effluents which cause water and land pollution, e-waste is also becoming a major area of concern for India [30]. Estimates suggest that only 5% of e-waste goes for recycling process, remaining either goes into landfills or being processed at informal recycling yards [31]. The study suggests that to overcome these challenges, or to minimize these adverse impacts, the Indian manufacturing sector will need to take synergetic actions on all three areas, (i) Green energy (ii) Green products and (iii) Green processes in business operations [32].

Apart from this, Tractor Manufacturing Industries are facing challenges to stringent Government regulations on environmental footprints, demands of product which are sustainable, and associated societal attributes [33]. This sector is facing challenges in all facet of sustainability in terms of operational waste and improper utilization of available resource as growth of any country depends upon the optimum utilization of available resources, effectively and efficiently [34]. Table 1.1, manifest the challenges to Indian Tractor Manufacturing Industry in all facet of sustainability [35].

Table 1.1— Challenges to Indian Tractor Manufacturing Industry

S.No.	Ecological	Economical	Societal
1.	Climate change	Small and marginal farmers	Old aged workmen
2.	Decreasing ground water level	Fragmented lands holdings	Scarcity of skilled workforce
3.	Soil degradation	Inadequate finance	Religion
4.	Deforestation	Lack of testing facilities	Social organization
5.	Bio-Diversity loss	Technological advancement	Food choices

As Lean is only capable of reducing waste but not figure out environmental effects [36]. Therefore, the adoption of Lean Green Manufacturing strategies could be the alternative to said issues in Tractor Manufacturing Industry as Lean provided good gains in conventional manufacturing sector [37]. Thus, present study attempts an investigation of Integrated Lean-Green (LG) manufacturing strategies in Indian Tractor Industry by using Lean principles, tools and techniques [38-39], along with Green Manufacturing Processes in business operations by refusing, reducing, recycling and using Lean Green Value Stream Mapping (LGVSM). LG manufacturing strategies is sustainable development methodology that put forward to increase productivity and bottom line profitability through reductio of wastes, defects and environmental foot prints [40].

Further, Corporate Social Responsibility (CSR), along with the Triple Bottom Line (TBL), is a business strategy commonly adapted from the three pillars of sustainable development (i.e. Economic Social, Environmental), Figure1.1[41].While organizations have always taken economic concerns into priority for performance management, but the current environmental crisis has acted as an impetus to link them to more comprehensive sustainability goals [42].

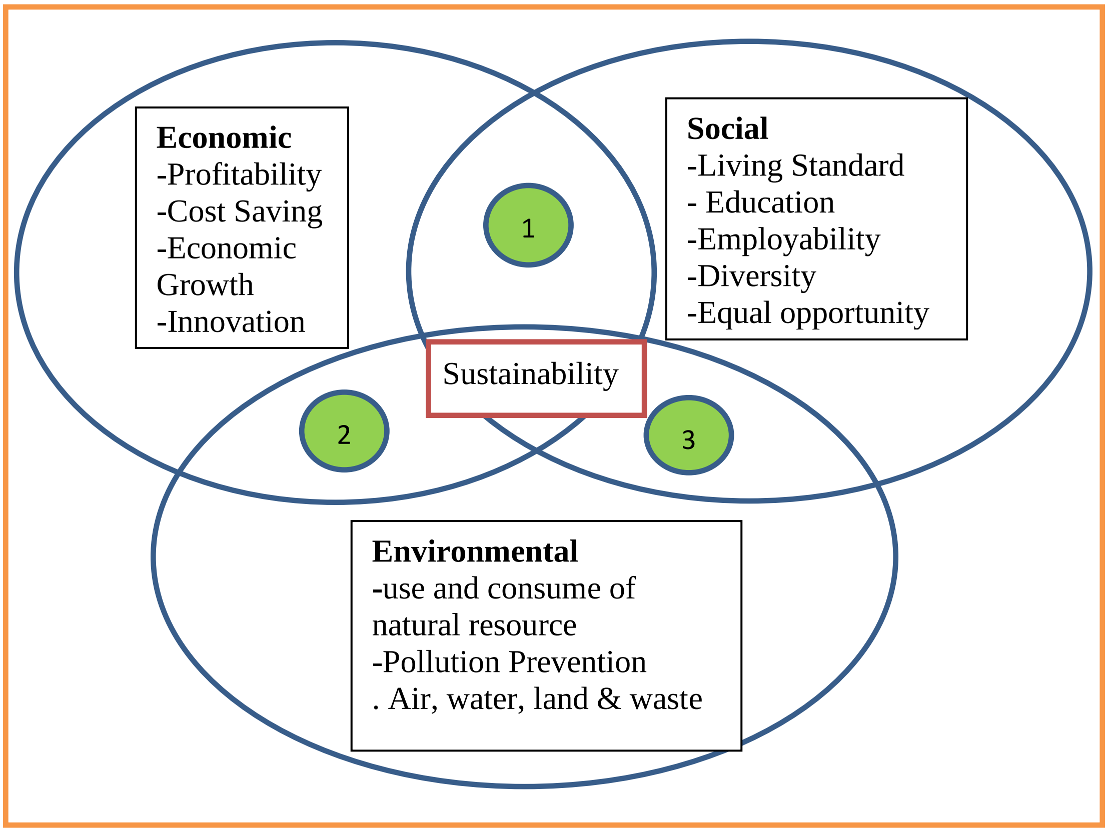


Figure 1.1— Pillars of Sustainability Performance

The present research has been conducted using “LG strategies". The study aims to highlight Industry Best practices related to Lean manufacturing and Sustainable development. Linking Industrial performance to sustainability goals leads to promote eco-efficiency strategies and the relationship between Lean manufacturing and Green concerns appears to be in tangible way [43]. Therefore, it is of growing interest to both academics and industrialists.

Common things amongst each cross section of pillar circle shown in Table 1.1 are designated as serial number 1, 2 and 3, details of which are manifested in Table 1.2 [44].

Table 1.2— Common Things amongst Pillars of Sustainability

S.No.	Economic–Social	Environmental-Economic	Social-Environment
1.	- Fair business - Business Ethics - Rights of workers	---	---
2.	---	- Energy Efficiency - Incentive for the use of natural resources	---
3.	---	---	- Environmental Justice - Natural resource Management locally and globally

1.3 Lean Manufacturing Strategies

After the world war second, Toyota introduced ‘Lean concept’ in Japan after realizing that they were not in position to do heavy investment to reinstate their damaged buildings and facilities [31]. Initially, it was known as Toyota Production System (TPS) and later, it was termed as Lean production in 1990 [45]. The term ‘Lean was coined by Krafcik and Womack, Jones, and Roos used the term ‘Lean production’ in their book ‘The Machine That Changed the World’ which has conceived as widely accepted [46]. The modern concept of Lean paradigm discovered through the Toyota Production System (TPS) in automotive industry, pioneered by Japanese engineers Taiichi Ohno and Shigeo Shingo [47]. Lean Manufacturing is an approach of waste reduction that intensifies the product value by waste minimization [48]. Lean manufacturing is a productive and well accepted effective tool in most of manufacturing operations and service sector to deal with non-valued activities and wastes in processes [36].Any kind of wastage in the process, in the practical sense the process that doesn’t add-up any value to the final product, require to be scaled down or if feasible, eliminated to minimize operational cost [49]. Lean philosophy describes value of the product and services as perceived by end user [50]. The main essence behind Lean technique is to refine the prevailing manufacturing processes and practices by minimizing waste, thereby reduction in cost, improvement in quality standards, gaining profit and increase the value of customer [51]. Concept of Lean has helped automobile industries to reduce their manufacturing conversion cost by reducing waste in their value chain [52]. Lean manufacturing provides a competitive edge to organisation by enhancing productivity and quality with reducing cost [53]. A repeated and common challenge before the operational industries is to identify the operational waste (Muda), which in-fact require skill set from management to recognize. Eliminating production waste as manifested in Table 1.3, imparts various benefits such as lead time reduction, cycle time and Takt time reduction, performance improvement, reduction in inventory and associated risk, increase customer delight, quality enhancement, as well as increase bottom line profitability, etc [54]. The concept of Lean has been framed on five fundamental principles such as (1) value, (2) value streams, (3) flow, (4) pull and (5) perfection, which is manifested in Table 1.4 [55].

Table 1.3— 8 types of Lean Operational Waste with Description

Types of waste	Description
Transportation	Movements of materials and parts unnecessarily, it may cause damage to product, deployment of extra manpower to manage transportation. Main reason may be poor designed layout
Inventory	Keeping excess material in stock, which add cost and lead time. It is a necessary evil in any operations. High inventory results in blocking up the flow of cash.
Motion	Operations' Non-value-added movement that lowers worker's efficiency. Excess movement might result from inadequacy of standard operating procedures, poor layout design etc.
Waiting time	An operational idle time faced by employees or machine during the manufacturing process due of lack of information and resources.
Over- Production	Producing in excess quantity against the asking demand rate. It is well-considered as prime waste and will spark the other 7 wastages.

Over- Processing	Performing un-essential activities during the course of work that do not add value in the process or product
Defects	This waste related to cost of poor quality due to rework, rejection and re-inspection, it's also producing the product at specification which is not demanded by customer.
Human Knowledge	Waste due to under-utilization of human's knowledge and skills

Table 1.4— Fundamental Lean Principles with Description

S.No.	Lean Principles	Description
1.	Define Value	It refers to the value perceived by the customer. Customer can only define the need and eagerness to buy product, which is valuable to them.
2.	Identify Value stream	The sequence of measures taken by company to device value to end-user by analysing the process for identifying value added and non-value-added activities.
3.	Smooth Flow	This refers to movement of product from one station to another continually in value chain, till it reaches smoothly to end-user. For achieving smooth flow, identification and elimination of non-value-added activities in value stream is essential.
4.	Designing pull-based manufacturing operations	It refers to produce product based upon customer demand for it. Scheduling of production based upon the receipt of order from customer, and internally, up-stream stations demands from down-stream station for production.
5	Perfection	It refers to continually improving the process, as there is no finish line for perfection.

So, Lean Principles creates the work-flow based upon the pull from the customer to achieve perfection by continual improvement to reduce and minimize waste and eliminating Non-Value-Added activities (NVA). Wastes elimination in entire value chain in manufacturing process is obtained by the successful execution of Lean manufacturing tools and techniques, manifested in Table 1.5. It has been observed in literature, single perspective of Lean element was given most weightage in many studies, more than one perspective of Lean elements was taken into consideration by only very few studies [56]. Therefore, for comprehensive execution of Lean, the organization has to give attention on all perspective such as, value stream mapping (VSM), cellular manufacturing (CM), U-shaped layout etc. [57].

Table 1.5— Distinguished Tool of Lean Manufacturing

Lean Tools	Description	Reference
5'S	It refers to keep the things at right place, well preserved and accessible at the time of need, thereby helping to organize working space and eliminate waste due to poor organization.	[58]
Kaizen	It refers to continual improvement strategic approach by combined efforts of all the personnel in the organization for improvement in their functional processes.	[59]
Gemba	It refers to actually going at a place where processes are going to happen in order to understand the Process flow effectively and efficiently.	[60]
VSM	For recognizing and removing non-value-added activities in entire process flow, Value stream mapping is a practical visualization approach to map the flow of entire process, inclusive flow of material and information.	[61]
Poke- Yoke	It refers to designing a mechanism in the production process for detection and prevention of mistakes with an aim to achieve no fault forward and attain zero defect in process flow.	[62]
Just- in Time	It refers to the strategy of pull system, where products are produced as per demand, thereby reduces waste of inventory, wating time and defect in process flow	[63]
Work Standardization	It refers of standardized the best solution implemented by proper documentation with unique number for future reference.	[64]

Continuous flow	It refers to eliminating the obstacles, delays and bottlenecks in process for initiating smooth work flow	[65]
Kanban	It refers to pull strategic approach, that use indication for in each manufacturing process for regulating the flow in entire value chain in the organization.	[66]

1.4 Green Manufacturing Strategies

Climate change and climate crises has provoked the concern before community across the world, where society and governments agencies are paying more concentration in focussed way by adopting policies and regulations for environment protection [67]. The improvement of Lean for achieving operational parameters of performance in the manufacturing operational organizations has exhibited inadequacy of close attention for performance related environment [68]. Green Manufacturing is comprehensively well-known as sustainable manufacturing, which have connection with the strategy of a business organisation, that aims on profitability through operational processes, which are eco-friendly and sustainable [69-70]. In the early 1990s, the concept of Green Manufacturing was predominately pioneered with the advancement of Green-Innovation and revolution [71]. The Green Innovation is well-known as Operational Systematic Methodology, which is pioneering to the manufacturing industry, that mitigates environmental risk and other adverse effect related to consumed resources [72].

Green Manufacturing is appraised as integrated approach to drive environmental and economical strategies to reduce and keep waste at minimum level in value-stream by design of process, products and materials consumption [73]. Green Manufacturing methodology supports to gain better economy significantly without striking a balancing act relating to environment [74]. All operational and functional activities that helps to minimize waste, termed as Green Productivity and it impacts on overall performance of manufacturing operations [75]. Green Manufacturing aims on a feedback-controlled operation by adopting re-cycling and re-covering exercises to reduce wastages, obtaining the product's residual value, while implementing Green-technologies and Pollution prevention by optimizing logistics [76]. Green Manufacturing can source of growth in economic, ecological, and societal performances by reducing waste and cost in processes [77]. An organization, which take up on sustainable-management and sustainable-innovation are capable to increase performance related to environment, while fulfilling the customer demand, thereby creating the image of organization in the society [78]. The adaptation of Green-Energy in manufacturing as an essential ingredient for Industries, that will likely to enhance the demand of manufacturing [79].Green manufacturing is one that edge on controlling an ecological and societal concerns by use of techniques like as reverse logistic [80] and SCM (Supply chain Management) [81], LCA (life cycle assessment) [82], and Sustainable VSM (value stream mapping) [83].

Green-Technology is considerate common run-over of manufacturing as it minimizes wastages and reduces impacts on environment [84]. Green manufacturing looks through with less pollution and waste reduction after products' life cycle [85]. These can be obtained by re-cycling, reducing, re-using, and re-placing parts [86]. Many approaches have considered to provide a green environment of Controlling, Preventing, Product Preserving, Protecting and LCA technique [82], is distinguished as best suitable approach for evaluating 'consequence on the environment. To accomplish green results, the conventional model of production and consumption must be replaced, where products are well-used and ultimately discarded [87]. This conservative approach has popped up green crises in various ways, like de-gradation of environment and resources inadequacy. A paradigm shift from non-resumption materials to regeneratable material for encouraging a blue economy for resource recovery is essential for every manufacturing system to resolve challenges related to environment and economic [88]. Green manufacturing encompasses strategies such as, Green-Supply-Chain, Sustainable design, Green construction, Re-cycling stations, Waste-water treatment [89]. In addition, Green wastes concept can be helpful for both environmental and financial evaluations [90]. There are seven green wastes, which can be seen in Table 1.6 [91].

Table 1.6— Seven Types of Green Waste

Green Waste	Description
Energy uses	Over-consumption and misuse of power emanating from lightening, power-motor running, heating etc.
Water consumption	Over-consumption of water by using than actually needed and also not treated, is the system's green waste.
Material consumption	Non-degradable or rejected material accounts to waste, treated as dump, which cause pollution as green waste.

Material movement	Non-essential movement of material, things and human constitutes green waste.
Emissions	Irrelevant discharge of harmful gases and pollutant in the surrounding causes adverse impact on environment.
Waste Material	The item that has been produced caused adverse impact on environment, again have to pay extra for disposal, contribute to ecological interrogation.
Biological-diversity	Discarding of wasteful items, that is challenging to bio-eco-system

1.4.1 Green Manufacturing- Principles and Tools

In an endeavour to create a healthy and safe working environment and related performance in manufacturing operations, need of an hour to design appropriate approach for realization the benefits of Green Manufacturing. Twelve Principles of Green Manufacturing engineering as the ground rules for design of process [92]. The literature affirms, assessment of energy and material for both input and out-put should be harmless fundamentally including lifecycle of product, afterwards proposed an easier and clear composition that consists of five principles of Green Manufacturing, tabulated in Table 1.7 [93]. The prime objective of principles to signify and manifest a strong attention on power and environmental issues, can be thought of reflection in Green manufacturing approach. In the manufacturing context, the structure of Green manufacturing concentrate on management of resources, production and planning control, assembly operations, storage and packaging [94]. In a design of Green manufacturing approach, use and consumption of Green energy, and cutting–edge technology that can enhance environmental performance should be given more weightage [94]. Therefore, the tool, Design of Environment (D-f-E) is initiated to incorporate green elements into design of process. Normally, D-f-E recognizes and establishes product and process which come out from the environmental effect of all through product's lifecycle [95]. Another important tool, the Lifecycle Assessment (LCA) of a product is essentially of prime importance at early design stage of development [96]. LCA assesses the promising ecological impact all-through the life-cycle of a product starting form extracting raw material, conversion into production, usage of product, and disposal at the end [97]. The association amongst LCA and DfE is intimately linked to minimizing the ecological waste. Apart from this, energy and water consumption play a significance contribution in Green manufacturing strategic approach [98]. Therefore, to develop a comprehensive Green technology system, it is essential to develop a green manufacturing procedure that leads to enhance capacity utilization, reduce waste and carbon footprints.

Table 1.7— Simplified Five Principles of Green Manufacturing Strategies

Principle	Definition
1.	An all-inclusive systematic approach should be exercised to assess and creating robustness in manufacturing operational process considering the outlook in green context
2.	The systematic approach must be absolutely looked covering both the vertical (system's different magnitude of information from the company assigned to the process level) and horizontal (the systems at the identical magnitude of information).
3.	Toxic and dangerous intake and outcome of the operational system to the surroundings and human- being must be minimized or eliminated
4.	Overall utilization of resources must be depreciated.
5.	Ecological effect must be given consideration in the stage of design to recognize superior accessibility to look for a substitute in minimizing the future impact.

1.5 Integration of LG Manufacturing Strategies

Lean manufacturing strategy is a systematic approach of continual improvement in up and down value stream of operational activities [99]. Lean concept focus on removal of all kinds of wastes from operational activities and supply-chains function to enhance quality standards, reduction of manufacturing conversion cost and value addition for end-user [100]. Green manufacturing strategy is a concept, that concentrate on the effect of manufacturing operations on the environment. It focusses attention on the removal of ecological wastes related to water consumption, energy consumption, air usages, solid and hazardous waste material etc., [101]. As, both concepts likely to have specific resemblance with in their approaches like, reduction of waste, continual improvement, efficiency and performance orientation, concentrate on eco-friendly production. The existing research work have attempted to apply synergy amongst both strategies. It is to understand that the 5 prime lean principles may lead to an improvement of ecological performances by minimizing unnecessary wastes in operational activities [102]. Lean-Green as concept signifies a model having attributes of synergy for operational excellence [103]. Lean manufacturing strategies performs as a driving force for Green development of manufacturing strategy [104]. An endeavour to integrate both models has grown recently due to extreme pressure from Green promotors and the normal strive of manufacturing organisations to run their business in a limited resource environment [105]. Synergy of Lean-Green waste has been tabulated in Table 1.8 [90].

Table 1.8— Synergy of Lean-Green Manufacturing Waste

Types of lean waste	Outcome	Type of Green waste
Transportation	Motion loss due to excessive movements	Excess consumption of material and energy
Inventory	Rejection and storage of material	Excess consumption of material and energy
Motion	Loss of time	Wasteful material
Waiting time	Loss of time	Energy consumption
Over-production	Rejection, operation time loss and use of additional space	Excess consumption of material and energy
Over-Processing	Loss of operational time	Energy consumption
Defects	Rejection and operation time loss	Energy and wasteful material

The fundamental principles direct the synergy of Lean and Green manufacturing practices are reduction of waste, process-oriented focussed approach, and involvement of all employees in the organization [106]. The acceptance of lean manufacturing strategies can lead to enhancement of the green manufacturing strategies in the organization [107]. Therefore, fundamentally both Lean manufacturing and Geen manufacturing strategies can be used to gain comprehensive benefits [36]. So, an organisation can prioritize the identified Lean cum Green approach by executing strategies related to environment. These strategies may support, as become more effective and efficient for waste reduction [108].

In spite of similarities and synergy between Lean and Green, literature also highlighted the dissimilarity between these two strategies in the definition of waste, as

Lean strategies are concentrated on manpower and space reduction, effective resource utilisation and enhancing operational flexibility, while Green manufacturing strategies aims at reducing, re-using, re-cycling, re-working, re-turning, and re-manufacturing [109].

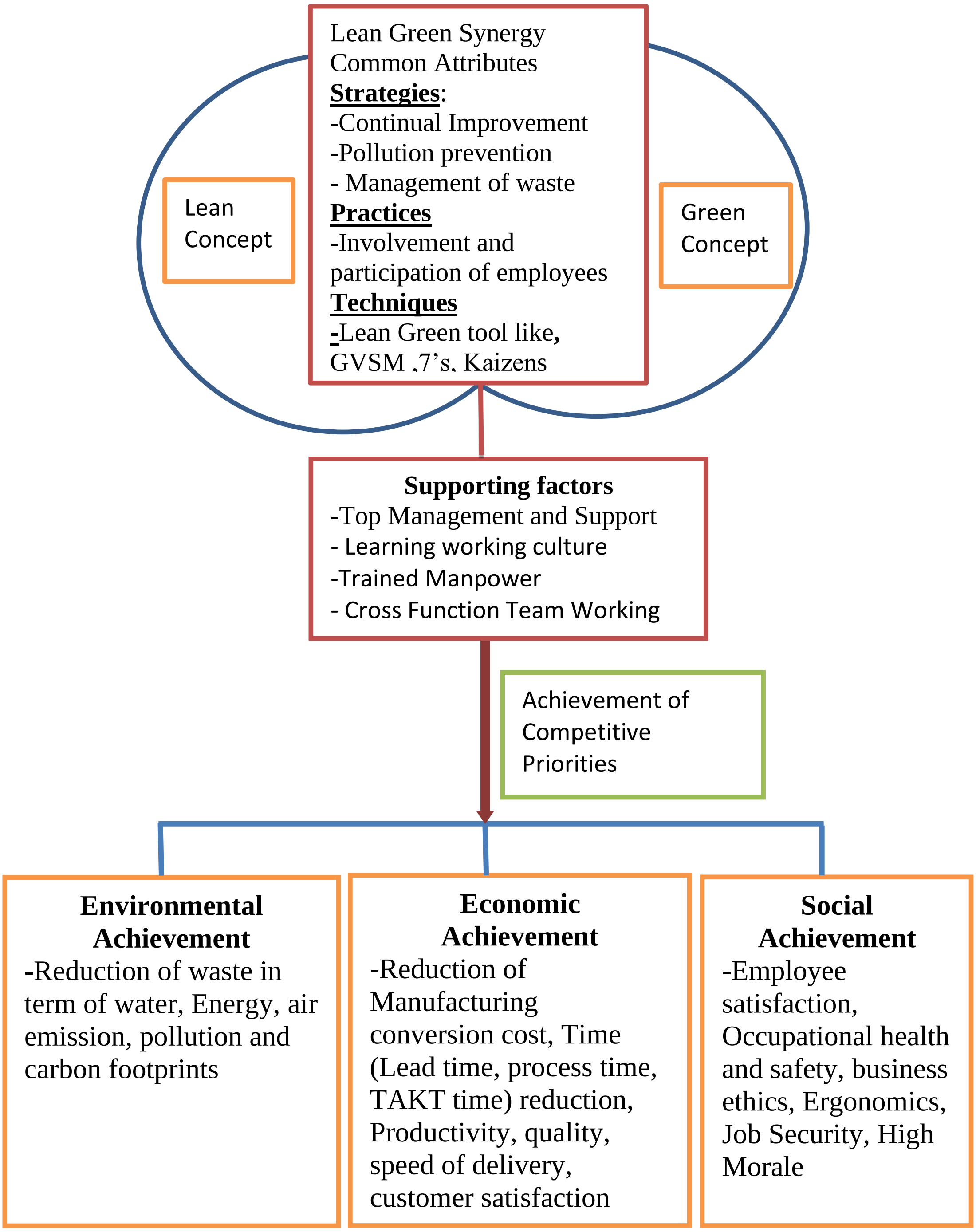


Figure 1.2— Lean Green Strategies- Conceptual Synergetic Model

Conversely, it is claimed that, in spite of the fact, Lean and Green manufacturing waste strategies' definition of waste may be unlike, but Lean strategies non-value-added improvements can be appraised as waste of power and natural available resources, connecting with the wastes identified in lean, and wastes defined in Green strategies within manufacturing environment [100]. Therefore, Lean-Green combined approach is effective and practical approach for achieving competitive priorities in the organization, which are economic, environmental-friendly and uplifting of society [110]. Lean-Green strategies conceptual model is manifested, based upon aforementioned reviews shown in Figure 1.2.

1.5.1 Benefits of Integrated Lean-Green Manufacturing Strategies

Lean concepts and techniques practiced in today's globally environmental protection activities, and Green strategic projects can intensify profit in combination. In essence, Lean strategies can enable the motivation of approaches related to pollution prevention resulting, bottom line profitability and share of business at market place of the organisations increases post implementation of integrated approach. Table 1.9, shows the benefits of Lean and Green strategies [111].

Table 1.9— Benefits of Lean and Green Strategies

Lean Benefits	Green Benefits
Consumption of less material and reduction of associated inventory level helps in cost saving and elimination the waste of over-production.	Re-use and re-cycling of material helps to eliminate waste and improvement in economy.
Reduction in operation downtime results in elimination or reduction of waiting time.	Cost of power reduction during operational activities.
Price associated with the product decreases due to reduction in transportation through innovation.	Air pollution, emission, carbon footprints reduction by optimization of transportation activities.
Elimination of defects by use of less material, Poke- yoke and less WIP etc.	Consumption of less energy is achieved with the utilization of the suitable number of materials.
Excess movement and handing of material improvement.	Less consumption of energy due to avoidance of excess movement and proper handling.

Therefore, finally concluded that adoption of LG manufacturing strategies and approach could be an alternative to issues in Farm equipment sector as LG provided tremendous results in conventional manufacturing sector. So, there is need to study LG manufacturing approach in Tractor Industry in India.

1.6 Significance of the study

The thesis contributes to the existent body of knowledge on LG manufacturing strategies for academicians, researchers, and practitioners alike. The systematic literature review can be a building block for the potential researchers to explore the newer research areas in identifying better LG manufacturing strategies. The measurement framework for LG manufacturing strategies in the Indian Tractor Industry is comprehensive and encompasses various functional areas of an organization and to some extent, on achieving competitive priorities like Productivity, Delivery, Quality, Cost, Safety and Morale of employee in Indian Tractor Industry. The role of Lean-Green approach focussed on streamlining manufacturing processes to eliminate wastages and enhance efficiency by minimizing excess inventory, improving product design, reducing non value-added activities in manufacturing processes along with making green operations in entire value chain in Indian Tractor Industry. From the literature review success factors and barriers are identified, which can be used by the practitioners for leanness assessment and improvement of their organizations irrespective of the type of industry. The study also helps the practitioners to use framework to leverage the better performing areas and improve the poor performing areas. The concept of continuous kaizen can be used to improve the leanness of a system.

1.7 Scope of the Study

The importance of LG manufacturing strategies for strategy formulation and improving operational excellence in organizations cannot be ignored. Lean-Green methods are all about minimizing the wastes using environmental-friendly operations. It is about continuous improvement in the working of the organizations for customer satisfaction by understanding the needs of the customers [112]. Lean-Green methodologies have a long way to go before they are adopted by all organizations. Leadership, cultural transformation and sustainable operation are the keys to the effective implementation of LG strategies [113]. Waste minimization and Green practices are some of the most important attributes in getting the organizations systems towards operational excellence [114]. Without enhancing these skills, an organization can't achieve operational excellence. In the implementation of these methods' Leadership and skill level of human resources of an organization plays a pivotal role. The present study is an investigation on LG manufacturing strategies /approach in Indian Tractor Industry for operational excellence. The study takes Tractor Industry in India into 'scope of the study', because the automobile industry is a huge sector that includes different automobiles. Implementation of LG Strategies provides a competitive weapon for organizations due to its impact on leadership, human resource management practices, and culture. The present study will help in understanding the concept from the automobile industry perspective in general and the Tractor Industry in particular. The study suggests further investigation of the barriers, that may face the firms in implementing LG Strategies. In highly competitive business environment, LG strategies can go a long way in achieving a competitive advantage. This study will contribute to a better understanding of these strategies. The recommendations provided, will help the organizations to formulate their strategies in better way, which are related to the automobile Industry in general and the Tractor Industry in particular.

1.8 Thesis Structure

This thesis is divided into seven chapters. The content of the thesis has been presented as follows:

Chapter—1: **Introduction**

This chapter starts with background about Lean and Green strategies, and then it introduces challenges to manufacturing organization in the perspective of Indian Tractor industry. The pillar of sustainability discussed in this chapter, also covers the Lean manufacturing strategies, Lean waste, Lean principles and distinguished Lean tools and techniques in manufacturing. Further, Green manufacturing Strategies, Green waste and Green principles are presented. Finally, conceptual model of LG strategies was developed considering the integrated and synergetic approach.

Chapter—2: **Literature Review**

This chapter presents a Systematic Literature Review (SLR) related to Lean manufacturing, Green manufacturing, and Integration of Lean Green manufacturing. The literature is concentrated on taking out of Barriers, Success Factors, Framework, and plan for implementation. In-accordance with the availability and review of literature, gaps has been identified and further, the objectives of the research work in current study are manifested at the last of this chapter.

Chapter—3: **Research Methodology**

This chapter presents research design used in research work. Problem formulation was drafted with the support of selected case plant. Further, LG manufacturing strategies framework has been formulated and concisely described the LG strategies tools used in this research study. Various Multi criteria decision making approached used in this research work also presented.

Chapter—4: **Investigation of Success Factors of Lean-Green Approach**

This chapter presents the identification and analysis of Success Factors (LGSFs) in Indian Tractor Industry. Initially, 26 LGSFs identified through literature review. It was screened up using statistical analysis. Finally, 22 LGSFs presented in this chapter for further analysis. Success factors were identified using Interpretive Structural Modelling (ISM) approach and further analyzed with Cross-Impact Matrix Multiplication Applied to Classification (MICMAC), a MCDM approach.

Chapter—5: **Investigation of Barriers of Lean-Green Approach**

This chapter presents Barriers (LGBs) pertains to Tractor Industry. Initially, barriers were identified through Systematic Literature Review (SLR) and expert opinion with in sustainable parameters. These were further screened up through statistical analysis. Criteria weights were calculated using Analytical Hierarchy Process (AHP) approach. The outcome of this approach is further used for outranking of LGBs using Elimination and Choice Translating Reality (ELECTRE), a multi criteria decision making approach.

Chapter—6: **Implementation of LG Strategic Framework in Indian Tractor Industry**

This chapter presents the validation of proposed framework in practical way and in actual scenario by implementation of LG approach in Indian Tractor Industry. In this research study, the project has been selected in case company using Best Worst Method (BWM) approach and various improvement initiatives taken using Lean-Green tools and techniques in selected line of case industry. The managerial implications and inferences of case implementation have been presented at the last of this chapter.

Chapter—7: **Conclusion and Scope for Future Research**

This chapter presents the conclusion and future scope of this research for professionals and prospective researchers.

CHAPTER-2
LITERATURE REVIEW

2.1 Introduction

Investigators from manufacturing operational industries and academic institutions are inclined, giving close and due consideration towards LG integration due to rising environmental and societal concerns globally. Until now, abundance of research study related to Lean manufacturing, Green manufacturing, Sustainable manufacturing prevails in the published literature. But barely sufficient research study related to synergetic LG strategies, associated SFs, barriers, and conceptualized integrated framework persists. The relevant preceding research work related to LG in manufacturing have been re-assessed through systematic re-search approach and strategy to search gaps in foregoing studies for taking forward in this research study. The re-appraised sources include published research papers, books, journals and reports.

2.2 Objective of Research Literature Review

The primarily purpose of literature review is manifested as:

- To work upon the research scope that has been concluded in promising approaches like Lean, Geen and Lean-Green.
- To accumulate maximal information and complete understanding about continual strategic approach, such as Lean, Green, Lean and Green.
- To identify and acknowledge the re-search gaps in the LG implementation in manufacturing industries.
- To acknowledge and status the research work communicated in the execution of Lean-Green approach.

2.3 Methodology Adopted for Literature Review

The systemized and organized review of literature creates a ground for the evolution of theoretical hypothesis and also reveal potential areas for research in future [104]. The SLR utilize specific, transparent and comprehensive approach that includes exclusive steps to ensure that accuracy, clarity and uniformity can be obtained in review process [115]. The SLR uses different steps starting from the questions or objectives formation, location of studies, selection of studies, and reporting of the findings [116]. Table 2.1, depict the distinctive steps of SLR approach adopted for comprehensive literature [117].

Table 2.1— Step of SLR Methodology

SLR Steps	Objective of Review	Method Adopted	Tools used
Formulate Procedure of research (scope and criteria)	Main objective of research study and defined the goal.	Screening of each significant article for quality collection.	
Outline relevant criteria (Fix-only pertinent papers)	Search, download, collect the pertinent articles from famous and reputed data-base.	Electronically stored data-base.	Elsevier, Emerald, Springer, Taylor & Francis, Scopus,
Papers selection based upon formulate criteria, intended on related study.		Criteria of inclusion and exclusion.	Inclusion– Research papers on lean, green, lean green, barriers, critical success factors, LG framework, Lean six Sigma Exclusion– Unpublished, an English related work.
		Search Key words used.	Lean, Green, Lean Green, Sustainability, Lean Green framework, Success factors, barriers, Lean Six Sigma, enablers, drivers.

The appropriate research papers were explored using search keywords ‘Lean manufacturing’, ‘Green manufacturing’, ‘Lean Green Manufacturing’, ‘Sustainability’, ‘Life cycle assessment, ‘Manufacturing’, ‘LG Framework’, ‘Success factors’, ‘Barriers’, ‘Lean Six Sigma’. The research papers were retrieved using the electronically stored data-base of Elsevier, Emerald, Springer, Taylor & Francis, Wiley, etc. These stored data- base reflected the main ground of getting information to identify and establish the concept of LG manufacturing and its consequence on environment. The insignificant papers, unpublished paper, and paper apart from English language are disposed from the literature. Conclusively, 320 articles were chosen after qualitative and quantitative analysis for an investigation and to formulate the objectives. The primary criterion for choosing the published research papers was to discover the integration of Lean and Green manufacturing, sustainability perspective related to Lean, Green, and Lean Green Six Sigma, and articles investigating the area of Lean and Green. An in-depth review of literature is crucial for focussed investigation in area of research, and to discover the latest development in particular field of study. For this reason, review of literature is categorized as manifested below:

- Literature based on Lean and Green Manufacturing,
- Literature based upon Lean, Green success factors and barriers
- Literature based upon Lean, Green integration and Framework

From the all-inclusive assessment of research papers from 2010 to 2023, the research gaps have been identified.

2.4 Literature pertains to Lean and Green Manufacturing

This section presents review of literature related to Lean and Green Manufacturing, concept of both approaches individually and practiced in the manufacturing along with other sectors for operational benefits. The brief explanation of the review is manifested as follow:

2.4.1 Review of Literature on Lean Manufacturing

This sub-section presents the review of literature related to Lean Manufacturing, which are described as follows:

Aadithya et al., (2023), did comprehensive investigation of lean from different perspectives in fabrication and heavy engineering industry. They proposed a framework for consolidating various lean perspectives such as barriers, lean-principles, lean-tools and related performance parameters for their adoption in systematic way. The outcome of the study revealed the contribution of lean perspectives in selected industry [57].

Islami, X. (2023), examined the mediating role of strategic supplier partnership and information sharing (IS), in the association amongst lean manufacturing and organization's financial performance. The study used data from 157 manufacturing organizations. The outcome is produced on SEM using AMOS software. The result revealed, the strategic supplier partnership is partially mediating in association between lean manufacturing and financial performance, whereas, empirically, it could not claim that IS remarkably moderates the association between lean manufacturing and financial performance [118].

Kumar et al., (2022), in their study on lean manufacturing techniques and its implementation takes out various approaches to enhance the implementation of lean manufacturing ideas for improving and increasing productivity, while keeping product cost low. The intent behind this study is for analysis of lean-waste methods and simplify the existing state of LM [119].

Deshmukh et al., (2022), analyzed the concept of lean manufacturing, lean wastes including strategies and obstacles. Literature attempted a critical review, which focused on lean manufacturing and reverse engineering in propeller shaft joint by systematically categorization of lean design, organization, material and tool use base. This study also reflected the integration of LM and Industry 4.0 for flexibility and increase in productivity. The outcome of this study revealed the increase in performance measures and highest improvement [120].

Naeemah (2022), investigated the positive impact of lean manufacturing tools on sustainability outlook. Research work identified 36 Lean Manufacturing tools which were impacting manufacturing sustainability. Finally, identified top 10 LM tools, including six-sigma and kaizen along with 20 sustainability matrices like 8 wastes and air emissions. The outcome of the study showed that maximum impact was observed on economic aspects such as reduction in cost [121].

Palange (2021), in their paper on, 'Lean manufacturing a vital tool to enhance productivity in manufacturing,'' presented a focused review to see the impact of lean manufacturing on different manufacturing sectors. The study suggested to focus on maximum utilization of resources initially followed by waste reduction in manufacturing activities. The result showed, cycle time reduction, removal of NVA activities, clean and hygienic workplace, smooth flow, productivity improvement, reduction in production cost, employees involvement, inventory and breakdown reduction etc. after implementation of lean manufacturing techniques [122].

Dieste et al., (2021), in their paper on, 'Influence of lean manufacturing on firm's financial performance,' examined to understand the improvement in financial performance of lean companies. Literature examined and analysed the degree of lean execution and measurement of financial results. Descriptive and content analysis in this study showed that JIT and TQM are two suggested approaches to increase the financial performance in terms of sales and profits [123].

Tortorella et al., (2021), performed an analytical approach for identifying integrated cultural profiles and leadership styles of organisation that best suits for executing lean manufacturing practices. The clustering of respondents and their respective organizations was performed based on above-mentioned attributes, and tested for frequency differences between clusters. The outcome of study presented that cultural profile of any organization depends upon the style of leadership and execution level of lean manufacturing, recommending different from expected impacts of this connection on lean manufacturing execution [124].

Hernandez-Matias et al., (2020), analysed different human related lean practices in depth and their relevancy for successful implementation of LM using factor analysis and SEM as statistical tools. The result showed that Management (cultivation of lean culture and support to lean), Employee's human related lean practices (involvement and precipitation) and operational performance (reduction of waste and flexibility) are associated human related lean practices [125].

Singh (2020), implemented a case study approach using VSM in manufacturing organisation and validation in real scenario in U-Bolt Section. The results comprise as, reduction in cycle time by 87.59%, WIP inventory reduction by 76.47%, lead time reduction by 95.41%, Increase in VA ratio by 66.08% and change over time reduction by 70.67% [126].

Jimenez et al., (2019), implemented lean manufacturing tools to understand the production process flow in the value chain of processing and marketing in fishing industry for an improvement in productivity and quality. A case study approach using VSM, heijunka strategy and flow of current process, which resulted 40 % reduction in displacement route and 44.2 % time used in displacement of process [127].

Chauhan (2019), provided mixed approach for lean implementation in three phases. 30 measures are identified for implementation in phases in engineering manufacturing industry using Analytic Hierarchy Process.10, 14 and 6 measures are considered for lean implementation in three phases respectively considering practical limitations faced by companies. The outcome of study is presented in the phases as, Phase-1, revealed for preparing and implementation of actions for labour flexibility. Phase-2, revealed that skill set require for labour productivity. Phase-3, revealed the increasing flexibility of machine, while summarizing the gains of lean implementation in previous phases [128].

Marodin et al., (2018), analysed the moderating role of Lean Product Development (LPD) on the effects of Lean Manufacturing (LM) on the quality and inventory performance, extracted on configuration theory. The developed hypothesis was tested using least square regression models along with moderation tests. The outcome revealed that an execution of LPD has positive moderate effect of LM on quality and inventory turnover. The study further suggested that systematic implementation of both LPD and LM as combined approach in companies can bring more gains [129].

Singh et al., (2018), evaluated the performance of various LM tools in manufacturing industry situated in northern part of India. The study uncovered the significance of LM technique in manufacturing environment. The significant level of various LM tools, benefits achieved after successful implementation of LM approach with LM tools are identified. The results of the case study approach revealed that Just-in-time strategy is most essential strategy for execution of lean manufacturing. Results manifest that overall production rate increased by 42.08% with net saving Rs. 242208 / Annum after implementation of LM technique [130].

Dhiravidamani et al., (2018), implemented a case study in foundry section of an auto parts manufacturing organization using lean kaizen and VSM as Lean tools for an improvement. The findings of the study were integrated with computerized based lean-audit for enhancing production performances and measuring lean attributes. The results of case study revealed that, core rejection is reduced by 2.02%. VSM was also executed, which resulted in 60% NVA activities shop area / machine [131].

Garre et al., (2017), implemented lean concept, tools and techniques in precision industry like aerospace manufacturing. After successfully execution. Cycle time for welding process for different vessel capacity, has reduced from 48 min to 36 mins and 54 min to 40 mins for 500L and 200L vessel capacity respectively. Layout improvement and implementation of 5’s resulted increase in output / day from 30 tanks to 42 tanks for both models [132].

Bevilacqua et al., (2017), analysed the network of effect amongst the lean practices (Supplier management, HRM, JIT and TQM practices), operational responsiveness (Product-mix variety, Innovation and Effectiveness of time) and company growth performance in Italian companies. Analysis of testing the hypothesized relationship for structural model was performed using SEM and second order CFA. The outcome of study revealed that operational responsiveness is only partially influence by the lean strategy of the company. Product variety and effectiveness of time both positively influence for growth of company, but only effectiveness of time could be observed as a mediator amongst lean best practices and growth of the firm [133].

Panwar et al., (2015), analysed the applicability of lean concept in process industry. The study highlighted that some of the lean tools, which are not related with process characteristics like, 5S, TPM, quality management programmes, work standardisation, team-based problem-solving technique and continual improvement approach were largely applicable in process industries. However, outcome revealed that more empirical studies required for the practical application of lean is process industry [55].

Sundar et al, (2014), developed a lean road map for execution of lean manufacturing system in the company. The study highlighted the group of lean elements like VSM, Cellular Manufacturing, SMED, pull system, Kanban, Inventory control, line balancing, SMED, Cellular manufacturing, pull system and levelling of production for successful execution of lean. The outcome further illustrated the implementation of lean elements in sequence way in dynamic business environment in order to develop integrated theory for achieving excellence [134].

Bhamu (2014), highlighted divergent LM definitions, scopes, objectives, adopted research methodologies, tools and techniques used after review of 209 research papers. The outcome of study reflects, Lean manufacturing has progressed as an integrated system formulated with many merged elements, an ample variation in management practices and widely adopted in different sectors. But there is no standardized lean manufacturing implementation process or framework [36].

Vamsi Krishna Jasti (2014), highlighted the current status of empirical research in Lean Manufacturing after review of 178 research papers in 24 journals related to empirical research design. The outcome of this review concluded that number of empirical research studies are increasing. However, there is requirement of lean manufacturing framework developed with large sample size and longitudinal data collection methods. The framework should provide sequential direction to eliminate the waste in organization, which is reflected through descriptive statistics of empirical research in lean manufacturing [135].

Dorota (2014), highlighted the various challenge for lean implementation in SMEs. The potential challenges for implementation of lean are outlined by comparing the different manufacturing environments and characteristics of organisations. The research study utilized the deductive approach and obtained outcome through case study approach. The results present the evaluation of current situations of the companies. The study highlighted that early identification of weakness will help organisations to explore their own capabilities. Major emphasis was given on the factors which predominantly influence for lean implementation [136]

Gupta (2013), identified the important and useful contribution in LM philosophy, LM tools and techniques. The study reflected that there are various factors responsible for success of lean concept. Choice of use of tool is specific to prevailing situation. The outcome of study revealed that transformation of organization culture is utmost important instead of implementation of all lean tools. The operational flexibility and increase in market share have been observed in the organisation, who adopts lean manufacturing. Further, operational and cultural environment is created by LM adoption, which is utmost favourable to minimization of waste [137].

Wahab et al., (2013), designed a conceptual model for measurement of leanness in manufacturing sector. The conceptual model developed and designed at two prime levels, namely dimension(s) and factor(s). Thus, the result highlighted the seven main dimensions in manufacturing commit to measurement of leanness. The model also highlighted the relationship of lean dimensions and 8 types of lean wastes [54].

Mostafa et al., (2013), examined 28 lean implementation initiatives considering human aspect in this study. The literature explored five categories of initiatives and framework was developed. The identified initiatives are evaluated with regard to nine factors for implementation of lean. The investigation proved that executed frameworks have highest associations with factors of lean. This study suggested project-based framework, which was executed in four phases for creating a synergy for continuous improvements. The suitable decision tools and practices were exercised in each phase. The study highlighted that the failure in lean implementation is mainly due to poor mindset and in-sufficient understanding of lean concepts. The recommended work in this study invokes extension and application for validation and incorporation of advance method for lean implementation based upon organization Mission and Vision [138].

Chauhan (2012), identified and measured the affectionately related parameters of LM. Literature also examined the weight of contributing parameters to overall LM using AHP approach. The relationship strength between various parameters of LM was measured using coefficient of correlation analysis. The outcome of the study revealed that the “elimination of waste” to be the most essential element of lean manufacturing, then “just in time deliveries”. The factors which drive for practical understanding of LM are “Just-In-Time deliveries” and obtaining “continuous improvement”. The study revealed that waste elimination is the most important ingredient of lean manufacturing for which Indian manufacturing industries are still fail to observe [139].

Chowdary (2012), implemented various lean principles, tools and current good practices in pharma industry like VSM, 5’S, 5 whys, which resulted in 38 % reduction in storage area and 50 % reduction in production staff. The study also revealed that reduction in lead time, cycle time and work-in-progress inventory observed using LG methodologies. For systemic improvements, various lean strategies also suggested along with future state of VSM [140].

Hodge et al., (2011), identified various LM tools, principles and implemented in textile industry in US. A case study approach is executed in this research after examined the data, which was collected through interviews and plant visits. LM tool, Value stream mapping is applied in textile industry, which resulted reduction in production lead time from 48.8 days to 23.8 days [141].

Anand (2010), proposed framework, which consists of 65 LM elements. All identified LM elements are categorized according to the decision levels and the role of internal stakeholders in an organization. The study revealed that the proposed framework is comprehensive, which provides a complete integration of elements with logical reasoning as whole. However, the proposed framework is conceptual and needs to be validated [142].

Upadhyay et al., (2010), implemented lean manufacturing through SAP-LAP analysis, TPM and kaizen approach in one of the Indian MSME, which resulted 50 % improvement in machine set up time reduction, cycle time reduction by 15 %, 25 % reduction in rejection, 15 % improvement in current capacity, m/c breakdown reduction from 22 % to 18.90 % [143].

2.4.2 Literature related to Green Manufacturing

This sub-section presents the review of literature related to Green Manufacturing, which are described as follows**:**

Punj et al., (2023), identified three important clusters for Green manufacturing namely; fundamental practices of sustainability, role / purpose of lean manufacturing and cutting-edge technologies like 3D printing. The bibliometric investigation in this study imparted insights into the developing area of green manufacturing. The study focussed for critically recognising the fundamental themes, and inter-connections of identified clusters. The study also set the stage for development of more effective green practices, formulating policy decisions and encouraging competitive and environmental-friendly manufacturing practices globally [144].

Bendig et.al., (2023), developed green manufacturing framework based upon content analysis by use of MAXQDA approach. The research identified 290 codes from foregoing literatures and clustered into division of influences, factors, and results. The developed cluster is further sub-divided into seven additional categories and 30 sub-categories. Using in-depth analysis, three main new research streams covering 'Green manufacturing performance', 'People', and 'Inter-disciplinary orientation' are suggested. This work contributed novel prospective by offering additional knowledge of green manufacturing concept [145].

Haleem et.al., (2023), emphasised the importance of Green Manufacturing in exhibiting a sustainable environment. The literature identified various green manufacturing strategic tools and specialised methods for environmental sustainability. The study identified critical applications of green manufacturing for green environment. The outcome of the study revealed that 5'R strategic approach of green manufacturing leads to effective resource utilization. The Green manufacturing approach helped the manufacturing firms to reflect their efforts for reduction of hazardous emissions. The study also reflected that GM is essential for sustainable and green business [146].

Kannan et al., (2022), developed two metrics of Green manufacturing; GM challenges, and GM critical success factors (CSFs). The theory-based framework of CSFs has been developed by which GM adoption challenges were drawn for mitigating the risk through corresponding CSFs of Green manufacturing. The study categorized the challenges and CSFs of GM into diverse dimensions for better understanding for manufacturer. The outcome of this study allows manufacturers to identify the real challenges of Green Manufacturing and to appreciate how risk be mitigated particularly through CSFs of GM [147].

Singh et al., (2022), identified and investigated the Critical Success Factor (CSFs) of green manufacturing sustainability in the automotive industry. Pair-wise comparison matrix was formulated using Fuzzy-AHP technique post prioritization of CSFs. The study suggested various improvement measures and implementation of Green manufacturing in the automotive industry. The outcome of study also revealed that adoption and implementation of GM lead to achievement of sustainability not only in automobile sectors and in other sectors too [148].

Sharma et al., (2022), identified the benefits of GM and effects of technological progression on sustainable development. The study also concluded that the organizations are facing tremendous pressure to become greener and eco-friendly. Therefore, suggested the adoption of Green innovation and GM as advanced tool for sustainable development in which society and economy operates. The study further emphasized the development of Green economy which needs help of green innovations to affirm the improvement in climate and economy together [149].

Shukla (2021), developed a contingency-based model to realize that with the GM maturity level of firms, how GM technologies and GM performance measures are evolved. The model of research study was developed in conceptual form and validated through a case study approach in paint manufacturing company under five prime green initiatives. The data was collected through interviews and analysis of documents. The outcome of the study revealed that the five green initiatives, choices of technologies and usage of GM performance measurement validated through recommended model. The study highlighted that at the start, the endeavour of GM encouraged to abide by comply with regulations, afterwards shifted to achieve strategic benefits, like cost reduction and clarity with perceptibility [150].

Jamwal et al., (2021), conducted a systematic review of application of MCDM approach for GM. The study highlighted the benefits of MCDM techniques in quick decision making by GM firms. The outcome of study revealed that in GM decision making, the techniques assessed to examine GM practices have used both qualitative and quantitative data. Currently, GM development, assessment of GM practices, GM performance measures has become complicated due to societal, economical, technological and ecological benchmarks. Therefore, more MCDM approaches are required to practice, as currently GM area are based upon fuzzy-based unique model approaches [151].

Sharma et al., (2021), proposed GM framework with six GM indicators, which was empowered by a steering manufacturing company in India having three plants. Framework validated using MCDM (F-AHP-ELECTRE) approach for ranking six identified indicators and ranking of the three plants for GM execution. Study revealed that Efficiency of EMS and Hazardous Waste-Management are the significant factors for GM implementation. Plant -1 was the best substitution among three plants for six performance indicators. The outcome of this study will help organizations for prioritizing the prime indicators for an improvement action plan [152].

Agarwal et al., (2020), identified unique factors that impact green manufacturing and recommended sequence to be followed by operational company to form themselves as GM organisation. As a result, GM organizations will be competent of manufacturing green and eco-friendly products. DEMATEL approach is used to categorized eleven drivers into group of cause effect. The outcome of the study revealed that ecological development consists of three methods of transforming manufacturing activities; utilization of green energy, production and marketing renewable products and utilizing green technologies in operational activities for GM. [153].

Karmugilan (2020), presented four broad themes like green-management, green-manufacturing, green-logistics and green-marketing, which re-presents the different depth of a Green product. A sentiment analysis is performed using the software r-studio to make the social media data more reliable on green aspects [154].

Narayanamurthy et al., (2020), developed an assessment framework to analyse the greenness performance of a redial tyre manufacturing in India by capturing the interactions between the executed green practices. The developed framework was proposed on stake-holders based GM practices. The empirical data was collected through case study approach in manufacturing unit on the interactions of GM practices and within stake-holders. The study used the graph-theoretic approach to incorporate the interactions between different green practices and assessed the systemic greenness of the case organisation. Based on the systemic greenness obtained, further ranked the green practices within stakeholders and also between the stakeholders. The outcome of the study revealed the formulation of greenness-index for assisting professionals in investigation and benchmarking performance [155].

Mao (2019), explored weather the GM is costly affairs and how the pressure from outside environmental institution impact the cost of GM amongst the industrial organizations in appearing economies. The study was conducted in manufacturing organizations which were listed in Chinese share market. The study revealed that adoption GM increases operating cost. The study suggested that, with the reduction of pollution level in city will help to increase the positive relationship between GM and operating cost. The study highlighted the synergetic effect of local pollution level and local governments' information transparency was observed. The result of study reflected that operating cost of GM increases in high synergy and low synergy level between local pollution level and government information system [156].

Raut et al., (2019), analysed hard and soft performance measures in Green value chains in agroindustry in India. The hard performance measures consist of operational and technological factors, while soft measures linked with human resources. The performance measures were analysed through quantitative approach. The study formulated many hypotheses for discovering the association between green practice and performance of business. The outcome revealed that 'Collaborative Green Transportation and Cold storages' are topmost influencing factors for operational excellence. The study suggested the need for understanding the relationship amongst the green-focused operation, human resource related factors and business operational performance in context of Agro food supply. The study also suggested based on the investigation that the strategic makers need to formulate policies for enhancing the overall efficiency of this sector [157].

Li (2018), investigated the factors that control the effect of carbon moderation on ecological productivity growth. The study examined the productivity growth linked with carbon moderation using data envelopment analysis under regulated or non-regulated operational technologies. For establishing the linkage, pollution moderation index was constructed. The data was collected from 10 European countries in paper, pulp and coke sectors and analysed. The study outcome revealed that carbon moderation might positively or negatively impact ecological growth of productivity, which depends upon availability of technology type in a sector, capabilities of the innovation and regulations related to environment [158].

Song et al., (2018), created theoretical framework for getting greater insights on green innovation strategy. The theory of Green organisational identity and Green organisational creativity used for development of framework. The literature highlighted that the green innovation is most critical factor for sustainable development. The outcome suggested that green innovation strategy have definitive impact on both green identity and green creativeness of organisation. Positive connection is observed between green identity and green creativeness, and green creativeness positively influences green innovation. Additionally, green identity of organization partially mediates the association between strategy of green innovation and green creativity. The outcome of study further highlighted, green identity of organization fully mediates the connection between strategy of green innovation and green innovation. This indicated that green innovation strategy does not direct impact on green innovation, but in-direct way, it energizes such innovation by the way of green identity of organization.

Therefore, the result suggested that policy makers should look for increasing organizations' sensation of green identity and inspire green creativity, as this will boost organizations' capabilities for sustainable development [159].

Salem et al., (2017), proposed an assessment tool, named Greeno-meter for assessing the greenness level of manufacturing operational companies. The approach adopted for an assessment is relied on taking the greenness position of any firm compared with firms in same or other sectors. Green attributes and their formulated indicators are the bases of this assessment. GMM (Geometric Mean Methods) and DEA (Data Envelopment Analysis) techniques adopted for assessing cross industries and intra-industries respectively. The study incorporated three different industrial applications the illustrate the suitability of developed Greeno-meter. The study suggested, the outcome of assessment scores will support for setting up an effective planning by prioritizing an improvement area in journey of transformation [160].

Mirghafoori et al., (2017), analysed the positive impacts of supply-chain agility on green level performance in manufacturing industry. The study was conducted in the Yazd ceramic tile company with 7 hypotheses of developed conceptual model. SEM technique was used to discover the association between variables. The result of the study revealed that, agility of supply chain has positive impact on strategy of organization, performance related to finance and satisfaction of customer. Additionally, development of variables' relationship requires improvements in applying agility, strategy, customer satisfaction, financial performance and green performance related to Green Technology [161].

Rehman et al., (2016), presented an empirical assessment and guidelines for estimating the effect of GM practices on the performance of organization. The study conducted for development of model connecting critical factors and performance measures. The developed model simulated for its robustness using sensitivity analysis. Further, analysed the capabilities of presented model for predicting patterns and trends by using ANN simulation technique. Model is validated through a case study approach in company and reduction in carbon footprints was noticed. The study also provided insight to manufacturing organisations for taking green manufacturing initiatives in their organization for an improvement in ecological, economical and operational performance [162].

Verma (2016), developed EVSM for identifying non-productive energy consuming process by analysing energy and material flow within manufacturing process. The study focussed on achieving overall productivity of GM. The outcome of the study revealed the potential saving of energy 1912.83 MW hr / year through improvements initiatives [163].

Sangwan (2015), studied green manufacturing and similar framework to find out in terms of origin, scope, similarity and differences in frameworks. The study revealed that eight frameworks were used in previous literature, but standardization is observed missing among all frameworks. The outcome of study suggested that, the investigators need to have clarity in various approaches like life cycle engineering approach, end-to end strategies used, various components of triple bottom line concept used, inclusion of the complete supply chain and synergy of improvement strategies of environment with strategy of business for developing standardization between frameworks. [164].

Govindan et al., (2015), investigated best green manufacturing practices based on dimensions and significant criteria using hybrid DEMATEL based on ANP (DANP) approach with ranking prioritization methods for enriching evaluations. The framework was proposed and validated in rubber and tube tyre industry situated in southern part of India. The outcome of this study revealed the identification and implementation of GM practices in the organisation can lead to increase in profitability and performance outcome in manufacturing systems. The work is more well-grounded in fluctuating real-life scenarios [165].

Paul et al., (2014), focussed on designing the green manufacturing system related to environment and conservation of energy using GM strategies. The study highlighted for creating a sustainable, re-usable and shorter life cycle product with GM strategies. The outcome of study revealed that green manufacturing approach help to protect the environment and decrease product cost [89].

Kumar Mittal (2014), investigated drivers of Environmental Conscious Manufacturing (ECM). The inter-relationships and hierarchal positions amongst identified drivers are analysed using ISM model and MICMAC analysis respectively. The outcome of the study revealed that formulated model categorised the identified drivers into 5 hierarchical level displaying their inter-relationship and manifesting the driving-dependence association between them. Further, 5 levels are classified into 4 categories; namely, Awareness, external, organizational and benefit(s) for leveraging the successful adoption of drivers of ECM [166].

Sezen et al., (2013), analysed the impact of green manufacturing and environmental-innovation on corporate environmental performance. The model was formulated after conducting questionnaire-based survey in 53 companies from different sectors in Turkey. The developed model was validated through regression analysis. The outcome of study revealed that applications of green manufacturing have prominently positive impact on societal and environmental performance. The study further manifested that environmental- innovative process has a prominently positive impact on corporate sustainability [167].

Tsai et al., (2013), investigated the synergy of Actvity-Based-costing (ABC) with Theory of constraints (TOC), as well as application of Mixed Integer Programming mathematical model (MIP) for taking decision about product-mixed by using Green Manufacturing Technologies (GMT). The study proposed Mathematical programming model for analysis of product-mixed decision relied on ABC and TOC. Using a numerical example from a metal component parts manufacturer in the automotive industry, the outcome of study provided insights about the value of MIP on GMT investments and decisions based on ABC approach, while simultaneously, enhancing the value of GMT investments [168].

Helu (2012), highlighted the basic principles of GM by establishing a framework of principles, where relevant examples can be depicted to know the about the green system and explore prominent areas for an improvement [93].

Deif, A.M. (2011), presented a systemic model related to new concept of green manufacturing. The presented model captured the different planning activities for mitigating into more eco-efficient and greener manufacturing. The various planning stages are accompanied by the required control metrics as well as various green tools in an open mixed architecture. The systemic model is exhibited by case study in an industry. The presented model provides all-inclusive qualitative insight, how to design and/or enhance green manufacturing systems [169].

Menzel et al., (2010), investigated the trend and effect of eco-friendly manufacturing on the company's financial performance in the European automotive and pharmaceutical organizations. The study revealed that the resource utilization was the major focus area in both organisations. The outcome of the study reflected that, there is no prominent association among greener manufacturing and corporate performance. Instead, reduction in resources such as electricity along with reducing trend of CO_2 was observed [170].

2.5 Literature related to LG Success Factors and Barriers

This section presents the review of literature related to LG success factors and barriers in the manufacturing context and other sectors for operational excellence. The brief explanation of the review is manifested as follows:

2.5.1 Literature pertains to LG Success Factors

This sub-section presents the review of literature related to LGSFs, which are described as follows**:**

Debnath et al., (2023), identified sixteen most significant Critical Success Factors (CSFs) for execution of Sustainable Lean Manufacturing (SLM)in the furniture industry. These CSFs were grouped into clusters, like ‘organizational and governmental cluster’, ‘supply chain, inventory, resource management cluster’, ‘performance and technological cluster’. The Best Worst Method (BWM) was used to analyse the significance of these factors. The results of the study depicted that, lead time and non-value-adding activities reduced though sustainable resource utilization, sufficient management support, adoption of innovative and emerging technologies. The study highlighted, the afore-mentioned critical success factors are essential for executing sustainable lean manufacturing effectively in the furniture manufacturing industry [171].

Ahmad, T. (2023), identified 73 success factors and 82 sub-factors through an exploratory investigation in this study for green building projects. The network of success factors was developed along with their association, which depicts the reasons of their significance. The network model was tested for its robustness by progressive elimination of CFs and exhibits only critical and significant SFs. The significant success factors includes ‘Educating project team regarding Green Building development’, ‘Proficiency of project client’, ‘Proficiency of project team’, ‘Project team collaboration’, ‘Alignment of team interest with project interest’, ‘Early engagement of project team’, ‘Project team motivation to achieve sustainable outcomes’, ‘Client’s motivation to achieve sustainable outcomes’, ‘End-users’ building operations sustainably’, ‘Early introduction of project targets’, and ‘Rigor of project design development’. The network robustness analysis revealed to consider factors collectively rather than individually and practice for Green Building project development [172].

Ahmed et al., (2023), explored the CSFs for integrated lean and ISO 14001 execution in the manufacturing industry for attaining benefits of operational and environmental. The outcome of the study identified combined success factors are competitive strategy, managerial position, environmental, temporal, internal/external, monitoring and building/adapting factors for successful implementation [173].

Barclay et al., (2022), conducted survey worldwide for data collection and analysed using regression technique to identify CSFs. The several CSFs were identified, which were directly co-related to deeply-rooted culture of lean. for implementation of lean. The outcome revealed, 13 featuring parameters related to survey questions were accountable for 90 % variation in survey data. Additionally, 4 featuring factors were identified, which accounted for variation of over 82 % [174].

O. Connor (2022), explored the magnitude of the implementation of lean practices by the functional team leaders with focussed approach on role of leadership, empowerment and culture. The study collected empirical data and investigated from 34 team leaders in three functional areas such as engineering, quality and manufacturing. The outcome of study revealed that lean is implemented with good management practices, but cultural issues needs to address. The study suggested that commitment and communication from top management, discrepancy in time and allocation of resources need to bridge for successful implementation [175].

Chahal et al., (2021), identified ranking of success factors using AHP technique for removing barriers by implementation of success factors in the organization. The study focussed on success factors which are crucial and barriers with their solutions for lean implementation. The result depicted the four top ranking success factors mentioned orderly, such as, 'motivational approach', 'upgrade job environment and satisfaction', 'leadership and responsibility', and 'develop new behaviour pattern/strictly implementation of lean tools and methods' for reducing wastes and addressing barriers [176].

Kota et al., (2021), identified 17 CSFs for Sustainable Production System (SPS) and screened up to 13 CSFs with the help of expert opinion by combining similar types. The study established the relationship and hierarchy among screened CSFs using ISM approach and proposed a conceptual model in Indian consumer durable industry. The outcome of the study revealed that 'customer demand and management commitment' are the most prominent factors to drive SPS with the support of innovation in processes, efficient operations and life cycle thought process. The study suggested that for implementation of strategies in the firm, further detailed study is required for establishing relationship. The conceptual model further needs to undergo vigorous validation for its generalization [177].

Kumar et al., (2020), identified and analysed CSFs for Sustainable Lean Manufacturing (SLM) in Indian automobile industry using ISM approach. The outcome revealed that 'Top Management' is most influential CSFs, which support in execution of SLM and other leading CSFs. The study also identified the driving and dependent factors in the perspective of Indian automobile industry. The analysis manifested that sustainable manufacturing (Lean-Green practices) delivers excellent results. The study suggested for conducting a case study with this outcome for SLM. [178].

Elkhairi et al., (2019), depicted the consistency between barriers and CSFs for implementation Lean manufacturing in SMEs, such as, 'lack of expertise' is barrier and to overcome this barrier, the CSFs are 'competency, education and training'. The study facilitated by providing an opportunity to design and direct SMEs to meet the challenges in dynamic market environment. The study highlighted that; organization needs to find ways for strengthening lean culture for all employees [179].

Toke et al., (2019), identified and analysed CSFs of Green Manufacturing (GM) for successful accomplishment of environmental sustainability in Indian manufacturing industry. The analysis was conducted through pairwise comparison using AHP technique. The outcome of analysis recommended set of measures for successful implementation of GM practices. The SAP-LAP analysis and construct validation conducted for three case studies. This validation has examined the extent and effectiveness of proposed GM framework in Indian context. The study is confined to selective segment of manufacturing industries. The model developed can be further extended for specific category of industries after identification of different GM attributes [180].

Sreedharan (2018), reflected CSFs for various Continuous Improvement (CI) programme and performed Content Analysis (CA). CA is based upon the review of 41 papers peered review journals. Four stages constructs used in this research work for prioritization and evaluation of CSFs using clustering and Pareto analysis. The outcome of study revealed that CSFs assessment is found to be far from significant compared to CI implementation. The assessment methodologies ranging from qualitative to quantitative models. This study did not reflect on KPIs at organization level for excellence, which needs to explore. Further, need to focus on action-based research work for case studies and field work [181].

Knol et al., (2018), examined the extent to which success factors are crucial for various degrees of lean practice execution. The study conducted multiple-respondent self-assessment from manufacturing SMEs situated in DUTCH. The literature used necessary condition analysis and outcome revealed that success factors' critically advancement dependent. The study highlighted that the improvement is only possible in progressive stage with more success factors. At initial stage SMEs could improve by adoption of local factors such as, 'focus on training and learning'. The literature highlighted that the factors like 'Top Management Support', 'Shared improvement Vision', and 'Supplier links' are key factors in advanced stage. The finding interrogates on applicability of success factors universally. Identified factors are generic in nature, which indicated the need for a more dynamic model of lean execution [182].

Belhadi et al., (2018), identified 28 CSFs, and grouped into five categories. The literature reflected that, for ranking and prioritization of factors at initial level, an AHP-based approach was proposed and conducted in a typical small automotive supplier. A framework was established to provide relative importance of identified categories and CSFs. Afterwards, compared each other's using a structured approach. Priority order among the identified categories and CSFs are monitored through sensitivity analysis. The study highlighted the gap in this research work, that generalization of the outcome cannot be guaranteed. The important aspect of inter-dependency between categories and CSFs is missing in this study. Therefore, more detailed study is required [183].

Seth et al., (2018), focussed on Indian SMEs and large industries in context with Indian manufacturing. The study identified CSFs for GM and analysed using ISM approach. The outcome of this study manifested, the mutual understanding of green success factors for leveraging in strategic manner has potentially increased. This study reflected qualitative analysis using MCDM approach but missing in term of quantitative analysis for calculation of weights for each factor. Therefore, further study supporting green measurement initiatives is required [184].

Alhuraish et al., (2017), investigated CSFs by statistical analysis using comparative study of Lean manufacturing and Six-sigma. Investigation revealed the levels of importance of the CSFs for lean manufacturing and six sigma implementations. Limitation in comparative study is that, it cannot help organizations to identify which methodology is suitable with their goals and available resources. The study further highlighted; it is very difficult to implement both simultaneously in SMEs environment. Therefore, further deep analysis with practical implementation is required [185].

Digalwar et al., (2017), identified success factors for establishing structural relationships amongst various factors for effective execution of GM. 12, SFs are identified in this study and analysed using ISM approach. The analysis presented relationship model. The study highlighted the gap, that the developed model is not validated statistically, which need further deep diving for successful implementation of GM approach [186].

Ainul et al., (2017), identified CSFs and barriers for lean implementation using qualitative case study research method conducted in two printing firms in Malaysia. Only two firms. The study highlighted that the identification was done after taking interviews of two managers and 3 employees at each of 2 printing firms. The identified CSFs are, 'Practitioners' understanding of lean philosophy', 'Principles and methods', 'Management leadership and commitment', 'Upfront training in lean' and 'Effective communication'. The limitation of the study is that, the outcome is based upon the interview of only 10 numbers of people. The study highlighted that the testing of the various hypotheses and establishment of relationship between CSFs and situational variables would decide the success and failure of lean implementation. Therefore, further scientific study is required [187].

Netland, Torbjørn H (2016), Investigated how contingency variables influence success factors for implementation of lean. The study collected the data from 83 factories of two multinational companies involving 432 practitioners using survey method. The survey asked for their opinion for successful factor-level implementation of lean production. The responses of the survey were grouped as general SFs and tested for differences between four contingencies as corporation, size, lean implementation stage and culture of the nation. The analysis supported the generic CSFs. However, in this study, the effect of contingencies on CSFs for improvement programmes has largely been ignored. Identified CSFs are generic depends upon managers actions. Further, research should go deeper than just studying CSFs for various programmes, to get real benefit of lean practically [188].

Gonzalez Aleu et., (2016), synthesized and assessed the published literature related to CSFs for Continuous Improvement Projects (CIPs). The study identified and analysed comprehensive set of 53 CSFs extracted form 98 publications for continuous improvement projects for relevancy of one factor with respect to other. The factors were analysed based on the frequency in communicated literatures. The study highlighted for the need to create a methodology that integrate qualitative and quantitative information, which is missing in this research. As a result of this, empirical research study is required to examine the relationship between CSFs and success of CIPs. Further, investigation is required for differences in CSFs across industry types, and type of Continuous improvement projects [189].

Govindan et al., (2015), identified 12 common SFs for GM from literatures, inputs from Industrial Managers and experts in GM domain. The data was collected through questionnaire survey on common factors from 120 leading firms. Based upon the reply, pair-wise comparison was made and analysed using fuzzy-AHP approach. The obtained results were validated through sensitivity analysis in two stages using de-fuzzification and spearman coefficient by assigning weights to common factors respectively. The outcome of the study helped organisations to energize critical driver for quick and better adoption of GM. The Extent of this study is confined to SMEs only. All SMEs don't practice green approach and are not aware about green regulations. The SMEs manage operations as per their convenience. So, this study did not contribute much practically. There is need for further study with different MCDM approach for other common drivers with practical outcome [190].

Bakar et al., (2015), gathered the latest CSFs of lean approach and performed cluster analysis using affinity diagram and new header mapping. The result of analysis revealed that only 5 prominent CSFs were recognized (from 97 CSFs) out of nine groups listed in cluster analysis. The outcome of the study manifested that, most of organizations were aware about lean and six-sigma, but did not consider its CSFs. This research work provided the guidelines for deployment lean, six-sigma approach in the organization through detailed analysis of CSFs [191].

Chuang (2014), proposed three-layers assessment model for assessing the Green Manufacturing System (GMS) performance and identified Key Success Factors (KSFs) for implementation in real world scenario. The first and top layer of model included three dimensions, such as green-design, green-manufacturing processes and green-packaging. The second and third layers included 10 strategic subjects and seventy-four assessment factors respectively. The weights in each layer were calculated and analysed using ANP approach. The outcome of the analysis showed that 5 CSFs were identified for implementation of GMS in companies. The practicality of suggested model was illustrated by investigating three companies. The result indicated that green-design (GD) is significant, which helps for green-process and green-packaging. Therefore, implementation of GD should be prime objective for successful implementation of

GMS in the organisation. However, there is need for developing a procedure for building a model for accurately identification of factors [192].

2.5.2 Literature pertains to LG barriers

This sub-section presents the review of literature related to LGBs, which are described as follows**:**

Sahu et al., (2022), investigated reasons for (RF), i.e. determinants and reason against (RA), i.e. barriers in adoption of Lean Manufacturing Practices (LMPs). For an implementation of Lean manufacturing practices, the utilized attempted Behavioural Reasoning Theory (BRT) for representing behaviour reasoning outlook of MSMEs employees for execution of lean implementation. The relationship between employee values, reasons, attitude and behavioural intentions for LMPs execution was investigated. The study also analysed the effect of education level of employee on LMPs execution. The cross-sectional survey conducted on 299 Indian MSME employees, investigated through SEM approach and hypotheses analysis. Positive and negative impact both analysed regarding behaviour of employees impacting lean LMPs. The outcome of the study revealed that RF has significant positive impact on both attitude and intention, but RF signify positive influence on attitude not with intention. This study is not generalized to other industry and country. This study is performed on cross section data, which shows biasness on social aspects. This gap needs to further analyse [193].

Chaple et al., (2021), prioritized and analysed the barriers related to lean for better awareness and explanation. The Total Interpretive Structural Modelling (TISM) approach was used for effective implementation and validation of lean. The outcome of the study revealed that, 'in-sufficient time-management, supervisory and management skills' are identified significant barriers with highest driving power and lowest dependence. The cost and funding related barriers are observed to be less significant. In this study, only ten lean barriers are identified, there is need to recognize more barriers for developing TISM model, other MCDM approach can be exercised and compared with this study for effective lean implementation [194].

Singh et al., (2021), identified 12 barriers for adopting Green Lean practices in manufacturing industries using DEMATEL approach. The impact of barriers was analysed by cause-and-effect diagram and further categorized for analysis of inter-interrelationships between barriers. The outcome of the study revealed that, 'resistance to change', 'lack of top management', 'lack of training to employees' were observed most significant barriers having threshold value 0.134 obtained after analysis. The study manifest that, there may be biasness in developing model, as inputs were taken from experts. The further gap in this study was observed that, the barriers used for the analysis are not from a specific type of manufacturing industry. Therefore, large numbers of barriers for specific type of industry is needed for effectiveness. Moreover, another MCDM technique can be useful for identification and ranking of barriers in green context [195].

Singh et al., (2020), analysed the barriers of GM implementation in Indian small and medium scale manufacturing units. Total, 20 barriers were identified and bucketed into six mains latent challenges using factor analysis, which further ranked using VIKOR technique. The outcome of the study revealed that, 'economic constraints' found to be major barrier in SMEs. This study is only confined to small scale industries, which is major limitation and not applicable to large scale industry as parameters are likely be different [196].

Sodhi et al., (2020), identified the various barriers in the execution of waste management techniques in manufacturing units. The study assessed the relative impact of barriers in the technique of waste management in manufacturing units, by surveyed in 121 SMEs of the manufacturing sector. The research used Analytical Hierarchy process (AHP), for identification of weight of significant criteria. The gap in this study is that, the ranking of significant barrier need to be explored by use of other MCDM technique and implementation in real scenario [197].

Yadav et al., (2019), analysed Lean Implementation Barriers (LIBs) in SMEs through three case studies. The ISM approach for modelling inter-relationship amongst lean implementation barriers wase used in research work. The study revealed that, 'lack of management commitment, leadership and resources' are the critical barriers for lean implementation in SMEs. The study also highlighted that poor communication at different level of organization and in-adequate knowledge about lean benefits also create obstacle in implementation of lean. The study revealed that, empirical analysis is required for generalization of findings [198].

Ramadas (2018), presented the factors linked with employee barriers, while executing lean manufacturing in SMEs. The barriers for lean implementation were identified through detailed survey of 133 SMEs and further analysed using Structural Equation Modelling (SEM) approach. The outcome of the study revealed that, 'lack of well-trained and experienced staff', 'lack of knowledge about existing specialist', 'cultural resistance to change' are acting as the employee barriers, while implementing lean in SMEs. Further, the employee model was developed using fit function criteria based upon above mentioned barriers. The results revealed that the external professionals are essentials to overcome the barriers for successful implementation of lean in SMEs [199].

Zhang et al., (2017), identified and evaluated lean barriers with respect to level of importance in execution. The lean barriers and performance measures were analysed through Interpretive Ranking Process (IPR) approach. The outcome of the study revealed that the organisation should provide sufficient time and training to employees, inculcate conducive culture, foster effective communication, focus on low-cost production for successfully implementation of lean. The study highlighted that, empirical investigations need to carry out for identification of the most important lean barriers and measures of performance for testing of this model [200].

Almeida et al., (2015), introduced a framework for managing barriers for Lean Production Implementation (LPI) in specific company in five stages. The framework was developed by using ISM technique. The developed framework was validated through case study in manufacturing plant. The data was collected through interviews, observations and analysis of documents. The outcome of the study revealed that proposed framework contributed as perspective theory related to LPI. The gap observed in this study is that, the developed framework in not tested in cyclic process. Further, framework was tested in an environment having long term experience about lean, so identified barriers may not likely influence at present time. Therefore, frame work need to validate in better and new perspectives [201].

Jadhav et al., (2014), identified 24 lean barriers through peer reviewed journal articles and other sources. The study highlighted that the success of lean implementation is not entirely dependent on lean tools and techniques, but involvement of top management and leadership, attitude of workers, utilization of resources and culture of the organisation. In this study, only barriers are identified and there is still further scope for development of manufacturing strategy for successful implementation of lean approach. The interaction among the barriers also need to analyse using MCDM techniques [202].

2.6 Literature pertains to Lean-Green Integration and framework

This section is re-presenting review of literature relating to Lean-Green integration and framework in the manufacturing context and other sector for operational benefits. The brief explanation of the review is manifested as follow:

Singh et al., (2022), evaluated integrated framework for execution of LG practices to conquer barriers in manufacturing industry. Total 20 sub-barriers are identified under six categories and proposed fuzzy AHP and fuzzy TOPSIS based framework. In this study, barriers are divided into various categories such as, managerial, technological, cultural, individual and quality barriers. The outcome of the study revealed that, application of QC tools, use of first-time right methodology, adoption of advanced technology, innovation in product are most significant solutions to conquer barriers in execution of LG integrated approach. Limitation of this study is that the study is conducted in automotive sectors. Therefore, findings cannot be generalized as barriers and solutions might change in different manufacturing sectors. Further, uncertain and dynamic environment and technological advancement might differ for selection of barriers sand associated solutions [203].

Singh et al., (2021), identified 12 CSFs for Green-Lean Practices (GLPs) implementation in manufacturing industries. The study established relationships amongst 12 identified CSFs with the use of ISM approach. The identified CSFs are further analysed using MICMAC approach for dependence power and driving power. The outcome of the study revealed that, 'Top Management commitment', 'Government support', are most significant CSFs for integrated GLPs. However, further study is required for statistical validation of this method and testing in real world scenario in manufacturing industries Moreover, this study is based upon general manufacturing industries; further study is required for specific industries [204].

Moro et al., (2021), identified Lean and Green strategies to design eco-efficient Product-Service Systems (PSS) for using sustainable production patterns. LG strategies were grouped using content analysis to add value in PSS design according to their eco-efficient potential. The outcome of study revealed that, PSS allowed multiple life-cycles and enabled strategies that considered the value of flow, design efficiency and improved longevity. The proposed construct manifests, how organizations can initiate the PSS design using LG strategies systematically for allowing green consumption. However, an empirical study is required to verify the proposed theory to develop a real PSS solution based upon integrated LG strategies [205].

Ferreira et al., (2020), presented a conceptual framework related to LG practices, indicated the convergent and divergent points between them. The final constructs demonstrated the positive impact of LG combines and their influences on other variables related to environment. The study also illustrated to focus on waste reduction and waste reduction techniques concept integrated with LG practices. However, social aspect is not considered in this conceptual model, which need further investigation for understanding the sustainability of LG integration [206].

Bhattacharya et al., (2019), highlighted the synergy between LG and exhibited that, LG shares the common features. The study revealed that integration of LG boosts the performance outcomes of manufacturing operational system. However, study also highlighted that the association between LG and sustainability performance is not always follow a straight path. The variations are due to different criteria under investigation. In spit, the commonalities between two concepts, but integration do not exhibit perform automatically. The overall impact is regulated by various contingencies. So, contingency factors contributing to sustainable performance require for further scope of the study [207].

Siegel et al., (2019), identified and analysed through SLR the challenges, success factors, tools and techniques used, frameworks with sustainability aspects and advantages of LG in SMEs. The outcome indicated that most significant challenge to LG execution is, 'lack of matrices and measurements.' The 5's is considered is most significant tool for achieving excellence. The study also investigated that, the merging of three dimensions of sustainability parameters with continual improvement initiatives helped organizations to utilize and sustain as benefits of LG concepts. The study focussed that, the constraints in resources, support, involvement of employee are critical parameters for implementation in SMEs. This study exhibited the conceptual view of LG and sustainability. Understanding and application of LG and sustainability need to study further. A took-kit along with a comprehensive and simplified LG framework needs to explore [208].

Choudhary et al., (2019), exercised Green Integrated Value Stream Mapping (GIVSM) tool through a case study approach in UK packaging manufacturing SMEs. The study revealed that integrated deployment of LG having synergetic effect, which exhibited benefits in operations and environmental performance. The study also proposed CI (Continuous Improvement) framework with sustainable procurement to conquer LG misalignments. However, this case study is confined to SMEs, so further more case studies are required in industries to realize the synergetic benefits of LG practices [90].

Inman et al., (2018), exercised SEM technique to test the hypothesis to know the effect of lean practices to environmental performance in manufacturing unit located in US. The outcome of the study indicated that there is direct relationship between lean practices and environmental performance. However, analysis of contingency factors relating to integrated LG practices / strategy, which are affecting performance, and addition with intangible factors, are further scope of this study [209].

Duarte et al., (2017), developed a framework of Lean-Green supply chain of an organization which includes criteria, guidelines and scoring method relating to lean and green initiatives. The conceptual framework was validated with multiple case study approach of five different organisations in automotive industry. The outcome of study revealed the high score are obtained from interaction of LG execution in these companies. This study is only restricted to automotive sectors and from supply chain perspective. Therefore, further study is required for other manufacturing sectors including another function in organisation' value chain. [210].

Hallam (2016), investigated the association between Lean and Green management in the view of developing integrated model using PRISMA approach. The study highlighted that both qualitative and quantitative articles are documented. The outcome observed push relationship between green and lean synergy. The study also manifested that the documented model is not exhaustive and complete, thereby exhibit weak association. Therefore, further study is required for expanding new knowledge in the area of LG combined for enhancing performance of the organization [111].

Fercoq et al., (2016), presented quantitative study of LG integration, which focussed on reduction of wastes in manufacturing operational processes. The techniques of waste reduction are considered as overlapping between Lean and Green perspectives. The study used Design of Experiment (DOE) tool for measuring the influence of various methods obtained from LG integrated approach on management of solid waste. The outcome indicated that, the '3R' hierarchy of progress factors on waste elimination programme was analysed using ANOVA, exhibited improvement on solid waste reduction. The study measured the degree of compatibility between Lean-Green and their combined impact on performance. However, use of waste reduction techniques can be further scope of study for improving energy efficiency and reduction in water consumption [114].

Garza-Reyes, J. A. (2015), identified and structured, 6 prime streams of research through concept map, which incorporates both conceptual and empirical research within the context of industry and function of the organization. The study suggested for in-depth analysis for better awareness of relationship and impact of LG initiatives on organizations performance [104].

Greinacher et al., (2015), presented simulation-based technique for tangible evaluation of Lean and Green manufacturing systems considering non-monetary sustainable limits. The consumption of material and energy were combined for simulation. However, the detail development of this approach combined with generic optimization algorithm to identify the ideal combination of both LG strategies in manufacturing systems is further scope of this study [211].

Pampanelli et al., (2014), proposed a new Lean and Green model, in which Green issues for environmental sustainability integrated with Lean thinking using kaizen approach suggested. The adopted approach focussed on improving mass and energy flows in manufacturing operational environment. The developed model investigated for potential benefits of integrated LG thinking for waste reduction and found beneficial. The outcome of the study revealed that, LG model helped to reduce resource use from 30 % to 50 % on average and reduction in total cost of mass and energy flows in cells by 5 to 10 %. The scope of study to extent in entire value chain for realization of more benefits of this integration [75].

Galeazzo et al., (2014), used case study methodology to observe, how LG practices interact and yield maximum synergy for improving operational and ecological performance of manufacturing organisation. The outcome of the study revealed that Lean and Green practices can be used sequentially or simultaneously. The outcome was observed based on analysis of three pollution prevention projects in two firms. The study investigated that, by use of sequential and reciprocal interdependencies, pollution prevention project can be blended with combination of LG practices. Operational excellence is the outcome of integration of LG implementation. However, this study does not provide useful information about the moderating effect at plant level attributes. Further, qualitative analysis is required for understating the moderating effect for operational performance due to integration of both paradigms [212].

Fercoq et al., (2013), presented a model for waste management as an application of Green concern to Lean manufacturing. The study highlighted that the combination of two concepts leads to waste reduction. Three levels framework for optimizing the waste reduction / minimizing programme is presented in this study. The level 1, consists of 'integrated process improvement'. The level 2, consists of 'integrated tool kits and strategic matrix'. The level 3, consists of 'advanced 3R'. However, study suggested, there is need to perform statistical analysis to demonstrate the eco-efficiency and impact of advance 3R for better realization of integrated LG strategies [213].

Duarte (2013), examined how different business models, standards, frameworks can support for modelling of LG approach in organization. The study suggested few guidelines to connect and integrate LG principles, which were emerged after analysis of 12 business models. The study identified the model, that influence on LG culture and proposed LG model of transformation, for better awareness of model and data. The study considered issues pertaining to the environment, societal, safety, quality and innovation. This suggested model provided the guidelines only, need to further explore by use of tools and technique with qualitative approach, such as; exploratory case study etc. [100].

2.7 Research Gaps

Built on the conclusion drawn from the systematic review of literatures, the following research gaps have been identified.

- As Government of India has set a target to take India's GDP by $5 trillion by 2025, much focuses are on agricultural growth by enhancing the quality of life of our farmers. So, Farm equipment sector should be able to support to Govt policies by making their product competitive and economical. But no study found on competence level of Tractor manufacturing in literature.
- Due to rising concerns of environmental pollution globally, Govt. of India has set a target for tractor industry for TREM Stage V, which will be applicable from April '2026. So, there is no specific study available for validating the process in Farm equipment sector for environmental viability.
- To provide cost effective and competitive product to customer and, meeting environmental norms, there is need for research study for an improvement in processes in Farm Sector to bridge the Gap.
- There is hardly study available, which exhibit implementation of integrated Lean-Green approach in Tractor Industry in Indian context for achieving operational excellence.

2.8 Research Objectives

Based on the literature review and above-mentioned research gaps, the following objectives are articulated.

- Identification and analysis of Lean Green strategies critical success factors in the tractor industry.
- Identification and analysis of Lean Green strategies barriers pertains to the tractor industry.
- To develop an integrated lean green strategies framework for achieving the competitive priorities in the Indian tractor industries.
- With a case study, to evaluate the competence of Lean and Green strategies for ameliorating the Indian tractor industry.

CHAPTER-3
RESEARCH METHODOLOGY

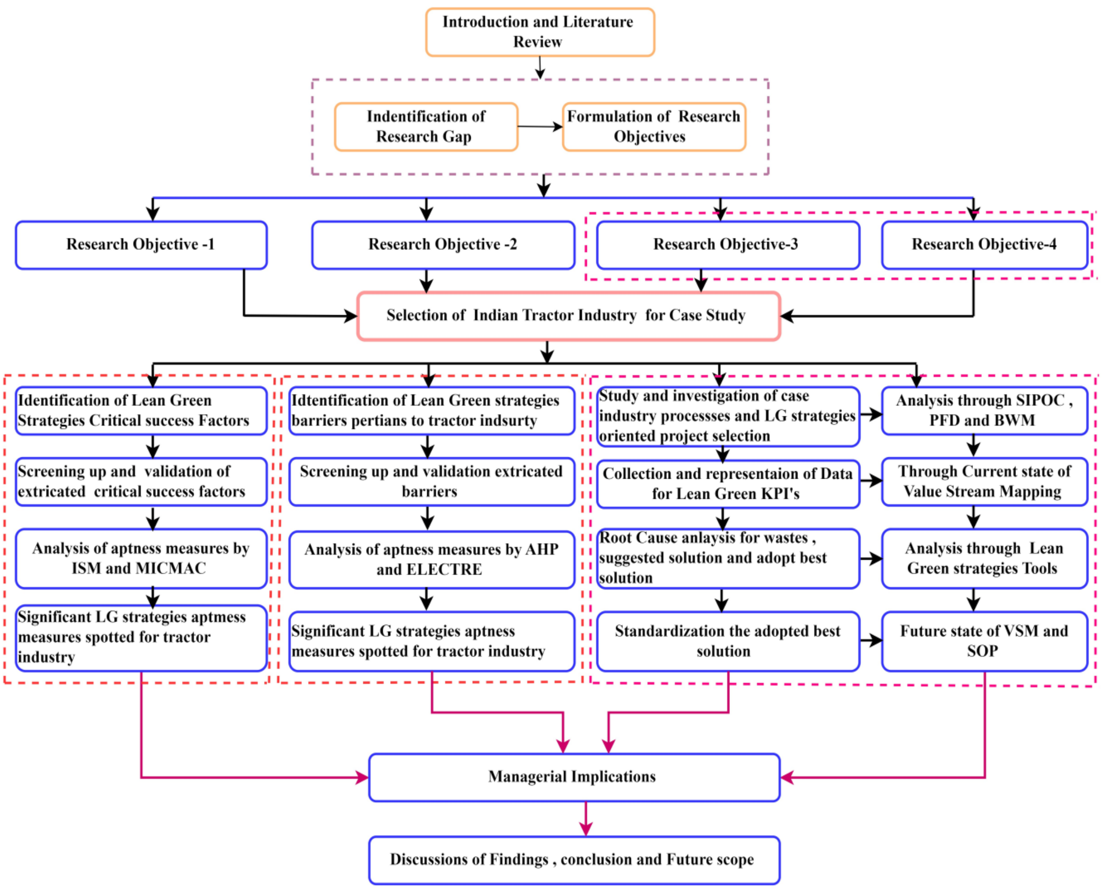
Research Methodology (RM) is a series of sequential steps in research study which are commonly carried out by an investigator in analyzing research challenges and reasons behind it. This chapter presents an analysis of problem and research design flow with LG tools used to conducted this research study.

3.1 Analysis of Problem

In current dynamic and competitive environment, emerging of cutting-edge technologies and meeting environmental regulations for future generation, the Tractor Industry in India are facing challenges for meeting norms and remain competitive. To overcome these challenges, there is need to design and improve their operational processes, which could produce economic, environmental-friendly product to customer with on-time delivery and inbuilt quality standards. Apart from this, guidelines from Government of India to design and produce Farm Equipment', which could provide farm solutions to farmers for agricultural growth [214]. Agriculture is backbone of our economy and 70 % of Indian populations are directly or indirectly engaged with in agricultural [215]. Moreover, the living standards of our farmers are poor in financial and societal status and having fragmented lands in families, which creates more challenge before the industries [216]. Government of India has launched various schemes for uplifting the life of our farmers, but support is required from Tractor Industries for realization of agricultural growth exponentially by robust product design with advanced features along with farming solutions. Keeping the above challenges in mind, getting insight about benefits of LG and gaps identified from SLR was considered for analysis of problem. The problem related to competence of LG strategies was to reduce resource waste, eliminate rework and rejection, and the reduction in ecological footprint was analyzed. An aim for taking the problem under consideration, pre-dominantly LGSFs and LGBs are identified for effective execution of LG approach. For addressing the concerns related to current investigation, LG framework was formulated and its realistic validation was conducted within in an Indian Tractor Industry through a case study.

3.2 Research Design

The design of research work is the objectively articulated, analytical flow chart that demonstrates the various sequential phases used to achieve the ultimate objectives. It consists of an investigation methods, evaluation and valuable resources needed for implementation. The appropriate and expected results will only obtain, if the research design is all-inclusive, as much as, ‘must have’, requisite information. A definitive and robust research design is formulated for the current case study and manifested with the help of flow chart in Figure 3.1.



Figure—3.1 Research Design

In phase 1, of research design work, a detailed SLR on Lean Green Success Factors (LGSFs), Lean Green Barriers (LGBs), Integration of LG and framework carried out to reap the research objectives. SLR utilize crystal clear and definitive approach that consists different phases to ensure that preciseness and clarity can be collected in the Literature Review Process [217]. From the comprehensive literature review, gaps in research work pertaining to LG approach have been determined and in accordance with, the objectives of the research study are articulated.

In next phase, a Tractor Industry was selected as a case industry for addressing the challenges in the implementation of LG approach and validating the developed framework. In spite of the progression of LG strategies, industry managers were not confident to adopt this approach within organization due to readiness inadequacy and fear of failure. LGSFs are the prompt measures that give expression to an organization to execute any progressive technique. The LGSFs not only influence the effective execution of LG within the company, but have an effect on each other also. Therefore, it is essential to recognize an interactive relationship amongst LGSFs for an identification of determined CSFs. For this, LGSFs have been identified using review of literatures and further tested by the use of opinion from experts. To signify the contextual relationship amongst LGSFs, Interpretive Structural Modelling (ISM) had been exercised in this research work after screening in the manufacturing plant, which shows an inter-dependency [218]. These were further grouped using MICMAC analysis for prioritization, progressively achievement and comprehensively implementation [219].

Along with LGSFs, it is vitally essential to recognize LG barriers with in sustainability criteria. Initially, LGBs were identified through Literature Review, then modelled for ranking through criteria's weight calculations using AHP approach [220]. Afterwards, outranking of barriers was analyzed through ELECTRE approach [221], for smooth execution of LG strategies program. Despite the fact about the progression of LG approach, very few advocations turned out to be for the actualization of this approach in sustainable environment in Indian Tractor Industry.

In the last phase, the key logical thinking for few advocations can be assigned to inadequacy of Green, Lean, and Lean Green integration, and frameworks execution. For this reason, comprehensive integration of LG strategies was determined based on theoretically elements and LG five phase dimensional framework rooted with various LG tools was established. Conclusively, to validate the effectiveness of LG approach in measuring and improving various KPIs of LG strategies, the proposed framework was tested practically in a real-life in Tractor Industry. Based on the execution of LG approach in the case industry, inferences were extracted for the professionals, researchers, and industrial managers.

3.3 Integration Measures and Conceptual model of LG strategies

The LG strategies have acquired adequate attention in recent past due to its potential to increase productivity, bottom-line profitability, and mitigate environmental risk [222].

The Green, Lean, and integration of Lean and Green are three recognizable techniques, and are synergetic as, all-together focus on reduction of waste and effective utilization of resources. As a result, the comprehensive principles and toolsets of both techniques can be unified under the canopy of a one approach called LG strategies. LG approach is an all-inclusive approach that focus to accomplish improvements in the processes, economics, operations, emission and pollution [111]. The synergetic LG strategies can be established as new revolution to Industrial farm organizations for achieving competitive priorities under external and internal environment, for which the conceptual LG integrated model is depicted in Figure 3.2.

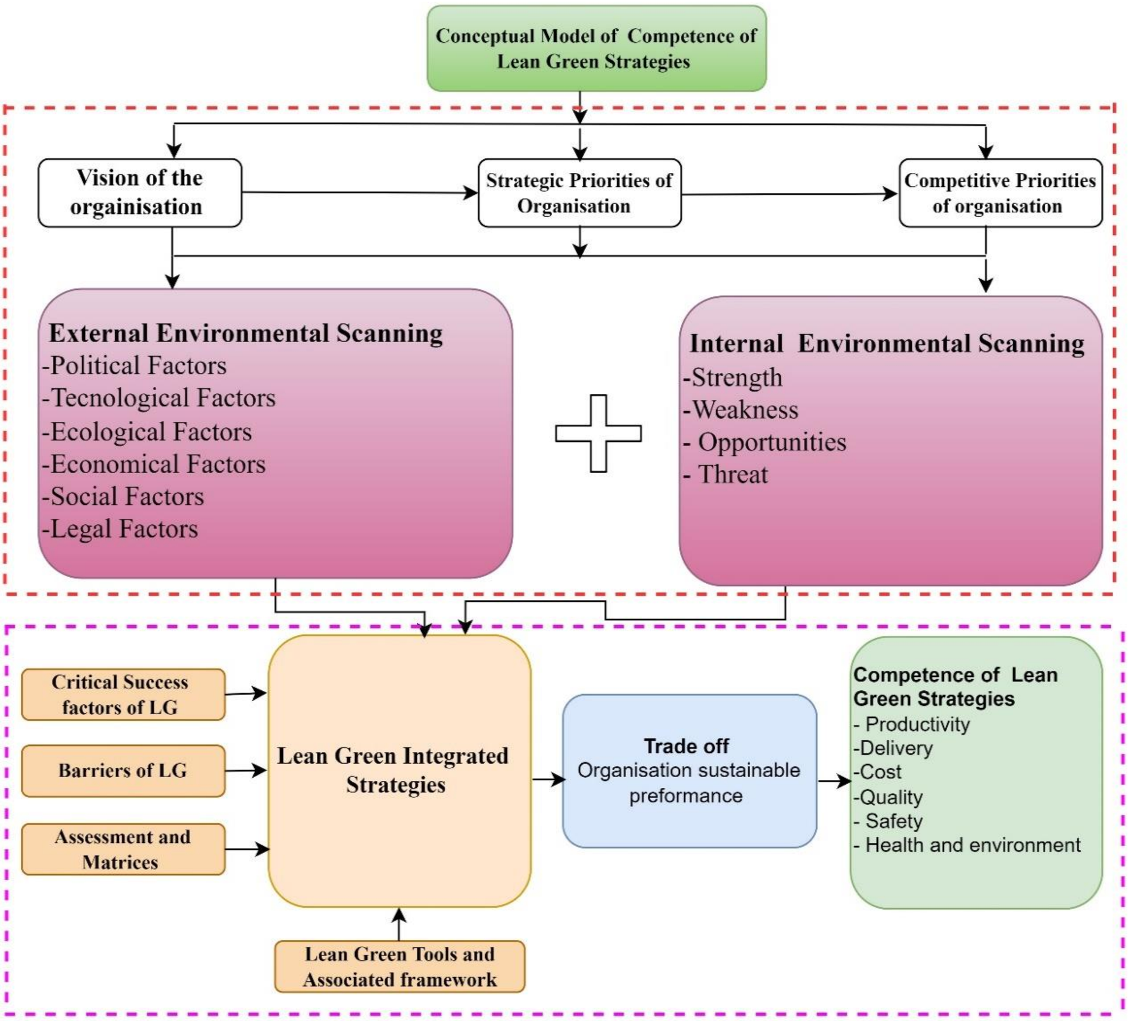


Figure 3.2— Integration Model of Lean Green Strategies

The companies who have practiced LG approach are likely to have better performance indicators than those executed with individual technique [223]. In the literature, no structured and comprehensive method for the integration of the LG strategies linked with strategic and competitive priorities of an organization along with associated internal and external risk persists. The current work suggests a conceptual integrated model of the LG strategies. The main aim of integration model is to characterize the key facts required for industrial organizations to enhance ecological achievement. The suggested model signifies the conceptual resemblance amongst Lean and Green. The CSFs act as the significant inputs that encourage the integration of LG strategies, while the output consists of competence of LG strategies. The challenges for the LG integration are the restrictions that limits the organizational activities to improve the dynamics of sustainability. The LG tools and associated LG frameworks considered as the supporting mechanism that encourages the integration and execution of LG strategies.

3.4 Proposed Framework of Integrated LG strategies

Owing to raising awareness and understanding along with strict environmental regulations by Government, organization needs to shift their operational activities which are eco-friendly and sustainable. This calls for unification of both individual approaches to development of integrated approach as 'Lean Green Strategies'. But for execution of comprehensive LG strategic approach, there is requirement of exclusive framework that provides sequentially ground rules for accomplishment of sustainability. The sequential steps of proposed LG integration framework shown in Figure 3.3, can be adopted by operational industry and service industry as well. The suggested LG integrated framework has been exercised in five sequential steps mentioned below.

Step-1: Selection of Ecological-Focused LG Manufacturing Strategic project

The starting step of the LG integrated framework is to identify a suitable project grounded on the level of waste like DM water, power consumption, and other wastes like Rework, rejection, wrong fitment of parts and economic, social sustainability of industry along with recourse utilization. BWM (Best Worst Method) technique [224], was used for selection of LG strategic project, under various LG criteria and associated sub-criteria. The process was further analysed through SIPOC and Process Flow Diagram [127]. Project Plan in term of Project charter was prepared for depicting LG Project implementation strategy [225].

Step-2: Collection of Data for LG KPIs by assessment of current state of Project

The second step of the LG framework deals with the assessment of the current state of project under study. Here the outcome of the chosen LG project is measured against the several key process matrix elements of LG. For an assessment of the current state of various linked wastes, the Lean Green value stream mapping (LGCVSM) [84], serves as an effective LG tool. LGCVSM come up with an estimation of TAKT time [226], Value added time (VAT) [227], Water and power consumption [228], covering the all process stages.

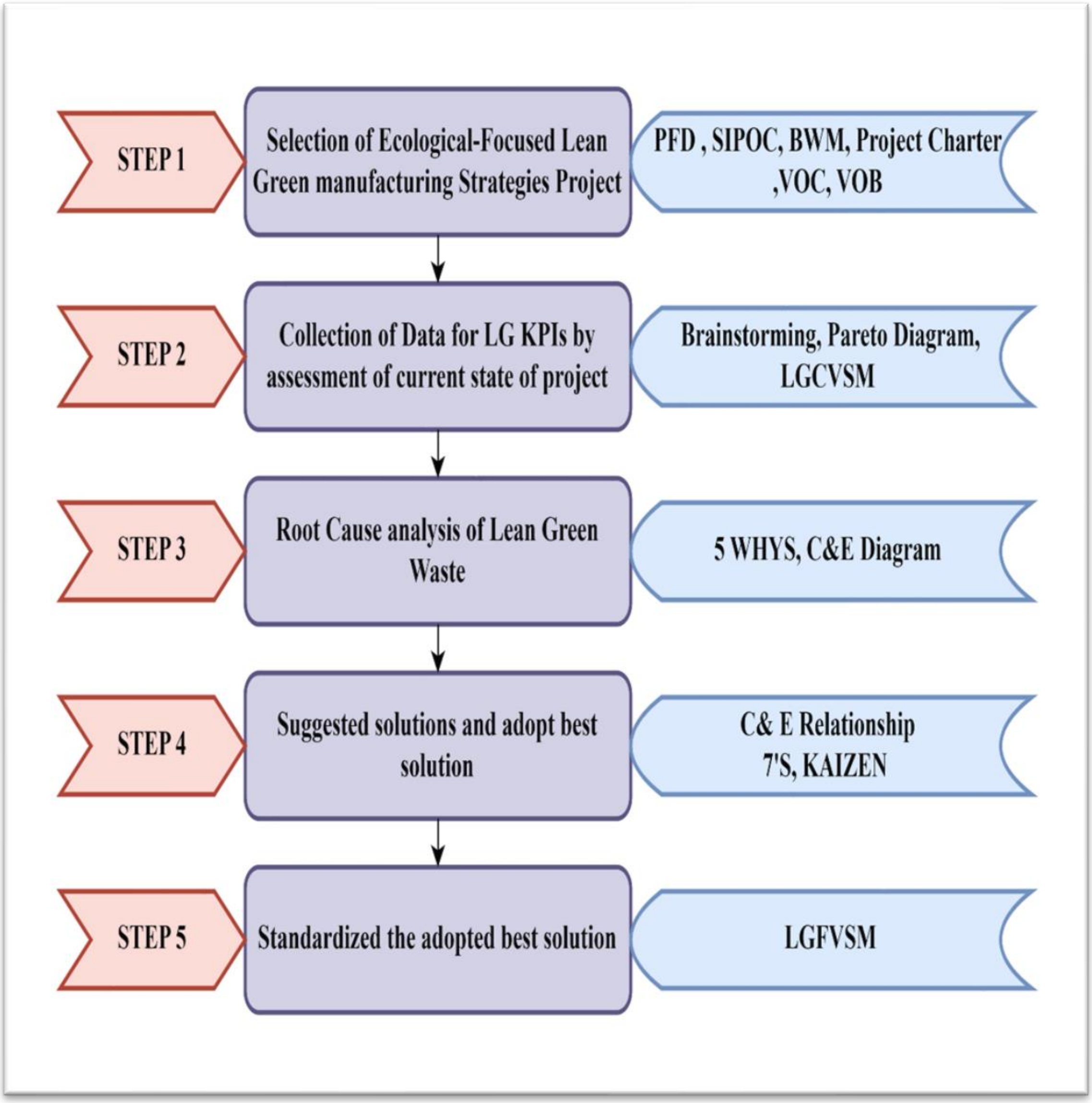


Figure 3.3— Sequential Steps of Proposed LG Integrated Framework

Step-3: Root cause Analysis of LG Waste

The next sequential step of the LG Strategic framework relates to find out the principle causes leading to high wastes, emissions and defects in the processes associated with selected project. In this step, Initially, VA (value-added) and NVA (non-value added) activities are determined, both from the view point of customer and business [229]. The proper investigation of the project is built to identify bottlenecks areas and an obstruction in the chosen project. After the detailed and comprehensive investigation of the project under study, then the feasible causes for the wastages, pollution and emission and defects / rework are realized. The Lean and Green tools such as, Process Failure Mode Effect Analysis (PFMEA) [230], five whys investigation [231], Cause and Effect Diagram [232], 5's [53], etc. are exercised at this point of time to draw the prospective causes for the observed defects. Once the feasible causes have been investigated, a search is now restricted to discover some leading causes for project in-efficiencies. The tools like Pareto chart [233], brainstorming [234], Grey Rational Analysis [235], 7 QC tools [236], etc., are exercised at this point of time to detect the prominent root causes. Therefore, main causes of in-efficiencies were explored in this step, which needs to take forward for an improvement.

Step-4: Suggested Solution and Adopt Best solution

Once the prominent reasons for wastages and in-efficiency have discovered, prospective solutions are suggested, tested, and the best solution is exercised to getting benefits after eliminating the prominent reasons. The Cause and Effect (C & E) relationship, process mapping is exercised at this point of time to find wide range of prospective solutions. After selecting and adopting the best possible solutions, the current LGVSM is revised to reveal, what the process will appear subsequent to changes are formed. The best solution is now pioneered as a model solution. The performed tasks are well-documented, and persons involved in pioneered activities are well-trained in various facets of the model solutions.

Step-5: Standardized the Adopted Best Solution

This sequential step relates to sustaining or controlling the model solutions, if the significant improvements are standardized by the current system or process under study. The whole process is re-examined by use of LGFVSM to draw out the waste level, reduction of pollution level and solution is sustained. An audit check-sheet is also initiated to identify a suitable solution. Once best solution for the selected project has sustained for a long period of time till next improvement, the same is embarked in other sections of the plant. The comprehensive execution of LG strategies in the case industry leads to sustainability improvement by achieving competitive priorities through the competence of LG strategies in Tractor Industry.

3.5 Lean Green Strategic Tools

In the suggested LG Strategic framework, the LG tools adopted in this research work are briefly described as follows:

- **Voice of Customer (VOC)**: VOC [40], is a substantial LG tool used for accumulating the view-point of end-users internally or externally regarding the product and process. Every business entity survives by virtue of its customers, who is whole-heartedly willing to pay his /her hard-core money for the product, as he or she admires the value for money in the product. If any organization desires to execute LG integrated framework, the few questioning are crucial to be craved and look forward to get the solution by personal interviews. Why should customers buy our product? What value is giving by product to customer? Initialy, find out customer's reaction/ response to the product and then accordingly, need to give logically thought about the measures that could be beneficial.

- **Voice of Business (VOB)**: Voice of business [40], is the term used as expressed or unsaid, want or must (Qualitative or Quantitative), expectation and preferences of the all stakeholders who run the business, such as shareholders, persons involved in corporate governance etc. Sources of VOB data are financial and market analysis, competition analysis, Survey from employees etc.; Return on investment and share on equity are some of key performance indicators. Further, VOB as an internal process that are required to support the processes that navigate value for the customers. For examples, requirement here is zero defect, zero waste and employee motivation. Therefore, for getting the value for the customer, VOC and VOB should be used together.
- **Brainstorming**: Brainstorming is a tool, which is used for an improvement activity. This activity is exercised in group, as involved persons furnishes his / her ideas as soon as strike in mind. It was presented by Alex Osborne in 1930s. This group activity is using prompt suggestions from individual team members to swiftly bring out huge number of suggestions relating to possible causes of specific problem / concern. Psychology says, ability of human mind as an individual is limited, but more ideas can be accumulated with the involvement of group of people. The prime objective of this problem-solving technique is to dispense criticism free environment for creative exploration of solutions. This technique has potential and ability to discover spontaneous and passionate ideas. Therefore, it can lead the way to novel and innovative solutions to the problems and higher chances of accepting the suggested solutions. Brainstorming dispense immediate responses, active and full participation of team members and prone to provide input to other tools for an improvement.

Steps to Effective Creative Brainstorming are as follow:

1. Define the problem you want to resolve. It looks like common sense, but team must clearly know the problem definition.
2. Fine tune your objectives.
3. Create possible solutions individually.
4. Collectively explore the most effective solutions.

- **Project Charter:** A project charter is a proceeding of the complete project work plan displayed in a tabular form. Table dispenses crystal-clear details and guidelines related to objectives of project, details illustration, scope of the projects, advantages, deficiency, tools and techniques to be exercised, schedule of project and end-product. It also furnishes the experts' details, suppliers, stake-holders, program coordinator, customers, project target date, roles and responsibilities of cross functional team members, project start and closing date. Comprehensively, project-charter is having all adequate piece of information related to project from origin till end. This may be used as an internal-benchmark for inscribing the project in future.
- **SIPOC diagram**: SIPOC chart records all the detailed facts related to complete manufacturing operational process of particular product from origin till end, which is outlined in the form of a Supplier, Input, Process, Output, and Customer. This diagram is appropriate for imparting comprehensive visualization of the product starting form raw material to end-product.
- **Process Flow Diagram**: Process Flow Diagram (PFD) is graphically way to describe the flow of process, associated elements / activities in sequence. Process flow diagram assists with brainstorming and communication of design of the process. This is very effective visual diagram for understanding the tasks in process sequentially and associated outcome. The tool also helps to understand valuable, non-valuable activities, wasteful outcome and current control measures for an improvement planning.
- **Value Stream Mapping**: Process mapping is a critical and decisive step in the LG strategic project. VSM, deploys a flow diagram of every steps of the process. VSM is an essentially fundamental tool to recognize waste, reduction in cycle time / Takt time of the process and execute improvement in processes. More importantly, VSM' utmost priority is for mapping the current process. Using

VSM, it is easy to investigate material flow and information exists in current state and identify for improvement opportunities during the process. There are four steps involved in VSM process. 1) Determine the family of the process with define the objective and scope 2) Draw the map of current state of the process to identify wastes, in-efficiency and area of improvement 3) Determine and draw the map of future state of process and create an improvements action plan to understand how the product will look like after an improvements 4) Compose a plan to arrive at future state with customer and supplier icons.

- **Cause and Effect Diagram**: C&E diagram is a graphically improvement problem solving tool used to investigate the possible cause of particular effect. The motive behind this diagram is to assess the number of imperfections appearing in the product/Process and explicate the real source of imperfections from which they are revealed. This diagram displays different categories for root cause identification such as, the impact of man, material, method, machine environment, on statement of problem in the operational sector. The cause and effect diagram also better known as a fishbone diagram or Ishikawa diagram, because of its finally appears as skeleton of fish. This diagram is investigated by figure and facts arranged at each characteristic and forms actionable items.
- **Pareto Chart**: Pareto chart are frequently used to identify areas to focus on priority in the improvement of process. The chart is based on the ‘80/20’ rule, which means 80 percent of issues (Outcomes or outputs) appear due to 20 percent of all causes (Inputs) for any given event. This investigation is used for ranking the problem graphically from the most repeated down to the less repeated. Based on investigation, the pareto chart is formulated, which is visualization of combined bar and line. The individual values are reflected on bar and cumulative value is reflected by line diagram. The most critical problem can be recognized very easily, assisted by Pareto chart. For articulation of Pareto chart, a minimum of 6 to 8 past data is required for predicting real problem at glance.
- **FMEA**: Failure Mode Effect Analysis (FMEA) is a systematic and structured problem-solving technique to examine the prospective failure that may present in the design or process of a product. "Failure modes" signifies the way in which product may fail. Failures are errors or defects in process or product, indicates

the way in which these leads to generation of waste, especially when it affects the customer, which can be potential or actual failure. “Effects analysis” relates to the impact of these failures. In totality, failure mode and effect analysis are considered to recognize, ranking and compelled these failure modes. In FMEA Study, there are vital Likert scaling (1–10) of severity, occurrence, and detection. The severity is given as ‘1’ for almost negligible severe and ‘10’ for most severe, occurrence is rated as ‘1’ for not occurring and ‘10’ for very high occurring, detection rated as ‘1’ for easily detectable and ‘10’ for difficult to detect. Apart from this, the Risk Priority Number (RPN) is calculated using Equation (3.1), and prioritize the improvement actions to reduce the failure risk from high to low RPN.

$$RPN = Severity \times Occurrence \times Detection \tag{3.1}$$

- **7’S**: It is a technique originated from Japanese used for an improvement for creating a self-sufficient and self-sustaining work place culture, which preserves a clean and well-regulated working station and pull out all surplus items from the working area. The arrangement and fixing of essential items in such a way, that they can be easily to locate, use and sustain. This is 7 steps methodology, which stands for Sorting, Set-in-order/ Straighten, Shine, Standardization, Sustain, Safety and Sustainability. Sorting means assessing the working area and discarding unnecessary items, which cannot be used in the process and ensure to have only those items, which are essential to be available in working area. Set-in-order / Straighten stands for organizing the items, which have left over after sorting process, also incorporate thinking of end-users related to modifications in design resulting improvement in quality. Keeping the things at designated place after working, makes working smooth, creates all flow easy and safer working place. Shine aims to the keep working area clean all the time and inspect the working area on regular basis. The items used during the working should be keeping back to original place at the end of working for ease in traceability. Standardization stands for working operating practices in stable and standardized way to obtain the end-results. Sustain stands for cultivating the well-established process in previous four steps for longer duration of time. Sustainability and Safety stands for creating the working process and working area environmental -friendly and Safe to work respectively.

- **Kaizen:** Kaizen is Japanese philosophy and a strategy of process-oriented approach for continual improvement in the processes, thereby making process robust by involving all the employee of organization. It is top-driven approach and flow down to worker's level. It works on the principles of 1) Knowing your customer, 2) Let the flow as it is, 3) Go at Gemba and observe the process 4), Giving empowerment to working employee 5) remain crystal clear and transparent. It endorses the concept, that small-small improvements may bring many huge improvements in the processes. It is used in little changes in existing plant layout, scientific methodology with use of analytical tools, commutable framework of company's ideals, management and workman thinking for achieving on zero defects. It is never-ending process with continual improvement and creates basis for innovation as well.

3.6 Multi Criteria Decision Making Methods

Multi Criteria Decision Making (MCDM), is a structural approach for resolution of research problems. The approach encompasses outcome extracted from multiple objectives (criteria), which required to be considered all-together for ranking and choosing amongst the criteria [237]. This decision-making approach provides and leads to counteract the available information to obtain expected solution. These methods need to have pair-wise comparisons among each chosen criterion and accommodate appropriate deliberations. The crucial elements need to make conducive decisions relied on MCDM structural approach includes, selection of criteria, each criteria's weight, available substitutes, measuring the performance against criteria. MCDM approach imparted highly effective outcomes in complex decision-making activity in an industrial environment. MCDM approach classified as multi-attribute and multi-objectives method of decision making. This approach has enough competency to surface out the best possible alternatives from available resources within the plant. In current research work, various MCDM techniques Such as ISM (Imperative Structural Modelling), MICMAC (Cross Impact Matrix Multiplication Applied to Classification), AHP (Analytic Hierarchy Process), ELECTRE (Elimination and Choice Expressing Reality) and BWM (Best Worst Method) have been exercised to perform the case study in real application. Afore-mentioned approaches have been executed under Fuzzy-logic environment.

CHAPTER-4

INVESTIGATION ON CRITICAL SUCCESS FACTORS OF LEAN-GREEN APPROACH

The present chapter aims to explore the Critical Success Factors (CSFs) of Lean-Green (LG) practices and establishing a relationship in context of Indian Tractor Industry. LGSFs are the readiness estimates that help and support an organization for gearing-up to implement a new innovative approach for attaining competitive edge [238]. This chapter outlines key SFs of LG strategies and dependent relationship among the LGSFs using ISM and MICMAC approach. The outcome of this research work assists to industrial managers and practitioners of Tractor Industries to embrace LG practices in their running system efficiently.

4.1 Introduction

In today's incredibly competitive business atmosphere, to regain and satisfy customer obligations is a remarkable challenge under the nose of operational business units. The quality product at least cost with scheduled and expected delivery is predominant desire of today's customers [239]. Therefore, to magnify overall productivity, quality of products manufactured with profitable manufacturing, companies are striving to grab quality tools and techniques in their manufacturing operational set ups. Thus, in an industry of any kind, quality and productivity with design thinking play significant roles. The organization's potential to commit the high-quality product at an affordable and economical price is a guarantee for an assurance of fund flow and wealth of whole organization [119]. In an enhancement of economic growth of any country, manufacturing industries identify all-important contribution in operational assignments [240]. LG strategies affirms a positional improvement at least value of all these kinds of junks in the form of wastages [241]. Lean effectively manage to get rid of all those activities which are not adding value in value stream [242-243]. Besides this, a process-centric well-focussed approach and endeavours for zero defects in the processes is essential for achieving excellence [244]. So, manufacturing companies needs to animate and design their process setups that not only support to bring down wastes in the processes, but also reduction in variations in the process. This will support to have practical and economical operations, attain competitive advantages with respect to competitors for more profitability, inspired people-centric organization and contributing to society development [4]. Many big companies globally in various sectors have concentrated and attained benefits in terms of amplification in productivity, quality excellence and customer delight with reduction in manufacturing operational cost. This has been achieved by grabbing reduction in LG wastes and variation in set of actions in the chain of valuable activities [245]. Many organisations in various sectors globally are getting enormous business gains by successful execution of LG business strategy. Still, an Indian Tractor Manufacturing Industry are facing challenges and attempting ruthlessly for successful implementation as not well up upon the realization of gains [6]. Indian Tractor Manufacturing Industries are mostly relying on manual controlled processes due to lack of technological advancement in operational set up, bounded cash flow and funding capacity. Apart from, lack of limited and skilful resources, low quality work due to poor management capabilities and poor commitment of delivery of quality standard product and services [246].

Literature uncover that no organization can accomplish and outshine great prosperity without enfolding new way of thinking and robust process [247]. For this, an attentiveness steps are need of an hour for fulfilment covering the wider scope. Attentiveness strategic steps are the components that are believed to be significant for the successfully implementation of big level thinking and new strategic approach [248]. LG strategy is an approach of environmental development that minimizes the waste at source by the way of reduction in process variation using the Green conviction of recycle, reuse and reduce (3R’s) [114]. In such mindfulness actionable LG strategy, LGSFs are holding leading place for delivery of prospective results consistently and efficiently [249]. SFs are the preconditions that impart an impetus to the organization to greet a new strategic approach [250]. Prior to outlining on new way of strategic thinking approach in manufacturing units, it is necessary to have an essential knowledge about such success factors [185]. An investigators and industry managers are striving to realize those attributes that illustrate the success and failure of LG in an organization. Apart from this, the literature inadequacy shows enough indication for recognition and modelling relationships of LGSFs. Modelling of extracted SFs is very crucial for the success of LG strategy, as it furnishes the inter-linkage amongst various SFs at distinct levels, which is a demanding endeavor. So, it is essential to measure optimum workout in terms of modelling the relationships amongst LGSFs using a robust approach [251]. Therefore, there is extensive need to adopt critical SFs based upon their impact and driving attributes for successful adoption of LG strategies in an Indian Tractor Industry.

From this perspective, the current chapter focus on analysis and modelling of LGSFs and prioritization them using ISM and MICMAC analysis [252].

4.1.1 Research Objectives

The main objectives of this chapter are as follows:

- Investigate the Critical SFs for LG strategies for an Indian Tractor Industry.
- Frame the mutual interaction model of key LGSFs by using ISM approach.
- Segregate the key LGSFs in four quadrants based on their driving and dependence power by using MICMAC analysis.

The prime objective of current work examines to suggest the critical SFs for Lean-Green practices in an Indian Tractor Industry with the support of mathematical modelling. The present results enable the industrial practitioners to create an effective strategy and policy of LG implementation in the existing running system. Apart from this, the Tractor manufacturing company can reduce the wastes and amplify the working environmental scenario through this study.

4.2 Exploration of LGSFs

The practical implementation of LG strategies depends on few key factors, known as Success Factors of LG strategies. SFs are those attributes that are vital to accomplish objectives of the organizations. These attributes are appropriate from an initiation to the maturity of LG execution within an organization.

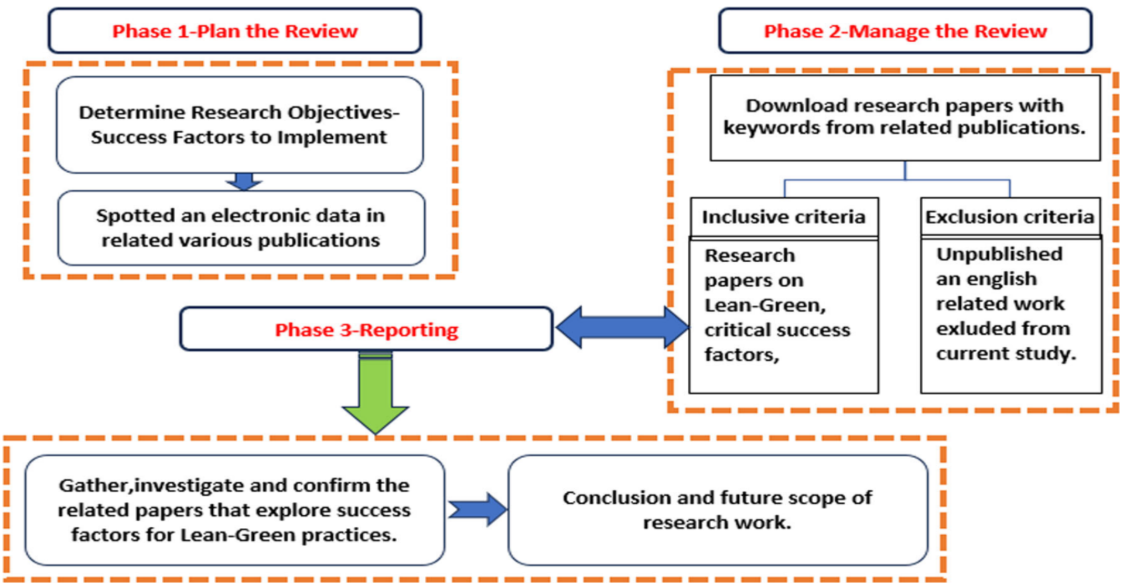


Figure 4.1— Systematic Literature Review

The existing literature on Lean, Green, Success Factors, Manufacturing Industry, are explored through adopting Systematic Literature Review methodology (SLR) as shown in Figure 4.1. As per SLR, in first phase, key words were selected based on the objectives of research. In Second phase, the articles were downloaded from the electronics database like Scopus, Emerald, Elsevier, web of science etc. In last phase, selected articles were gone through in details and explored the list of success factors of LG practices. Total 26 critical SFs of LG practices in an Indian Tractor Industry has been extracted through SLR as shown in Table 4.1.

Table 4.1— Identified LGSFs in Indian Tractor Industry

S. No.	Lean Green Key success factors in tractor industry	Literature's support
1.	Resource Adequacy	[143]
2.	Superior business capabilities	[253]
3.	Structured Training module	[180]
4.	High human potential	[254]
5.	Administrative active participation	[258]
6.	Vision clarity	[257]
7.	Appropriate tools picking	[256]
8.	Abundance Consciousness about LG practices	[210]
9.	Logical Project Nomination	[255]
10.	Adequacy of coaching funds	[259]
11.	High attainment of organization's beliefs	[260]
12.	Controlled expenditure execution	[261]
13.	Acceptability of cultural transformation	[262]
14.	Sufficiency of timeline for Lean Green execution	[181]
15.	Leadership Potential	[263]
16.	Full employee participation	[174]
17.	Tactical intelligence	[181]
18.	Structured performance review practices	[182]
19.	Constructive communication between functional units	[183]
20.	Alignment between business's purpose and consumer gratification	[184]
21.	Right selection of employee for needed training	[186]
22.	Strong Suppliers affinity	[187]

23.	Well perceptiveness of LG as a tactics, instruments and actions	[188]
24.	Certain use of longer shelf items	[189]
25.	Pursuit of Productive Time	[186]
26.	Considerable execution cost	[192]

4.3 Adopted Research Design

The prime objective of the study is to identify the key SFs of LG strategies implementation in Indian Tractor Industry. To realize this aim, an appropriate research design approach has been adopted as shown in Figure 4.2.

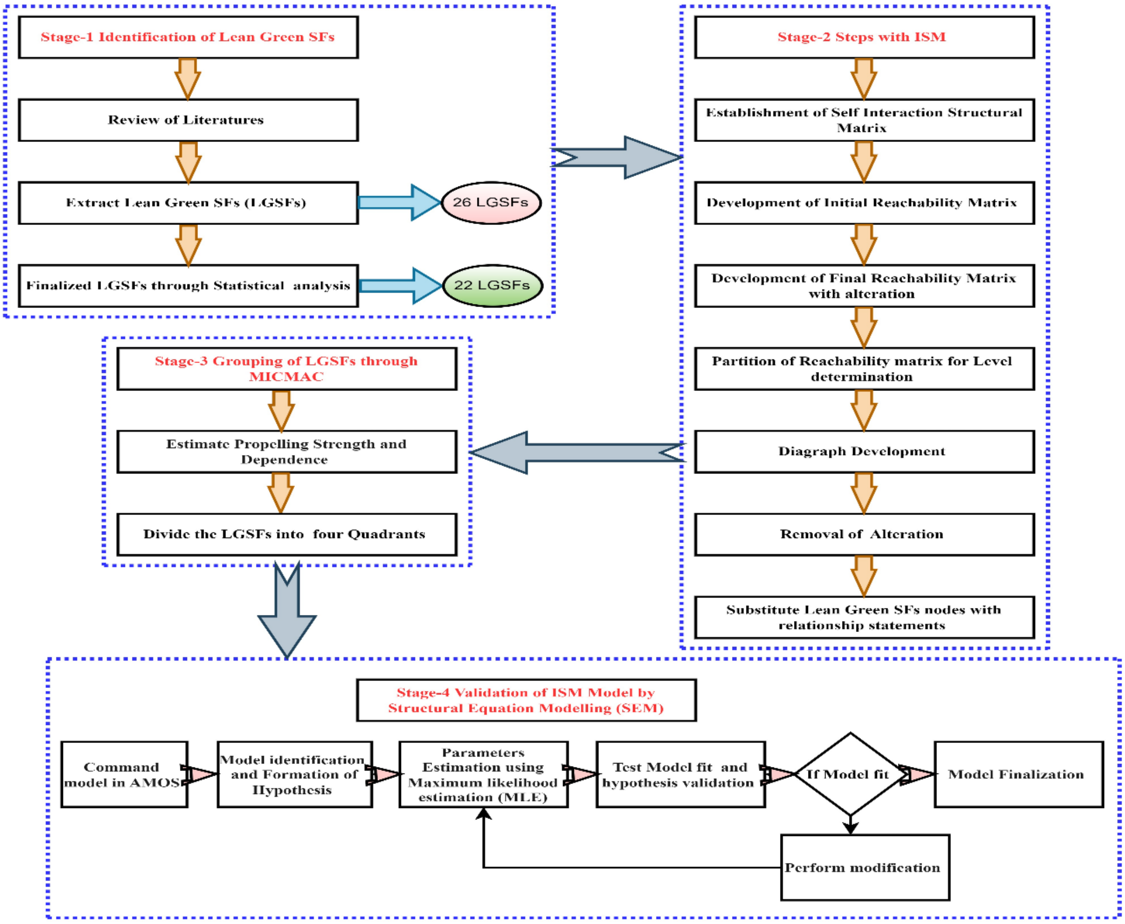


Figure 4.2— Adopted Research design

This approach consists of mainly four phases, as (1)-Literature Review, (2)-steps of ISM, and (3)-steps of MICMAC analysis. In the phase-1, initially 26 LGSFs, have been recognised through SLR and screened them using proficient input from industry and academic backgrounds and reliability analysis. At the end of phase-1, 22 LGSFs have been concluded for further investigation. In Phase-2, a model of concluded LGSFs has been framed by the use of ISM methodology. In phase-3, MICMAC investigation was applied for clustering the LGSFs into categories. In Phase-4, developed ISM model was validated using Structural Equation Modelling (SEM) technique.

4.3.1 Screening of LGSFs through Statistical Analysis

To acquire grouping of precisely identified and related LGSFs to stimulate study under analysis, refinement is executed using analytical instruments, especially importance-index analysis and CIMTC (Corrected Item-Minus Total Correlation). Five experts from academia and 5 from Tractor Industry background were selected for collecting the data used for statistical analysis. Factors having low-lying linkage for which, CIMTC value less than 0.3, such factors have been discarded for advancement to stimulate study. Table 4.2, manifests the described analytics with outcome and CIMTC for LGSFs.

Table 4.2— Statistical analysis of Identified LGSFs

S.N0.	Notation	LGSFs in Tractor industry	Mean	SD	CII	CIMTC
1	LGSF01	Resource Adequacy	4.3732	0.484	0.875	0.559
2	LGSF02	Superior business capabilities	3.8947	0.364	0.779	0.560
3	LGSF03	Structured Training module	4.1626	0.369	0.833	0.530
4	LGSF04	High human potential	3.8421	0.365	0.769	0.502
5	LGSF05	Administrative active participation	4.8995	0.301	0.980	0.524
6	LGSF06	Vision clarity	4.0956	0.518	0.819	0.515
7	LGSF07	Appropriate tools picking	4.1100	0.313	0.822	0.501
8	LGSF08	Abundance Consciousness about LG practices	4.0334	0.463	0.807	0.523
9	LGSF09	Logical Project Nomination	3.8755	0.384	0.775	0.597
10	LGSF10	Adequacy of coaching funds	4.2583	0.438	0.852	0.564
11	LGSF11	High attainment of organization’s beliefs	3.8564	0.402	0.771	0.590

12	LGSF12	Controlled expenditure execution	4.1483	0.356	0.830	0.535
13	LGSF13	Acceptability of cultural transformation	4.3588	0.480	0.872	0.561
14	LGSF14	Sufficiency of timeline for LG Practices execution	4.4545	0.498	0.891	0.564
15	LGSF15	Leadership Potential	4.2488	0.432	0.850	0.561
16	LGSF16	Full employee participation	4.6842	0.465	0.937	0.448
17	LGSF17	Tactical intelligence	4.1578	0.365	0.832	0.415
18	LGSF18	Structured performance review practices	4.0622	0.428	0.813	0.480
19	LGSF19	Constructive communication between functional units	4.1004	0.522	0.820	0.497
20	LGSF20	Alignment between business's purpose and consumer gratification	4.1866	0.390	0.837	0.426
21	LGSF21	Right selection of employee for needed training	4.1961	0.397	0.839	0.477
22	LGSF22	Strong Suppliers affinity	4.0191	0.437	0.804	0.455
23	LGSF23	Well perceptiveness of LG as a tactics, instruments, and actions	2.8947	0.307	0.579	0.114
24	LGSF24	Certain use of longer shelf items	2.0095	0.097	0.402	0.108
25	LGSF25	Pursuit of Productive Time	2.0191	0.137	0.404	0.162
26	LGSF26	Considerable execution cost	2.9712	0.194	0.581	0.181

It reveals from analysis that CIMTC values of LGSFs, labeled as 'well perceptiveness of LG as a tactics, instruments and actions', 'Certain use of longer shelf items', 'Pursuit of Productive Time', 'Considerable execution cost', having less than 0.3, hence, essentially to be eliminated from final list. Significant twenty-two LGSFs having CIMTC significance range from 0.415 to 0.597 are considered for further investigation in evaluation. Additionally, Importance-index analysis applied for providing the weightage of expert's inputs collected using survey in the form of questionnaire. The numeric facts are conclusively filtered through Corelative Importance Index (CII), which lies between zero to one. The value of LGSFs having CII lies between 0.6 to 1 considered significant. The same four LGSF's resulted having CIMTC less than 0.3 and CII value less than 0.6, Refer Table 4.2, which further confirms the rest twenty-two LF's are much significant.

4.3.2 Reliability Computation of Screened LGSFs

The analytical examination furnishes the collection of twenty-two finalized LGSFs in an Indian Tractor Industry. To check the validation of the LGSFs distinguished by means of screening analysis and biasness elimination, a questionnaire-based assessment was used. To check the internal-consistency of questionnaire, reliability test was conducted. Furthermore, a questionnaire enabled assessment was used to establish an inter-relationship matrix for commencing modelling of LGSFs. Besides, for checking internal-consistency of questionnaire and validation of selected LGSFs, Cronbach's alpha was calculated in reliability analysis using software SPSS (Statistical Package for Social Sciences).

The LG experts from Indian Tractor Industry were targeted for conducting this survey. With a population size (N) of 455 LG experts in tractor industries, considering 95 % confidence level with Z score 1.96, margin of error (e) equal to 0.05 and for large group considering 50 % variability, the value of standard deviation (P) was taken 0.5, the sample size (n) was calculated by using the equation (4.1), which is manifested below , whose value come out to be 209.

$$n = \frac{(Z^2 * P(1-P))/e^2}{1+\frac{1}{e^2 N}(Z^2 * P(1-P))} \tag{4.1}$$

The expert's data which were selected for survey was taken through internet sources and direct / indirect linkage with industry working professional, who were practicing Lean and Green in their working area and had theoretical knowledge. In total, 221 questionnaires were shared and 209 were received back using snow ball sampling technique, which were used for further analysis. The outcome of Cronbach's α value assisted to compute internal consistency or reliability of LGSFs, and it checks their accuracy. The SPSS outlines a high value of α, if there is high internal consistency amongst the factors. The consistency assessment outcome discloses the value of internal consistency as 0.802, refer Table 4.3, that shows positive internal consistency. The value of alpha ranging between 0.70 to 0.90 recommended for the better internal consistency [264]. The standard error of mean, which estimates how much discrepancy is likely in the mean values of samples of the population, which came out to be 2.6%, refer Table 4.4, and computed by dividing the average of standard deviation (SD) of all samples to the square root of sample size. The value of standard error of mean equal to or less than 5 % is recommended for better internal consistency [264].

Table 4.3— Results of Reliability Test

Cronbach's α	Cronbach's α just after un-related SFs are removed	No. of Key Success factors (SFs)
0.802	0.805	22

Table 4.4— Standard Error of Mean for LGSFs

S.No.	Notation	LGSFs in Tractor industry	Valid	Missing	Std. Error of Mean
1	LGSF01	Resource Adequacy	209	0	0.0335
2	LGSF02	Superior business capabilities	209	0	0.0252
3	LGSF03	Structured Training module	209	0	0.0256
4	LGSF04	High human potential	209	0	0.0252
5	LGSF05	Administrative active participation	209	0	0.0208
6	LGSF06	Vision clarity	209	0	0.0358
7	LGSF07	Appropriate tools picking	209	0	0.0216

8	LGSF08	Abundance Consciousness about LG practices	209	0	0.0320
9	LGSF09	Logical Project Nomination	209	0	0.0266
10	LGSF10	Adequacy of coaching funds	209	0	0.0303
11	LGSF11	High attainment of organization's beliefs	209	0	0.0278
12	LGSF12	Controlled expenditure execution	209	0	0.0246
13	LGSF13	Acceptability of cultural transformation	209	0	0.0332
14	LGSF14	Sufficiency of timeline for LG Practices execution	209	0	0.0345
15	LGSF15	Leadership Potential	209	0	0.0300
16	LGSF16	Full employee participation	209	0	0.0322
17	LGSF17	Tactical intelligence	209	0	0.0253
18	LGSF18	Structured performance review practices	209	0	0.0296
19	LGSF19	Constructive communication between functional units	209	0	0.0361
20	LGSF20	Alignment between business's purpose and consumer gratification	209	0	0.0270
21	LGSF21	Right selection of employee for needed training	209	0	0.0275
22	LGSF22	Strong Suppliers affinity	209	0	0.0303

23	LGSF23	Well perceptiveness of LG as a tactics, instruments, and actions	209	0	0.0213
24	LGSF24	Certain use of longer shelf items	209	0	0.0068
25	LGSF25	Pursuit of Productive Time	209	0	0.0095
26	LGSF26	Considerable execution cost	209	0	0.0134

4.3.3 Implementation Steps of ISM Approach

ISM is a logical approach, implemented in a consecutive way. The various steps of Interpretive Structural Modelling [218], are as follows:

- **STEP 1: Identification of various LGSFs**
  The Lean green success factors were recognized through extensive literature reviews and conversation with Lean-Green domain experts. In present study, 22 LGSFs have been identified through questionnaire survey, brain storming and expert's opinion.
- **STEP 2: Establishment of dependent inter-relationship between LGSFs**
  Drive from the recognized 22 LGSFs in the step 1, frame the dependent inter-relationship between LGSFs and create systemic Self-Interlinkage grid / matrix (SSIG) for the pair-wise analysis between them. The dependent inter-relationship is based on directional relationship between two SFs and structure like intend, preference, and numerical reliance process.
- **STEP 3: Shaping of Reachability Matrix**
  The systemic self-interlinkage grid / matrix (SSIG) attained from previous step -2, further employed for formulating reachability grid matrix network. The data in every cell of SSIG grid are changed into binary numbers (0 and 1) to obtained initial and final reachability matrix. The 1* entrance in cell is fused in the initial reachability grid to cross over the subjective gap if any, carry after the collection of experts' outlook and final reachability grid is obtained by integrating transitivity.
- **STEP 4: Splitting of the final reachability grid into varied position levels**
  The achieved final reachability grid in previous step was split into varied positional level. Commencing from final reachability matrix, the reachability

array and Predecessor array for each success factor were formed through series of iterations called level splitting.

- **STEP 5: Creating diagraph of LGSFs**

  Diagraph of LGSFs are created in this step by taking into consideration the transitivity amongst SFs (that means, if success factor X is linked to success factor Y and success factor Y is linked to Z, then success factor X should be linked to success factor Z).

- **STEP 6: Development of ISM model**

  From the derived diagraph from previous step, ISM model can be created by removing the transitive linkage based on the association specified in reachability matrix. For development of this model, the diagraph's arbitrary nodes are replaced with statements.

4.4 Application of ISM

The objective of current study is to successfully incorporation of LG strategies in Indian Tractor Industry by execution of favourable LGSFs according to their attributes. Initially, twenty-six SFs were investigated through Systematic Literature Review and further using expert opinion, twenty-two LGSFs were screened up. The statistical investigation furnishes a concluded list of 22 LGSFs in Indian Tractor Industry. Thereafter, a model of mutual relationship between concluded success factors is created with the support of ISM methodology and clustered them as per their suitable attributes with the help of MICMAC investigation. The cross-examination of ISM model steps was conducted by case organisation's designated experts and people from academics. The detailed illustration of ISM model steps with case analysis are furnished in subsequent sections.

4.4.1 Analysis of LGSFs

The LGSFs were recognised by the way of publications and conversation with Lean Green proficient. In existing research, twenty-two LG practices SFs have been recognized from exhaustive publications review and proficient' beliefs.

4.4.2 Compose Systemic Self-Interlinkage Matrix among LGSFs

Build on dependent inter-relationship between finalized LGSFs, SSIG was constructed, refer Table 4.5. To depict the directional linkages between two LGSFs (p, q), four letter signs were used. L is employed if LGSF "p" governs or gets to LGSF "q"; M is employed if LGSF "q" gets to LGSF "p"; N is employed if "p" and "q" leverage each other; O is used if both LGSFs are unrelated.

Table 4.5— Systemic Self-Interlinkage Grid / Matrix (SSIG)

LGSFs	22	21	20	19	18	17	16	15	14	13	12	11	10	09	08	07	06	05	04	03	02	01
01	L	L	L	L	L	N	L	N	L	L	L	L	N	L	L	L	L	M	L	L	L	N
02	L	L	L	L	L	M	L	M	L	L	L	L	M	N	N	L	L	M	L	N	N	
03	L	L	L	L	L	M	M	M	L	L	L	L	M	N	N	L	L	M	L	N		
04	L	M	M	N	M	M	N	M	L	L	L	L	M	M	M	M	M	M	N			
05	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	N				
06	L	N	N	L	L	M	L	M	L	N	L	L	M	M	M	N	N					
07	L	N	N	L	L	M	L	M	L	L	L	L	M	M	M	N						
08	L	L	L	L	L	M	L	M	L	L	L	L	M	N	N							
09	L	L	L	L	L	M	L	M	L	L	L	L	N	N								
10	L	L	L	L	L	N	L	N	L	L	L	L	N									
11	M	M	M	M	M	M	M	M	M	M	N	N										
12	N	M	M	M	M	M	M	M	N	M	N											
13	L	M	M	M	N	M	L	M	L	N												
14	N	M	M	M	M	M	M	M	N													
15	L	L	L	L	M	N	O	N														
16	L	M	M	M	N	M	N															
17	L	L	L	L	L	N																
18	L	M	M	M	N																	
19	L	M	M	N																		
20	L	M	N																			
21	L	N																				
22	N																					

The below mentioned demonstration will describe L, M, N and O letter signs used in SSIG.

- LGSF5 is root of Success Factor LGSF15. It signifies, LGSF "Administrative active participation" would be ingrained of LGSF "Leadership potential" Consequently, the linkage between LGSF5 and LGSF15 is symbolize by "L" and assigned to cell (5, 15) in SSIG grid. It means, if LGSF 'p' effects to LGSF 'q', then symbol "L" is used.
- LGSF8 would be outset of LGSF7. It signifies, LGSF "Abundance Consciousness about LG practices" would be formation of LGSF "Appropriate tools picking.''. Thereupon, the association between LGSF8 and LGSF7 is symbolize by "M" and assigned in cell (8, 7) of SSIG grid. It means, if LGSF 'p' influences to LGSF 'q', then symbol "M" is used.

- LGSF4 is associated the other LGSF16. It is signified LGSF "High human potential" would be associated with LGSF "Full employee participation". There-upon, the relationship between LGSF4 and LGSF16 is denoted by "N" and allotted to cell (4, 16) in SSIG grid. It means, if' 'p' and 'q' impacts to each other, then symbol "N" is used.
- LGSF15 is not having any possessions on LGSF16. Its signified LGSF "Leadership Potential" would not associate LGSF "Full employee participation." Thereupon, the association between LGSF15 and LGSF16 is symbolize by "O" and assigned to (15, 16) in SSIG grid. It means, if both success factors are isolated, then symbol 'O' is used.

4.4.3 Construction of Reachability Matrix

Initial reachable grid / matrix was formed by modification of each entry in SSIG with '1' (one) and '0' (zero), manifested in Table 4.6. The mentioned rules are followed for assimilation of binary descriptive entries.

- For (p, q) entry, if this is L in SSIG, then corresponding (p, q) listing in reachability grid becomes "1" and (q, p) set off "0".
- For (p, q) entry, if this is M in SSIG, then corresponding (p, q) listing in reachability grid becomes "0" and (q, p) set off "1".
- For (p, q) entry, if this is N in SSIG, then corresponding (p, q) listing in reachability grid becomes "1" and (q, p) set off "1".
- For (p, q) entry, if this is O in SSIG, then corresponding (p, q) listing in reachability grid becomes "0" and (q, p) set off "0".

Table 4.6— Initial Reachability Grid / Matrix

Success Factors	**LG SF01**	**LG SF02**	**LG SF03**	**LG SF04 …**	**LG SF11…**	**LG SF12…**	**LG SF20**	**LG SF21**	**LG SF22**
LGSF01	1	1	1	1	1	1	1	1	1
LGSF02	0	1	1	1	1	1	1	1	1
LGSF03	0	0	1	1	1	1	1	1	1
……	….	….	….	….	….	….	….	….	….
LGSF07	0	0	0	1	1	1	1	0	1
……	….	….	….	….	….	….	….	….	….

LGSF10	0	1	1	1	1	1	1	1	1
……	….	….	….	….	….	….	….	….	….
LGSF20	0	0	0	1	1	1	1	1	1
LGSF21	0	0	0	1	1	1	1	1	1
LGSF22	0	0	0	0	1	1	0	0	1

The 1* cell entry is fused in the initial reachability grid to bridge the subjective gap, if any, exit after the collection of experts' outlook and final reachability grid is obtained by integrating transitivity, revealed in Table 4.7.

Table 4.7— Final Reachability Grid / Matrix

Success Factors	**LG SF01**	**LG SF02**	**LGS F03**	**LG SF04…**	**LG SF11…**	**LG SF12…**	**LG SF20**	**LG SF21**	**LG SF22**
LGSF01	1	1	1	1	1	1	1	1	1
LGSF02	0	1	1	1	1	1	1	1	1
LGSF03	0	1*	1	1	1	1	1	1	1
……	….	….	….	….	….	….	….	….	….
LGSF07	0	0	0	1	1	1	1	1*	1
……	….	….	….	….	….	….	….	….	….
LGSF10	1*	1	1	1	1	1	1	1	1
……	….	….	….	….	….	….	….	….	….
LGSF20	0	0	0	1	1	1	1	1	1
LGSF21	0	0	0	1	1	1	1	1	1
LGSF22	0	0	0	0	1	1	0	0	1

4.4.4 Splitting of the Final Reachability grid into varied Position levels

The reachability matrix derived in previous step was split up into various positional levels. The reachability set and preceding set for each critical factor was formed from the finally concluded reachability grid / matrix, Table 4.8.

Table 4.8— Level Partition of LGSFs

Success Factors	Reachability array	Predecessor array	Convergence array	Positional level
LGSF01	1-10-15-17	1- 5-10-15-17	1-10-15-17	2
LGSF02	2-3-8-9	1-2-3- 5- 8-9-10-15-17	2-3-8-9	3
LGSF03	2-3-8-9	1-2-3- 5- 8-9-10-15-17	2-3-8-9	3
LGSF04	4-16-19	1-2-3-4-5-6-7-8-9-10-13-15-16-17-18-19-20-21	4-16-19	6
LGSF05	5	5	5	1
LGSF06	6-7-20-21	1-2-3-5-6-7-8-9-10-15-17-20-21	6-7-20-21	4
LGSF07	6-7-20-21	1-2-3-5-6-7-8-9-10-15-17-20-21	6-7-20-21	4
LGSF08	2-3-8-9	1-2-3- 5- 8-9-10-15-17	2-3-8-9	3
LGSF09	2-3-8-9	1-2-3- 5- 8-9-10-15-17	2-3-8-9	3
LGSF10	1-10-15-17	1- 5-10-15-17	1-10-15-17	2
LGSF11	11	1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18-19-20-21-22	11	8
LGSF12	12–14-22	1–2-3-4–5-6-7–8–9-10–11-12–13-14–15-16-17-18-19–20-21–22	12–14-22	7
LGSF13	13–18	1-2–3-5–6,7–8-9–10-13–15-17–18-20–21	13–18	5

LGSF14	12–14-22	1–2-3-4–5-6–7-8–9-10–11-12–13-14–15-16-17-18-19–20-21–22	12–14-22	7
LGSF15	1-10-15-17	1- 5-10-15-17	1-10-15-17	2
LGSF16	4–16-19	1–2-3–4-5–6-7–8-9–10-13–15-16–17-18–19-20–21	4–16-19	6
LGSF17	1–10-15–17	1- 5–10-15–17	1–10-15–17	2
LGSF18	13–18	1-2–3-5–6,7–8-9–10-13–15-17–18-20–21	13–18	5
LGSF19	4–16-19	1–2-3–4-5–6-7–8-9–10-13–15-16–17-18–19-20–21	4–16-19	6
LGSF20	6–7-20–21	1–2-3–5-6–7-8–9-10–15-17–20-21	6–7-20–21	4
LGSF21	6–7-20–21	1–2-3–5-6–7-8–9-10–15-17–20-21	6–7-20–21	4
LGSF22	12–14-22	1–2-3-4–5-6–7-8–9-10–11-12–13-14–15-16–17-18- 19–20-21–22	12–14-22	7

The reachability set as regards to selected success factor comprises of itself and the remaining success factors, which it may help to obtain. The predecessor's collection comprises of success factor's own identity and remaining success factors may extract from another. Convergence of one and other positions additionally arrived logically in favours of key SFs. If the reachability array and the intersection array for a selected success factor is identical, then that success factor is considered to be at level-1 and is given the lower positional level in the ISM hierarchy. With this split up, iteration-1 is achieved. After the 1st iteration, the SFs forming level-1 are dropped and with the remaining SFs, the aforementioned process is repeated in 2nd iteration. The same process is replicated till each success factor was covered in iteration and combined iterations of LGSFs are manifested in Table 4.8.

Success factor “Administrative active participation” (LGSF05) reposes at positional level-1 of ISM framework. Integration of LG strategies which takes part as decisive contributor for instituting success factors like, “Adequacy of training funds (LGSF10),” “Resource adequacy” (LGSF01), “Leadership Potential” (LGSF15) and “Tactical intelligence” (LGSF17) are manifested in the positional level-2. Aforesaid, 4 success factors further influence and emanates LGSFs like “Abundance Consciousness about LG practices” (LGSF08), “Structured training module” (LGSF03), “Superior business capabilities (LGSF02) and Logical Project Nomination” (LGSF09), that are revealed in the 3rd positional level.

At positional level-4, allied to ISM framework, LGSFs, “Appropriate tools picking” (LGSF07), “Right selection of employee for needed training” (LGSF21), “Alignment between business's purpose and consumer gratification” (LGSF20) and “Vision clarity” (LGSF06) are linked and interconnected. The workable key success factors appearing due to the positional level-4 are, “Structured performance review practices” (LGSF18), “Acceptability of culture transformation’’(LGSF13), as shown in positional level-5. Key SFs making an appearance at positional level-6, which comprises as: “High human potential” (LGSF04), “Full employee participation” (LGSF16) and “Constructive communication between functional units” (LGSF19). At the positional level-7, “Controlled expenditure execution” (LGSF12), “Sufficiency of timeline for LGSF practice execution” (LGSF14) and Strong Suppliers affinity” (LGSF22) are exhibited. If aspiring Indian Tractor Manufacturing organization can strengthen-out the LGSFs that are appraised up to the 7th positional level, then “High attainment of organization’s beliefs” level takes place, accordingly, positioned this success factor at the upper 8th positional level.

4.4.5 Creation of Diagraph and Formation of ISM model

The systemic model is depicted out from the concluded reachability grid, partition level out and relationship among LGSFs. In the occurrence, there is a relationship among the success factor p and q, this is manifested by an arrow, locus from p to q. This model is known as arrow diagraph, as shown in Figure 4.3. In Diagraph, all feasible reliance or intransitiveness among the LGSFs are created from one positional level to another positional level. The in-transitiveness of LGSFs is appraised as success factor p affiliated with q, success factor q affiliated with r, then success factor p will be affiliated with r. In the uppermost positional level, only one SF is filled, followed along three key SFs that have been formed at positional levels two and three, taking into consideration an in-transitiveness. Positional level four hold two key SFs, followed along by 4 LGSFs one at a time in each positional level, five to seven individually. At the end, one LGSF is loaded in positional level eight at the ground position of the diagram.

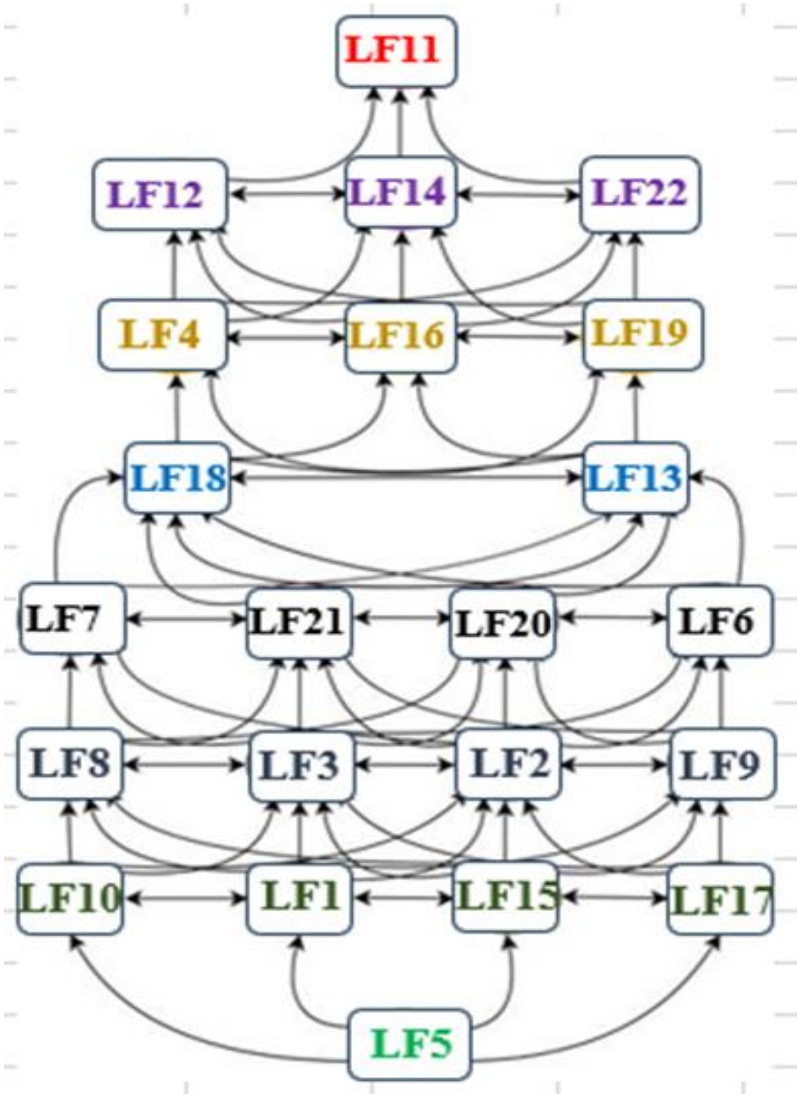


Figure 4.3— Diagraph of LGSFs

Built on diagraph, the ISM model has been shaped by removing intransitiveness between the LG practices' key SFs, which is shown in Figure 4.4. This model proposes that the LGSFs positioned as LGSF5, LGSF17, LGSF15, LGSF 1, and LGSF3 found the most leading LG success factors due to positioned at lower level. LGSF5 success factor as 'Administrative active participation' assures the adequate skilled human resources, best manpower for directing the project, proper production, planning and control etc.

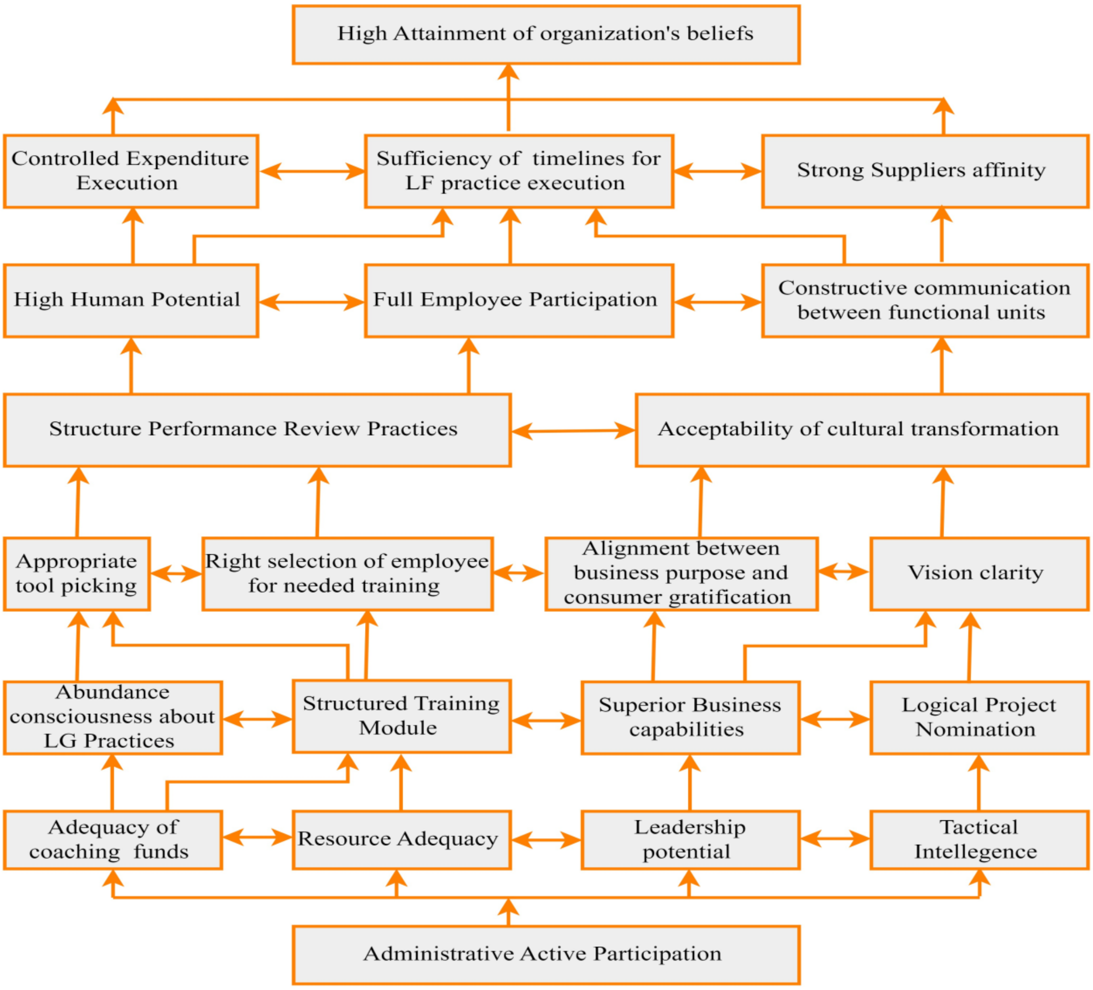


Figure 4.4— ISM Model of LGSFs

With the active involvement from administrative side, all identified factors are likely to be leading ahead for successful implementation of LG strategies and practices. Furthermore, timelines plan for acceptance of operating procedures, communication at different stages, review of project status, proper training for staff at all levels, creating cross functional team working culture in project execution are some of key ingredients for successful implementation of LG strategies. Administration should create a conducive working environment, where all persons at all the level should actively participate in improvement activities with focus on end customer delight for successful implementation of LG programme in an organisation. Eventually, this ISM model imparts guidelines to industry practitioners to plan the activities according to positional level of success factors from bottom to top for their implementation strategy for achieving operational excellence.

4.5 Clustering of LGSFs using MICMAC approach

MICMAC approach is used to investigate the driving power together with dependence of the LGSFs. The driving and dependency power of each SF are additionally cast-off to realize the self-governing, propelling, relative and associated success factors using MICMAC examination, refer Figure 4.5. The various steps of MICMAC [219], are as follows:

- **STEP 1:** Deduce driving and dependency power of each SF by addition of the row-wise and column-wise entry of binary number '1' is completed respectively in final reachability grid / matrix, manifested in Table 4.6.
- **STEP 2:** Classification the LGSFs into various groups according to driving and dependence power.
- **STEP 3:** Deducing self-governing LGSFs according to their classification.

On the basis of observations, the LGSFs are classified into four groups namely dependent, independent, autonomous and linkage, Figure. 4.5. The 1st quadrant composed of autonomous LGSFs, that manifest weak driving as well as weak dependence. The 2nd quadrant composed of dependent LGSFs, that have weak driving power and high dependence. The 3rd quadrant shows the linkage LGSFs, that has strong driving power as well as strong dependence. Furthermore, the 4th quadrant allocates independent LGSFs, that manifest strong driving, but little dependence power. The grouping of prime vital LGSFs calls for strategic managers to be more focussed on the untold driving success factors:

- From Figure 4.5, it has been established that there are no autonomous success factors revealed during evaluation of LGSFs execution. Autonomous success factors have weak driving power and weak dependence, so they come out with rare regulation on practice.
- The key success factors as, 'Vision clarity' (LGSF6), "Appropriate tools picking" (LGSF7), "Alignment between business's purpose and consumer gratification" (LGSF20) and "Right selection of employee for needed training" (LGSF21) are linkage factors. All the success factors graded with this class occupy strong driving as well as dependence.
- The key success factors like "High human potential" (LGSF4), "High attainment of organization's beliefs" (LGSF11), "Controlled expenditure execution" (LGSF12), "Acceptability of cultural transformation" (LGSF13), "Sufficiency of timeline for LG practice execution"(LGSF14), "Full employee participation" (LGSF16), "Structured performance review practices"

(LGSF18), “Constructive communication between functional units” (LGSF19) and “Strong Suppliers affinity” (LGSF22) are dependent factors. The relative success factors have in proportionally week driving power but show high dependence on other factors.

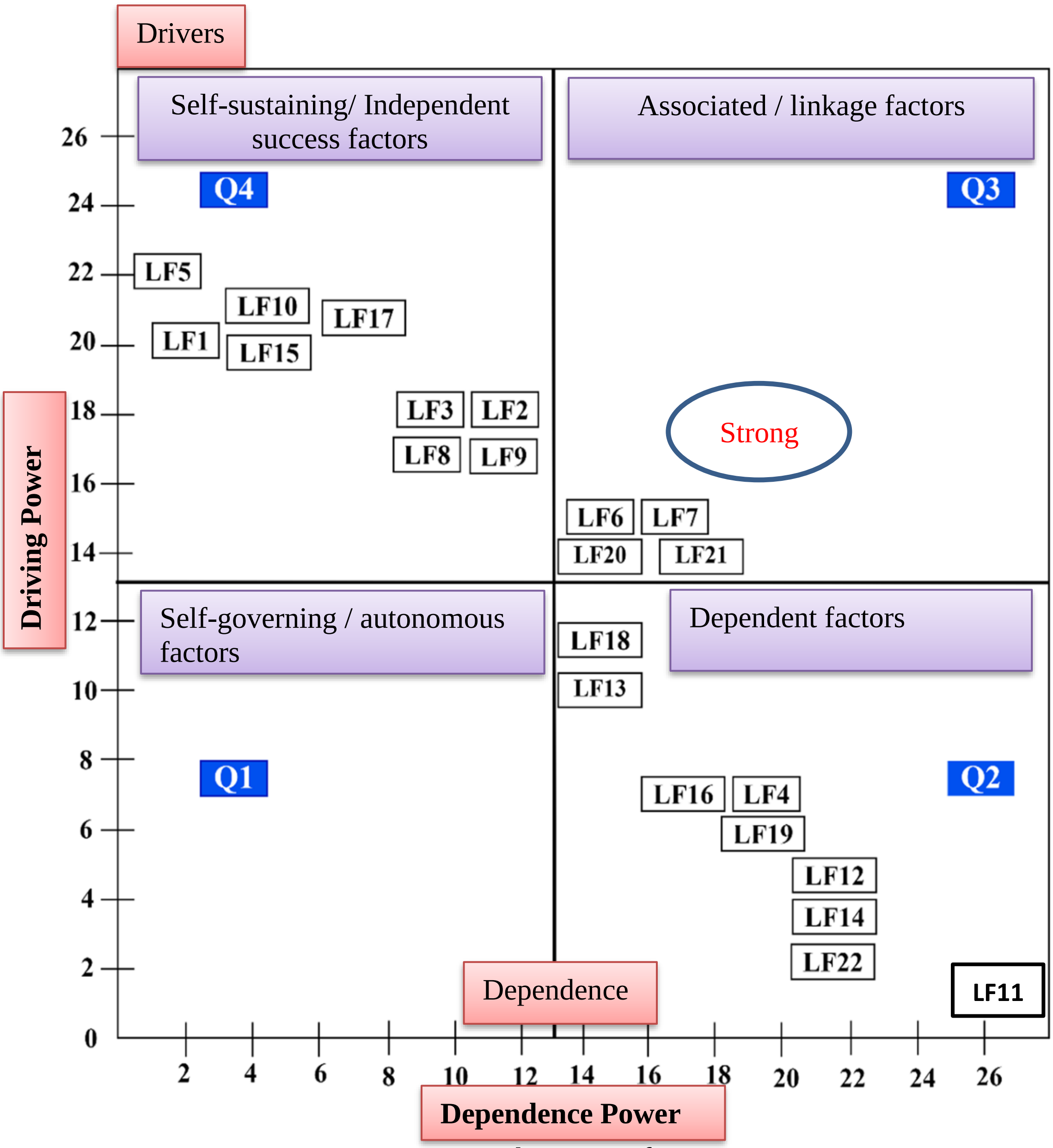


Figure 4.5— Clustering of LGSFs

- The key success factors like “Resource Adequacy” (LGSF1), “Superior business capabilities” (LGSF2), “Structured Training module” (LGSF3), “Administrative active participation” (LGSF5), “Abundance Consciousness about LG practices (LFSF8), ‘Logical Project Nomination” (LGSF9), “Adequacy of training funds” (LGSF10), “Leadership Potential” (LGSF15) and “Tactical intelligence” (LGSF17) are independent success factors. They have high driving power but weak dependence and covered as common land success factors.

4.6 Structural Equation Modelling (SEM)

The developed ISM model was validated by using SEM, which is highly developed, innovative and state-of-art statistical technique that facilitate researchers to investigate and analyse interconnection between observed variables and intrinsic latent constructs [265]. It effectually integrates fundamentals of 'factor analysis', which relates the underlying factors from observed variables and 'multiple regression' investigation, which evaluates how one set of variables estimates another. For factor analysis, it takes place in two stages such as, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). Firstly, EFA has realized the inter-relation amongst the observed, unobserved variables and errors. Secondly, CFA is beneficial step to discover uniformity in measured and structure models and also for validation. The procedure of SEM has six basic steps, which are stated below [266].

- **STEP 1: Define Constructs**

  The first step consists of theoretically specifying the constructs and run pre-tests to investigate the items, which shows the principle inter-connection between observed and latent variables. CFA is then exercised to verify the measurement model.

- **STEP 2: Identification and developing the measurement model**

  This step creates the inter-relationship between exogenous and endogenous variables by the way of indicating arrows bonding to the principle of one-dimensionality. Identification of model is imperative prior to estimation of parameters. Three types of possibilities occur for model identification. Firstly, it is identified, if degree of freedom (DOF) is zero. Secondly, if degree of freedom is positive, then model is over-identified. Thirdly, if degree of freedom is negative, then model is un-identified. The variation between number of sample variables and estimate variables is considered as DOF. The concluded model might have identified or over-identified, but never be un-identified.

- **STEP 3: Collection of data and study of design for empirical results**

  This step is vital for model specifying and design study to curtail identification issues, employing order condition and rank condition methodology to label prospective concerns. Collection of data is critical for SEM investigation than other multivariate techniques. The data size should be reasonable, otherwise less data may give incorrect results [267]. In current research work, sample size of 209 responses were collected from the respondents relating the industrial and academia background.

- **STEP 4: Estimation of Parameters**

  When data set is not normally distributed and to get efficient and unbiased results, the maximum likelihood estimation (MLE) is proven technique which is most of time used for estimation of parameters. Moreover, if the data sizes are less than 300, MLE technique is more precise and also exercised in this research work.

- **STEP 5: Examine for structural model fit testing**

  This step involves the examination of proposed structural model for absolute model fit, an incremental model fit and parsimonious model fit. The chi-square and probability value (p) should be greater than 0.05, root mean square error of approximation (RMSEA) should be less than 0.08 and goodness of fit index (GFI) should be greater than 0.9 in absolute model fit testing. The value of comparative fit index (CFI), normed fit index (NFI), and Tucker-Lewis index should be between 0 and 1 for incremental model fit testing. The value of chi-square statistics divided by degree of freedom (CMIN/DF) should be greater than 5 for parsimonious fit testing.

- **STEP 6: Model re-specification**

  For freeing the variables that are fixed or fixing which are free, model re-specification should be performed. For this, the value of chi-square in model should have minimum specified value.

4.7 Model Validation using SEM

SEM is an integration of multiple regression and factor analysis which is logical and structured tool appraising the unreliability of data obtained from survey response [268].

4.7.1 Exploratory Factor Analysis (EFA)

EFA is applied in this research work on sample size 209 (i.e. n=209) for factor loading on 22 LGSFs by use of SPSS version 20 software. During this research work, using Principal Component Analysis (PCA) along with varimax rotation, items are grouped for estimation of Kaiser-Meyer-Olkin and Bartlett test of sphericity of indicators are evaluated. The Eigen value is the criterion for extracting the factors whose value should be greater than 1, and significant factor loading should be greater than 0.40 with at least three items per factor [269]. In the current study, LGSFs are loaded into 4 constituents namely management oriented (M-LGSFs), resource based (R-LGSFs), process oriented (P-LGSFs) and organisation level (O-LGSFs). All the constituents are having Eigen value higher than 1 and remarkable factor loading is higher than 0.40 along with three or more components per constituent. The value of Cronbach alpha should be more than 0.60 for measuring internal reliability for items for each constituent [270]. The result of EFA revealed that all the constituents are having Cronbach alpha higher than 0.60, hence the constituents are reliable, which is manifested in Table 4.9.

Table 4.9— EFA Results

S. No.	**Constituents**	**Variables / Items**	**Factor Loading**	**Cronbach's Alpha**
1	Management Oriented Success Factors (M-LGSFs)	LGSF-05	0.890	0.839
		LGSF-06	0.901	
		LGSF-15	0.881	
		LGSF-16	0.837	
		LGSF-19	0.912	
		LGSF-20	0.871	
2	Organisational Level Success Factors (O-LGSFs)	LGFS-04	0.863	0.801
		LGSF-11	0.911	
		LGSF-13	0.845	
		LGSF-17	0.702	

3	Resource Based Success Factors (R-LGSFs)	LGSF-01	0.932	0.851
		LGSF-03	0.917	
		LGSF-08	0.844	
		LGSF-09	0.875	
		LGSF-10	0.890	
		LGSF-21	0.842	
4	Process Oriented Success Factors (P-LGSFs)	LGFS-02	0.930	0.871
		LGSF-07	0.918	
		LGSF-12	0.899	
		LGSF-14	0.910	
		LGSF-18	0.878	
		LGSF-22	0.886	

4.7.2 Formation of Hypotheses

The below mentioned research hypothesis are suggested to extract significance from the data collected.

H1: Management oriented success factors (M-LGSFs) positively affect resource-based success factors (R-LGSFs).

H2: Management oriented success factors (M-LGSFs) positively affect organisational-level success factors (O-LGSFs).

H3: Management oriented success factors (M-LGSFs) positively affect process-oriented success factors (P-LGSFs).

4.7.3 Confirmatory Factor Analysis (CFA)

CFA is beneficial procedural step used in SEM to realize the consistency in structured and measurable models. The inter-relationships between items and latent variables covered in measured model, the kinship between common and unobserved variables covers in structure model. The CFA is calculated using AMOS software, version 26, the results are tabulated in Table 4.10.

Table 4.10— CFA Results

S. No.	Constituents	Variables / Items	Standardized Estimates	p-value (Significant at p < 0.005)	C.R	AVE
1	Management Oriented Success Factors (M-LGSFs)	LGSF-01	0.747	***	0.827	0.684
		LGSF-03	0.646	***		
		LGSF-08	0.859	***		
		LGSF-09	0.759	***		
		LGSF-10	0.767	***		
		LGSF-21	0.856	***		
2	Organisational Level Success Factors (O-LGSFs)	LGFS-04	0.735	***	0.808	0.663
		LGSF-11	0.639	***		
		LGSF-13	0.748	***		
		LGSF-17	0.733	***		

3	Resource Based Success Factors (R-LGSFs)	LGSF-05	0.790	***	0.801	0.622
		LGSF-06	0.645	***		
		LGSF-15	0.601	***		
		LGSF-16	0.684	***		
		LGSF-19	0.655	***		
		LGSF-20	0.612	***		
4	Process Oriented Success Factors (P-LGSFs)	LGFS-02	0.685	***	0.898	0.725
		LGSF-07	0.577	***		
		LGSF-12	0.745	***		
		LGSF-14	0.607	***		
		LGSF-18	0.655	***		
		LGSF-22	0.687	***		

As per the CFA results revealed, the constituents are looks to be considerable as value of Cronbach's alpha observed more than 0.6, also the value of Composite Reliability (CR) noticed higher than 0.7 [271]. There is positive impact on other constituents as standardized estimate values are also observed more than 0.5. The level of significance is examined at 5 %, in this work *** appears for p value less than .005, which imparts significant constituents.

4.7.3.1 Testing for Model Fit

The model fit testing is conducted in AMOS software, version 26. The outcome revealed that in absolute fit, the probability value (p) is 0.000, RMSEA and CFI value observed as 0.06 and GFI value comes to be 0.978, which disclose model fit. For incremental model fit, CFI value is observed as 0.839, NFI value is 0.931 and TLI value is 0.895. CMIN/DF value come out to be 1.927, as manifested in Table 4.11. The judgement of the model has been concluded based upon relied on various fitness pointers with various threshold values. For fitness of absolute model, the chi-square and p value should be less than 0.05, RMSEA and CFI value should be less than 0.08 and GFI value should be greater than 0.9. For the fitness of incremental model, the value of CFI should be greater than 0.8, NFI should be greater than 0.9, and TLI should be greater than 0.8. For the fitness of parsimonious model, CMIN/DF value should be less than 3 [272].

Table 4.11— Summary of Model Fit

S. No	Parameters	Model Fitness values
1	Chi- Square value and Probability value (p)	0.000
2	Root mean square error of approximation (RMSEA)	0.06
3	Goodness Fit Index (GFI) Value	0.978
4	Comparative Fit Index (CFI) Value	0.839
5	Normed Fit Index (NFI) value	0.931
6	Tucker-Lewis Index (TLI) value	0.895
7	CMIN/DF for parsimonious fitness	1.927
8	Chi- Square Value	185.67

As per the outcome revealed, all indices values are greater than threshold values, which shows the fitness of model with sample data.

4.7.3.2 Construct Validity

An estimation of convergent and discriminant validity is the basis for establishment of construct validity. The outcome for measuring the variables by other methods dispense the same results as reflected by construct validity [273]. It can be built via CR and average value explained (AVE) of variables having CR value greater than 0.6, AVE having value greater than 0.5 and CR must be greater than AVE. In current model, the derived values of AVE for all the tested factors are greater than 0.5, which acquired construct's convergent validity [274]. Discriminant validity is the extend which shows the variation amongst the measuring the latent variables to each other [275]. It can be instituted, if AVE values are higher than squared inter-construct co-relations [276]. The diagonal variables along with AVE values, flip side off-diagonal variables with squared inter-connected co-relations are manifested in Table 4.12.

Table 4.12— Discriminant Validity

S. No	Items	M-LGSFs	R-LGSFs	P-LGSFs	O-LGSFs
1	**M-LGSFs**	0.684			
2	**R-LGSFs**	0.433	0.622		
3	**P-LGSFs**	0.547	0.538	0.745	
4	**O-LGSFs**	0.422	0.395	0.583	0.663

It has been noticed that the value of AVE is greater than the squared inter-construct co-relations of complete individual constructs which dispense the discriminant validity of the constructs. Hence, the model furnishes good construct validity, hypotheses testing can be done further using empirical results.

4.7.4 Hypotheses Testing

SEM is validated for hypothesis testing of sample as it estimates and evaluates dependency and co-relations in solo investigation.

Table 4.13— Model Relationship Estimates

S. No	Variable Association	Hypotheses	Estimates	SE	CR	p value
1	**R-LGSFs < ------- M-LGSFs**	H1	0.678	0.05	6.371	***
2	**O-LGSFs < ------- M-LGSFs**	H2	0.575	0.09	6.270	***
3	**P- LGSFs < ------ M-LGSFs**	H3	0.889	0.04	6.315	***

In present research work, CFA and EFA outcomes unfold that model fit is good and MLE is managed to minimize the co-variance between factors. Component M-LGSF positively influences "R-LGSFs'', "P-LGSFs" and "O-LGSFs', as value of p is less than 0.005 as manifested in Table 4.13. Besides, the value of estimates is greater than

0.5, which indicates significant outcomes. The hypothesized relationships between variables are presented in path diagram as revealed in Figure 4.6.

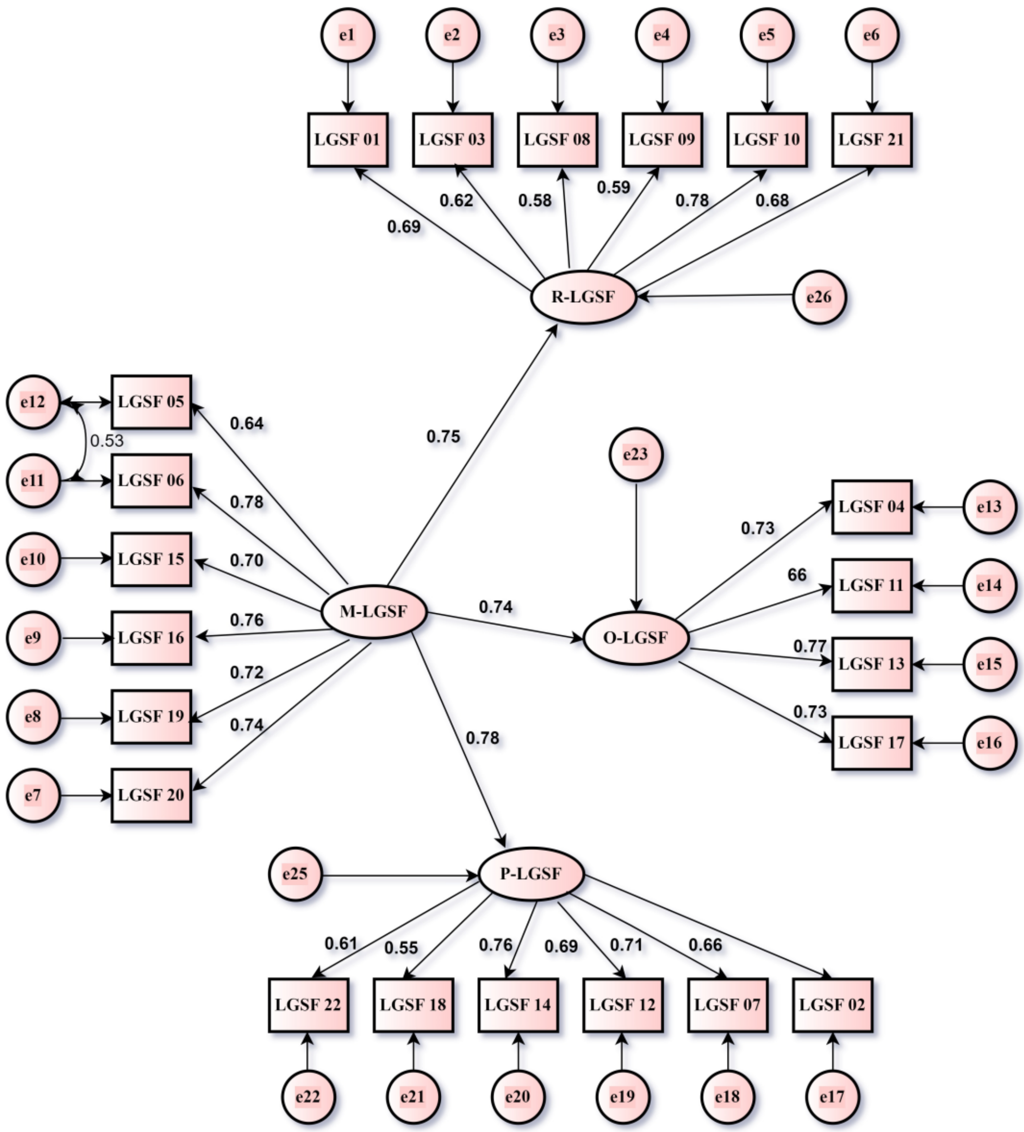


Figure 4.6— Path Diagram of hypothesized associations

The normalized regression weight described on the arrow line in the path diagram was applied to accept or reject the hypotheses. If the value of regression weight is more than 0.5, the outcomes shows a good fit between observed and unobserved components, as a result of this, the whole research hypothesis was accepted.

4.8 Managerial Implications

The current study would support and encourage LG champions, investigators, and Tractor manufacturers to look forward SFs of LG strategies and practices implementation in their business units effectively and efficiently. As a result, the advantages of ISM energize LG consultants and engineers for decision making for accepting LGSFs approach in their conventional manufacturing system to change in sustainable operational system. All LGSFs are not having equal weightage for commencement of LG strategies in Tractor manufacturing. As manpower and money is involved in implementing LG strategies, so implementation of all SFs at a time is not justified. The current study provides relative ranking of LGSFs in such a way that practitioner can focus on particular success factor with top priority to gain from this LG model. The strategic manager must consider more relevant to driving LGSFs ahead of dependence success factors, as if they are capable to handle driving LGSFs, then dependence LGSFs by default would be manageable. The outcome of this study will help industries to increase their productivity, delivery, minimum wastes with increase in morale of employees, consequently customer delight. Successful implementation will help an industry to increase efficiency and effectiveness in running the business.

4.9 Conclusion

The present chapter has featured leading SFs, and it appraises the synergy between them, which will guide exceptionally LG implementation in an Indian Tractor manufacturing Industry. Initially, twenty-six LGSF's have been put on surface after Literature Review and opinion from experienced personnel. These were further assessed with the help of statistical tools and study for uniformity with the use of uniformity check in software, SPSS. The statistical investigation furnishes a list of twenty-two prime LGSFs, and reliability test outcome revealed that an adequate regularity exists between finalized LGSFs, for which value of Cronbach's α value 0.811 observed, refer Table 4.3. Finally, combined ISM and MICMAC analysis helped to observe the interaction, relationship and grouping between LGSFs. The outcome of ISM model, Figure 4.3 recognised the ranking of estimates to be put forward by strategic managers to maximize the outcome of LGSFs in successful implementation. The MICMAC analysis, Figure 4.5 reveals that the groups of LGSFs have been formulated based on their driving power and dependence. The MICMAC outcome reveals that there are nine dependent, nine independents, no autonomous and four linkage LGSFs exists. The fundamentally LGSFs are bonded with strong driving power and weak dependence, integrated at base positional stages of ISM design. The acquired results were validated with SEM model, which divides the success factors into four items, i.e. M-LGSFs, R- LGSFs, P-LGSFs and O-LGSFs. All success factors are observed with factor loading value more than 0.40, and each item has been preserved value of Cronbach's Alpha more than 0.6, refer Table 4.9. With rigorous investigation of gathered facts, the outcomes revealed that the ISM model of Success Factors in Indian Tractor Industry is an authentic model. In academic literature, no evidence communicated using ISM model relating to Tractor Industry. Therefore, the present research work dispenses realistic and practical validation for the predicted research model, which investigates the relations between the critical success factors of Lean Green Strategies deployment in Indian Tractor Manufacturing Industries.

More focus required on fundamental LGSFs to go with them before LG strategies execution. The result of this study can lead the way and advantage to generate innovative decision in Tractor Manufacturing Industry to shift from conventional manufacturing line set up to an efficient and effective LG strategies systematic approach.

CHAPTER-5
INVESTIGATION ON BARRIERS OF LEAN-GREEN APPROACH

Barriers are the stumbling blocks that obstruct an organization from an implementation of new and innovative avenues for an improvement initiative. This chapter aim to analyze the barriers for enhancing operations in the era of green revolution. As companies are struggling to dominance the rising opportunities for preserving sustainability considering green regulations in global marketplace. To achieve the objective of Lean-Green strategies Barriers (LGBs), a systemized literature reviews conducted along with professionals' opinion. An analysis distinguished significant nine Lean-Green Sustainable Parameters (LGSPs) and fifteen LGBs within feasibility relationships for LG-friendly operations. An integrated technique depicts AHP–ELECTRE is used to analyze LGBs for achieving LG operations in an organization's value chain. An examination of present study is determined based upon the opinion of five experienced in field of manufacturing operational units. Finally, constructive and actionable guidelines from study's outcome and an implication were recommended for professionals.

5.1 Introduction

With magnifying population, an advancement in financial and economic eco-system along with better living standard of society, undergoing increased utilization of resources which are naturally available. The certain need of these natural available resources, which are keep on increasing continuously are recognised [277]. Due to escalating need of natural available resources, companies are confronting many operational barriers [195]. The inadequacy of natural available resources is instigating increased input cost and as a consequence of this, commodities remain not so much sustainable in the marketplace [278]. Many manufacturing companies are even now running with conventional linear economy framework [279]. The traditional prospective of re-use and re-process of physical material is less cost effective and marching towards wastes of invaluable natural available resources [280]. Worldwide, organizations are confronting an aggravated push from government authorities to become green covering complete operational functions [281]. Green, ecological and societal concerns are pressuring organisations for changeover from conservative to circular operations to pause the non-productive disposition of consumer or end of goods life cycle [282]. The Green revolution philosophy incorporates 3r's, (Reduce–Eliminate Waste, Reuse-circulate commodities at their highest value, and Recycle-rejuvenate nature) which mark the process more simplified [283]. The organisation of 3r's is deployed as productive device to foster inbuilt green operations [284]. Production and consumption concurrently allow to use and recycle resources effectively to the significant extent through implementing an appropriate design model and operational procedure [285]. LG strategies is an ecological progressive approach that steers to enhance performance of processes by the way of waste reduction, reducing variations and ecological emissions [286]. The transition from the conventional way of doing business to Lean-Green strategies is a significance responsibility as many LG strategies have cease to function during their formation level [287]. This can be credited to various organizations, nevertheless, are not reasonably adept to leverage their competency for green development in an international market-place. Taking into consideration of fact, that they hold lack of understanding of the fundamental and basic concepts of LG tools and techniques, causes of waste and pollution, LG matrix and LG adoption barriers [288]. The barriers are the restraints or track-disrupter that, if get discarded from a system or process, leads the way to smooth achievement of an operational activities in sustainable way [289].

Previous studies have not put considerable efforts to seek the investigation of the Lean Barriers for Green manufacturing within the atmosphere of green revolution. Apart from this, no structured study linked to investigation, forming the contingent bonding amongst LG barriers for understanding compelling nature of barriers exists in the literature. Besides, no work of LG barriers dispenses prioritization and ranking of barriers that assist the industrial professionals to comprehensively eliminate the most hyper-critical barriers from the execution perspective. So, there is an extensive requirement to re-examine LG endorsement barriers in the manufacturing operational environment. With regard to, the present research inscribes the following succeeding objectives of the study.

- Recognition of LGSPs in the context of green revolution.
- Recognition of LGBs in the stages of green revolution.
- Plotting of LGBs for prioritization of significant barriers and rank them for effectual pathways using integrated AHP-ELECTRE model.

- The AHP and ELECTRE are established MCDM techniques and significantly exercised in diverse domains introduced by Saaty and Roy respectively [290]. AHP approach has turned into a prime strategic capable methodology in MCDM investigation. It functions on the competency of human-being to achieve significant decisions of barriers. The cohesion of AHP integrates the complex range of measurement into a unit-dimensional range of precedence. AHP is specifically credible by virtue of the pair-wise co-relation, forms the process unaffected to comparative inaccurate. One of the remarkable significant capacities is that the values are assigned as regards to skills, wisdom, and logical data in the pair-wise differentiation. Furthermore, the AHP combines an essential procedure for examining the stability of estimations of the contributor's common-sense, thus curtailing the favoritism in decision making [291]. Primarily, the crystal-clear structural process of AHP builds this approach easily accepted and acknowledge by an intellectuals and professionals. Considering the aforementioned reasons, the AHP technique has been preferred for this research work.

Besides, ELECTRE method has been preferred for this study, because it involves alternatives in MCDM problems. This is also competent to weigh the contributor's choice and is broadly used as an outranking approach in different sectors. This approach too reflects the preference of resemblance with criterion by way of outranking co-relations to curtail the biasness of decision-takers [292]. The ELECTRE approach can be exercised in concerns, where the possibility of choices credibly demonstrated in different and specific scales. An essentially, both quantitative and qualitative data can be handled effectively by ELECTRE in the variety of measurement scales. The capability of ELECTRE method testifies both in its workability and mathematical reliability [291].

Accordingly, the capabilities of the AHP and ELECTRE techniques can be integrated to evolve a useful decision tool to identify LGBs by upholding inter-relationships with respective dimensionality and to connect feasible path with corresponding barriers by decision matrix. The evolved investigated framework will inspire professionals to commit a creative ground of research. The established integrated AHP-ELECTRE framework will also direct the decision-makers to select efficacious paths for barriers. The outcome of this study will also motivate the strategic managers for developing guidelines for LG processes with sustainable parameters in

Indian Tractor Industry. This chapter presents study and testing of algorithmic processes which has scientific, mathematical and engineering features for enhancing operational processes by focusing on barriers for Sustainable Manufacturing. The outcome may also support an industries expert to utilize opportunities through management of challenges and obstacles.

5.2 Extraction of LGBs and LGSPs from Literature

Systematic Literature Review (SLR) strategy was adopted to conduct the literature as shown in Figure 5.1. Literature study was conducted considering recent trends of LG smart technology, which drives smart manufacturing and digitization in process and also leads to simplification in business processes and operations [293]. Other aspect was considered as Green revolution along with Lean, which is rooted on the close-loop feedback-control structure of the operational setup, leading to enhance resource efficiency [207].

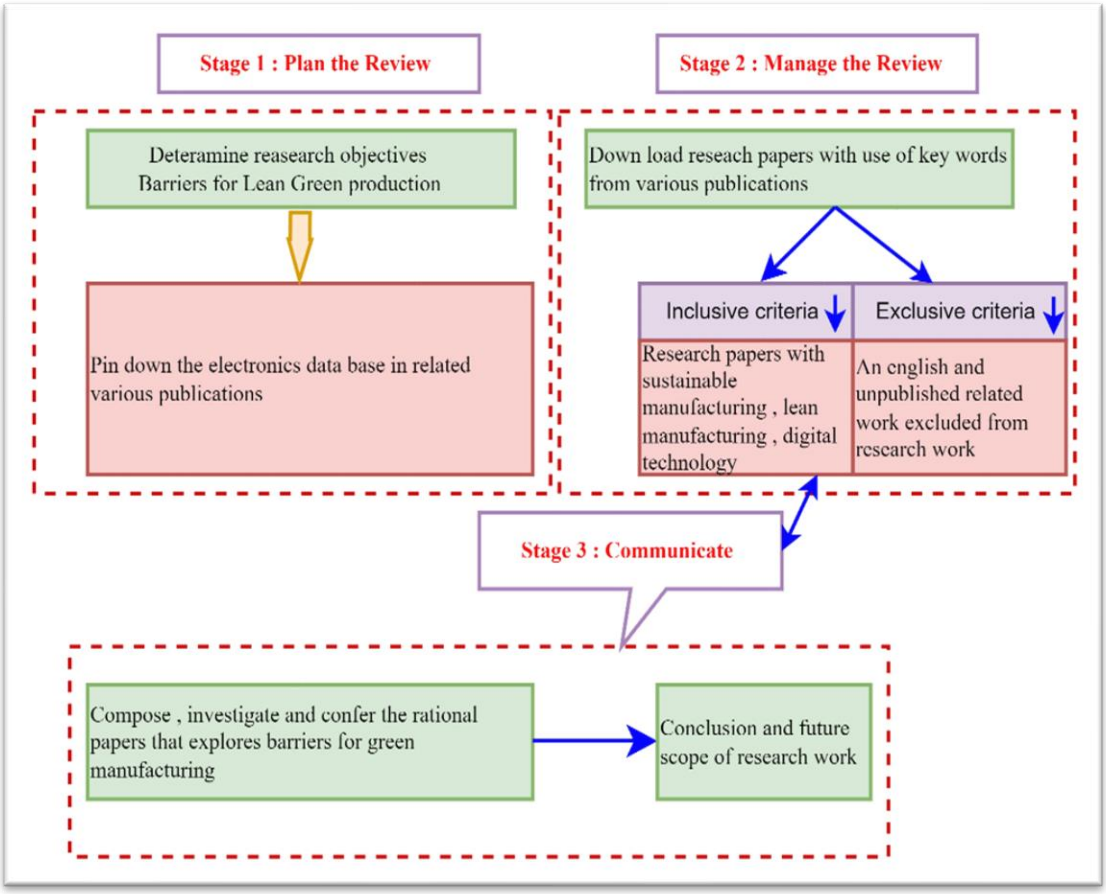


Figure 5.1: Systematic Literature Review

As per SLR, in first phase, key words were selected based on the objectives of research. In Second phase, the articles were downloaded from the electronics database like Scopus, Emerald, Elsevier, web of science etc. In last phase, selected articles were gone through in details and explored the list of barriers of LG practices and strategies. Total 19 LGBs for implementation are manifested in this chapter by the way of literature study and expert view, which are outlined in Table 5.1.

Table 5.1— Identified LGBs for Implementation in Tractor Industry

S.No.	LGBs in Tractor Industry	Literature's support
1.	Threat of forged expenditure / mis-investment	[193]
2.	Inadequate sustainable regulations & command	[193]
3.	Poor plan for integration of Lean digital technology & Circularity	[193]
4.	Inadequacy of practiced manpower	[194]
5.	Lack of finance for Lean digitization and Lean Green technology	[194]
6.	Ineffective performance framework	[195]
7.	Utilize materials as source of energy	[195]
8.	Poor waste management	[195]
9.	Lacked resources / quality of infra-structure for LG practices	[196]
10.	Inadequate Management support	[197]
11.	Employees confrontation to change / switch	[198]
12.	Fluctuating demand from market	[199]
13.	Absence of effective governance from top management	[200]
14.	Focus on short-term targets	[201]
15.	Inadequate knowledge and lack of continuous improvements of LG strategies and practices.	[294]
16.	Inadequacy of Corporate Social Responsibility (CSR)	[295]
17.	Absence of environmental certification (ISO: 9001:14001)	[296]
18.	Lack of hazardous waste disposition	[297]
19.	Lack of reward and recognition	[298]

5.2.1 Green Revolution and Eco-Friendly Lean Production

Circular sustainability is built on the belief of '0' (zero) waste, which incorporates re-formative-based system [299]. The idea compels that waste originate across an organization has potential to exercise and use as a favourable adeptness at another organization. Circular sustainability as "An attainment of automatic controlling system of flow of material in an overall value-added process" [300]. Few of the vital elements of circular sustainability in connection with literature study is Economic Performance, Business Ecosystem [301], Cradle to Cradle (C2C) approach [302], Economic Commodities approaches [303], Natural Capitalist Business [304], Business Symbioses Ecological processes [169], Bio Diversity [305], Circular Movement of Substances [16], Business Eco-sphere, Ecological-Competence [306], Low-Emission [307], etc. Use of circular sustainability, for the prolong period, the value of material can be maintained in value system; the operational sustainability is crucial circular economy's obligation [308]. With the measurement of various kind of effusion, Lean Operational Sustainability may be determined. The study of literatures identified 11 significant eco-friendly LGSPs is tabulated in Table 5.2.

Table 5.2— Lean Green Sustainable Parameters

S.No.	LG Strategies Sustainable Parameters	Literature's Support
1.	Resource Circular sustainability	[309]
2.	Economizing by the way of product and process quality	[310]
3.	Reducing emission in operational value chain	[310]
4.	Reduction of waste in lean system operational value chain	[203]
5.	Designing processes efficient energy system	[311]
6.	Enhancing revenue from green product and services	[312]
7.	Focus on green transport planning	[32]
8.	Focus on community health	[313]
9.	Enhancing green buying	[314]
10.	Reliability and operational quality specification	[31]
11.	Benchmarking system and practices	[315]

5.2.2 Research Gap and Contribution

Based on the literature review, the following gaps have been identified.

- Benefits of LG revolution and ideology of Circular Sustainability (CS) is mentioned in many literatures which are available. For the execution of LG strategies to look at feasibility related concerns, further study is required.

- Research for Integration of SPs and LG revolution parameters is required, so far study pertaining to these terms addressing the individual concerns are analysed in isolation.
- The past research worked out the barriers that hamper the value chain of sustainable lean operations and enhanced operational technologies in isolation and unable to represent proper route to eliminate barriers. That leads to further investigation of the barriers that obstruct LG Manufacturing through inter-linkage of feasible path to LG strategies. This research study addresses the gaps by use of an integrated AHP-ELECTRE methodology.

5.3 LGBs and Sustainable Parameters

The key objective of this work is to examine the ranking of major barriers from identified list of 19 LGBs from Literature Review and opinion from subject matter experts from Tractor Manufacturing Industry and Academia for facilitating the management for priority wise elimination of these barriers. The examination, analysis, and validation of critical LGBs are expressed in this section.

5.3.1 Research Design for Analysis of LGBs

Literature review provides information about the various MCDM approaches used for decision making. All have many advantages and disadvantages associated with these approaches. In current investigation, methodology of an AHP along with ELECTRE is used for research analysis. By virtue of an opportunity of linking subjective and numeric parameters and indicators with rational framework, the approach AHP is preferred [316]. Decisions related to barriers can be recognizable in an effective way and endorses featured quality with the use of consistency indicators [317]. Nevertheless, AHP suffers the possible rank reversal phenomenon with in decision models in case by addition and subtraction of criteria along with an alternative. This can be avoided by unauthorizing the user using addition and subtraction of criteria from decisive model [318]. Furthermore, for signifying substitutes with high level of uncertainty, ELECTRE method is capable of handling facts and factual data which are both subjective and numeric [319]. In the outlook of available feasible facts, more precise model can be worked out with an integrated effect of the AHP and ELECTRE methods after an investigation of realizable alternatives, designating criteria for best substitutes and ranking rather ranking of models in isolation. In this present research, ELECTRE model is used for decision making. The barriers which hinder sustainable manufacturing lean operations in value chain are mapped in current analysis with

LGSPs, are presented. With use of AHP, green operations standards with importance of their ranking has been found. The consensus for pair wise comparison linking criteria and associated weights occurred at the time of discussion with experts. Eventually, inside the sustainable atmosphere, to realize the ranking of barriers of LG operations within value chain, ELECTRE technique is exercised. Research design for analysis of LG strategies barriers are manifested in Figure 5.2.

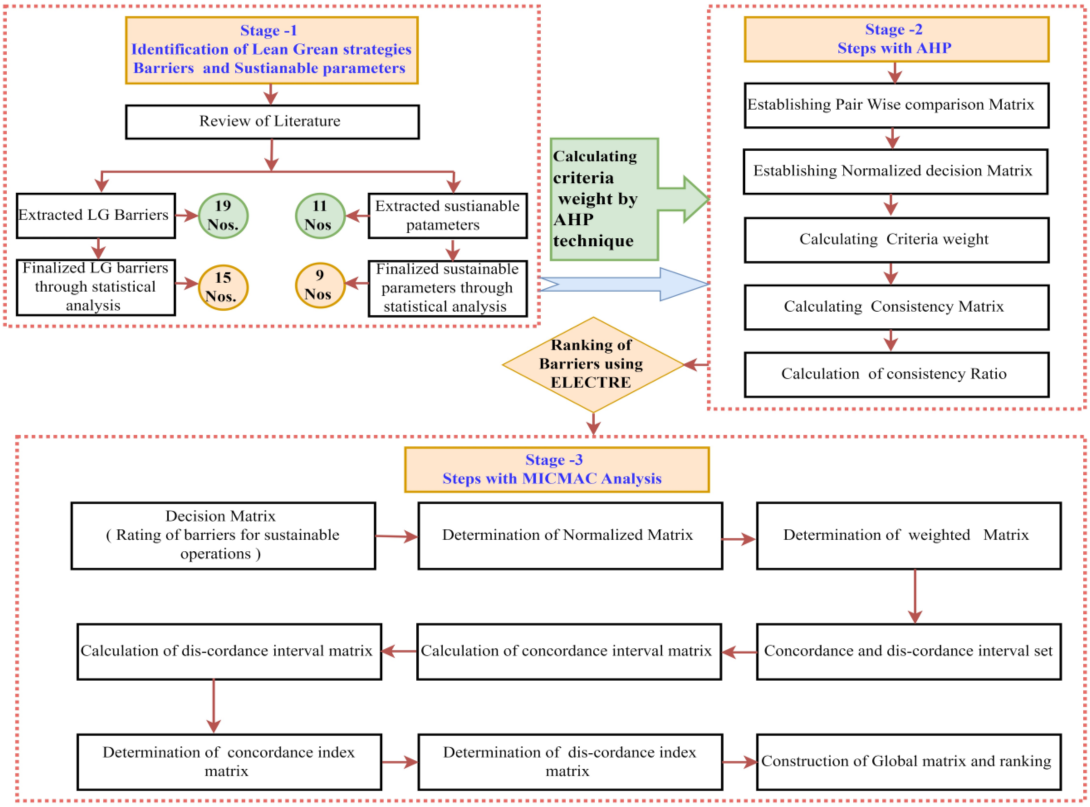


Figure 5.2: Adopted Research Design

The prime objective of the study is to identify the LGBs pertaining to Indian Tractor Industry. This approach consists of mainly three stages, as 1-literature review, 2-steps of AHP, and 3-steps of ELECTRE analysis. In the Stage-1, initially 19 LGBs and 11, LGSPs have been recognised through SLR and screened using inputs from Industry and academic professionals. At the end of stage-1, 15 LGBs and 9 LGSPs have been concluded for further investigation. In stage-2, weight of each LGSP has been calculated by the use of AHP approach. In stage -3, ELECTRE approach was used for out-ranking the LGBs.

5.3.2 Screening of LGBs

Screening of identified LGBs was done using statistical analysis in order to obtain significant LGBs pertaining to Tractor Industries for stimulating further analysis, which is tabulated in Table 5.3.

Table 5.3- Statistical Analysis of Identified LGBs

S.No.	Notation	Lean Green key barriers pertaining in Tractor Industry	Mean	SD	CII	CIMTC
1	**LGB01**	Threat of forged expenditure / mis-investment	4.7	0.46	0.938	0.778
2	**LGB02**	Inadequate sustainable regulations & command	4.7	0.46	0.938	0.778
3	**LGB03**	Poor plan for integration of Lean digital technology & Circularity	4.3	0.46	0.858	0.757
4	**LGB04**	Inadequacy of practiced manpower	4.1	0.74	0.811	0.676
5	**LGB05**	Lack of finance for Lean digitization and Lean Green technology	4.8	0.42	0.955	0.687
6	**LGB06**	Ineffective performance framework	4.6	0.50	0.911	0.694
7	**LGB07**	Utilize materials as source of energy	4.4	0.49	0.881	0.682
8	**LGB08**	Poor waste management	4.2	0.40	0.839	0.579
9	**LGB09**	Lacked resources / quality of infra-structure for LG practices	4.5	0.50	0.908	0.563
10	**LGB10**	Inadequate Management support	4.8	0.41	0.957	0.623
11	**LGB11**	Employees confrontation to change / switch	4.5	0.50	0.907	0.664
12	**LGB12**	Fluctuating demand from market	4.7	0.46	0.938	0.778
13	**LGB13**	Absence of effective governance from top management	4.2	0.40	0.839	0.779
14	**LGB14**	Focus on short-term targets	4.1	0.31	0.821	0.726

15	**LGB15**	Inadequate knowledge and lack of continuous improvements of Lean Green strategies and practices.	4.4	0.49	0.881	0.682
16	**LGB16**	Inadequacy of corporate social responsibility (CSR)	2.1	0.52	0.425	0.116
17	**LGB17**	Absence of environmental certification (ISO: 9001:14001)	1.9	0.29	0.380	0.170
18	**LGB18**	Lack of hazardous waste disposition	2.1	0.27	0.415	0.169
19	**LGB19**	Lack of reward and recognition	1.7	0.44	0.347	0.102

The data for conducting this statistical analysis, five experts selected from academia and 5 from Tractor Industries. Barriers having mean value less than 3, CII value less than 0.6 and CIMTC value less than 0.3, such barriers have been discontinued in advancement to stimulate study. Table 5.3, put through the described analytics with outcome LGBs. Analysis revealed that mean estimates of LBGs, labelled as 'Inadequacy of corporate social responsibility (CSR)', 'Absence of environmental certification (ISO: 9001:14001)', 'Expansive hazardous waste disposition', 'Lack of reward and recognition', having mean value less than 3, hence, essentially to be eliminated from final list. The significant fifteen LGBs are considered for further investigation in evaluation. Similar analysis was performed for sustainable parameters, revealed in Table 5.4.

Table 5.4— Statistical Analysis of LGSPs

S.No.	**Notation**	**Lean Green Sustainable Parameters (LGSPs)**	**Mean**	**SD**
1	**LGSP01**	Resource Circular sustainability	4.8	0.41
2	**LGSP02**	Economizing by the way of product and process quality	4.6	0.50
3	**LGSP03**	Reducing emission in operational value chain	4.6	0.50
4	**LGSP04**	Reduction of waste in lean system operational value chain	4.6	0.50
5	**LGSP05**	Designing processes efficient energy system	4.6	0.50

6	**LGSP06**	Enhancing revenue from green product and services	4.1	0.31
7	**LGSP07**	Focus on green transport planning	4.1	0.31
8	**LGSP08**	Focus on community health	4.8	0.41
9	**LGSP09**	Enhancing green buying	4.6	0.50
10	**LGSP10**	Reliability and operational quality specification	1.8	0.41
11	**LGSP11**	Benchmarking system and practices	1.8	0.41

The analysis revealed that mean estimates of LGSPs, labelled as 'Reliability and operational quality specification', 'Benchmarking system and practices', having mean value less than 3, hence, essentially to be abolished from final list. The significant nine LGSPs are considered for further investigation in evaluation.

5.3.3 Reliability computation of screened LGBs and LGSPs

The statistical analysis furnishes the collection of 15 finalized LGBs pertains to Indian Tractor Industry. To test the validation of the barriers and sustainable parameters distinguished by means of screening analysis and biasness elimination, a questionnaire-based assessment was conducted. To check the internal-consistency of questionnaire, reliability test was conducted. Furthermore, a questionnaire enabled assessment was used to establish an inter-relationship matrix for commencing modelling of LGBs and LGSPs. Besides, for checking questionnaire' internal-consistency and validation of selected barriers and sustainable parameters, Cronback's alpha was calculated in reliability analysis using software SPSS. The LG experts from Indian Tractor Industries were targeted for conducting this survey. The experts were selected through internet sources and direct / indirect linkage with industry working professional. Total, 221 questionnaires were shared and 209 were received back, which were used for further analysis. The outcome of Cronbach's α value assist to compute internal consistency or reliability of LGBs and LGSPs, and it checks their consistency. The SPSS outlines a high value of α, if there is high internal consistency amongst the factors. The consistency assessment outcome reveals the value of internal consistency as 0.810 for barriers and 0.804 for sustainable parameters; Table 5.5 and 5.6 respectively shows positive internal consistency. The value of alpha ranging between 0.70 to 0.90 recommended for the better internal consistency [264]. The standard error of mean, which estimates how much discrepancy is likely in the mean values of samples of the population, which came out to be 3.1 % for barriers and 2.97% for sustainable parameters for all 209 with no missing value, refer Table 5.7 and Table 5.8 respectively, and computed by dividing the average of standard deviation (SD) of all samples to the square root of sample size. The value of standard error of mean equal to or less than 5 % is recommended for better internal consistency [264].

Table 5.5— Results of Reliability Test for LGBs

Cronbach's α	Cronbach's α just after un-related LGBs are removed	No. of LGBs
0.810	0.843	15

Table 5.6— Results of Reliability Test for LGSPs

Cronbach's α	Cronbach's α just after un-related LGSPs are removed	No. of LGSPs
0.804	0.841	9

Table 5.7— Standard Error of Mean for LGBs

S.No.	Notation	Lean Green Barriers in Tractor Industry	Valid	Std. Error of Mean
1	**LGB01**	Threat of forged expenditure / mis-investment	209	0.0320
2	**LGB02**	Inadequate sustainable regulations & command	209	0.0319
3	**LGB03**	Poor plan for integration of Lean digital technology & Circularity	209	0.0315
4	**LGB04**	Inadequacy of practiced manpower	209	0.0500
5	**LGB05**	Lack of finance for Lean digitization and Lean Green technology	209	0.0289
6	**LGB06**	Ineffective performance framework	209	0.0344

7	**LGB07**	Utilize materials as source of energy	209	0.0340
8	**LGB08**	Poor waste management	209	0.0275
9	**LGB09**	Lacked resources / quality of infra-structure for LG practices	209	0.0345
10	**LGB10**	Inadequate Management support	209	0.0282
11	**LGB11**	Employees confrontation to change / switch	209	0.0346
12	**LGB12**	Fluctuating demand from market	209	0.0319
13	**LGB13**	Absence of effective governance from top management	209	0.0275
14	**LGB14**	Focus on short-term targets	209	0.0213
15	**LGB15**	Inadequate knowledge and lack of continuous improvements of Lean Green strategies and practices.	209	0.0341
16	**LGB16**	Inadequacy of corporate social responsibility (CSR)	209	0.0357
17	**LGB17**	Absence of environmental certification (ISO: 9001:14001)	209	0.0204
18	**LGB18**	Lack of hazardous waste disposition	209	0.0185
19	**LGB19**	Lack of reward and recognition	209	0.0305

Table 5.8— Standard Error of Mean for LGSPs

S.No.	**Notation**	**Lean Green Sustainable Parameters in Tractor Industry**	**Valid**	**Std. Error of Mean**
1	**LGSP01**	Resource Circular sustainability	209	0.0282
2	**LGSP02**	Economizing by the way of product and process quality	209	0.0343
3	**LGSP03**	Reducing emission in operational value chain	209	0.0344

4	**LGSP04**	Reduction of waste in lean system operational value chain	209	0.0343
5	**LGSP05**	Designing processes efficient energy system	209	0.0344
6	**LGSP06**	Enhancing revenue from green product and services	209	0.0212
7	**LGSP07**	Focus on green transport planning	209	0.0212
8	**LGSP08**	Focus on community health	209	0.0282
9	**LGSP09**	Enhancing green buying	209	0.0343
10	**LGSP10**	Reliability and operational quality specification	209	0.0282
11	**LGSP11**	Benchmarking system and practices	209	0.0282

5.3.4 Implementation steps of AHP approach

For implementation of an effective decision-making process by investigating the co-relative significance of criterion, AHP helps decision makers for gaining effectiveness [320]. AHP has been observed much better and preferable technique as compared with Analytic Network Process (ANP) on the strength of less hierarchy difficulty owing to lesser pair-wise comparability [321]. In research work, sustainable parameters ranking has been done using of AHP on 9-point rating Saaty's scale, these standards are collated with one another [322]. In current study, the selected method, APH, calculates the weights of criteria used, which are further used in ELECTRE technique. This process is decision analysis technique that deduces the data which are quality and quantity based, also reflects preference of decision makers. The step wise technique of calculation using AHP has been outlined as following [323].

- **Step-1: Establishing of pair wise comparison matrix**

  Suppose, there are n numbers of criteria in a number of ranges, the pair-wise methodology proposed by Saaty in 1980, Table 5.9, can be tested for estimating pair wise comparison matrix, displayed by matrix P, as shown in equation (5.1).

$$P=\begin{bmatrix} 1 & p_{12} \dots. & p_{1n} \\ p_{21} & 1 & p_{2n} \\ \vdots & \cdots \ \ddots & \vdots \\ p_{n1} & p_{n2} \cdots & 1 \end{bmatrix} \tag{5.1}$$

Where p_{ij} signifies the relative significance of criteria i co-relating with j. The equation (5.2), can determine the relative significance of criteria j co-relating with i.

$$p_{ji}=\frac{1}{p_{ij}},\quad p_{ij>0},\ [i],[j]=1,2,3,4....n \tag{5.2}$$

Table 5.9— Fundamental scale of AHP (Saaty, 1980) [310].

Severity of importance (1-9 scale)	Definition
1	Equal importance
2	Weak or slight
3	Moderate importance
4	Moderate Plus
5	Strong Importance
6	Strong Plus
7	Very strong or demonstrated importance
8	Very-Very strong
9	Extremely importance
Reciprocal of above	If activity i has non-zero numbers as assigned and compare with activity j , then j has reciprocal value when relate with i.

- **Step-2: Calculation of weights**

  Utilizing pair-wise relationship matrix, coefficient of weights with regards to each criterion are derived by way of calculating the principal eigenvectors of pairwise relationship matrix as revealed in equation (5.3).

$$\begin{bmatrix} 1 & p_{12} \cdots & p_{1n} \\ p_{21} & 1 & p_{2n} \\ \vdots & \cdots \ \ddots & \vdots \\ p_{n1} & p_{n2} \cdots & 1 \end{bmatrix} \begin{vmatrix} w_1 \\ w_2 \\ | \\ \vdots \\ w_n \end{vmatrix} = \lambda_{\max} \begin{vmatrix} w_1 \\ w_2 \\ | \\ \vdots \\ w_n \end{vmatrix} \tag{5.3}$$

where λ_{max} is the maximum eigenvalue of matrix P. Equation (5.4) can govern the maximal eigenvector of the pairwise relationship matrix.

$$W_{max} = [w_1, \quad w_2, w_3, \cdots w_n] \tag{5.4}$$

Through the normalizing, the maximum eigen-vectors of weights of criteria can be achieved, as shown in equation (5.5).

$$W = \left(\frac{w_1}{n}, \frac{w_2}{n}, \frac{w_3}{n}, \cdots\cdots, \frac{w_n}{n}\right)^{T} \sum_{i=1}^{n} w_i \;\; \sum_{i=1}^{n} w_i \sum_{i=1}^{n} w_i \qquad (5.5)$$

where 'W' represents the weight co-efficient vector, whereas, $'w_i'$ re-present about weight of criteria and 'n' re-present about total numbers of criteria.

- **Step-3: Calculation of consistency Matrix and consistency ratio**

  If, $P_{im}= P_{ij}\, P_{jm}$, where j,m= 1,2,3, -----,n , then the pairwise relationship matrix P can be registered as a consistent matrix. Hypothesis reveals, that if the dimensional pair-wise relationship matrix is a consistent matrix, it's maximum eigenvalues should be equal to number of criteria (n). Nevertheless, it is tough to build pairwise relationship matrix, which is consistent with matrix. In practical situations, several relationship grids that satisfy the consistency study signify the consistent grids. The consistency ratio is the persistent way to analyse, if in case, a pairwise comparison matrix is consistent or not, as revealed in equation (5.6).

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} \qquad (5.6)$$

where 'CI' signify, Consistency Index and 'RI' signify, Random Index for the equal proportions with matrix P. The standard value of RI can be set up from Table 5.10 and the value of CI can be computed using equation (5.7).

$$Consistency\ Index = \frac{\lambda_{max} - n}{n-1} \qquad (5.7)$$

Table 5.10— The Average Value of RI

N	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

where λmax stands for the maximum eigenvalue of the pairwise relationship matrix P, 'n' stands for the proportions of this matrix. When the CR of a relationship matrix is less than 0.1 (10%), then the matrix is adequate enough as consistent matrix. Specifically, if CR is more than or equal to 0.1, the matrix should be modified until it becomes consistence.

5.3.5 Implementation Steps of ELECTRE Approach

For ranking the barriers for LG operations in value chain, ELECTRE technique is used in present research. By adopting outcome of AHP, decision making can be taken forward. Multi-Criteria Decision-Making approach anyhow, delivers exceptional outcomes, when blended with tools of decision-making. For ranking and outweighing of substitutes, in 1965, ELECTRE approach was proposed. In process for ELECTRE, normalization of these ratings was done, and weighed-formalized grid was formulated [221]. By virtue of out-ranking inter-relationships, ELECTRE methodology discloses the supremacy of inter-relationships amongst various alternatives. Therefore, it is viable that, these out-ranking inter-relationships can discriminate amongst the alternatives. In this ELECTRE method, for pair-wise comparison of alternatives, two types of matrices are used, Concordance and Discordance matrices. ELECTRE technique was adapted by investigating these two matrices to select the possible alternatives in this chapter. We assume that LGSP01, LGSP02, ..., LGSPm are ‘m’ possible criteria for LG implementation in Indian Tractor Industry, LGB01, LGB02, …, LGBn are barriers, which can express the properties of possible criteria. x_{ij} defines the level of criteria LGSPi concerning barriers LGBn. Again, Wn signifies the weight of significance of LGBn, which is obtained from the AHP method. Following are the formulation steps of ELECTRE approach manifested in next sections [324].

- **Step-1: Establishing Decision Matrix**

  The barriers of LG strategies of an organization value chain have been assessed regards to the varied sustainable parameters on a rating scale of 5 points using equation (5.8).

$$X = [x_{ij}] \tag{5.8}$$

- **Step-2: Determination of Normalized Matrix**

  The decision matrix mentioned in Step-1 is normalized by the use of equation (5.9), manifested below.

$$P = [\, p_{ij} \,] \tag{5.9}$$

  Where $p_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}$, $i = 1,2,3 \cdots \cdots n$,symbolizes specific sustainable criteria and $j = 1,2,3, \cdots \cdots, m$, symbolizes specific barriers in LG strategies implementation.

- **Step-3: Determination of weighted Matrix**

  The normalized matrix (weighted) has been developed by the use of equation (5.10), manifested below.

$$N = [n_{ij}] \tag{5.10}$$

where $, [n_{ij}] = p_{ij * W_i}$, w_i stands for weight of sustainable parameters obtained from APH technique.

- **Step-4: Concordance and Discordance Interval Set**

  The set of criteria for concordance and discordance are developed for each barrier by making use of threshold as explained in equation (5.11) and (5.12).

$$Con_{kl} = \{1|n_{ik} \geq n_{il}\} \quad (5.11)$$

$$Dis_{kl} = \{1|n_{ik} < n_{il}\} = 1- Con_{kl} \quad (5.12)$$

  where , Con_{kl} is the interval set of concordance criteria and Dis_{kl} is the interval set of discordance criteria.

- **Step-5: Determination of concordance interval Matrix**

  The concordance interval matrix has been prepared by using formula mentioned in equation (5.13).

$$Con\ (m) = \lfloor c(m)_{kl} \rfloor$$

$$\lfloor c(m)_{kl} \rfloor = \sum_{1 \in c(m)\ kl} w_i \,/\, \sum_{i=1}^{n} w_i$$

  (5.13)

  Where $0 \leq c(m)_{kl} \ll 1$

  Here, $c(m)_{kl}$ is a summation of the weights of concordance criteria for which , k^{th} barrier is preferred over the l^{th} barrier.

- **Step-6: Determination of discordance interval Matrix**

  The discordance interval matrix has been developed by using formula mentioned in equation (5.14).

$$Dis\ (m) = [d(m)_{kl}] \text{ and}$$

$$[d(m)_{kl}] = \frac{\max_{1 \in Dis(m)_{kl}} |n_{ik} - n_{il}|}{\max_{i \in} |n_{ik} - n_{il}|} \quad (5.14)$$

  Where, $0 \leq d(m)_{kl} \ll 1$

  Here, the numerator reflects the maximum absolute difference among the weighted normalized components of k_{th} and l_{th} barriers acknowledging only those criteria for which k_{th} barrier is low-grade to the l_{th} barrier. Denominator reflects the maximum absolute difference among k_{th} and l_{th} barriers for all the sustainable criteria.

- **Step-7: Determination of Concordance Index Matrix**

  The average value $\bar{c}(m)$ of $c(m)_{kl}$ is observed using equation (5.15) and an index matric (Boolean matrix E) is developed pertaining to the values of $c(m)_{kl}$

and $\overline{c}(m)$ as manifested in equation (5.16).

$$\bar{c}(m) = \sum_{k=1,\ k\neq 1}^{q} \sum_{k=1,\ k\neq 1}^{q} c(m)_{kl} \Big/ q(q-1) \quad (5.15)$$

$$e(m)_{kl} = 1, \text{ for } c(m)_{kl} \geq \overline{c}(m)$$

$$= 0, \text{ for } c(m)_{kl} < \overline{c}(m) \quad (5.16)$$

- **Step-8: Determination of Discordance Index Matrix**

  The average value of $\bar{d}(m)$ of $d(m)_{kl}$ is observed using equation (5.17) and an index matric (Boolean matrix F) is developed pertaining to the values $d(m)_{kl}$ and $\bar{d}(m)$ as manifested in equation (5.18).

$$\bar{d}(m) = \sum_{k=1,\ k\neq 1}^{q} \sum_{k=1,\ k\neq 1}^{q} d(m)_{kl} \Big/ q(q-1) \quad (5.17)$$

$$f(m)_{kl} = 1, \text{ for } d(m)_{kl} \geq \bar{d}(m)$$

$$= 0, \text{ for } d(m)_{kl} < \bar{d}(m) \quad (5.18)$$

- **Step-9: Construction of global matrix and ranking**

  The elements of the matrix E with the corresponding elements of matrix F are multiplied to get the aggregate dominance (Global) matrix G using equation (5.19).

$$G = [\, g(m)_{kl} \,]$$

$$g(m)_{kl} = [\, e(m)_{kl} \, X \ \ f(m)_{kl} \,] \quad (5.19)$$

  Based on the final dominance matrix, we can find the dominance of one alternative over another, and we can map the outranking relationship of the substitutes with respect to the other dominant substitute.

5.4 Application of AHP-ELECTRE Approach

The objective of current study to successfully identification and ranking of LGBs within sustainable environment in Indian Tractor Industry for chalking out actions and execution for elimination barriers based on priority. Initially, nineteen barriers and eleven sustainable parameters were identified through Systematic Literature Review and further, with the support of statistical investigation and opinion from experts, fifteen LGBs and 9 LGSPs were screened up. The statistical investigation furnishes a concluded list of 15 LGB and 9 LGSPs in Indian Tractor Industry. Thereafter, a model of mutual relationship between concluded criteria through pair-wise comparison and calculation of weight of each criterion compare with other criterion is computed with the support of AHP methodology. Using weights computed in AHP, ranking the barriers after calculation of concordance and discordance index matrix and finally global matrix for outranking of barriers with the help of ELECTRE investigation was performed. The cross-examination steps of AHP model was conducted by case organisation's designated experts and people from academics. The detailed illustration of ISM model steps with case analysis are furnished in subsequent sections.

5.4.1 Analysis of LGBs with in criteria LGSPs

For the data collection process, a panel of five experts were constituted; three form case industry and two from academics, and the details of experts are tabulated below in Table 5.11. The necessary data was collected from industrial professionals' and experts from academia. Unfortunately, for modelling MCDM approach, there is no such common consent in literatures for numbers of experts needed. For instance, [325], considered the view-point of five proficient to model a fuzzy- TOPSIS concern. [326], appraised four proficient to model a grey-DEMATEL concern. For simplicity, this research appraised five experts in the process of data collection. Experts input was taken for further analysis for concluded 9 LGSPs and 15 LGBs and computed as per the steps mentioned for both MCDM techniques used in this chapter, mentioned in previous section.

Table 5.11— Details of Experts

Expert	Working zone	Area of expertise	Exp. (Yrs.)	Industry type	Position
1	Industry	Lean and sustainability	21	Manufacturing	Senior Management
2	Industry	Lean and sustainability	18	Manufacturing	Middle Management
3	Academics	Lean Manufacturing	22	University	Professor
4	Academics	Sustainability	16	University	Assistant Professor
5	Industry	Lean and sustainability	19	Manufacturing	Senior Management

5.4.2 Establishing Pair-wise Comparison Matrix for Sustainable Parameters

The pair wise comparison matrix was prepared for sustainable parameters using fundamental scale of AHP proposed by Saaty, 1980 with severity of importance ranging from 1 to 9 scales, Table 5.9. The structure of matrix using equation (5.1) and (5.2), after converting fractional cell values in decimal values was tabulated in Table 5.12.

Table 5.12— Pair-wise Comparison Matix for Sustainable Parameters

Notation	LG SP01	LG SP02	LG SP03	LG SP04	LG SP05	LG SP06	LG SP07	LG SP08	LG SP09
LGSP01	1	4	5	3	2	3	7	6	7
LGSP02	0.25	1	2	3	0.5	0.5	4	5	5
LGSP03	0.2	0.5	1	0.25	0.33	0.5	2	2	3
LGSP04	0.33	0.33	4	1	0.5	0.33	3	2	3
LGSP05	0.5	2	3	2	1	0.33	5	3	4
LGSP06	0.33	2	2	3	3	1	2	2	2
LGSP07	0.14	0.25	0.5	0.33	0.2	0.5	1	0.5	2
LGSP08	0.17	0.2	0.5	0.5	0.33	0.5	2	1	2
LGSP09	0.14	0.2	0.33	0.33	0.25	0.5	0.5	0.5	1
Sum	**3.06**	**10.48**	**18.33**	**13.41**	**8.11**	**7.16**	**26.5**	**22**	**29**

The heterogeneous input data from experts in Table 5.12 are pre-processed for making dimensionless data for normalizing and removing data redundancy, potential biases and minimizing errors in data modification. This is done by dividing each cell value of pair-wise comparison matrix of Table 5.12 with sum of their respective column value to get normalized decision matrix, which is manifested in Table 5.13.

Table 5.13— Normalized Decision Matrix

Notation	LG SP01	LG SP02	LG SP03	LG SP04	LG SP05	LG SP06	LG SP07	LG SP08	LG SP09
LGSP01	0.327	0.382	0.273	0.224	0.247	0.419	0.264	0.273	0.241
LGSP02	0.082	0.095	0.109	0.224	0.062	0.070	0.151	0.227	0.172
LGSP03	0.065	0.048	0.055	0.019	0.041	0.070	0.075	0.091	0.103
LGSP04	0.108	0.031	0.218	0.075	0.062	0.046	0.113	0.091	0.103
LGSP05	0.163	0.191	0.164	0.149	0.123	0.046	0.189	0.136	0.138
LGSP06	0.108	0.191	0.109	0.224	0.370	0.140	0.075	0.091	0.069
LGSP07	0.046	0.024	0.027	0.025	0.025	0.070	0.038	0.023	0.069
LGSP08	0.056	0.019	0.027	0.037	0.041	0.070	0.075	0.045	0.069
LGSP09	0.046	0.019	0.018	0.025	0.031	0.070	0.019	0.023	0.034

5.4.3 Calculation of criteria weights

The average of each row values of sustainable criteria of normalized decision matrix shown in Table 5.13 are calculated, which gives the weight of each criteria as per equation (5.5), which are manifested in Table 5.14. Ranking of criteria has been done with highest weight as 1 and 9 having lowest weight in Table 5.14.

Table 5.14— Criteria Weight

LGSP / LGSP	1	2	3	4	5	6	7	8	9	Weight	Rank
LGSP1	0.327	0.382	0.273	0.224	0.247	0.419	0.264	0.273	0.241	0.294	1
LGSP2	0.082	0.095	0.109	0.224	0.062	0.070	0.151	0.227	0.172	0.132	4
LGSP3	0.065	0.048	0.055	0.019	0.041	0.070	0.075	0.091	0.103	0.063	6
LGSP4	0.108	0.031	0.218	0.075	0.062	0.046	0.113	0.091	0.103	0.094	5
LGSP5	0.163	0.191	0.164	0.149	0.123	0.046	0.189	0.136	0.138	0.144	3
LGSP6	0.108	0.191	0.109	0.224	0.370	0.140	0.075	0.091	0.069	0.153	2
LGSP7	0.046	0.024	0.027	0.025	0.025	0.070	0.038	0.023	0.069	0.038	8
LGSP8	0.056	0.019	0.027	0.037	0.041	0.070	0.075	0.045	0.069	0.049	7
LGSP9	0.046	0.019	0.018	0.025	0.031	0.070	0.019	0.023	0.034	0.032	9

comparisons numbers relate to 36; CR value equal to 7.36% PGV equal to 8.871; eigenvector solution equal to 6 iterations, delta value related to 1.99 E-8.

5.4.4 Calculation of Consistency matrix and Consistency ratio

The pair wise comparison matrix, Table 5.12 calculated by using input from experts in the scale of 1 to 9, which is also called random values. Values in Table 5.13 are normalized and weights are calculated for each criterion. For calculating the consistency matrix, calculated weight of each raw in Table 5.14 is multiplied by each value of cell of respective column of pairwise matrix to get the consistency matrix, Table 5.15 and Table 5.16. The consistency matrix thus obtained, each raw of the matrix are sum up to get the weight sum value.

Table 5.15— Pair-wise Matrix with Calculated Criteria Weight

Criteria Weight	**0.294**	**0.132**	**0.063**	**0.094**	**0.144**	**0.153**	**0.038**	**0.049**	**0.032**
Notation	**LG SP01**	**LG SP02**	**LG SP03**	**LG SP04**	**LG SP05**	**LG SP06**	**LG SP07**	**LG SP08**	**LG SP09**

LGSP01	1	4	5	3	2	3	7	6	7
LGSP02	0.25	1	2	3	0.5	0.5	4	5	5
LGSP03	0.2	0.5	1	0.25	0.33	0.5	2	2	3
LGSP04	0.33	0.33	4	1	0.5	0.33	3	2	3
LGSP05	0.5	2	3	2	1	0.33	5	3	4
LGSP06	0.33	2	2	3	3	1	2	2	2
LGSP07	0.14	0.25	0.5	0.33	0.2	0.5	1	0.5	2
LGSP08	0.17	0.2	0.5	0.5	0.33	0.5	2	1	2
LGSP09	0.14	0.2	0.33	0.33	0.25	0.5	0.5	0.5	1

Table 5.16— Consistency Ratio and Weighted Sum Value

LGSP \ LGSP	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Weighted Sum-value**
LG SP01	0.294	0.528	0.315	0.282	0.288	0.459	0.266	0.294	0.244	2.950
LG SP02	0.074	0.132	0.126	0.282	0.072	0.077	0.152	0.245	0.160	1.319
LG SP03	0.059	0.066	0.063	0.024	0.048	0.077	0.076	0.098	0.096	0.605
LG SP04	0.097	0.044	0.252	0.094	0.072	0.050	0.114	0.098	0.096	0.917
LG SP05	0.147	0.264	0.189	0.188	0.144	0.050	0.190	0.147	0.128	1.447
LG SP06	0.097	0.264	0.126	0.282	0.432	0.153	0.076	0.098	0.064	1.592
LG SP07	0.041	0.033	0.032	0.031	0.029	0.077	0.038	0.025	0.064	0.368
LG SP08	0.050	0.026	0.032	0.047	0.048	0.077	0.076	0.049	0.064	0.468
LG SP09	0.041	0.026	0.021	0.031	0.036	0.077	0.019	0.025	0.032	0.307

After that, calculated the ratio of weight sum value to criteria weight value to get of each criterion eigen vector, and sum up all ratio values to get λ max, which stands for the maximum eigenvalue of the pairwise relationship matrix, shown in Table 5.17.

Table 5.17— Maximum Eigen Vector (λ max) of Pairwise Comparison Matrix

Criteria	Weighted Sum Value (1)	Criteria weight (2)	Ratio of (1) / (2)
LGSP01	2.950	0.294	10.023
LGSP02	1.319	0.132	9.958
LGSP03	0.605	0.063	9.615
LGSP04	0.917	0.094	9.740
LGSP05	1.447	0.144	10.026
LGSP06	1.592	0.153	10.410
LGSP07	0.368	0.038	9.601
LGSP08	0.468	0.049	9.579
LGSP09	0.307	0.032	9.734
Maximum eigen value of pairwise matrix (λ max)			**9.854**

Next step to calculate the consistence index by use of equation (5.7).

$$Consistency\ Index = \frac{\lambda_{max} - n}{n-1} = 0.1067$$

which comes out to be 0.10675 for $n = 9$ (Concluded criteria), now the consistency ratio was calculated using equation (5.6), for which CI is 0.1067, $n = 9$ and RI from Table 5.10 =1.45, the value of CR calculated to be 0.073621, which is less than 0.1. So, we can assume, the matrix is reasonable correct.

5.5 Ranking of LGBs Manufacturing Strategies

For ranking the LGBs of manufacturing strategies, ELECTRE method is used. The weight outcome and rating of SPs of AHP has taken forward for analysis in this approach. The analytical steps of ELECTRE technique are furnished below.

5.5.1 Decision Matrix

After calculating the importance rating of the sustainability criterion, a decision matrix, Table 5.18 of different barriers impeding LG manufacturing operations of Tractor Industry using a five-point rating scale, input taken from expert has been devised using equation (5.8).

Table 5.18— Decision Matrix: Rating of Barriers for LG approach

Notation	LG SP01	LG SP02	LG SP03	LG SP04	LG SP05	LG SP06	LG SP07	LG SP08	LG SP09
LGB01	4	3	3	3	3	3	2	2	2

LGB02	4	2	3	4	4	3	2	2	2
LGB03	5	3	3	3	4	2	4	2	2
LGB04	5	3	3	3	5	2	2	2	2
LGB05	4	3	2	3	3	2	3	2	2
LGB06	5	2	3	4	5	2	2	2	2
LGB07	3	3	2	4	4	3	2	2	2
LGB08	3	3	5	4	4	2	3	2	2
LGB09	3	4	2	4	4	3	2	2	2
LGB10	4	2	3	3	3	2	3	3	3
LGB11	4	2	4	4	4	2	3	2	2
LGB12	3	2	2	3	3	2	2	2	2
LGB13	3	2	2	3	3	2	2	2	2
LGB14	4	4	3	3	3	4	2	3	2
LGB15	3	3	2	3	3	2	2	4	2
Weight	0.294	0.132	0.063	0.094	0.144	0.153	0.038	0.049	0.032

5.5.2 Normalized Decision Matrix

After developing the decision matrix of barriers of the sustainability criterion, a Normalized decision matrix, Table 5.19 of different barriers impeding LG strategies manufacturing operations of Tractor Industry has been derived using equation (5.9). Normalization of decision matrix is essential to make sure; all components of matrix are on identical scale between 0 and 1.

Table 5.19— Normalized Decision Matrix

Notation	LG SP01	LG SP02	LG SP03	LG SP04	LG SP05	LG SP06	LG SP07	LG SP08	LG SP09
LGB01	0.267	0.275	0.265	0.225	0.208	0.313	0.209	0.221	0.248
LGB02	0.267	0.183	0.265	0.301	0.277	0.313	0.209	0.221	0.248
LGB03	0.333	0.275	0.265	0.225	0.277	0.209	0.417	0.221	0.248
LGB04	0.333	0.275	0.265	0.225	0.346	0.209	0.209	0.221	0.248
LGB05	0.267	0.275	0.177	0.225	0.208	0.209	0.313	0.221	0.248
LGB06	0.333	0.183	0.265	0.301	0.346	0.209	0.209	0.221	0.248
LGB07	0.200	0.275	0.177	0.301	0.277	0.313	0.209	0.221	0.248
LGB08	0.200	0.275	0.442	0.301	0.277	0.209	0.313	0.221	0.248
LGB09	0.200	0.367	0.177	0.301	0.277	0.313	0.209	0.221	0.248
LGB10	0.267	0.183	0.265	0.225	0.208	0.209	0.313	0.331	0.372

LGB11	0.267	0.183	0.354	0.301	0.277	0.209	0.313	0.221	0.248
LGB12	0.200	0.183	0.177	0.225	0.208	0.209	0.209	0.221	0.248
LGB13	0.200	0.183	0.177	0.225	0.208	0.209	0.209	0.221	0.248
LGB14	0.267	0.367	0.265	0.225	0.208	0.417	0.209	0.331	0.248
LGB15	0.200	0.275	0.177	0.225	0.208	0.209	0.209	0.442	0.248

5.5.3 Weightage Normalized Decision Matrix

Post normalization, with the multiplication of components with relative weightage of sustainable parameters calculated form APH, weighted normalized matrix is generated by the using equation (5.10), which is manifested in Table 5.20.

Table 5.20— Weighted Normalized Decision Matrix

Notation	**LG SP01**	**LG SP02**	**LG SP03**	**LG SP04**	**LG SP05**	**LG SP06**	**LG SP07**	**LG SP08**	**LG SP09**
LGB01	0.078	0.036	0.017	0.021	0.030	0.048	0.008	0.011	0.008
LGB02	0.078	0.024	0.017	0.028	0.040	0.048	0.008	0.011	0.008
LGB03	0.098	0.036	0.017	0.021	0.040	0.032	0.016	0.011	0.008
LGB04	0.098	0.036	0.017	0.021	0.050	0.032	0.008	0.011	0.008
LGB05	0.078	0.036	0.011	0.021	0.030	0.032	0.012	0.011	0.008
LGB06	0.098	0.024	0.017	0.028	0.050	0.032	0.008	0.011	0.008
LGB07	0.059	0.036	0.011	0.028	0.040	0.048	0.008	0.011	0.008
LGB08	0.059	0.036	0.028	0.028	0.040	0.032	0.012	0.011	0.008
LGB09	0.059	0.048	0.011	0.028	0.040	0.048	0.008	0.011	0.008
LGB10	0.078	0.024	0.017	0.021	0.030	0.032	0.012	0.016	0.012
LGB11	0.078	0.024	0.022	0.028	0.040	0.032	0.012	0.011	0.008
LGB12	0.059	0.024	0.011	0.021	0.030	0.032	0.008	0.011	0.008
LGB13	0.059	0.024	0.011	0.021	0.030	0.032	0.008	0.011	0.008
LGB14	0.078	0.048	0.017	0.021	0.030	0.064	0.008	0.016	0.008
LGB15	0.059	0.036	0.011	0.021	0.030	0.032	0.008	0.022	0.008

5.5.4 Concordance Interval set, Concordance Interval and Index Matrix

The concordance set of criteria are fragmented for all the LG manufacturing strategies barriers from the weighted normalized matrix using equation (5.11). Further, the concordance interval matrix is derived from the summation of the concordance criterion as manifested in equation (5.13). Concordance interval matrix is manifested in Table 5.21.

Table 5.21— Concordance Interval Matrix

LGB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.00	0.76	0.52	0.56	0.95	0.45	0.76	0.66	0.63	0.87	0.66	1	1	0.65	0.94
2	0.86	0,00	0.53	0.43	0.82	0.56	0.86	0.76	0.86	0.87	0.89	1	1	0.65	0.81
3	0.83	0.74	0.00	0.85	1	0.77	0.74	0.84	0.70	0.91	0.84	1	1	0.65	0.94
4	0.83	0.74	0.95	0.00	0.95	0.90	0.74	0.80	0.61	0.87	0.80	1	1	0.65	0.94
5	0.87	0.44	0.46	0.50	0.00	0.41	0.60	0.70	0.47	0.85	0.70	1	1	0.59	0.94
6	0.70	0.83	0.82	0.86	0.82	0.00	0.70	0.76	0.70	0.87	0.89	1	1	0.65	0.81
7	0.64	0.64	0.60	0.50	0.66	0.50	0.00	0.89	0.86	0.42	0.60	1	1	0.27	0.94
8	0.54	0.54	0.66	0.56	0.70	0.56	0.83	0.00	0.70	0.62	0.70	1	1	0.36	0.94
9	0.64	0.64	0.60	0.50	0.66	0.50	1	0.89	0.00	0.52	0.60	1	1	0.43	0.94
10	0.70	0.60	0.39	0.43	0.86	0.47	0.47	0.63	0.47	0.00	0.70	0.7	1	0.70	0.81
11	0.70	0.83	0.53	0.43	0.86	0.56	0.70	0.80	0.70	0.91	0.00	1	1	0.65	0.81
12	0.35	0.25	0.33	0.37	0.53	0.41	0.47	0.43	0.47	0.42	0.37	0	1	0.30	0.81
13	0.35	0.25	0.33	0.37	0.53	0.41	0.47	0.53	0.47	0.52	0.37	1	0	0.30	0.81
14	1	0.76	0.52	0.56	0.95	0.47	0.76	0.64	0.76	0.92	0.64	1	1	0.00	0.94
15	0.48	0.25	0.46	0.50	0.60	0.41	0.60	0.66	0.47	0.57	0.37	1	1	0.35	0.00

From the Table 5.21, summation of all the rows values and column values are same, which comes out to be 146.24. Using equation (5.15), $\bar{c}(m)$ value is calculated, which comes out to be 0.696. Further, using value of $\bar{c}(m)$ and equation (5.16), Concordance Index matrix are derived as manifested in Table 5.22.

Table 5.22— Concordance Index Matrix

LGB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	1	0	0	1	0	1	0	0	1	0	1	1	0	1
2	1	0	0	0	1	0	1	1	1	1	1	1	1	0	1
3	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1
4	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1
5	1	0	0	0	0	0	0	1	0	1	1	1	1	0	1
6	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1
7	0	0	0	0	0	0	0	1	1	0	0	1	1	0	1
8	0	0	0	0	1	0	1	0	1	0	1	1	1	0	1
9	0	0	0	0	0	0	1	1	0	0	0	1	1	0	1
10	1	0	0	0	1	0	0	0	0	0	1	1	1	1	1
11	1	1	0	0	1	0	1	1	1	1	0	1	1	0	1

12	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
14	1	1	0	0	1	0	1	0	1	1	0	1	1	0	1
15	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

5.5.5 Discordance Interval set, Discordance Interval and Index Matrix

The discordance set of criteria are fragmented for all LG manufacturing strategies barriers from the weighted normalized matrix using the requirements in equation (5.12). Further, the discordance interval matrix is derived from the conditions as manifested in equation (5.14). Discordance interval matrix is manifested in Table 5.23.

Table 5.23— Discordance Interval Matrix

LGB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.00	0.61	1	1	0.86	1	0.86	0.35	0.42	0.33	0.58	1	1	1	0.86
2	0.62	0.00	0.42	1	0.25	1	0.87	0.87	0.61	0.33	0.88	1	1	1	0.42
3	0.62	0.70	0.00	0.39	1	0.81	0.86	0.87	0.43	0.29	0.87	1	1	1	0.29
4	0.72	0.40	0.81	0.00	0.65	0.87	0.85	0.87	0.43	0.29	0.86	1	1	1	0.86
5	0.71	0.58	1	1	0.00	1	0.86	0.72	0.86	0.46	0.69	1	1	1	0.87
6	0.70	0.66	0.66	0.59	0.87	0.00	0.86	0.87	0.87	0.29	0.87	1	1	1	0.89
7	1	1	1	1	1	1	0.00	0.65	0.59	1	1	1	1	1	0.87
8	1	1	1	1	0.56	1	0.62	0.00	0.63	1	0.56	1	1	1	0.87
9	1	0.81	1	1	1	1	1	0.65	0.00	0.81	0.61	1	1	1	0.87
10	0.69	0.66	0.87	1	0.66	1	0.86	0.42	1	0.00	0.78	1	1	0.45	0.86
11	0.58	0.50	0.60	1	0.76	1	0.48	0.86	0.45	0.57	0.00	1	1	1	0.86
12	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0.81
13	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0.71
14	1	0.85	0.58	0.48	0.86	0.58	0.87	0.32	0.87	0.13	0.29	1	1	0	0.78
15	0.02	1	1	1	1	1	1	1	1	1	1	1	1	1	0.00

From the Table 5.23, summation of all the rows values and column values are same, which comes out to be 178.148. Using equation (5.17), $\bar{d}(m)$ value is calculated, which comes out to be 0.848. Further, using value of $\bar{d}(m)$ and equation (5.18), discordance Index matrix is derived as manifested in Table 5.24.

Table 5.24— Discordance Index Matrix

LGB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	1	1	1	1	1	0	0	1	0	1	1	1	1
2	0	0	0	1	0	1	1	1	0	1	1	1	1	1	0

3	0	0	0	0	1	0	1	1	0	1	1	1	1	1	0
4	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1
5	0	0	1	1	0	1	1	0	1	1	0	1	1	1	1
6	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1
8	1	1	1	1	0	1	0	0	0	1	0	1	1	1	1
9	1	0	1	1	1	1	1	0	0	0	0	1	1	1	1
10	0	0	1	1	0	1	1	0	1	0	0	1	1	0	1
11	0	0	0	1	0	1	0	1	0	1	0	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0
13	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0
14	1	1	0	0	1	0	1	0	1	1	0	1	1	0	0
15	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0

5.5.6 Construction of Global Matrix / Dominance Matrix

Finally, a dominance matrix or Global Matrix 'G' was framed by multiplying the corresponding values of the Concordance and Discordance Index Matrix, [5.22] and [5.24] respectively, which is revealed in Table 5.25.

Table 5.25— Global Matrix (Dominance Matrix)

LGB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	0	0	0	1	0	1	0	0	1	0	1	1	0	1
2	0	-	0	0	0	0	1	1	0	1	1	1	1	0	0
3	0	0	0	0	1	0	1	1	0	1	1	1	1	0	0
4	0	0	0	-	1	1	1	1	0	1	1	1	1	0	1
5	0	0	0	0	-	0	0	0	0	1	0	1	1	0	1
6	0	0	0	0	0	-	1	1	1	1	1	1	1	0	1
7	0	0	0	0	0	0	-	0	0	0	0	1	1	0	1
8	0	0	0	0	0	0	0	-	0	0	0	1	1	0	1
9	0	0	0	0	0	0	1	0	-	0	0	1	1	0	1
10	0	0	0	0	0	0	0	0	0	-	0	1	1	0	1
11	0	0	0	0	0	0	0	1	0	1	-	1	1	0	1
12	0	0	0	0	0	0	0	0	0	0	0	-	1	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1	-	0	0
14	1	1	0	0	0	0	1	0	1	1	0	1	1	-	1
15	0	0	0	0	0	0	0	0	0	0	0	1	1	0	-

The Boolean value in Table 5.25, indicates that the i_{th} barrier outranks the j_{th} barrier, here, $'i'$ specifies the row and $'j'$ specifies the column. For example, in row 2 of Table 5.25, barrier LGB2 outranks the barriers LGB7, LGB8, LGB10, LGB11, LGB12, and LGB13. This shows that barrier LGB2 will be ranked higher than the barriers LGB7, LGB8, LGB10, LGB11, LGB12, and LGB13 for the importance. Similarly, all barriers are ranked based on the dominance matrix G, the ranks are provided to the barriers for their importance in LG manufacturing strategies in Tractor Industry, which is revealed in Table 5.26.

Table 5.26— Ranking of Barriers of LG Manufacturing Strategies

Notation	Barriers	Out-ranking barriers	Rank
LGB01	Threat of forged expenditure / mis-investment	L5, L7, L10, L12, L13, L15	4th
LGB02	Inadequate sustainable regulations & command	L7, L8, L10, L11, L12, L13	4th
LGB03	Poor plan for integration of Lean digital technology & Circularity	L5, L7, L8, L10, L11, L12, L13	3rd
LGB04	Inadequacy of practiced manpower	L5, L6, L7, L8, L10, L11, L12, L13, L15	1st
LGB05	Lack of finance for Lean digitization and Lean Green technology	L10, L12, L13, L15	6th
LGB06	Ineffective performance framework	L5, L7, L8, L9, L10, L11, L12, L13, L15	2nd
LGB07	Utilize materials as source of energy	L12, L13, L15	7th
LGB08	Poor waste management	L12, L13, L15	7th
LGB09	Lacked resources / quality of infra-structure for LG practices	L7, L12, L13, L15	6th
LGB10	Inadequate Management support	L12, L13, L15	7th
LGB11	Employees confrontation to change / switch	L8, L10, L12, L13, L15	5th
LGB12	Fluctuating demand from market	L13	9th
LGB13	Absence of effective governance from top management	L12	9th

LGB14	Focus on short-term targets	L1, L2, L5, L7, L9, L10, L12, L13, L15	2nd
LGB15	Inadequate knowledge and lack of continuous improvements of Lean Green strategies and practices.	L12, L13	8th

5.6 Discussion

The analysis revealed that, barrier LGB4 which is 'Inadequacy of practiced manpower' is graded as the most significance barrier in the path of attaining LG manufacturing strategies in an Indian Tractor Industry. To implement LG practices in the atmosphere of sustainability criteria, a skilled workforce is required. For any new initiative in an organization like execution of latest LG technology, the major driver is the 'skill set of the employees', which are to keep updated on regular intervals. However, the priority must be given for awareness and training of the employees prior to use of latest technology. The barriers LGB6 and LGB14, such as, 'ineffective performance framework' and 'focus of short-term targets,' have been mutually positioned as 2nd significant barriers. In the environment of sustainability and focus on waste reduction, the performance of an organization value chain for LG operations must be assessed through structured designed performance framework.

Many organizations put their more attention on achieving goal LGB14 relatively for short period of time, such as, gaining surplus at the cost of quality of product and sustainable operation. The achievement of goal for short period of can be related to the economy curb of an organization. For an integration and execution of LG technology, monetary constraint is one of the significant barriers. A creative and transparent economic perception and sustainable environment is required for long term existence of community and country. The initiatives related to investment should be stimulated by the government after framing policies for supporting those initiatives.

There should be long-term goal, incorporate progress of company affairs integrating with LG practices. Barrier LGB3, 'Poor plan for integration of Lean digital technology and circularity' is the 3rd significant barrier. In many occurrences, to increase the productivity and optimum utilization of available resources, this has been noticed that automation of processes is the sole purpose of latest technology. The 4th significant barrier for lean sustainable operations of value chain is LGB1 and LGB2, 'Threat of forged expenditure/mis-investment' and, 'Inadequate sustainable regulations &

command'. The threat of mis-investment is mainly attributed to an absence of visionary management and lack of realization about the advantages of waste reduction for longer period. Inadequate regulations and command also lead the way to the resisting frame of mind of the management concerning sustainable operations.

The 5th significant barrier is LGB11,'Employees Confrontation to change / switch'. Workforces have an impression that emerging LG technology might set down their job at threat. Therefore finally, workforces must be encouraged for long period benefits delivering from such creativity and that likely initiatives will not constitute any threat to their jobs. The resistance from the workforces at the beginnings may be conquer through instigate suitable inspiration and support to workforces through engagement. Balance barriers are too significant, which needs to properly managed. Mostly are the outcome due to hesitance for initiating change through administration, lack of acknowledgement of the workforces, inadequate regulation, and command of eco-friendly LG manufacturing activities. The after-effect of this study will assist organizations to build constructive and combined actionable guidelines, which will promote LG practices in operational value chain using refined understanding of LG strategies and technology. As the value of CR is coming 7.3%, which is well less than 10%, so inconsistency is acceptable.

5.7 Implications

For the execution of LG manufacturing strategies, exhaustive planning and policies of management should be covered in the framework. The plan and policy must be reviewed on regular basis as per needs and feedback of company to make more effective. The implication of the study is mentioned below.

5.7.1 Practical Implications

The outcomes of the research work may aid industry experts to call attention for putting efforts to automatize operating processes for LG manufacturing as useful resource. Preservation of resources is especially significant relating to green revolution. This would accelerate towards protecting surroundings and nature. Present chapter helps to boost awareness about numerous barriers regarding LG manufacturing of whole value-added chain. At the same time, preference ranking of divergent barriers are well investigated. The management must build a constructive plan of action for eco-friendly LG in the existing company' conditions regarding green revolution. To remain competitive and sustainable, manufacturing processes must be integrated with the principles of green revolution and regulations. The requirement of green revolution, regulations and planning in processes technology for LM must be considered for designing the performance framework for LG strategies.

5.7.2 Theoretical Implications

The proper attention on barriers of LG manufacturing operations of an organizational value chain with regard to waste reduction and green revolution parameters, investigators / educators might get an inspiration to investigate and verify feasible outcomes to eliminate barriers in an unrelated situation. The preference of various barriers would assist educators and investigators to put forward and initiate policies for eco-friendly growth of companies in fast changing market environment. Enhanced ability, aptitude as per demand by a company can be worked out by investigators. The outcome will help in suggesting and verifying an exhaustive achievement construct to make sure eco-friendly operations.

5.7.3 Implications for Policy Makers

For creating an environment for lean sustainable operations, government policies play a vital role. The outcomes of this research work will be helpful to the policymakers for developing circular economy for their country as per requirement, as they can frame effective guidelines to enhance the culture of green processes and lean processes. Countries that are still in developing stage, companies are still hesitant to embrace sustainability and technological advancements. Strategist must therefore compose directions for sharpening the skill set of employees to accept new initiatives in the stage of eco-friendly operations. There should be encouragement from government for embracing turning up technologies in operational activities for green operations. By embracing convictions of green eco-friendly and related technologies, companies will have more sustainable operations of value chain and competitive edge in globally. There will be productivity enhancement and indulgent of competitiveness and green in every process as benefit to society.

5.8 Conclusion

To remain competitive and gain competitive edge, LG strategies in the processes has become key achieving factor in business environment with zero waste. For making certainty of eco-friendly operations, automation of processes needs affinity with green revolution features. Companies are encountering various barriers which hamper the advantages of LG practices. The key threat of prevailing operations set up is the way to adopt this LG strategy in constructive and unified way. Sustainability barrier in current business atmosphere must be handled with holistic approach by the companies. This chapter reflects about end-to-end operating value chain in manufacturing set up. In this analysis, nine eco-friendly indicators of green revolution (LGSPs) and 15 barriers for eco-friendly operations (LSBs) are taken into considerations. A merged approach incorporating of AHP–ELECTRE has been used for ranking of eco-friendly parameters with divergent barriers. Resource circularity, economizing by the way of product and process quality, designing processes efficient energy system are significant sustainable parameters. This has brought into noticed, significant barriers in the path of LG manufacturing strategies of organization value chain," Inadequacy of practiced manpower, In-effective performance framework, focus of short-terms targets by an organization".

Most of the current employees are not user friendly with the emerging LG parameters. Due to absence of acknowledgement and wisdom, companies are unable to utilize their potential for achieving objectives of sustainability. Focus of short-term targets of administration is another reasonable barrier. This deflects management concentrations from merging green technologies with eco-friendly parameters in the evaluation of performance. Companies pause to make huge financial investments in latest technologies for eco-friendly operations. Moreover, conventional performance constructs are not suitable in the changing dynamic atmosphere.

Performance framework must be designed by an organization considering existing business atmosphere of LG revolution parameters. Threat of mis-investment, Inadequate regulations & command, and Employees confrontation to change / switch within the current operational systems also act as barrier opposed to the execution of sustainability. There are many popping up sustainable applications, like, assessment of life cycle, design for recovering, re-build /reproducibility, design for flexibility, bio-derived materials, product / process levelling, power management system, society engagement and social responsibility. To overpower barriers and attain the objective of sustainable lean operations of organization value chain, organizations need to extrapolate sustainable applications as per specific need. The organisations to ensure that, use of these applications has maximum impact for operational excellence which are waste free and eco-friendly.

CHAPTER-6

IMPLEMENTATION OF LEAN-GREEN STRATEGIC FRAMEWORK IN INDIAN TRACTOR INDUSTRY

In the current decade, rapidly change in economic conditions across the world, market dominance, strict regulations, informative and demanding customer has exerted influence on intense competition. As a result, Indian manufacturing industries not have to fight and compete with the domestic competitors, but must have upper edge from the global point of view. Consequently, to be competitive and remain in business, at times of severe competition, manufacturing organizations have been urged and obligated to reform their functional entities from conventional way to eco-friendly and sustainable in entire operational value chain. Therefore, the adaptation of LG manufacturing processes and methodology has become the most essential ingredients for business organizations as long-term player in competitive marketplace and achieve experience of sustenance in running the business. Hardly, sufficient research stands on eco-friendly elements to manufacturing frameworks from the lens of the Lean-Green dynamic manufacturing excellence approach and strategies. This chapter presents a novel five phase LG framework for the operating organization to enhance performance in terms of various Lean and Green parameters. The framework has been developed after taking insights from literatures, author experience and employees from case organization. For systematically implementation of framework for achieving LG operational excellence parameters, integrated LG tools are used. The developed framework has been credible with the help of a case study in Indian Tractor Manufacturing company, from where key conclusion has been extracted.

6.1 Introduction

In the era of intense competition, customers are demanding eco-friendly products and services [203]. To mitigate the issues due to an environmental impact and to remain in business as a long-term visionary plan, manufacturing organizations need to swift their traditional functional strategies to LG strategies as business model [203]. In various location of earth, a rise in surface temperature to 1.5-degree centigrade has been observed due to rapid industrial growth and manually driven actions along with discharge of nearly 30 percent of Greenhouse gas emissions that have far ranging impact on health and environment [327-328]. Under these circumstances, there is need to reduce wastes, carbon footprints, current status of emissions discharge through adaptation of LG practices by manufacturing industries [329]. This will also help organizations to remain in competition by adhering the environmental norms and regulations [330]. Due to changing manufacturing dynamics, operational sectors are extensively focusing and investing in Research and Development to explore alternative ways of green specified products and services [331]. As a result of this, a novel standard of eco-friendly technology has risen with times. Eco-friendly technology intensify environmental adequacy, decreases carbon dioxide footprint and sustain monetary security of an organization [332]. To achieve operational excellence, various methods has been suggested, but integration of Lean-Green strategy is powerful tool for operative eminence [333]. The LG combined strategy contributes for organizational success by systematically reduction of wasteful activities, environmental discharge and variation in processes that resulted into defects [207]. The LG strategic approach also addresses the systematic execution of various allied tools at different product's value addition phase in manufacturing [37]. The manufacturing organization needs to design their operations, which are economical and eco-efficient apart from delivery of product in shortest possible time with best quality and low cost [334]. Under-utilized resources may result to wastages and high operational cost with longer lead time to delivery of end-product to customer. The resource utilization can be enhanced by involvement of all employees for cultural change and improvement activities [280]. Therefore, to confirm long-lasting progress of entire value chain of an organization, need of an hour to complete utilization of available resources and focused attention on waste reduction [335]. The prevailing number of emissions can be reduced in different sizes of an organization using related course of actions, specific and cross cutting technologies [336]. Recycling is the most desirable approach for minimization of waste [213].

Due to changing Government policies and regulations for protecting environment and use of an environmental-friendly product, adaptation and use of sustainable practices has become the part and parcel of manufacturing processes to adhere the regulations [1]. The past research emphasized on performance and economic sustainability, but not much focus on human ecology [2]. A judgemental assessment of LG perspectives, which highlights their significance to realize practicable capabilities are evolved [337]. This chapter furnishes broad LG framework hunting to help professional to search the path of standardization in various kinds of services by implementation of framework. Gholami et al. [338], utilized LG framework to amplify the set of capabilities and an environmental feature, however introduced framework need experimental validity in deploying LG tools.

Thus, previous research work affirms that the study for the LG framework is non-specific and generic in nature, deployed in defined environment, and incorporate all factors of ecology [3]. Moreover, many designed LG framework have high chances of failure in execution practically in broad way, which is required validation experimentally. Apart from this, to be competitive globally, there is need to focus on social sustainability. In addition to that, there is need to focus on health and safe working environment as social sustainability into LG strategies into practice. Many manufacturing industries are facing challenges for reducing cost of products by optimum utilization of resources [4]. In previous literatures, not much emphasis given on manufacturing capacity, social aspects and human ecology all three together. This study reflects to address these aspects by developing a framework with in Tractor Manufacturing environment and practical implementation through case study to achieve these aspects. The LG strategies in Tractor Industry are an original approach, which make use the waste management concept of reduction, upcycling and reprocessing. This concept has been utilized to build an integrated LG framework by the use of LG tools, that will help industry managers and organization for performance improvement, smooth implementation and significant contribution to manufacturing. In current chapter, the below mentioned research questions have been put forward.

- What are the pertinent steps to execute LG framework in Tractor Manufacturing Industry?
- How to execute LG strategic framework with green aspects to improve resource fulfillment and enhancement in Indian Tractor Industry?
- What divergence begin in parameters related to performance, tangible and in-tangible gains in Tractor Industry before and after execution of LG framework?

6.2 Proposed LG Framework

The proposed LG framework was depicted in such a fashion, that it communicates the concerns which linked to quality, green operations of undertaken case, improves the operational efficiency and effective resource utilization of the Tractor Industry in operational environment. The LG strategic framework derived are based on three designed aspects as shown in Figure 6.1. This acquired combination of best, latest and specified conceptual expertise in developed LG framework. Initially, the design aspect integrated by use of considerable theoretical and practical competence of the individuals as LG experts, industrial professionals, and scholastic researchers to support the development of the intended framework. Garza-Reyes et al. [339], advocated that expertise, experience and knowledge of professionals plays a decisive role, while evolving theoretical frameworks which are necessary to be executed in an industry.

Next design aspect takes into consideration of significant inputs from the case organization. Thus, the researcher debated with a team of practitioners. Consequently, 14 professionals were identified from different functional units of the selected Tractor Industry and academia. Out of 14 professionals,10 manufacturing experts acknowledged, to furnish their input about the LG strategic framework. The panel of experts consists of Joint General Managers (JGM), Senior Managers (SM), Master green / black belts, Systems leads from selected Tractor Industry, and professional from an academic background. Each panel member, which was the part of this process was having more than 15 years of experience in their professional domain. The experts furnished valuable inputs, their viewpoint and critique to upgrade relevancy and maturity of LG strategic framework. Thereafter, the matured framework was validated in one of Tractor Manufacturing Industry in India.

After execution of LG strategic framework in case Tractor Industry in India, the gained outcome in operational and green outlook was analyzed with status before execution of the framework. Such differentiation furnished the actual scene of improvements and validation of the developed LG strategic framework in manufacturing environment. The executed ideas are documented as an appropriate action plan for long term reference. The current work progressed with a case study approach for executing the evolved framework, as this approach has the feasibility to dispense the accurate synchronous evaluations and real outcomes comprehensively. This approach also has ability to make evident the developed framework gradually and meet objectives of the research. The elaborated series of steps right from emergence of the LG framework till its execution has been exhibited by adopted methodology of research to accomplish operational excellence in business. The LG framework was progressed to inscribe issues related to environment, attributed measures of projects and intensify functional improvements of manufacturing units. Various activities are associated with LG framework in each and every step, reduces wastages in process value chain and associated environmental impacts. The intellectual features of the developed LG framework in phase wise is described below.

Step 1: In phase-1 of LG manufacturing strategic framework, this step is more inclined for identifying and describing the suitable project for case Tractor Industry for which the problem was taken into consideration. The project is considered to take a look on environment, social and attributed inferences, so that clear idea of objective

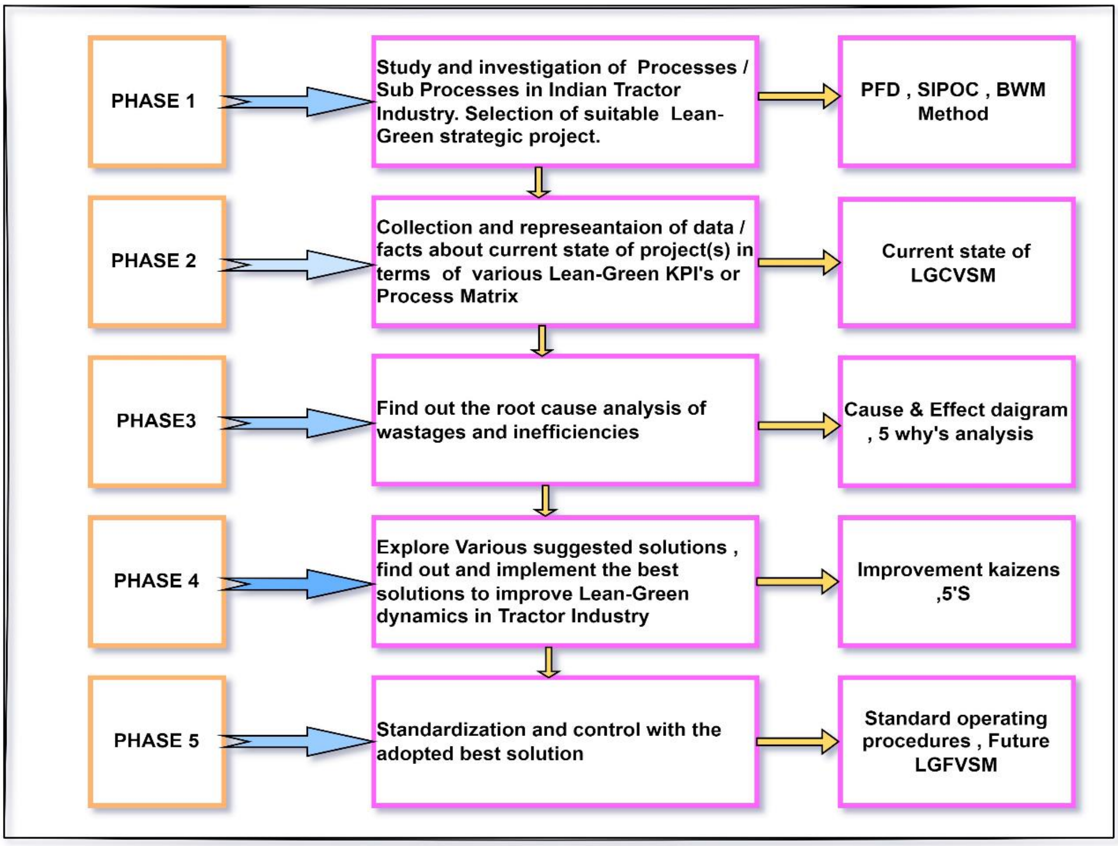


Figure 6.1— Intended Lean Green Framework and Adopted Methodology

and confinement of project could be demonstrated. The need, choices and inferences of business and customers are legibly expressed through voice of business and voice of customer for project selection through BWM [224]. To understand the various facets of project, a transparent picture of complete process in value chain from supplier to the consumer is drawn by SIPOC diagram, entire internal process explained through Process Flow Diagram (PFD) [127]. The various ingredients of intended LG framework have been demonstrated by drawing Project Charter [225].

Step 2: In Phase-2, collection of data related to wastages was brought out to express the current state of project selected in phase-1. Furthermore, Lead time, power consumption and water consumption, etc. of current state of selected project was evaluated through LGCVSM [84]. The data related to rework also captured in selected project for an improvement action plan on critical rework problems. The data was collected in quantitative forms.

Step 3: In Phase-3, focused on admiring the leading sources of wastages, reviewed the problems and process related ecological in-efficiencies. The reasons for wastes and in-efficiencies are also identified in this phase. The tools and techniques, like brain-storming [234], Cause & Effect Diagram [232], and 5 why's [231] analysis is employed at the current stage to determine possible causes. When the potential and possible causes are identified, then the expedition is distributed to derive significant contributors for reduction in wasteful activities.

Step 4: In Phase-4, the various solutions are suggested; the promising solutions are acknowledged, organized and thereafter executed to ease potential reasons of wasteful and in-efficient process or activities. The implementation of promising solutions is documented appropriately along with comparison from previous outcomes for sustainable results in term of quality and cost parameters. For constructive implementation of LG strategies; coaching, training and communication has been imparted regularly to employees of selected Tractor Industry. Lean tools, like Kaizens [59], 5'S [58], are employed for creating a continual improvement culture in the organization.

Step 5: In Phase -5, which is final phase of LG framework. The process of change is accomplished, and documented to prolong actions taken for an improvement. The upgraded process is handed over to the owner of the process along with complete Standard Operating Procedures (SOP) for standardized the achievements. This phase also affirms that results achieved from an improvement are maintained after the accomplishment of the LG project.

6.3 Case Study

In this section, the proposed LG framework was validated through a case study approach in selected Tractor Industry in India. The LG framework was comprehensively executed during case study to improve the LG matrices of case industry. The exhaustive depiction of sequence of steps are furnished in subsequent sub-sections.

6.3.1 Case company background

The selected case ABC company is one of Tractor Manufacturing Company in India and situated in north part of India. The selected ABC Tractor company has very compact manufacturing unit, which is spread in 4.30 acres area, having 4 assembly lines and two machining lines with daily production gross capacity of 228 tractors / day operating in 2 shifts.

The Nomenclature of manufacturing lines are as follows:

- Transmission Assembly and Testing
- Hydraulic (VTU) Assembly and Testing
- Engine Assembly and Testing
- Tractor Assembly
- CC & CH machining

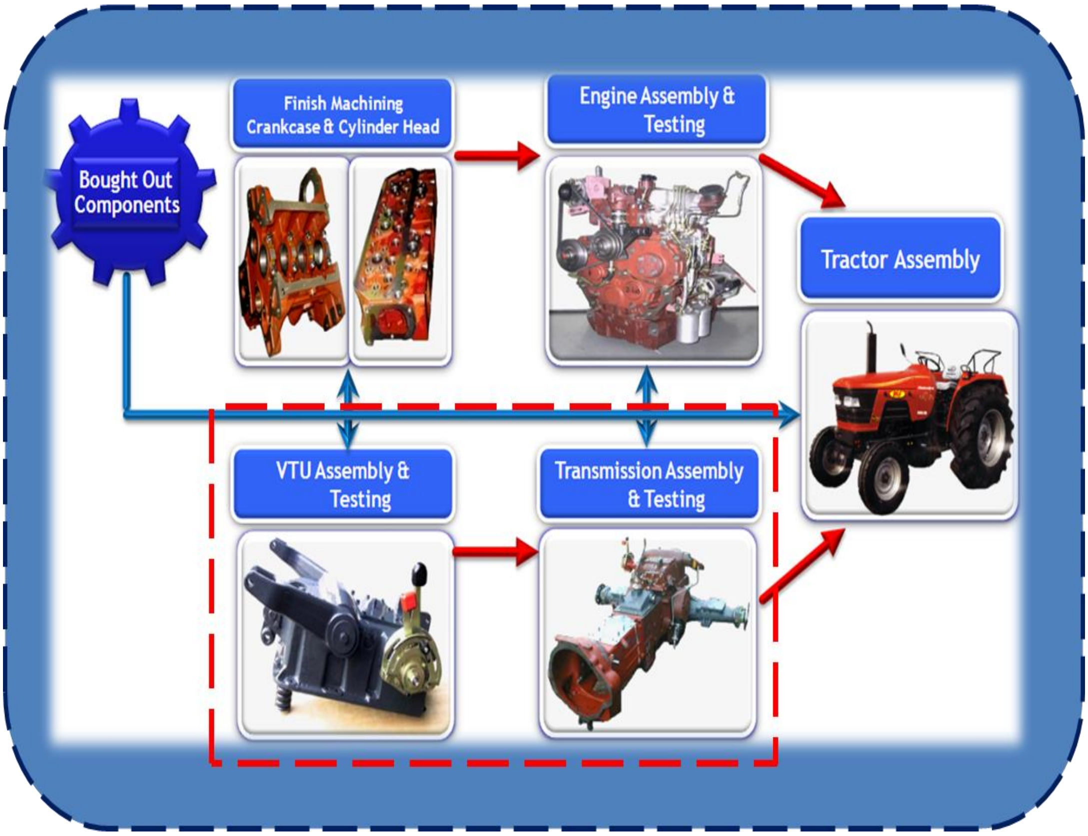


Figure 6.2—Manufacturing Processes of Case Tractor Company

The company has Tractor assembly line, which is divided into three sub-lines, named: Pre-Paint assembly line, Painting of Chassis assembly and Post Paint assembly line well supported by three aggregates. The Tractor company has in-house facility of assembly of Transmission aggregate, Hydraulic aggregate and Engine aggregate along with testing of all aggregates. These all tested and finished aggregates are coupled together along with brought out parts to produce tractors, as shown in Figure 6.2. Apart from this, the company has two machining line for machining of Crank Case (CC) and Cylinder Head (CH) in-house to feed for producing engine aggregates. The Indian Tractor Company is awarded with ISO 9001: 2015 and ISO 14001: 2015 QMS certification, which is aiming to provide complete Farm Solution to farmers through advanced technological features in product and services along with establishing green processes and green product as per standard laid down by an environmental regulating authority of India. The Tractor company displayed issues over capacity constraints, environmental waste along with social facet related with industry. Therefore, to ease these pertaining challenges, the proposed framework has been executed in case industry with subsequent steps.

6.3.2 Selection of Ecological- Focused LG strategic Project

This section covers the proposed LG framework with the identification and an illustration of the project in the case industry. The project scope is manifested to examine the quality features, ecological factors and related social indices. The imperatives and preferences for the business and consumers are legibly manifested with reference to voice of consumers (VOC) and voice of business (VOB) to realize the bright outlook from product being manufactured. An analysis from voice of consumers and trade preferences, it was articulated that manufacturing organization be in need of customer delight, capacity fulfillment with optimum resources and employee participation, whereas consumers require products which are sustainable and with high standard of quality.

The execution of LG project demands enthusiastic and committed team having multi skills for operational activities. In current research work, the team included subject matter expert having vast knowledge of plant operational business excellence activities, program coordinator from the senior management, and four members from managerial staff. The steps like, consecutive process flow of manufacturing, SIPOC, and project charter furnishes the real and thorough identification of various facet of the intended LG project. Senior management of plant organized a meeting to communicate and give direction to down line workforce about the need of the project and its expected benefits. This encouraged in conveying with complete understanding and alertness for execution of project to the workers for their active participation. Senior management of selected firm showed their concerns about bottleneck of capacity, operational waste like Demineralized Water (DM), power consumption, other wastes like rework, rejection, wrong fitment of parts and economic, social sustainability of plant.

6.3.3 SIPOC diagram

The sequence of the process for Tractors begins with receiving of various housings like Transmission housing, Clutch housing, Hydraulic (VTU) housing, Crank case housing and Cylinder head housing along with Front-Axle assembly. Apart from these, Sheet

Metal parts along with various brought parts are coming from suppliers, which are stored at store location, from there feeding to respective locations for processing. The finished Transmission housing, Clutch housing, Hydraulic housing is directly being used for their sub-assemblies. Crank case and Cylinder head housing are being processed as finish for producing Engine sub-assembly. Front Axle sub- assemblies is critical component was coming from supplier. For the Tractor Manufacturing process, input of all mentioned sub-assemblies after in-house testing along with stored parts is primary step with the use of tools and tooling.

The Tractor so produced, after all inspection is handed over as custody transfer to Supply chain and Production Control (SCPC) department for movement to warehouses for shipping to various locations across India and abroad. To exhibit a crystal conceptual diagram of the Supplier flow, Input flow, Process flow, Output flow, and Customer of product produced, an eminent SIPOC (Suppliers, Inputs, Processes, Outputs and Customers) systematic re-presentation was formulated in Figure 6.3.

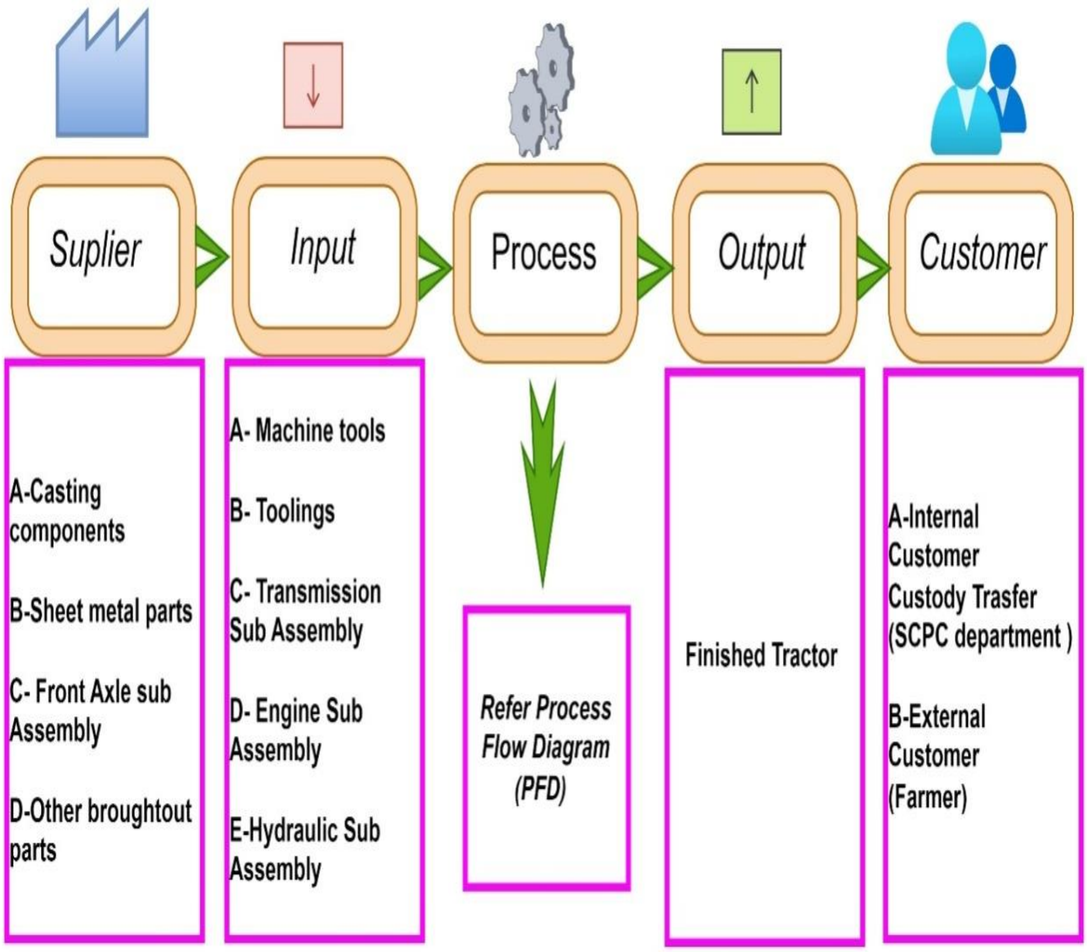


Figure 6.3—SIPOC Diagram of Case Tractor Company

The supplier is the provider of input into a process. Inputs are required like, material, information and other resources to complete the process. Process is the structured steps to convert inputs into outputs. Outputs is the product and services resulting from the process. The customer is receipt of outputs. Conclusively, SIPOC is a process mapping and improvement method that summarizes the inputs and outputs of one or more processes using a SIPOC diagram.

6.3.4 Project Plan

A project plan is an exclusive canvas to describe the whole project's strategic approach like clear definition of problem statement, objectives and goals to be achieved, scope related to project execution, limitations of project, gains after execution of project, cross functional team members details, application of tools and techniques for project execution, timelines for execution of project and detail of manufactured product.

This also demonstrates the acts and duty of members of the project, supplier's detailed summary, stakeholders involved, start and end date of project. For simplification of details about the project from inception till completion, project charter is vital to build. In current case study, the project charter, which is a short document used in project planning to outline the prime aims and benefits of a project. This is at-a-glance guide to reflect the reasons of selecting the project. It's used both to get buy-in from stakeholders, and a reference point to keep the project on track. is shown in Figure 6.4.

6.4 LG Strategies Project Selection -Best Worst Method (BWM)

In the era of competition and meeting customers' needs and high expectations, operational organizations are embracing various techniques for an improvement in their processes for enhancing manufacturing capabilities. Regardless of suitability of all improvement's initiatives, manufacturing firms are experiencing significant wastes, defects in processes leading to customer dissatisfaction. This is primarily attributed for not identifying and focusing on actual area of an improvement due to not selection of right project.

At case organization level, real selection of project has been committed during this work through a method of practical evaluation technique of best LG projects. There are large numbers of factors, which are involved in selection of project. At the time of study, diversified LG elements for selection of project are recognized and analysed to identify the most suited project.

Project Plan	
Statement of problem	**Business Requirements**
To amplify firm's productivity by de-bottlecking of resource constraints , improving sustainability by eliminating rework and rejections during processes.	The case industry is ready to execute Lean-Green strategy in their firm for improving resource utilization and ecological sustainability. The management believes ,an execution will be turning point in their business profitablity.
Projects' goals and objectives	**Scope of Project**
A) To improve the capacity of plant with optimum utilization of resources. B)To minimize the wastages during the processes.	A) To improve the capacity of plant with optimum utilization of resources. B)To minimize the wastages during the processes.
Organization Name	**Product Name**
Tractor Plant in India	**Tractor**
Deployed Tools and Techniques	**CFT Members**
SIPOC , Best Worst Method , Process flow Diagram, LGVSM, Cause & Effect Diagram , 5Why's , Kaizens	A)Business Excellence Expert - Mr X. B)Programme Coordinator- Mr. Y C) Members- Mr. L , Mr.M, Mr.N & Mr. O

Project Itinerary		
Steps of Activities	**Beginning date**	**Completion date**
Project Identification through BWM technique.	15th November , 2022	10th Janurary , 2023
Identification of current state of system of LG matrices.	16th Janurary , 2023	16th February , 2023
Identification of the probable causes of wastages.	20th February , 2023	20th March , 2023
Explore best possible solution and apply for an improvements.	22nd March , 2023	28th June , 2023
Standardization of adopted solutions for sustenance.	1st July , 2023	28th Ausust , 2023

Figure 6.4—Project Charter for LG Project Implementation

The significance weight calculation for the selection of project with selected elements and its classification of attainable project(s) are computed by the use of start-of-the-art BWM approach in Tractor Plant under this study. Weight computation in BWM approach holds few calculation steps as contrast to numerous MCDM approaches. Classification of five projects considering all profit center shops were taken in this case let and pairwise comparisons was conducted. In present study, most significant seven criteria for project selection and 30 sub-criteria under seven main criteria have been chosen through proficient views and literature reviews. The optimal development of ranking of project is experimented with sensitivity analysis, the result observed least sensitivity that asserted powerful findings. The uniqueness of this work is evident, as very few testimonies of ranking of projects taking large numbers of criteria and sub-criteria available using BWM methodology. Moreover, BWM is the most appropriate and consistence procedure for ranking the options having enormous number of criteria are associated with, which deliver persistence results with lesser input(s). The practiced approach will assist senior management to pick-out the precise workable project and possibilities in complex state of affairs. Policy makers and LG specialist can also contest to the same outlook for constructive measurement of most favorable LG projects for sustainable growth.

6.4.1 Identification of LG Project Selection Criteria

For any continuous improvement initiatives, ranking of fair LG project is one of the ‘‘Key Result Areas (KRAs)”, which are crucial for success of any project [340]. Moreover, before execution of any project, it is remarkably essential to identify several factors, which have an impact on process improvement initiatives [104]. Inadequacy of right selection of project show the way to an assignment of insufficient resources and unaccomplished targets [341].

The study has hunted the literature having relevance to Lean and sustainable selection of project. LG indicators for selection of project and procedure for ranking of project is mentioned here. The author discussed 10 numbers of criteria and approach for Lean six sigma project selection with the use of rough AHP methodology [342]. A classified case study in automobile industry was suggested with 14 indicators for Lean project selection with use of ANP methodology [343]. Another classified case study in automobile industry was discussed with 20 elements for project selection by the use of Fuzzy DEMETAL-ANP-TOPSIS methodology [344]. A non-classified lean project section study with five criteria was conducted by with the use of DEA methodology [345]. The theoretical non-classified study which consists of 6 elements of project selection which is common for all sectors [346]. A classified case study on paper manufacturing with a purpose of sustainable projects portfolio selection with 26 elements using fuzzy TOPSIS approach [347]. A banking sector non- classified with 15 criteria for Lean project selection with the use of fuzzy cognitive map- TOPSIS approach [348]. Non-classified case study on medical and surgical equipment industry with seven criteria for lean project selection with fuzzy TOPSIS and VIKOR methodologies [243]. A classified case study on plastic industries for the purpose of

Green lean six sigma project selection with 28 elements with DEA-ANFIS approach [349]. The present study is classified LG project selection with 7 main criteria with 30 sub criteria with the use of Best Worst Method in an Indian Tractor Plant.

6.4.2 BWM application in Selection of Projects

The affinity of numerous criteria, and analysis of their consequence on the processes for an improvement, has been very complicated task. MCDM is well organised and structured process to deal this complicated obstacle and diagnose the impact of the most pivotal indicators. Numerous MCDM approaches are convenient to puzzle out these complications, like, AHP (Analytical Hierarchy Process), ANP (Analytical Network Process), and TOPSIS (Technique for Order Preferences Similarity to Ideal Solution). The aforementioned methodologies assess and rank the criteria by establishing connections and determination of weights.

A BWM is a novel MCDM model, which was suggested by Jafar Rezaei in 2015 [224]. The approach is managed to compute the weights of the opted criteria. For obtaining stable results, least numerical quantity of pairwise comparisons is essential in this approach. BWM approach to address MCDM obstacle by the use of five steps [350]. All short-list indicators are used to select best and the worst criteria among them. Best worst method distributes preference of best criteria above all the other criteria and vice-versa. Further, by the use of two comparative matrices, fundamental optimization model was constructed, that made use for calculation of optimal weights of criteria and consistency ratio. An alternative for pairwise comparison is discharged as well after calculation of weights. To regulate the comparative consequences of performance of project, the principal eigen-value of each pairwise comparison grid is analysed. The principal eigen-values accompanying weight of each criterion are used to evaluate the comprehensive project performance.

6.5 Adopted Methodology

There are various processes which entails for selection of LG project. This process incorporates the recognizing and preference of LG selection criteria of the project. The prioritization of the LG project is emerged from selected criteria. The LG project selection has been identified by the way of investigatory process of literature review. Industry proficient made significant contribution for criteria selection. For optimal LG project selection, BWM methodology has been used. The selection process is illustrated with specified steps in the form of structural outlines as revealed in Figure 6.5.

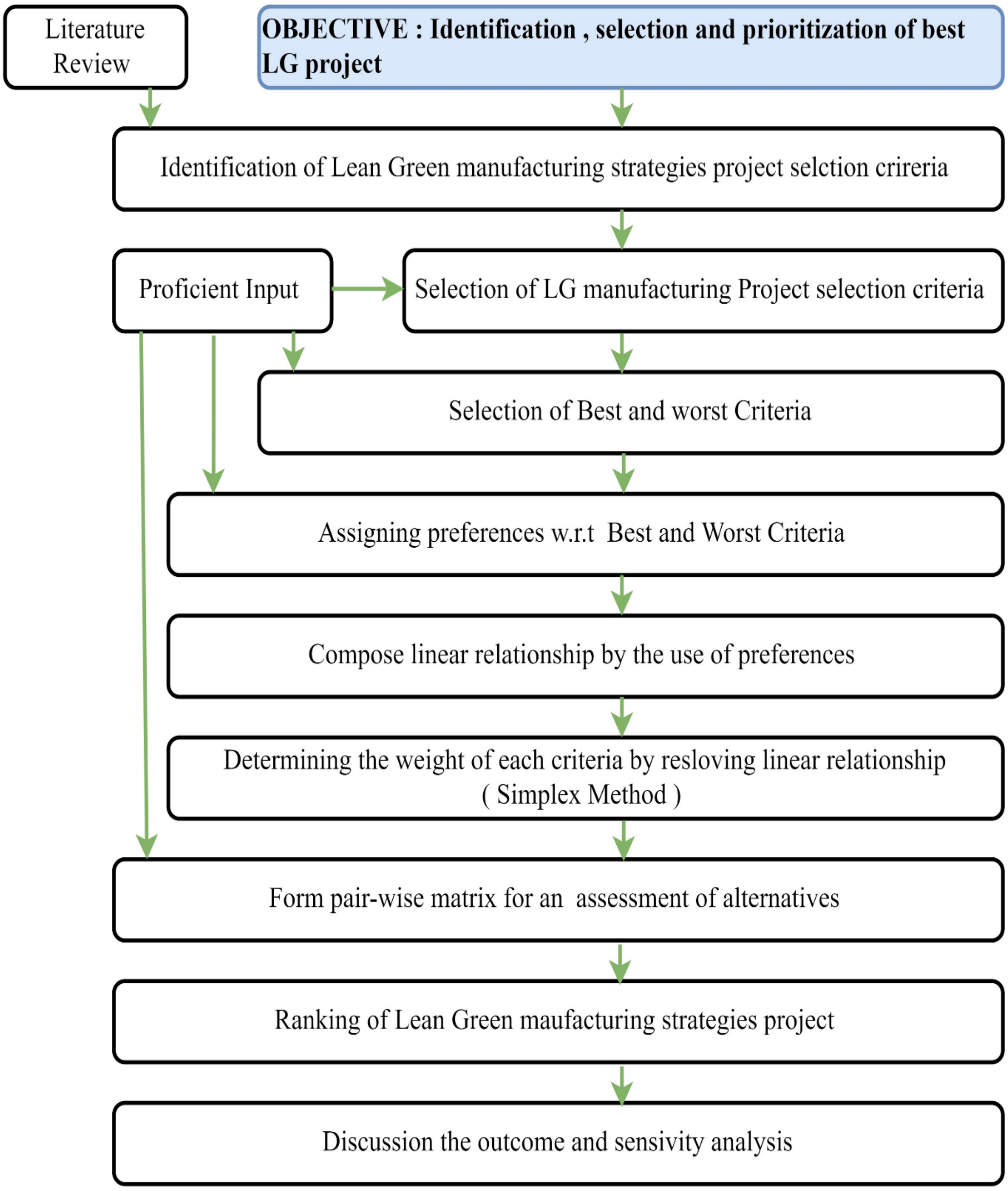


Figure 6.5—Research Design for LG Strategies Project Selection

6.6 Mathematical steps for Lean-Green Project Selection

The steps which have been associated at the time of the project selection are mentioned below.

Step 1: Identification and selection of LG project selection criteria in an Indian Tractor Industry.

Lean-Green project selection criteria and sub-criteria have been identified from SLR and proficient judgements. Different data base like goggle scholar, Scopus indexed papers were used for searching relevant literatures. The literatures were searched with suitable keywords like factors for project selection, LG factors for project selection and criteria for LG project selection. All identified LG criteria and sub-criteria were placed on Microsoft excel sheet. A panel of proficient consisting of ten members was constituted for concluding the criteria, which are to be considered for LG project selection. Five proficient were selected from case Tractor Industry and balance five were from different organization in the panel. All the panel members were having sound knowledge in their respective areas including LG strategies. Proficient panel members details are tabulated in Table 6.1.

Table 6.1—Detail of Panel Proficient

Proficient	Working Zone	Area of expertise	Experience	Type of industry	Position
1	Industry	Lean and sustainability	22 years	Automotive	Sr Management
2	Industry	Safety, Health & environment	18 years	Manufacturing	Middle Management
3	Academic	Lean Manufacturing	24 years	University	Department professor
4	Academic	Sustainability	13 years	University	Assistant Professor
5	Academic	Environmental	18 years	University	Associate Professor
6-10	Industry	Lean, SHE & Business Excellence	12 to 20 years	Case Industry	All Managerial Positions

For criteria finalization, a simple questionnaire was framed for taking input from panel proficient on Likert scale of 1 to 5, where 1 stands for ‘Not essential at all’ and 5 stands for ‘Essential’ The score of each criterion was analysed after collection of inputs from proficient for final conclusion. The mean score of concluded criteria was observed more than 4.3. The total 7 main criteria and 30 sub-criteria were finally concluded with the same strategy and all sub criteria were blended into seven main criteria after taking proficient interview.

Lastly, we counter-checked, even if all the identified sub-criteria were specifically grouped and observed accurately in place. The final criteria which are considered for study are tabulated in Table 6.2.

Table 6.2— Concluded LG Project Preference Criteria

S.No.	Major Criteria	Nomenclature	Sub- Criteria
1	Morale of the employee	ME	• Top Management Encouragement (TME) • Employee Contribution (EC) • Rewards & Recognition (RR) • Employee healthcare Policy (EHP)
2	Operational Utilization	OU	• Employee empowerment (EE) • Training & Education (TE) • Effective and transparent Communication (ETC) • People engagement & Innovation (PEI)
3	Skill & Kaizen culture	SKC	• Technical Capability (TC) • Timely Delivery (TD) • Productivity Improvement (PI) • Effective Project execution (EPE) • Lean Waste Management (LWM)
4	Cost Management	CM	• Project execution Cost (PEC) • Return on investment (ROI) • Investment Risk (IR) • Inventory carrying cost (ICC) • Manufacturing Coversion cost (MCC)
5	Functional Strategy and core competency	FSCC	• Strategic Planning (SP) • Flexible workforce (FW) • Organization Skills (OS)
6	Green Impact	GI	• Sustainability Management (SM) • Government Regulations (GR) • Energy Management (EM) • Water Management (WM) • Materials and supply Chain Management (MSCM) • Store Management & effectiveness (SME)
7	Quality Impact	QI	• Culture of organization for NFF (COO) • Customer delight (CD) • Analysis of Customer Complaints (ACC)

With the help of SPSS software, we conducted reliability test to ensure the consistency of the prepared questionnaire. In the reliability test, we found the value of Cronbach's alpha is 0.803, which affirms the high degree of consistency of prepared questionnaire.

Step 2: Selection of Best & worst criteria

In this step, the best (significant) and worst (least required) criteria are required to identify. In connection with, the proficient were asked to provide their knowledgeable opinion for selecting the desired and least desired criteria. In this study, firstly from major criteria, selection was done. After that, the best and worst criteria were selected from each group of main criteria. To select the opinion provided by the proficient, we used frequency analysis in this research study. Furthermore, the proficient were asked to provide responses to equate two criteria with all the other with the use of nine-point

(1 to 9) Likert's scale, for which comparison scale along with their syntax notation is tabulated, in Table 6.3.

Table 6.3— Semantic Scale for LG Strategic Project Selection

Semantics Terminology	Abbreviations	Scales
Equal Importance	EI	1
Somewhat between equal and moderate	BEM	2
Moderately more important than	MMI	3
Somewhat between moderate and strong	BMS	4
Strongly more important than	SMI	5
Somewhat between strong and very strong	BSVS	6
Very strongly important than	VSI	7
Somewhat between very strong and absolute	BVSA	8
Absolutely more important than	AMI	9

The priority and classification of best criteria over the others and priority of worst over all others provided by proficient for the main criteria, which are tabulated, in Table 6.4 and Table 6.5 respectively.

Table 6.4— Best Criteria Over all other Criteria

Proficient	Best	ME	OU	SKC	CM	FSCC	GI	QI
P1	OU	3	1	5	2	9	7	4
P2	OU	4	1	5	2	9	7	5
P3	OU	4	1	6	2	9	8	5
P4	OU	3	1	6	2	9	7	4
P5	OU	5	1	6	3	9	7	4
P6	OU	5	1	6	2	9	8	4
P7	OU	3	1	6	2	9	7	5
P8	OU	3	1	6	2	9	7	5
P9	OU	4	1	6	2	9	7	5
P10	OU	3	1	6	2	9	7	5

Table 6.5— Other Criteria to Worst Criteria

Proficient	Worst	ME	OU	SKC	CM	FSCC	GI	QI
P1	FSCC	6	9	4	8	1	4	6
P2	FSCC	6	9	5	8	1	4	4
P3	FSCC	6	9	4	8	1	2	5
P4	FSCC	7	9	4	8	1	3	4
P5	FSCC	5	9	4	7	1	3	6
P6	FSCC	5	9	4	8	1	2	6
P7	FSCC	7	9	4	8	1	3	5
P8	FSCC	7	9	4	8	1	3	5
P9	FSCC	6	9	4	8	1	3	5
P10	FSCC	7	9	4	8	1	3	5

Step 3: Determine weights of criteria

The optical weight of each criterion and sub criteria has been determined by use and solving of linear programming model equations developed, which are as: $Minimum\ \xi_L$

$$| W_b - a_{bj}\ W_J | \leq \xi_L \text{ for all } j \tag{6.1}$$

$$\left| W_j - a_{jw} W_w \right| \leq \xi_L \text{ for all } j \tag{6.2}$$

$$\sum W_J = 1 \tag{6.3}$$

$$W_j \geq 0, \text{ for all } j \tag{6.4}$$

Here, W_b: best criteria weight, W_j: Other criteria weight,W_w: worst criteria weight, a_{bj}: best criteria with respect to other criteria's preference, a_{jw}: other criteria with respect to worst criteria's preference. The final weights were considered by taking the mean of weights of criteria and tabulated in Table 6.6. As the value of Ksi* came out to be 0.081809 which is nearly to zero indicates the reliability of the rational comparison. The criteria which have high weight are more significant than having less weight. The prioritization of alternatives is done on basis of weight of the criteria.

Table 6.6— Major Criteria calculation using Best Worst Method

Proficient	ME	OU	SKC	CM	FSCC	GI	QI	Ksi*
P1	0.1487	0.3685	0.074	0.223	0.032	0.063	0.089	0.077
P2	0.1143	0.3758	0.092	0.229	0.033	0.065	0.092	0.081

P3	0.1171	0.3848	0.078	0.234	0.033	0.059	0.094	0.083
P4	0.1454	0.3605	0.072	0.218	0.032	0.062	0.109	0.075
P5	0.1007	0.4136	0.084	0.168	0.036	0.072	0.126	0.089
P6	0.0936	0.3848	0.078	0.234	0.034	0.059	0.117	0.083
P7	0.1487	0.3685	0.074	0.223	0.032	0.064	0.089	0.078
P8	0.1487	0.3685	0.074	0.223	0.032	0.064	0.089	.078
P9	0.1161	0.3816	0.077	0.232	0.033	0.066	0.092	0.082
P10	0.1487	0.3685	0.074	0.223	0.032	0.064	0.089	0.078
Final Weight	0.1282	0.3775	0.078	0.221	0.033	0.064	0.098	0.081

Step 4: Establish evaluation for alternatives

After determining the weights of criteria, an assessment on alternatives has been executed. Our case study consists of five alternatives operational lines of selected Indian Tractor Industry such as, LGP1(Tractor Assembly: Pre paint, Paint shop and Post Paint), LGP2(Machine shop: CC and CH machining), LGP3(Engine Assembly), LGP4(Transmission Assembly) and LGP5(Hydraulic Assembly) were studied to choose the best alternative option for LG execution. To create an assessment, each criterion has undergone a pairwise comparison of all the alternatives. In our case context, a total of thirty pairwise matrices are devised. The inputs are given by the proficient in these matrices. For more clarity, an example of one pairwise comparison matrix for Top management encouragement (TME) is highlighted in Table 6.7.

Step 5: Ranking of LG Manufacturing Strategic Project

The ranking of LG alternatives considered in our case study has been done and presented in concluded super-matrix by blending weights and eigen-vectors of all pairwise matrix in this step. The global weights of each criterion have been calculated, through equation (6.5) by use of weights of each criterion, which is presented in Table 6.8. Furthermore, LG project score of each alternative, refer equation (6.6) has been calculated by use of the calculated global weights of each criterion, refer Table 6.11. The average of each alternative score was taken for ranking and preference based upon result obtained.

Table 6.7—Pairwise Comparison Matrix of alternative Top Management Encouragement (TME)

TME	LGP1	LGP2	LGP3	LGP4	LGP5	Eigen Vector
LGP1	1	3	6	7	9	0.515
LGP2	0.333	1	3	6	7	0.260
LGP3	0.167	0.333	1	3	8	0.133
LGP4	0.143	0.167	0.333	1	4	0.063
LGP5	0.111	0.143	0.125	0.25	1	0.29

Table 6.8— Resulting Weights for the Criteria based on Pairwise Comparisons

Cat	Project	Priority	Rank	(+)	(-)
1	LGP1	51.50%	1	21.40%	21.40%
2	LGP2	26.00%	2	9.40%	9.40%
3	LGP3	13.30%	3	5.80%	5.80%
4	LGP4	6.30%	4	2.70%	2.70%
5	LGP5	2.90%	5	1.60%	1.60%

Number of comparisons = 10, Consistency Ratio CR = 9.3%, Principal eigen value =5.417 Eigenvector solution: 6 iterations, delta = 2.6E-8

$$G_W = MC_W * SC_W \tag{6.5}$$

$$P_i = W * A_i \tag{6.6}$$

Here, G_W : Global weight, MC_W: Major criteria weight, SC_W:Sub-criteria weight, P_i Project (s), W:Weight(s), A_i= Relative impacted weight for project performance.

6.6.1 LG Project Prioritization: Sensitivity Analysis

The proficient prejudice in decision making process and ensuring robustness in prioritization of LG project, study outcome requires to be tested for validation. For hierarchizing of LG projects, the application of sensitivity analysis has been executed. In this process, main factors weight varies between 0.1 to 0.9, and variation in other corresponding weights needs to notice. In our present case study, operational utilization (OU) criteria have the maximum weight, and Project LGP1(Tractor Assembly: Pre-Paint, Paint Shop and Post Paint) is the most significant LG project with the highest performance score (0.453123847) and corresponding weights variations are tabulated in Table 6.11.

6.6.2 Discussion on Findings

At each phase of manufacturing, decision-making issues are stepping up, complications are popping up before the manufacturing organization to make a right decision for the selection the best targeted project among the options available. This investigation conducted a resolution for the issue related to decision-making for LG project ranking in Tractor Manufacturing unit. The current study populated the significance of the Best-Worst-Methodology to resolve ranking concern for selection of project. Based upon the input and feedback given by proficient, the weights of the concluded LG project selection criteria and relative influence on performance of project were computed. Furthermore, the projects ranking was done on the basis of result attained in term of scoring. The outcome of the current case investigation unfolded that project LGP1(Tractor Assembly: Pre-Paint, Paint Shop and Post Paint) secured the maximum score (0.453123847), subsequently project LGP2, (0.244058548), project LGP3 (0.13528343), project LGP4 (0.073462958) and project LGP5 (0.032133683) orderly. The result of study advocated, project LGP1 as the considerably important operational line for the deployment of LG project in Tractor unit. The result of study was also conversed with panel proficient. The panel members were agreed and satisfied with the end-result. The proficient advocated that, efficiently execution of the LG strategies' framework in project LGP1 may potentially dispense reap benefits like, Takt Time improvement, Reduction in Process Wastages, Reduction in overall Lead Time, Reduction in Repair per Hundred, Reduction in Conversion cost, Influence on Society and Environment, and Improvements in Productivity. Moreover, the outcome was also presented and discussed with senior management team of the case organization, they also satisfied with the outcome. An execution process also conversed and agreed by case organisation. The LGP1 project execution plan is as follows: At first step, Identification of the genuine problem in the case organisation was done; afterwards, Process Flow Diagram (PFD) was prepared grounded on systemized examination of the LGP1 line. The project execution plan was also composed for realization of the project' objectives. Afterwards, the composition of project plan, 'the Current State of LG Value Stream Mapping (LGCVSM) was formed to make out status of current process at LGP1 line. The next level consists of data collection form case organisation and prepared fishbone diagram to understand the causes and their effect based upon the data collected to know the key source points of concerned. Furthermore, to focus attention on the effect of significant causes Pareto Chart was drawn and noticed causes were validated.

Further, a future stage of Lean-Green Value Stream Map (LGFVSM) was drawn to spot the kaizens. The final step consists of making a matrix for comparing before and after improvements. Moreover, SOP was prepared for standardization and sustaining the improvements done for future reference. The calculated outcome was tested by the use of sensitivity analysis for their soundness and agility. The uncovering the variation of weight of manufacturing workability criteria ranging from 0.1–0.9 are tabulated in Table 6.9 and the fluctuations in the concluded ranking score of LG projects are tabulated in Table 6.10. Thus, the outcome affirmed that the ranking of the LG project is robust.

Table 6.9— Lean Green Project Selection Major Criteria - Sensitivity Analysis

Major criteria	**Normal**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
ME	0.1282404	0.1757405	0.1610739	0.1444072	0.1277405	0.110739	0.0944072	0.0777405	0.061074	0.043407
OU	0.3775527	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
SKC	0.0779200	0.1233488	0.1066822	0.0900155	0.0753488	0.0577822	0.0420155	0.0153488	0.007682	0.006984
CM	0.2207912	0.2632127	0.2455461	0.2278794	0.2132127	0.1965461	0.1789794	0.0612127	0.105546	0.102879
FSCC	0.0329706	0.0813939	0.0627273	0.0480606	0.0304939	0.0138273	0.0030393	0.019706	0.016273	0.012939
GI	0.0638082	0.1126292	0.0959626	0.0792959	0.0617292	0.0450626	0.0281959	0.0117292	0.006037	0.001704
QI	0.9871775	0.1446743	0.1290077	0.112341	0.0947743	0.0781077	0.062341	0.0117292	0.019008	0.011341
Total	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**1**

Table 6.10— Final Ranked Lean-Green Project - Sensitivity Analysis

Major criteria	**Normal**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
LGP1	0.4531238	0.4531238	0.4531238	0.4531238	0.4531238	0.4531238	0.4531239	0.4531238	0.4531239	0.4531238
LGP2	0.2440585	0.2440585	0.2440585	0.2440585	0.2440585	0.2440585	0.2440586	0.2440586	0.2440586	0.2440585
LGP3	0.1352283	0.1352283	0.1352283	0.1352283	0.1352283	0.1352283	0.1352283	0.1352284	0.1352283	0.1352284
LGP4	0.0734629	0.0734629	0.0734629	0.0734629	0.0734629	0.0734629	0.0734630	0.0734629	0.0734630	0.0734629
LGP5	0.0321336	0.0321336	0.0321336	0.0321336	0.0321336	0.0321336	0.0321337	0.03213368	0.0321337	0.0321336

Table 6.11— Final Super Matrix of Lean-Green Project Selection

Criteria	(MC_W)	(S_C)	(SC_w)	(G_w)	A1	A2	A3	A4	A5	LGP1	LGP2	LGP3	LGP4	LGP5
ME	**0.1282404**	TME	0.4952954	0.0642482	0.515376	0.259934	0.133479	0.062525	0.028686	0.03311198	0.016700292	0.008575785	0.004017112	0.001843043
		EC	0.211271	0.0293024	0.504206	0.238155	0.160647	0.067105	0.029887	0.014774446	0.006978513	0.004707343	0.001966326	0.000875752
		RR	0.0883628	0.0104303	0.478635	0.285423	0.157787	0.050713	0.027442	0.004992307	0.002977048	0.001645766	0.000528951	0.000286231
		EHP	0.0411023	0.0036041	0.437846	0.268709	0.186631	0.066466	0.040349	0.001578041	0.000968454	0.000672637	0.000239549	0.000145423
OU	**0.3775527**	TC	0.1546907	0.0589153	0.474832	0.254183	0.150556	0.08239	0.038038	0.02797487	0.014975268	0.008870052	0.004854055	0.002241008
		TD	0.2475339	0.0942856	0.450824	0.241569	0.194522	0.081642	0.0314424	0.042506211	0.022776478	0.018340623	0.007697674	0.002964566
		PI	0.041748	0.0156515	0.516348	0.186288	0.170339	0.091141	0.035884	0.008081621	0.002915687	0.002666061	0.001426489	0.000561642
		EPE	0.0855139	0.0326784	0.469351	0.237322	0.165456	0.089281	0.03859	0.01533764	0.007755303	0.005406837	0.002917573	0.00126105
		LWM	0.4923136	0.1835802	0.475543	0.284081	0.11985	0.089752	0.030774	0.087300279	0.052151647	0.022002087	0.016476764	0.005649552
SKC	**0.07792002**	EE	0.0473079	0.0037025	0.479373	0.246671	0.161247	0.069485	0.043224	0.001774879	0.000913299	0.000597017	0.000257266	0.000160038
		TE	0.5199712	0.0422522	0.539214	0.24775	0.118361	0.061766	0.032908	0.022782978	0.010467983	0.005001013	0.002609741	0.00139044
		ETC	0.1634385	0.0126814	0.567356	0.236834	0.110616	0.055717	0.029477	0.007194868	0.003003387	0.001402766	0.000706573	0.000373803
		PEI	0.2772814	0.0214862	0.54415	0.238597	0.125905	0.063276	0.028072	0.011691716	0.005126543	0.00270522	0.001359569	0.000603161
CM	**0.2207916**	PEC	0.4342719	0.0950202	0.459458	0.274867	0.143368	0.089488	0.032819	0.043657791	0.026117917	0.013622856	0.008503139	0.003118487
		ROI	0.2316766	0.0498391	0.513233	0.204153	0.161619	0.079294	0.041702	0.025579071	0.010174802	0.008054946	0.003951952	0.00207837
		IR	0.0789721	0.0169939	0.459968	0.310194	0.127272	0.061934	0.040632	0.00781665	0.005271406	0.002162848	0.0010525	0.000690498
		ICC	0.0377095	0.0091147	0.468466	0.265393	0.161582	0.069797	0.034762	0.004269927	0.002418978	0.001472771	0.000636176	0.000316849
		MCC	0.1221188	0.0263926	0.443083	0.247215	0.174723	0.088897	0.046081	0.011694112	0.006524647	0.004611394	0.002346226	0.0012162
FSCC	**0.0329706**	SP	0.2586918	0.0095659	0.451529	0.309919	0.123482	0.07821	0.036861	0.004319281	0.002964654	0.001181216	0.000748145	0.000352606
		SW	0.0481977	0.0015117	0.485	0.273469	0.149503	0.061924	0.030105	0.000733175	0.000413403	0.000226004	9.36105E-05	4.55097E-05
		OS	0.1455404	0.0045234	0.474809	0.296701	0.123225	0.07195	0.033315	0.002147751	0.001342097	0.000557396	0.000325457	0.000150696
GI	**0.0638082**	SM	0.1398545	0.0100289	0.454794	0.249073	0.160791	0.092757	0.042585	0.004561084	0.002497928	0.001612557	0.000930251	0.000427083
		GR	0.4166005	0.0270147	0.478154	0.255884	0.135406	0.085455	0.045101	0.012917187	0.006912629	0.003657952	0.002308533	0.00121839
		EM	0.1055199	0.007688	0.517935	0.226952	0.140052	0.070304	0.044756	0.003981884	0.001744807	0.00107672	0.000540499	0.000344086
		WM	0.0812463	0.0061983	0.497233	0.254723	0.120825	0.078391	0.048829	0.003081999	0.00157885	0.00074891	0.00048589	0.000302657
		MSCM	0.2254365	0.0164352	0.478586	0.280576	0.128291	0.061383	0.051165	0.007865657	0.004611323	0.002108488	0.001008844	0.0008409
		SME	0.0363261	0.0025404	0.516841	0.236197	0.143104	0.06869	0.035168	0.001312983	0.000600035	0.000363541	0.0001745	8.93413E-05
QI	**0.0987175**	COO	0.3015087	0.0294425	0.417266	0.33086	0.145985	0.071091	0.034799	0.012285354	0.009741346	0.004298163	0.002093094	0.001024573
		CD	0.4983401	0.0486633	0.527954	0.252067	0.130139	0.060309	0.029531	0.025691984	0.012266412	0.006332993	0.00293485	0.001437086
		ACC	0.0437403	0.0042713	0.493087	0.273316	0.140816	0.063599	0.029182	0.002106123	0.001167415	0.000601467	0.000271651	0.000124644
∑Pi										**0.453123847**	**0.244058548**	**0.13528343**	**0.073462958**	**0.032133683**

6.7 LGP1 (Tractor Assembly Line) Project Analysis

The finalized systematically selected project LG P1 line is Tractor assembly line, which is main final product of case organization, where this framework was supposed to implement with the use of LG tools and techniques. The Tractor line consist of three divisions of line, but in continuous fashion. The nomenclature of lines are as follows: 1) Pre-Paint line, which is also called Chassis line, 2) Pre- Treatment and Paint booth line, and 3) After Paint line or Post Paint line. As discussed in previous section, this assembly line was underdone systematic and structured examination and Process Flow Diagram was prepared (PFD) for understanding the flow of process, manifested in Figure 6.6.

In Pre-Paint line, first station process consists of docking of Engine, Transmission and Front-Axle. Engine and Transmission assembly are in-house manufacturing and Front-Axle supply from supplier. After docking, Tractor assembly operations were being processing on conveyer with assembly of brought-out parts, which were kept in store and sub- assemblies at line side to complete the chassis. There are 8 main stations at Pre-paint assembly line on conveyor. Assembled chassis from Pre-Paint enter into for Pre-Treatment process.

In Pre-Treatment process, Chassis passes through 4 stages of Pre-Treatment process, i) Degreasing-1, ii) Degreasing-2, iii) Cold Water Rinsing and iv) Hot Water Rinsing following by manual air blowing, dry in Dry Off Oven and cooling in Zone-1 before entry in Paint Booth in continuous flow.

In Paint Booth, there are three Chassis at a time. One for Priming process and other two for Painting process, First Coat and Final Coat. After Painting process, painted Chassis enters into oven for Paint baking process though Flash Off Zone. Baked Chassis after baking process comes in cooling Zone-2 for cooling purpose and connect with post paint line as shown in Figure 6.6 and Figure 6.7. In Post Paint process, various processes like Electrical, Steering, Radiator, Tyres, Fenders, Bonnets, Driver Seat, Fuel Tank Fitment, Battery Fitment and Decals Fitment take place. There are 13 stations on Post Paint line. Assembly operations takes place with brought out parts and sub-assemblies connected with main line. Tractor rolls out from Post Paint line after all assembly processes and inspection, which further goes for Road Testing and Roller Testing for functional validation. Afterwards, it enters into PDI (Pre-Delivery Inspection) line for process inspection and correction as rework for observed abnormalities. The Tractor, after complete final inspection process get handover to SCPC as custodian for further moment as per order demand.

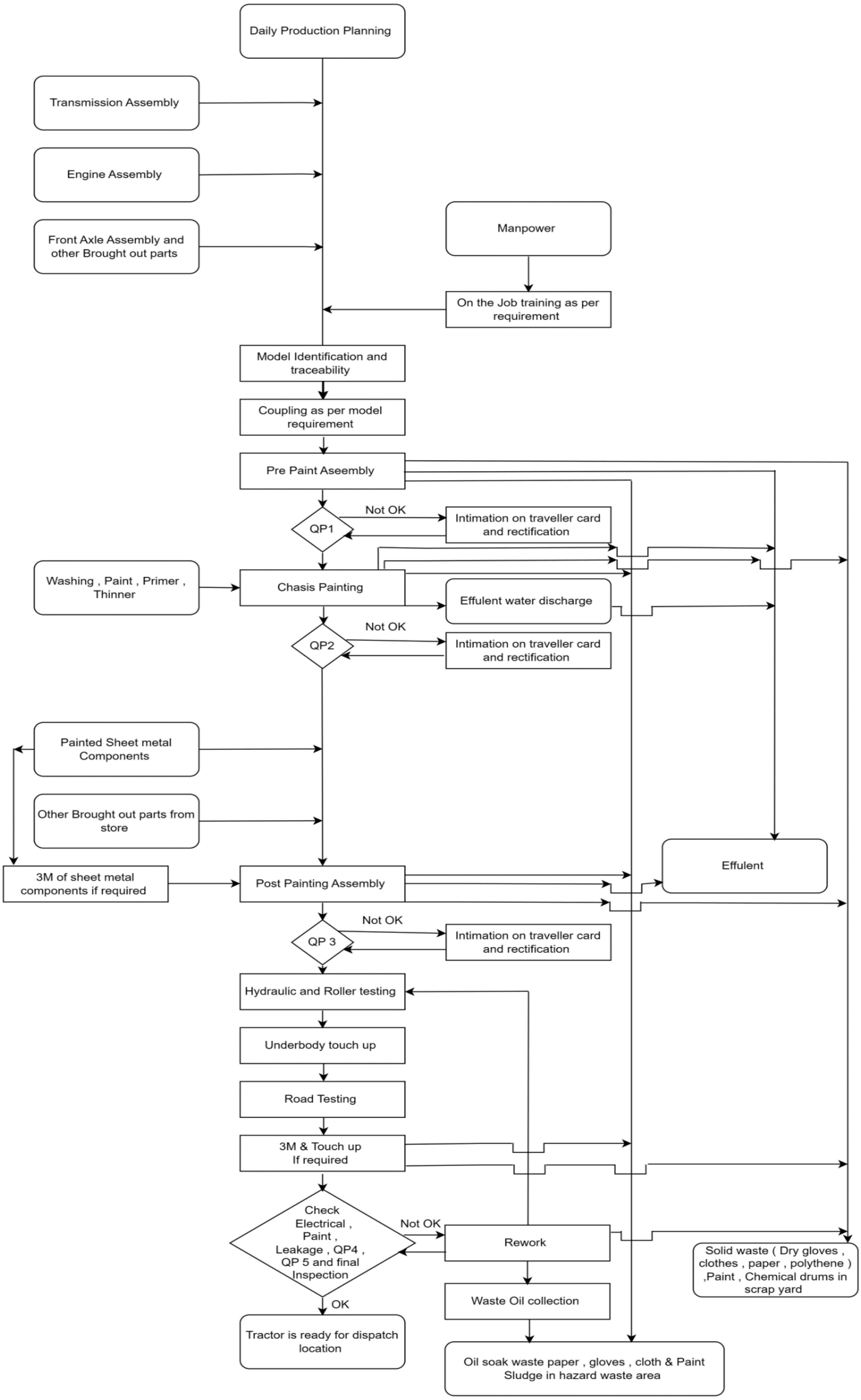


Figure 6.6— Process Flow Diagram of Tractor Line

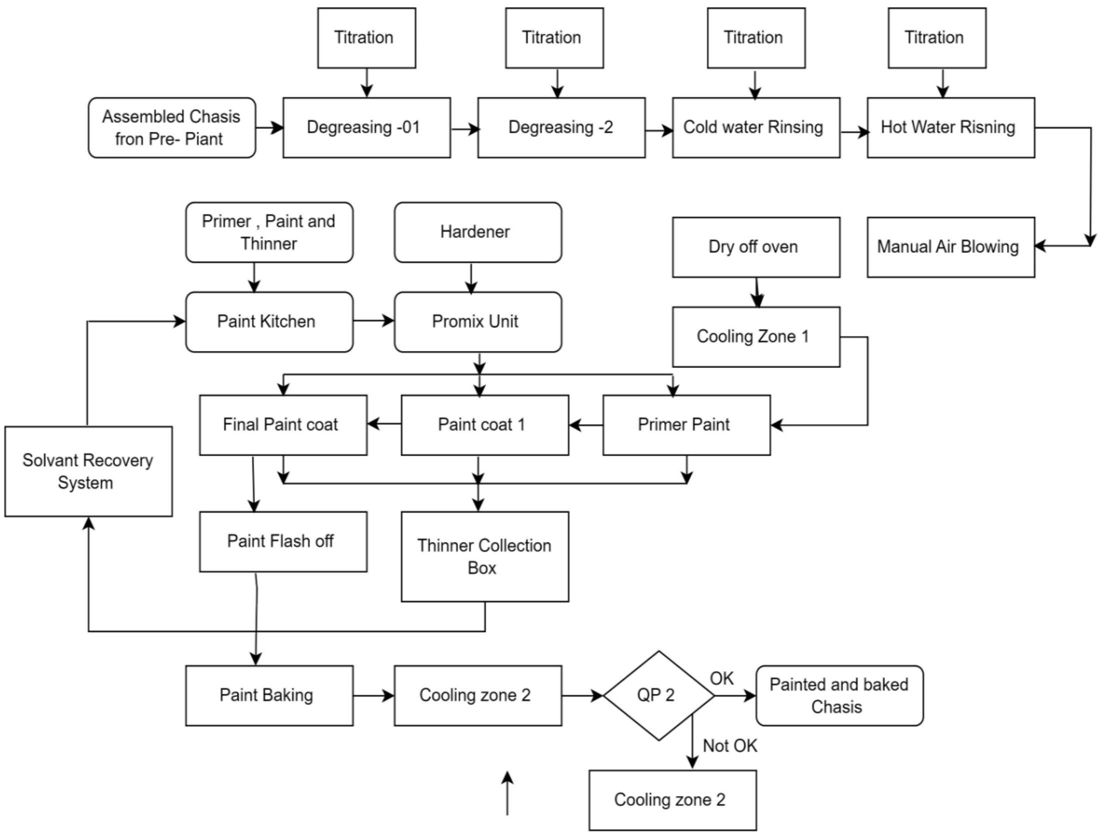


Figure 6.7— Process Flow Diagram of Paint Process

The top management of this plant expressed their concerns for not meeting customer orders due to resource constraints and operational waste resulting high conversion cost due to wastes, excess consumption of power, fuel and water used for manufacturing. Management was not only concerned about conventional indicators of business excellence but keen to know for ensuring ecological and social beneficial processes Current gross production of plant was 216 tractors / day in two shifts working. From last one-year data, it was observed, tractor line was operating with 80 % of gross capacity and 20 % production waste. The Tractor department cultivated substantial amount of ecological emission with 163 $\mu g/m^3$ (10 particulate), and no dynamic system is prevailing to estimate societal eco-friendly indicators of the plant.

6.7.1 Operational Waste-Recognition of Vital Indicators

Vital indicators of operational waste were recognized in this sub-section after discussion with proficient and manufacturing units visit. At that time, Pie graph is framed to demonstrate the % contribution of indicators in the operational waste of the selected manufacturing line, shown in Figure 6.8. The Pie graph indicated that poor handling of materials (38%), Muda of man movements and utilization of space (25%), eco-logical concerns integrated with societal problem (19%), Rework due to defects, missing parts and wrong parts (11%) were the compelling contributing elements for operational waste of selected line of case organization.

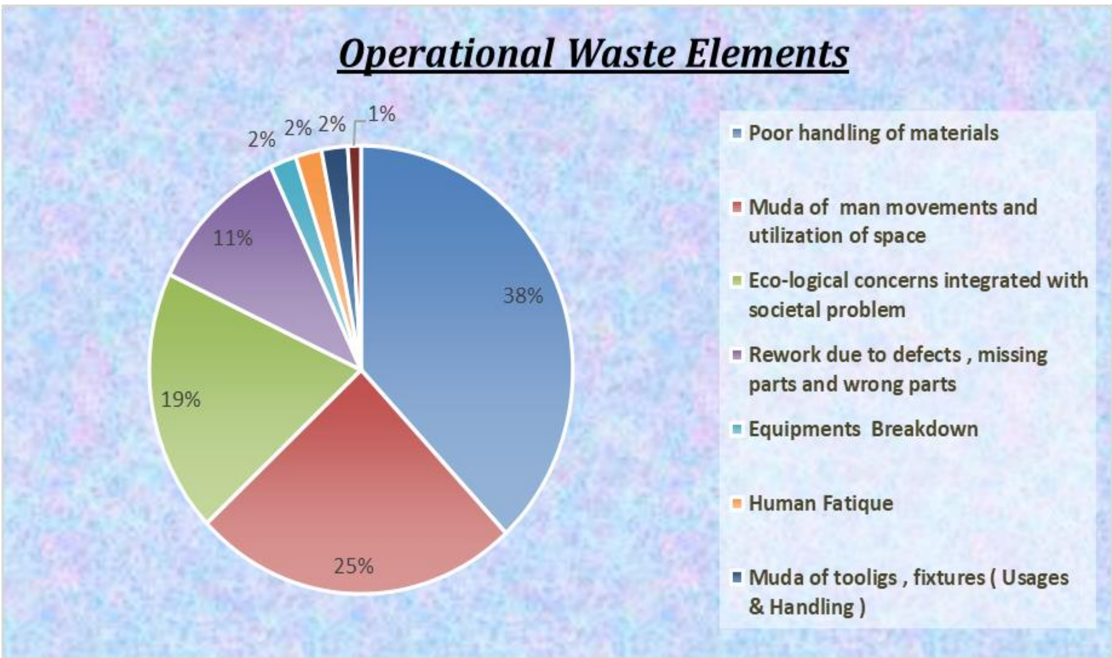


Figure 6.8— % Contribution of Operational Waste Indicators

6.7.2 Assessment of Production Resource Constraints

In this sub-section, assessment was done for the concerned raised by top-management for not meeting customer order on time due to bottlenecks in production improvements. Case company had gross capacity of 216 Tractors / day in 2 shifts working, and the asking rate was average 240 /day. For exploring the underlying cause and effect of production bottlenecks, 5-whys 1-H problem solving method was used to determine the root cause of the problem by successively asking the question ‘’why’’ and one How? Figure 6.9. With 5-whys analysis, it revealed that speed of conveyor cannot increase with reduced TAKT Time to increase the production within existing facilities. For this, there would require major modification in paint booth with addition of huge capital investment and plant shut down. Additionally, line balancing in pre-paint and post paint line would also require to meet the customer demand. But, due to space constraints, it was not possible to increase the length of paint shop for modification. There was need to go for an alternative thinking, unique and innovative solution to address this problem. Preliminary observation during examination and discussion with plant team CFT, this was concluded that line balancing on Pre-Paint line and Post-Paint line is not a concerned area.

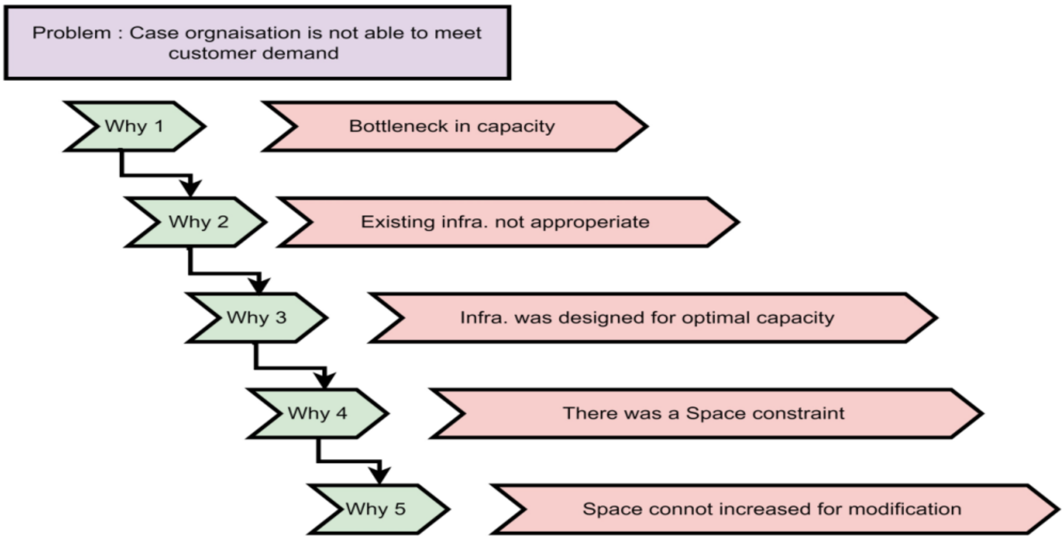


Figure 6.9— 5 Whys I-H for Production Resource Constraints

But we need to study the scope for an improvement in complete painting process, as paint quality parameters are important for product quality, which is directly linked with speed of the conveyor, flow of paint, temperature of cleaning, drying, baking and cooling. Study was conducted with the LG tool of LGVSM to understand the current state of process.

6.7.3 Estimation of Time for the Material Handling between Shops

In this sub-division, critical shop and section, who are responsible for poor material handling had been checked for material handling time. This examination provides guidelines and direction to choose the significant project for an improvement in operational waste in the Tractor plant. The data was collected for items relating to finished, semi-finished parts and other goods. This data was analysed and plotted on quality assurance tool, “Pareto bar chart’’, that places the data classification in the descending order from the highest chances of appearing to lowest chances of appearing, to decide the areas that were significant to high-operational waste of plant under study. In this chart, the horizontal axis represents independent sections in the plant. The bar graph signifies the times engaged for the material handling corresponding to individual section of the case plant. The adjacent bars with a cumulative frequency at each step govern, which shop related to handling of material will bow the significant gain, if dealt with. The Pareto evaluation advocates that the Tractor Assembly section and commodities wise different store location are the paramount contributors for poor handling of material and operational waste of the case company. The past 11 months data was taken for searching time of material in different shop, which is depicted in Figure 6.10.

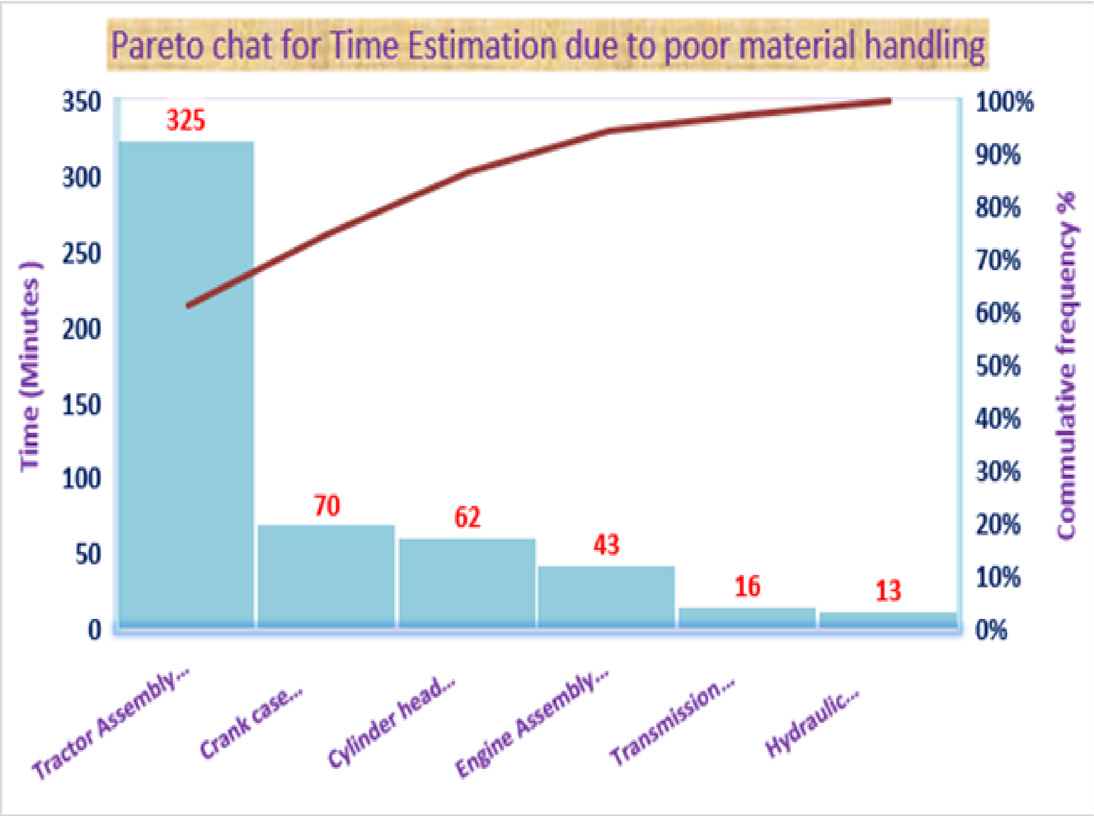


Figure 6.10— Time Estimation due to Poor Material Handling

6.7.4 Assessment of Current State of Process Mapping

In this division, the LG current state of process mapping has been instituted to disperse high level of understanding about existing operational processes. The process mapping of current state assessed, to find the crucial measures and metrics having relevance to wastages and in-efficiencies. The collection of data was carried out to determine the number of defects, construct LGCVSM as shown in Figure 6.11. Lean-Green Value Stream Mapping (LGVSM), is an empirical visual representation, which identify steps, course of actions or promising spots that create value within entire value chain [351]. LGCVSM analysis includes specifically, power consumption, water consumption, green effects, and traditional value stream elements like TAKT Time, Lead Time, Value Added Time, Throughput Time, Value Added Ratio for each operational process in current state of process mapping. The data related to rework was also accumulated to determine critical rework concerns.

Developing LGCVSM, facilitate in visualization the actual manufacturing set-up and assign insights on the resource utilization and consumption in lieu of the green point of view. The critical LG process matrix is depicted in Table 6.12.

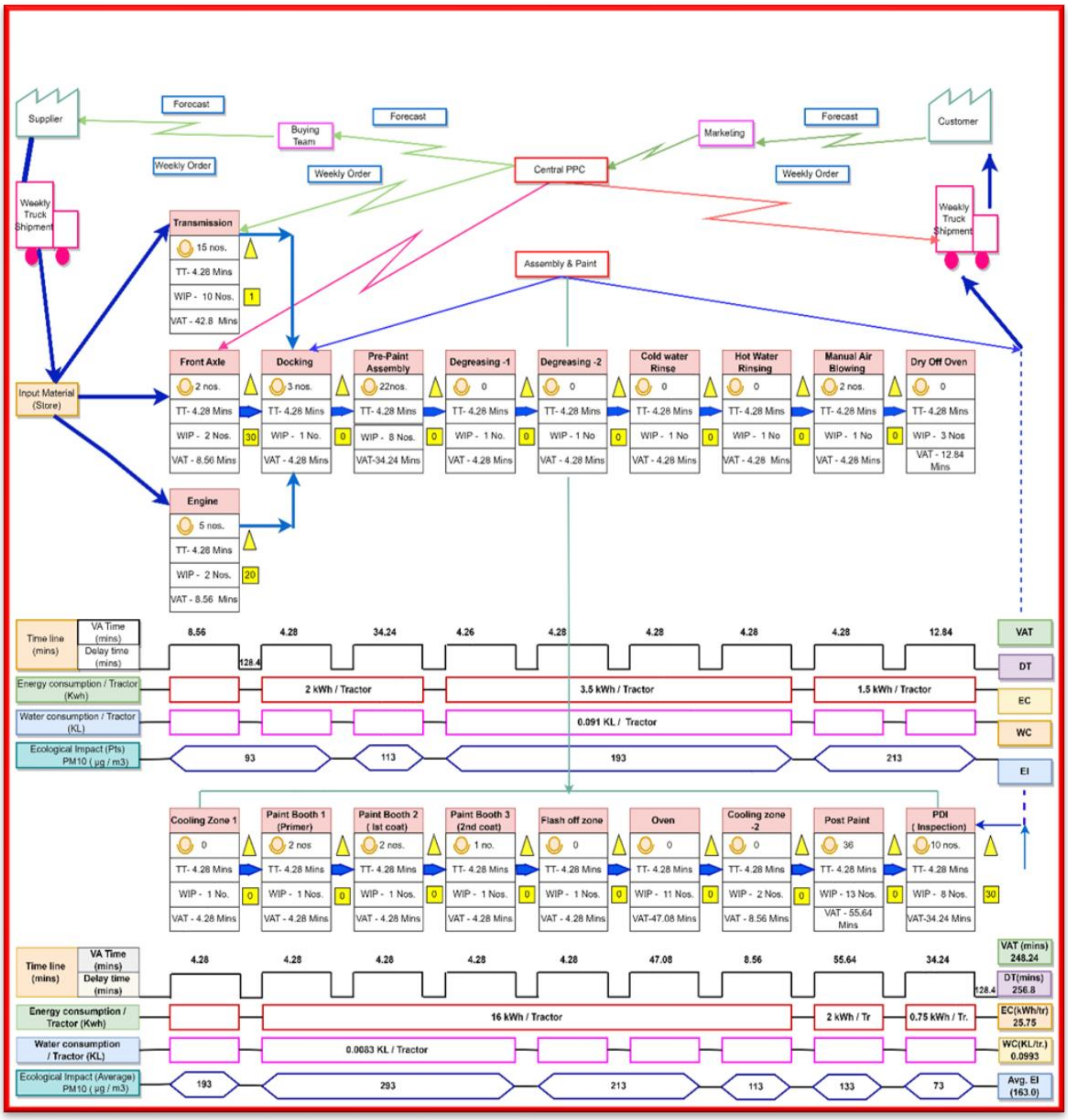


Figure 6.11— Lean Green Current State of Value Stream Mapping (LGCVSM)

6.7.5 Assessment of Environmental Impact in Current State of Process

The ecological effect of process was calculated based upon the data collection of power and water consumption in the process. Demineralized Water (DM) with chemicals used for pre-treatment process comes in contact with cast iron housings, other steel parts, rubber and plastic parts, oil and grease spills on the chassis etc. The discharged effluent water decreases dissolved oxygen. As a result of this, ecological impacts are climate change, radiation, ozone layer, ecotoxicity and acidification considering Tractor line complete process. Apart from this, data was also taken for disposal of paint sludge, which is generated during painting process**.** Paint sludge contains high volatile organic compounds, make chemical reaction with environmental oxygen and creates ozone layer in sight of sunlight. This ozone is considered to be one of cause of pollution of air. In LGCVSM, calculated ecological impact for each individual process is specified in the box below the line of water consumption. Altogether, ecological impacts for the current Tractor line process were observed to be 163.00 $\mu g/m^3$.

Table 6.12— Critical LG Process Matrix elements

Crucial process Matrix elements	Units
Takt Time	4.28 Mins
Lead Time	505.04 Mins
Value added time	248.24 Mins
Consumption of water	0.1 kl / Tr.
Consumption of power	25.75 kwh/ Tr
Ecological effect **PM10-Particulate less than 10 micron**	163 $\mu g/m^3$

6.8 Establishment of Root Causes for Wastes and Inefficacy

In this section, the root causes of various operational wastes and inefficacy are determined. Rooted on fact and factual, data set are collected, possible prospective causes for poor handling of material, cost of poor quality (rework on Tractors), degraded ecological performance, and an enhancement in societal sustainability are spotted using tools like Brainstorming (Idea Generation Exercise), Fish Bone Diagram (Cause & Effect), 5 whys analysis, Failure Mode and Effect Analysis (FMEA). Once the possible prospective causes are identified, the search is curtailed to detect consequential contributor(s) to an operational wastes and inefficacy by using techniques such as decision-making approaches, Pareto distribution chart (80/20 rule), hypothesis validation, etc.

6.8.1 Determination of Possible Causes for Poor Material Handling

The Fish bone diagram (Cause & Effect diagram) was instituted with the irritant of interest of poor handling of material in assembly section and store location in case organization, as shown in Figure 6.12.

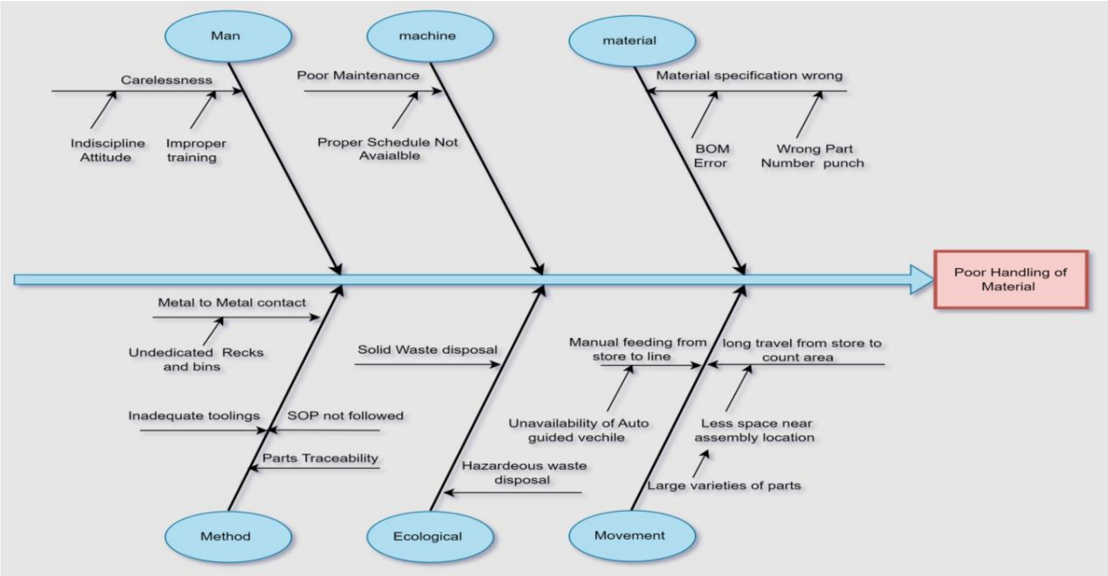


Figure 6.12— Cause and Effect Diagram for Poor Material Handling

Six pivotal categories were accommodated in this process like man, machine, movement, method, material and ecological to take forward for analysis of prospective causes. An idea generation exercise (brainstorming) was coordinated in structured way, involving front line officers, managers and department heads**.** Thirteen prospective causes are identified with this analysis, those were accountable for poor handling of material, as revealed in Table 6.13.

Table 6.13— Causes for Poor Handling of Material

S.NO	Causes accountable for poor handing of material	Level
1	BOM Error	WC1
2	Wrong Number Punch	WC2
3	Large Variety of parts	WC3
4	Un-Availability of Auto Guided Vehicle	WC4
5	Proper PM schedule not available	WC5
6	Solid waste disposal	WC6
7	Hazardeous waste disposal	WC7
8	Undedicated bins / recks and Poor material storage	WC8
9	Inadequate toolings	WC9
10	Parts traceability	WC10
11	SOP not followed	WC11
12	Indiscipline Attitude	WC12
13	Improper Training	WC13

Additionally, to search most significant causes amongst the identified causes, an investigation was done with the help of GRA (Grey Relational Analysis) technique. GRA furnishes obvious benefits compared to other available methods, as it provides immediate solution by changing the specifications and alteration in computer algorithm due to its dynamic nature [289]. Table 6.14, describes the ranking of elements accountable for poor handling of material. The analysis revealed that undedicated racks and bins, poor storage of materials and parts traceability were the most significant causes accountable for poor handling of material. Therefore, improvements action plan was required to conquer these wastes.

Table 6.14— Ranking of Elements for Poor Handling of Material

Level	CR1	CR2	CR3	CR4	GRG	RANK
WC1	0.550	0.593	0.560	0.570	0.568	**6**
WC2	0.701	0.699	0.680	0.670	0.688	4
WC3	0.788	0.811	0.789	0.790	0.795	**3**
WC4	0.620	0.630	0.615	0.601	0.617	**5**
WC5	0.510	0.515	0.519	0.505	0.512	**7**
WC6	0.490	0.485	0.483	0.470	0.482	**8**
WC7	0.414	0.390	0.395	0.398	0.399	**9**
WC8	0.844	1.000	0.855	1.000	0.924	**1**
WC9	0.244	0.256	0.223	0.234	0.239	**12**
WC10	0.833	0.993	1.0	0.860	0.921	**2**
WC11	0.210	0.190	0.180	0.203	0.196	**13**
WC12	0.336	0.367	0.347	0.327	0.334	**10**
WC13	0.310	0.290	0.283	0.273	0.289	**11**

6.8.2 Analysis of Rework, Un-productive Man Movements and Space

To uncover the source of the concern in absence of analytical investigation, 5-Why's analysis is a powerful reiterative questionable technique. The exercise of repeatedly cross- questioning, 'Why?'', covering of concerns and associated symptoms are uncovered, which leads to the identification of root-causes of the concern under analysis. This analysis was conducted by involving Front-line supervisors, Cell members and Department managers. Figure 6.13, illustrates the analysis, which was conducted to identify the causes related to rework on Tractors. Rework on Tractors was categorized into two heads, Wrong Parts fitment and Process defects. The analysis was performed under both heads. Un-availability of dedicated bins / recks, un-organized systems and controls were surfaced out as root cause for concerns related to rework in selected project line.

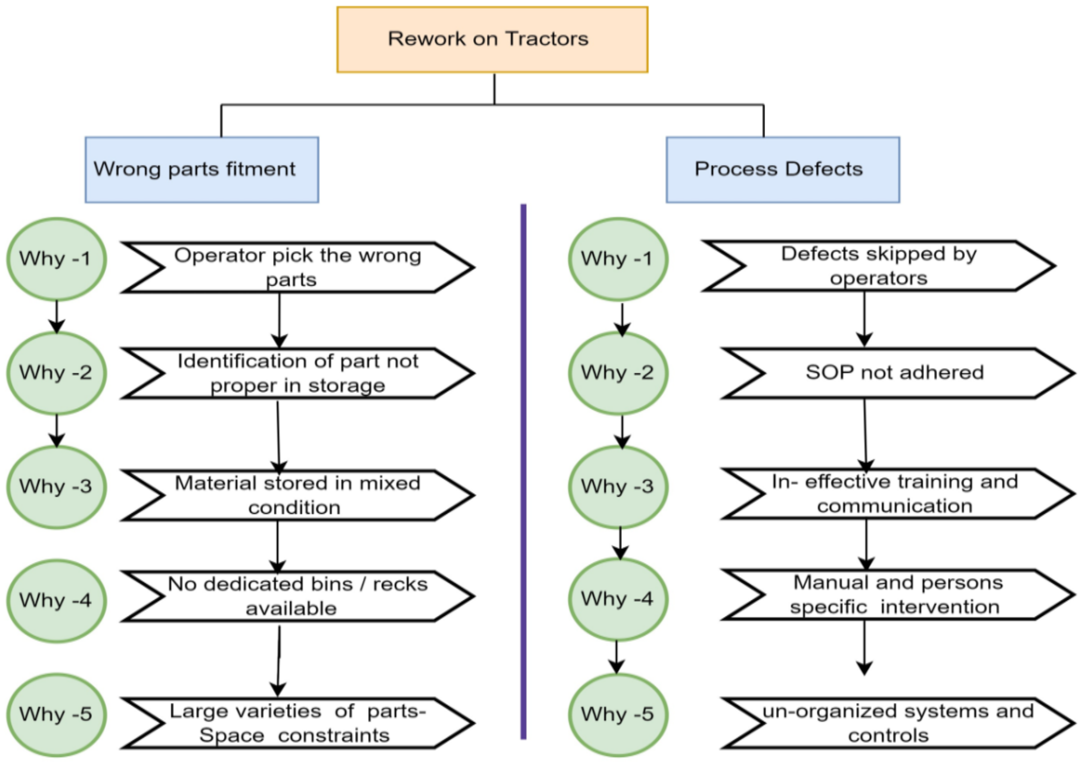


Figure 6.13— 5 whys Analysis for Rework on Tractors

The cross-functional team also conducted 5 whys analysis for un-productive man movements and use of available space. It was noticed from analysis, that inappropriate layout was accountable for this concern and improvement plan was needed to address this waste, as shown in Figure 6.14. Apart from this, project CFT team along with other team members of line after structured brainstorming session identified the significant elements such as water consumption, power and fuel consumption for poor sustainability outcome. Further, some team members also thrown an idea of improvement in packaging and modification in waste water re-cycling.

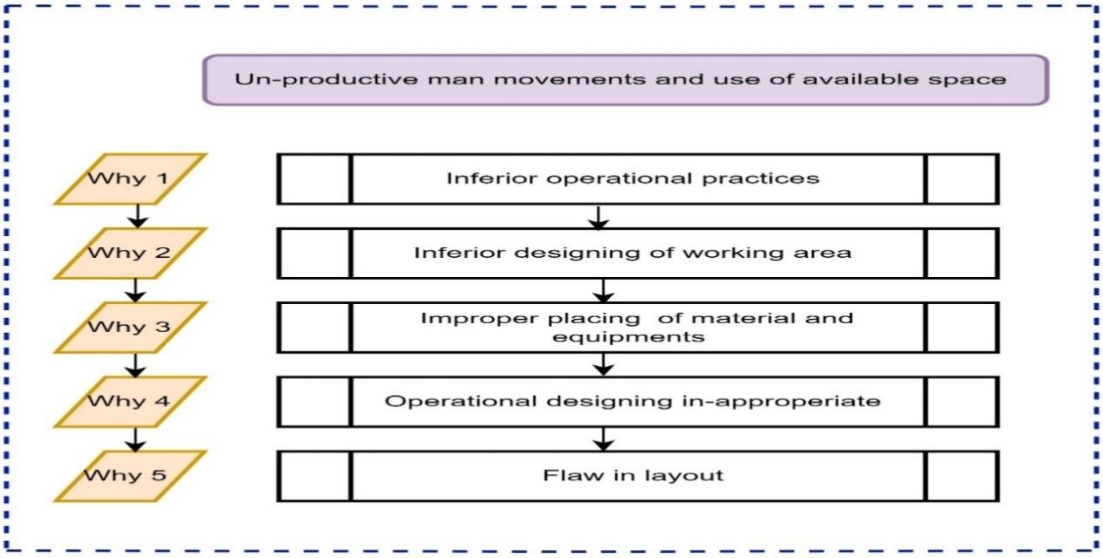


Figure 6.14— 5 whys Analysis for Un-productive Man Movement

This was also picked out for boosting towards socially sustainable. Therefore, the selected plant organization must focus on community at large. With the use of the various LG tools and techniques, Table 6.15 depicts the leading factors for wastages and in-efficacy of selected case organization. In the succeeding step of the LG framework, various improvement actions were implemented to increase the LG parameters of the Indian Tractor industry.

Table 6.15— LG Problems with Significant Reasons

S. No	Lean Green Problems	Vital Areas	Significant Reasons
1	Bottlenecks in capacity enhancement	Pre-paint , Paint Shop and Post paint	Space constraints for infra-structure modifications
2	Poor handling of material	Assembly and store location	Un-dedicated bins and recks , poor material storage and parts traceability
3	Un-productive man movement and use of available space	Assembly line	Flaw in layout
4	Rework on Tractors	Tractor PDI area	Wrong parts fitment and process defects
5	High water and power consumption	Paint shop	Design of booth's water circulations , recycling of water ,Paint backing
6	Socially sustainable fulfillment	Community at large	New appointments , local people deployment , Society funding

6.9 Implementation of Best Possible Solution.

After carrying out improvement tasks, pilot study is to be performed to register the selections of modified design and cost-benefits study to estimate full expense emanated through project. In this module, many solutions are suggested and the best possible solutions are spotted to minimise the wastages and inefficacy.

6.9.1 Bottlenecks in Production Recourse Enhancement

As per the analysis in previous sections, space constraint is a major issue with this plant. Consequently, large modification in infra-structure was not possible in increase in production. There was need to think innovatively with alternate thinking to de-bottlenecking the constraint. Initially, CFT members conducted a brainstorming session and spotted that in Pre-paint line and Post-Paint line. With re-balancing, it was possible to increase conveyor speed, but it will adversely impact on Paint quality parameters. Therefore, this project was taken with two objectives in mind.

- Increase the production from 216 to 240 in Phase manner (Target:240 / day) to meet the customer demand.
- Enhancing Resource Optimisation in 2 shifts working.

CFT decided to set target of 240 in 2 shifts working. In the current capacity of 216 Tractors, which were supposed to produce in 2 shifts working production. With the increase of demand, it was required to run 3 shifts working, which will add cost of operations. Therefore, CFT decided to increase capacity in phase wise, also for ensuring the achievement of quality parameters. Table 6.16, depicts the existing parameters and phase wise proposed parameters to achieve the target and consequently plan for best solution.

Table 6.16— Phase wise Production Improvement Details

Project : Capacity Improvement of case plant						
Existing details - 216 tractors / day			Proposed details (Phase 1) 228 tractors/ day		Proposed details (Phase 2) 240 tractors/ day	
S,No	Description	Details	Description	Details	Description	Details
1	Conveyor Speed	0.945 mtrs./ mins.	Conveyor Speed	0.99 mtrs./ mins	Conveyor Speed	1.035 mtrs./mins
2	Pitch	3.97 meters	Pitch	3.97 meters	Pitch	3.97 meters
3	TAKT Time	4.28 mins	TAKT Time	4.07mins	TAKT Time	3.855 mins
4	Capacity (Nos) / shift	A- 109 B-107	Capacity (Nos) / shift	A- 115 B-113	Capacity (Nos) / shift	A- 121 B-119

Figure 6.15, manifest the Process Mapping of Bottlenecks in current setup of 216 Tractors/day.

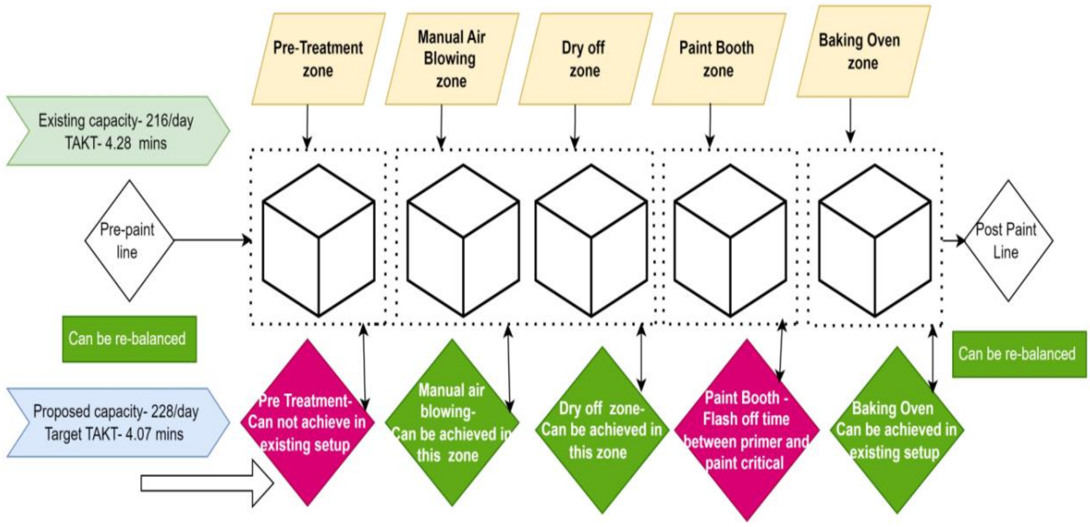


Figure 6.15 — Process Mapping of Bottlenecks in Existing Set up

It is evident from the bottleneck process papping study, Pre-Treatment Zone and Paint Booth Flash-Off time between Primer and Paint is key factors which require further study in phase -1 of this project.

6.9.1.1 PT Zone Study and Solution Implementation

Pre-Treatment zone consists of four chambers, namely i) Decreasing-1, ii) Decreasing-2, iii) Cold Water Rinsing, iv) Hot Water Rinsing. Each zone has different riser, which has distributed across the length. Processes are defined in each zone along with subsequent drain in each zone as shown in Figure 6.16.

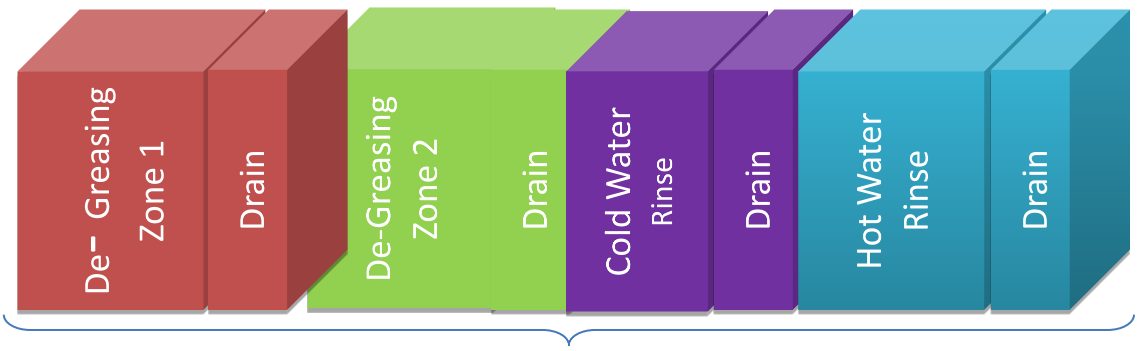


Figure 6.16— Pre-Treatment Zones

The dimensional study of zones along drains chambers was conducted. The detailed dimensional study of each zone is tabulated as follows at existing level, Table 6.17.

Table 6.17— Dimensional study of Pre-Treatment Zones

S.No			Nos. of tractors in WIP (Nos.)	Ideal Time for each zone (mins)	Actual Process Length (mm)	Conveyor Speed (Meters / mins)	Process time as per existing conveyor speed (mins)
1	Chassis load to overhead conveyor		0	0			
2	Transfer up-to entrance of PT		0.3	0.3	1200	0.94	1.28
3	Pre-treatment System	Entry Vestibule	4		2900	0.94	3.10
		Decreasing -1		2.5 -3.5	3500	0.94	3.74
		Drain		NA	1470	0.94	1.57
		Decreasing -2		2.5-3.5	2490	0.94	2.66
		Drain		1-1.5	1300	0.94	1.39
		Cold Water Rinse		1-1.5	1500	0.94	1.60
		Drain		1-1.5	1030	0.94	1.10
		HW rinse (Passivation)		1.5-2	1750	0.94	1.87
		Drain and exit Vestibule			1570	0.94	1.68

At the existing setup, after brainstorming, team decided to validate the performance outcome with targeted speed of 0.99 meters / mins from existing set up of 0.945 meters / mins. Sample of five Tractors were taken for validation purpose in pre-treatment area only. Table 6.18 manifests all related parameters and specifications used in Pre-Treatment process.

Table 6.18— Parameters and Specifications used in PT Process

Details	DG Tank-1	DG Tank 2	Cold water	Hot water	Additional Information
Tank capacity	7KL	5KL	3.5KL	3.5 KL	
water use	DM	DM	DM	DM	Conductivity-Less than 30 µS/cm
Chemical use	DG-28	DG-28	No Chemical	NDL 6800	
Total Acid	10-15 ml/ litre	4-6ml / litre	0-1.5ml/litre	0.1-1.0 ml / litre	
Spray Pressure	1.0-1.20 kg/cm²	0.8-1.0 kg/cm²	0.8-1.20 kg/cm²	0.6-0.8 kg/cm²	
DM - Water (PH)	3.5-5.5	3.5-5.5	5.5-7.5	4.5-6.5	PH-6.0 - 7.5
Oil content	4.0 gm/liter max	4.0 gm/liter max	-	-	
No of risers	12	6	6	8	Total Risers - 34 Nos
No. of nozzles	222	149	116	129	Total Nozzles -616
Tank Temperatures	50 C° - 60 C°	50 C° - 60 C°	No Temp.	50 C° - 60 C°	
Filter type	Nylon Bag Filter (150 micron)	Nylon Bag Filter (150 micron)	Nylon Bag Filter (150 micron)	Nylon Bag Filter (150 micron)	Size - 7*32 - 14 nos 10*32 - 2 nos
Quantity	8	6	1	1	Total =16

During trail and validation with increased conveyor speed, the following challenges are observed.

- Mixing of water in different tanks, Bath carries over in PT Zone due with increased speed.
- At existing Flash off time, no merging of Primer and Paint
- Pre- paint and overhead conveyor mismatch due to increased speed

To address the water mix problem and accumulation of water in zones for maintaining Total Acid (TA), and PH values, thereby reducing the water consumptions for process sustainability, the following modifications has been proposed by team after proper measurements and observations at Gemba, Table 6.19.

- Pro-actively addition of nozzles in vestibule.
- Modification and shifting of drain holes for cascading and chemical back to zone 1
- Modification and shifting of supply pipe, header, flange shifting, exhaust duct etc and re-partitioning.

Table 6.19— Proposed Dimensional Modification in PT Zone

				Maximum Existing (216 tractors /day)				Proposed Modification (228 tractors /day)		
S.No			Nos. of tractors in WIP (Nos.)	Ideal Time for each zone (mins)	Actual Process Length (mm)	Conveyor Speed (Meters / mins)	Process time as per existing conveyor speed (mins)	Actual Process Length (mm)	Conveyor Speed (Meters / mins)	Process time as per existing conveyor speed (mins)
1	Chassis load to overhead conveyor		0	0						
2	Transfer up-to entrance of PT		0.3	0.3	1200	0.94	1.28	1200	0.995	1.21
3	Pre-treatment System	Entry Vestibule	4		2900	0.94	3.10	2900	0.995	2.91
		Decreasing -1		2.5 -3.5	3500	0.94	3.74	3500	0.995	3.52
		Drain		NA	1470	0.94	1.57	1000	0.995	1.0
		Decreasing -2		2.5-3.5	2490	0.94	2.66	2490	0.995	2.50
		Drain		1-1.5	1300	0.94	1.39	1500	0.995	1.51
		Cold Water Rinse		1-1.5	1500	0.94	1.60	1500	0.995	1.51
		Drain		1-1.5	1030	0.94	1.10	1200	0.995	1.21
		HW rinse (Passivation)		1.5-2	1750	0.94	1.87	1850	0.995	1.86
		Drain and exit Vestibule			1570	0.94	1.68	1570	0.995	1.58

The proposed modification concept, Figure 6.17 was sent to PT chemical supplier and supplier given approval for further validation. Modification was carried out in seven days. Afterwards, trials were conducted and found ok in Pre-Treatment process. Simultaneously, team explored the fast evaporative thinner with paint supplier for maintaining the flash off time between 2 min to 2.5 mins to avoid paint defects like blisters. Merging issue was addressed with use of evaporative thinner supplied by paint supplier. Third challenge of this phase-1 was conveyor mismatch with increased speed. Further, investigation revealed the followed mentioned observations.

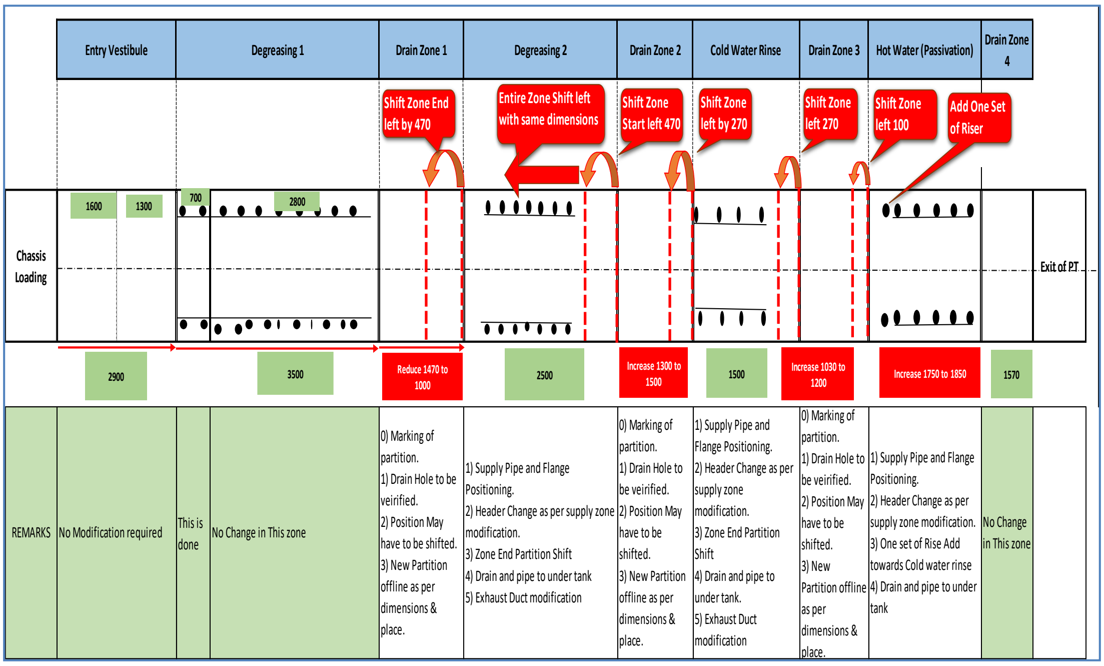


Figure 6.17— Proposed Modification Concept of PT Zone

- Pre-paint conveyor is having pitch of 4.57 meters
- Paint booth conveyor (overhead) is having pitch of 3.97 meters
- Post Paint conveyor is having pitch of 4.57 meters.

With the increased speed of overhead conveyor, mismatch is observed due to synchronization between three conveyors. Afterwards, with brainstorming, two suggestions were surfaced out.

- To increase the pitch of Paint Booth to 4.57 meters
- To reduce the pitch of Pre-Paint and Post Paint to 3.97 meters

In both the cases, solution was found not feasible. Pitch of Paint Booth cannot be increased due to space constraints and Pitch of Pre-Paint cannot reduce due to constraints in material feeding and movements. After lot of deliberation, 'Relay Race relative movement concept' innovative idea came into existence, Figure 6.18.

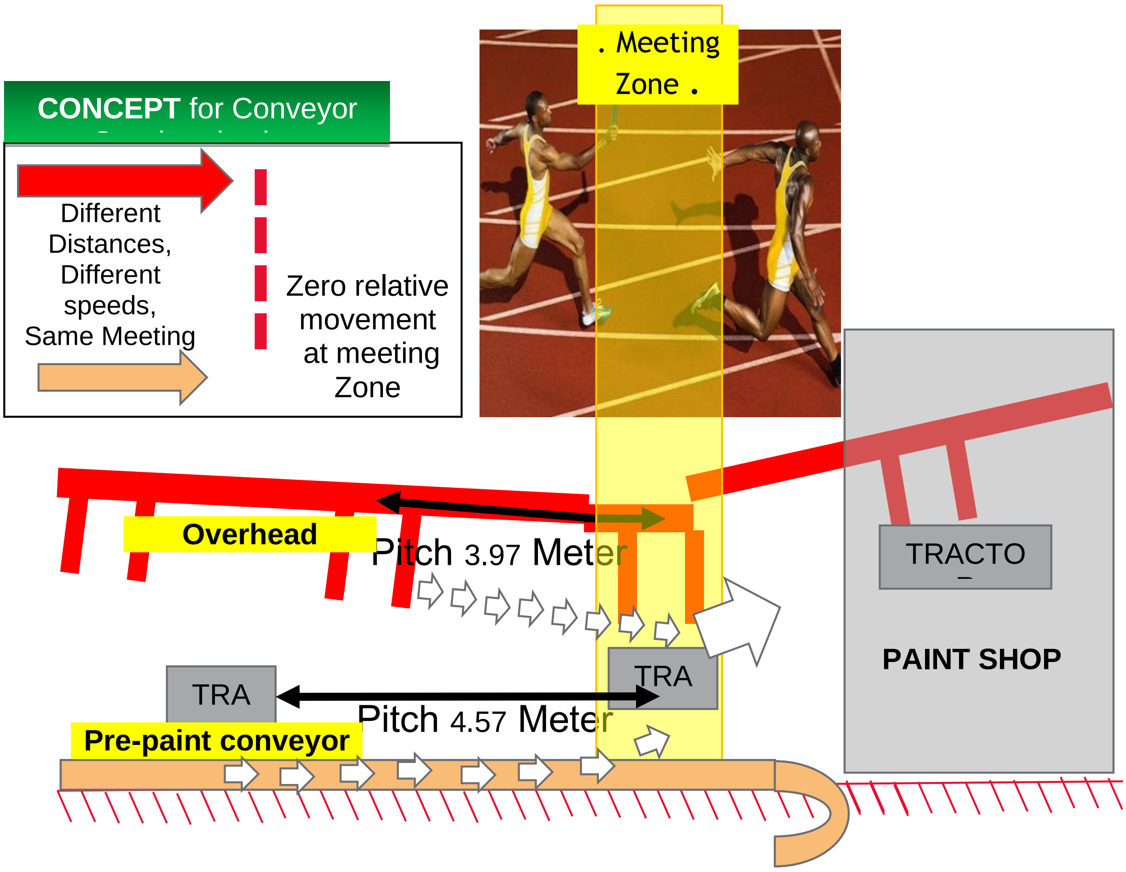


Figure 6.18— Concept of Matching Conveyor Speed

Challenge was to develop auto synchronization system to monitor and control all three different conveyors (Pre-Paint, Over Head & Post Paint) having three different pitches at three different speeds with close loop feedback. In-house plant maintenance team developed this idea of auto-synchronizer inhouse, Figure 6.19 and this vital challenged was addressed.

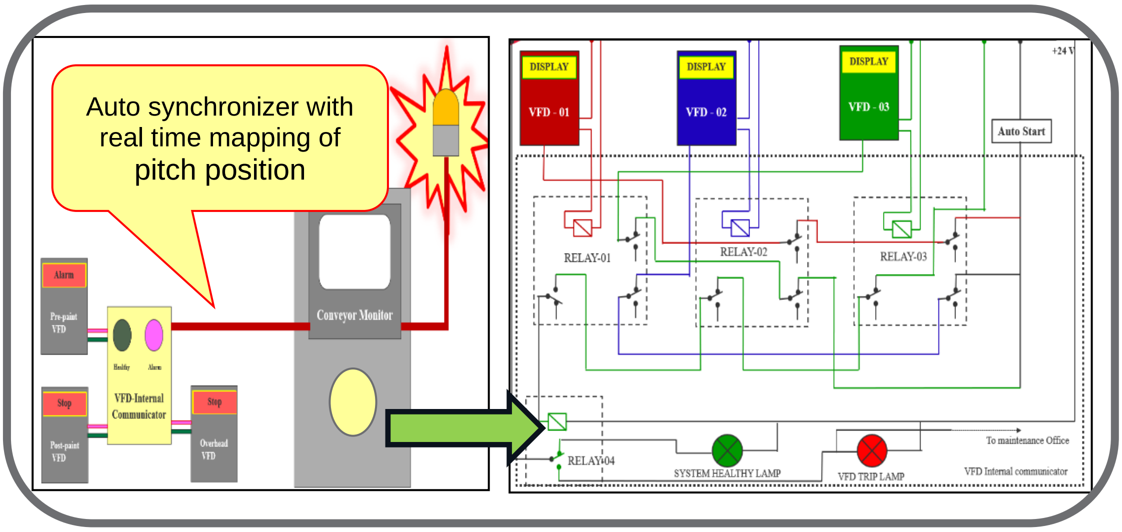


Figure 6.19— Concept of Auto-Synchronizer

After addressing all the three vital challenges with low cost solution, trials were conducted and the following KOP of Painting process found 'OK', refer Table 6.20.

Table 6.20— Key Output Parameters of Painting Process

KEY output Parameters (Painting Process)			
S.No	Parameters	Specification	Status
1	Paint Adhesion	No paint peel off after tape test	Ok
2	Dry Film Thickness (DFT)	70 -130 micron	within range
3	Pencil Hardness	Pass H grade	Ok
4	Gloss value	90 GU @60 degree	Ok
5	Solvent Rub Test	No paint out with PU thinner	Ok
6	Effective Metal Temperature (TTR)	20 Mins at 70 degree C	Ok

Production run successfully and achieved output of 228 tractors / day in Phase-1 with these innovative working with team. Team had taken challenging target for 240 tractors / day and started working on phase 2. As major modification was done in Phase -1, so team conducted trail with further increased speed of 1.03 meters / min, Figure 6.20. Further analysis revealed, TTR (Total Thickness Range) is not achieved with proposed speed in oven. Effective Metal Temperatures test was conducted at after every six hours and noticed, at the starting tractors entering in oven, results were not in favour.

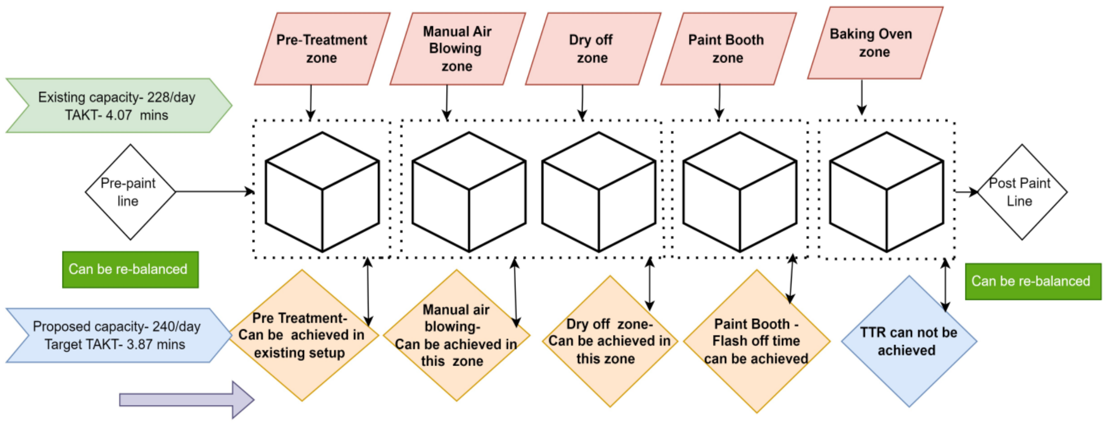


Figure 6.20— Phase- 1 Modifications and Trials

As further modification is not possible due to space constraints, team suggested the below mentioned ideas to work upon.

- Increase the temperature of oven.
- Increase the heat flow.

An increase in oven temperature is ruled out due to adverse impact on rubber and plastic parts, also leading to environmental concern further. Only, feasible solution was to increase the heat flow inside the oven, especially in the morning time before the entry of Chassis in oven, which were kept in dry off zone (6 nos.) from the previous shift end in night. Team proposed the following actions for increase in air flow inside the oven, Figure 6.21.

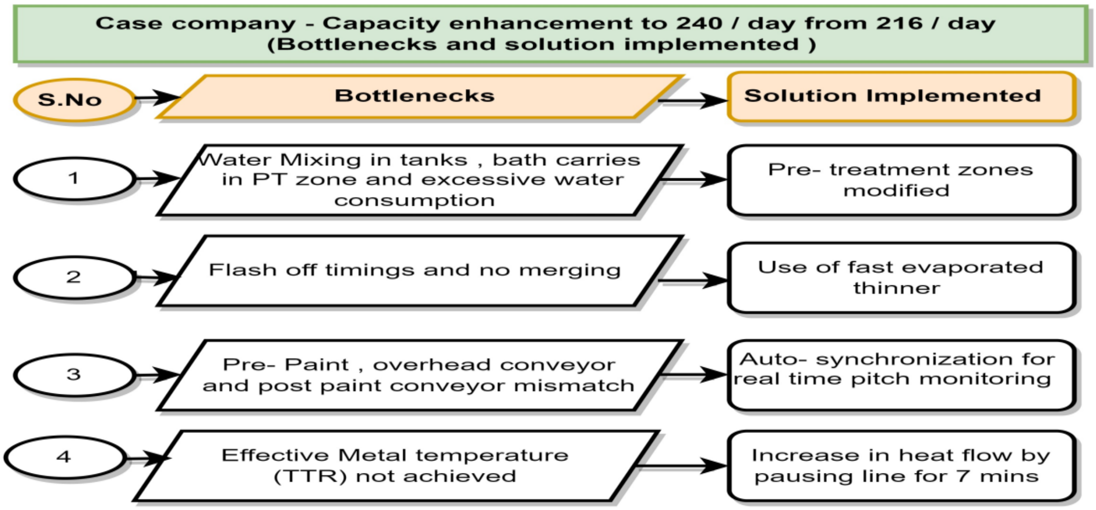


Figure 6.21— Bottlenecks and Solutions for Phase-2 Improvement

- Start-up of oven in the morning with temperature at regular practice
- Increase the temperature by 3^0C after half an hour of start.
- Further, after half an hour, pause the line for 7 mins.
- Reduce the temperature to original set temperature and run the line.

With this modified process, trials were conducted and TTR found ok. 25 tractors were also undergone for KOP painting test and found ok. Production was run and successfully achieved the capacity enhancement without any major infra- structure modification.

6.9.2 Improvement Action Plans related to Quality Concerns

In previous section, it has been identified that wrong parts fitment and process defects was the major root cause for quality related concerns in case organization. From the problem data bank of department, two months data was analysed. Total, 168 problems are identified. For addressing the problem(s), 8 steps QC story approach was adopted in structured way for addressing quality concerns related to process.

Step 1: Identification of problem

In this step, 168 issues are identified, which are bifurcated into categories, Figure 6.22.

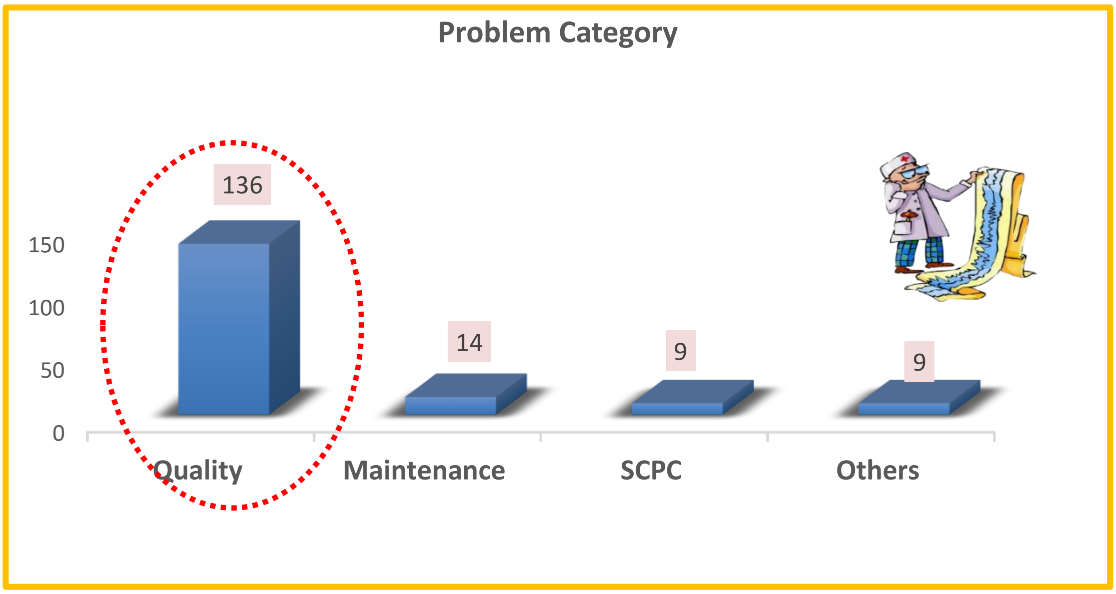


Figure 6.22— Bifurcation of Identified Problems

It was observed during categorization of problems, 136 problems were observed related to quality, which were further categorized into different types of quality problems, which is depicted in Figure 6.23. It was observed that Major contribution of

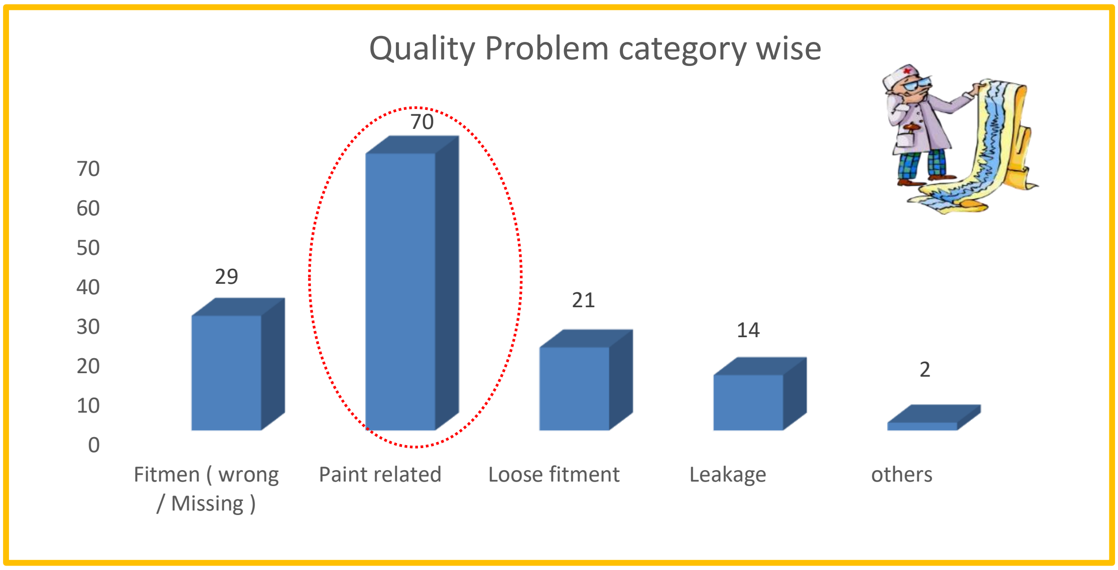


Figure 6.23— Categories of Quality Problems

defects were related to paint which were accounting to 70 numbers for the period of data collection. Paint related defects were listed separately for further analysis to paint defects, which were listed separately for further analysis in step-2.

Step 2: Selection of problem

The listed down 70 paint related defects have been further divided into three categories A, B and C. The category 'A' related problems are those, which can be resolved independently by operator, 'B' related problems can be resolved with the help of other department and 'C' category problems needs support from management. The data reveals, that 40 % problems related to A category, 60 % with B category and Zero in C category, Figure 6.24.

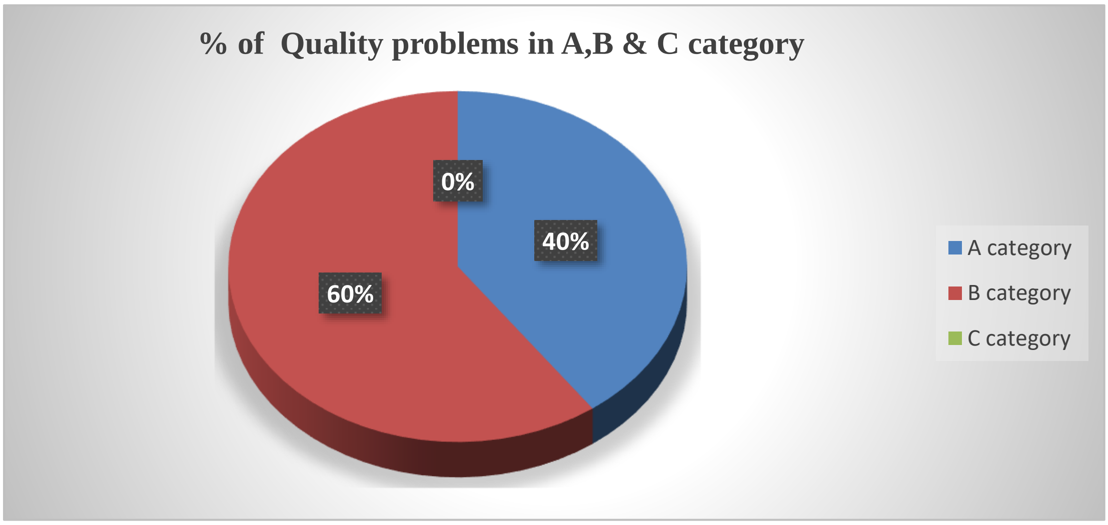


Figure 6.24— Bifurcation of Problem in A, B & C categories

For selection of top contributing problems from category 'B', which need support from another department to resolve, Pareto chart was prepared Figure 6.25.

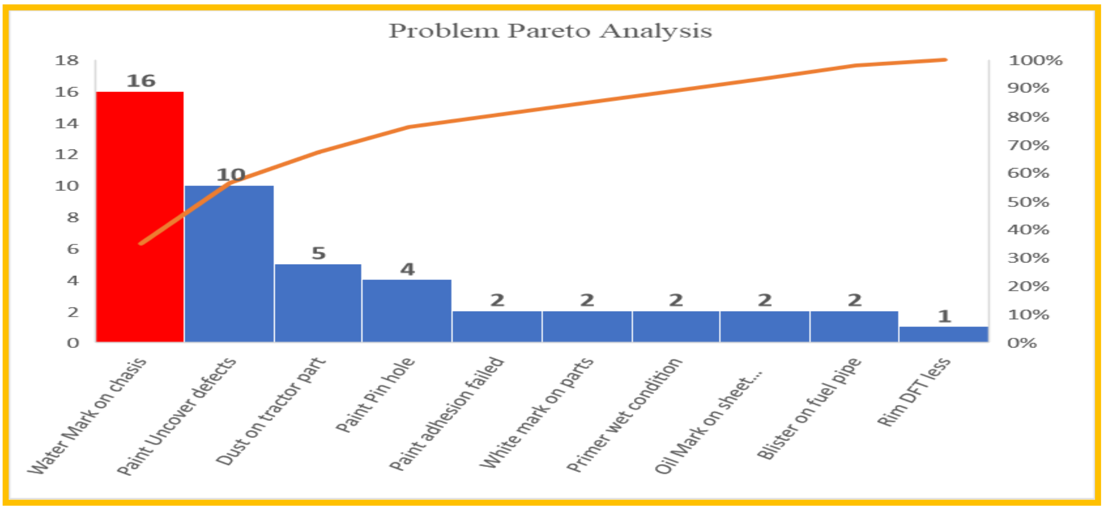


Figure 6.25—Pareto Chart for 'B' Categories Problems

Top-most problem was identified as ‘water mark on chassis’, which was taken for further analysis with the use of LG tools. Figure 6.26, displays the exiting paint booth set up and location of water mark on chassis

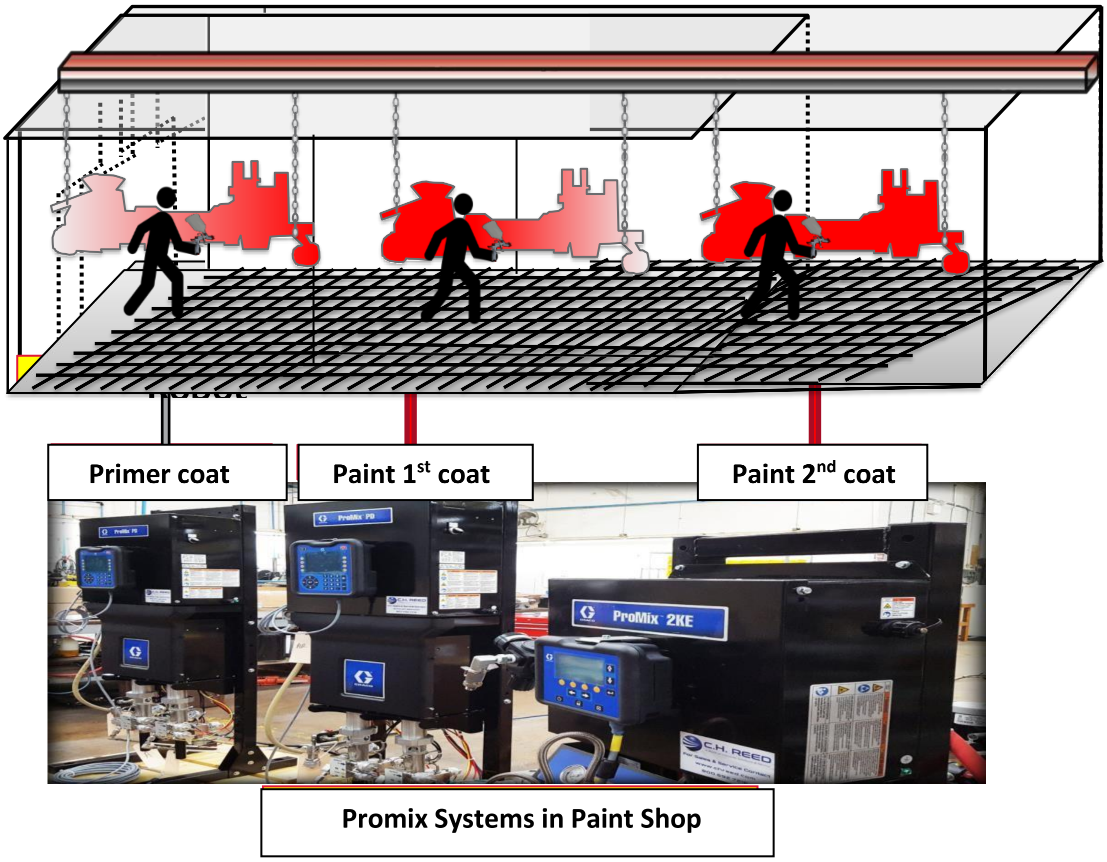


Figure 6.26— Promix System in paint Booth

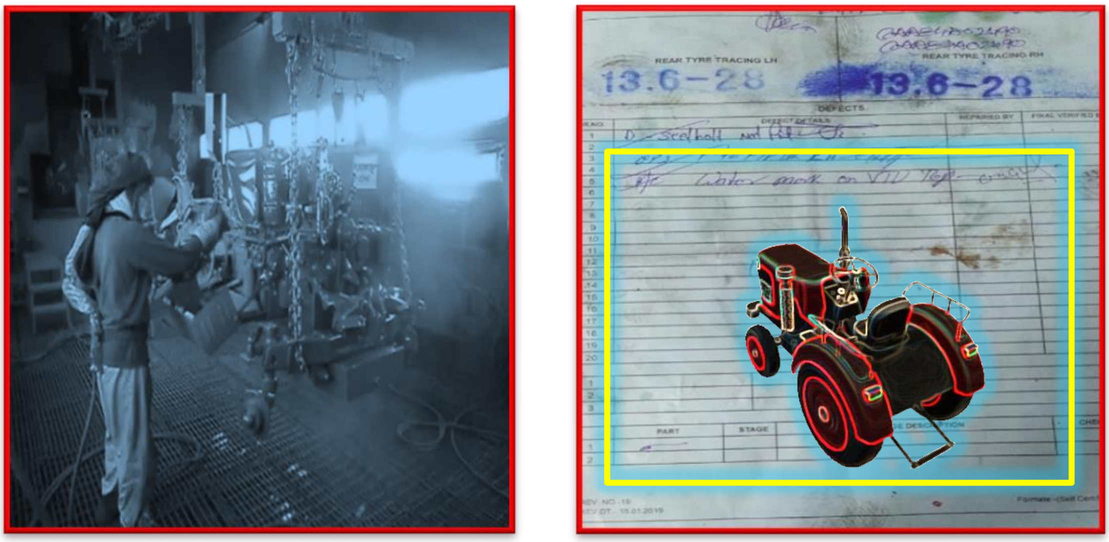


Figure 6.27— Painting Process and Water Mark Problem Written on Traveler Card

Water mark on chassis was observed during painting process. At quality inspection stage, this defect was captured and registered in history traveller card for rework purpose, Figure 6.27. The location of water mark on chassis is shown in Figure 6.28. The impact of water mark on Chassis is shown in Figure 6.29.

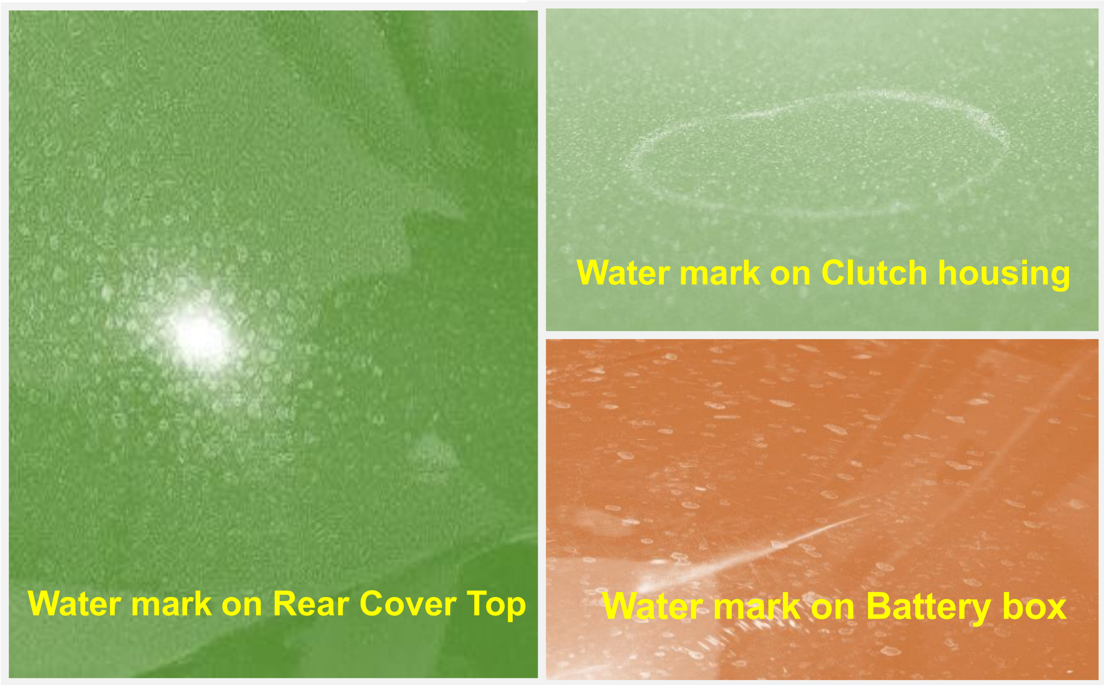
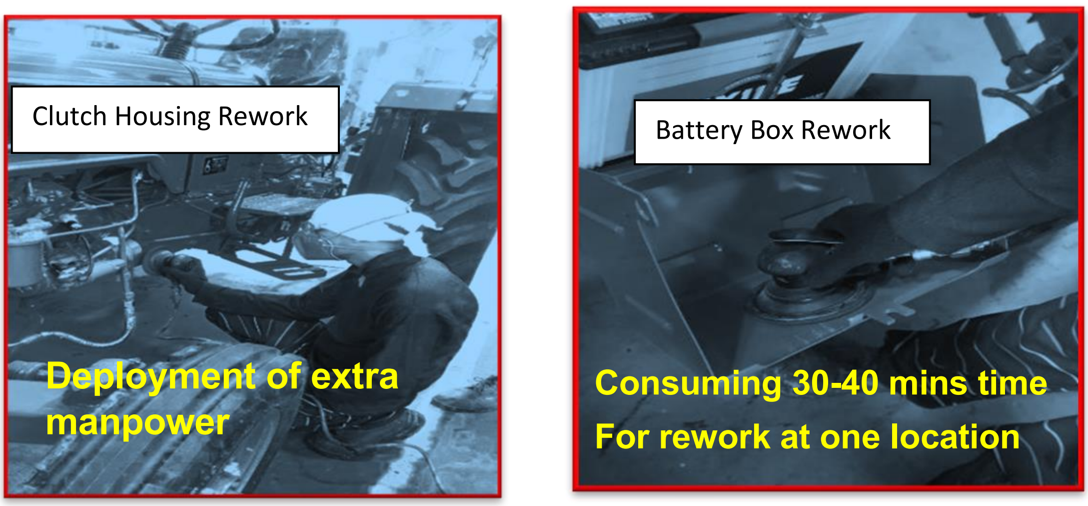


Figure 6.28— Location of Water Mark on Chassis

Impact of water Mark on Chassis

Impact of water mark on the surface of chassis led to deployment of extra man power for rework activities, 30 to 40 mins time was consuming to do rework at one location. In one case, it was observed to dismantle the tractor for changing the engine and other parts as rework was not possible.



Cost of one manpower for this activity was Rs. 800 / day and impact on direct pass ratio within TAKT was also hampered. Furthermore, there are high chances of paint peel off early due to poor rework and touch up process.

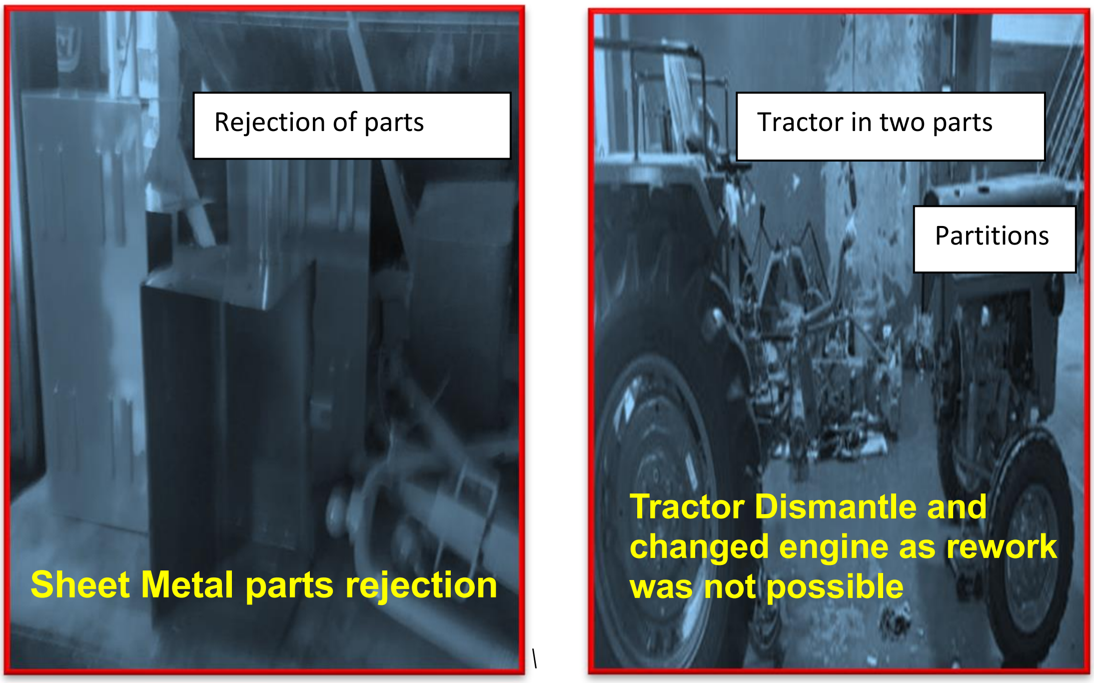


Figure 6.29— Impact of Water Mark on Chassis

So, this problem was selected for further analysis as major process quality defect.

Step 3: Define the problem

The defect generation point was observed in Paint Booth and captured in PDI stage. Further, we studied six months trends of same defect, 61 cases were observed. Consequently, there was rework and rejection cost of 2.56 Lacs /Year, Direct pass Ratio was dipped by 1 % only due to this defect, Traveller card RPH (Repair per hundred) increased by 0.5 RPH along with low morale of Front-line Workers. Therefore, Target was taken to eliminate the problem under continuous improvement initiatives.

Step 4: Analysis of problem

The problem was analysed in 4 W and 1 H problem analysis tool, which is depicted in Figure 6.30, which states, 'What was the problem? ', 'where it was generated'?' When is it was captured?', 'Who was responsible for the problem'? and 'How much Qty'?

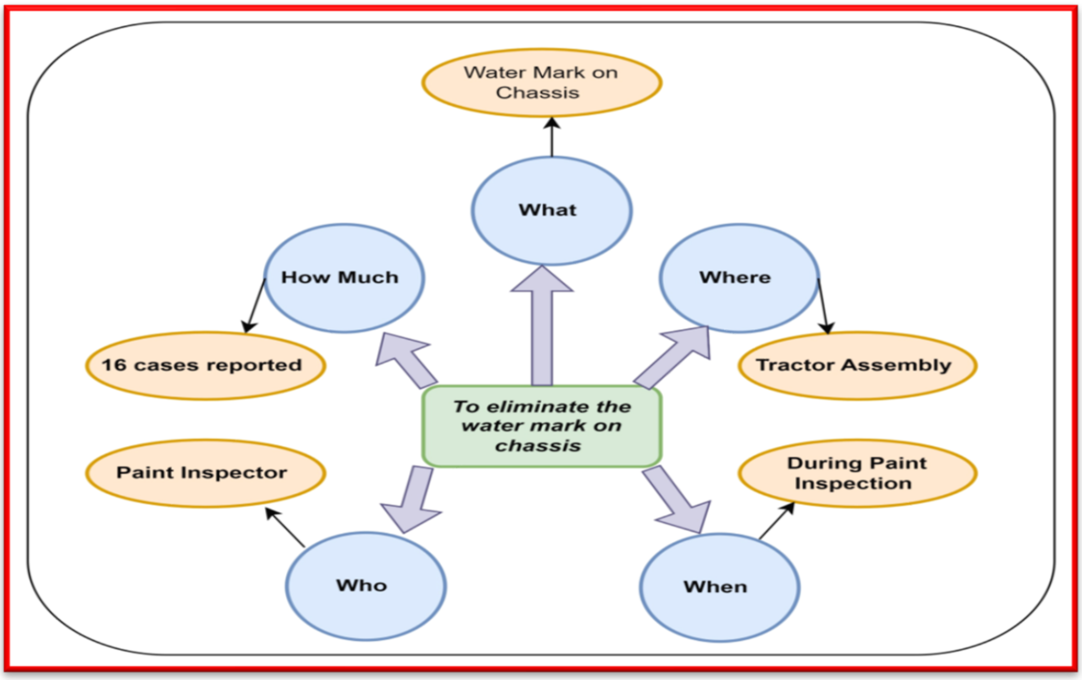


Figure 6.30— 4W and 1H Analysis of Water Mark Problem

Step 5: Identification of the Cause

A brainstorming session was conducted by circle team. The possible causes were identified through this ideation process, Table 6.21.

Table 6.21— Possible causes through Ideation process

S.No.	Possible Causes
1	Air Pressure not controlled
2	Manual Air wiping properly not done
3	Dry off oven temperature less
4	Air piping lay outing not ok
5	Moisture in mixing air
6	Air dryer system leakage
7	Nitrogen cylinder pressure less
8	Paint Quality Not OK
9	Supplier primer surface not ok

For finding the root cause of the problem, causes are bifurcated into 4M and C&E diagram was prepared as shown in Figure 6.31.

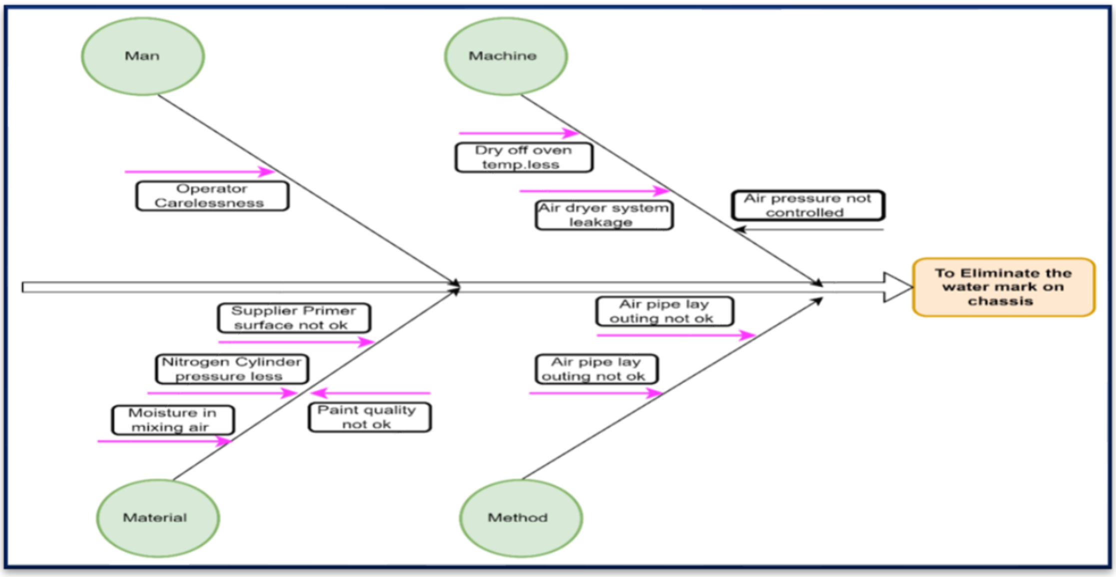


Figure 6.31— Cause & Effect Diagram for Water Mark on Chassis

Each circle members except leader of circle has given the rating on each cause individually, named as Cause Rating Chart, Table 6.22. For identifying the most assignable cause, rating value 40 and above were set with scale (1-3= less, 4-6= moderate, 7-10= strong), which further validated through hypothesis testing.

Table 6.22— Cause Rating Chart

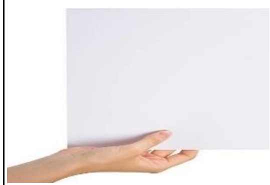
S.No.	Cause	Leader	M-1	M-2	M-3	M4	M-5	M-6	Total
1	Moisture in Mixing air	x	10	9	10	10	9	10	58
2	Air Pressure not controlled	x	9	9	10	8	8	9	53
3	Nitrogen pressure less	x	8	9	8	9	8	7	49
4	Dry off oven temperature less	x	9	7	7	8	7	7	45
5	Manual air wiping proper not done	x	7	7	6	7	6	6	39
6	Air pipe lay outing not ok	x	8	6	6	7	5	6	38
7	Air Dryer system not ok	x	5	5	6	5	5	5	31
8	Paint quality not ok	x	5	5	4	3	4	4	25
9	Supplier primer surface is not ok	x	4	5	3	4	3	4	23

With the rating chart, it was identified four assignable causes, which were underdone hypothesis testing for find the root cause in next step

Step 6: Find the root cause

The hypothesis testing for valid cause (s) has been shown in Table 6.23.

Table 6.23— Hypothesis Testing

S. No.	Assignable Cause	Specification	Actual	Validating Instrument	Valid / un-valid
1	Air Pressure not controlled	45-60 psi	60.05 to 60.2 psi (Running condition) 61.4 to 65 psi (Stop condition)	 	Pressure found ok. -Cause Invalid
2	Moisture in mixing air	No Moisture in air	Moisture observed Moisture checked by hands Moisture checked by chromatography paper and moisture observed	  	Moisture observed -Cause valid
3	Nitrogen cylinder pressure less	1-2 bar	1.4, 1.5 bar		Pressure found ok. -Cause Invalid
4	Dry off Temp. less	108-122 ^0C	111. ^0C		Temp. Found Ok -Cause In-valid

Step 7: Data Analysis

Analysis was carried out for validating and re-validating the root cause by the use of 5 whys analysis, Figure 6.32, and Process Flow analysis, shown in Figure 6.33.

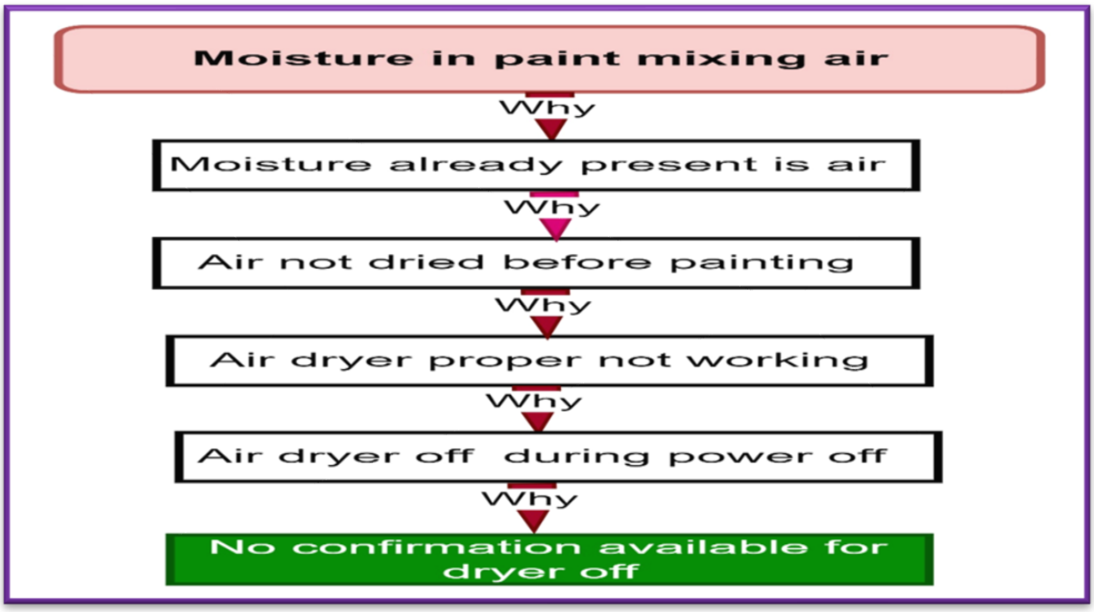


Figure 6.32— Moisture in Paint Air Mixture

Air was supplying from desiccant type air dryer, which was installed in utility department from where air was supplied to first air dryer near paint booth having

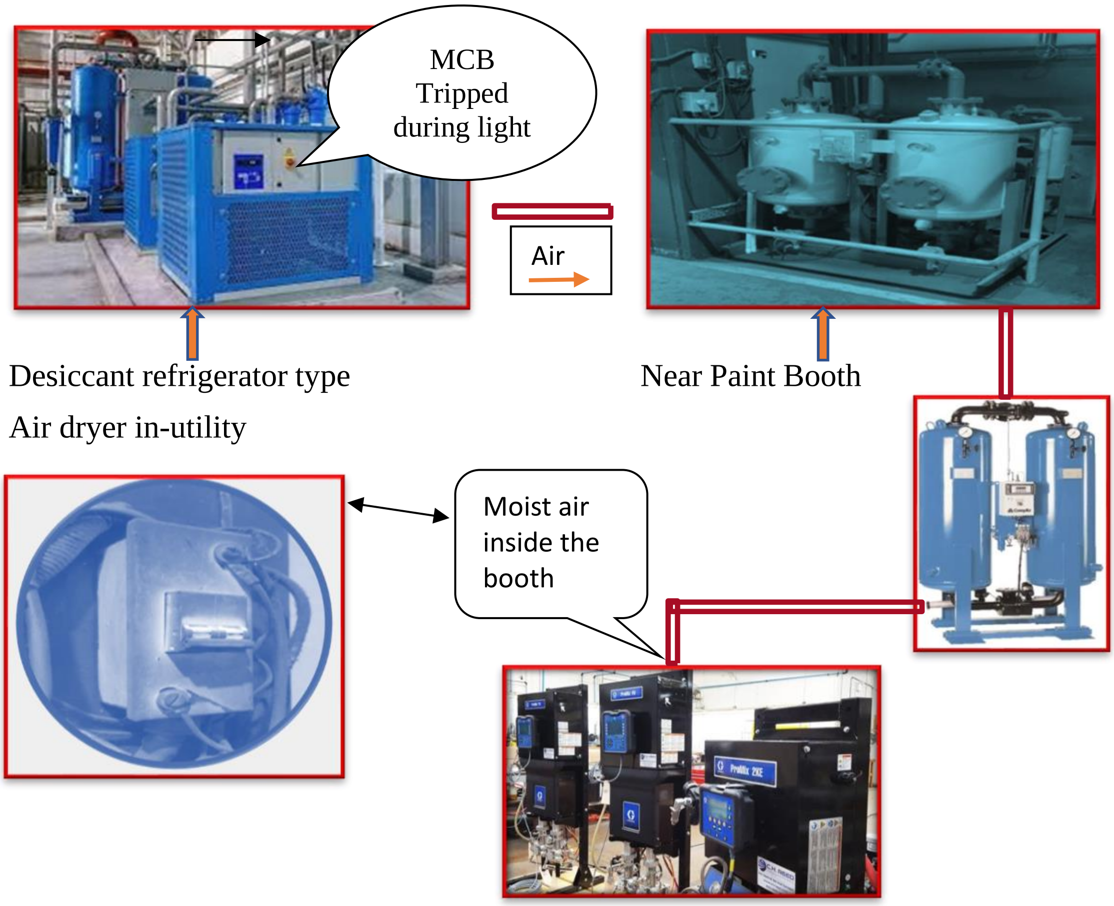


Figure 6.33— Paint Process Flow Analysis

activated silica ball. From there, air was being flow to painting gun after mixing with paint. It was observed, during light cut or fluctuation, dryer also stop working, but air supplies is continuous. From the analysis and re-validation, it was concluded that, fool proof mechanism is required to plug this major concern.

Step 8: Development of solution

The team conducted a brainstorming session, various ideas were noted down. Finally, two solutions were identified for execution, Figure 6.34

- Buzzer visual indication during power MCB tripping
- Air supply cut off when MCB gets tripped

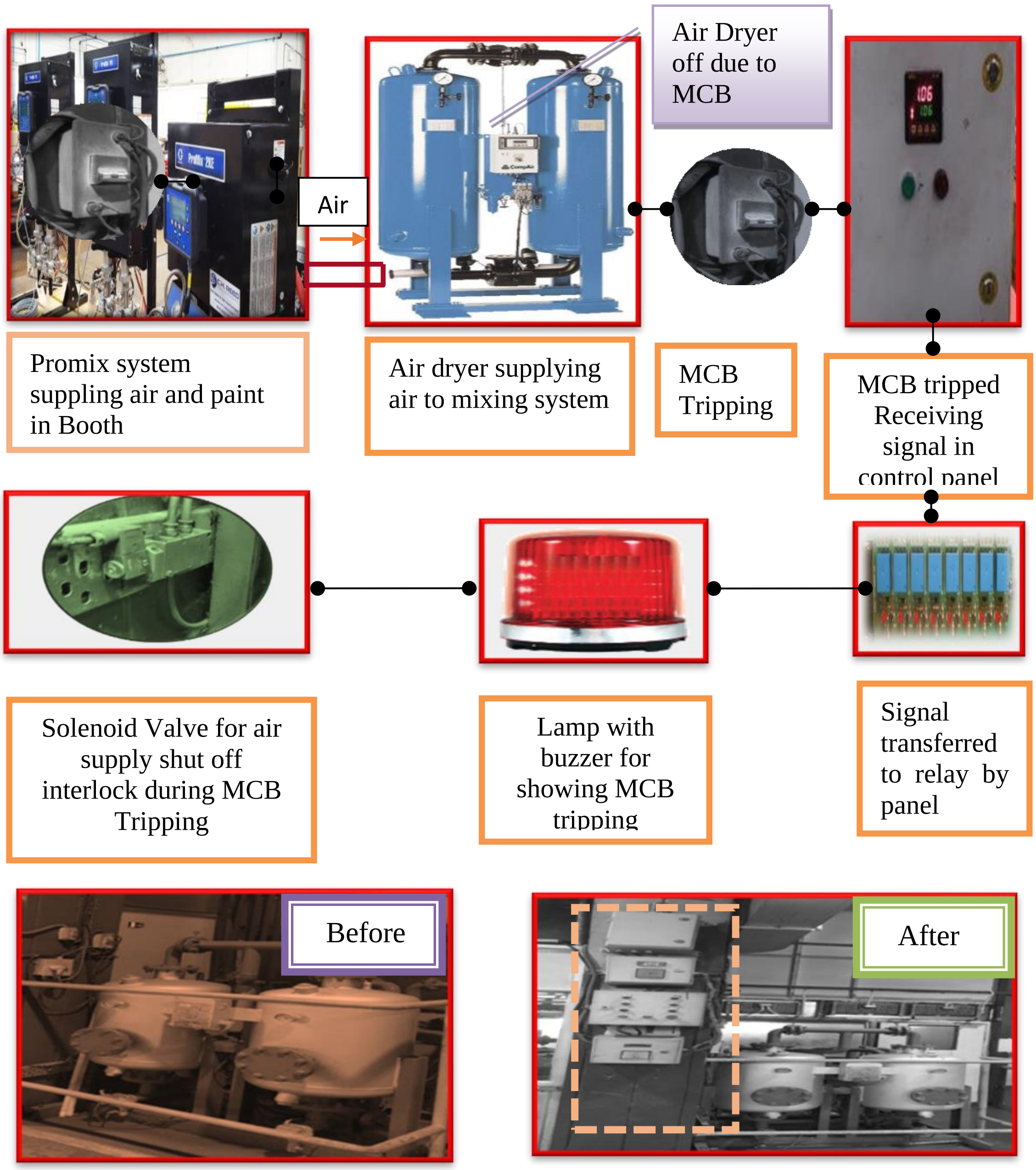


Figure 6.34— Implementation of Solution for Water Mark Problem

Regular trails were conducted and system found fool proof. This prevention improvement was standardized with unique number for future reference. As a result of this improvement, problems eliminated permanently. One-month card RPH data was zero for this defect. Chances of potential customer complaints also killed. Employees felt high morale and encouraged with this achievement. Cost associated with this project was only Rs 5000 /-, an associated benefit is tremendous including saving of Rs 2.56 L / Year as rework and rejection cost. Apart from this, all front-line workers and managerial staff were trained for QC steps problem solving techniques. As a consequence, 52 process related defects were solved by team members.

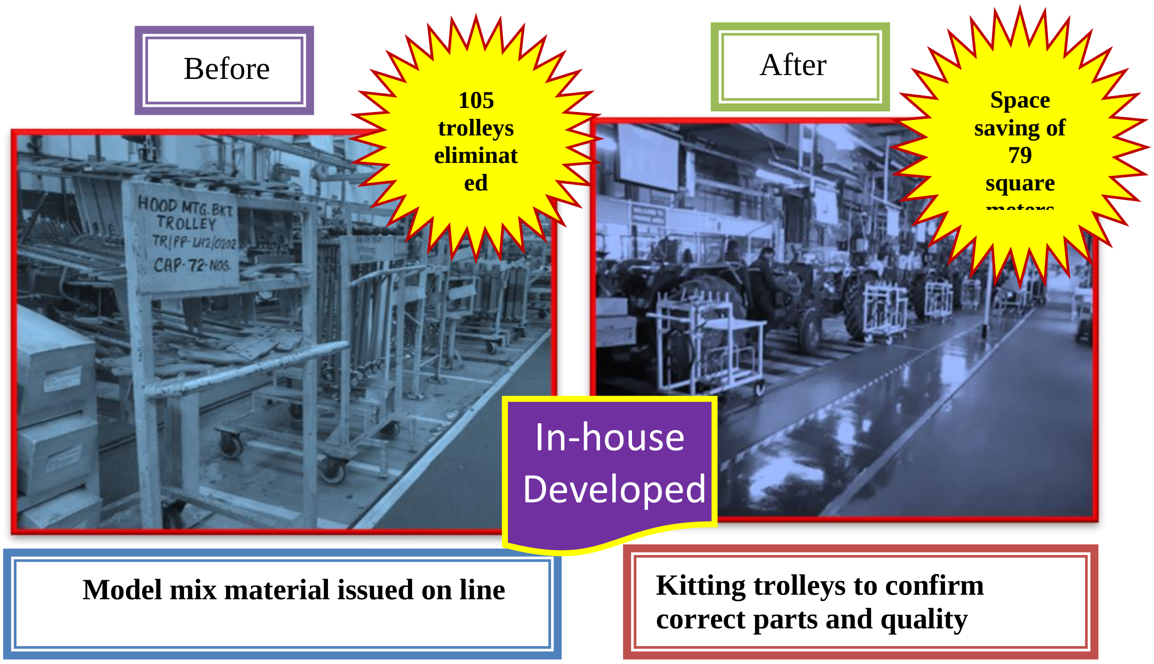
6.9.2.1 Improvements for Wrong Parts Fitment

Due to complexity of model-mix and variety of parts, wrong fitment was another concern along with space issue. Few of major wrong fitments along with other parts revealed from data, which were reported in house as well from customers.

- Wrong Tyre fitment as per make
- Wrong Sheet metal fitment
- Wrong DCAL fitment
- Wrong front Axle fitment

Therefore, simplification in processes was much needed for an improvement. For this, the following suggestions were proposed to Management and got approval, Figure 6.35.

- Implementation of kitting for reducing of parts.
- Process integration with bar codes for critical wrong fitments parts



Before

After

Chassis line kitting Trolley

Post Paint Kitting Trolley

Further, part selection automation for critical parts was done through simple PLC controlled kaizen for kitting trolleys material.

Before

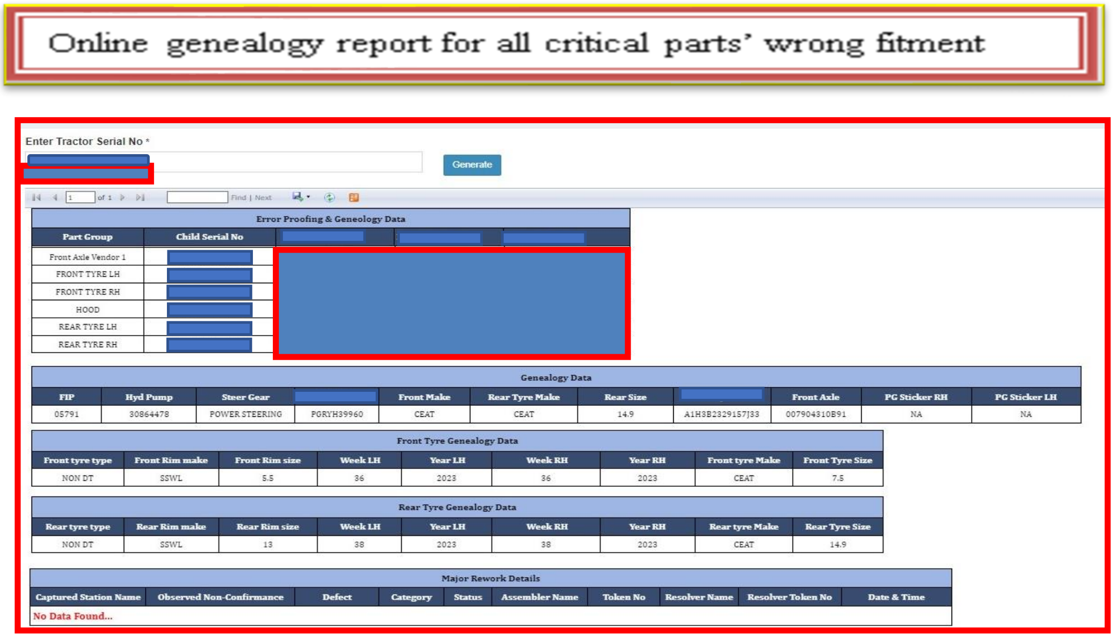
After

Manual process of checking kitting trolley after filling

PICK TO LIGHT system to select the right

Figure 6.35— Improvement Kaizens for Wrong Parts Fitments

For reducing the model information time at different locations, an approach for input in process and output-controlled through digitized solutions with line interlocking was adopted, which can be seen in history with tractor serial numbers for critical parts, resulting zero wrong fitment of critical parts


Online genealogy report for all critical parts' wrong fitment

Enter Tractor Serial No *

Generate

Error Proofing & Geneology Data				
Part Group	Child Serial No			
Front Axle Vendor 1				
FRONT TYRE LH				
FRONT TYRE RH				
HOOD				
REAR TYRE LH				
REAR TYRE RH				

Genealogy Data										
FIP	Hyd Pump	Steer Gear		Front Make	Rear Tyre Make	Rear Size		Front Axle	PG Sticker RH	PG Sticker LH
05791	30864478	POWER STEERING	PGRYH39960	CEAT	CEAT	14.9	A1H3B2329157J33	007904310B91	NA	NA

Front Tyre Genealogy Data								
Front tyre type	Front Rim make	Front Rim size	Week LH	Year LH	Week RH	Year RH	Front tyre Make	Front Tyre Size
NON DT	SSWL	5.5	36	2023	36	2023	CEAT	7.5

Rear Tyre Genealogy Data								
Rear tyre type	Rear Rim make	Rear Rim size	Week LH	Year LH	Week RH	Year RH	Rear tyre Make	Rear Tyre Size
NON DT	SSWL	13	38	2023	38	2023	CEAT	14.9

Major Rework Details									
Captured Station Name	Observed Non-Confirmance	Defect	Category	Status	Assembler Name	Token No	Resolver Name	Resolver Token No	Date & Time
No Data Found...									

Figure 6.35— Improvement Kaizens for Wrong Parts Fitments

With an application of various combination of approaches for quality improvements, there was considerable reduction in rework cost and enhanced product quality.

6.9.3 7'S Implementation for Poor Handling of Material

Post extensive discussion with section managers and senior management team, which accelerated to an idea for the advocacy of Five 'S' deployment in selected assembly line and associated store for curtailing the poor handing of material. In present study, Sustainability and Safety integrated with 5's methodology was employed for intensifying the ecological dynamism of an organisation. To frame consistent, safe and secured, cleaned, accidentally- free, eco-friendly shop floor, 7'S methodology was used in this present study in case organization. Apart from this, to have productive and neat clean working ecosystem, disciplined housekeeping at working area to get rid of dirt was also put in place. Figure 6.36, portray the before condition and after improved condition with implementation of 7's approach. The implementation of 7's technique helped in saving of around 200 mins in the operational activities of organization on daily-basis. To institute steady way of executing assignments regularly on daily basis inclusive sorting (Separating, which is not necessary for smooth flow), Set in orderly way and shining. Standardization builds the processes more prudent and rational to produce the things which are morally justified, upright and an apparent time. For placing the things at defined place and to encourage the front-line workers and staff, visual and pictorial process control approach were executed at shop. To make sure the successful implementation of 7's at shop floor, standard working operating procedures for uniformly and steadily monitoring of shop floor medical first aid box, amending ecological rules and keep posting on regular basis for green safe environment.

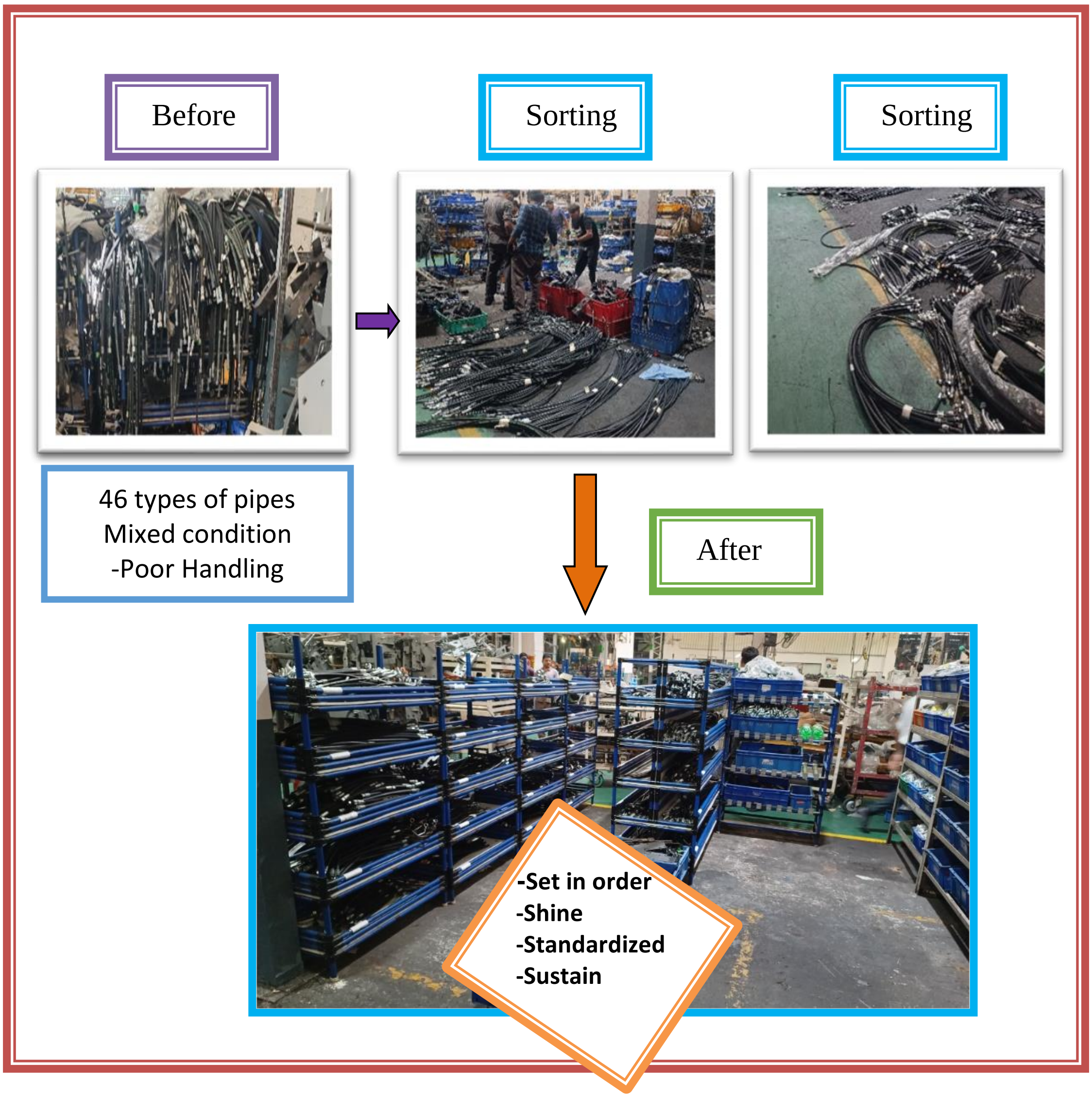
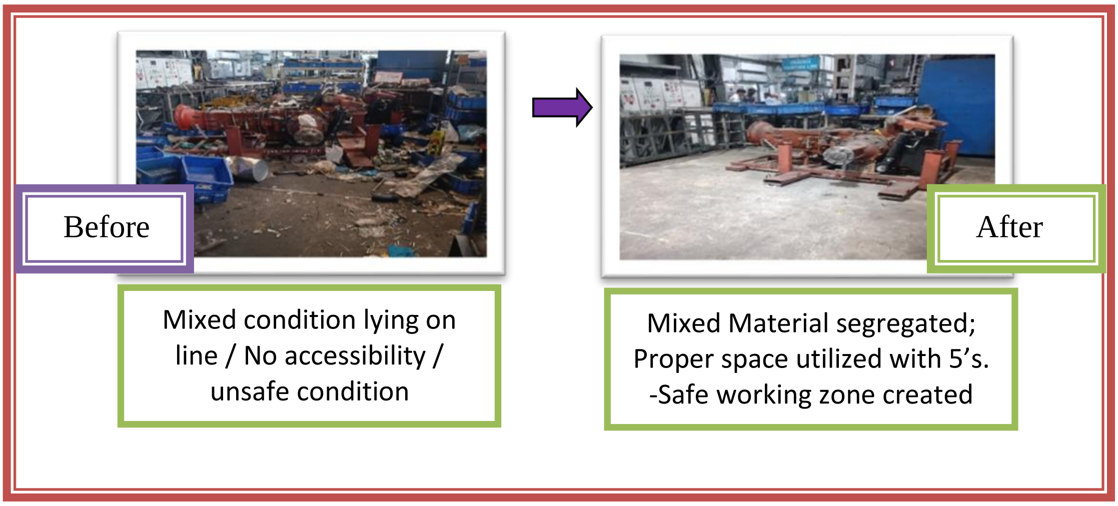


Figure 6.36— 5'S related Kaizens at shop With Before and After



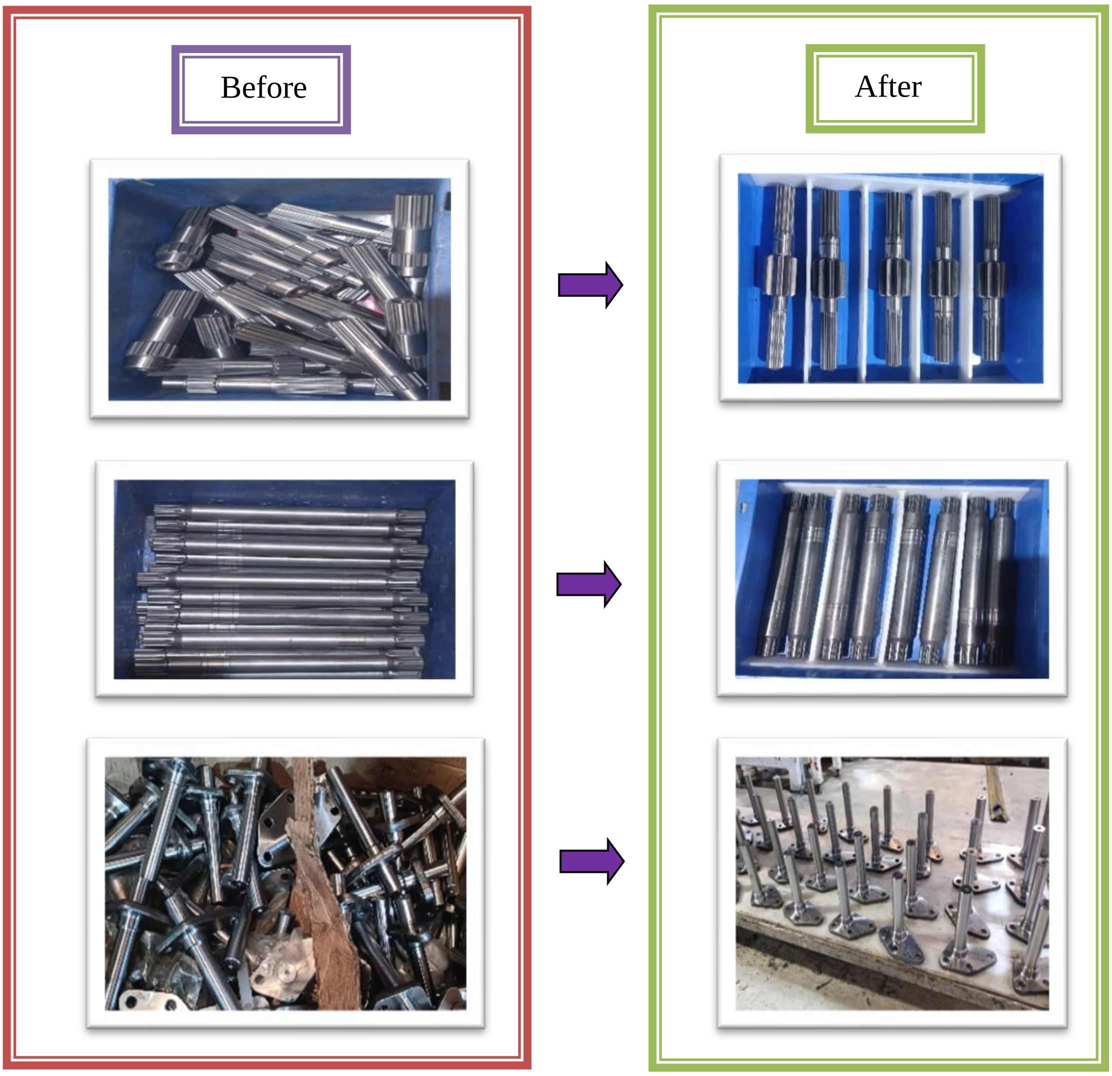


Figure 6.36— 5'S related Kaizens at shop with Before and After

To make sure safe working environment, check for potential accidents prone areas are identified and corrected. An audit check sheet of 7's was formulated in the form of questionnaire related to wastages and potential safety risk at shop. Responses were collected from manufacturing persons. Non–Favourable responses were reviewed for initiation of action plan. After execution of actions, it was ensured all responses be favourable. Conclusively, audit check sheet documentation was ready to display at shop floor. The 7's audit document helped the organization to connect its LG drive along with action taken for safe working and furnished pathway for consistent growth with green profitable business, as shown in Figure 6.37.

7'S Audit Check Sheet	Y (Yes)	N (No)
Sorting		
Are red tags are put on un-necessary items ?	Y	
Are red tags items are kept separately ?	Y	
Are segregated material being disposed as per defined procedures ?	Y	
Set-in-order		
Are the material placed in order and defined locations ?	Y	
Are the waste properly piled in container and secured in case of non-use ?	Y	
Shine		
Are there not any oil / air / water leakage from pipes and equipments?	Y	
Is shop floor being cleaned on regular basis ?	Y	
Is proper exhaust system available and working properly ?	Y	
Standardization		
Are SOP available for each process and followed strictly?	Y	
Are material kitting trollies and supplies are sync with each other ?	Y	
Sustain		
Are cell wise audit schedule being followed up?	Y	
Is 7's display board is updated in term KPI's and KAI's	Y	
Safety		
Is there no obstruction in aisle for safe movement of trolleys and forklifts ?	Y	
Are safety equipment like fire hydrants , fire extinguisher in place ?	Y	
Is first aid box available at floor with details of medicines ?	Y	
Sustainability		
Is there reduction in MUDA during process on continual basis ?	Y	
Are ecological rules and regulations being followed ?	Y	
Is there reward and recognition to employee for sustainable business ?	Y	

Figure 6.37— 7'S Audit Check Sheet

6.9.4 Intensification to Boost Sociable Dynamics

To preserve the position globally, gaining eminence in SHE (Safety, Health and Environment), employability, socially engaged must be part value formation strategic plan. From the analysis, it has been revealed that case plant creeping in the specification of employability and investment on community. Even so, case organisation exhibiting sociable sustainability up-to some extent, but to further enhanced the status quo to superior level, the organisation should incorporate some improvement plan for an employability and investment on community dimensions. An effectual sociable achievement in long-term navigate value formation strategic plan, case plant should infuse focus on sociable concerning under-profit organisation. An implied sociable outcome on an investment on community dimensions will steer cultivation of effective strategy, augmented human capital commitment, culture and business development for the selected plant. The education and training, up-gradation of skill level should be the focus area of case company under CSR activity (Corporate social responsibility). With these improvement action plan will aid to operational sectors to induct potential expertise from local regional community, thereby boosting sociable dynamism.

6.9.4.1 Mitigation in Environmental Footprints

The overall reduction in environmental footprints has been achieved through mitigation plan by the decrease in consumption pattern of water, electricity, fuel and packaging improvement. Table 6.24, displays the executed Green improvement actions for each ecological element to elevate Green stability of Case Industry.

Table 6.24— Recommended Actions for Sustainability

Elements	An applied improvement actions	Recommended actions
Water consumption	1) Modification in PT stages drains to avoid mixing at different stages. 2) Cascading water from tank 2 to tank 1 due to use of similar type of chemical in both tanks. 3) Cleaning frequency of Tank 1 and tank 2 has been changed from weekly to fortnightly due to incorporation of oil skimmer in tank 1. 4) DM water treatment plant , 50 micron filtration system has been incorporated along with existing 5 , 10 and 20 microns , 3 stages filtration units. 5.Exposed top area of water tank has been covered and insulation has been provided in tank to reduce heat loss. 6.Level indicator has been provided in all tanks with auto cut off to avoid overflowing.	Embrace and adopt accustomed actions for handling water and steam for reduction in consumption
Electricity and fuel consumption	1) Conventional blower has been replaced with EC motor blower 2) Identification and closure of dormant air points (34 points closed) 3)Replacement of high pressure air line into low pressure air lines used for cleaning purpose. 4) Installation of timer's circuit on assembly line industrial fan for switching of in tea and lunch timings 5) Application of Thermo ceramic coating in internal walls, nozzles and floor of oven	Integration of Power management and monitoring system for identification and improvement on wastes on energy

Improvement Kaizens related to Sustainability improvements in selected line of Case Industry are manifested in Figure 6.38 and Figure 6.39.

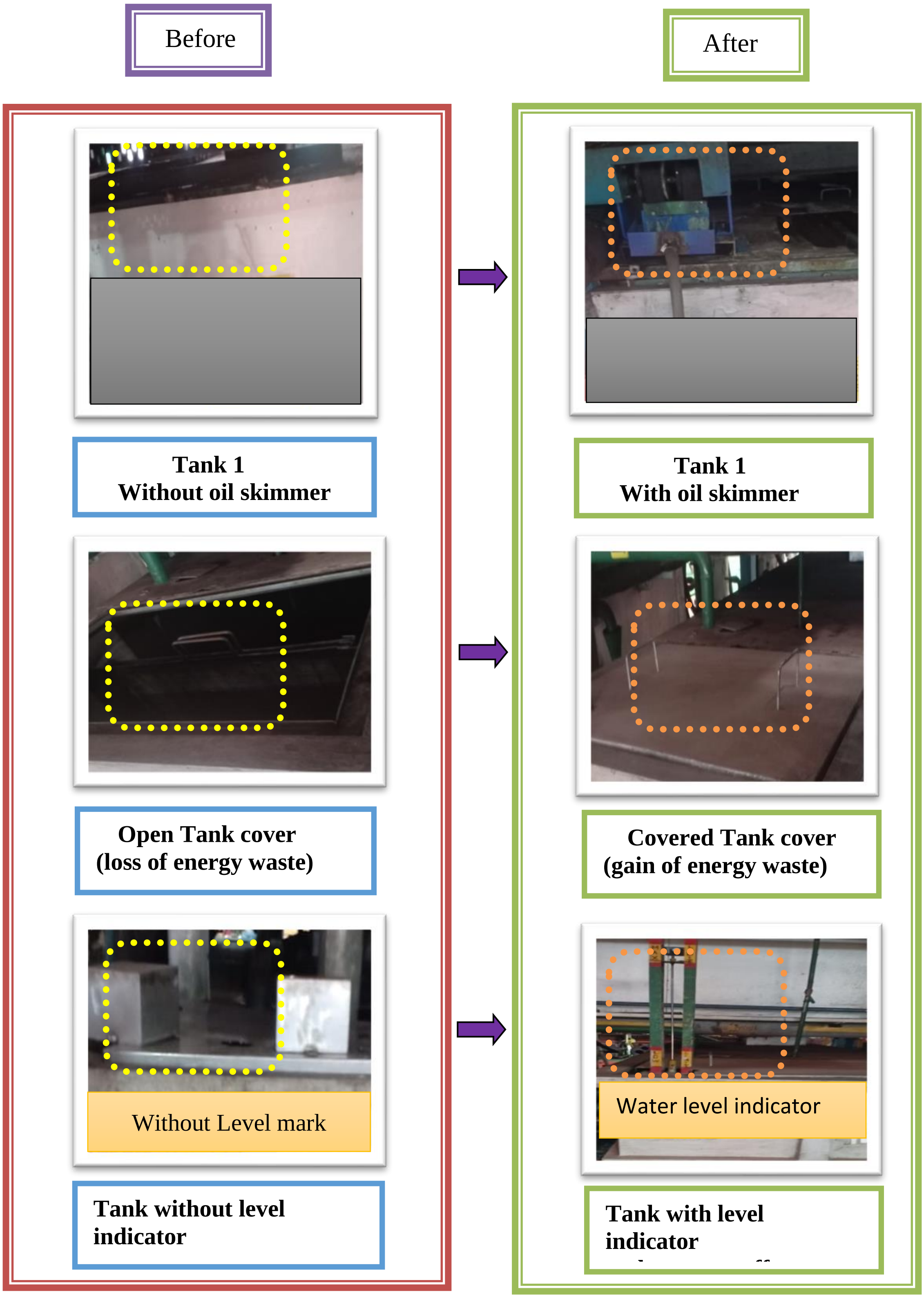


Figure 6.38— Water Consumption Reduction Kaizens

Apart from this, Figure 6.40, displays the improvements done to protect land contamination, consequently the reduction in ecological footprints / impacts.

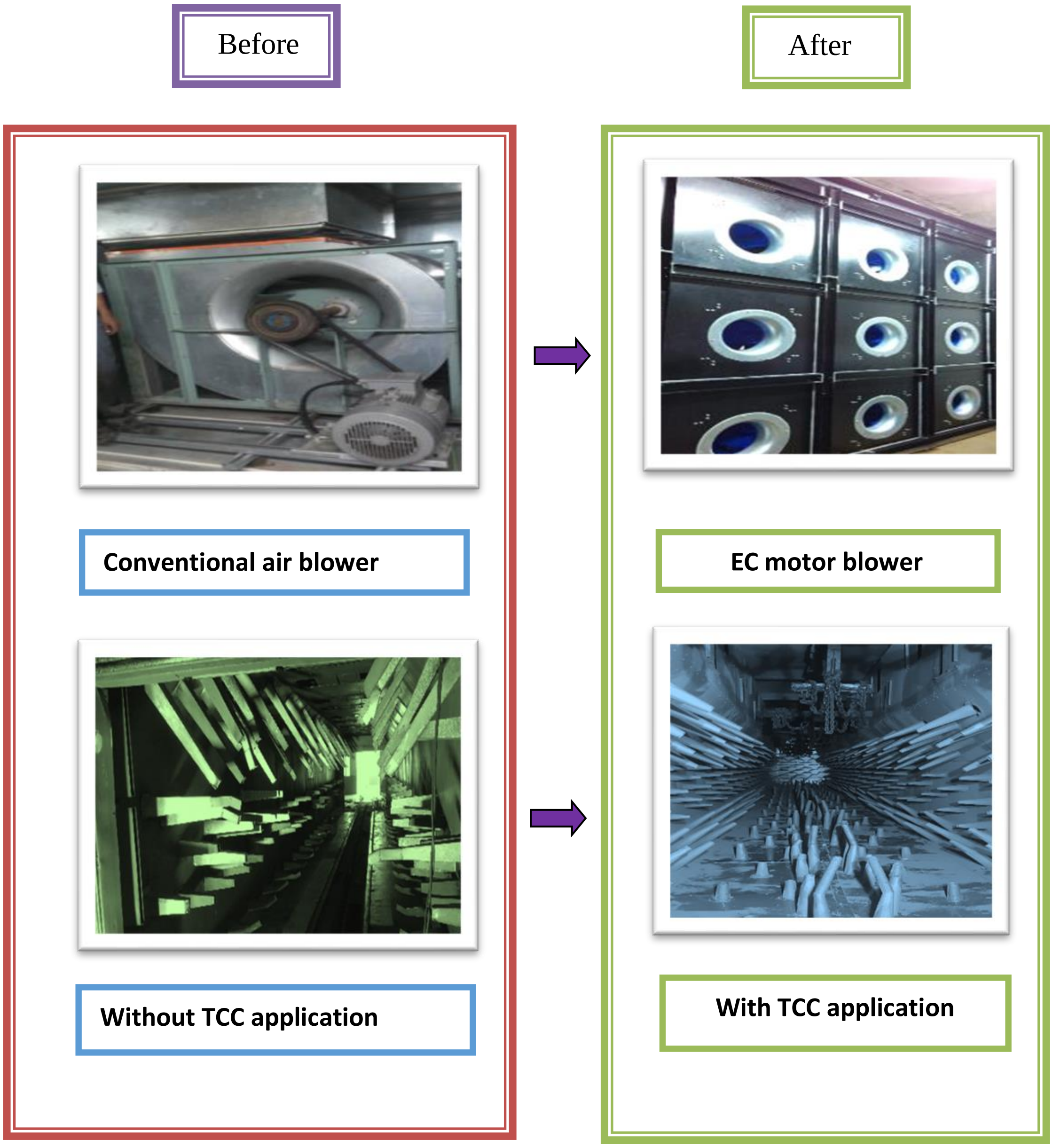


Figure 6.39— Power and Fuel Consumption Reduction Kaizens

Post execution electrical and fuel-saving kaizen, power and fuel consumption has been reduced from 25.75 kWh /tractor to 21.5 kWh / tractor. The overall power and fuel consumption reduction has led to significant reduction in manufacturing conversion cost of case company, resulted in reduction of overall product cost. The water decay was also reduced from 0.099 kl / tractor to 0.82 kl / Tractor due to various initiatives taken, mentioned in Table 6.25. After an execution of improvement kaizens, overall ecological impact was further noted and observed signification reduction from 163

$\mu g/_{m^3}$ to 98.2 $\mu g/_{m^3}$ .However, still there is a green improvement scope through reduction in consumption of material.

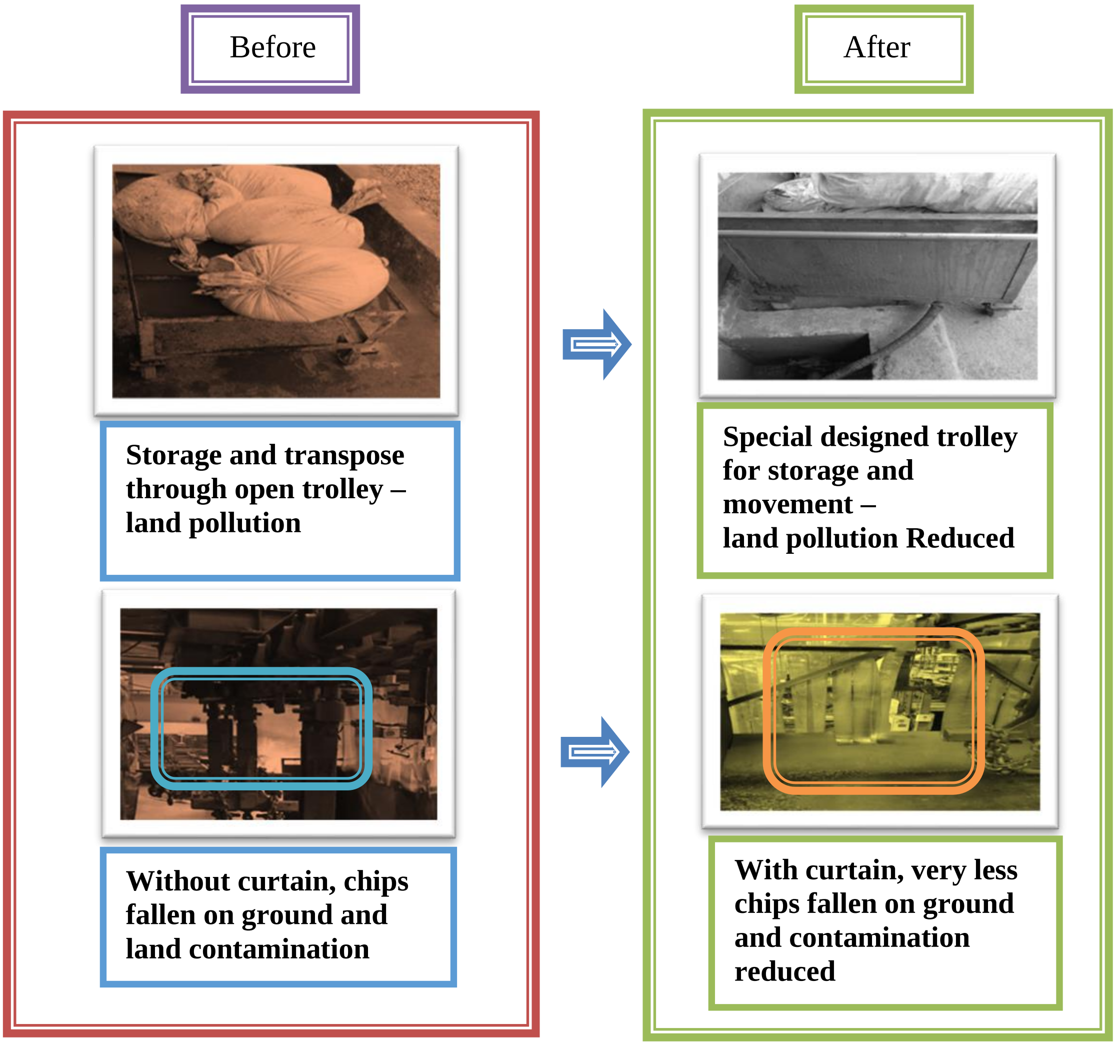


Figure 6.40 — Land Pollution Protection Kaizens

6.9.5 Layout Modification for Space Generation and NVA Movements

For smooth flow of material and men movement for ensuring effective sync. of all the processes, an effective layout of the facilities is required. Due to constraints of space, there was unnecessary movement in plant as layout was not appropriate. Due to excess movement of Tractors to another location for inspection was NVA for men and environmental impact as well. The proposed solutions have been implemented for space creation and challenge of NVA movements.

- Use of mezzanine in place of floor space wherever possible for electrical panels, equipment, storage areas and offices, refer Figure 6.41.

With these improvements, 855 square meter area has been generated for making valuable activities, such as tractors inspections in line with rolling of tractors. As a result of this, NVA movements has been reduced drastically, refer Figure 6.42.

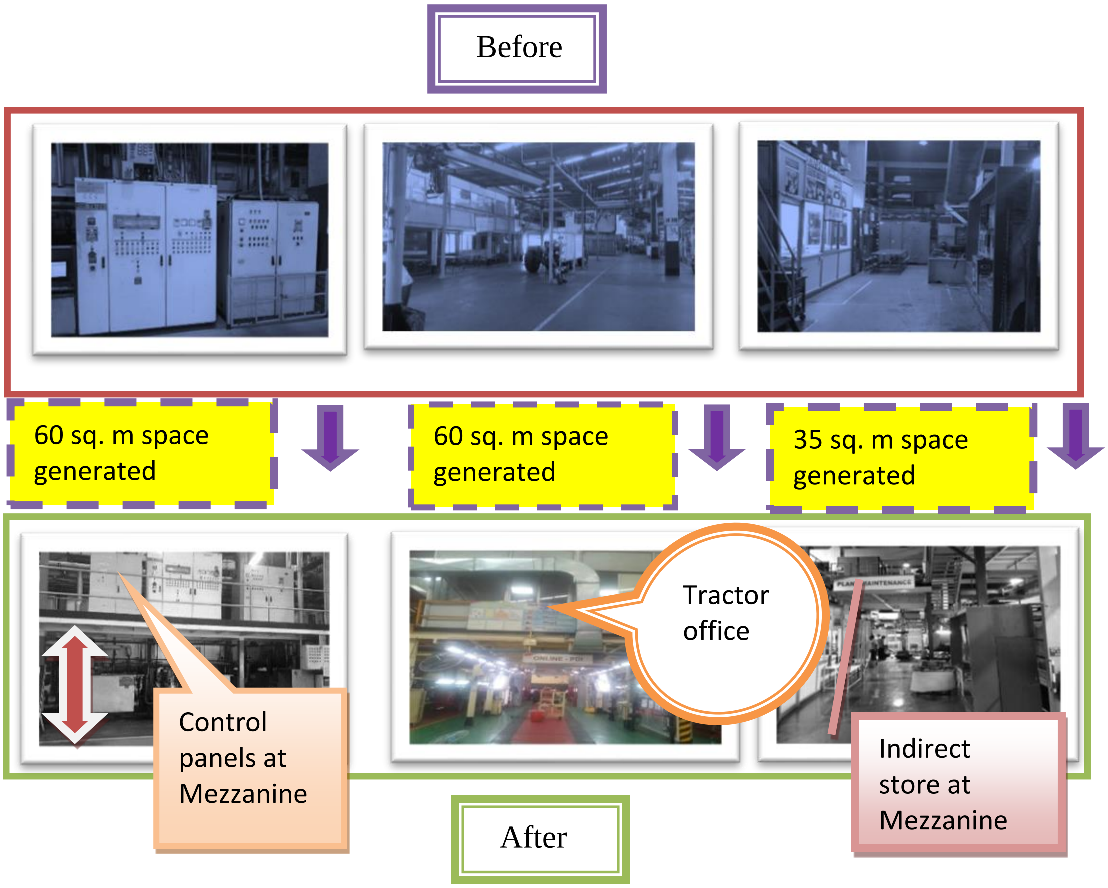


Figure 6.41— Space Generation through Innovative Kaizens

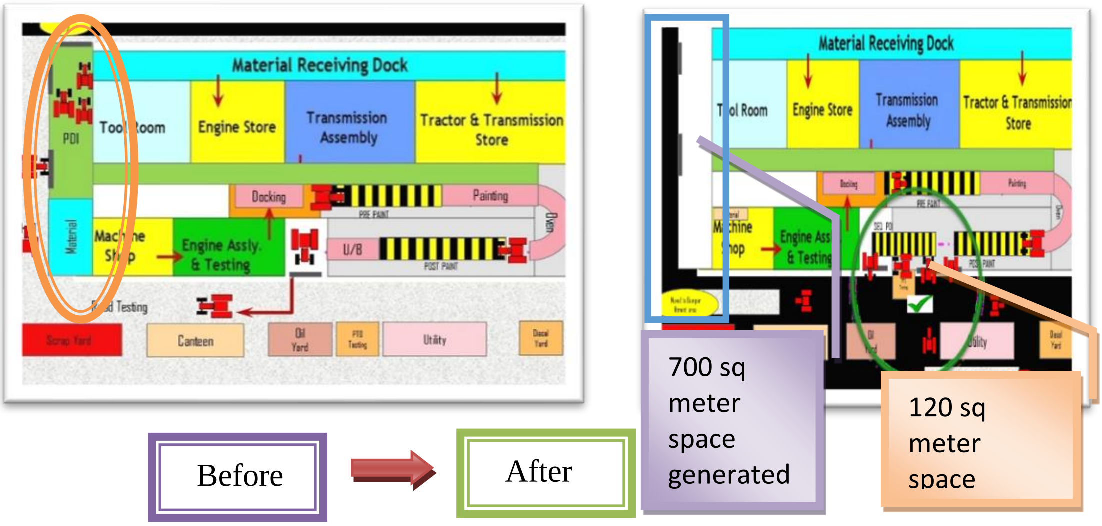


Figure 6.42—Space Generation through Re-Lay Outing at PDI Area

Apart from this, re-lay outing has been done at front axle are after reducing WIP inventory for space creation, elimination of high congestion and cross jig jag movements. Figure 6.43 displays the improvements done at dock area.

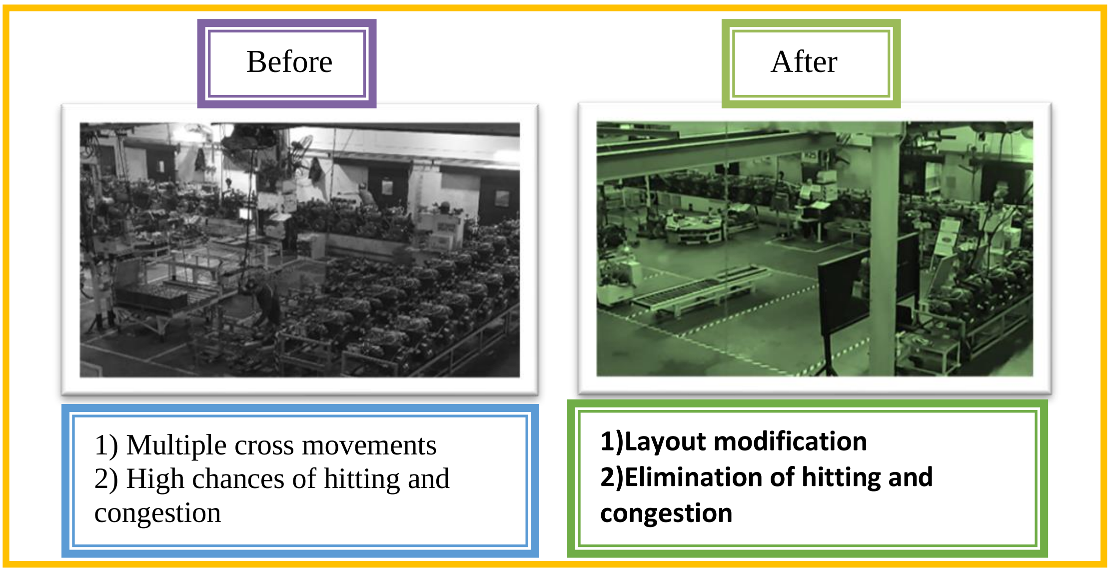


Figure 6.43— Space Generation through Re-Lay outing at Dock Area

The effective space utilization with these improvements along with removal of un-wanted material from shop resulted in an increase in overall efficiency of plant, safe and green working environment. This has also resulted in reducing MUDA of transportation and achievement of smooth work flow.

6.9.6 Control and Standardized the Implemented Best Solutions

In this section of LG implementation, all the improvement actions, which are made need to keep in record to control and standardized the improvement activities. At this stage, the improved and modified process is conveyed and transfer to the owner of the functional area, coupled with the thorough procedural approach for preserving achievements. This stage secures that achievements earned from the improvement activities are conserved and keep alive post-acquisition of this project. To begin with, it is vital to record and regularized the process for standardization to illustrate a real picture of the changes made and how to preserve the alterations. Various improvement activities and data were monitored for next three months to confirm the sustenance of action taken. Separate measures relate to LG Wastes, and quality faults were evaluated again to validate for any divergence from the improvements done. The achievements acquired from the implementation of the LG project are conveyed to all the associates entailed in the project along with defined roles and responsibilities to preserve improvements made. Grounded on the examination of the LGCVSM, kaizens were planned and executed to enhance the diverse process matrix of the case company. Post outstanding implementation of the suggested improvements, the LGFVSM was constructed as shown in Figure 6.44.

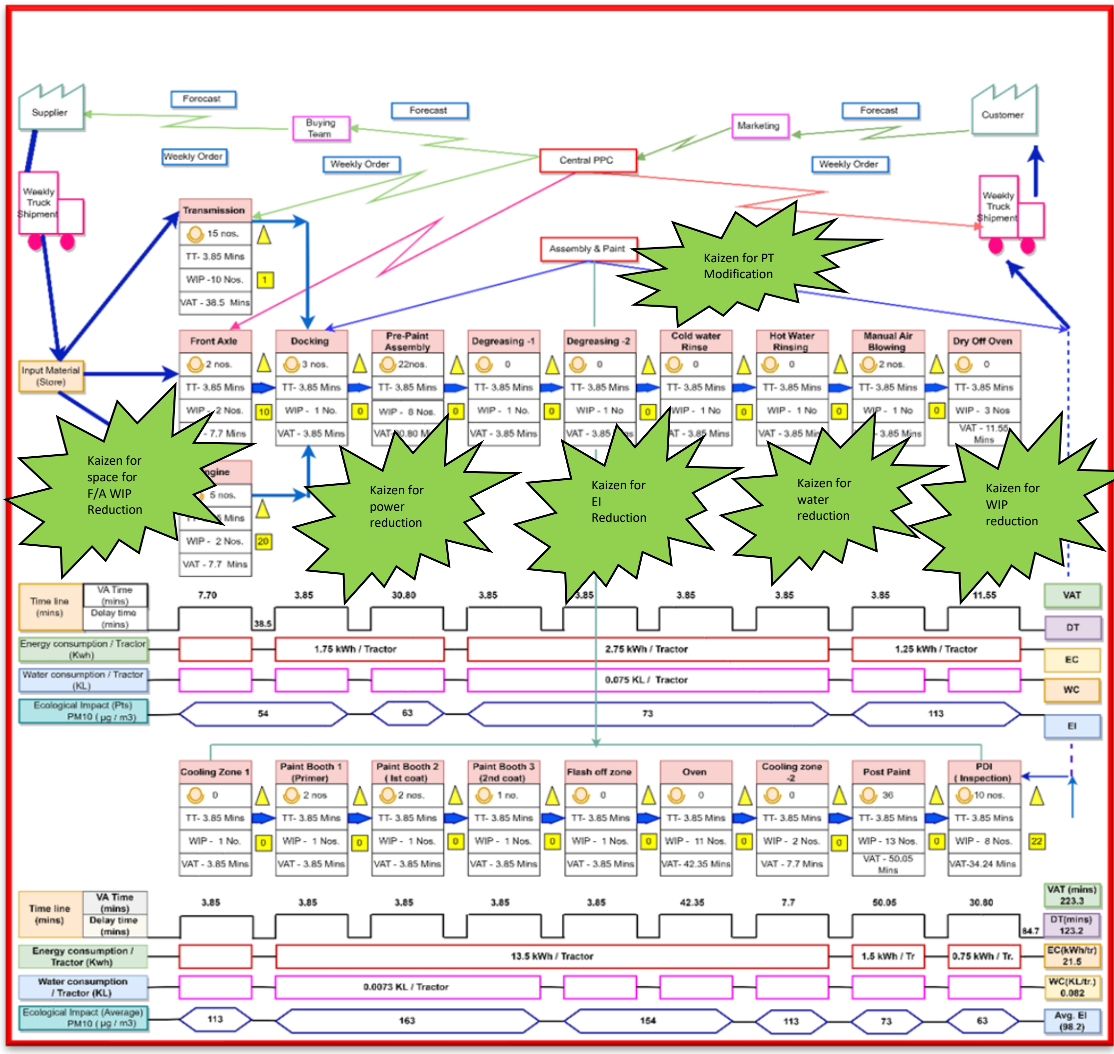


Figure 6.44— Lean Green Future state of Value stream Mapping (LGFVSM)

It is mandatory to impart adequate coaching to all the human resources associated in this improvement process to control and manage with these modifications done and preserve the acquired good improvement practices. In current study, Poka-Yoke, Visual controls and Audit check sheet have been made use to impart visual assistance, to control and mange vital input-output variables related to manufacturing operations and sustainable practices. This will enhance societal and LG performance of case company.

6.10 Results and Discussion

On practical implementation of the LG approach through initiated framework, the selected industry was in position to intensify its operational performance and eco-friendly viability. Improvements were appraised in the operating processes and environmental conditions by implementation of suggested LG framework. The magnification observed in Lean estimates such as TAKT time and Operation Lead-time. The structured and well organised 7'S methodology, creation of space through modification in Layouts, fostering Kaizens culture and Pre-Treatment area modification resulted in a reduction of the TAKT time from 4.28 minutes to 3.85 minutes (11.20%), which in turn production per day on 2 shifts basis has increased from 228 to 240 per day (5.26%). Apart from this, operational process lead time was also reduced by 45.75%, which benefits in a considerable saving in waiting period of delivery of final product. Value Added ratio (VAR) has increased from 49 % to 64%. Traveller card RPH was reduced to 50 %. Rework on Tractors was reduced to 50%. Table 6.25, display the process related parameters before and after the implementation

Table 6.25— Critical LG Process Parameters Results (LGKPIs)

Critical process elements	Before implementation	Post Implementation	% Gain
TAKT Time (Mins)	4.28	3.85	11.20 ▽
Lead Time (mins)	505.04	346.5	45.75 ▽
Value added Ratio (%)	49	64	14.7 △
Production / day (Nos)	228	240	5.26 △
Water consumption (Kl / Tractor)	0.099	0.082	21% ▽
Energy Consumption (kWh / Tractor)	25.75	21.5	19.76 ▽
Ecological Impact (ug/m3)	163	98.2	66 ▽

of LG project in the selected plant. The exercised elevated activities yield intensification in the ecological factors like consumption of water, consumption of power, and overall sustainability footprints. Power consumption, and water consumption were reduced by 19.76% and 21% respectively. As there is a reduction in the leading resource depletion, a decrease in overall ecological impacts was also noticed. An improvement in ecological impacts were recorded by 66%. Furthermore, with an improvement activity during LG framework execution case company was case company was able to reduce cost of poor quality by approx.50 %. As a result of this, there is possible financial gain of $64320 for reduction in rework cost / annum, Table 6.26.

Table 6.26— Rework Reduction and Gain post Improvements

Particulars	Before Implementation	After Implementation
Total Nos of tractors produced / Three months	14775	16416
No of tractors reworked in three months	1625	821
Rework cost / tractor (2 manpower deployed) $	20	20
Total Rework cost in one qtr. (US dollars) $	32500	16420
Cost of poor Quality (US dollars) Annually $	130000	65680
Potential saving in COPQ after implementation of project $	**$ 64320**	

The case organisation accomplished substantial benefits in terms of Lean Manufacturing Parameters, Green Measures through the successful implementation of the LG project. This signifies the adeptness of the suggested LG framework to mitigate the global challenges of the manufacturing operational industries.

Operational organisations are one of the foremost promotors of waste and advocator of ecological contaminations, causing a risk to ecological sustainability. Community and eco-friendly issues have forced organizations, mainly manufacturing organizations, to link up sustainability development goals. Inflexible government policy on atmospheric conditions for manufacturing companies in progressing nations like India has been steer to the development of strategies like Zero defect and Zero effect to reduce GHGs. From the lens of new environmental strategies and policies for operations, manufacturing companies need to re-evaluate operational processes and estimation of ecological and related wastes. Therefore, to deal with ecological challenges, manufacturing organizations require valuable evaluation, an analysis of various waste/ carbon emissions. LG is ecological approach that inscribe latest challenges of operations, impart productive estimation, investigation of wastes, carbon footprints and institutes estimate to manage and decrease the same.

The LG strategy and its significance are boosting persistently due to its pragmatic outcomes on quality decisive ecological influence, and the societal features of ecology. Combined LG approach makes a company more competing in long period of time globally through delivery of elevated parameters and sustainable products in market-place. But this combined approach calls substantial tracking to recognize definitive tools and related framework to appreciate this ecological approach. The key challenge for organisations, that prefer to submerge sustainable technology within Lean manufacturing is an inadequacy of an exclusive framework that impart complete direction to logically eliminate lean-wastes, quality-defects, carbon footprints and leads to manufacturing excellence. Inherently, previous work has attentive on hypothetically frameworks, but these have inadequacy of factual justification and inventive validation. Therefore, past work dictates the research for the LG framework that is generic in nature, applied in a discrete context, and an encompass all facet of ecology. In addition, there is a high chances of execution failure of ecological LG frameworks in diverse projects. Therefore, to commit to the operation literature by bridging the aforesaid gaps, this study bloomed a LG framework as a unique action. The current research study imparts an inclusive framework of LG along with use of various tools that are executed at various stages of the implementation of the LG strategic plan. The suggested framework can be used as a pilot project for the fulfilment of LG in other lines of the plant for more gains.

6.11 Managerial Implications

The LG framework which is presumed in the current research work will inspire the industrial manufacturing sectors to carry out the LG approach within the company in a practical way. The proposed LG framework exercised with each step have been demarcated in such a way that it helps to the well-regulated step by step series of actions to inscribe both operational and sustainable concerns. In the course of execution of the LG framework, the organisations must be attentive on the prevailing culture of the company in the direction of eco-friendly measures. The companies may make use of the LGVSM to extract the complete process in the estimated value viably. A training and education discussion about LG implementation are also be in need for front level workers and officers, so that they become involved in LG execution with full passion and consciousness. Therefore, the present work's distinctive contribution lies in an encouraging manufacturing sector to determine various operational, ecological, and community measures and disburse strategy to increase and sustain the competitive advantages of organization against the competitors.

6.12 Inferences Drawn

The advancement to environmental performances should be integrated with the traditional organisational drives to improve measures like Process productiveness, customer delight, an effective utilization of resources, fostering health of employees, security and safety. LG framework in this research work consists of combined two directional approach, one is ecological and other is community, which directs towards waste reduction. The benefits of present study have double-barrelled. First, LG framework has been recommended to control implementation actions of this strategy. The introduced framework furnishes a hope to operational sectors to improve Green waste, improvement in production, handling of parts together with elevation of societal sensitivity by the use of tools like LGVSM, Kaizens etc. Second, this study presents the factual benefits of LG framework by its practical execution in a manufacturing environment by the use of Lean and Green tools. Practical implementation of proposed framework helped for reduction in defects and rework level, ecological wastes, altogether, gain in operational and financial parameters. The effective execution of 7's approach , Kaizens , space generations , infrastructure modification with least cost resulted in reduction TAKT time from 4.28 mins to 3.85 mins (11.20%) , lead time reduction from 505.04 mins to 346.5 mins (45.75%), improvement in VAR from 49 % to 65 % (14.7%) , Production / day increased from 228 tractors / day to 240 tractors/ day (5.26%) , water consumption has been reduced by 21 % , energy consumption has been reduced by 19.76% and overall environmental impact has been reduced by 66 %. Tractor rework has been reduced by 50 %, resulting potential saving of 64320 $ per year. Apart from this overall operational cost has been reduced by 10 % (Rs 6000 / equivalent tractor to Rs 5400 /equivalent tractor) by effective implementation of LG framework. This LG framework also had a positive impact on the sociable signification as improvements were distinguished related to environment.

CHAPTER-7

CONCLUSION AND SCOPE FOR FUTURE RESEARCH

This chapter represents the conclusions extracted from this research study. Additionally, this chapter also proposes the scope for future research work for the potential researchers, professionals, and managers from Industry

7.1 Conclusion

The existing research study examined the competence of LG Manufacturing Strategies to minimize resource wastes, inclusive of environmental emissions, enhance financial and social perspectives of sustainability for Indian Tractor manufacturing industry. Literature had significant evidence of LG in Indian context. Therefore, the research study focused on finding the research gap in terms of LG application in Indian Tractor industry. On the basis of research gap, four objectives were suggested in this research study to enable the LG adoption realistically in India. This research encompasses hybrid approach that includes a questionnaire survey, inputs from professional and experts, and brainstorming sessions with the employees of the case industry to assist LG execution in Indian Tractor Industry. After successfully executing the LG approach in the selected Plant, the following inferences are drawn from the existing research study.

- To meet the environmental regulations and perceived quality by customer, an essential need before the industries to realize the characteristics and inter-connection of Lean Green SFs. Investigation and prioritization of SFs associated with LG execution in Indian Tractor Industry are essentials for smoothly initiation of the LG program. Twenty-Two LGSFs relating to Lean Green approach have established essentials, to be modelled, and investigated by using an advanced MCDM approach, such as ISM and MICMAC adopted. Modelling of LGSFs facilitates the organizational managers to realize the mutual relationships and inter-linkage of various SFs and that will almost result in successfully implementation of LG program.
- In progressive countries like India, the execution of LG program in the manufacturing operational environment is bit tough due to lack of technological substitution and reluctant to accept any new initiatives within an organization.
- Keeping this in mind, screening of LG success factors in the manufacturing operational environment and thereafter grouping these factors in an analytical

way, so that companies may pay focused attention for highly-grouped success factors at the very primary stage of the LG implementation. The Tractor manufacturing sector during the first stage of implementation must give highly focus on these SFs and in due course of time, shift focus to other SFs. ISM model represents that administrative active participation, resource adequacy, structured training module and leadership potential are the most critical SFs and needs to focus at upmost priority. Besides, MICMAC investigation splits the LGSFs into four clusters according to their driving power and dependency. The MICMAC results manifest that, out of 22 LGSFs, 9 dependent, 9 independent, 4 existing linkage, and 0 autonomous success factors are persisting. These results give clear mind-set to industrial manager for paying more focus on LG success factors with higher driving power and lower dependency.

- Identification of critical barriers of LG execution in Tractor manufacturing industry is vitally important for successful initiation of this program. Based on inputs from experts and support from literature, 19 LGBs are identified and further 15 LGBs are screened using statistical investigation. Apart from this, 11 LGSPs are identified and 9 LGSPs are screened using statistical investigation. With the inputs from Industrial and academic experts, Pair wise comparison matrix was established for sustainable parameters using AHP, a MCDM approach. Further, Weight of each criterion along with ranking and consistency ratio was calculated, which is less than 0.1. So, matrix is reasonably correct. Further, using the calculated weights in AHP approach, ranking of LGBs was done using another MCDM approach, such as ELECTRE was adopted [352]. Finally, 'Inadequacy of practiced manpower', is identified the most significant barrier in the path of obtaining LG program in case industry. For an implementation of LG approach at first level successfully, skilled manpower is required. Subsequently, organizations managers need to focus on next LGBs with clear mind-set according to their ranking obtained during this study.
- Organizations should realize essential factors and execution methods of LG approach to meet customer demand, which are sustainable oriented. The synergy of the LG has been demonstrated based on theoretical factors: critical success factors, barriers, set of tools and inputs from experts. The SFs energizes integration of LG approach, and barriers serve as an obstacle in the integration of LG. The related tools and methods of implementation boost the synergy of

the LG approach. Besides, to implement LG in an industrial organization, a novel framework has been suggested in this study. The suggested 5 phased framework, presents a structured and methodical path for LG implementation starting from project selection for assessing the improvement of the system under consideration. The step-by-step framework augmented with LG tools that enable and encourage the industrial managers to implement this sustainable approach in their industry.

- The optimal LG project selection at the selected plant is done using BWM approach with seven main criteria and 30 associated sub-criteria. The inputs from industry and academic professionals were taken for selection of criteria and sub criteria of LG approach. This approach evident that out of five available sections in plant, the Tractor assembly section ranked top amongst all and considered as pilot project for an improvement activity. Initially, using SIPOC, Process Flow Diagram of Tractor assembly was done for process mapping to identify operational wastes in processes.
- The waste data revealed during process mapping as, 38% poor handing of material, 25 % unnecessary man movements, 19 % ecological and societal concerns,11 % rework due to defects, missing and wrong parts fitments resulting 20 % production waste in gross output along with societal issues.
- In next phase, using GVSM, data was collected for current state of the project in terms of Lean Green KPIs. Data reveals, TT 4.28 mins, LT 505.04 mins, VAT 248.24 mins, Water consumption 0.1kl /tractor, Power consumption 25.75 kWh / tractor and ecological effect 163 $\mu g/m^3$.
- In next root cause analysis phase of wastes and inefficiencies, the possible reasons are explored using LG tools, such as cause and effect diagram and 5 whys. The results manifest that the critical issues are space, undedicated bins / recks and poor storage of material, large varieties of parts along with un-organized system and controls and flaw in layouts. These issues are resolved using LG tools such as 5's along with more 2's (safety and sustainability) and kaizens as an improvement plan.
- From the improvement execution plan, it was motivation to note that the implementation of suggested solutions had a positive impact on the key performance indicators like TT reduction (11.20 %), LT reduction (45.75%), production / day increased (5.26%) with respect to gross output, unnecessary

movement reduced (63%),water consumption reduction (21%), Power consumption reduction (19.76%), ecological impact reduction (66%) along with tangible benefits of $64320 as potential saving in reduction of cost of poor quality after successful implementation of framework. The successful execution of LG approach increased confidence amongst team members and employees along with top management to work with more dedication and passionately. Moreover, the intangible gains like, the level of customer satisfaction increased by receiving the product with expected quality along with a green-effect and on-scheduled delivery. Apart from this, increase in employees' participation, positive outlook in employees' behavior and attitude which stepped forward for bringing cultural change in the case organization. Further, LG approach enhanced user experience and contributed to the organization strategy with increased compliance in case organization. This research study facilitated the industry to acknowledge its current intensity of sustainability impacts and empowered to strategize further on reducing emissions and wastes by adaptation of more green technological measures. The current research study presents to the environmental balance and well-being of man-kind by reducing emission, wastes, and defects through systematically deployment of the suggested LG framework.

7.2 Scope for Future Research

The work presented in this thesis reveals that the limitations of Lean and Green as an individual approach can be tackled by integrating them under the umbrella of Lean Green. This work shows success factors, barriers, integration, and framework of LG to improve all perspective of sustainability in the case industry. The outcomes of the current research study can be supplemented in future by potential researchers, professions and academicians etc. The scope for future research of the current study are as follows:

- The current study examined the success factors of LG approach based on input from experts' and the suggested ISM based model of LGSFs has been assessed analytically and practically using SEM, also validated within manufacturing industry, which reveals its robustness. However, direction for future work as model can be further tested through other MCDM approaches like BWM for prioritization of success factors and can be validated through AHP and ANP.
- In the selected Tractor industry for case study, there are other departments also

exists like Transmission, Engine, Hydraulics, Machining areas etc. The LG strategic approach can be implemented at these sections also to improve overall competitive priorities in term of PDCQSME in broader sense in the case organization.

- In the current study, 26 SFs considered and further screened 22 SFs of LG for Tractor manufacturing sector, but still, it cannot be assumed that no other than these success factors affect the effective execution of LG approach. Therefore, coming prospective researchers may search more SFs of LG, and can also propose success factors based on LG framework. Furthermore, this research study spotlights on the Tractor manufacturing industry and the outcome of this study may differ from industry to industry. The current work can be researched further in the view of other industrial sectors like academics, health system, tour and travels, food-processing, information and communication, construction, fabrics, etc., other public and service sectors.
- Future research work could pay attention on wide-ranging application of the suggested framework in diversified industrial organizations for further testing of the framework. The developed and executed framework is only limited to the tractor manufacturing environment. In future, investigators can enlarge framework with further moderation in the steps, tools and techniques to other sectors. Future research work may also reflect on measures to synergize mechanism and model with the proposed framework for enhanced effective utilization of employee, customer and transporter involvement, etc. to part with and quantify noteworthy improvements. In immediate future, researchers and professionals may investigate other options to integrate measures and tools for better management of labor force, better process control/monitoring employee wellness. Moreover, the researchers and professionals in future can pay attention on dark areas in the development of Lean Green approach like, an assessment of impact of integrated Lean Green approach and Industry 4.0 /5.0 in circular economy for reduction of waste in manufacturing organizations. Future research can also pay attention on the role of Lean Green for sustainability improvement through digitization, modelling and analysis of success factors and barriers pertain to integrated Lean Green and industry 4.0 /5.0, Block Chain Technology and AI approaches.

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PUBLICATIONS

1) Arora, A., Singh, M., & Singh, V. K. (2023). Empirical analysis of success factors to implement lean-green practices in an Indian automotive manufacturing industry using ISM-MICMAC approach. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 1-16. (Indexing: ESCI, Impact Factor: 2.1) ***(Published)***

2) Arora, A., Singh, V. K., & Singh, M. (2023). An analysis of hurdles for ecofriendly lean production in Indian manufacturing industries using AHP–ELECTRE approach. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 1-16. (Indexing: ESCI, Impact Factor: 2.1) ***(Published)***

3) Arora, A., Singh, V. K., & Rathi, R. (2023). Sustainable Lean and Green Manufacturing: An Empirical Review of Their Strategies. *Advances in Functional and Smart Materials*, 1-11. (Lecture Notes in Mechanical Engineering, Scopus Indexed Book series, Oline ISBN 978-981-19-4147-4, Publisher: Springer, Singapore, *https://doi.org/10.1007/978-981-19-4147-4_1* , Impact Factor: 0.46 ,ISNN: 21954356, 21954364, SJR rank: 0.160) ***(Published)***

4) Arora, A., & Singh, V. K. (2022). Future of Indian Manufacturing: Lean and Green Manufacturing System (LGMS). In *Advances in Functional and Smart Materials: Select Proceedings of ICFMMP 2021* (pp. 225-233). Singapore: Springer Nature Singapore. (Lecture Notes in Mechanical Engineering, Scopus Indexed Book series, Oline ISBN 978-981-19-4147-4, Publisher: Springer, Singapore, *https://doi.org/10.1007/978-981-19-4147-4_1* , Impact Factor: 0.46, ISNN: 21954356, 21954364, SJR rank: 0.160) ***(Published)***

5) Arora A., Singh M., Singh Jai I., Singh V. K., (2023). Lean understanding and prospects for lean fulfilment: An applied investigation in context of Indian automotive sector, Opsearch, Springer publisher. ESCI, Impact Factor: 1.6. ***(Under Review)***

APPENDIX -A

Publication Details

International Journal on Interactive Design and Manufacturing (IJIDeM)
https://doi.org/10.1007/s12008-023-01472-9

ORIGINAL PAPER

Empirical analysis of success factors to implement lean-green practices in an Indian automotive manufacturing industry using ISM-MICMAC approach

Arun Arora[1] · **Mahipal Singh**[1] · **Vijay Kumar Singh**[1]

Received: 13 May 2023 / Accepted: 10 July 2023

Abstract

The present study aims to explore the key success factors (KSFs) of lean-green (LG) practices and establishing an association between them in context of Indian automotive industry. Twenty–Six KSFs of LG practices are identified through comprehensive literature reviews and screened them using statistical analysis. During screening of KSFs, the expert's input was collected through questionnaire survey and analyzed it using Importance-Index and CIMTC method. The statistical result reveals that twenty–two KSFs are found the most significant out of twenty–six KSFs. Also, the consistency of statistical output was checked through reliability analysis and observed that screened KSFs are reliable and consistent with Cronbach's alpha of 0.870. Further, the mutual interaction among finalized KSFs is observed using Interpretive Structural Modelling (ISM) and clustering them into four quadrant (dependent, independent, linkage, autonomous) using MICMAC analysis. The ISM model reveals that the KSFs of LG practices are administrative active participation, Resource Adequacy, Structured Training module, Tactical intelligence. Moreover, in MICMAC analysis, the finalized KSFs are clustered into four quadrants as per their driving and dependence power. The result of this study facilitates to industrial managers and practitioners of tractor industries to adopt LG practices in their running system efficiently. The managers of automotive industry can pay attention on those KSFs which lies at the bottom level in the ISM model.

Keywords Lean · Green manufacturing · Success factor · Manufacturing industry · Interpretive structural modelling · MICMAC

1 Introduction

In today's competitive atmosphere, to redeem and satisfy customer obligations is a notable challenge under the nose of business units. Featured product at the minimal possible cost with scheduled delivery is paramount desire of today's consumers [1]. Therefore, to enhance overall productivity, quality of products produced with cost effective manufacturing, organizations are attempting to embrace quality tools and techniques in their manufacturing set ups. Hence, in an industry of any kind, quality and productivity with design thinking play a remarkable personification. The organization's ability to vow the high-quality product at economical charge is a guarantee for generation of cash flow and wealth of entire organization [2]. In the magnification of build economy of country, manufacturing industries pen down vital contribution in operational task [3, 4]. Lean postulate a positional contribution at minimal value of all these kinds of junks in the form of wastages in the opinion of Toyota [5] [6]. Lean speaks to deal with get rid of activities which are not adding value in value stream [7, 8]. Apart from this, very importantly as process owner approach to focus and put efforts for zero defects in the processes [9] So, organizations and start up units needs to infuse and design their setups that not only help to reduce wastes in the processes but also reduction in process variations for cost effective operations, gain upper

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Published online: 26 August 2023

Springer

International Journal on Interactive Design and Manufacturing (IJIDeM)
https://doi.org/10.1007/s12008-023-01470-x

ORIGINAL PAPER

An analysis of hurdles for ecofriendly lean production in Indian manufacturing industries using AHP–ELECTRE approach

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Received: 21 April 2023 / Accepted: 6 July 2023

Abstract

The aim of current work is to analyze the hurdles for enhancing sustainable lean operations in the generation of digital era and green revolution. As companies are struggling to edge the appearing opportunities for preserving sustainability considering green regulations in global marketplace. To achieve the objective of sustainability, Systemized literature reviews conducted along with professionals' opinion. An analysis distinguished significant nine sustainable parameters of green revolution (SPCE) and 15 lean sustainable hurdles (ELH) within desirability bonds for lean environmental-friendly operations. An integrated technique represents AHP–ELECTRE is used to examine these hurdles for achieving sustainable lean operations in organization value chain. Numerous hurdles are related to digitization, such as, lack of practiced manpower that realize digital technology, Inadequate regulations & command, purposeless achievement framework and focus of short timing targets. This research work finds incompetent policies for combination of digitization alongside green estimates, integrated along with deficiency of capital for digitization drives, consist of 2 vital hurdles. An investigation of current study is built upon the viewpoint of 5 knowledgeable in field of manufacturing units. Consequently, outcome of current work may not universal due to opinions might disagree from company to company. The research work can help industry experts to call attention for putting efforts to digitalize or automatize operating processes regarding sustainable operations and resourcefulness circularity. Preservation of resources are especially significant in current situation of circularity. The outcomes of this work will assist organizations to build a constructive and combined actionable guidelines which will promote lean eco-friendly production in value chain using refined understanding of digitization and zero waste.

Keywords Green Revolution · Lean eco-friendly operation · Hurdles · AHP · ELECTRE

1 Introduction

With intensifying population and growing financial and economy system along with better living standard of community undergoing increased utilization of resources which are naturally available [1] recognized a certain need of these natural available resources which are keep on increasing continuously. Because of this escalating need of natural available resources, companies are encountering various operative obstacles [2]. The scarcity of natural available resources is inducing increased input expense and because of this, commodities remain not so much sustainable in the marketplace [3]. Many operational establishments are even now operating with conservative linear economy framework [4]. The conservative prospective of re-use and re-process of physical material is less cost effective and marching towards wastes of invaluable natural available resources [5].

Globally, establishments are encountering intensified pressure from government authorities to become green covering whole operative tasks [6]. Ecological and societal issues are pressurizing establishments for conversion from conservative to circular operations to pause the non-productive disposition of consumer or end of commodities life cycle [7]. The Green revolution (circularity) philosophy incorporate 3r's [8] (Reduce – Eliminate Waste, Reuse-circulate commodities at their highest value, and Recycle- rejuvenate nature). The arrangement of 3r's is utilized as an effective

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Published online: 19 July 2023

Sustainable Lean and Green Manufacturing: An Empirical Review of Their Strategies

Arun Arora, Vijay Kumar Singh, and Rajeev Rathi

Abstract Sustainable lean green manufacturing research is the primary emphasis of this study (SLGM). Manufacturing Organizations can benefit from a combination of lean practices and environmental practices, according to this paper. Despite countless studies, there is no definitive definition of lean and green. In terms of social, economic, and environmental concerns, studies have linked lean manufacturing to green manufacturing. A review of previous research is undertaken in this study to assess the manufacturing industry's shortcomings. Research papers from well-known databases were analyzed to identify the gaps in sustainable lean and green manufacturing practices. After a thorough analysis, it is recommended that sustainable lean and green manufacturing be further developed. Reduced implementation gaps for lean and green manufacturing will increase industrial sustainability. The essay also discusses lean and green manufacturing, as well as lean waste, lean processes, and lean green implementation. Finally, the research closes with a literature survey in order to better understand the present state of lean manufacturing and its varied approaches.

Keywords Sustainability · Lean manufacturing · Green manufacturing · Systematic review

1 Introduction

Organizations of all kinds are using the term "sustainability" as a marketing gimmick. Previous research has suggested links between environmental sustainability and lean and green practices. Reducing the amount of resources used to manufacture something while also improving the environment is central to the lean philosophy. Literature reviews reveal that economic development and societal well-being are inextricably linked to environmental sustainability (Fig. 1). According to Dombrowski and Mielke [1], lean and green refer to the effective use of resources, pollution

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C. Prakash et al. (eds.), *Advances in Functional and Smart Materials*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-981-19-4147-4_1

Future of Indian Manufacturing: Lean and Green Manufacturing System (LGMS)

Arun Arora and Vijay Kumar Singh

Abstract There is a lot of demand on Indian manufacturing companies these days to keep their processes running by overcoming environmental and sociological difficulties as well as adhering to government regulations. However, neither lean manufacturing nor green manufacturing principles can offer a viable solution to these issues. As a result, now is the time to create a hybrid production system that combines lean and green manufacturing. However, implementing a lean and green manufacturing system will not be simple, as it will be hampered by a number of obstacles. The authors of this study considered all potential hurdles to the implementation of lean and green manufacturing methods, and they ranked the most essential barriers to be eliminated first for a successful lean and green manufacturing system implementation. A self-designed questionnaire was distributed to respondents, and data was collected on a 5-point Likert scale, with factor analysis used to identify the primary hurdles out of the potential 57 limitations. Resistance to change, a lack of practical expertise, and cost/benefit limits are the key roadblocks to implementing lean and green manufacturing practices.

Keywords Manufacturing firms · Lean manufacturing · Green manufacturing · Lean and green manufacturing and barriers

1 Introduction

Many researchers have looked into why companies do not use lean and green manufacturing systems in their own company, and the answer is that top-level management lacks commitment and the government does not support it enough. Consequently, high management and government support are required for the implementation of a lean and green manufacturing system [1]. Lean and environmentally friendly manufacturing processes can only be implemented with the full support of senior management and a clear grasp of the implementation process [2]. A lack of resources,

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C. Prakash et al. (eds.), *Advances in Functional and Smart Materials*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-981-19-4147-4_24

Conference Presentation

LOVELY FACULTY OF TECHNOLOGY AND SCIENCES

[Under the Aegis of Lovely Professional University, Jalandhar-Delhi G.T. Road, Phagwara (Punjab)]

Certificate No. 233434

Certificate of Presentation

This is to certify that Dr./Mr./Ms. **Arun Arora** has Authored/Presented research paper titled **Future of Indian Manufacturing: Lean and Green Manufacturing System (LGMS)** in "**2nd International Conference on Functional Materials, Manufacturing and Performances (ICFMMP - 2021)**" held on 17th to 18th September 2021 organized by School of Mechanical Engineering at Lovely Professional University, Punjab.

Date of Issue : 01-10-2021
Place of Issue: Phagwara (India)

Prepared by (Administrative Officer-Records) | Convenor | Conference Chairman

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Paper ID 7957

This is to certify that
Arun Arora
from Lovely Professional University, Phagwara, Punjab
presented a technical paper titled
Lean Awareness and Potential for Lean Implementation - An Empirical study on Indian Automobile industries

in the First International Conference on "Advanced Materials, Manufacturing and Industrial Engineering (AMMIE 2023)" conducted by School of Mechanical Engineering, Vellore Institute of Technology, Chennai during 23rd & 24th March 2023.

Dr. A. Giridharan, *Co-Convener* | Dr. R. Mohan, *Convener* | Dr. K. Annamalai, *Dean - SMEC* | Dr. V. S. Kanchana Bhaaskaran, *Pro Vice Chancellor*

VIT – A place to learn: A chance to grow

APPENDIX -B

Survey Instrument (Questionnaire)

This survey instrument is part of my PhD thesis work for investigation of Lean Green Manufacturing Strategies in an Indian Tractor Industry. It is divided into two parts. Part (a) consists of organizational and personnel details and Part (b) consists of questionnaire for **Lean Green Critical Success factors in an Indian Tractor Industry.**

Part-(a) – Organizational and Personnel Details

1. Manufacturing Industry Name: ______________________________

2. Work Location: ____

3. Manufacturing Industry Type: ________________________________

4. Number of Employees: _____________________________________

5. Name of Respondent: ______________________________________

6. Designation: ____

7. Work Experience: ____

8. Functional Section / Email ID / Contact No.:

____

Part (b) -QUESTIONNAIRE FOR RESPONDENTS

An Investigation on Lean Green Manufacturing Strategies in Indian Tractor Industry

This questionnaire seeks your perception on assessment of Lean Green Manufacturing Strategies in Indian Tractor Industry. Thank you for your assistance as this survey will allow us to understand your needs and improving the delivery to your satisfaction. Your participation in this study is entirely voluntary and all replies are confidential and anonymous. On a Likert scale of 1 to 5, please indicate your response by ticking the appropriate level of satisfaction for the questions mentioned below.

SD=Strongly Disagree, D=Disagree, N=Neutral, A=Agree, SA=Strongly Agree

	SD (1)	D (2)	N (3)	A (4)	SA (5)
Lean Green Strategies Critical Success Factors (LGSF's) in Tractor Industry					
LGSF 01-Resource Adequacy					
LGSF 02-Suprior Business Capabilities					
LGSF 03- Structured Training module					
LGSF 04- High human potential					
LGSF 05- Administrative active participation					
LGSF 06- Vision clarity					
LGSF 07- Appropriate tools picking					
LGSF 08- Abundance Consciousness about LG practices					
LGSF 09 - Logical Project Nomination					
LGSF 10- Adequacy of coaching funds					
LGSF 11- High attainment of organization's beliefs					
LGSF 12 - Controlled expenditure execution					
LGSF 13 - Acceptability of cultural transformation					
LGSF 14 - Sufficiency of timeline for LG Practices execution					

LGSF 15 - Leadership Potential					
LGSF 16 - Full employee participation					
LGSF 17- Tactical intelligence					
LGSF 18- Structured performance review practices					
LGSF 19- Constructive communication between functional units					
LGSF 20- Alignment between business’s purpose and consumer gratification					
LGSF 21- Right selection of employee for needed training					
LGSF 22- Strong Suppliers affinity					
LGSF 23- Well perceptiveness of LG as a tactics, instruments, and actions					
LGSF 24- Certain use of longer shelf items					
LGSF 25- Pursuit of Productive Time					
LGSF 26- Considerable execution cost					

Survey Instrument (Questionnaire)

This survey instrument is part of my PhD thesis work for investigation of Lean Green Manufacturing Strategies in an Indian Tractor Industry. It is divided into two parts. Part (a) consists of organizational and personnel details and Part (b) consists of questionnaire for **Lean Green Barriers and Sustainable parameters in an Indian Tractor Industry.**

Part-(a) – Organizational and Personnel Details

1. Manufacturing Industry Name: ______________________________

2. Work Location: ____

3. Manufacturing Industry Type: _______________________________

4. Number of Employees: ____________________________________

5. Name of Respondent: _____________________________________

6. Designation: ____

7. Work Experience: ____

8. Functional Section / Email ID / Contact No.:

____

Part (b) -QUESTIONNAIRE FOR RESPONDENTS

An Investigation on Lean Green Manufacturing Strategies in Indian Tractor Industry

This questionnaire seeks your perception on assessment of Lean Green Manufacturing Strategies in Indian Tractor Industry. Thank you for your assistance as this survey will allow us to understand your needs and improving the delivery to your satisfaction. Your participation in this study is entirely voluntary and all replies are confidential and anonymous. On a Likert scale of 1 to 5, please indicate your response by ticking the appropriate level of satisfaction for the questions mentioned below.

SD=Strongly Disagree, D=Disagree, N=Neutral, A=Agree, SA=Strongly Agree

	SD (1)	D (2)	N (3)	A (4)	SA (5)
Lean Green Barriers (LGB's) pertaining to Tractor Industry					
LGB 01-Threat of forged expenditure / mis-investment					
LGB 02-Inadequate sustainable regulations & command					
LGB 03- Poor plan for integration of Lean digital technology & Circularity					
LGB 04- Inadequacy of practiced manpower					
LGB 05- Lack of finance for Lean digitization and Lean Green technology					
LGB 06- Ineffective performance framework					
LGB 07- Utilize materials as source of energy					
LGB 08- Poor waste management					
LGB 09 - Lacked resources / quality of infra-structure for LG practices					
LGB 10- Inadequate Management support					
LGB 11- Employees confrontation to change / switch					
LGB 12 - Fluctuating demand from market					
LGB 13 - Absence of effective governance from top management					
LGB 14 - Focus on short-term targets					

LGB 15 - Inadequate knowledge and lack of continuous improvements of LG strategies and practices.					
LGB 16 - Inadequacy of Corporate Social Responsibility (CSR)					
LGB 17- Absence of environmental certification (ISO: 9001:14001)					
LGB 18- Lack of hazardous waste disposition					
LGB 19- Lack of reward and recognition					
Lean Green Sustainable Parameters (LGSP's)					
LGSP 01- Resource Circular sustainability					
LGSP 02- Economizing by the way of product and process quality					
LGSP 03- Reducing emission in operational value chain					
LGSP 04- Reduction of waste in lean system operational value chain					
LGSP 05- Designing processes efficient energy system					
LGSP 06- Enhancing revenue from green product and services					
LGSP 07- Focus on green transport planning					
LGSP 08- Focus on community health					
LGSP 09- Enhancing green buying					
LGSP 10- Reliability and operational quality specification					
LGSP 11- Benchmarking system and practices					

Survey Instrument (Questionnaire)

This survey instrument is part of my PhD thesis work for investigation of Lean Green Manufacturing Strategies in an Indian Tractor Industry. It is divided into two parts. Part (a) consists of organizational and personnel details and Part (b) consists of questionnaire for **consists of Criteria and Sub- Criteria for Lean Green Project selection in an Indian Tractor Industry**

Part-(a) – Organizational and Personnel Details

1. Manufacturing Industry Name: ______________________________

2. Work Location: ____

3. Manufacturing Industry Type: ________________________________

4. Number of Employees: ____________________________________

5. Name of Respondent: _____________________________________

6. Designation: ____

7. Work Experience: ____

8. Functional Section / Email ID / Contact No.:

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Part (b) -QUESTIONNAIRE FOR RESPONDENTS

An Investigation on Lean Green Manufacturing Strategies in Indian TractorIndustry

This questionnaire seeks your perception on assessment of Lean Green Manufacturing Strategies in Indian Tractor Industry. Thank you for your assistance as this survey will allow us to understand your needs and improving the delivery to your satisfaction. Your participation in this study is entirely voluntary and all replies are confidential and anonymous. On a scale of 1 to 5, please indicate your response by ticking the appropriate level of satisfaction for the questions mentioned below.

SD=Strongly Disagree, D=Disagree, N=Neutral, A=Agree, SA=Strongly Agree

	SD (1)	D (2)	N (3)	A (4)	SA (5)
Lean Green (LG) Project Preference Criteria and Sub Criteria					
1) Morale of Employees (ME)					
1.1) Top Management Encouragement (TME)					
1.2) Employee Contribution (EC)					
1.3) Reward and Recognition (RR)					
1.4) Employee healthcare Policy (EHP)					
2) Operational Utilization (OU)					
2.1) Technical Capability (TC)					
2.2) Timely Delivery (TD)					
2.3) Productivity Improvement (PI)					
2.4) Effective Project execution (EPE)					
2.5) Lean Waste Management (LWM)					
3) Skill & Kaizen culture (SKC)					
3.1) Employee empowerment (EE)					
3.2) Training & Education (TE)					
3.3) Effective and transparent Communication (ETC)					

3.4) People engagement & Innovation (PEI)					
4) Cost Management (CM)					
4.1) Project execution Cost (PEC)					
4.2) Return on investment (ROI)					
4.3) Investment Risk (IR)					
4.4) Inventory carrying cost (ICC)					
4.5) Manufacturing Conversion cost (MCC)					
5) Functional Strategy and core competency (FSCC)					
5.1) Strategic Planning (SP)					
5.2) Flexible workforce (FW)					
5.3) Organization Skills (OS)					
6) Green Impact (GI)					
6.1) Sustainability Management (SM)					
6.2) Government Regulations (GR)					
6.3) Energy Management (EM)					
6.4) Water Management (WM)					
6.5) Materials and supply Chain Management (MSCM)					
6.6) Store Management & effectiveness (SME)					
7) Quality Impact (QI)					
7.1) Culture of organization for NFF (COO)					
7.2) Customer delight (CD)					
7.3) Analysis of Customer Complaints (ACC)					