

**DEVELOPING A MODEL FOR OPTIMIZATION OF
QUALITY MANAGEMENT SYSTEM WITH LEAN AND
GREEN MANUFACTURING IN ENGINEERING
INDUSTRY**

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in
Mechanical Engineering

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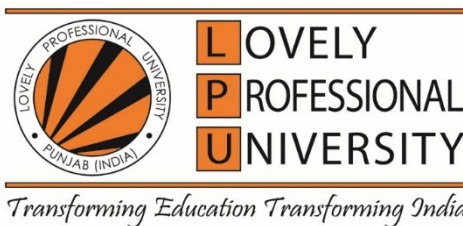
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DECLARATION

I, hereby declared that the presented work in the thesis entitled “**Developing a model for optimization of Quality Management System with Lean and Green Manufacturing in Engineering 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 Singh, working as 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 other 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 “**Developing a model for optimization of Quality Management System with Lean and Green Manufacturing in Engineering 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 Suresh Kumar Kashyap, Registration No. 41900717 is bonafide record of his 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

The quality management system is the mother of all the management systems. The present study is demonstrating an assessment and analysis for optimization of quality management system with lean and green manufacturing (QMS-LG) in an engineering industry. Initially, research gap was identified through literature survey, input from industrial and academia expert. The gap was isolation of quality management system with lean and green manufacturing. Finally, four numbers of research objectives were formulated and analyzed using statistical analysis. Afterwards, a QMS-LG framework that consists the four objectives is developed and validated in engineering industry through a case study. The industry is selected which is manufacturing hand tool's spanners and located in Punjab of India. In objective-1 of framework, the study on manufacturing processes aims to minimize the rejection level is conducted wherein forging process is selected using tools like Process Flow Diagram (PFD), SIPOC Chart, Pareto Analysis, Taguchi Method and Cause-Effect Diagram. In objective-2, the study on waste elimination to optimize lean manufacturing is conducted. In this study, the lean waste and categorization were identified in forging and trimming process for manufacture of Combination and Double Open-Ended Spanners. The value stream mapping for current state and future state was carried out to optimize the result. In objective-3, the study on aspect analysis to enhance environment performance is conducted.

The model of process-based environment management system was developed to identification of environmental core and supporting processes. The assessment of document level was carried to evaluate the status of effectiveness. Environment objectives formulated for actual status against the target. Further, analysis of significant environment aspects were identified and ANOVA approach was applied. After the analysis and significance level, the stack emission of forging furnace was selected for the study of environmental impact assessment. To validate the environment parameters of stack emission, an autonomous maintenance check list was developed. In last objective-4, the study on implementation of Quality Management System with Lean and Green manufacturing is carried out. In this objective. Process interaction map was identified and assessment of document level was conducted. Internal audit and ANOVA

analysis was carried out for identification of non-conformance in weak process and check list developed for further improvement. The lead time for manufacture for final product in single cycle was identified for current state value stream mapping and after the control measure, future state value stream mapping was drawn to obtain the results. The training provided to all the core members of the case study for effective implementation to optimization. All the improvements were monitored for next three months for ensuring of sustainability. After implementation of QMSLG framework, the achievement of the study is documented. The obtained results reveal that defect rate in hot forging was reduced from 1.56 percent to 0.85, value added (VA) activities optimized with respect to non-value added (NVA) by 9 percent, lead time of forged product is reduced from 9 days to 5 days, 5S audit score improved by 7 percent, effectiveness of internal audit in context of quality management system improved by 50 percent and environment impact of forging furnace stack emission was reduced by 52 percent. The outcome of case study motivates to industrial practioners, experts and future Research Scholars for gaining maximum benefits by implementation this QMSLG approach in similar or other sectors and further research study.

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ABBREVIATIONS

FMCG	: Fast-Moving Consumer Goods
FMEA	: Failure Mode and Effect Analysis
GDP	: Gross Domestic Product
GLM	: General Linear Model
GOI	: Government of India
IAQ	: Indoor Air Quality
JIT	: Just in Time
LGM	: Lean-Green Manufacturing
LGS	: Lean-Green-Social
LM	: Lean Manufacturing
LMP	: Lean manufacturing practices
LPG	: Liberalization, Privatization and Globalization
MSME	: Micro, Small, And Medium-Sized
MSMED	: MSME Development
MSS	: Mean Sum of Squares
NVA	: Non-Value Added
PFD	: Process Flow Diagram
QFD	: Quality Function Deployments
QMS	: Quality Management System
QM	: Quality Management
QC	: Quality Control
QVSM	: Quality VSM
QA	: Quality Assurance
SME	: Small and Medium-Sized Enterprise

SF	: Success Factor
TMC	: Toyota Motor Company
TPM	: Total Productive Maintenance
TPS	: Toyota Production System
TQM	: Total Quality Management
VSM	: Value Stream Mapping
WIP	: Work-In-Progress

CHAPTER 1

INTRODUCTION

1.1 Overview

Trade liberalization and globalization of business have brought new challenges and opportunities to many countries, especially developing countries, making it necessary for organizations around the world to develop competitive strategies (Ahmad, W. 2019). In this scenario, many organizations have realized that to maintain their competitive advantage, keeping in view of product quality and services. Therefore, quality is recognized as one of the major factors for improving organizational performance and customer satisfaction. (Bazrkar et al., 2017). The survival of an organization depends primarily on quality products. A thorough quality management system is necessary for competitive advantage in order to guarantee the high caliber of goods and services in the worldwide market.

Over the past several years, the focus of manufacturing practices has to meet consumer needs with maintaining competitiveness in product quality, market responsiveness and innovation. Notably, lean manufacturing, which originated in Japan's automotive sector, has emerged as a highly influential paradigm in the manufacturing landscape. This approach equips organizations with methodologies to enhance their competitive edge by delivering greater value to customers through productivity improvements, all achieved by minimizing resource consumption through waste reduction. Such manufacturing philosophies, driven by consumer demand and accompanied by rising living standards, have resulted in an increased demand for quality products, which in turn has led to a substantial rise in production levels, which have impact to the environment.

The quality management system provides a common framework that can be used by any kind of organization. MSME sector significantly contributes to social and economic growth in India. MSME plays a major role in the economy; Represent more than 90% of all industrial facilities, 40% of the country's total production, 40% of total exports of India, 45% of industrial employment in India, and about 9% of the GDP.

(SME Sector Performance, 2012–2013 Annual Report) it comes to quality challenges, SMEs in India take a more conventional approach.

Regardless of an organization's size or the nature of its goods, the QMS is a globally recognized framework that can be used in a variety of settings (David, H. 2017). This strategy promotes a culture of constant improvement and customer focus by highlighting the significance of consistent quality in goods and services. Organizations can increase operational efficiency, streamline procedures, and eventually boost customer satisfaction by following ISO 9001 standards. The evolution of manufacturing practices has been significantly influenced by the need to adapt to changing consumer preferences and market dynamics. As consumers become more discerning and demand higher quality products, manufacturers are compelled to innovate and refine their processes. This has led to the adoption of advanced technologies, such as automation and data analytics, which further enhance productivity and efficiency. Moreover, the integration of sustainable practices into manufacturing has gained grip in response to growing environmental concerns (Abubakr et al., 2020). Companies are recognizing the importance of minimizing their ecological footprint while still meeting consumer demands. This shift towards sustainability not only addresses regulatory pressures but also aligns with the values of environment friendly consumers, thereby enhancing brand loyalty and market competitiveness. Micro, small, and medium-sized enterprises (MSMEs), also known as small and medium-sized businesses (SMEs), play a significant role in shaping the economies of most countries (Bhamu and Sangwan, 2014). In literature, the terms MSMEs and SMEs are used interchangeably. MSMEs are promoting social stability and economic growth by generating direct and indirect job opportunities (Hu et al., 2015; Wang, 2016).

The quality management systems when combined with lean manufacturing principles, give businesses the means to successfully handle these difficulties. Manufacturers strike a crucial balance between satisfying client demands and reducing their environmental impact by concentrating on waste reduction, process optimization, and customer happiness. This eventually helps to create a more sustainable future (Hegab et al., 2023).

As per Ganapathy et al. (2014), manufacturing companies throughout the globe

are expected to face their sustainability performance in order to satisfy their various stakeholders. Instead of only maximizing shareholder profit, the "business entity ought to be used to serve as an instrument for synchronizing stakeholders' interests," according to stakeholder theory. Businesses adopt sustainable strategies because of the stakeholders and how their interests are expressed. Most forward-thinking increasingly prioritize sustainability, which has emerged as a new competitive criterion in recent years (Wang et al., 2015). As a result, improving the sustainability performance of industrial processes is now commercially necessary (Cherrafi et al., 2016). The focus of sustainability is the "triple bottom line" of "people, profit, and planet" (Mitra and Datta, 2014), which considers not only the financial significance of a company's evaluations but also their social and environmental aspects.

MSMEs contribute significantly to manufacturing production in the majority of developed nations (Arifin et al., 2021). In contrast to major enterprises, MSMEs around the world face numerous obstacles and issues when conducting business. In the modern industrial environment, it is essential to ensure the MSMEs' performance and sustained expansion (Verma, 2020). The elements of the Triple Bottom Line (3BL) present a conflict of interest for small and medium-sized businesses (SMEs) primarily due to a predominant focus on profit over social and environmental factors (Wong and Wong, 2014). This conflict complicates the determination of how to effectively balance operational or financial performance with sustainability initiatives in SMEs. To address these challenges, SMEs have increasingly adopted various production strategies that are characteristic of larger industries, aimed at fostering sustainable development (Panizzolo et al., 2012). Research was conducted to identify and recommend solutions for the obstacles faced by micro, small, and medium enterprises (MSMEs). These transformations have enabled MSMEs to serve as crucial drivers of economic growth (Singh et al., 2008; Hu et al., 2015; Wang, 2016) and as essential facilitators of sustainable development within the economy (Klewitz and Hansen, 2014).

1.2 Manufacturing Sector

The economic development of nations, for example India is profoundly influenced by the robustness of their industrial sectors (De, P.K., Nagaraj, P. 2014). The industrial landscape has experienced substantial growth, now comprising a wide

array of consumer, intermediate, and capital goods. To enhance their competitive edge, companies in the automotive industry have implemented various strategies, such as lean manufacturing, innovations in product and process design, and, more recently, the adoption of green manufacturing techniques. Being one of the biggest sectors, the automotive industry helps to develop a number of infrastructure services, including electricity, rail, and road transportation (Yash Mehta and John Rajan A, 2017; S. Miglani 2018). Indian steel has emerged as one of the fastest-growing industries as a result of globalization and the expanding needs of the real estate, infrastructure, and automotive sectors.

Both the light and heavy engineering sectors have had remarkable expansion over the years, and they have a solid foundation in the manufacturing of a wide range of consumer durables and capital goods (Birky, 2015). With many unique sub-sectors, including medical and surgical instruments, castings, seamless steel pipes and tubes, control instruments, electrical appliances, transformers, welding equipment, pumps, motors, etc., light engineering is a broad business. It is the foundation of almost all commercial and economic endeavors in India and is very significant to the country's economy. As India has become a manufacturing hub because to its large domestic market, highly qualified and technically trained labor force and affordable production and R&D expenditures (Devi et al., 2021). In essence, the heavy engineering business uses light engineering products as inputs. Given that it employs more than 3 million people and makes up nearly one-third of the organized sector's productive capital, value added, and output-all of which significantly contribute to the production and export of engineering goods-the engineering industry in India is significant (Mitra, A., Jha, A.K., 2016).

The engineering goods sector is regarded by most economists as the engine of economic growth. Moreover, it is a known fact that manufacturing industry depends heavily upon the engineering goods manufacturing firms. The SMEs work in the light engineering sector includes low-tech products including electrical devices, instruments, fasteners, bearings, pumps, castings, and forgings. Hence, this research study was carried-out focusing the Engineering Goods Manufacturing firms in India (Das, A. and Das, M., 2023).

The impressive growth in engineering goods exports during the April to October period of 2016-17, which reached over US \$23 billion, emphasizes the sector's increasing importance in the global market. This 29% increase comparing with the last fiscal year highlights the sector's robust performance and potential for further expansion (Centobelli, 2020). An engineering exports are anticipated to reach \$34 billion by the year 2026-27, positioning it as the most significant category within India's total merchandise exports. The rationale for investigating this sector is twofold: firstly, the engineering goods sector is vital for the economic advancement of the country; secondly, a substantial number of firms engage in batch-type production, which aligns well with the lean concept (Verrier et al., 2016).

1.3 Indian Manufacturing Industries

Over 90% of India's industrial companies are classified as Micro, Small and Medium Enterprises (MSME). Dixit and Pandey (2011) highlight that the SME sector is considered the cornerstone of India's economic structure, significantly contributing to the Gross Domestic Product of nation through its production activities. It is imperative for MSMEs to boost their competitiveness and secure their place within the Indian manufacturing landscape. Consequently, MSMEs are encouraged to engage with both national and global supply chains through participation in various organizations.

Figure 1.1 highlights the contributions of SMEs in uplifting employments and intern enabling economic and GDP growth.

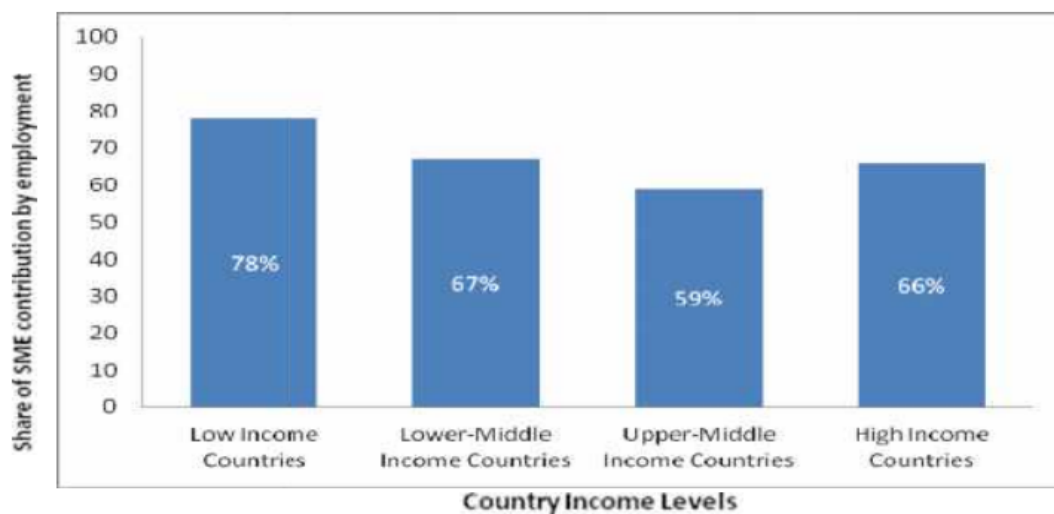


Figure 1.1: Contributions of SMEs in Employments (Maximilian Robu, 2013)

Considering the points made above, it is essential for SMEs to improvise the product quality and adopt advanced technology.

MSMEs are the official designation for SMEs in India. The MSME Development (MSMED) Act of 2006 defines it as an investment in plant and machinery, excluding the value of buildings and land. The definition is thought to be suitable for the current research since it is limited to the manufacturing SME sector. To help micro, small, and medium-sized businesses grow and become more competitive, the Micro, Small, and Medium Enterprise Development (MSMED) Act 2006 was passed in India. The Act became operative in October of 2006. It offered the first-ever legal framework for combining the three levels of these businesses-micro, small, medium and recognizing the idea of "enterprise" for the service as well as the manufacturing industries presented in Table 1.1

Table 1.1: MSME Classification in India as per MSMED Act, 2006

S.No	Manufacturing Enterprises – Investment in Plant & Machinery	
1.	Micro Enterprises	upto Rs. 25 lakhs
2.	Small Enterprises	above Rs. 25 lakhs & upto Rs. 5 crores
3.	Medium Enterprises	above Rs. 5 crores & upto Rs. 10 crores
Service Enterprises – Investment in Equipments		
4.	Micro Enterprises	upto Rs. 10 lakhs
5.	Small Enterprises	above Rs. 10 lakhs & upto Rs. 2 crores
6.	Medium Enterprises	above Rs. 2 crores & upto Rs. 5 crores

Source: (Ministry of MSME, 2017)

MSME sector manufactures the products, from conventional to advanced technology which, following the agricultural industry, offers the greatest potential for jobs as well as self-employment (Dey, 2014). Compared to the rest of the manufacturing industries, the MSME sector has continuously seen faster development (SME Whitebook, 2011–12).

Globalization and economic liberalization have attracted many multinational organizations and foreign direct investments to India. These organizations are providing high quality products at low prices to Indian customers and their products

and services have become strong competition for local SMEs. This has led to an increase in quality consciousness among Indian industries, especially SMEs, to provide quality products. To leverage globalization for the growth of India's economy, SMEs are urged to find competitive strategies. Enhancing operational efficiency and focusing on quality control are key areas for SMEs in India to excel.

In this context, it is essential to investigate the impact of a QMS on an organization's operational performance. The SME sector in India requires a quality management system because they are a major employer and exporter. SMEs need to be able to put in place an effective QMS if they want to stay competitive in the global market. SMEs must be able to provide high-quality, timely goods and services at a reduced cost. Many SMEs have implemented the quality management system in response to these customer and competitor demands.

Many industries in India started adopting various QMS practices in the late 1990s and early 2000s to ensure product quality to ensure survival and growth. During this period, large companies began to require ISO 9001 certification from their suppliers to ensure standardization of product quality.

1.4 Concept of Quality Management System

Over the past three decades, the era of industrial growth, characterized by the strategies of Liberalization, Privatization, and Globalization (LPG), has seen the emergence of a new approach to company management, emphasizing quality and its related initiatives (Ahmad, W. 2019). In the business context, these initiatives encompass quality management programs, certifications, award models, and methodologies. Initially, this approach was confined to the industrial sector, but as the models of Quality Management (QM) evolved naturally, it also found its way into the service sectors (Sreedharan et al., 2018). Key competitive strategies in business involve reducing costs while enhancing value to improve competitive edge through QM.

The advantages of focusing on quality improvement extend beyond cost reduction, leading to increased business profits. The Quality Management (QM) practices have gained significance as they offer the means to elevate the product quality provided by a firm, thereby achieving customer satisfaction. The current trend of

globalization has compelled all industries, regardless of their size or manufacturing location, to adopt more effective quality management practices to survive in a highly competitive and demanding environment (Tahat et al., 2015). Faced with competitive pressures, many manufacturing companies are constantly looking for ways to improve quality.

Quality management systems (QMS) in manufacturing industries play a crucial role in ensuring product excellence and operational efficiency. A QMS integrates various processes and procedures that guide organizations towards achieving consistent quality, meeting customer expectations, and complying with regulatory requirements. At the core of a QMS is the commitment to continual improvement, which emphasizes the importance of monitoring and assessing processes to identify areas for enhancement (Muhammad Asif Ali, 2023). This approach enables manufacturers to reduce defects, minimize waste, and optimize resource utilization. By implementing standards such as ISO 9001, companies can establish a systematic framework that defines all aspects of quality management, from leadership and customer focus to process improvement and performance evaluation (Liu et al., 2023).

Another essential component of a QMS is the emphasis on employee engagement and training. Workers on the manufacturing floor are often best positioned to identify problems and suggest improvements (Bakotic and Rogosic, 2015). Organizations can empower their staff to take responsibility for their work and boost morale and productivity by cultivating a culture of quality. Regular training programs ensure that staff are well-versed in quality standards, which enhances their ability to contribute to the organization's quality objectives. The effective communication is vital in a QMS. As reporting systems allow for feedback loops where information about quality issues can be shared readily across all levels of the organization. This promotes accountability and collective problem-solving, ensuring that quality is everyone's responsibility. Finally, a well-implemented QMS provides manufacturers with a competitive edge in the marketplace. By consistently delivering high-quality products, manufacturers can enhance customer satisfaction and loyalty, ultimately driving sales and profitability. In conclusion, a robust quality management system within manufacturing industries is fundamental not only for meeting compliance standards but

also for fostering a culture of continuous improvement that enhances overall operational performance ((Zivaljevic et al., 2022).

A well-implemented QMS focuses on continuous improvement, meeting customer needs, and reducing waste, concurrently addressing environmental concerns (Pacana and Ulewicz, 2020). In the context of sustainable manufacturing, a QMS can streamline operations and ensure adherence to regulatory requirements, thereby promoting eco-friendly practices. One of the core principle of a QMS is to establish processes and procedures that enhance product quality and reliability. By integrating sustainability principles into these processes, manufacturers can minimize resource consumption, reduce emissions, and decrease waste (Clancy et al., 2023). For example, utilizing Lean Six Sigma methodologies helps in identifying inefficiencies and optimizing resource use throughout the production cycle. This not only leads to cost savings but also contributes to sustainability to minimize surplus materials and consumption of energy (Ani et al., 2016). Furthermore, a QMS fosters a culture of collaboration and accountability within organizations. Employees at all levels are encouraged to take ownership of their roles in ensuring quality and sustainability. This collective responsibility ensures that sustainable practices are consistently applied across all processes and encourages innovation in product development and service delivery. Engaging with stakeholders including suppliers, customers and regulatory bodies is another crucial element of an effective QMS in the manufacturing sector (Singh et al., 2023).

Therefore, establishing clear communication channels and feedback mechanisms, manufacturers can better understand market demands and environmental regulations, resulting in better decision-making. In conclusion, integration a robust QMS within any manufacturing industries is essential for not only enhancing performance but also for ensuring sustainability. By aligning quality initiatives with sustainable practices, organizations can achieve operational excellence while contributing positively to the environment. This holistic approach positions manufacturers to thrive in a competitive marketplace, ensuring long-term success and sustainability (Anwar et al., 2022).

For example, in case of Hindustan Motors – the manufacturers of Ambassador

brand of passenger cars in India. There was mono-poly and they were ruling the Indian passenger car segment till the multinationals like Suzuki, Toyota, Honda, Hyundai from the East and Ford, General Motors, BMW, Audi, Mercedes-Benz from the West came to India. Hindustan motors failed to improve their products Quality and customer expectations. So, they started declining and today operations are closed (Jacob, 2017).

On the other hand, we look at the case of TATA Motors or Mahindra – Indian car makers. Despite the above listed foreign companies dominating the Indian market, still Tata and Mahindra are selling their cars. This is because they have the constant and continual improvement and up gradation of their business performance and are customer focused (Sunil, 2017). But to do that they need – Technology, Skill and Knowledge, other infrastructure such as Software, Information, Communication technology etc.

All these require huge capital investments. Large corporate industries are somehow organizing these capital requirements. But, in case of MSME industries it is totally different as this is a very big challenge for MSME industries (Anwar, 2022). To improve their performance continuously industries started looking for some Performance improving methods, tools and technique

There are so many tools and techniques being employed by industries. QMS – Quality Management System, Lean Management, TQM – Total Quality Management, TPM – Total Productive Maintenance are few to name. QMS – Quality Management System implementation and getting ISO 9001 certification is a widely practiced methodology being adopted by the industries to improve their performance (Piskar, F. and Dolinsek, S., 2006). MSME industries also show lot of inclination to implement QMS and get certified for the ISO 9001 standards. They spend money, efforts, time to implement QMS and getting certification.

As Quality Management System is a key activity aimed at continuous improvement in an organization's performance. However, managing a QMS presents challenges for managers, with a shared goal of satisfying customers and maintaining global competitive pressure for long-term success. Both ISO 9001 and Total Quality Management (TQM) are recognized approaches that, when implemented in industries,

can provide a competitive edge to firms (Wilson, J. P. and Campbell, L. 2018).

Therefore, it is crucial for any organization to consider adopting either QMS or TQM as part of its business strategy. There are certain characteristics that set large firms apart from Small and Medium Enterprises (SMEs), which can influence approach and implementation of quality practices. The diverse sectors and supply chains across Asian countries are also aiming for a higher level of quality excellence (Das, A. and Das, M., 2023). In India, SMEs play a critical role in the country's industrial economy, accounting for about 39% of the manufacturing output and 33% of the total export value. Moreover, in recent years, The growth rates of SMEs have consistently outpaced those of the industrial sector as a whole. The potential of the industrial sector to generate employment possibilities at a low capital cost is its main benefit (Nallabala and Gugloth, 2011).

The notion of quality management, or QM, focuses on improving an organization's processes' performance over time as well as the caliber of the goods and services that come from it (J. Antony and M. Sony, 2023). It is a collaborative endeavor that needs a new culture, focus, discipline, and high-quality information. From the adaptive whole quality approach to world-class manufacturing, several Japanese, European, and American efforts for quality management and process excellence have been proposed since the 1960s.

Due to mounting demand from many stakeholders, industrial businesses have made sustainability their top concern. Customers, workers, and society at large demand that the negative environmental consequences of industrial activities be lessened and that the social results be improved. In a highly competitive and international market that demands constant upgrades to keep a competitive advantage, shareholders simultaneously want improved economic and financial outcomes. Lean manufacturing has become the dominant paradigm in manufacturing operations in this setting, enabling businesses to improve competitive criteria, including cost, quality, flexibility, and delivery time.

Research on sustainability is becoming increasingly important as companies that care about the environment discover more ways to cut expenses and improve

performance through quality products (Nidumolu, Prahalad, & Rangaswami, 2009). Millennials are willing to pay more for products and services offered by businesses that are committed to sustainability, according a survey with 30,000 respondents from 60 countries (the Nielsen Company, 2015). Akbar and Irohara (2018) define SM as the process of producing goods and services by fusing economically viable and ecologically friendly methods. While addressing energy and natural resource conservation (Akbar & Irohara, 2018) and ensuring the safety and well-being of all stakeholders (Jawahir, Badurdeen, & Rouch, 2015), SM creates goods and services of the proper quality. SM is said to use a more comprehensive and holistic strategy than conventional manufacturing, which is primarily centered on an economical or value-creation standpoint (Stark, Seliger, & Bonvoisin, 2017).

Lean and green manufacturing have been utilized as synonyms for SM in the literature that is currently available. Nonetheless, there are some parallels and differences between these terminologies. Stakeholder involvement in the company and supply chain, waste reduction or optimization, process lead time, key performance indicators, as well as comparable implementation strategies are all areas of attention for lean and green manufacturing facilities (Dües, Tan, & Lim, 2013). But there are also differences between lean and green production; for example, their views on waste are different (Dües, Tan, & Lim, 2013). Therefore, as SM includes both ecologically and socially responsible production, lean manufacturing could be considered a component of SM. Furthermore, SM requires that the three facets of sustainability—people, planet, and profit—be given equal weight, claim Ren, Manzardo, Mazzi, Zuliani, and Scipioni (2015). However, the scientific community has been increasingly concerned about whether the resources needed for an effective implementation of lean can negatively impact environmental and social performance, or whether lean manufacturing adoption can effectively help businesses achieve their environmental and social sustainability goals.

1.5 Lean Manufacturing

A lean manufacturing uses a methodical approach to remove waste by emphasizing quality of the product as well as delivery along with manufacturing costs. Lean combats waste, which is defined as everything superfluous and detracting from the final product's value. Waste may be managed and removed in an organized way when it has been discovered (Orlando Valota, Yi Sun, and Z Zhang, 2005).

Lean manufacturing is based on reducing waste both within the organization and across the distribution network (Womack & Jones, 1996). Taiichi Ohno, who developed the Toyota Just-in-Time production method, laid the philosophical and cultural groundwork for lean manufacturing and waste reduction in the 1950s. In an attempt to attain excellence, lean manufacturing aims to find out and eliminate waste (non-value-adding procedures) and make the product flow at the customer's request. Furthermore, it is widely acknowledged that lean manufacturing processes constitute the emerging modern manufacturing methodology, as well as those lean principles govern the aims of lean manufacturing. Although, lean manufacturing is usually thought of as the purview of major OEMs, smaller contracted manufacturing companies and workshops may also benefit greatly from implementing a lean concept. When associated members and industrialists were approached to inquire about their opinions on this concept out of curiosity, their responses varied.

Many of the concepts of Lean Manufacturing originate from the Toyota Production System, which have been progressively adopted over time. Toyota is regarded as one of the world's most efficient manufacturers and the firm that sets the benchmark for Lean Manufacturing best practices. These days, as manufacturing organizations look for methods to better compete against global competition, lean manufacturing has grown in importance. Activities that don't improve the product's value are considered waste. The goal of the lean technique is to attain industrial excellence by consistently cutting waste. Lean manufacturing makes use of methods and ideas that increase the productivity of value-added operations. Japanese engineers Taiichi Ohno and Shigeo Shingo invented the Toyota Production System, which is where this production method originated (Bhamu and Singh, 2014). These days, LM is extensively used by companies all over the globe to increase operational efficiency and

production (Prasad et al., 2016).

The deployment of lean tools and processes across the business to the extent that they provide benefits is known as widespread lean adoption. Production management is not the only use of lean methods. Production and management of stocks, overall organizational buy-in, as well as overall quality management via the use of lean manufacturing methods are sectors that need focus. A lean transformation paradigm is necessary for the implementation process at both the corporate and functional levels. Employee involvement, supplier coordination, and management support might all help to accomplish the advantages. A basic approach, systems thinking, leadership, a knack for strategy, and an understanding of the realistic constraints on resources are all essential for success (Quarterman Lee, 2007). Because it employs a number of tactics to concentrate on the removal of nonvalue-added operations and resource consumption, lean is one of the most popular ways in the current environment (Syreyschikova et al., 2021; Vinodh et al., 2010).

In the context of process optimization, non-value-added activity is waste that occurs on the shop floor and never adds value to a product (Morales Méndez & Rodriguez, 2017). To find these nonvalue-added tasks, a number of methods are used, such as value stream mapping, just-in-time, Gemba walk, total productive maintenance, single-minute die swap, and 5S. These methods were created as part of the lean methodology. By removing sources of nonvalue-added work and cutting lead times and inventories, the literature study demonstrates that the lean manufacturing method has improved production performance (Tayal et al., 2021; Yadav et al., 2020).

On the other hand, green manufacturing improves the performance of the environment in industries with small financing. The aim of the idea of green manufacturing is to increase the efficiency of operational performance by removing environmental waste (Leong et al., 2020). Environmental waste is described by Cherffi et al. (2017) as an unethical use of natural resources that could endanger human health and ecosystem. Scientists focus on the elimination of activities produced by environmental waste because it directly affects the operational performance, economic conditions, safety of workers, health and readiness.

Figure 1.2 displays the possible waste sources such as shop floor and environmental waste that were found through a comprehensive literature review.

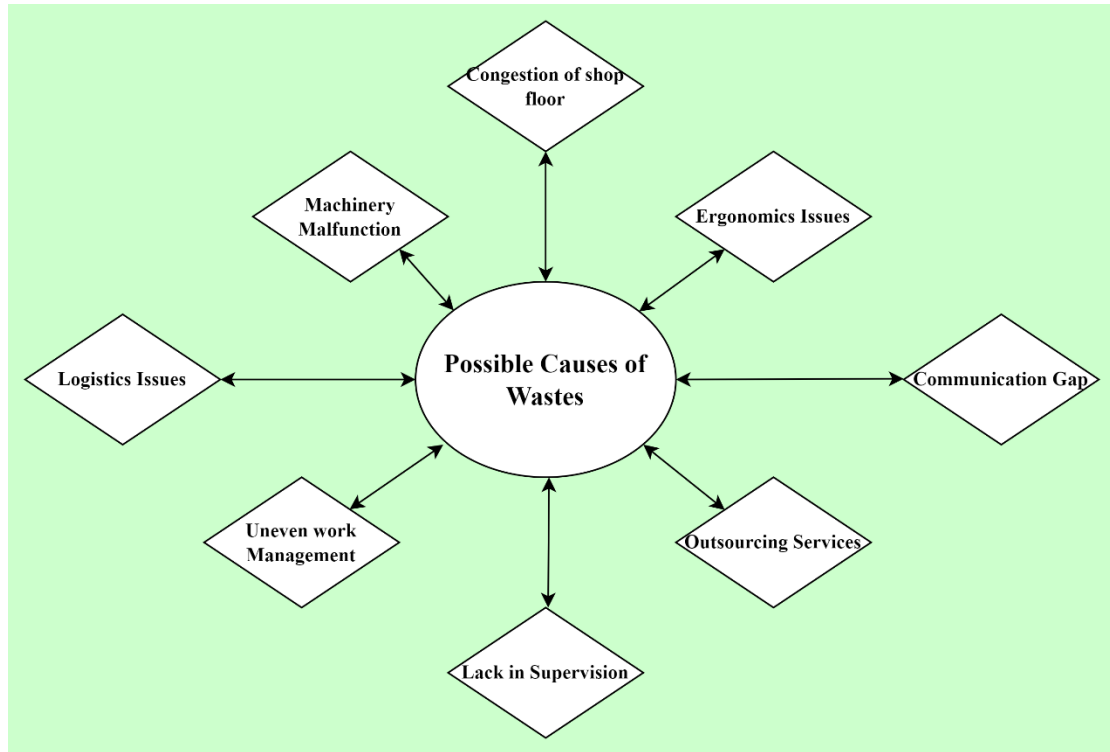


Figure 1.2: Possible Causes of Wastes

Prior studies have posited that waste has a direct effect on employee performance, both environmental factors and conditions on the shop floor (Syreyshchikova et al., 2020; Syreyshchikova et al., 2021). These studies highlight the multifaceted nature of waste, indicating that it is not merely a byproduct of production processes but a significant factor that can hinder employee efficiency and productivity. Specifically, the researchers illustrated that environmental waste, which includes pollutants and inefficiencies related to resource use, leads to unfavorable operational circumstances that can demoralize workers and reduce their overall effectiveness.

1.6 Green Manufacturing

The impact of processes related to green manufacturing - especially green investments, activities and product categories - in the field of financial success of enterprises. The study uses the theory of self-determination to explore how the amount of green activities, the size of green investment and the type of product affects economic

results using data from the survey of small and medium -sized enterprises (small and medium -sized enterprises) in India. The finding shows that economic performance is improved by more green activities and there is an inverse -shaped relationship in green for green investments and economic success. When businesses provide both green and non-green items, this dynamic is further reinforced. The study adds to our knowledge of how green manufacturing affects company performance and offers managers useful advice on how to maximize the advantages of green projects. By increasing focus on the "green" initiatives of companies stems from rising concerns about environmental issues that pose significant threats globally (Centobelli et al., 2020). Environmental challenges are among the most urgent and unresolved global objectives that need addressing (Cappa et al., 2022). Since it became clear that human activity has a major role in resource depletion and environmental deterioration, governments, organizations, and individuals have made these challenges a key priority (Michelino et al., 2019). In this context, the Government of India (GOI) has set various emission targets and regulations aimed at reducing the environmental impact of small-scale industries.

These targets are part of broader initiatives to combat with climate change and air quality. As per NCAP-2025 scheme, the aim set by GOI to reduce the particulate matter (PM10 and PM2.5) levels by 20-30% by 2025, compared to 2017 levels (Government of India, 2017). Due to various factors, manufacturing companies are increasingly following green manufacturing initiatives. These practices aim the benefit to the environment, enhance brand image and reputation (Fercoq et al., 2016), and customers who favor eco-friendly businesses, ultimately boosting companies' economic performance (Verrier et al., 2016). Using renewable energy sources and taking part in sustainable supply chains are examples of how green manufacturing incorporates environmental consciousness into production (Dieste et al., 2019).

The increasing popularity of green manufacturing has drawn more attention to the ways in which these practices affect all facets of business performance, including financial, operational, and environmental results (Ye et al., 2023). As per previous literature review, green efforts have a favorable impact on a number of economic performance metrics (Li et al., 2021). Gandhi et al. (2018) find that green initiatives, like hazardous material minimization, reducing waste, as well as reverse logistics, with

an impact on the financial results. However, other initiatives, like eco-friendly purchasing practices, environmental collaboration with suppliers, and ISO 14001 certification, which certifies efficient environmental oversight systems, do not always result in better economic outcomes.

Environmental preservation for sustainable development without sacrificing to the future generations is referred to as "green manufacturing" (Singh, Singh, et al., 2023). Legislation, environmental pressure from pollution, wasteful resource usage, changes in the climate, inappropriate disposal of waste, decline in biodiversity, including ecosystem degradation have all contributed to the evolution of societal expectations for accountability, environmentally friendly development, and transparency (Goyat et al., 2020).

All organizational levels must be committed to the environment system's effective implementation, with senior management providing particular attention (Singh et al., 2019). By implementing environment governance and connecting the environment system with the business process framework and strategic direction, top management may effectively manage both threats and possibilities. A project activity's economic, environmental, and social factors are identified by the environmental evaluation of aspect-impact, which also discloses any prospective environmental effect (Singh and Rath, 2024).

Using the most recent manufacturing processes, Indian firms produce a wide range of goods (Singh, Rath, et al., 2023). However, ignores the part that environmental-impact play both during and after manufacturing, leading to a number of environmental problems. If environmental risks are adequately managed by qualitative and quantitative technique for aspect-impact evaluation, plant setup and deployment operation may be both safe and ecologically sustainable (Singh et al., 2024).

1.7 Nexus of Lean-Green Manufacturing

The combination of environmentally friendly practices with Lean Manufacturing concepts is known as "Green Manufacturing" or the "Lean-Green" method (Abualfaraa et al. 2020). The combining lean and green practices gives

operations strategies a competitive edge and produces long-term economic and environmental benefits., which is why approach suggested as the way to increase competitive edge (Bhatt et al. 2020; Duarte and Cruz-Machado 2019; Siegel et al. 2019; Sanchez and Kumar 2019).

An emerging strategy of industry 4.0 is smart lean-green approach, which is useful for creating an aesthetically pleasing and sustainable shop-floor management system (Touriki et al., 2021). Industry professionals may get a fresh chance to enhance their operational performance, especially in terms of working strategy and environmental circumstances, by using the smart lean-green method. In order to eradicate wastefulness from production processes and workplaces, lean-green methodology combines two techniques (Duarte, 2017). Figure 1.3 illustrates how the nexus of lean-green manufacturing's goal is effective in the current Industry 4.0 environment.

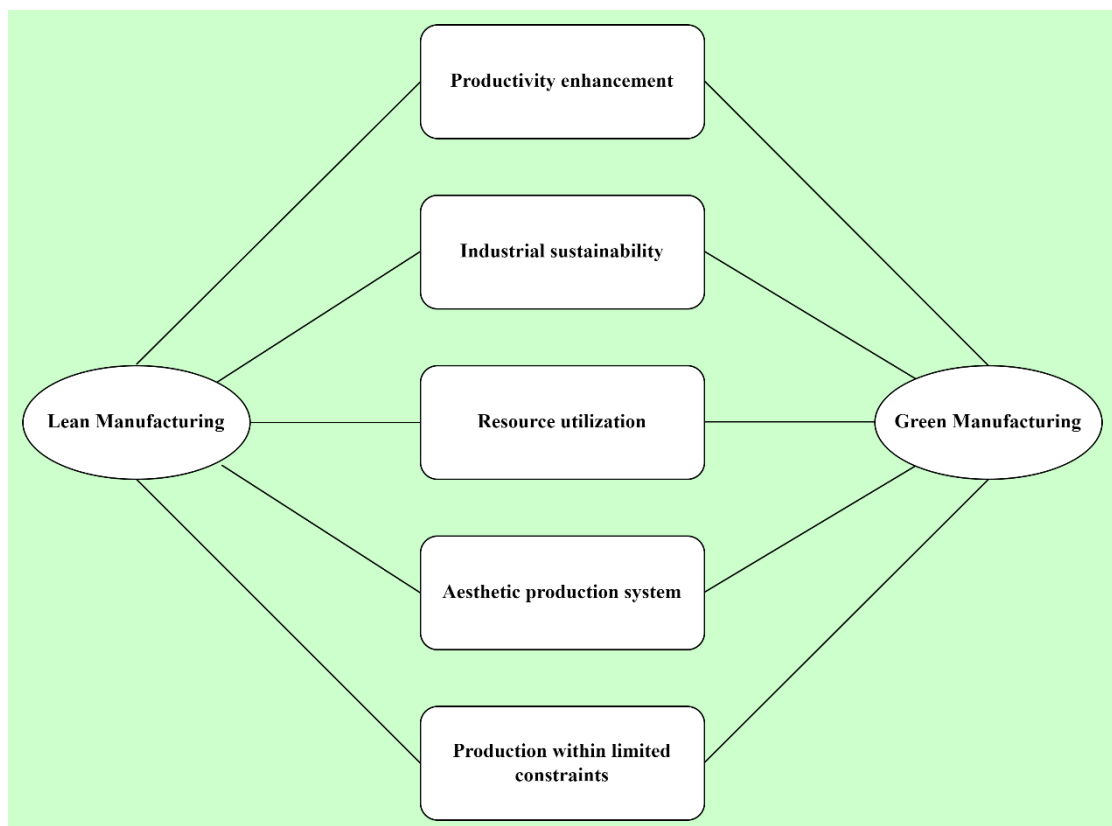


Figure 1.3: Nexus of Lean and Green Manufacturing

The exploration of lean manufacturing and green manufacturing as individual methodologies is progressing; however, there remains a significant gap in research concerning their synergistic effects when integrated into a unified framework (Garza-Reyes, 2015; Marques et al., 2019; Tripathi et al., 2021). A recent literature review highlights the existence of conflicting findings regarding the compatibility of lean and green manufacturing within an operational model (Garza-Reyes, 2015; Govindan et al., 2015; Leong et al., 2020). Some studies explore for their integration, suggesting that it enhances a firm's sustainability performance by fostering a synergistic relationship where the strengths of each approach complement one another, thereby alleviating systemic weaknesses (Garza-Reyes, 2015; Kurdve et al., 2014; Teixeira et al., 2021). This perspective proves that lean manufacturing, which focuses on waste reduction and efficiency, can complement green manufacturing's emphasis on environmental sustainability, leading to a more holistic approach to operational excellence. By aligning their goals, organizations may achieve improved resource utilization, reduced environmental impact, and enhanced overall performance (Marques et al., 2019; Tripathi et al., 2021).

In contrast, other investigations argue that lean and green manufacturing may be at odds with one another in achieving their core objectives, leading to incompatibilities in certain scenarios (Sundar et al., 2014). There is a contrasting viewpoint that highlights potential conflicts between lean and green manufacturing. Some researchers argue that the core objectives of these methodologies may not always align, leading to challenges in their integration. For instance, lean manufacturing often prioritizes cost reduction and efficiency, which may sometimes conflict with green manufacturing's focus on environmental considerations that could incur additional costs or require changes in processes (Sundar et al., 2014). This divergence in priorities can create tensions within organizations attempting to implement both strategies simultaneously, resulting in inefficiencies or compromised outcomes.

Furthermore, it is noteworthy that many reviews that discuss the lean and green principles often fail to address an aspect of social performance. Moreover, it is crucial to recognize that many existing literature reviews the intersection of lean and green manufacturing frequently neglect aspect of social performance. While environmental

and economic dimensions are often emphasized, the social implications of integrating these methodologies remain underexplored (Leong et al., 2020). Social performance encompasses factors such as employee well-being, community engagement, and ethical practices, which are essential for a comprehensive understanding of sustainability. Ignoring this dimension may lead to an incomplete assessment of the true impact of combining lean and green principles.

Limitations and Challenges in Implementing Lean and Green with QMS in India:

While the integration of Lean and Green approaches within a Quality Management System presents significant potential for improving efficiency, waste reduction and sustainability, several challenges limit its effective implementation in the Indian context.

- Organizational resistance – reluctance to change established workflows and culture.
- High initial investment – cost of green technologies and Lean infrastructure.
- Skill gap – shortage of trained workforce to manage Lean–Green integration.
- Technological limitations – limited access to energy-efficient machinery and monitoring systems.
- Policy and regulatory gaps – weak enforcement and fragmented government support.
- Scalability issues – MSMEs often struggle to adopt due to financial and resource constraints.

1.8 Need for Study

Most of the MSME industries in India face a number of challenges – like lack of access to low-cost capital/finance, lack of availability of skilled manpower/human resource, market, technology/infrastructure and government (Hemendra Singh Bisht and Dilpreet Singh, 2021). In addition to these they have to keep their customers' happy by supplying Quality products at a competitive price. Implementing an effective QMS can help MSME industries in maintaining a systematic work environment and helps them to improve their products and processes. Besides this, getting an international certification, after a rigorous audits conducted by a third-party certification body, helps them to get a good image in the market and its customers also. So, most of the MSME industries are positively inclined towards implementing QMS despite high financial

investment involved in it. However, they face a lot of difficulties and challenges, not only in implementing it, but also maintaining it on a sustained basis. Though there are many views and opinions about this topic, a detailed scientific study is a requirement in this area, which have been adequately addressed.

1.9 Scope of the Study

At present, Quality Management System is designed as per the International Standard of ISO 9001:2015 that is specifically covering the minimum requirements. The proposed research area will enhance additional requirements, which is covering for reduction of process waste, energy conservation, material flow management and environmental performance. The developed model will provide value added process to the Society and Industrial Sector.

Societal and Industrial Issues are facing a huge burden of additional loss of waste which includes unitized human talent, lack of developed model for system enhancement, lost time due to incident and environmental concern where depletion of natural resources from manufacturing processes. The waste control process with respect to the green manufacturing will give the enhancement of environmental performance.

The proposed topic will address international level to cover up the requirements. The International Community of Industry Sector in undeveloped area will be taking advantage of this model. The model will not only be covering the basic need to operational excellence but also improve the work culture in the organization. The proposed model would lead to Policy making of the organization. During formulation and document of Policy, the contents of the model can be selected to incorporate into integrated management system which indicates for the setting of operational goals and consistent with the Policy.

This research work is aimed at studying the impact of QMS with LGMPs on the performance of the industries and the difficulties and challenges faced by the MSME industries.

The major segment of industries that are covered in this study includes – foundries, light engineering industries, pumps and motors manufacturing industries, metal fabrication industries, plastics and plastic product manufacturing industries,

metal heat treatment and surface finishing industries amongst others. Similarly, the industries though all fall into the broad Manufacturing category – they produce different types of products and are divergent on many factors like size, age of the company, sales turnover and legal structure.

1.10 Summary

The thesis contributes to the knowledge on lean green manufacturing practices for academicians, researchers, and practitioners. The systematic literature review is a building block for the potential researchers to explore the newer research areas in identifying lean green manufacturing strategies. The measurement framework for the strategies in the Indian Industry is comprehensive and encompasses the functional areas of an organization. From the literature review gaps and limitations are identified, which can be used by the practitioners for assessment and improvement of their organizations irrespective of the type of industry. The study helps the practitioners to use framework to leverage optimize areas and improve the weak areas.

1.11 Organization of Thesis

This thesis consists of seven chapters. Content of thesis has been presented as below:

Chapter-1: Introduction

This chapter provides an overview of research study that includes background about Lean and Green manufacturing, research motivation, research aim, and contribution of research.

Chapter-2: Literature Review

This chapter outlines a Systematic Literature Review (SLR) related to Lean manufacturing, Green manufacturing, and overview of Quality Management System. In accordance with the review of literature, research gaps have been identified and the objectives of the research work in the study are formulated.

Chapter-3: Research Methodology

This chapter presents research design used in the research work. Problem formulation was identified with the selected case study. Further, Lean-green tools strategies

framework has been formulated and described in this research study.

Chapter-4: Implementation of Lean Manufacturing

This chapter presents the identification of manufacturing processes which aims to reduction of rejection level in industry. The value stream mapping (VSM) was conducted and analysis to current and future state to evaluate the outcome. Furthermore, the rejection of in-process identified and pareto analysis applied for defects contribution. Finally, the comparison was carried out before and after by taking corrective measures.

Chapter-5: Waste Analysis in Manufacturing Industry

This chapter refers to the analytical study of the lean and green waste in the manufacturing set up. Current state of the waste aspect was analyzed and it was validated in the future state of the study which have significant reduction of the lean and green waste.

Chapter-6: Environmental Aspect Analysis

This chapter presents the framework of environmental aspect-impact study to enhance the environmental performance for green manufacturing.

Chapter-7: Lean and Green Approach for Quality Management System

This chapter presents case study of Quality Management System. The implementation of the quality management system was assessed and analysis through 5'S and internal audit with respect to the process interaction processes. The validation of the proposed framework of the study was conducted before and after analysis results.

Chapter-8: Managerial Implications

This chapter presents the managerial implications and inferences of case implementation.

Chapter-9: Conclusion, Limitations and Future Research Direction

This chapter presents the findings, conclusion, limitations, and future research direction of this research for professionals and prospective researchers.

CHAPTER-2

REVIEW OF LTERATURE

2.1 Introduction

Investigators from manufacturing operational industries and academic institutions are inclined, giving close and due consideration towards Lean-Green (LG) integration due to rising environmental and societal concerns globally. Until now, abundance of research study related to Lean-Green manufacturing, Sustainable manufacturing prevails in the published literature. But very few 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 research approach and strategy to search gaps in foregoing studies for taking forward in this research study.

Objective for Review of Literature:

Primarily 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.

2.2 Methodology Adopted for Literature Review

The literature compiled for the development of the theoretical framework was sourced from a variety of materials, including articles from academic and scientific journals, doctoral and master's theses, as well as reports from reputable government and non-profit organizations. The literature review was established through a three-phase methodology, adapted from the works of Gahm et al. (2016) and Stindt (2017), as

illustrated in Figure 2.1. Initially, narrative literature search was performed focusing on QMS, lean manufacturing and sustainability topics. This process facilitated the conceptualization of these subjects and the identification of commonly used terminology (Ceulemans et al., 2015) and keywords for use in the subsequent phase.

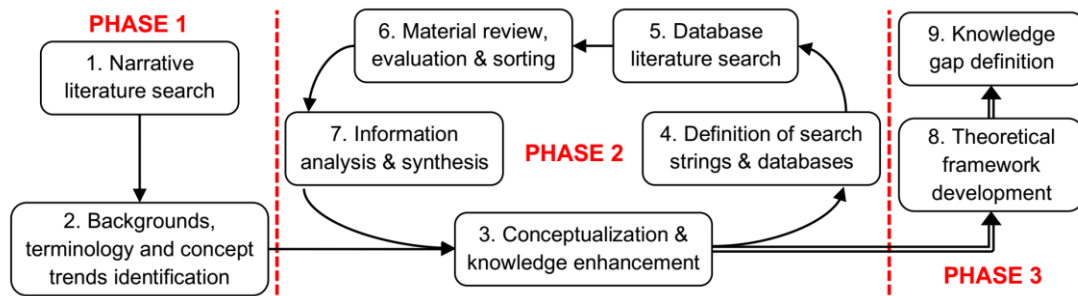


Figure 2.1: Phases for literature review

The second phase is characterized by a systematic literature review, as depicted in Figure 2.1. The objective of this review is to achieve objectivity, reproducibility, and transparency, in accordance with the principles outlined by Garza-Reyes (2015). It seeks to deliver a comprehensive assessment of the existing literature in a particular research area. The initial search string yielded a limited number of publications, suggesting that this research trend is still in its early stages. To enhance the breadth of topics covered, a second search string was subsequently employed. This process was conducted iteratively on a semi-annual schedule to ensure the inclusion of the most current literature, with Figure 2.2 serving as evidence of the rapid development within this research represent the SLR flow diagram for selection of research papers.

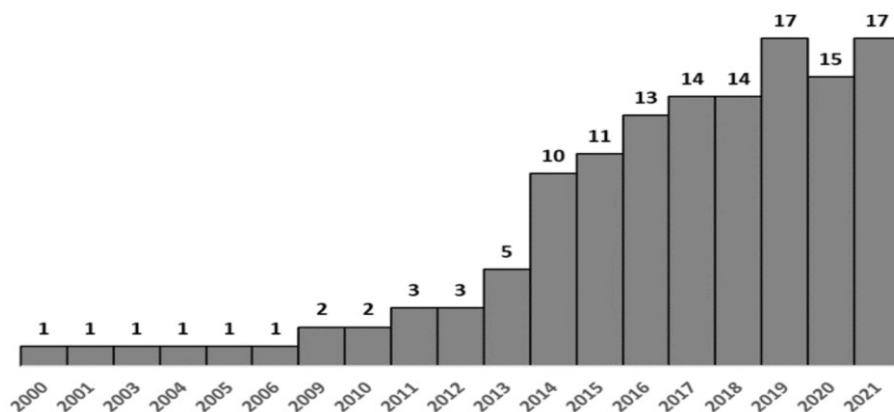


Figure 2.2: Papers with lean-green and sustainable manufacturing (Garza-Reyes, 2015)

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.	Elsevier, Emerald, Springer, Taylor & Francis,
Outline relevant criteria (Fix-only pertinent papers)	Search, download, collect the pertinent articles from famous and reputed data-base.	Electronically stored data-base.	Inclusion– Research papers on lean, green, lean green, barriers, critical success factors, LG framework.
Papers selection based upon formulate criteria, intended on related study.		Criteria of inclusion and	Exclusion– Unpublished
		Search Key words used.	Lean, Green, Lean Green, Sustainability Lean Green framework, Success factors, barriers, enablers,

2.3 Literature on Lean Manufacturing

Concept of lean manufacturing originated from Japanese businesses and gained popularity in western nations under many names (Chiarini et al., 2018). Since M/s Toyota Motor Company (TMC) is acknowledged as the birthplace of lean manufacturing, lean has also been referred to as the "Toyota Production System" (TPS) (Shah & Ward 2007). Because these ideas also included some of the lean principles, lean has also been referred to by other names with Just in Time (JIT), pull manufacturing, and Total Quality Management (TQM) (Sundar et al, 2014). The mass production idea of assembly or transfer lines, which Henry Ford created and used in the car industry, revolutionized the manufacturing system that had previously been in place. In 1927, Henry Ford presented his ideas, which became known as the "Ford Production System" (FPS). Later, this idea was adopted by other industries in other nations, including American businesses. The greater competitiveness that resulted from American corporations' mass manufacturing processes during World War II generated intense rivalry among enterprises worldwide. The competitiveness of these American enterprises also threatened the position of Japanese companies. This prompted TMC to conduct a comprehensive analysis of the American car industry's manufacturing system, with a focus on FPS. In an effort to save costs, Toyota implemented Ford's transfer line procedures. In addition to introducing the quality movements-such as the quality circle, team building, cellular production, setup time reduction, and small batches-they also recognized the crucial role that inventory plays (Palange, 2021). Following tests on its assembly line, Toyota provided a solution and modifications that resulted in a total overhaul of the business and the quick adoption of a different and distinctive production system known as the TPS.

Numerous writers have examined the relationship between lean and sustainability (Piercy and Rich, 2015; Alves and Alves, 2015). These studies have mostly focused on large-scale sectors where the effects of the connection are more pronounced than in MSMEs, such as the automobile, pharmaceutical, and fast-moving consumer goods (FMCG) industries (Bhasin, 2012; Piercy and Rich, 2015). Furthermore, whereas MSMEs often lag behind, big organizations are more aware of and have access to lean manufacturing systems (Pannizzolo et al., 2012; Upadhye et

al., 2013).

According to the findings of Achanga, Shebab, and Roy (2006), a significant proportion of SMEs have not embraced the concept of lean manufacturing with any conviction. To get a more tangible multi-variant study of the relationships between autonomously and owner-managed SMEs, they propose that future research should include a larger range of SMEs. The study placed a strong emphasis on the need of thinking about how to control and reduce the implementation risks while also promoting the observable advantages of lean manufacturing, maybe via creative dissemination initiatives. The research suggested creative ways to provide appropriate instruments that reduce risk.

Additionally, MSMEs have difficulties in mobilizing resources, which will push them to function with less resources and maybe disregard social and environmental criteria (Theyal and Hofmann, 2012). Due to the detrimental effects of all these issues, the company is neglected, and initiatives for sustainable growth are marginalized. MSMEs need extra care in their sustainable growth to get beyond this obstacle (Loucks et al., 2010).

According to Upadhye et al., (2013), lean manufacturing is giving businesses a lasting competitive edge as a change and improvement approach, although Indian industries as a whole have not effectively adopted it. The majority of published research offers substantial evidence of the lean manufacturing system's use in the West, although there aren't many examples from India. Their study comes to the conclusion that putting lean concepts into practice calls for a strong foundation, a thorough comprehension of the idea, a culture of teamwork, employee engagement and incentive, and most importantly, the readiness and unwavering commitment of upper management. Better outcomes are achieved when a dedicated management team leads a motivated and well-trained staff.

Prior research in MSMEs has independently investigated lean manufacturing practices (LMPs) with operational productivity, financial, and environmental (Zhou, 2012; Khanchanapong et al., 2014; Filho et al., 2016). The LMPs on various sustainability performance aspects has not been examined in single research by any of

these studies. Furthermore, the connection between LMPs and sustainability performance has not been the focus of these studies. As a result, it is yet unclear how LMPs would affect MSMEs' economic, environmental, and social sustainability performances.

Prasad et al. (2016) used an approach to the exploration questionnaire to collect data on 16 slender and green techniques from 71 experts in middle to seniors in the Indian foundry industry. A number of literature materials, as well as formal discussions with scientists and foundry sectors, were used to develop a questionnaire for exploration of slender and green practices. The five -point Likert scale was used to collect the answers, from the least relevant to the most suitable. For the quantification of Cronbach's α (consistency coefficient) and obtain and verify the constructions, reconnaissance factors and reliability studies are carried out.

Main areas of lean and green approaches include management, inventory management processes workplace organization procedure, as well as industrial production and quality improvement strategies. Descriptive statistics are also used to determine the relative importance of green and lean approaches. Factor and reliability experiments show that all four concepts are adequate and reliable for illustrating lean and green activities. Descriptive data suggests that the foundry industry may employ lean and green practices to a significant extent. Correlation studies show a reasonably positive association between lean and green practices. Thus, the results offer strong evidence that lean and green practices may be applied in the foundry industry with a moderate level of success (Prasad et al., 2016).

An automobile manufacturer employed the LM to reduce the quantity of manufacturing component defects. The cause-and-effect diagram was used to identify the corrective measures, which include the proper application of anti-scale coating, the venting technique to prevent non-filling, the software for material flow, and the appropriate lubricant (Singh and Singh, 2013). One research found that Just-in-Time (JIT) was regarded as a crucial lean approach tool when LM was used to a manufacturing sector in North India to improve overall performance. Following the effective integration of LM into the operational system, the firm was able to save 242208 rupees a year via JIT adoption (Singh et al., 2018).

According to published research, SMEs in both developed and developing nations continue to have difficulties effectively implementing LM in their systems (Maware et al., 2022). In order to reduce non-value-adding tasks and achieve some degree of success, other type of industries such as electronic sector are also attempting to implement LM in the operational systems (Venkat Jayanth et al., 2020). In one research, the LM implementation framework was put out in the setting of developing nations' manufacturing sectors, and the case study benefited from the findings (Yadav et al., 2020).

Another research in the literature investigated product defects in manufacturing companies using LM and a fishbone diagram to investigate potential sources of defects such as scale pits, mismatches, and non-filling (Gandhi et al., 2020). Remedial measures such as anti-scale coating and the use of the right lubricant during the forging process were implemented by the use of LM in a production context, and the rejection level was reduced from 2.73% to 1.48% (Mathiyazhagan et al., 2022). Using LM implementation, another research examined casting flaws in automobile components. Analysis was done using quality tools such a control chart, histogram, Pareto diagram, check list, and cause and effect diagram. The gross rejection of the crankshaft is 4.45%. Under-filling alone is over 84% of issues. Defects decreased from 4.45% to 0.8% after preventative measures (Anwar et al., 2022). A few studies looked at the LM tools that manufacturing companies often utilize to boost operational efficiency. The synergistic outcomes of the combination between LM and green practices were also examined in other research (Campos and Vazquez-Brust, 2016; Prasad et al., 2016). Some study looked at how LM tools affected economic, political, environmental, technical, and legal variables (Ansah and Sorooshian, 2017), while others assessed the LM tools and their degree of adoption in manufacturing enterprises (Tortorella et al., 2016a). The goal of another PhD thesis was to fill up the information gap about how lean manufacturing affects triple bottom line sustainability. Two models were put out to explain how lean and sustainability interact after a thorough analysis of the most recent research. According to the first, known as the "sand-cone" model, lean adoption leads to cumulative performance gains across all sustainable performance metrics. The first step in the suggested sequence is lean, which improves operational performance. This

settles the bases and provides resources to promote environmental performance improvements, which may next lead to social performance improvements. The "trade-offs" method is the second model. In this instance, performance suffers because the resources needed to maintain one or both of the sustainability dimensions conflict with those needed to enhance one. Data was collected from a sample of metalworking businesses in Colombia and analyzed in order to evaluate the assumptions. The findings supported the cumulative "sand-cone" model and demonstrated that lean manufacturing had a favorable impact on sustainable performance. There was no clear evidence found in the "trade-offs" model. Partial data, however, indicates that trade-offs may be made at the expense of social performance when lean manufacturing is used to concurrently increase all sustainability characteristics (Arango, 2021). The findings provide a fresh theoretical and scientific perspective by putting the two previously stated models to the test in the context of sustainability and shedding further light on how it interacts with lean manufacturing. They also help practitioners by giving businesses a tried-and-true way to boost performance in a series of steps that will enhance long-term outcomes.

The value stream is the route the product takes from the raw materials to the final product, which is necessary to deliver the product according to the customer's specifications. Problem-solving from design to launch, information flow from order placement to delivery, and transformation from raw material to finished product are the three business operations that make up the value stream. Whether they are value-added or not, all of the processes necessary to create a good or service are included in the value stream (Seth et al., 2017).

The mapping of the VSM process is used to document, examine and improve the information and material flow needed to create a good or provide a service. The steps associated with product production or service, as well as the movement of materials and resources, are defined and displayed by VSM. There is some confusion between process mapping or procedural flows and mapping of values. Although both are useful, there is a significant difference in their format, the level of resolution, focus and applications.

VSM is often an integral part of lean thinking, linking quality improvement initiatives with LM to maximize overall organizational benefits through waste

reduction and value-added activities (Kumar et al., 2023). VSM serves as a visual tool that facilitates the implementation of lean by identifying value-added (VA) steps and eliminating non-value-added (NVA) waste (Singh and Rathi, 2020). It has emerged as the preferred method for implementing LM in factories and has been instrumental in waste identification (Singh et al., 2021). Lean methods have a lot of room to be implemented in the Indian manufacturing sector, and VSM is essential for process simplification as the first step in adopting LM (Seth and Gupta, 2005). It gives a thorough overview of all operations, including NVA, and a graphic depiction of the steps involved in meeting client needs (Deshkar et al., 2018). Numerous empirical studies have examined how the lean methodology affects a range of performance metrics, including the operational, financial, and marketing outcomes of manufacturing and service companies. To determine the effects, these research employ case studies, conceptual studies, and simulation studies. Upon deeper inspection, it is evident that the majority of researches have focused primarily on the predicted effects of the lean approach on these performances (Shah and Ward, 2003), with little attention paid to the philosophy's theory. The majority of researches have looked into the distinct impact that lean approaches have on performance. Subsequently, a number of researchers suggested that lean practices be categorized and studied as a collection of internally consistent practice groupings called lean bundles. It is evident that the researchers have attempted to understand the implications of these bundles on performance by grouping interdependent lean practices with shared characteristics into meaningful lean bundles.

The conventional nature of VSM necessitates process monitoring, and since transactional data flow is not accessible inside the business, the operator cannot examine the result. VSM does not allow data to store or identify the system process improvement. VSM limitation is

- (i) inability to map or visualize the flow of process in real -time environment and capture dynamic aspects of the manufacturing system,
- (ii) inability to monitor and project the current status of resources used in the process and level of inventory work (WIP) in each of its processes,
- (iii) VSM mapping, larger number of products of products and their

appropriate product movements cannot be monitored.

The number of studies in the field of VSM has significantly expanded since 2018. This growing tendency highlights the significance and encourages the author to use VSM in the research to guarantee sustainable practices for long-term fixes. Traditional VSM, Dynamic VSM, Smart Sustainable VSM, and Digital VSM are the several VSM types that can be found in the literature. As can be shown from the study studies on VSM, around 79.56% of them reported using old VSM instead of an upgraded version. It was observed that other VSMs gave less thought to the range of sustainable and intelligent indicators to prioritize. Regarding this, the several forms of VSM-such as classic, dynamic, smart, and sustainable digital-are explored in the literature.

Smart VSM is a lean manufacturing technique that is evaluated using sustainable metrics including social and environmental effects and value stream mapping to visualize sustainable results. Mapping criteria for green production, such as the use of ecological raw materials, product design, ecological packaging, energy saving and using three R to maintain a green environment, is called sustainable VSM or green VSM. VSM 4.0 and sustainable VSM are integrated into an intelligent sustainable VSM. Through IOT, it enhances material flow and self-governing decision-making. Using simulation program software, Digital VSM is a tool for process mapping and scenario analysis in the present and future. Analyzing stock availability and modeling changes in a dynamic context are two further uses for it.

The invention of transistors and microprocessors during Industry 3.0 led to the emergence of automation. Concepts of Industry 4.0 are mass customization and personalization. In order to increase automation in the manufacturing process, the current authors concentrate on developing effective ways to use Industry 4.0 technologies. In the present situation, industries must manufacture goods without sacrificing quality in order to satisfy consumer needs. In the manufacturing sector, Industry 4.0 serves as a catalyst for both industry and customer benefits. Industry 4.0 has emerged as a crucial necessity for the competitive industrial operations of today. Automation has increased significantly as a result of the technology enables for the adoption of Industry 4.0 in the Indian industrial sector. These new technical approaches

improve automation on a broader scale. Bonavia and Marian (2006) conducted an empirical assessment of lean practices on 76 tile manufacturing businesses in Spain and found that a number of strategies, such as group technology, kanban, reducing setup time, developing multifunction personnel, and visual factories, are rarely used. Furthermore, a different set of techniques, such as quality controls, total productive maintenance (TPM), and standardization of activities, are widely used. These results show that the extent to which lean principles are used varies by the size of the company and is positively correlated with operational performance.

Kumar et al. (2006) reported that a Lean Six Sigma program was successfully implemented in a SME using an organized framework. This framework incorporates Lean principles into Six Sigma's DMAIC phases. According to reports, this SME has saved \$140,000 annually by the implementation of Lean Six Sigma. Different approaches to Six Sigma implementation are used by Su et al. (2006) in VSM, flow, pull, and Six Sigma. The effectiveness of this application in an IT help desk service has been evaluated. In this instance, the application of Lean Six Sigma resulted in a significant 47.5% reduction in service processing time.

Filho et al. (2016) surveyed to identify that LMPs are being implemented on Brazilian SMEs and investigate the effect of these practices on operational performances using SEM technique. The study found that despite the uneven implementation of LMPs by Brazilian SMEs, these practices have improved operational performance. Three methods used in the integrated strategy for Brazilian small and medium -sized companies are statistical management of processes, TPM and employee involvement. Infly, methods and medium -sized enterprises such as suppliers, continuous flow, draft production, reducing settings, interaction with customers and supplier feedback are accepted. Throughout the world, scientists have also been involved in how LMP affects MSME. A study conducted between and medium -sized food processing in Belgium, Germany and Hungary by Dora et al. (2013) revealed that the use of LMP in these countries is in the early stages. Small and medium -sized food companies are less aimed at improving the process; Their main attention was on food safety and quality management. The analysis also emphasized that the use of LM helps to improve operational performance, especially productivity and quality. Pannizolo et

al. (2012) carried out a study to investigate how lean practices are adopted and used in Indian SMEs. According to case studies conducted on four Indian SMEs, the deployment of LM resulted in notable operational gains for each of the four companies, which were categorized into upstream, internal, and downstream value stream performances.

According to Kumar and Bajaj (2015), the setup operations were investigated using the SMED concept. Its main focus was on evaluating the external and internal setup operations in terms of their necessity (i.e. replacement, adjustment, or preparation), time required, and potential reductions, simplifications, or eliminations. It offers a quick and effective method of switching from producing the current product to producing the next one in a production process.

Other businesses throughout the globe were very interested in M/s TMC as a result of the innovative production and management technique's effectiveness in increasing productivity and quality. Furthermore, a few American firms, like General Electric, and Kawasaki (Lincoln, Nebraska), also achieved success in the 1980s and were awarded the distinction of World-Class manufacturing. In his book "The Machine That Changed the World," Womack provided a straightforward overview of the history of car production along with a comparative analysis of LM-using automotive assembly facilities in Japan, the United States, and Europe.

It is unclear and discouraging how the lean idea is being used and understood in Indian industry. (MSME, 2013; Saboo et al. 2014; Thanki and Thakkar, 2014). A recent research by Filho et al. (2016), there have been very few studies published on the lean performances of SMEs in the BRIC countries-Brazil, Russia, India, and China-all of which are thought to be at a comparable stage of rising economies. Similarly, as the BRIC nations move together as a result of advanced economic reforms, Thurer et al. (2013) have noted the need for more study on SMEs in these nations. One crucial element in bolstering and maintaining the Indian economy is the creation of sustainable MSMEs (MSME, 2013).

The Indian government has put in place a program to increase MSMEs' competitiveness in lean manufacturing and is anticipating their long-term success. But

when it comes to important metrics like output, employment, and their place in the global economy, Indian MSMEs have continuously performed well (MSME, 2012). Lean techniques aim to empower employees, improve job satisfaction, and foster a sense of pride in one's work, as shown by Indian MSMEs (Jain and Malik, 2013). These businesses are essential to the future economic development of the Indian society and the global market as they have shown a steady growth rate in both protected and open economies (MSME 2012). They need assistance in identifying their unique management requirements and determining the best course of action to address them in order to continue in this capacity.

The LSS strategy must be combined with sustainability techniques to solve the problems of decreased production with poor IAQ. As a result, the Environmental LSS (ELSS) method combines the classic LSS strategy with environmental management techniques. In terms of facilitating waste elimination, employee engagement, and continuous development, the LSS and environmental improvement programs have guaranteed similarities (Habidin and Yusof, 2012).

Such an approach minimizes the resource wastage, consumption of materials and IAQ levels in the manufacturing process (Ben Ruben et al., 2018). By creating affordable, high-quality, environmentally friendly products and lowering employee health problems, it can also increase external consumer satisfaction and boost productivity (Garza-Reyes, 2015). Employee health and well-being are improved by high IAQ, which also increases organizational sustainability. According to available studies, manufacturing companies are primarily responsible for industrial pollution and make significant contributions to environmental deterioration (Dieste et al., 2019). Manufacturing companies must successfully implement the ELSS approach in order to address such environmental challenges and preserve sustainability. This calls for appropriate structures and rules that motivate industrial companies to successfully apply the ELSS approach for sustainability improvement.

Value stream mapping, Kaizen, Kanban, 5S, Poka Yoke, and total productive maintenance (TPM) are a few of the tools used in lean manufacturing. To advance the Lean Six Sigma framework, the majority of researchers have added Lean manufacturing tools with DMAIC of Six Sigma (Kumar et al., 2006; Natarajan et al.,

2011). This has served as the basis for creating a synergy between the Six Sigma and Lean concepts. When compared to implementing Lean and Six Sigma independently, the advantages of executing the Lean Six Sigma program have grown as a result of this foundation. These advantages have helped businesses and organizations who have adopted Lean Six Sigma.

India's manufacturing sector contributes significantly to the country's economic growth (Singla et al., 2019). Many nations around the world are successfully improving their nations by boosting their industrial sectors. On the list of those developed nations, India is also rising. Although India was once classified as an under-developed country, its current status as a developing country can be attributed to the growth of its industries (Raj et al., 2019). The economy is strongly supported by the manufacturing and industrial sectors. The manufacturing sector is primarily separated into three sectors: heavy industries, micro, small, and medium-sized businesses (MSME), and the automotive industry. The heavy and automotive industry is large corporations and has sufficient resources for development. However, it is still necessary to improve the MSME sector. There is a wide range of LSS deployment in MSME in India in the manufacturing sector because it is not yet explored in the context of the Indian manufacturing sector.

2.4 Literature on Green Manufacturing

In recent years, a large number of studies on quantitative approaches in lean green practices have been published. For example, an approach based on a simulation to integrate slender and green practices into the production system was designed by Diaz-Elsayed et al. (2013). To deal with compromises between lean and green methods, Fahimnia et al. (2015) and Carvalho et al. (2017) offered various mathematical models. Thank you and Thakkar (2016) introduced a load diagram as a tool for evaluation of operating (slim) and environmental performance of the production system. Fercoq et al. (2016) provided quantitative analysis of the integration of slim green with an emphasis on waste reduction techniques in production processes. In addition, Sartal et al. (2017) examined how environmental and information technology affects lean approaches to improving the industrial sector.

Based on the available data, the objective to improve both production and environmental performance by slim approaches to reduce waste, reduce costs and increase efficacy (Qi et al., 2009). The more well-known lean approaches include Jidoka, mapping of values (VSM), control of the statistical process, Kanban, Kaizen, TQM, Time, 5S and Poka-Yoke (Folinas et al., 2014). Plenert (2007) and Abdulmalek and Rajgopal (2007) placed special emphasis on using VSM as a tool in lean production. According to NG et al. (2015), some scientists have developed methods that rely on VSM to improve lean and ecological performance. According to the authors, VSM enables visualization of production processes that emphasizes the areas of improvement. In addition, scientific studies have shown that VSM is effective in integrating lean and green (environmental) steering (Simons and Mason, 2003; Ng et al., 2015; thank you and Thakkar, 2016).

A paradigm for combining Lean, Green, and Six Sigma was presented by Banawi and Bilec (2014) in an effort to lessen the negative impact of environmental factors on building processes. Through a retrospective diagnostic, the framework's structure, which is based on the DMAIC approach, may decrease waste and was used in the construction industry for the installation process. Lean, Green, and Six Sigma methodologies was presented by Sagnak and Kazancoglu (2016) through empirical examination for validation in the applications, since it is only dependent on conceptual elements.

By combining environmental factors with LSS, Ben Ruben et al. (2017) created a framework for ongoing improvement. The DMAIC technique served as the foundation for the framework, which combined environmental aspects assessment tools with lean tools. The effectiveness of this approach has been evaluated in the automobile sector, yielding outcomes that the researchers had hoped for. The framework's primary drawback is that it only applies to the automobile industry and is completely inappropriate for small and medium-sized businesses (SMEs). An integrated Green and LSS model was created by Sreedharan et al. (2018) to enhance public sector processes.

The manufacturing industry is not a good fit for the generic integrated model. A paradigm based on the combination of LSS with the Green concept was presented by Sony and Naik (2020). The Lean thinking cycle and the DMAIC phase serve as the

foundation for the framework. The framework was put into practice in the mining sector using a few LSS fundamental tools. However, in order to increase efficiency and effectiveness, the framework needs further validation and the use of sophisticated tools and approaches.

An LSS model for lowering pharmaceutical mistakes in Thai hospitals was put out by Trakulsunti et al. (2021), although the study's approach was restricted to the same kind of scenario. In different research, the LSS approach used to minimize inpatient stays at the university hospital and had noteworthy outcomes. However, the research did not examine any environmental-focused tools in the model, nor did it provide a generic technique (Scala et al., 2021). A green LSS model for continuous improvement was put out in the context of SMEs, however it is unable to capture the model's real-time implementation (Yadav and Gahlot, 2022).

In a case study presented by Raman and Basavaraj (2019), the Six Sigma DMAIC approach was used to identify and analyze the several primary causes of the capacitors' deteriorating problems that impact industrial operations and to provide remedies. Gandhi et al. (2019) presented a case study of the casting cylinder block business, where the rejection rate of cylinder blocks is around 31%. The DMAIC approach of Six Sigma was then used to lower this rejection rate. In order to solve quality problems in the automotive parts manufacturing environment, Ani et al. (2016) used the DMAIC method of Six Sigma and quality tools. They found the necessary and appropriate tools based on the DMAIC model. This study was carried out at a bicycle component manufacturing company, and output of frame lugs was increased by the industry's use of LSS. In this research, we use a DMAIC technique to analyze the reasons behind component rejection and production loss, and we utilized LSS to enhance MSMEs.

Romero et al. (2012) used a strong technique that included DFC and SMED. The application was submitted to a small business. Planning, analysis, design, execution, and control for improvement were the five phases that were employed. The product (anvil), which was produced using a computer numerical control (CNC) machine, had a shorter setup time. About 70% of the time was saved when the setup time was cut from the original 50 minutes to 13 minutes.

Improvements in the efficiency of the manufacturing plant engaged in the production process were documented by Tilkar et al. (2013). The primary cause of the rise in downtime was setting downtime. To cut down on setup time, three production cells (B, NB, and E) were chosen. The manufacturing process flow was briefly reviewed and machine setup time was measured using the statistical data approach. SMED approaches reduced the mean time of failure. Setting downtime at the leak testing station was decreased from 315 to 195 seconds after the assembly line's use of SMED tools.

An ideal standard process for changeover operations was prepared by Raikar (2015) via research in the automobile sector. Both internal and external operations' time requirements are measured. The loading and unloading of the component took 70 seconds. The transition time was lowered to 24.5%, according to the results.

Because operational methods for large-scale businesses vary from those for small-scale industries, factory size is one of the criteria in the implementation of LM. Furthermore, this finding also holds true in the context of sustainability (Wu et al., 2015). Many international large-scale industries are setting up shop in India and expecting low-cost raw materials and finished or semi-finished parts from Indian manufacturing SMEs as the government of India works to expand the manufacturing sector through programs like "Make-In-India" (OECD, 2013; GOIMSME, 2015). Furthermore, SMEs must defy expectations and respect the efforts of larger industries by adopting some, if not all, of the LM and GM practices. This is because SMEs' managerial choices are heavily impacted by the strategies used by large industries to which they serve as tier I/II suppliers (Thanki et al., 2016).

With the goal of lowering PM10 concentrations from the industrial sector by 20–30% by 2025, the Government of India (GOI) started the "National Clean Air Programme" in 2019. Particulate matter with a diameter of 10 mm or smaller is referred to as PM10. According to the 2019 Health Effect Institute (HEI) report, high levels of indoor air pollution are to blame for the deaths of 1.2 million industrial workers in India. In addition to minor illnesses like headaches and eye irritation, poor indoor air quality (IAQ) can cause serious health issues including allergies and respiratory disorders. These conditions can create discomfort and distraction, which can ultimately result in

decreased productivity (Siegelet et al., 2019). This has encouraged manufacturers to include eco-friendly procedures and green production into their operations (Singh and Rathi, 2019).

Wu et al. (2015) examined the relationship between the triple lower line and the practices of lean-green-social (LGS) and concluded that the integrated LGS methods can achieve an optimal line. In addition, some research suggests that the administration of the supply chain and sustainability should be combined to improve the long-term performance of the organization (Shi et al., 2017; Wu et al., 2016). In order to gain a competitive advantage in the face of uncertainty, Wu et al. (2017) also identified important factors and created the Agility of the Supplier Chain.

While some research have examined beneficial links between LM and GM adoption (Dues et al., 2013; Hajmohammad et al., 2013), a part of the literature ended with the synergistic advantages of lean and green integration (Galeazzo et al., 2014). It is clear that a harmonic integration of lean and green manufacturing may be seen as a good step towards sustainability, since certain academic research have emphasized that lean techniques are partly green without the express desire to be green (Bergmiller and McCright, 2009b).

Caiado et al., 2021 proposed model was subjected to a test in actual production equipment. The finding shows that the proposed model can provide a reliable diagnostic tool for digitization companies. Abubakr et al. (Abubakr et al., 2020) discussed difficulties in integrating sustainable intelligent production performance in the manufacturing sector. Finding out the study shows that the idea of intelligent production has increased the quality of the environment.

According to Saxby et al. (Saxby et al., 2020), the lean manufacturing concept promoted continual improvement in Industry 4.0. Five industry quality professionals were interviewed in order to analyze the lean concept. The study's findings indicate that combining lean with certain other novel approaches might increase its flexibility. The Internet of Things framework was presented by Saqlain et al. (Saqlain et al., 2019) to facilitate online monitoring, smart manufacturing, and industrial control data. The study's findings demonstrate that by turning gathered data into actionable knowledge,

the framework may regulate manufacturing lines' productivity and outlook.

Gaspar et al. (Gaspar et al., 2021) surveyed the small, micro, and agro-food businesses to examine the technical potential of the Internet of Things. The study's findings show that there are a number of potential for Internet of things solutions, chief among them being the ability to measure and monitor production factors, which may assist managers in making accurate choices.

Garza-Reyes (2015) highlighted the paucity of research on LM and GM integration. Furthermore, in order to provide SMEs a straightforward route for effective adoption, Verrier et al. (2014) call for thorough research on the application of combined LM and GM.

Strategies like LM and GM are implemented effectively and efficiently in developed economies with strict rules and a clear roadmap. However, the majority of SMEs are unaware of this integrated strategy and are restricted by resources, therefore the adoption of such techniques is still in its early stages in emerging countries like India (Thanki et al., 2016; Thanki and Thakkar, 2014).

Regional culture along with policy and economic situation change from one country to another, and as a result, so does the success of implementation (Govindan et al., 2014). This forces industry professionals to develop lean and green implementation solutions that are particular to each nation. Numerous motivational elements, also referred to as "drivers," make it simple to implement LM and GM tactics. Accordingly, this research provides a ranking of the factors that have a major impact on the effective use of LM and GM in Indian manufacturing SMEs.

First, fifteen factors that contribute to the effective implementation of LM and GM were selected based on a thorough assessment of the literature and the views of experts. Moreover, multi-criteria decision making (MCDM) methods were used to prioritize these drivers. Multiple contradictory criteria are often compared and evaluated using MCDM approaches (Mittal and Sangwan, 2015).

The elements and characteristics needed for thorough, practical and sustainable improvement of environmental performance in the industrial sector are limited and closely focused (Skellern et al., 2017). The closure of this gap requires methods and

approaches that integrate, measure, control and improve productivity and environmental procedure (Muñoz-Villamizar, Santos, Viles and Amstabal, 2018). The combination of these strategies has many advantages for the current improvement of productivity and environmental performance over, on the other hand, over at that time.

According to Molina-Azorín, Tarí, Claver-Cortés, and López-Gamero (2009), these advantages include increased organizational efficacy and efficiency, preventing duplication of effort, goal, process, and resource alignment, as well as collaborative training and enhanced communication amongst all levels.

Additionally, Cherrafi et al. (2016), Sunder (2016), and Sunder et al. (2018) demonstrated that organizations can enhance the efficiency and effectiveness of any internal project, service, or process by integrating continuous improvement methodologies and/or management philosophies. This could also help boost revenue, cut expenses, and foster better teamwork. Lean production methods might be considered crucial instruments for implementing certain environmental principles in this regard (Alayón et al., 2017).

Logical integration of Lean Management with Green Paradigm and its methods and resources seems to be a system that finds and removes waste (ie everything that does not add value to customers) (Garza-Reyes et al., 2016). Lean Management is used worldwide (Folinas et al., 2014). It is considered one of the most important production paradigms (Forrester et al., 2010) and means to create chances for the development of production systems that are effective sources (Netland et al., 2015; Andersson and Bellgran, 2015).

Using less resources to get the same result is one of lean's objectives. Given that less resources are utilized in manufacturing and that waste, resource consumption, and pollution costs are all decreased, this is obviously ecologically good. Furthermore, there are shared implementation strategies between lean and green management systems (e.g., leadership, training, and continual self-assessment and improvement).

As Jiang et al. (2016) noted, the research to until has exclusively focused on efficiency calculations, ignoring the potential interplay between environmental efficiency and ideal productive efficiency. As far as we are aware, there aren't any

methods or instruments that specifically aim to combine and enhance environmental and productive performance. Additionally, the majority of methods concentrate on separate metrics like energy use or CO2 emissions. As a result, it is possible that the VSM tools' existing indications may not accurately link environmental conditions and productivity.

2.5 Background of Quality Management System

The world in which we live is becoming smaller every day. No, the planet is not becoming smaller, but because to ongoing developments in global trade and communications, components and goods may now be found anywhere in the world. If a company wants to stay competitive and not only survive, but flourish, cost reduction is essential. We need to find methods to perform things more effectively while producing less trash. Every action we do must contribute to the value of our goods and services. Many businesses and sectors are now implementing lean strategies. We need to be able to assess and quantify progress if we want a lean program to succeed. A vital tool in the Lean arsenal, Value Stream Mapping (VSM) may help your operations become even more transparent. We can better understand the job being done, which procedures or process stages are generating waste, and which are really producing value by mapping a process.

The quality management systems and organizational performance is still up for debate in the research. In addition, several research examine whether organizational performance is impacted by the degree of process and quality management system maturity. This report presents a thorough evaluation of the literature on quality management and organizational performance from 2001 to 2023 in light of these shortcomings.

The development of quality management and standards across the globe has been the subject of several investigations and studies. The number of businesses obtaining ISO 9001 certification has significantly grown during the last ten years (Siazarbitoria, 2006). It should be mentioned that, despite their widespread use, these quality standards first gained traction in the European Union, which was the subject of the 2003 ISO reports.

According to Elg et al. (2011), businesses devote a great deal of time and attention to their quality management systems (QMS). It is crucial that QMS helps the companies because of this (Lenning and Gremyr, 2017). The field pays more attention to the QMS potential to promote sustainability activities through integrated control systems or to improve environmental management systems using QMS lessons (Siva et al., 2016). However, this potential has not yet been fully realized and it is believed that more formalization and bureaucracy caused by certified QMS may be the reason why quality management sometimes makes it difficult rather than easier to implement sustainability initiatives (Allur et al., 2018; Barouch and Kleinhans, 2015).

QMS has been criticized for suppressing creativity, disconnected from real practice and offering little support to improve quality (Poksinska et al., 2006), with harmful impacts on process compliance (Gray et al. This criticism is valid, although QMS is not intended to support the environmental management system, but rather to focus on QM in general. However, it has been shown that QMS provides a basic and proven frame that can increase the value, increase the value of pure asset (Ochieng et al., 2015), supports constant improvement (Lenning and Gremyr, 2017), and improve the operational performance and quality of the product (Iyer et al., 2013; Kafetzopoulos et al., 2015). To guarantee that QMS contributes as much value as possible, the management and valuation of quality management work is essential (Beer, 2003; Dubey et al., 2018; Kafetzopoulos et al., 2015). In addition, the leadership must show and express that they understand the targets of QMS (Zelnik et al., 2012).

In early years, a notable growth in business was recorded and academic understanding of environmental challenges (Pipatprapa et al., 2017). Additionally, there is growing pressure on both small and big firms to improve their resource use and lessen their environmental impact. The effects of manufacturing processes on the environment are a major issue in the contemporary global market because of rules, non-governmental organizations, and consumer demands. The environmental performance is a commercial need, and environmental awareness has become a new competitive criterion (Garza-Reyes, 2015; Cherrafiet al., 2016). However, if certain economic aspects (such as the ratio of full income to full expenses) are not taken into account, the problem of how to adopt methods (i.e., planning and executing) that increase environmental performance may prove to be an expensive undertaking.

According to a number of studies, lean management may play a significant role in enhancing environmental performance in this situation (Cherrafi et al., 2017). Because lean and green methods both focus on waste reduction, there are really a lot of similarities between them. While environmental management focuses primarily on pollution in the form of air and solid and hazardous waste emissions, lean management focuses on waste because it concerns the process of inefficiency. Additionally, there are a number of instances when businesses have adopted lean and environmental policies extensively, often in tandem (Verrier et al., 2014).

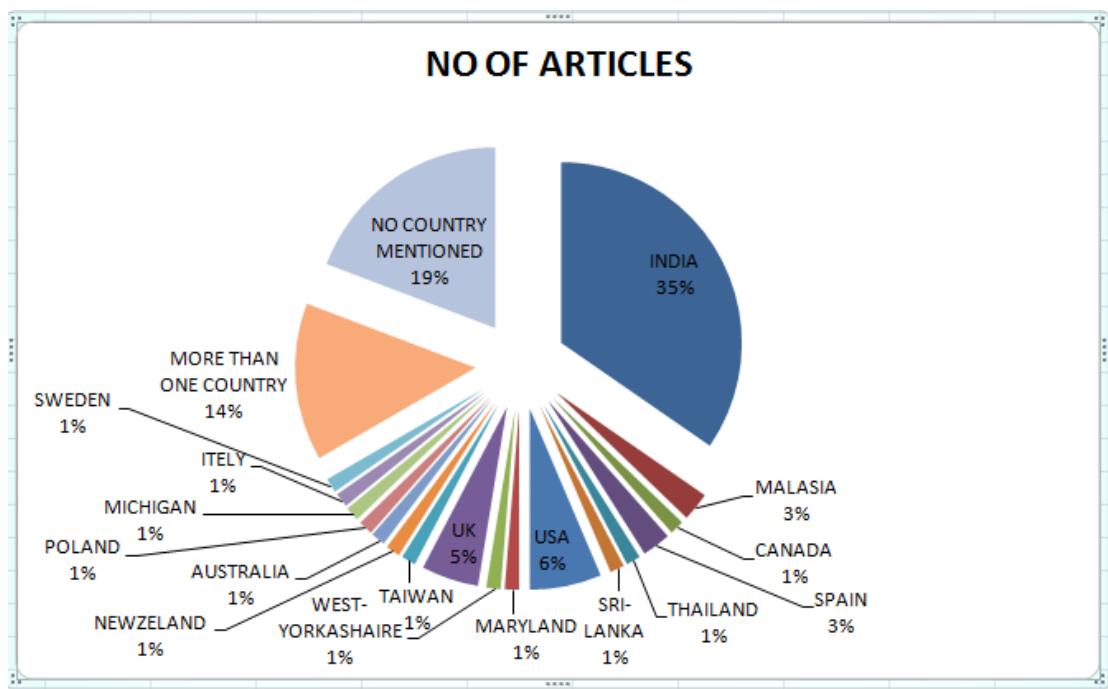


Figure 2.3: Countrywide literature publications (Pathak et al., 2017)

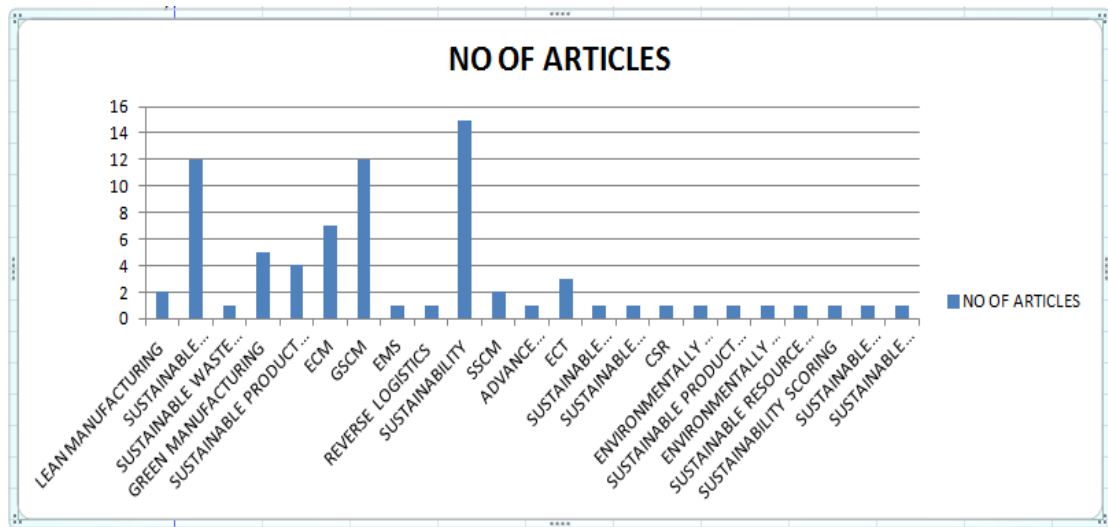


Figure 2.4: Number of articles based on various topics (Pathak et al., 2017)

Based on the many approaches to quality management that Maguad (2006) suggests, the study examines three different ways that QMS can be used as a tool for standardization and documentation, as well as for day-to-day management, and as support for improving the quality of an offering. This article aims to investigate the relationship between management's views of quality management in terms of cost, strategic relevance, and respect and these three distinct applications of QMS. The certified QMS is the subject of this study. According to ISO 9001:2015, a The QMS is a part of a quality management system that is built on a number of interconnected or interacting organizational components to set up the operation, organization, policies, goals, and procedures to accomplish those goals. Therefore, such an elemental system may be seen as a tool and assistance to achieve an organization's goals. Methods, results, and a discussion of the findings are presented in the section that follows, which also provides some background information on the three ways that QMS is used. Lastly, conclusions are made. Despite the fact that many businesses have adopted these kinds of procedures, managers still need data-driven indications to guide their choices (Domingo and Aguado, 2015). As a result, their businesses either do not take advantage of environmental management's potential or are still hesitant to implement environmental reforms. Furthermore, many businesses may not even have an environmental management system, while others are content with only having one via a certification like ISO 14001 (Ormazabal et al., 2018). Muñoz-Villamizar, Santos,

Viles, and Ormazábal (2018) contend that a metric of environmental efficiency must be included with productivity. To accomplish that, however, businesses must first adopt suitable strategies for combining environmental performance with productivity. Companies that pursue environmentally friendly performance face a number of obstacles, but they also have the chance to stand out in the market because of enhanced brand recognition and more trust in business partnerships (Lintukangas et al., 2015). But we still don't completely understand the factors that influence environmental efficiency (Jiang et al., 2016). Companies must use new and creative methods in response to the growing environmental concerns, since they cannot react with traditional economic or narrowly focused tactics (Skellern et al., 2017).

Loughton (1997) investigated the motivations for ISO 9001 certification as well as the advantages that enterprises experience to adopt for main reasons. The development of efficiency and quality is an internal element. The second is marketing-related or external factors. They also come to the conclusion that ISO 9001 certification is a useful starting point for quality improvement for certain firms.

Research on the impact of ISO 9001 deployment on production characteristics and competitive priorities was conducted by Tufan Koc (2006). A sample pool of 106 SMEs was analyzed for this purpose, and 79 of them adopted ISO 9000 standards. The results demonstrate that the performance of certified and non-certified enterprises is significantly impacted by the application of ISO 9000. Analyses of production factors and competitive objectives also show similar findings, suggesting that businesses profit greatly. The researcher examines seventeen manufacturing factors in this study, such as machine setup, production planning performance, product design, manufacturing time utilization, etc. To examine the effect of improving production metrics on real company performance, they are contrasted with competitive priorities. The researcher has adopted quality, cost, delivery, and product adaptability as competitive criteria.

The conundrum regarding the efficacy of ISO 9001, the controversy surrounding it in the literature, and the nearly exponential rise in certifications among businesses worldwide served as the impetus for Borut Rusjan and Pavel Castka's (2010)¹² conceptual study. Researchers believe that in order to comprehend the outcomes of ISO 9001 implementation, we must step back from empirical research and

attempt to examine ISO conceptually while simultaneously considering the outcomes of previous empirical investigations.

Durai Anand Kumar and Balakrishnan (2011) carried out study on the causes of ISO 9001 Certified organizations' failure. They investigated the QMS-certified companies in the United Arab Emirates and determined the possible causes of ISO 9001-certified companies' failure. Despite the fact that ISO 9001 certification is a strong framework for managing quality systems, the study's findings showed that those certified organizations had common gaps that could be divided into four main categories: a) Leadership-related issues; b) Strategy-related issues; c) Quality system-related issues; and d) Social responsibility-related issues.

Eight of the nine theoretically evaluated constructs showed a significant association that affected the system's overall performance. Only four of these eight important components are specifically mentioned in the ISO 9001 Standard. This study assessed the efficacy of Quality Systems, despite the fact that there have been around 15 research studies conducted on the same topic globally to far. Additionally, it will bring value and vitality to the Quality Management System (QMS).

Furthermore, Psomas and Pantouvakis (2015) demonstrated that management system does have an impact on service quality. Business management-oriented quality, they said, requires an integrated strategy implementation and focus on key success criteria, such as the company's vision, markets, and core operations. Additionally, it calls on all staff members and upper management to participate in ongoing improvement initiatives.

Sadikoglu and Zehir's (2010) study has found that all the procedures they looked at - fabric, employee management, continuous improvement, information and analysis have led significant and positive correlation with employees' measures, innovative performance and performance. As shown in the case of health and safety in the workplace, QMS has an impact on employers and employees in addition to the effectiveness and caliber of goods and services (Levine and Toffel, 2010).

Additionally, Levine and Toffel (2010) demonstrated that businesses that obtained certification had a much faster increase in revenue and employment than those

that did not get certification. Therefore, the authors made the case that management need to value an ISO 9001 certification. One element that has received attention in relation to participation in different quality efforts is the initiative's clear ability to meet a perceived and current need. For instance, the initiative's training and organized deployment should be provided just in time to allow for direct practice in response to an urgent requirement (Lee, 2004).

In another study by Moolna Kawthar and Sannasee Raja Vinesh (2011) evaluates the effect of ISO 9001 certification on Mauritius company sales and aims to determine if the average revenue from sales of ISO-certified enterprises are appreciably higher than those of their non-certified counterparts. The results show a favorable and strong correlation between ISO 9001 certification and sales, as well as a significant difference in the mean sales of the two groups (in favor of the certified enterprises). Additionally, this favorable link is confirmed by the dynamic panel analysis. Therefore, it can be said that Mauritius' ISO-certified businesses gain from their certification by seeing a rise in sales, which also suggests a wider client base and more consumer loyalty and trust. According to the study's findings, sales as well as ISO status have a positive and substantial ($z\text{-value} = 2.10$) association, indicating that ISO certification increases sales.

Since it serves as a common foundation for a QMS, the standard of ISO 9001 quality management system is now widely used (ISO Survey, 2018) and a major topic in quality management research (Carnerud, 2018). According to some, ISO 9001 may help with both operational performance (Psomas and Pantouvakis, 2015) and improvement in quality (Sousa and Voss, 2002). However, it is stated that a variety of elements, including attitudes of management and goals (Willar et al., 2015), as well as maturity of quality management, strategy for implementation, and personnel participation (Poksinska, 2010), determine the value and impact of a QMS.

It is also claimed that QMS implementation motive affects how well the system is doing. Organizations that prefer to improve quality and organizational needs benefit from their implementation of QMS in areas such as quality and operational improvements than organizations that implement and seek to certify their QM for external reasons such as image or customer requirements (Boiral and Amar, 2009; del

Castillo-PECES et al. 2009). Accordingly, a QMS that is put into place in response to external constraints tends to prioritize control and compliance above organizational effectiveness (Alic and Rusjan, 2010). Three distinct approaches to dealing with QMS will be described in the section that follows. The three approaches are based on Maguad's (2006) contention that quality in the twenty-first century might be divided into three groups according to orientation: compliance, improvement, and business management. Nonetheless, it is argued that for an organization to succeed in producing high-quality work, all three orientations must align.

The quality of the management system and the process both affect the final product's quality. Continuous improvement of the quality of goods and processes would not be effective if management did not offer sufficient resources and engagement in improvement efforts. Performance was not directly impacted by quality management system certification. The results showed that certified firms' procedures were greater than those of non-accredited companies. The ISO 9001-based quality management system and the five S's have commonalities in that they both allow for the integration of improvement tools.

In order to create a QMS based on ISO 9001, those firms implemented the 5'S, which have the highest productivity and best quality. 5'S is a technique for development and organizational progress. It increases productivity, quality, teamwork, employee participation, and work flow, all of which boost competitiveness. It may be integrated with other quality tools, such ISO-based quality management systems. Through a safe environment, the 5'S strategy reduces waste and organizes a workplace for productivity. The shadow board's examination of the 5'S implementation shows how to operate effectively while cutting down on tool search time. This method enhances productivity, equipment searches, and the working environment.

A pragmatic research on the "Real Quality Practices" of manufacturing industries in Gujarat was conducted by Jaina and Samratb (2015). They come to the conclusion that the majority of firms (94.44%) either have facilities for quality checking in-house or have third-party testing labs or their suppliers do so. Production staff are allowed to communicate with upper management and have the authority to halt the production line in the event of any quality-related problems. In-process quality

assurance practices are seen as a shared responsibility of the quality and production departments. However, communication between manufacturing staff and suppliers and consumers is discouraged. This demonstrates that employee trust is subordinated to secrecy.

Production workers are permitted to halt the line if there is a quality-related problem, but quality training is disregarded. Customers are requesting Third Party Certified QMSs at a rate of 70.01%. 83.34% of respondents agree that consultants are necessary for the implementation of QMS. Sincerely, staff members are interested in resolving customer complaints. It was discovered that 32% of respondents were not responding to customer concerns. The researchers come to the conclusion that internal and, most crucially, managerial levels of the organizations play a key role in the effective adoption and use of quality in the sector.

Yahia-Berrouiguet, Mankouri, and Benarbia (2015)²⁴ This research examines how management perceives the impact of ISO 9001 certification on the performance of the Beni Saf organization. The findings showed that Beni Saf Company's performance is positively impacted by the ISO 9001 certification. The primary benefits were those associated with marketing, whereas the benefits pertaining to human resources held the lowest place within the organization. It seems that the degree of each ISO certification advantage varied. As per the study, the main advantages are "increasing sales" and "increasing market share." This could be explained by Algeria's growing need for cement products, particularly as a result of the government's accomplishment of development plans, which necessitates that suppliers implement an effective quality management system.

Researchers also discovered that the lowest benefits were "better relations management/employees," "improved employee training," and "enhanced internal communication." This could be explained by the company's management looking for immediate benefits from ISO 9001 certification and human resource development. As a result, Beni Saf Company's HR management is not significantly impacted by ISO certification.

Companies enhancing their performance towards environmental will benefit from a number of factors, such as the ability to charge more for their eco-friendly

products, an improvement in their company's reputation, the opening of reputed markets, and a competitive advantage, claim Carvalho et al. (2017). According to Duarte and Cruz-Machado (2017), environmental management has become an approach that aims to improve an organization's operations' environmental efficiency and lessen the adverse ecological impact of its goods and services, all while meeting its financial goals. The QMS Standard is becoming more widely used, and scholars largely agree that putting it into practice might have a number of advantages, including better performance and outcomes. Research has shown that internal motivation produced superior outcomes compared to external incentive.

A project activity's economic, environmental, and social factors are identified by the environmental evaluation of aspect-impact, which also discloses any prospective environmental effect (Singh and Rathi, 2024). Using the most recent manufacturing processes, Indian firms produce a wide range of goods (Singh, Rathi, et al., 2023). This, however, ignores the part that aspects-impact play both during and after manufacturing, leading to a number of environmental problems. If environmental risks are adequately managed by qualitative and quantitative technique for aspect-impact assessment, plant installation and commissioning may be both safe and ecologically sustainable (Singh et al., 2024).

Existing surveys of the literature have looked at a variety of viewpoints about the relationship between manufacturing and sustainability. This covers SM (Eslami, Dassisti, Lezoche, & Panetto, 2019; Gbededo & Liyanage, 2018; Gbededo, Liyanage, & Garza-Reyes, 2018; Lee et al., 2019; Zarte, Pechmann, & Nunes, 2019), green manufacturing (Pang & Zhang, 2019; Paul, Bhole & Chaudhari, 2014; Shrivastava & Shrivastava, 2017), technological application perspectives for SM, and design for SM (Ahmad et al., 2018). These review studies failed to provide a comprehensive paradigm of the study topic since they mostly used qualitative methodologies to analyze the body of current literature (Pang & Zhang, 2019).

Researchers tried to investigate the knowledge relevant to the connection between manufacturing and sustainability using both qualitative and bibliometric analytical approaches (Pang & Zhang, 2019). However, recent studies have also brought attention to the dearth of thorough techniques for SM literature analysis

(Gbededo et al., 2018). Few studies, as far as we are aware, use both qualitative and quantitative methods to link the fundamental works in SM. It is demonstrate the evolution of SM literature. In order to pinpoint its flaws and, as a result, provide a solution, it is crucial to evaluate the practice and research done in the SM field up to this point critically.

Because the lean approach has been shown to be effective in resolving nearly all production issues, prior researchers have valued its application in production management (Barbosa et al., 2014; Lu & Yang, 2015; Mwanza & Mbohwa, 2015; Rohani & Zahraee, 2015; Santos et al., 2015). According to evaluated study, management team members encountered a number of issues while attempting to use the lean concept to oversee operational performance in Industry 4.0. The authors suggested that combining strategies such as lean manufacturing, smart manufacturing, the Internet of things, and green manufacturing to get rid of these issues (Buer et al., 2021; Choudhary et al., 2019; Li, 2019; Zhu et al., 2020). The research' findings demonstrate that production management systems that integrated techniques produced greater levels of operational excellence. They also demonstrate that even in Industry 4.0, integration of approaches was possible to provide operational excellence.

The environmental waste is a big issue for industry in recent years (Thanki et al., 2016). By removing environmental waste, green manufacturing helps to overcome these issues. Understanding the origins of nonvalue-added activities in the manufacturing is made easier by the green concept (Mishra, 2022). Even while implementing the green idea in industries has produced noticeable gains, the industry does not completely embrace the concept because of its high limitations, which only allow for a limited increase in productivity. On the other hand, incorporating the green idea into operation management boosts industry competitiveness and sustainability while also benefiting industry personnel (Bhattacharya et al., 2019).

The use of lean technologies that are appropriate for MSMEs has been studied and documented by several writers (Rose et al., 2013). However, compared to big firms, there is a dearth of study on Lean in MSMEs. These studies generally suggest that SMEs are more selective than big firms when it comes to using lean methods (Hu et al., 2015). Due to time, money, and technological limitations, SMEs have been choosing

simple, low-cost lean tools (Mathur et al., 2012). Several technologies that are widely used and discussed in the SME lean literature include Value Stream Mapping, Kanban, 5S/6S workplace structure, standardized work, and TPM (Hu et al., 2015). Some lean tools that are primarily used in big organizations are not well-liked by SMEs (Bhasin, 2012). Internal production or operations, with the primary goal of reducing shop floor waste, are the most prevalent areas of lean implementation in SMEs.

Manufacturers adopted sustainable manufacturing techniques due to regulatory changes and strong statements from many stakeholders. Recent studies have acknowledged that lean approaches significantly impact industrial sectors' ongoing performance improvement accomplishments (Yusup et al., 2015). In tandem, scholars have begun incorporating lean concepts into manufacturing's sustainability elements. Lean implementation, however, has mostly been focused on big, international corporations, with MSMEs putting up less effort in this regard.

It is well known that MSMEs are the most crucial factor influencing the social and economic advancement of the majority of economies worldwide. In order to succeed in the cutthroat business environment, MSMEs must balance their strengths and shortcomings. They are seen as the foundation of a huge organization, but not as its microcosm (Islam & Karim 2011; Antony et al., 2005). Therefore, integrating MSMEs' competitive advantages into sustainable development would encourage the industrial world as a whole to make social, economic, and environmental contributions for both the current and future generations.

Clancy et al., 2023 studied that the Six Sigma DMAIC methodology was used to digitise their operations, enabling data-driven quality improvement to reducing waste in manufacturing operations and achieve improved supply chain management performance. The findings of the study by (Liu, J. et al., 2024) indicates that the green manufacturing of machining process applied for energy efficiency improvement and thus reducing cutting fluid for environment protection.

The findings of (Hegedi'c, et al., 2024) show that lean tools positively influence economic and environmental indicators. The decision-making model, tailored to chosen criteria priorities, was successfully validated using simulated and real company data, which makes it a potentially valuable resource for companies navigating integrated lean

and green methodologies.

The findings of (Ghasemibojd, et al., 2025) highlighted that Green Lean Six Sigma (GLSS) contributes to both efficiency and environmental performance, its adoption is constrained by the absence of standardized sustainability metrics and empirical validations. The study further emphasizes the need to integrate GLSS with Industry 4.0 technologies and Circular Economy models to address future sustainability challenges.

Virmani et al., 2025 demonstrated that Lean Six Sigma integrated with Industry 4.0 technologies, when evaluated through the Technology-Organization-Environment framework enhance operational excellence and competitiveness. However, challenges such as high costs, skill gaps, and organizational resistance highlight the importance of aligning Lean and Green QMS frameworks with digital readiness and contextual enablers.

2.6 Research Gap from Literature Review

Based on the systematic literatures review (SLR), the following research gaps have been identified.

- The lean performance studies pay little attention to the sustainable path and instead concentrate mostly on operational performances. The importance of the manufacturing MSMEs' performance and sustainable expansion was also highlighted by the evaluation. The lack of research on the lean and sustainability ideas in the manufacturing organizations, particularly MSMEs, was identified by this study. It is also noted that there is a lack of literature that uses the method to develop a model that connects lean and sustainability performance. Thus, this analysis identifies a glaring research gap that highlights the need for further investigation into the impact of lean-green manufacturing on sustainability performance as well as the potential for combining these ideas in MSMEs.
- The research has not yet thoroughly examined the effects of green initiatives in processes and products, which is not accountable to minimize environmental impact throughout the life cycle, and there are still few detailed assessments of how green manufacturing affects operations in small-scale industries (Liu et al.,

2024). This research vacuum is filled by the current study, which uses green manufacturing strategies to promote sustainable growth in small-scale enterprises in India.

- The current assessment highlights the absence of a unified framework for assessing the maturity level of the management system and the failure to take process management factors into account in organizational performance research. As stated in the study's subsequent chapters, such deficiencies will be filled in this investigation of quality management systems and organizational performance.
- Identification and analysis of Quality Management System with Lean Green manufacturing practices in engineering industry.
- Identification and analysis of rejection level in the manufacturing processes along with waste elimination strategies.
- To develop a model of Quality Management System with integrated lean green strategies framework for achieving the priorities of opportunities in engineering industries.
- With a case study, to evaluate the competence of QMS with Lean and Green practices for improving the engineering industry.

While a literature exists on Lean Manufacturing, Green Practices, and Quality Management Systems individually, the integration into a unified framework remains relatively underexplored. Prior studies have predominantly examined:

- Lean practices for waste reduction and efficiency improvement,
- Green initiatives for minimizing environmental impacts, and
- QMS frameworks for enhancing product quality, system, and standardization.

However, most of these investigations have addressed the three domains in partial combinations, often neglecting the synergistic effect that emerges when Lean, Green, and QMS are implemented together. Furthermore, existing studies tend to emphasize the economic and environmental dimensions (cost reduction, resource optimization, pollution control), while the social dimension a critical component of the Triple Bottom Line has received comparatively less attention.

Another notable gap lies in the empirical validation of integrated Lean, Green, and QMS frameworks across diverse industrial sectors. Much of the current research is either limited to case-specific contexts, which restricts the generalizability and scalability of findings. Additionally, there is limited discussion on the policy implications, managerial challenges, and long-term sustainability outcomes of adopting such a holistic framework.

Therefore, there is a clear need for research that develops and validates a comprehensive Lean, Green, and QMS framework that not only enhances operational efficiency and environmental performance but also incorporates social responsibility, thereby aligning with the Triple Bottom Line approach.

2.7 Objectives of Research Study

The following research study was formulated to achieve the intended outcomes:

1. To study the manufacturing processes aims to minimize the rejection level.
2. To study the waste elimination to optimize lean manufacturing.
3. To study the aspect analysis to enhance environment performance.
4. To study the implementation of Quality Management System with Lean and Green manufacturing.

2.8 Summary of Literature Review

The literature on lean and green practices highlights a strong conceptual and practical overlap, with both approaches emphasizing waste reduction, efficiency improvement, and value creation. Lean focuses on eliminating non-value-added activities to enhance process performance, while green practices concentrate on reducing environmental impacts and conserving resources.

Quality Management System emerge in the literature as a key enabler of this integration. Prior studies emphasize that QMS provides the structural foundation, process discipline, and performance measurement required to lean and green practices. By embedding sustainability objectives within QMS frameworks, organizations ensure consistency, accountability, and long-term adoption beyond short-term initiatives.

At the same time, the review highlights certain challenges and research gaps. Much of the existing literature has been tool-centric, focusing on individual practices rather than on holistic integration within organizational systems. Another gap lies in understanding

the cultural and managerial factors such as leadership commitment, employee engagement, and cross-functional team collaboration that determine the scalability of Lean and Green framework with QMS alignment.

Overall, the literature suggests that while lean and green integration is well-theorized, there remains a need for empirical studies that connect these approaches within QMS frameworks and explore organizational, cultural, and strategic dimensions. This gap provides the rationale for the present study, which aims to synthesize insights on Lean and Green framework alignment drives efficiency, sustainability, and quality management system.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Problem Formulation

This chapter aims at the model development for this research work. The theoretical foundation of the conceptual framework for the work has been outlined in this chapter. The constructs and the variables included in this theoretical model are identified and explicitly reported. The chapter starts with the description of the methodology adopted for this work. The selection of the appropriate and suitable method plays a significant role in any research work. This chapter also portrays the type of research, research framework, sample design, plans for the data gathering and the data analysis adopted for this work. The chapter ends with the conclusion of details of the model developed, identified constructs and variables in this model for further analysis.

The research problem is formed from the aspiration and vital necessity to improve on the conventional model of lean performance that espoused by the researchers so far. The existing lean performance models and studies concentrated on the effect of LMPs on operational, financial performances, mostly on large-scale industries.

There are very few studies that have focused on MSMEs to bring out the outcome of lean and green manufacturing practices (LGMPs) for performance of sustainability. The interrelationships among the sustainability performance produced by the LGMPs implementation in MSMEs are also unacquainted. Similarly, limited studies have been reported in the areas of linkage between lean operations and sustainability in MSMEs. Most of the prior studies on sustainability, considered lean, just as a means for waste reduction and the consequent benefits of environmental protection.

However, some prior studies have mentioned some of the broad areas of linkage between lean and sustainability in large-scale industries. There have also been many researches done in the above area – but predominantly in Western countries and Eastern

countries. The Indian context could be vastly different from these research conditions or could be similar. Only research can throw more light in this area. There is a need to identify all the relevant areas of linkage between lean practices and sustainability in MSMEs. The primary intention to certain the relationship between LGMPs and sustainability performances in Indian MSMEs. Hence, following research was proposed concerning QMS, sustainability and performance related to MSMEs under the light of Lean and Green Manufacturing practices (LGMPs).

Combining lean and green production techniques is a difficult and complicated undertaking. Furthermore, although a lot of study has been done on the use of lean and green manufacturing techniques separately, much more has to be done on how to combine them into a unified strategy. Furthermore, there have been contradictory findings in recent literature review research on the suitability of combining lean and green practices. On the one hand, some researchers advocate for their integration, claiming that they can complement one another and create a synergistic impact in which their flaws can be lessened and their strengths may be strengthened.

Although there are several studies for the relationship between quality and performance, the literature to date indicates that very little study has looked at the relationship between manufacturing performance in both big and small businesses and methods to quality adoption. Since these factors set MSMEs apart from large enterprises based on product quality and innovation, many empirical analyses in the past have also questioned the need to take into account other significant factors like industry age and size, annual sales turnover, and manufacturing technology when analyzing their association with quality manufacturing practices as well as performance.

3.2 Research Plan

The research, in general, comprises the search for knowledge (Kothari, 2004). According to Creswell (2008), “research is a process of steps used to collect and analyze information to increase our understanding of a topic or issue”. This process consists of three steps, namely raise a question, collect the relevant information or data to find the answer and suggest the solutions to the question for the advancement of knowledge

(Kothari, 2004). Descriptive research was chosen as the study's research design. One of the most basic types of research is descriptive research. It explains a situation and includes an investigation to gather facts with appropriate interpretation. The figure 3.1 represents a brief of the thesis plan, outlines the methodologies and tools used.

According to Kothari (2004), “primary goal of descriptive research is to describe the current condition of circumstances. It encompasses many types of surveys and fact-finding investigations”. A descriptive study is one in which information is collected without changing the environment. The survey method and case study method are adopted for this descriptive research work.

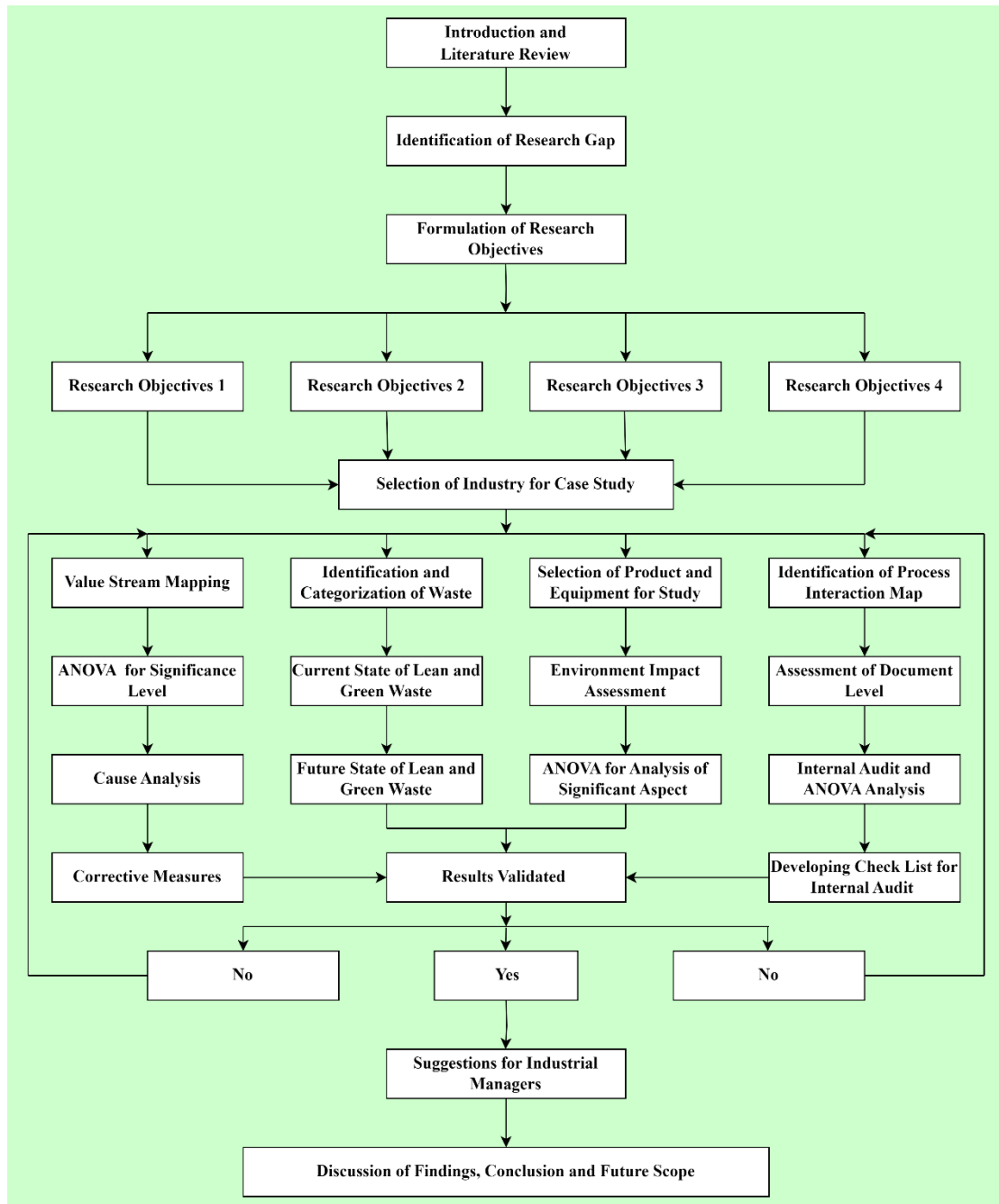


Figure 3.1 Research Plan

The selection of statistical tools was selected from the nature of the dataset and the objectives of the study. ANOVA was chosen over the comparison of mean value of defects and analysis of environment aspect to find the significance level based on the dataset included multiple independent variables which influence rate of defect and environmental performance. To ensure statistical validity, the assumptions underlying ANOVA were carefully assessed. The relationship between dependent and independent

variables factor was confirmed, and values kept within acceptable thresholds. The confidence level of ninety five percent was adopted to minimize Type I errors.

Sample size considerations were also addressed. The dataset comprised of multiple observations was taken for analysis of defect, stack emission and internal audit. This ensures sufficient degrees of freedom for reliable parameter estimation. Nevertheless, it is acknowledged that a larger sample size would increase statistical power and enhance the external validity of findings. Future research could therefore benefit from expanding the dataset across multiple operational cycles to further strengthen robustness and generalizability.

In this research plan, a detailed SLR on Lean Green manufacturing practice (LGMPs), Integration of LG framework with quality management system carried out to reap the research objectives. SLR utilize clear and definitive approach that consists different phases to ensure that preciseness and deep clarity can be collected in the Literature Review. From the comprehensive literature review, gaps in research work pertaining to Lean Green approach have been determined and the objectives of the research study are formulated.

In next phase, an engineering industry was selected as a case study for addressing the challenges in the implementation of quality management system with Lean Green approach and validating the developed framework. In spite of the progression of Lean Green manufacturing practices, industry managers were not confident to adopt this approach with organization due to readiness inadequacy and fear of failure. LGMPs are the prompt measures that give expression to an organization to execute progressive technique. The LGMPs not only influence the execution of LG within the company, but have an effect on each other as well. Therefore, it is essential to recognize an interactive relationship amongst LGMPs. For this, LGMPs have been identified using review of literatures and further tested by from the opinion of experts. To signify the contextual relationship, detail structural analysis using the ANOVA technique, data collection, brain storming with industry personnel had been exercised in this research work after mapping of the manufacturing processes.

The logical thinking for few advocations can be assigned to inadequacy of Lean

Green manufacturing integration and frameworks execution. For this reason, comprehensive integration of LG manufacturing practices was determined based on theoretically elements and framework rooted with LG tools was established. Conclusively, to validate the effectiveness of LG approach in measuring and improving various KPIs of LG manufacturing practices, the proposed framework was tested practically in a real-life in Industry. Based on the execution of LG approach in the case industry, inferences were extracted for the professionals, researchers, and industrial managers. This study is compiled with the detailed case study conducted in the industry. After the completion of study, the discussion on findings followed by managerial implication was conducted. In the last, this exhibits the concluded remarks of the study along with limitation and future research direction.

A framework was developed linking LGMPs with sustainable performance as shown in Figure 3.2. Lean manufacturing practices are the input parameters in this framework. In the transformation phase, basic lean performance leads the sustainability performance of the model.

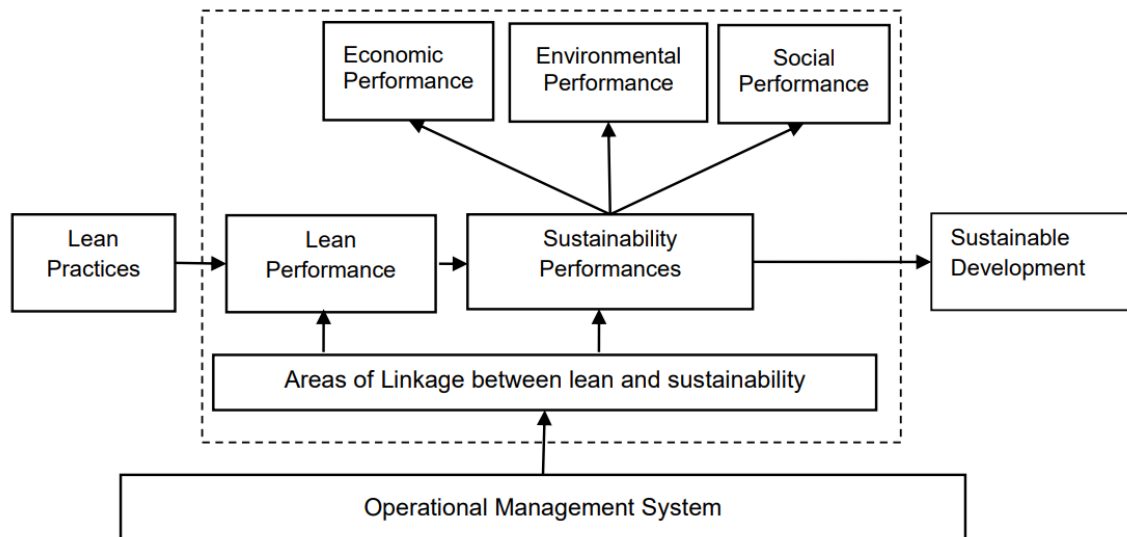


Figure 3.2: Lean Manufacturing Practices with Sustainability performances
(Yusup et al., 2015)

3.3 Lean-Green Tools

Lean-Green practices in MSMEs is an important step in resolving the concept's misconception (Lewis, 2000). SMEs are frequently hesitant to employ LMPs because

of the significant financial investment and consultation costs (Mathur et al., 2012). A lot of study on lean green methodologies was conducted on large companies. The analysis of the existing research on lean green practices in MSMEs reveals differing views regarding the significance of various lean green techniques.

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

- **Voice of Customer (VOC):** VOC is a powerful LG tool for gathering end-user opinions about the process and product, either internally or externally. A few key questions must be asked in order to obtain the answers through in-person interviews to use the LG integrated framework (Kaswan and Rathi, 2019). Finding out how customers react to the product should come first, and then consider any actions that might be helpful.
- **Brainstorming:** One tool for an improvement activity is brainstorming. Participants in this activity share their ideas as quickly as they come to mind, therefore it is done in a group setting. In the 1930s, Alex Osborne made the presentation. In order to quickly generate a large number of ideas regarding the causes of a certain issue or worry, this group activity incorporates immediate suggestions from individual team members. According to psychology, a group of people can contribute to the accumulation of new ideas, but the human mind's capacity as an individual is limited. This problem-solving method's main goal is to provide a critique-free atmosphere for innovative solution exploration. This method has the potential to uncover impulsive and passionate ideas. As a result, it can pave the way for creative and original answers to the issues at hand, as well as increased likelihood of the proposed ideas being accepted. Brainstorming provides quick answers, encourages team members to participate fully and actively, and makes them more likely to contribute ideas for new tools that could be improved.

Steps to Effective Creative Brainstorming are as follow:

1. Define the problem want to resolve.
2. Fine tune the goals.

3. Create as possible solutions.
 4. Examine the best solutions collectively.
- **Project Charter:** A project charter is a tabular representation of the project work plan. The table provides clear instructions and information on the project's goals, specifics, scope, benefits, shortcomings, tools and techniques to be used, schedule of project, and final product. This provides information on experts, suppliers, stakeholders, program coordinator, customers, project target date, cross-functional team members' roles and duties, and the start and end dates of the project.
 - **SIPOC diagram:** In the form of a Supplier, Input, Process, Output, and Customer, the SIPOC chart documents all the specific information pertaining to the entire manufacturing operational process of a given product from the point of origin to the end. This diagram works well for providing a thorough visual representation of the product, from the raw material to the finished product.
 - **Process Flow Diagram:** A process flow diagram (PFD) is a visual representation of sequence for related elements and process activities. Process flow diagrams help in process design communication and brainstorming. This visual graphic is really useful for comprehending the sequential tasks in the process and their corresponding results. Additionally, the instrument aids in understanding wasted outcomes, value and non-valuable activities, and current control mechanisms for improvement planning.
 - **Value Stream Mapping:** An important and crucial phase in the LG strategic initiative is process mapping. A flow diagram of each process step is deployed by VSM. VSM is a crucial tool for identifying waste, reducing cycle time or Takt time, and implementing process improvement. More significantly, charting the existing process is VSM's top priority. Investigating material flow and information in the existing state and seeing potential for improvement are made simple using VSM. The VSM process consists of four phases. VSM is a crucial tool that supports the evaluation process by pointing up important opportunities to reduce expenses, improve production flow, and reduce non-value-added time.

Rother and Shook (2003) state that VSM should be performed in the five phases as shown in Figure 3.3

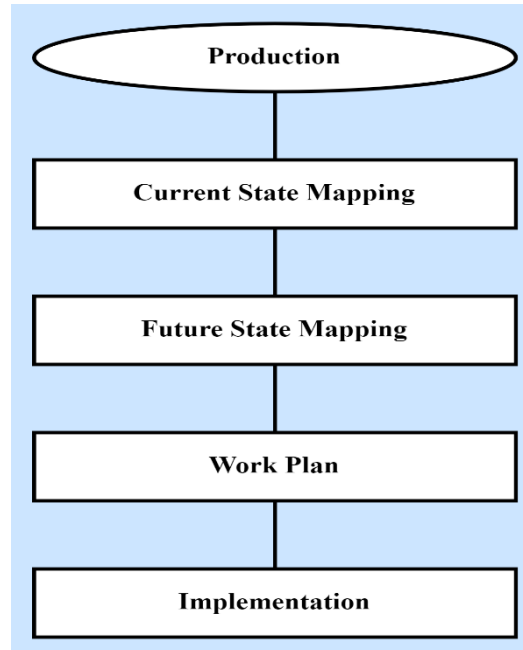


Figure 3.3: Process Flow for VSM (Rother and Shook, 2003)

First, a product family—a group of items that share equipment and manufacturing processes—is selected. A current status map of the selected product family is made in the second step. Applying the recommended changes to the future state map is the final phase. The arrows that connect the present and future state maps point in both directions to demonstrate that the two processes are overlapping undertakings. The work plan is described in the fourth stage, along with recommendations for how to execute it. Implementing the future state value stream map is the final stage.

Mapping is required to reconstruct the production line by VSM. It depicts the entire manufacturing process and waste in the value stream. This tool will look at the information and material flow as its main areas for improvement. Lean principles and practices is based on the application of VSM analysis. This study combines the concepts, procedures, and production flow principles from the schematic VSM. The link between information and material flows is a key component of the VSM tool. The phrase "supply chain value stream map"

describes a value stream map that is followed from suppliers to manufacturing or all the way to the final consumer.

- **Mapping of Environment Value Streams:** EPA (2007) proposed a value stream mapping event in the "lean-energy-toolkit" that explains how VSM allows the team to monitor and add data from energy consumed in each process while also gathering data from the process in its present form. Cycle time, change over time, and up time are the data gathered in the process of the current state. Having both process and energy use or waste statistics in the same chart is the main goal of this procedure.

The analytical team may work on future states and achieve efficiency using lean principles and energy-saving techniques with the help of Environment Value Stream Mapping (EVSM). According to EPA, the energy is utilized and added straight to the VSM process data box. By adding the average energy consumption or waste for each operation to the VSM and adding the cycle time for each process to the appropriate boxes, this strategy improves the VSM.

Kurdve et al. (2011) state that excessive resource use has been one of the main issues facing organizations, leading them to become more resource-conservative. Even if it is challenging to optimize the resources due to a lack of an appropriate assessment instrument, researchers confirm that manufacturers have engaged in very wasteful resource usage. According to Schmidt et al. (2007), the issue is described as follows: "The quantity and value parameters of material flows in the company must be recorded if possibilities for both material and energy savings are to be established within manufacturing enterprises."

- **Cause and Effect Diagram:** A C&E diagram is a visual aid for problem solving that is used to look into the potential causes of specific effects. This diagram's purpose is to quantify the quantity of flaws that are present in the process or product and to explain the true cause of those flaws. This figure shows several areas for identifying the root cause, including how the operational sector's problem statement is affected by man, material, method, and machine environment. Because it ultimately resembles the skeleton of a fish, the cause

and effect diagram is also more commonly referred to as an Ishikawa diagram or fishbone diagram. Figures and information are presented according to each attribute in this diagram, which creates actionable items.

- **Pareto Chart:** Pareto charts are often used to determine which regions should be prioritized for process improvement. The figure is based on the "80/20" rule, which states that for every occurrence, 20% of all causes (inputs) account for 80% of issues (outcomes or outputs). Through this analysis, the problem is graphically ranked from most to least recurrent. The pareto chart, which is a representation of a merged bar and line, is created based on research. The line diagram displays the cumulative value, while the bar displays the individual numbers. The Pareto chart makes it very easy to identify the most important issue.
- **5'S:** This Japanese practice, which keeps a clean and orderly workstation and removes any extraneous materials from the workspace, is used to improve the culture of a self-sufficient and self-sustaining workplace. the placement and organization of necessities such that they are convenient to find, utilize, and maintain. Sorting, Set-in-order/Straighten, Shine, Standardization, Sustain, Safety, and Sustainability are the acronyms for this seven-step approach. Sorting entails evaluating the workspace, getting rid of everything superfluous that is not needed for the task, and making sure that only the things that are necessary are present. To arrange the pieces, use set-in-order or straighten stands which remain after sorting, and take end users' opinions into consideration when making design changes that enhance quality. After working, putting everything in its proper place makes things run more smoothly and makes the workplace safer. Shine strives to maintain a clean workspace at all times and conduct routine inspections. For ease of traceability, the things used during the job should be returned to their original location at the conclusion of the project. Standardization is the process of using consistent, standardized working procedures to achieve desired outcomes. 5S or industrial housekeeping, enables the orderly and effective management of products to ensure their timely recovery and preserve a productive workplace (MSME

2013; Devadasan et al., 2012). It is the initial step toward lean thinking and the most basic and straightforward lean technique. "5S" stands for "sort, straighten, scrub, stabilize, and sustain," and it is a collection of five distinct processes. The most crucial part of this procedure is placing fixtures and instruments in their correct locations. This procedure lessens the waste that an unorganized workplace produces. These wastes include wasting of human time or machine time due to looking for a tool or accessories due to the unorganized workplace. By managing the workspace and workflow, getting rid of waste, and cutting down on process inefficiencies, this method can be utilized to achieve continuous quality improvement, continuous productivity improvement, and cycle time reduction.

- **Kaizen:** Kaizen is a Japanese concept and process-oriented approach that involves all employees in a business to continuously improve procedures and make them more robust. It is a top-down strategy that flows down to the level of the worker. It operates on the tenets of know your client, let things happen naturally, and visit Gemba and watch how things are done. Providing empowerment to working employees, continue to be transparent and crystal clear. It supports the idea that even minor adjustments can result in significant process benefits. It is utilized to achieve zero defects by management and worker thinking, scientific methods with the use of analytical tools, and minor adjustments to the current plant structure. It is an ongoing process that keeps getting better and lays the groundwork for new ideas.

3.4 Sustainability Performance Variables

The economic, social, and environmental performance of manufacturing companies is impacted by sustainable manufacturing practices (Dubey et al., 2015; Garbie, 2014). The impacts of lean toward the three aspects of sustainability were validated by the studies conducted by Thomas et al. (2012) and Wang et al. (2015). To determine the sustainability performance measurements of LMPs, the literature on lean-green manufacturing performance metrics in MSMEs as well as environmentally conscious methods is reviewed.

Through case studies in the automobile industry, examined the operational strategies, lean practices and green procedures to discuss whether lean and green practices were integrated and in accordance with the operational priorities of companies. We have found that companies use a number of approaches to operational strategies, taking into account operating objectives, decision -making areas that can change, and accepting slender and green techniques. Tested cases show different levels of adoption of lean and green production and integration lean and green methods. According to the study, the implementation of an operating strategy that includes the environment as one of the competitive priorities and includes the use of slender and green practices or the use of green procedures in production systems that have already accepted lean practices by demanding driving.

Analyzing lean methods on a single entity basis can be misleading because they are interdependent (Kim et al., 2012; Shah and Ward, 2003). Different scholars examined the impact of lean practices by classifying and analyzing them as internally consistent groups of practices. Numerous studies that examined the effects of lean bundles as opposed to the individual practices that make up each bundle can be found in the literature (Agarwal et al., 2013; Bonavia and Marin-Garcia, 2011; Rahman et al., 2010; Shah and Ward, 2003).

Although, previous research works have conducted factor analysis and assigned bundles/variables to latent constructs of LMPs and sustainability performance, there have been non-uniformity in the definition of bundles and their inclusion in constructs. In Indian context, attempts to define items and constructs of LMPs particularly in MSMEs have not been developed yet. Hence a factor analysis is to be conducted to identify the latent constructs and their composition of items in MSMEs.

3.5 Obstacles in Practicing Lean-Green Technologies in India

Implementing lean technology in Indian manufacturing sectors is hampered by a few key constraints in Indian organizations. R.O. Mohanty et al. (2007) state that the following aspects were noted:

- Power policy across different functional departments.
- Low investment in human resource development.
- Business executives' short-term interests.

- Most bosses have superficial opinions and quick fix expectations. However, international corporations have recently entered the Indian manufacturing sector and begun using lean principles there. Among the company's accomplishments are:
 - Cutting down on client lead times and cycle times.
 - Cutting down on stock.
 - Increasing output.
 - Cutting the price of materials.
 - Enhancing the supply chain's performance.
 - Successful networking with dealers and suppliers.
 - The workforce is multiskilled.

According to R.O. Mohanty et al. (2007), several studies have been conducted in the Indian manufacturing sector to use lean methods. Additionally, they must examine and restructure the company itself for implementation of lean methods in a sustainable manner.

3.6 Summary of Research Methodology

The research methodology adopted for this study combined a descriptive and analytical approach to examine the integration of lean and green practices within Quality Management Systems. Data were collected through a structured survey and semi-structured interviews with managers from selected manufacturing organization, supplemented by secondary data from reports and academic sources. A sampling method was employed to actively implementing lean, green, with QMS practices. The analysis involved both quantitative techniques such as descriptive statistics and ANOVA analysis to assess relationships between practices and performance outcomes and qualitative approach to capture managerial insights. This method design ensured triangulation, enhanced validity, and provided a comprehensive understanding of Lean and Green with QMS integration contributes to operational efficiency, sustainability, and quality system improvement.

CHAPTER 4

IMPLEMENTATION OF LEAN MANUFACTURING

The purpose of this chapter is to present and discuss the implementation of lean manufacturing related to objective No. 1 for the manufacturing processes aims to minimize the rejection level. Process mapping, SIPOC study, value added and non-value-added activities identified with the current state and future state value stream mapping was carried out. The ANOVA approach applied and root cause analysis find out to take corrective action. The further details of the study was discussed in this chapter to outcome the result.

4.1 Company Profile

Victor Forgings, Focal Point, Jalandhar, Punjab company is a medium scale industry which is manufacturing of hand tools. It manufactures majorly spanners of hand tools as well as other tools such as vices, pliers and wrenches.

The company has a competitive business environment with a flat level of demand. The company is certified to ISO 9001 – quality management system and ISO 14001 – environment management system. As the demand for the product is more than the daily production, the situation is not generating the overproduction or inventory of finished goods. At the initial time, the utilized capacity.

The production process flow diagram is prepared and documented to identify the process where rejection is generated during manufacturing. The inspection activity is carried out as per the inspection plan to follow the procedures and to control the rejection level.

4.2 Process Mapping

At present, the industry has embraced the utilization of advanced machinery since the onset of the industrial revolution in the eighteenth century. This era saw the introduction of numerous mechanical facilities on a global scale. To stay competitive in the highly dynamic market and optimize resource utilization, the manufacturing industry is rapidly evolving. The driving forces in the production environment are the need to keep pace with global competition and make efficient use of resources. Modern

companies are raising their standards by increasing awareness and incorporating recent technologies to enhance resource utilization. Small-scale industries like forging industry strive to enhance customer value, production efficiency, and scale, with the goal of evolving into larger organizations. This evolution involves the collaboration of owners, managers, and employees to serve a broader clientele. Given the constantly changing industry landscape, there is a demand for smart tools of continuous improvement approaches to enhance production efficiency. At this global industrial platform, Lean Manufacturing (LM) has become an emerging approach for improving overall company performance. Numerous studies have recognized the effectiveness of LM initiatives in enhancing company performance and operational excellence. Over the past decade, many organizations have either implemented or planned to implement LM principles and concepts in their running system. Some companies have adopted specific LM techniques, while others have embraced a comprehensive range of LM elements. LM encompasses various techniques that aim to achieve lean operations within manufacturing organizations. Value stream mapping (VSM) stands out as a suitable lean tool for fostering efficiency in production lines. However, it also has its constraints, as it forecasts system performance within a defined timeframe and under static production conditions, making it impractical for mapping multiple products. To tackle these challenges, the research aims to address the research study of possibilities to alter the conventional VSM to smart VSM for analysing the data in real-time scenario and to improve the production level of forging industry using smart VSM tool. The set research addressed to problem related to poor lead time and high defect rate of selected Indian forging industry. In this context, smart VSM facilitates the implementation of lean production principles by identifying value-added (VA) steps and eliminating non-value-added (NVA) waste. The unique aspect of the proposed smart VSM lies in its focus on practical implementation within the manufacturing context, specifically targeting defect reduction and lead time optimization. Unlike many advanced VSM tools that leverage complex data analytics and digital platforms, such as those offered by this model emphasizes a systematic approach to resource utilization and process improvement through traditional lean methodologies. While many modern tools provide real-time analytics and simulation capabilities, the interactive VSM model integrates these principles with hands-on techniques like SIPOC and cause and-effect

diagrams, making it accessible for operators and managers alike. This dual approach not only enhances understanding and engagement but also facilitates immediate application in manufacturing settings, ensuring that improvements are grounded in practical realities rather than solely reliant on sophisticated technology. Thus, it bridges the gap between advanced analytics and actionable insights in real world manufacturing scenarios. The Indian manufacturing industry offers significant potential for implementing lean practices, and smart VSM plays a crucial role in streamlining processes as the initial step towards LM adoption. It provides a comprehensive view of all activities, including NVA, and offers a visual representation of the elements in the process to satisfy the customer demands. Also, it motivates to managers and practitioners to re-assess the existing design, process, and inspection steps for continuous improvement in the existing manufacturing setting. Literature reveals that the study was conducted only on lead time reduction in case of metal tools factory where production performance improved by reducing lead times by 58.5% (Mullisa and Abdul-Kader). Lean implementation resulted in labour productivity, throughput, customer delivery, quality and change overtime in a MSME in a forging industry (Singh, M. and Rathi, R.). The study was conducted for only on implementation of lean initiatives to minimise defects in a forging industry using Taguchi's method of Design of Experiment and defects level significantly reduced. But the present study of lean manufacturing initiative for defect and lead time reduction is considered for addition of other tools with the help of smart VSM. The present study is being conducted in a manufacturing company located in North India to implement the lean principles using smart VSM in a forging industry. With increasing global competition, organizations face challenges in meeting customer demands for product quality, quantity, and cost. Prior to this research, only a few LM activities had been adopted in the organization. The present study demonstrates the application of smart VSM tool to minimize the defects of forged parts followed by Taguchi analysis. In the present case study, the hot forging process is selected due to its high defects rate and lead-time. Both the current and future state smart VSMs for hot forging are developed using smart VSM techniques. Additionally, statistical analysis is conducted to provide valuable insights.

The manufacturing process flow diagram is prepared and documented to

identify the process where rejection is generated during manufacturing. The diagram is presented in figure 4.1

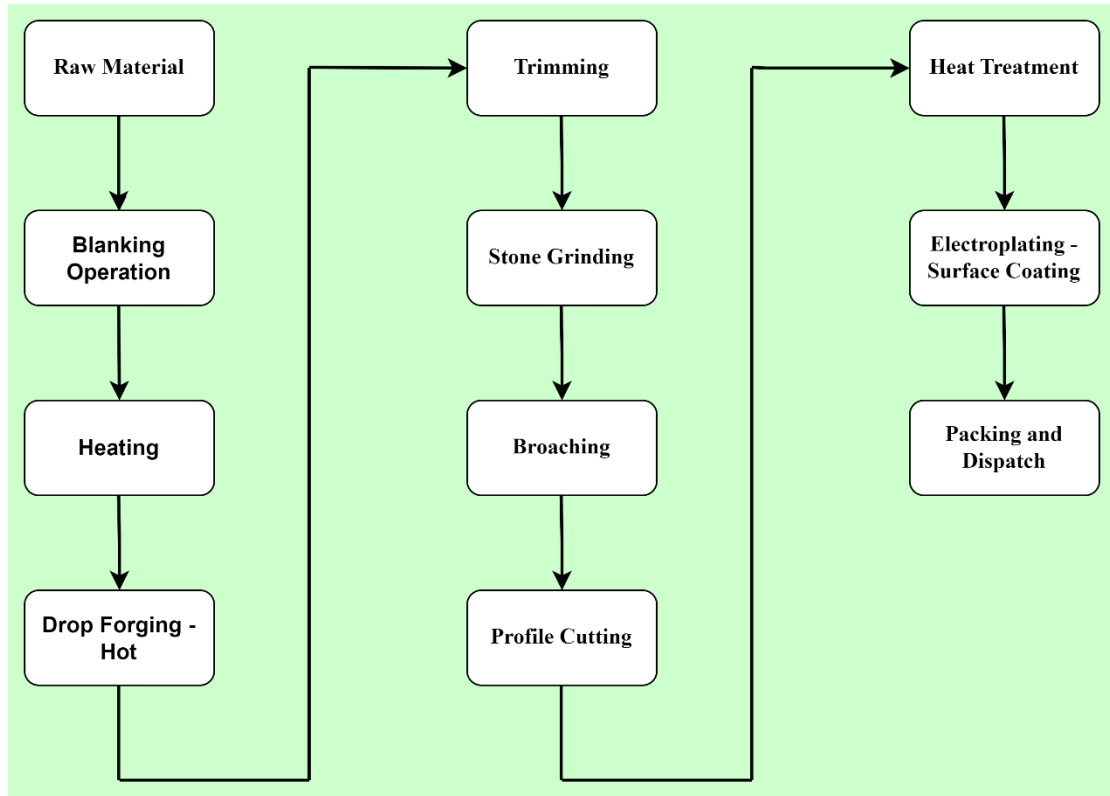


Figure 4.1: Manufacturing Process Flow Diagram

4.3 SIPOC Chart

SIPOC is useful tool and helps in identification of processes from supplier to customer which helps in improvements. In this table template, chart for hand tool spanners is prepared to indicate the process for visualization. The SIPOC chart is shown in Table 4.1

Table 4.1: SIPOC Chart

SIPOC Chart				
Supplier	Input	Process	Output	Customer
A	Orders from Customers	Inspection of raw materials	Forged Spanners of Hand Tool	X
B	Raw materials from suppliers	Manufacturing operations as per process flow diagram		Y
C		In-process and final inspection of components		Z
		Dispatch to the customers		

Explanation of SIPOC Chart

A SIPOC chart (Suppliers, Inputs, Process, Outputs, Customers) is a high-level visual tool used to map and understand business processes within the framework of Lean and Quality Management System. It provides a structured overview of how value flows through the system, from the initial suppliers of resources to the final customers receiving the outputs.

- Suppliers – that provide the resources, and raw materials required for the process.
- Inputs – The specific resources, and materials supplied that initiate the process.
- Process – A sequence of key activities performed to transform inputs into desired outputs.
- Outputs – The products generated by the process.
- Customers – The end users or beneficiaries who receive and evaluate the outputs, whether internal departments or external stakeholders.

In the context of Lean and Green with QMS, a SIPOC chart helps identify critical inputs, value-added and non-value-added steps, and environmental aspects within processes. It ensures clarity of roles, and provides a foundation for identifying inefficiencies, wastes, and opportunities for sustainable improvement.

4.3.1 Value added and Non-Value added activities at this Industry

The activities are identified as value added and non-value added as per the process flow chart. The activity which adds value in the process is said to have value added and those activities not adding any value are referred to as non-value-added activities. The purpose of categorization is to eliminate the process waste. Value added and non-value-added activities for the manufacturing of forging spanners of hand tool is developed which is shown in Table 4.2

Table 4.2: Value Added and Non-Value-Added Activities

S. No.	Process	Value-added (VA) / Non-value-added (NVA)
1	Blanking Operation	VA
2	Heating	VA
3	Drop Forging (Hot)	VA
4	Trimming	VA
5	Stone Grinding	VA
6	Broaching	VA
7	Profile Cutting	VA
8	Heat Treatment	VA
9	Surface Treatment	VA
10	Movement of components to Packing Section	NVA
11	Packing and dispatch	VA

4.4 Current State Value Stream Mapping

The objective of current state value stream mapping is to identify the processes and measure the current cycle time to make it value added with introducing the mechanized techniques. The current state value stream mapping is conducted for the production processes from forging, machining, heat treatment, electroplating and packaging where lead time to manufacture the final product is 9 days which is illustrated in figure 4.2

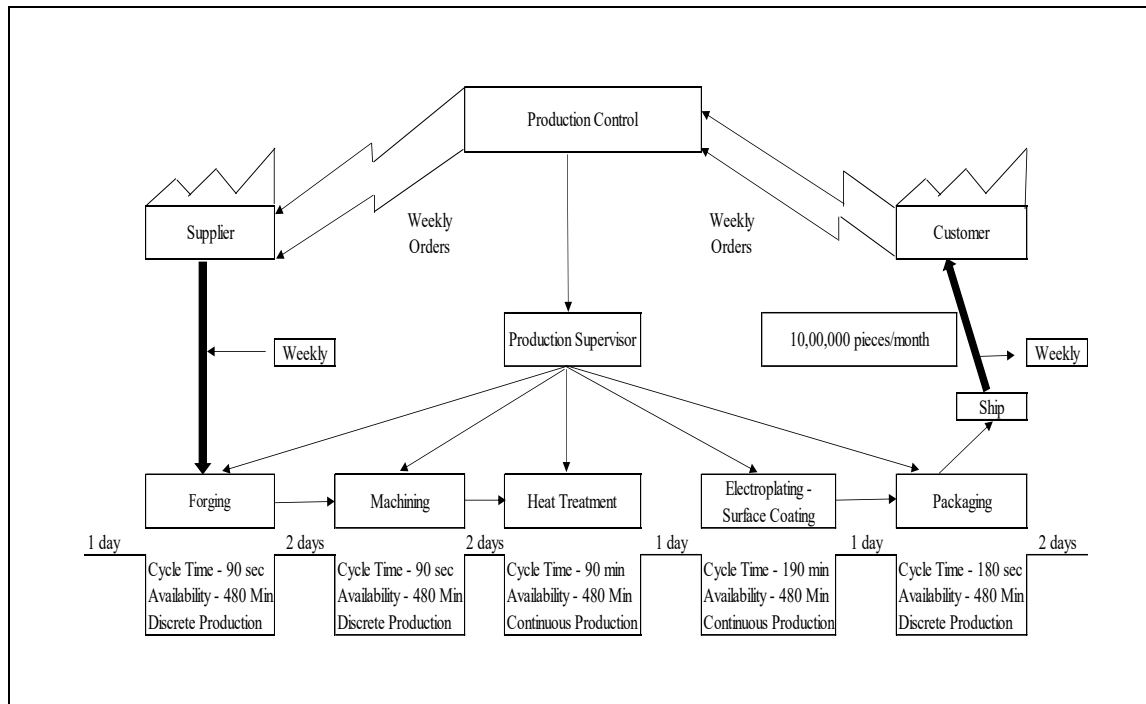


Figure 4.2: Current State Value Stream Mapping

4.5 Data Collection for Rejection Level

The present work deals with the objective of reducing of rejection level at forging operation. In this study, the rejection rate of forging operation was identified. During the production cycle it is measured that all the produced forged spanners do not conform to the required quality parameters. The rejection target of forging defects is 2.5% for the period of April 2020 to March 2021 and achieved average of 1.56% against the target set. Similarly, the target of forging defects is 2.0% for the period of April 2021 to February 2022 and achieved average of 1.24% against the target. There is implementation time given for the period of March 2022 to October 2022. After implementing the actions, the data collected for the month of November 2022, December 2022 and January 2023 where 26,85,894 pieces were manufactured in multiple machines and equipment and detail for the case study which is given in Table 4.3. The rejection rate was 1.09% wherein rejected quantity of 29491 pieces. Therefore, actual production was 26,56,403 pieces. The data for the study was collected from the production cycle of production and quality assurance department of the company.

Table 4.3: Data Collection of Forging Defects (November 2022 to January 2023)

Forging Defects - Nov 22 to Jan 23						
Defect	Nov-22	Dec-22	Jan-23	Total Pieces	Cum. Pieces	Cum. %
Crack	6349	5532	5663	17544	17544	59
Unfilled	3672	3672	1386	8730	26274	89
Scaling	581	581	644	1806	28080	95
Fold	342	342	244	928	29008	98
Twist	70	70	343	483	29491	100
Rejection Quantity	11014	10197	8280	29491		
Production Quantity	1044247	915991	725656	2685894		
Percentage of Rejection	1.05	1.11	1.14	1.09		

4.6 Data Analysis

It was observed from Table 4.3 which gives the rejection level of the item produced. From the table we can see the rejection level which is a higher rate and therefore the rejections must be minimized. The rejected quantity due to defects and percentage is shown in Table 4.3. From the table, we can find that crack, unfilled, scaling are the major causes for the rejection of the products. Even though 0.60% to 0.78% rejection is due to crack and average of 0.66% contribute for November 2022, December 2022 and January 2023.

Pareto analysis is prepared according to data obtained and from the Pareto Charts the major defects are highlighted as given in Figures 4.3. Hence crack and

unfilled defects detected from the chart which make up to 89% of rejection. These are studying the cause of defects for further analysis.

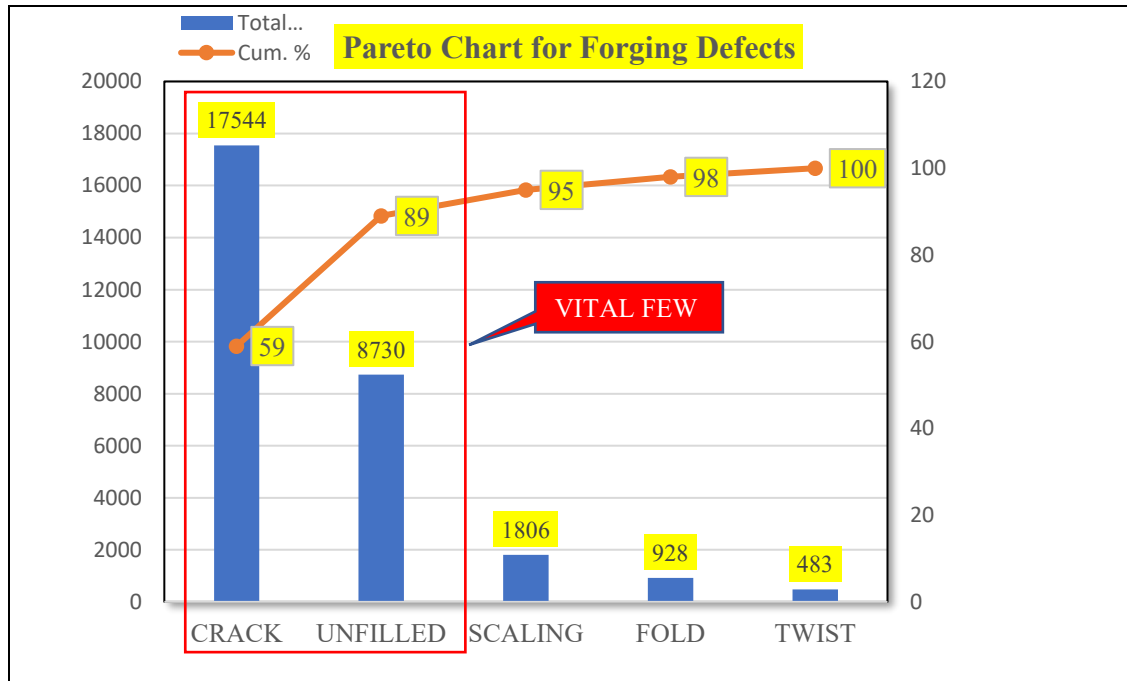


Figure 4.3: Pareto Chart of Forging Defects (November 2022 to January 2023)

Now the hypothesis is formulated to test the significance of forging defects between different months which is shown in table 4.4.

Null hypothesis, $H_0: T_1 = T_2 = T_3$

Alternate hypothesis, H_1 : Treatment means are not equal for at least one pair of the treatment means.

a = number of treatment (3)

n = number of replications under each treatment (5)

N = total of observations in the experiments ($3 \times 5 = 15$)

The defective number of pieces are mentioned against the defect in the corresponding month.

Table 4.4: Distribution of Defects

Dependent Variables ↓ → Independent Variables		November 2022 (Factor A1)	December 2022 (Factor A2)	January 2023 (Factor A3)	Sum
B1	Crack	6349	5532	5663	
B2	Unfilled	3672	3672	1386	
B3	Scaling	581	581	644	
B4	Fold	342	342	244	
B5	Twist	70	70	343	
Sum		11014	10197	8280	29491

The relationship between different sum of squares of this model is as follows:

Total sum of squares (SS total) = Sum of squares of treatments (SS treatments)
+ Sum of squares of errors (SS error).

$$SS \text{ total} = (6349)^2 + (5532)^2 + (5663)^2 + (3672)^2 + (3672)^2 + (1386)^2 + (581)^2 + (581)^2 + (644)^2 + (342)^2 + (342)^2 + (244)^2 + (70)^2 + (70)^2 + (343)^2 - (29491)^2 / 15 = 75,400,056.933$$

$$SS \text{ treatments} = (11014)^2 + (10197)^2 + (8280)^2 / 5 - (29491)^2 / 15 = 7,87,808.933$$

$$SS \text{ error} = SS \text{ total} - SS \text{ treatments} = 75,400,056.933 - 7,87,808.933 = 74,612,248$$

Table 4.5: Results of Forging defects with respect to month

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares (MSS)	F Ratio
Between treatments	a-1 (3-1) = 2	7,87,808.933	7,87,808.933/2 = 393904.47	393904.47/6217687.33 = 0.06
Within treatments (error)	N-a (15-3) = 12	74,612,248	74,612,248/12 = 6217687.33	

In Table 4.5, the value of the calculated F ratio is 0.06, The value of F ratio from statistical table for a significance level of 0.05 and degrees of freedom (2, 12) is 3.89.

Also,

F calculated [0.06] < F α = 0.05 and df = (2, 12) [3.89]

Hence, the null hypothesis (H0) should be accepted.

Inference: This mean that there is no significant difference in terms of forging defects between different months

Justification the reason to implement F-test:

1. F-test is used to test the significance of differences between two or more groups of data.
2. In ANOVA, means of all groups are equal in null hypothesis whereas in alternative hypothesis, at least mean of one group is different from the others. F value is used to find out that null hypothesis should be rejected or accepted.
3. F test is a hypothesis testing to analyze data variance in two or more populations.
4. F test is the ratio of source of variation to between treatments and within treatments.

Based on the inference of the hypothesis study, further analysis of forging defects was carried out. The methodology used for the analysis of root cause which include the man, material, machine and method. Brainstorming was conducted to find the possible cause and the following ideas were generated:

1. Insufficient heating
2. Inadequate training
3. Operational behaviour
4. Improper material cleaning
5. Die condition
6. Machine conditioning
7. Material specification variation

8. Thin flash

9. Improper die design

The cause-and-effect analysis is conducted for the major defects and given in the details. Root causes of these defects were found from the cause-and-effect diagram and corrective actions were suggested. The figure 4.4 presented the pictorial view of forgings defects.

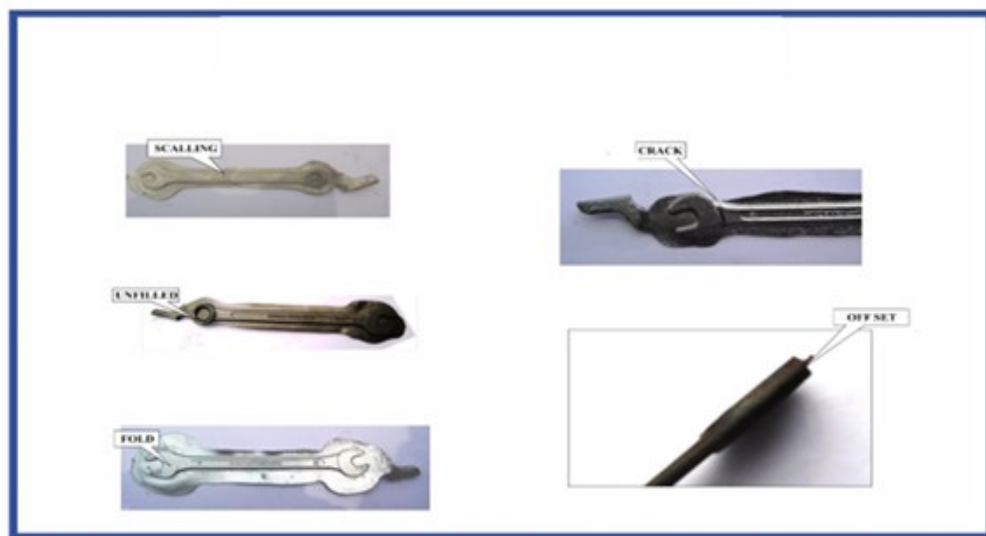


Figure 4.4: Pictorial View of Forgings Defects

4.7 Cause and Effect Diagram

Cause and effect diagram identifies possible causes for an effect and sort ideas into corrective actions. The analysis of data is mainly focused for continual improvement by cause-and-effect analysis through process improvement and identifying potential causes for rejection. The defects which are the factors for rejection are crack, unfilled, scaling, fold and twist.

The cumulative percentage of rejection due to crack, unfilled and scaling raises up to 95% which make to study the causes of these three defects more important which is identified in the Pareto Chart. All types of defects and causes were identified by brainstorming with the engineers and workers related to the forging production, quality assurance departments which is given in figure 4.5

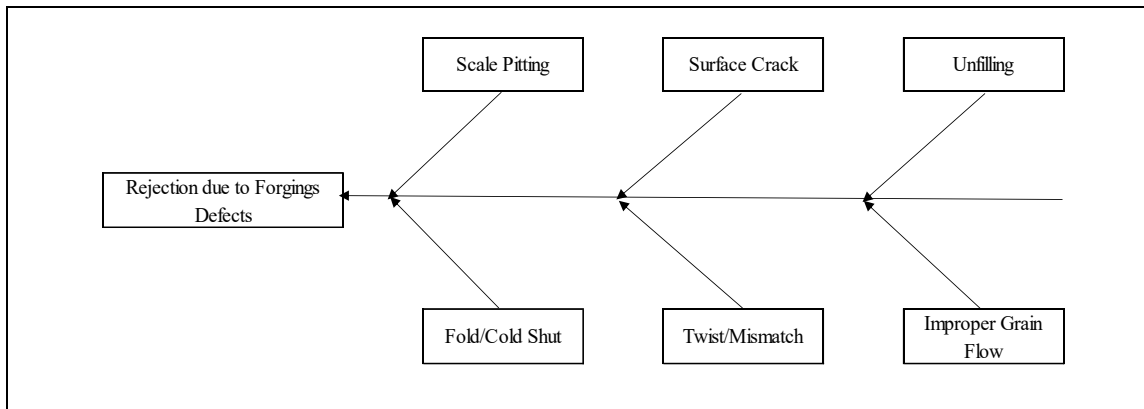


Figure 4.5: Cause and effect diagram for Defects

The cause-and-effect diagram was plotted and main causes were identified as in Figure 4.6. The causes which lead to the main cause was plotted and sub causes were identified. By brainstorming the causes for the crack are identified and corrective action suggested for improvement. Similarly causes for unfilling and scaling are identified and action suggested for the same.

- **Crack Defect:** This crack penetrates the interior after flash is trimmed off.

Root Cause: Excessive working on the surface and too low temperature. Variation of material specification and very thin flash.

Corrective Action: To increase the working temperature. To follow material dimensional specification and increasing flash thickness.

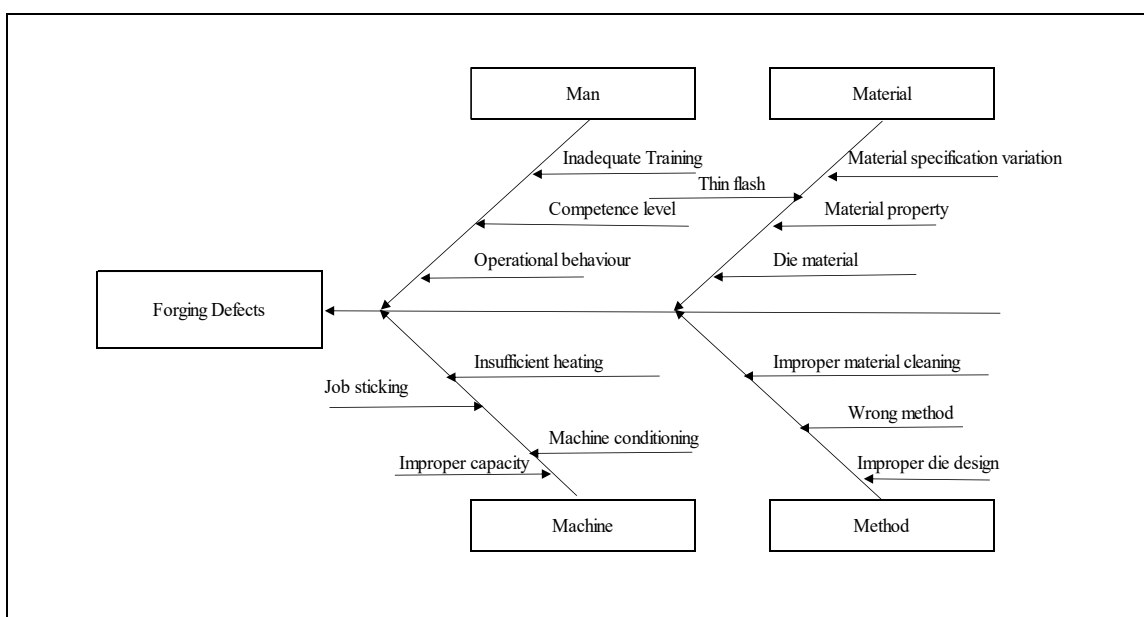


Figure 4.6: Cause and effect diagram for Causes

- **Unfilling Defect:** This unfilling defect occurs due to flowing metal not completely filled in die cavity.

Root Cause: Poor heating, improper die design, insufficient impact, variation of material specification, operator working behaviour.

Corrective Action: Heating temperature at required level, proper die design and machine conditioning and preventive maintenance. Operator training on productivity.

- **Scaling Defect:** Irregular depurations on the surface of forging.

Root Cause: Improper cleaning of the stock used for forging. The oxide and scale get embedded into the finish forging surface due to overheating. Die conditioning.

Corrective Action: Proper cleaning of the stock prior to forging. Polishing of die at defined interval.

4.8 Future State Value Stream Mapping

As per the customer rate of demand, the production orders being executed to supply the product on time. Lead time to manufacture the product was 9 days in the current state of VSM. After elimination of NVA and work flow improved in mechanized way of delay, down time and work-in-process. The lead time reduced from 9 days to 5 days for manufacture the product. There is improvement of 44% in lead time. The lean approach applied to reduce the lead time include single minute exchange of die, mechanized conveyor belt for handling of in-process material and design of trolleys. There is qualitative measures taken for recycling of waste heat on forging hammers which will save energy and reduce greenhouse gases for ecological sustainability. In comparison with the literature data of the same kind of study as referred for production of hand tool spanners on forging hammer where setup time reduced with SMED tool for change over time from 160 minutes to 124.40 minutes which was resulted in saving 36 minutes and contributed to 22.5% (Jaskaran Singh and Gurinder Singh Brar, 2017). While comparing this study with literature survey in the case of forging for crankshaft where it reveals that more than 84 percent of rejections attributed to forging defects with pareto and cause-effect diagram to un-filling only. After the preventive measures, the defect of un-filling would reduce from 4.45 percent to 0.8 percent (Solanki *et al.*, 2021). The future state value stream mapping is illustrated in figure 4.7

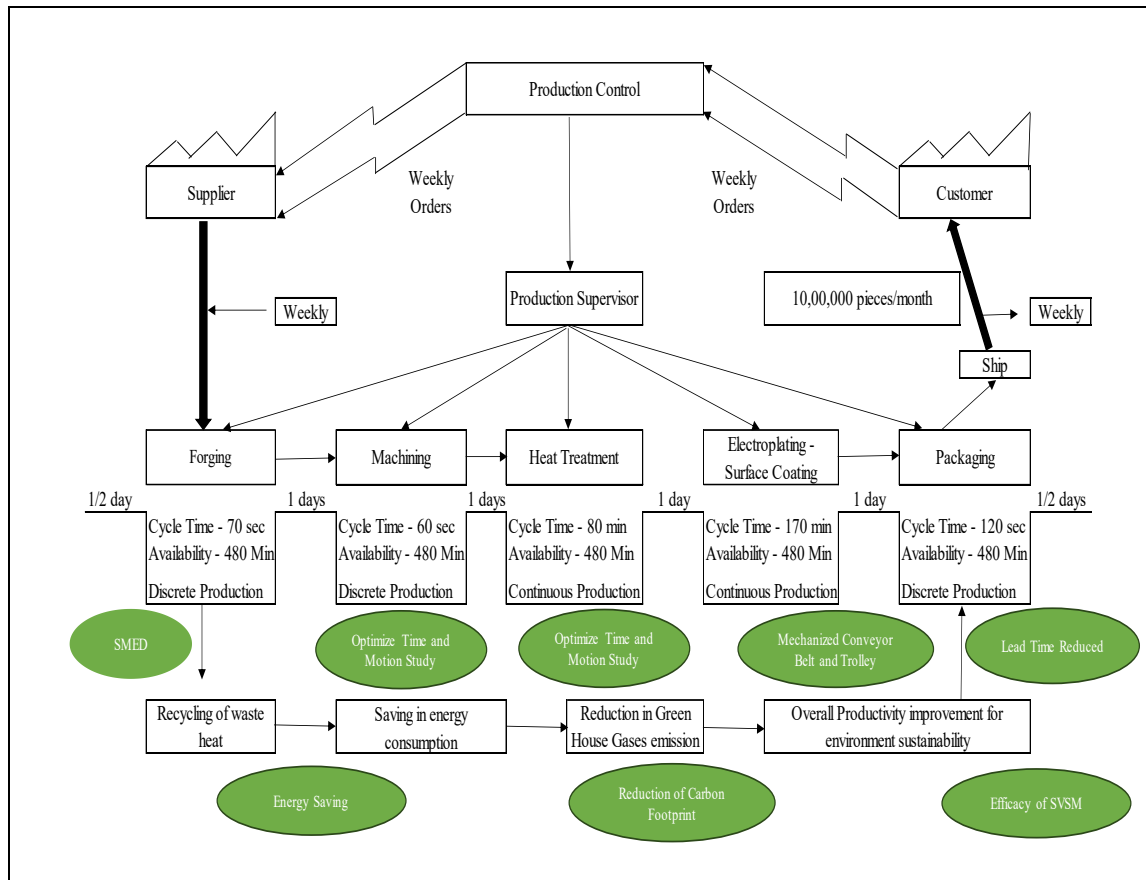


Figure 4.7: Future State Value Stream Mapping

4.9 Data Verification

For the verification of data after implementing the actions, the data further collected for the period of February to April 2023 which is shown in Table 4.6

Table 4.6: Data Collection of Forging Defects (February 2023 to April 2023)

Forging Defects - Feb 23 to April 23						
Defect	Feb-23	Mar-23	Apr-23	Total Pieces	Cum. Pieces	Cum. %
Crack	4635	3831	3688	12154	12154	59
Unfilled	1349	1339	1403	4091	16245	89
Scaling	492	630	711	1833	18078	95
Fold	553	396	301	1250	19328	98
Twist	62	0	0	62	19390	100
Production Quantity	877393	701794	700753	2279940		
Rejection Quantity	7091	6196	6103	19390		
Percentage of Rejection	0.80	0.88	0.87	0.85		

Before implementing the suggestions, the average rate of rejection was 1.09% for the period of November, December 2022 and January 2023 and after the same was 0.85% for February to April 2023 which is given in Table 4.7. Hence this is evident from the study that the rate of rejection was reduced and there was improvement in the system.

Table 4.7: Comparison Chart of Defect Analysis

Comparison Chart		
Defect	Defect Pieces (Nov-22 to Jan-23) Before	Defect Pieces (Feb-23 to Apr-23) After
Crack	17544	12154
Unfilled	8730	4091
Scaling	1806	1833
Fold	928	1250
Twist	483	62
Production Quantity	2685894	2279940
Rejection Quantity	29491	19390
Percentage of Rejection	1.09	0.85

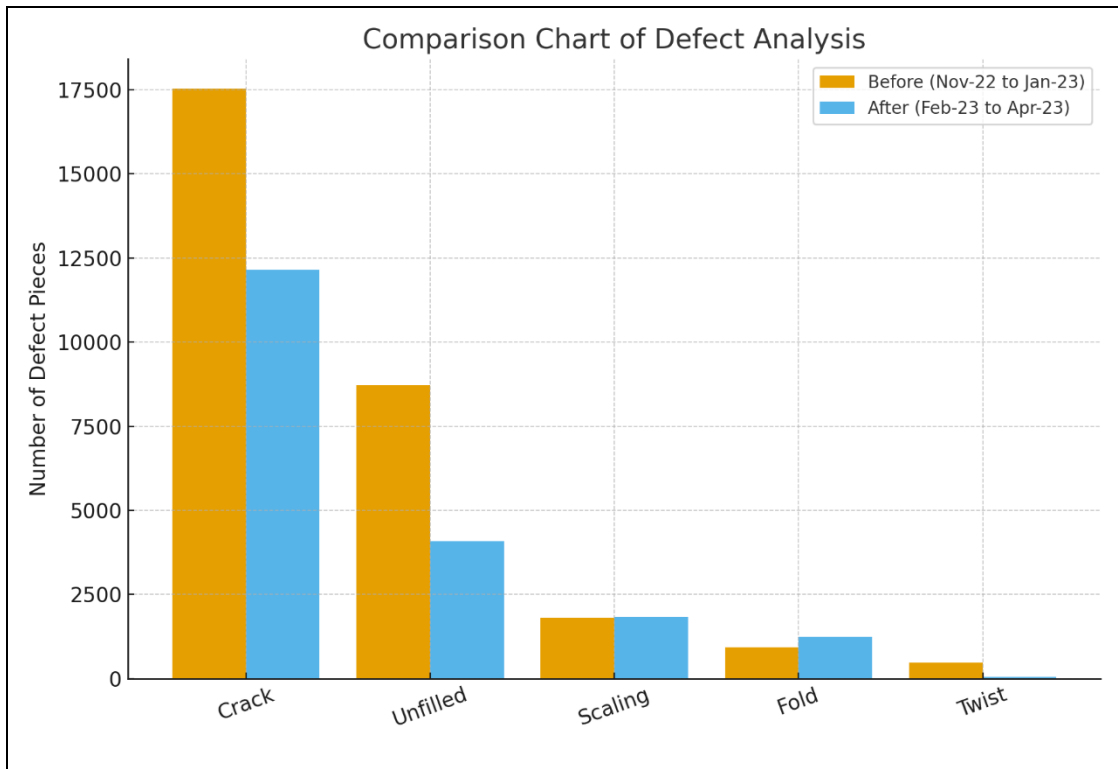


Figure 4.8: Comparison of Defect Analysis

In the other hand of future state value stream mapping, the lead time for manufacture the product is reduced from 9 days to 5 days. This is evident from the study that the reduction of more than 50% in time to manufacture the final product is carried out by introducing the lean approach.

The present study primarily focuses on the forging process within the manufacturing system. While this provides a detailed insight of energy consumption and operational efficiency in forging, limited attention is given to other related processes such as machining, electroplating, polishing and heat treatment. This narrowed scope may reduce the generalizability of findings, as energy use and defect patterns differ across processes. Future research therefore broadens the scope to include multiple processes, allowing for cross-comparison and the identification of process-specific as well as industry-wide trends.

Additionally, while detailed tables were presented to document the findings, some of these could be further summarized to highlight only the most critical insights. Summarized tables would enhance clarity, reduce redundancy, and allow decision-makers to more easily grasp the key outcomes without being overwhelmed by data complexity. This would strike a balance between comprehensive documentation and effective communication of the results. The critical findings are presented in table 4.8

Table 4.8: Critical Findings

Attributes	Before	After
Percentage of Rejection	1.09 %	0.85 %
Lead Time Reduction	9 days	5 days
Productivity Increase	10,00,000 pieces	12,00,000 pieces

4.10 Conclusion

In this section, the current state VSM and future state VSM was discussed and compared for cycle time and lead time to manufacture the product. The cycle time of forging process reduced from 90 second to 70 second, 90 sec to 60 sec in machining. 90 min to 80 min in heat treatment and 180 sec to 120 sec in the final packing section. The lead time in the current VSM was 9 days wherein 5 days in future VSM which significantly reduced to 55%. In the other hand of defect analysis, process mapping was

applied to identify the manufacturing processes for data collection to analysis the defects. With the help of pareto chart, the major defects were identified for cracks and unfilling which contributes to 89% of rejection. The hypothesis study was conducted to test the significance level of rejection between the different months. In the study, null hypothesis was accepted and inference conclude to no significance difference of rejection level between different months. Then cause and effect diagram was plotted to identify the potential cause with brain storming of shop floor personnel. The root cause analysis and corrective actions were suggested for the proposed changes in the forging process for reduction of rejection level. Hence after implementation, there is significant reduction in rejection level.

The conclusion of the implementation of lean manufacturing is given below:

- For the manufacturing processes aims to minimize the rejection level was implemented for identification of the root cause analysis to the defects and corrective action.
- Besides, lead time also decrease from 9 to 5 days. The obtained results were also validated through Taguchi analysis and observed that results are in the favour and valid.
- The Pareto analysis was done to check the major contribution of the defects to take action. After implementing the solutions, further real-time data related to rejection was collected, analysed, and found that rejection level decrease from 1.09 to 0.85% successfully.
- The overall productivity increased from 10,00,000 pieces to 12,00,000 pieces (20%) after the implementation of actions.
- The outcomes of present case study will facilitate to industrial managers to design the manufacturing system under full capacity utilization of company and minimal rejections.

4.11 Summary of Implementation of Lean Manufacturing

The implementation of lean manufacturing in the studied context focused on systematically eliminating non-value-added activities, streamlining workflows, and reducing rate of defects to enhance overall efficiency. Key tools such as SIPOC, process flow diagram, value stream mapping, pareto analysis and cause and effect analysis were applied to identify waste, optimize resource utilization, and improve process flow. Within the framework of Quality Management Systems, these lean practices were not implemented in isolation but integrated with structured quality procedures and performance monitoring mechanisms, ensuring consistency and accountability. The implementation highlighted that lean not only reduced operational inefficiencies but also reinforced green objectives by minimizing energy use, material consumption, and hazardous waste. This synergy demonstrated that lean manufacturing, when embedded in QMS, acts as both a driver of quality excellence and a facilitator of sustainable practices.

CHAPTER 5

WASTE ANALYSIS IN MANUFACTURING INDUSTRY

This chapter aims to present and discuss the waste analysis in manufacturing aspect for the objective No 2 to optimize lean manufacturing. In this chapter the type of waste identified into lean and green waste. The current and future state of lean waste for the forging and trimming process of manufacturing was carried out. Similarly, study of current and future state of green waste for forging, trimming, broaching, machining, electroplating and packing processes was conducted to achieve the outcome of the objective. The integration of Lean and Green practices has been discussed in the context of improving both operational efficiency and environmental sustainability in the forging industry.

5.1 Introduction

This study aims to present the preview of waste generation during the process of manufacturing operations and waste elimination on lean and green manufacturing.

The forging manufacturing industry plays a vital role in modern manufacturing by supplying critical components to sectors such as automotive, engineering and heavy machinery. However, forging processes are inherently resource-intensive, involving high energy consumption, material wastage, and generation of defective parts. As industries worldwide transition toward sustainability, waste analysis in forging has emerged as a crucial area of study, offering pathways to reduce inefficiencies and enhance competitiveness.

In the forging process, waste is not confined merely to material scrap but extends to multiple dimensions, including energy losses during heating, downtime due to equipment inefficiencies, rework from dimensional inaccuracies, and excessive lead times caused by process variability. Traditional approaches often considered defects and material rejection as the indicators of waste, but recent insights highlight that non-value-added activities such as unnecessary handling, waiting time, and poor utilization of dies contribute significantly to costs. These wastes directly affect profitability, product quality, and environmental performance.

Waste analysis therefore provides a structured framework to identify, quantify, and

categorize inefficiencies in forging. Techniques such as value stream mapping for current and future state allow researcher to pinpoint the most critical sources of waste. Moreover, the integration of Lean Manufacturing principles emphasizes the elimination of non-value-added processes, while Green Manufacturing practices focus on minimizing energy use, reduction of hazardous waste and reducing the carbon footprint. Together with a Quality Management System, these approaches create a holistic framework for achieving operational excellence.

Recent studies suggest that adopting digital technologies such as IoT-based monitoring, and predictive analytics can transform waste analysis from a reactive approach into a proactive strategy. This shift enables forging units not only to control waste but also to predict and prevent it. Furthermore, the Indian forging manufacturing sector, faces increasing pressure from markets to align with sustainability standards, making systematic waste analysis an indispensable practice.

The waste is generally categorized into hazardous and non-hazardous waste. Hazardous waste is mainly linked to the environmental aspect of green manufacturing whereas non-hazardous waste is referred to the lean manufacturing. The seven types of wastes are majorly one of the lean tools which can be used to optimize productivity. Systematic elimination of waste by focusing on product quality, delivery, and employee involvement. A philosophy that strives to remove waste in all aspects of production activities, human relations, relationships with suppliers and material management. The principles of lean thinking consist of value, stream, flow, draft and perfection. Other side, waste elimination works on 'Muri' which means unreasonable excessive, overburdening people, machines that can be avoided by standardized work. 'Mura' stands for irregular inconsistent i.e. work load fluctuations, defects, breakdown which is eliminated through Just-In-Time (JIT) and Total Productive Maintenance (TPM) and 'Muda' signify the waste. Lean manufacturing (LM) mainly focuses on waste elimination generated within a production process which improves manufacturing lead time and product quality. LM facilitates manufacturing organizations to become competitive through improved resource utilization, reduced human efforts and on-time delivery to customer.

Waste elimination for lean manufacturing provides productivity enhancement

with respect to lean aspect and environmental performance to an optimum level for green manufacturing. The manufacturing processes and type of waste are identified. The waste is categorized into lean and green waste. The main aim of the study was to review the current state of forging and trimming operation of lean aspect and future state lean waste after implementing the effective control measures. Similarly, the manufacturing processes of product realization was selected for the review of current and future state. The quantified figures were taken for the current state of actual working data and future state figures were proposed based on the effective operational control and corrective actions. These figures are an assumption which can further be validated by implementing the controls. By these actions of lean waste, the productivity can be enhanced and lead time can also be reduced. The future state operational controls of green waste can significantly be reduced generation of waste which will give positive impact to environment, human society, and ecosystem diversity.

After the literature review, seven types of waste identified in the industry during the study. This is represented in the below concept:

- 1) Overproduction: for production faster or in larger quantities than customer demand.
- 2) Inventory: raw material, unfinished work or finished goods that are not added to it.
- 3) Waiting: People or parts waiting to complete the working cycle.
- 4) Movement: Unnecessary movement of people, parts or machines within the process.
- 5) Transport: Unnecessary movement of people or parts between processes.
- 6) Reworking: It is not the first time, repetition or process correction.
- 7) Over processing: Processing outside the standard required by the customer.

Lean and Green manufacturing represents the integration of efficiency-driven Lean principles with environmentally focused green practices to achieve sustainable production. According to Kurdve and Bellgran (2021), this integration is effectively operationalized at the shop-floor level through the Green Performance Map, a tool that combines the Lean waste elimination philosophy with the environmental waste hierarchy. Their work highlights how production teams can systematically identify, prioritize, and implement green improvements while maintaining lean efficiency, thereby bringing the circular economy concept into daily operations. Beyond defect and

material waste reduction, their approach emphasizes energy savings, pollution control, and resource optimization. This contribution extends the literature by offering a practical model for aligning Lean Green objectives, addressing the common challenge that lean methods focus on productivity while green practices focus on environmental impact. By bridging this gap, Kurdve and Bellgran illustrate how Lean and Green can complement each other, transforming waste analysis from a cost-reduction tool into a driver of long-term sustainability.

Table 5.1: Definition of lean and green manufacturing
(Kurdve and Bellgran, 2021)

Manufacturing Aspect	Lean Manufacturing	Green Manufacturing
Difference	Lean waste Transportation Inventory Motion Waiting Over-processing Over-production Defect	Green Waste Solid wastes Hazardous wastes Air emissions Wastewater discharges
Similarity	Activities added without value in Lean are predominantly associated with energy, sources and link seven lean waste with waste described in green production.	

Lean Manufacturing (LM) focuses mainly on the removal of all types of waste generated in the production system, which improves the production time and the quality of the product. LM facilitates production organization to become competitive through improved use of resources, reduced human efforts and timely delivery to the customer. The definition of lean and green manufacturing is discussed in Table 5.1 which indicates the outcome of the concept for waste reduction.

Table 5.2 refers to drivers with lean and green manufacturing wherein outcome of the drivers is given for consequence.

Table 5.2: Drivers of Lean and Green Manufacturing

S. No.	Drivers	Consequence	Reference
1	Management Commitment	Commitment of Lean and Green Manufacturing	[M. Singh and R. Rathi, 2021]
2	Employee Training	Increase awareness	[Goyat et al., 2019]
3	Multi Skill Task Force	Ability to perform multifunctional activities	[Kaswan et al., 2021]
4	Preventive Maintenance of Machines and Equipment	Less rate of rejection, hazardous waste from manufacturing and reduction of lead time	[R. Rathi and M. Singh, 2021]
5	Standardization	Work practices improve which can be linked to productivity	[M. Singh et al., 2019]
6	Internal Audit	Internal audit identifies opportunity for improvement in the manufacturing processes	[M. Singh and R. Rathi, 2019]

The industry is manufacturing multi products where major production share is for Combination and Double Open-Ended Spanners. In this study both the product items are selected for the waste elimination of lean and green manufacturing which is produced on drop forging hammer.

The waste is identified into lean and green waste for elimination to productivity enhancement and sustainable development for the society. The waste streams are presented in the figure 5.1

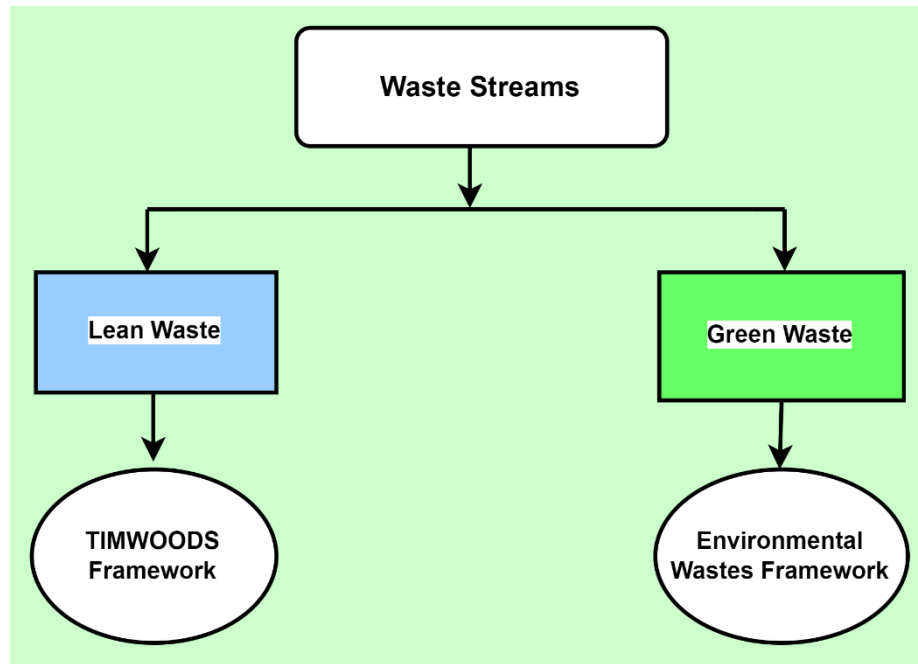


Figure 5.1: Waste Streams

5.2 Manufacturing Process - Forging and Trimming

Lean waste of forging and trimming operation is selected for the study of current and future state which is presented in table 5.3

Table 5.3: Current and Future State of Lean Waste

S. No.	Current State Waste Generation with respect to Lean Aspect	Future State Waste Generation with respect to Lean Aspect
1	Transportation – Moving material manually from blank cutting to forging furnace. Time Taken – 60 Sec.	Transportation – Mechanized conveyor belt, bin design modification and gravitational movement of material from blank cutting to forging furnace. Time Taken – 40 Sec; 33% Improved.
2	Inventory – 50 pieces of inventory of work in process was placed which results in variation of temperature.	Inventory – Pull system followed to zero inventory by modification of material handling mechanism from furnace to forging operation. 1 piece (single) taken out from furnace for uniform heating of workpiece. Cycle time – 5 Sec.
3	Motion – After the trimming process, put the flash into the bin before next trimming. Time Taken – 5 Sec	Motion – After the trimming process, gravitational movement of the flash material into the bin which has avoided unnecessary motion. Time

		Taken – 2 Sec; 60% Improved
4	Waiting – 1. Blank cutting time for forging operating. Time Taken – 10 Min. 2. Set up time in forging die. Time Taken – 3 hours / 8 hours 3. Rolling repair of forging die before production process. Time Taken – 15 Minutes / Die	Waiting – 1. Blank cutting to forging operating reduced by modification of material handling mechanism to avoid wait time. Time Taken – 2 Min; 80% Improved. 2. Single Minute Exchange of Die (SMED) introduced for set up time in forging die to reduce waiting time. Time Taken – 2 hours / 8 hours; 33% Improved. 3. Time management adjusted for rolling repair of forging die before 20 minutes of production process. Die design changed, time – 10 minutes/die; 33% improved.
5	Over Production – Forging over production due to wrong counting and measurement. 5350 pieces of production per 8 hours for combination spanner 17mm	Over Production – Counting meter installed on the machine to measurement actual quantity of production. Accurate 5000 pieces of production per 8 hours; 7% Improved.
6	Over Processing – 1. Three rolling before final forging of piece. Time Taken – 1 piece / 9 sec	Over Processing – Compound die used for operation to avoid any over processing of materials. Time Taken – 2 pieces / 9 sec. Productivity increased by 50%.
7	Defects – Average rate of rejection for the period of June, July, August 2023 was found to be 1.2% during the study period due to crack of material and offset of die.	Defects – After introducing effective corrective action based on root cause analysis which include material properties and on-time preventive maintenance of die; the rejection reduced by 0.2%. The rejection reduced by 0.2%.
8	Unutilized Skill of Operators – This is due to lack of motivational factors.	Unutilized Skill of Operators – Incentive scheme introduced for utilizing optimal skill of operators for effectiveness and productivity enhancement which resulted to increase the productivity by 5%.

Similarly, the green waste for the product realization processes is taken up for the study of current and future state which is given in table 5.4.

Table 5.4: Current and Future State of Green Waste

Manufacturing Process	Current State Waste Generation with respect to Green Aspect	Future State Waste Generation with respect to Green Aspect
Forging and Trimming	Generation of forging flash as solid waste for quantity of 125 Ton per month, generation of waste oil for quantity of 3 Litres per month and contaminated waste cloth as hazardous waste for quantity of 20 kg per month.	After implementing effective operational control procedures, generation of forging flash reduced by 5% (118.75 Ton per month), generation of waste oil reduced by 10% (2.7 Litres) per month and contaminated waste cloth, the quantity reduced by 5 kg (25%) per month .
Broaching	Generation of sludge of cutting oil for quantity 6 Kg per month.	After operational control for filtration process and centralized system , Generation of sludge of cutting oil, the quantity reduced to 10% (5.4 Kg/month) .
Machine Shop	Generation of hazardous waste (used oil) for quantity of 3 Litres per month and contaminated waste cloth for quantity of 10 Kg per month.	After operational control for spillage and arresting leakages , the generation of hazardous waste oil reduced to 2.7 Litres/month and contaminated waste cloth reduced by 10% (1 Kg per month) .
Electroplating	Generation of hazardous waste water for quantity of 6000 Litres per day which is sent to Central Effluent Treatment Plant (CETP) for treatment, authorized by Punjab State Pollution Control Board, a regulatory body of Govt.	After effective operational control for Nickle recovery plant and flow control validation , generation of quantity reduced by 200 Litres/day . Ref. (Consent to Operate – Water)
Packing	Generation of solid waste such as polyethylene bag, carton boxes, art work card paper, the quantity of 50 kgs/month.	Generation of such type of waste reduced after the effective control by 10% (5 kgs/month).

The results of this study indicate that targeted improvements in the processes lead to measurable efficiency gains. Specifically, waste reduction measures were associated

with decrease in material losses, which in turn contributed to a reduction in overall consumption. By quantifying the material savings, the present analysis strengthens the argument that waste reduction strategies are not only environmentally beneficial but also economically viable.

The improvements in manufacturing processes also highlight the potential for broader applications across systems.

Beyond the numerical outcomes, these findings emphasize the importance of adopting a systems-level view of manufacturing. Reducing waste not only lowers resource depletion but also reduces the downstream environmental burden associated with raw material extraction and processing. This supports current policy initiatives promoting cleaner production and circular economy practices in the manufacturing sector.

However, it must be noted that the study's dataset was limited to forging and trimming process for lean waste and sample size, which may restrict the generalizability of results. Future research therefore integrates additional processes which include machining, heat treatment and larger datasets to validate whether similar levels of efficiency can be achieved industry-wide.

There has been improvement after the implementation of actions which are given below:

Lean Waste:

- For the corrective action, there is 33% improvement in transportation
- 60% improved in motion
- 33% in waiting by introducing SMED
- Over production improved by 7%
- 0.2% rejection reduced to control the defects.

Green Waste:

- After implementing effective operational control procedures of die design and training, generation of forging flash reduced by 5% (118.75 Ton per month),

generation of waste oil reduced to 10% (2.7 Litres) per month and contaminated waste cloth, the quantity reduced by 5 kg (25%) per month.

- After operational control for filtration process and centralized system, Generation of sludge of cutting oil, the quantity reduced to 10% (5.4 Kg/month)
- After operational control for spillage and arresting leakages, the generation of hazardous waste oil reduced to 2.7 Litres/month and contaminated waste cloth reduced by 10% (1 Kg per month).
- After effective operational control for Nickle recovery plant and flow control validation, generation of quantity reduced by 200 Litres/day. Ref. (Consent to Operate – Water)

5.3 Discussion on findings

This section identifies the findings of the study for the waste elimination. The type of waste was identified and further categorized into lean and green waste. The lean waste further classified into eight sub categories which are transportation, inventory, motion, waiting, over production, over processing, defects, unutilized skill of operators. The study on current and future state of forging operation of lean waste was carried out wherein current state identifies the data on actual monitoring and measurement basis whereas future state guiding techniques on assumption taking effective corrective actions which will be validated after implementing the actions.

The study indicates that the most significant waste arises from material scrap, particularly in processes such as forging and trimming. These processes consume large amounts of raw material and any deviation in process parameters results in higher rejection rates. In contrast, machining processes, though generating smaller quantities of waste in the form of chips and coolant disposal, create hidden costs due to recycling, handling, and environmental compliance. The presence of rework also reflects inefficiencies in maintaining process accuracy, leading to additional labor and energy costs.

The material waste directly increases the industry's carbon footprint, as raw material extraction, processing, and disposal involve considerable energy and environmental impact. Similarly, inefficient use of energy in manufacturing processes

adds to greenhouse gas emissions. Hence, waste reduction is not only a matter of cost savings but also a strategic step towards sustainable and eco-friendly production.

The study also reveals that the waste is linked to human factors such as operator error, lack of training, and communication gaps. This underlines the importance of developing a culture of continuous improvement. Employee involvement, skill development, and systematic training programs helps minimize errors and align the workforce with waste reduction objectives.

On the other aspect of green waste, the manufacturing product realization processes were identified for current and future state. The data presented on the current state is actual basis whereas the future state data predicted on assumption after the implementing operational control procedures. This data was validated after the control.

The findings demonstrate that waste analysis provides valuable insights for decision-making in manufacturing. It emphasizes that effective waste management requires a combination of process optimization, employee's engagement, and strategic investment in technology. Addressing waste holistically will not only improve operational efficiency but also contribute to long-term sustainability and competitiveness of the manufacturing industry.

5.4 Conclusion and future scope

The aim of this study was to identify the type of waste and future state actions on the lean and green waste. Based on this aspect, corrective actions and control measures advised to implement the optimization of results through validation. The elimination of lean waste will enhances productivity through the implementation of eight type of lean tools. Similarly, elimination of green waste not only prevent wastage of material but provides positive impact to the environment which will control depletion of natural resources and increases environmental performance for green manufacturing. This study was conducted only in the engineering industry which is located in Punjab. In future scope, the proposed methodology can be implemented in other type of manufacturing industry i.e. automotive, fasteners and plastics industry.

5.5 Summary

This study facilitate to the engineering industries to implement the actions and

control measures of lean and green waste which were mentioned in the future state on both the aspects. The major barrier in the implementation of control of lean and green waste is non awareness of the employees. Thus, it becomes imperatives that skill level of the employees is monitored and provide training on the identified needs to effectively implement the actions on waste elimination. Waste elimination optimized the productivity enhancement and avoid depletion of natural resources for sustainability.

CHAPTER 6

ENVIRONMENTAL ASPECT ANALYSIS

The purpose of this chapter is to present and discuss the environmental aspect analysis related to objective No 3 to enhance environment performance. Process based environmental management system was created to map and integrate the environmental core and supporting processes with the product realization processes. Drivers of green manufacturing referred to explore the study. Environmental review along with the documentation study of manual, procedures and environmental objectives with key responsibilities was formulated. Environmental impact assessment of forging process was carried out to find out the significant impact to the environment to take the control mechanism. Analysis of stack emission for forging furnace and ambient air quality was conducted with the ANOVA approach and controls applied for conclusion of this chapter.

6.1 Introduction

This study outlines the impact of environmental aspects of specifically green activities, investment and product types on economic performance of companies. Using data from the survey from Indian small and medium -sized enterprises (MSP) Research uses the theory of self -determination to analyze how the number of green activities, the scope of green investment and the type of product affects economic results. The results show that a larger number of green activities increase economic performance, while the relationship between ecological investments and economic performance monitors the U -shaped inverted formula. This dynamic is further strengthened when companies offer green and green products. The study increases understanding the role of green production in business performance and provides practical instructions for managers who seek to optimize the benefits of green initiatives.

The society's increasing focus on the "green" initiatives of companies stems from rising concerns about environmental issues that pose significant threats globally (Centobelli et al., 2020). Environmental challenges are among the most urgent and unresolved global objectives that need addressing (Cappa et al., 2022). Since it became evident that human activities significantly contribute to environmental degradation and

depletion of natural resources, these concerns a top priority for governments, organizations, and individuals (Michelino et al., 2019). In this context, the Government of India (GOI) has set various emission targets and regulations aimed at reducing the environmental impact of small-scale industries. These targets are part of broader initiatives to combat climate change and improve air quality. As per NCAP-2025 scheme, the aim set by GOI to reduce the particulate matter (PM10 and PM2.5) levels by 20-30% by 2025, compared to 2017 levels (Government of India, 2017). Due to various factors, manufacturing companies are increasingly following the concept of green manufacturing. These practices aim to benefit the environment, enhance brand image and reputation among consumers (Fercoq et al., 2016), and appeal to customers who favor eco-friendly businesses, ultimately boosting companies' economic performance (Verrier et al., 2016). Green manufacturing involves environmental awareness in production, including the renewable energy sources and participation in sustainable supply chains (Dieste et al., 2019).

With the rising interest in green manufacturing, there is growing attention to how these practices impact different aspects of company performance, such as environmental, operational, and financial outcomes (Ye et al., 2023). Previous research indicates that green initiatives positively influence various aspects of economic performance (Li et al., 2021). However, while some green initiatives, such as waste reduction, hazardous material minimization, and reverse logistics, have a positive impact on financial performance, others such as environmental cooperation with suppliers and environmental purchasing procedures, as well as ISO 14001 certification (which certifies effective environmental management systems), do not necessarily lead to improved economic outcomes (Gandhi et al., 2018). Additionally, detailed assessments of the impact of green manufacturing on operations in small scale industries are still limited, and research has yet to fully explore the effects of green initiatives in process and products, which is yet not designed to minimize environmental impact throughout their life cycle (Liu et al., 2024). This research gap is occupied by conducting the present study towards sustainable development in Indian small-scale industries via green manufacturing initiatives.

The environmental assessment of aspect-impact identifies the economic,

environmental and social factor of a project activity in the manufacturing and gives up the potential impact on the environment. The Indian industries manufacture a multiple variety of products by latest manufacturing techniques. However, this neglects the role of aspect-impact during and after the production which results many environmental issues have been constituted. Installation and commissioning of plants can be safe and environmentally sustainable if environmental risks manage effectively by qualitative and quantitative methodology for aspect-impact assessment. The process-based model for environment management system is given in figure 6.1

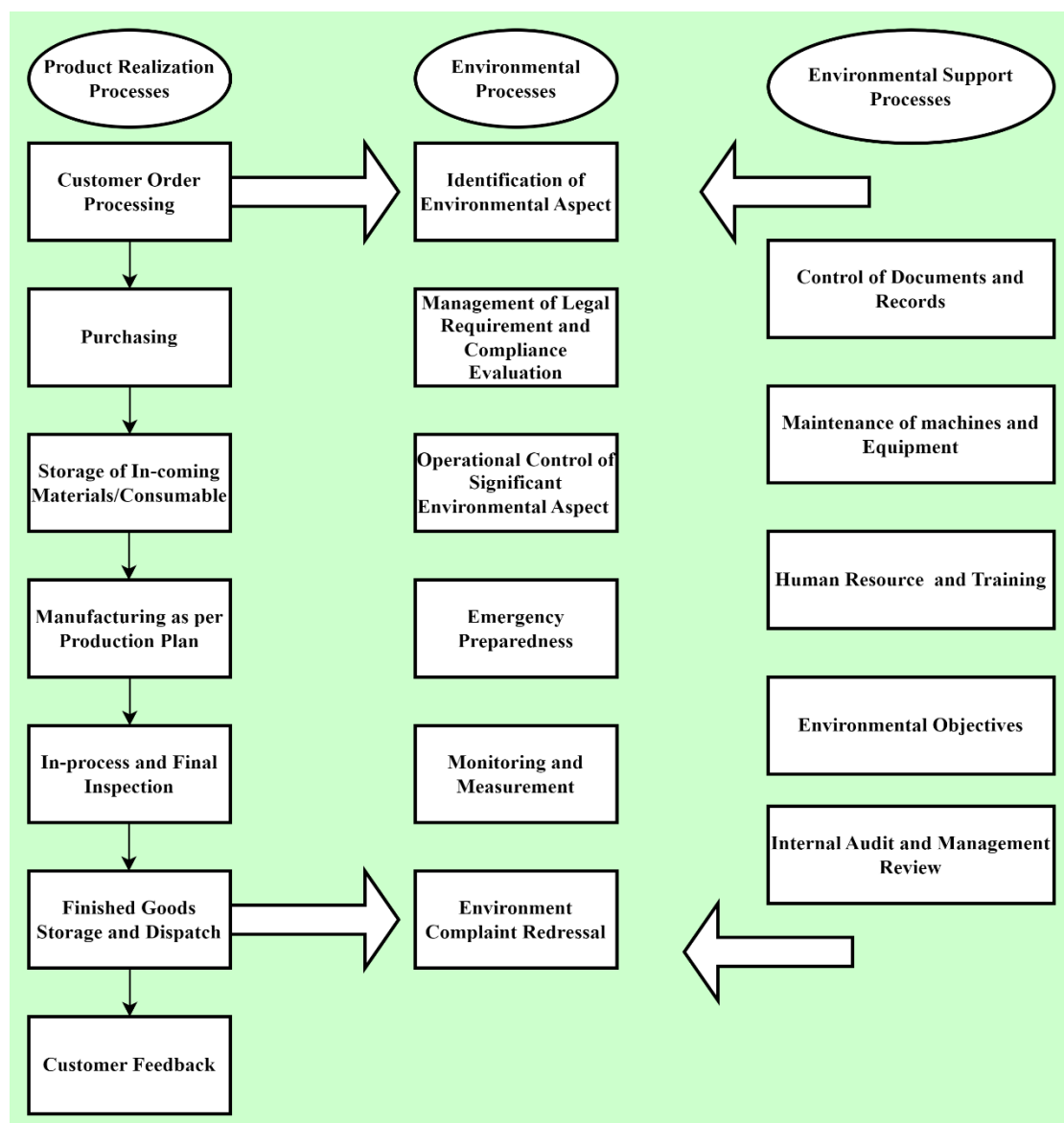


Figure 6.1: Model of Process-based Environment Management System
(Source: Scholar own creation)

Definition of green manufacturing, with focus on types of waste reduction are wastes including solid, hazardous wastes as well as emission to air and wastewater discharges. (Abualfaraa et al., 2020; Johansson and Winroth, 2009; Kurdve and Bellgran, 2021)

6.2 Drivers of Green Manufacturing

Rapid depletion of natural resources, increasing energy demand and customer awareness of products conscious products and the need to comply with the environmental regulations through the development of green processes led to the development of green production paradigm. GM paradigm helps minimize the impact of production processes on the environment and ensures improving pollution control, reducing natural resources, green brand image.

The drivers of green manufacturing with consequence is discussed in Table 6.1.

Table 6.1: Drivers of Green Manufacturing

S. No.	Drivers	Consequence	Reference
1	Top management commitment	Commitment towards green manufacturing	[Perminder Jit Singh, KS Sangwan, 2011]
2	Cost savings	Reduction in consumption of energy and resource	[Shah <i>et al.</i> , 2021]
3	Competitive advantage	Cost-savings give competitive advantage to the company	[Natalia, Irene and Ellitan, Lena, 2019]
4	Technology up-gradation	Utilization of energy and resource efficient advanced technology	[Polyanska, 2024]
5	Current legislation	Pollution control, Landfill taxes, Emission norms	[Hoogmartens, 2016]
6	Future legislation	Expected initiation of new laws, increased level of enforcement	[Murat C Mungan, 2018]
7	Incentives	Positive supportive working Environment	[Yusliza, 2021]
8	Green brand image	Environmental respective image in the view of society, CSR	[Alam, S.M.S., Islam, K.M.Z., 2021]
9	Public pressure	Local communities, politicians, NGOs, media	[Ahmad, 2020]
10	Internal Audit	Internal audit identifies non-conformity and opportunity for improvement in the manufacturing processes.	[Panhwar, 2022]

6.3 Environmental Review

Initial environmental review was conducted by the core functional team of the company which comprises of competent managers and engineers. The primary data is collected through site round observation, records, monitoring and measurement. The external source of data is publications, journals, articles and books. The processes of green manufacturing are given as a) Identification of environmental aspect b) Management of Legal and Compliance Evaluation c) Operational control of manufacturing and contracted services d) Emergency preparedness e) Environmental monitoring and measurement f) Maintenance of machines and equipment g) HRD and Training h) Management Functions – Internal audit, Management review, corrective action i) Control of documented information

6.4 Environmental Manual, Procedures, Documents and Formats: After the literature review, the environmental manual, operational procedures, documents and formats were studied. Interpretations and reference to processes are solved in the manual and approved by the director of the organization. Operation procedures prepared for how to carry out operation and management secured for environmental processes. Formats are records that have evidence of the activities. The environmental management system is divided into four levels:

Tier-1: Environment Manual: There are interpretations of standard requirements that are solved in the manual. The context of the organization for internal and external problems is solved. The needs and expectations of the parties of the addressed and monitored parties. Processes defined and criteria used to ensure operating control. Objectives to achieve are solved. Evaluation of resources, operation and performance are solved.

The deployment of the environment process matrix has been prepared to prove the ownership of the process to perform efficient operation and listed in Table 6.2

Table 6.2: Deployment of Environment Process Matrix

Sr. No.	Process	Process Owner (Responsibility)
A) Core Processes		
1.	Identification of Environmental aspects	Management Representative
2.	Management of Legal and Compliance Evaluation	HR/Admin Manager
3.	Operational Control of manufacturing and contract services	Management Representative
4.	Emergency Preparedness	HR/Admin Manager
5.	Environment Monitoring and Measurement	HR/Admin Manager
B) Support Processes		
6.	Maintenance of machines and equipment	Chapter 2 Maintenance Head
7.	Control of Documented Information	Management Representative
8.	HRD and Training	HR/Admin Manager
C) Management Processes		
9.	Corrective Action	All Functional Heads
10.	Internal Audits	Management Representative
11.	Management Reviews	Head of Plant Operation

The responsibilities and authorities of key personnel were documented. The detail matrix is documented and listed in Table 6.3

Table 6.3: Responsibilities and Authorities of Key Personnel

Sr. No.	Personnel	Responsibilities and Authorities
1.	Director	• Overall, in-charge of the operations related activities. • Overall guiding force behind all environmental activities. • Approval of Environmental Manual. • Provision of resources required for the effective functioning. • Review of environmental performance at defined intervals. • Overall authorize to take all decisions related to all operational aspects. • Approval of Environmental Objectives.
2.	HR/Admin Manager	• Responsible for the identification of legal & other requirements applicable to the organization. • Ensuring compliances to legal & other requirements. • Implementation of On-site Emergency Plan. • Authorized to obtain resources as per On-site Emergency Plan. • Liasoning with the external agencies for the Environmental related aspects. • Authorize to interact with the legal / Govt. officials.
3.	Head Production / Manufacturing	• Responsible for planning of production. • Responsible for production activities. • To provide required support and guidance to production personnel. • Analysing of Environmental Non-Conformities and implement corrective actions.

		• Review and Control of Non-Conformities. • Implementation of operational control for manufacturing processes.
4.	Head Maintenance	• Overall responsible for preventive, breakdown and shutdown maintenance of the plant & machinery ((including machinery associated with operations related to significant issues). • Preparation of maintenance schedules and their execution.
5.	All Heads	• Control of Records. • Communication within department. • The training needs identification of the department personnel. • Maintaining process effectiveness to achieve results. • Action on audit non-conformities
6.	Management Representative	• Responsibility for establishing, implementing and maintaining Environment Management System • Reporting to Management for review Meeting on performance and need for improvements. • Document Control. • Internal communication within organisation on effectiveness. • Ensuring awareness within the organization. • Co-ordination of the conduct of Internal Audits & Management Reviews. • Compilation and review of Environment Risk Assessment.

6.5 Environmental Objectives

Company's overall objectives have been framed for continual improvement in the performance with respect to Environment aspect based on the customer requirements, significant aspects / risks, The statutory requirements and other requirements for which the organization is regulated, technological possibilities, its financial, operational requirements, business requirements and opinions of the parties involved.

1. To reduce the overall energy consumption.
2. To reduce the overall water consumption.
3. To reduce the furnace oil consumption.
4. To improve the sapling/tree plantation.

Tier-2: Procedures: The procedures prepared and the list of procedures is given below in Table 6.4

Table 6.4: List of Procedures

Sr. No.	Title
1.	Procedure of Internal Audit
2.	Procedure of Management Review
3.	Procedure of Monitoring of Environmental Objectives
4.	Procedure for Aspect-Impact Analysis
5.	Procedure for Management of Legal Requirements and other requirements
6.	Procedure for Operational Controls of manufacturing and contract services
7.	Procedure for Emergency Preparedness
8.	Procedure for Monitoring & Measurement

Tier-3: Operational Control Procedures: The operational control procedures prepared for the control of environmental activity for effective operation on ecosystem. The operational control procedures are mentioned in Table 6.5

Table 6.5: List of Operational Control Procedures

Sr. No.	Title
1	Operational Control Procedures for Compressor
2	Operational Control Procedures for Diesel Generator Set
3	Operational Control Procedures for Power Management
4	Operational Control Procedures for Electrical and Mechanical Maintenance
5	Operational Control Procedures for Hazardous Chemical Storage and Handling
6	Operational Control Procedures for Hazardous Waste Management
7	Operational Control Procedures for Battery Management
8	Operational Control Procedures for Scrap Management

6.6 Environmental Impact Assessment

The environment impact assessment for the core and supporting activities is reviewed with a focus to find any adverse impact to the environment.

6.6.1 Criteria for Identification of Environment Aspect-Impact

A review of aspect for the manufacturing processes as per flow diagram was conducted by the Core Team which is consisting of all the Functional Heads at a frequency of once in a year wherein forging process was selected for the study to determine the significance level/issue as per the details given below:

- Consider the forging process.
- Consider the operation & divide into different activities, so that each activity considered for identifying the releases & discharges. Mention the activities in the ‘Environmental Impact Assessment Report’
- While dividing operations into activities, consider:
ACTIVITIES which include handling of hazardous materials, receiving activities, storage, forging processing, disposal activities.
SERVICES which are Maintenance and cleaning.
PRODUCTS are use of raw materials, consumable, packing materials, finished products and bye-products.
- Classify activities into ‘Direct’ and ‘Indirect’:
DIRECT: Those which are under the direct control of the organization
INDIRECT: Those which are not under the organization’s direct control, but over which it can be expected have an influence of the activities performed by the

contractors, sub-contractors, or suppliers.

- Identify Aspects of each activity by considering the following:
INPUTS: Use of raw materials, consumables, natural gas, Use of Water, Use of Energy.
OUTPUTS: Releases to Air, Discharges to Water, Solid Waste, Discharge / releases to Land, Noise, Nuisance (Smoke, Odour, Dust, Vibration, Light, Heat, Radiation), Visual Impact, Finished Products, Bye Products
- Identify issues under all the following conditions for each activity:
Normal running conditions of the activities, Abnormal conditions which can be start-up & shut down/breakdown activities, Emergency conditions are possibility of fire hazard, leakage of hazardous gas.
- Use following documents and reports as potential source for identifying aspects:
Permits and consents from regulatory authorities, Material Safety Data Sheets of materials, Reports of previous environmental incidents.

All identified Environmental Aspects related to products, activities and services was assigned an Impact Rating of Quantitative technique for each of the factors which are Quantity, Probability of Occurrence, Severity and Control as per the criteria defined in Table 6.6

Table 6.6: Quantitative Environmental Rating Criteria

Quantity (Q)		Probability of Occurrence (O)		Severity (S)		Control (C)	
Score	Criteria	Score	Criteria	Score	Criteria	Score	Criteria
5	Excessive	5	Continuous	5	Fatal to human life	5	Absence or not effective controls
4	High	4	Four times a day	4	Long term Human health effect	4	Mechanism in place but not reliable
3	Moderate	3	Once a day	3	Affects flora/Fauna, global issue, resource use, short term health effect etc.	3	Needs human intervention
2	Low	2	Once a week	2	Causes discomfort, Acid rain or Nuisance	2	Has in-built secondary control
1	Negligible	1	Once a month or less	1	Slight Impact or negligible visual impact	1	Available

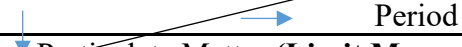
The total Impact Rating of an Aspect is calculated as per following formula:

1. Total Impact Rating is multiplied of Quantity, Probability of Occurrence, Severity and Control.
2. All aspects having Total Impact Rating equal to or more than '81' are considered 'Significant Aspects' based on the criteria of all factors of more than 50 percent or severity is rated as 5 which can be fatal to human life wherein operational control for the significant aspects was taken.
3. All aspects covered under legislation are considered as 'Significant Aspects' and compliance to legal was ensured for control of the significant aspects.
4. All emergencies' situations considered as 'Significant Aspects' and control ensured through 'On-Site Emergency Plan'

Table 6.7: Environmental Impact Assessment

ENVIRONMENTAL IMPACT ASSESSMENT																	
Activity	Environmental Aspect	Environmental Impact	Control		Condition			Qualitative			Quantitative				Score	Remarks	Control Method
			Direct	Indirect	Normal	Abnormal	Emergency	LC	IPC	BC	A	B	C	D			
Forging	Process Gas Emission	Air Pollution	Y		Y			Y	Y		3	5	3	3	135	S	Process Stack Monitoring
	Use of Lubricants	Resource Depletion	Y		Y					Y	2	2	1	2	8	NS	
	Spillage & leakage of lubricant oil	Land contamination	Y			Y			Y	Y	2	2	2	2	16	NS	
	Generation of Noise	Noise pollution		Y	Y			Y	Y		3	3	3	3	81	S	Monitoring Plan & Use of PPE
	Use of Electrical Power	Resource depletion	Y		Y				Y	Y	3	3	3	2	54	S	Plan for control of Electricity consumption
	Use of Furnace Oil (LDO)	Resource depletion	Y		Y					Y	3	2	2	2	24	NS	Monitoring of LDO consumption
	Leakage &Spillage of LDO	Land Depletion	Y			Y	Y			Y	3	3	2	2	36	S	Storage license, Emergency plan, Secondary containment.
	Scaling waste	Land pollution	Y		Y				Y		2	2	2	2	16	NS	
	Cooling Water	Resource depletion	Y		Y				Y		2	2	2	1	8	NS	Recycling through cooling tower
	Raw material(Steel)	Resource Depletion	Y		Y					Y	3	2	2	2	24	NS	
	Waste oily Clothes	Land pollution	Y		Y				Y		2	1	2	2	8	NS	

Table 6.8: Analysis of Forging Furnace Process Stack Emission

Test Parameters	Unit	December 2020	November 2021
↓  Period			
Particulate Matter (Limit Max 150)	mg/Nm ³	93	73
Sulphur Dioxide (SO ₂)	mg/Nm ³	139	214
Oxides of Nitrogen (NO _X)	mg/Nm ³	177	191
Carbon Monoxide (CO)	mg/Nm ³	87	156
Carbon Dioxide (CO ₂)	percentage	5.1	5.9

As per the significance level of environment impact assessment, stack emission of forging process was selected for the study which operates with furnace oil and known as low density oil.

Now ANOVA study is applied to know the effect of stack emission of forging furnace as below:

Step 1 - The hypothesis is formulated to test the significance of forging stack emission between different period which is selected the last two cycle of December 2020 and November 2021.

Step 2 – Introducing null hypothesis and alternate hypothesis.

Step 3 – Collection of data for study of two cycles of period.

Step 4 – Calculation the relationship between different sum of squares which is formulated as Total sum of squares (SS total) = Sum of squares of treatments (SS treatments) + Sum of squares of errors (SS error).

Step 5 – Calculation of F Test based on source of variation, degree of freedom, sum of square, mean sum of square for result of significance level.

Step 6 – Inference of the ANOVA approach which shows the null hypothesis accepted and there is no significant difference in terms of forging stack emission between different cycle of period.

Now the hypothesis is formulated to test the significance of process stack emission of different parameters between different monitoring period which is shown in table 4.39.

Null hypothesis, $H_0: T_1 = T_2$

Alternate hypothesis, H_1 : Treatment means are not equal of the treatment means.

Table 6.9: Process Stack Emission with respect to different parameters of different monitoring period

Dependent Factor ↓		Independent Factor →		
		December 2020 (Factor A1)	November 2021 (Factor A2)	Y_i
B1	Particulate Matter	93	73	166
B2	Sulphur Dioxide (SO ₂)	139	214	353
B3	Oxides of Nitrogen (NOX)	177	191	368
B4	Carbon Monoxide (CO)	87	156	243
B5	Carbon Dioxide (CO ₂)	5.1	5.9	11
Sum Y_j		501.1	639.9	1141
		Y_1	Y_2	Y^2

Where Y_{ij} , the i th observation under the j th treatment of the factor; monitoring period; T_j , the effect of the j th treatment of the factor, monitoring period; e_{ij} the random error associated with the i th observation under the j th treatment of the factor, monitoring period.

a = number of treatment (2)

n = number of replications under each treatment (5)

N = total of observations in the experiments ($2 \times 5 = 10$)

The relationship between different sum of squares of this model is as follows:

Total sum of squares (SS_{total}) = Sum of squares of treatments ($SS_{\text{treatments}}$) + Sum of squares of errors (SS_{error}).

$$SS_{\text{total}} = (93)^2 + (73)^2 + (139)^2 + (214)^2 + (177)^2 + (191)^2 + (87)^2 + (156)^2 + (5.1)^2 + (5.9)^2 - (1141)^2 / 10 = 48682.72$$

$$SS_{\text{treatments}} = (501.1)^2 + (639.9)^2 / 5 - (1141)^2 / 10 = 1926.54$$

$$SS_{\text{error}} = SS_{\text{total}} - SS_{\text{treatments}} = 48682.72 - 1926.54 = 46756.18$$

Table 6.10: Results of Process Stack Emission

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares (MSS)	F Ratio
Between treatments	a-1 (2-1) = 1	1926.54	$1926.54/1 = 1926.54$	$1926.54/5844.52 = 0.33$
Within treatments (error)	N-a (10-2) = 8	46756.18	$46756.18/8 = 5844.52$	

In Table 6.10, the value of the calculated F ratio is 0.33, The value of F ratio from statistical table for a significance level of 0.05 and degrees of freedom (1, 8) is 5.32.

Also,

$$F_{\text{calculated}} [0.33] < F_{\alpha} = 0.05 \text{ and } df = (1, 8) [5.32]$$

Hence, the null hypothesis (H_0) should be accepted.

Inference: This mean that there is no significant difference in terms of forging process stack emission of different parameters between different monitoring period.

Hence, Environmental parameters do not give any adverse impact to the environment as per the permissible limit of norms set by regulators. It is advised to the management of the company that natural gas can be used for heating of workpiece before the drop forging for which the output of the smoke will be environmentally friendly for release to atmospheric air.

To decrease the lower limit of environment parameters for enhancement of environmental performance, an autonomous maintenance plan and schedule is suggested which will be carried out by machine production operator on daily basis. The maintenance check list points are described below:

1. Clean burner as per the defined frequency
2. Lubricate the forging hammer
3. Check heating furnace for any abnormal function
4. Check draft fan is working properly for pre-heat of work piece to save energy.
5. Check any leakage of furnace oil, if detect immediate inform to maintenance department.
6. Check consumption of furnace oil and ensure optimum efficiency of the same.
7. Enhance operator working skill based on the latest technology of the day.
8. Identify unsafe condition of the machine and equipment before failure based on working exposure.

It is suggested that after implementation of these autonomous maintenance plan for atleast one year, the environmental parameters reviewed and compared with the previous data to validate the parameters.

**Table 6.11: Analysis of Forging Furnace Process Stack Emission
(Ref. Environment Protection Act, 1986)
(Before and After Analysis)**

Test Parameters ↓ Period →	Unit	October 2022 (Before)	October 2023 (After)
Particulate Matter (Limit Max 150)	mg/Nm ³	134	63.4
Sulphur Dioxide (SO ₂)	mg/Nm ³	269	40.7
Oxides of Nitrogen (NOX)	mg/Nm ³	211	139
Carbon Monoxide (CO)	mg/Nm ³	151	70.6

Inference: This mean that the comparison of data in table 6.11 for the year of October 2022 and October 2023 indicates wherein test parameters were improved to enhance the environmental performance after the implementation of suggestion.

The analysis of ambient air quality monitoring was conducted at the location near main gate of the organization to check the environmental parameters meet the standard requirements as set by the Regulatory Body of Central Pollution Control Board of India. The testing of parameters was carried out from the third-party testing agency

in the name of Eco Paryavaran Laboratories and Consultants Pvt. Ltd., accredited by National Accreditation Board for Testing and Calibration Laboratories vide reference certificate of TC-7477 for authentication of testing. The comparison of two-year environmental parameters is given in table 6.11.

Table 6.12: Analysis of Ambient Air Quality Monitoring

Test Parameters ↓ Period →	Unit	Standard Specifications	November 2021	October 2022
Particulate Matter as PM ₁₀	µg/m ³	100	92	91
Particulate Matter as PM _{2.5}	µg/m ³	60	53	51
Sulphur Dioxide (SO ₂)	µg/m ³	80	13	16
Nitrogen Dioxide (NO ₂)	µg/m ³	80	28	32

**Table 6.13: Analysis of Ambient Air Quality Monitoring
(Ref. Environment Protection Act, 1986)**

Test Parameters ↓ Period →	Unit	Standard Specifications	October 2023	October 2024
Particulate Matter as PM ₁₀	µg/m ³	100	87.5	91.3
Particulate Matter as PM _{2.5}	µg/m ³	60	48.3	49.6
Sulphur Dioxide (SO ₂)	µg/m ³	80	20.4	22.3
Nitrogen Dioxide (NO ₂)	µg/m ³	80	31.1	31.1

Inference: From the table 6.12 and table 6.13 we can find out that the environmental parameters are within the standard limit and does not give any adverse impact to the environment which indicates of green manufacturing in the industry.

6.7 Internal Audit

Internal audit is a process of an evaluation of the objectives and effectiveness of environmental processes.

The Internal Audit of Environment Management System was carried out as per the programme. The analysis of non-conformity identified in the internal audit of environmental management system is prepared and referred in Table 6.14 for study of significance level.

Table 6.14: Summary and Analysis of Internal Audit

Processes   Period	December 2022	June 2023
Store – Consumable and Waste	2	2
Production – Heat Treatment	0	0
Production – Electroplating	1	0
Production - Forgings	0	0
Environmental Management System – Management Functions	0	0
Legal Compliance	0	1
Total Non-conformity	3	3

It is evident from the analysis of table 6.14 for non-conformities where the Storage process is the weak area where in corrective action was taken to close out the detected non-conformity.

6.7.1 Non-conformity Corrective Action for June 2023

6.7.1.1 Store Process -No 01 - Description: Oils and chemical record was not maintained as per procedure, also chemicals name was not displayed in local language on the container.

Root Cause Analysis:

Why 1: Chemicals stock not maintained with name of chemical, receipt detail, issue detail, quantity balance in stock.

Why 2: Standard format provided for chemical record do not have this information.

Why 3: Old controlled format not updated with required information.

Why 4: Lack of awareness for required record & identification.

Correction - Chemicals/oils record maintained with required information. Chemicals/oils name displayed in local language

Corrective Action - Training provided to the concerned persons for the requirement of stock maintenance of chemicals/oils with required information. To check other areas for the same aspect.

6.7.1.2 Store Process -No 02 - Description: Different type of waste found mixed in the waste storage area near barrel section which are empty oil drums, chemical canes,

solid scrap found mixed in the same area

Root Cause Analysis:

Why 1: Area is defined for solid iron scrap but some other type of waste was not there.

Why 2: Concerned persons are not aware of different types of waste area.

Why 3: Different types of waste areas are not identified for the type of scrap to be hold in the area.

Why 4: Lack of training to the concerned persons.

Correction - Different type of waste segregated and stored in the specified waste storage area.

Corrective Action - Different types of waste/scrap areas identified with the name of waste/scrap to be stored in the area. Training to all the concerned persons including new appointed for the handling & storage of waste. To check other areas for the same aspect.

6.8 Management Review Meeting

In order to address the action plan and track the efficacy of the environmental management system, the management review meeting's mechanism and goal are to discuss the agenda items in accordance with the internal system that has been developed and to conform with external national and international standards. The review meetings are held by the organization at the predetermined interval of once every six months. The Director presided over the most recent management review, which took place on June 20, 2023. The meeting was attended by all the functional heads. the topics covered in the review meeting's agenda. The review consists of

- a) the status of previous actions from reviews;
- b) internal and external issues, needs and expectations of interested parties, compliance obligations, significant aspects of environment and risks and opportunities;
- c) status of environmental objectives, status of environmental performance and monitoring trends in non-conformities and corrective actions, monitoring and measurements results, evaluation of legal compliance and results of audit.
- d) resource requirements, environmental complaints and continual improvement.

After discussion of the agenda inputs; the outputs of review include actions on environmental objectives if not achieved, conclusions of environment management system and managerial imprecations.

6.9 Conclusion

This section highlights the results of the qualitative and quantitative findings of the research work. The ANOVA approach applied for the study of the significance level of environment aspect of forging furnace stack emission which was identified and selected for the study. The environmental performance for the parameters of the furnace stack emission was measured and compared with the last two cycle of 2021 and 2022 as per the standard specifications of the regulatory body. There was no significance difference in terms different cycle between the parameters. To further enhance the parameters to the lower limit for positive impact on the environment the autonomous maintenance check list is advised which will be carried out the machine operator on daily basis. On the other hand, the measurement of parameters for ambient air quality was carried out for the last two cycles wherein the results were found within the specifications limits which is the indication of green manufacturing in the company. The necessary documentation to maintain the environmental performance was defined and assessed which includes environmental manual, operational control procedures, environmental objectives, internal audit and management review meeting. The non-conformities identified in the internal audit were corrected with correction and corrective actions. In the management review, it was ensured the effectiveness of the environmental system.

The environmental aspects of forging are energy use, emissions to air, solid waste, noise, and water use which carry both ecological and financial consequences. While the cost of implementing environmental measures is high initially, the long-term cost savings, reduced risks, and improved market image outweigh these investments. Forging industries achieve both operational efficiency and environmental responsibility by addressing these aspects strategically.

Environmental measures in forging industries are often seen as added costs, but the analysis shows that act as strategic investments. Energy-efficient furnaces, emission controls, and recycling systems reduce operating costs over time while improving

compliance and sustainability credentials. The avoidance of regulatory penalties, potential downtime, and reputational risks further reinforces the economic justification. Thus, integrating environmental management in forging not only mitigates ecological impacts but also enhances profitability and competitiveness.

Since forging is a high-temperature, heavy-load, and high-noise process, its impacts are significant on both workers and surrounding communities.

Occupational Health Impacts

Heat Stress and Burns

- Forging involves furnaces operating at 1,000–1,200 °C.
- Workers are exposed to extreme heat, leading to dehydration, heat exhaustion, and risk of severe burns.
- Long-term exposure causes chronic fatigue and reduced productivity.

Noise-Induced Hearing Loss

- Hammering, presses, hydraulic and pneumatic tools generate noise levels often above 90 dB.
- Prolonged exposure without adequate protection results in partial or permanent hearing loss.
- Workers also experience stress, irritation, and communication difficulties due to excessive noise.

Respiratory Issues

- Scale dust, metal fumes, and combustion emissions (Nox, CO, SO₂) may cause respiratory irritation, bronchitis, or long-term lung disease.
- In poorly ventilated facilities, carbon monoxide poisoning is a serious risk.

Musculoskeletal Disorders (MSDs)

- Workers are often engaged in heavy lifting, awkward postures, and repetitive operations.
- This results in joint pain, back injuries, and long-term musculoskeletal disorders.

Eye and Skin Hazards

- Intense glare from furnaces can cause eye strain or temporary vision loss.
- Metal splashes and hot scale particles lead to skin burns and injuries.

Social Impacts

Worker Safety and Morale

- Frequent accidents and unsafe conditions reduce worker morale and lead to high absenteeism.
- Lack of safety culture creates fear and dissatisfaction among employees.

Family and Community Health

- Workers exposed to occupational hazards may carry long-term health issues affecting their families.
- Noise and emissions from forging plants also affect surrounding communities, leading to social resistance and complaints.

Employment Opportunities

- Forging industries provide significant local employment, but often at the cost of unsafe working environments.
- With better safety and environmental practices, the industry improves its social reputation and attract a more stable workforce.

Gender and Social Equity

- Forging is traditionally male-dominated due to its physically demanding nature, limiting opportunities for women and differently-abled workers.
- This creates social imbalance and limited workforce diversity.

Mitigation Measures

- Occupational Health & Safety Training: Regular training sessions for workers on safe handling of equipment, use of PPE, and emergency response.
- Personal Protective Equipment (PPE): Heat-resistant gloves, helmets, face shields, ear protection, and safety boots to reduce injuries.
- Engineering Controls: Noise enclosures, local exhaust ventilation, and ergonomic lifting devices to minimize direct exposure.
- Workforce Welfare Programs: Health check-ups, insurance coverage, and rest breaks in cool zones to prevent heat stress.
- Community Engagement: CSR initiatives, pollution control measures, and transparent communication to maintain good community relations.

6.10 Summary of the Environmental Aspect Analysis

The environmental aspect analysis conducted in this study evaluated processes and activities impact natural resources, emissions, and waste generation, with the aim of identifying opportunities for improvement through lean and green practices. Using Quality Management System, significant aspects such as energy consumption, and forging furnace stack emissions were systematically assessed and prioritized based on the magnitude and frequency of occurrence. The analysis revealed that environmental impacts are linked to process inefficiencies, thereby reinforcing the role of green manufacturing tools in addressing them. By integrating environmental performance indicators into QMS monitoring and reporting mechanisms, organization was able to align compliance obligations with proactive sustainability goals. This approach demonstrated that environmental aspect analysis is not only a regulatory requirement but also a strategic tool for embedding green objectives within quality and lean initiatives.

CHAPTER 7

LEAN AND GREEN APPROACH

FOR

QUALITY MANAGEMENT SYSTEM

This chapter presents the overview of quality management system with lean and green approach related to objective no. 4. Process interaction map was created to find out the core and supporting processes along with management processes. The objective of the processes was formulated and assessed through the internal audit. The findings of internal audit were analyzed and further check list implemented to make it as mistake proofing. The 5S methodology applied in details and assessed before and after the implementation. The detail of this study was discussed in this chapter.

7.1 Introduction

In the industry sector, the quality management system is a methodology used to establish a measurable performance indicator and carry out operational tasks.

The following are some benefits of the quality management system:

- Minimization the rate of rejection level.
- Meeting production delivery schedules.
- Improving work culture.
- Minimizing the consumption of electricity which helps in energy conservation.
- Avoid depletion Natural Resources.
- Control process waste.
- Meet Environmental Parameters.

Process approach is applied for identification and managing the process. Process is interrelated activities, which transforms inputs into outputs. The model of Quality Management System with respect to processes is developed based on the assessment which is presented in figure 7.1

Processes	Sales	Procurement	Stores	Quality Control	Production	Machine Maintenance	Human Resource and training	Management Process
Sales		√		√	√		√	√
Procurement	√		√	√	√		√	√
Stores		√		√	√	√	√	√
Quality Control	√	√	√		√	√	√	√
Production	√		√	√		√	√	√
Machine Maintenance		√	√		√		√	√
Human Resource and training	√	√	√	√	√	√	√	√
Management Process	√	√	√	√	√	√	√	√

Figure 7.1: Process Interaction Map

7.2 Documentation

The documentation is categorized in three levels which is given as **Level 1: Quality manual:** The standard contains ten clause and referred in the manual. Qualitative goals to achieve them are addressed. It deals with resource, operation and performance evaluation.

A process deployment matrix prepared for process ownership to perform efficient operations which is shown in Table 7.1

Table 7.1: Matrix of Processes

S. No.	Name of Process	Ownership of process
1	Sales	Head of Sales
2	Procurement	Purchase Manager
3	Stores	Head of Stores
4	Quality Control	QC Head
5	Production	Production Head
6	Machine Maintenance	Maintenance Head
7	Human Resource and training	HR Manager
8	Management process	Director

Responsibilities of employees are prepared and documented. The same is communicated to all for understanding. A detailed matrix is documented which is shown in Table 7.2

Table 7.2: Responsibility of Employees

S. No.	Name of authority	Remarks
1	Director	Documented
2	Head of Sales	
3	Purchase Manager	
4	Head of Stores	
5	QC Head	
6	Production Head	
7	Maintenance Head	
8	H.R. Manager	

Objectives of processes

The objective evaluates the specific activities to achieve the target which is presented in table 7.3.

Table 7.3: Index of Objectives

S. No.	Name of Process	Objectives
1	HRD & Training	Conduct training as per the plan
2	Sales process	Ensure Customer feedback on satisfactory
3	Procurement	Performance of Suppliers
4	Quality Control	Analysis of rejection
5	Production – Forgings	Ensure timely delivery 5'S score
6	Human Resource Development and training	Training plan verses actual.

Level 2: Procedures: Procedures are documented for the work to be performed. The procedures and work instructions of the manufacturing processes are documented and displayed in the relevant places of shop floor. The list of procedures are given below in table 7.4

Table 7.4: List of Procedures

S. No.	Title
1.	Procedure of Sales process
2.	Procedure of Procurement
3.	Procedure of Stores
4.	Procedure of Quality Control
5.	Procedure of Production
6.	Procedure of Machine Maintenance
7.	Procedure of Human Resource Development and training
8.	Procedure of Management process

Level 3: Work instructions: The work to be carried for the manufacturing operation is indicates in the instruction sheet. Table 7.5 lists the work instructions.

Table 7.5: List of Work Instructions

S. No.	Title
1	Work Instruction for Machining Operation
2	Work Instruction for Electroplating
3	Work Instruction for Heat Treatment
4	Work Instruction for Safe Working of Operation
5	Work Instruction for In-coming Inspection
6	Work Instruction for patrol and final Inspection
7	Work Instruction for House Keeping
8	Work Instruction for Forging Operation

7.3 Internal audit

Internal audit is a process that helps achieve goals and improve the system. It is carried out in order to evaluate and improve established processes.

Audit Schedule

Schedule No. 01/22

Date: 02-04-2022

An internal audit has been scheduled as detailed in the table 7.6

Table 7.6: Schedule of April 2022

Dated	Time		Name of Auditor	Name of Process
	From	To		
20-04-2022	1000 Hrs	1100 Hrs	Internal Auditor – 1	Sales process
	1100 Hrs	1200 Hrs	Internal Auditor – 1	Procurement
	1300 Hrs	1330 Hrs	Internal Auditor – 1	Stores
	1330 Hrs	1430 Hrs	Internal Auditor – 1	Production
	1500 Hrs	1530 Hrs	Internal Auditor – 1	Machine Maintenance
	1530 Hrs	1600 Hrs	Internal Auditor – 1	Quality Control
	1600 Hrs	1700 Hrs	Internal Auditor – 1	Human Resource Development and Training
	1700 Hrs	1800 Hrs	Internal Auditor – 2	Management process

Summary of Internal Audit

Dated: 20.04.2022

Table 7.7: Summary of April 2022

Name of Process	Non conformity	Status
Sales process	Nil	Nil
Procurement	Nil	Nil
Stores	Nil	Nil
Production	2	closed
Machine Maintenance	1	closed
Quality Control	Nil	Nil
Human Resource Development and Training	Nil	Nil
Management process	1	closed
Total	04	All closed

7.3.1 Why and Why Analysis of Internal Audit

To identify counter measures for the audit non-conformance, why-why analysis has been done. Figure 7.2 shows why and why analysis for the elimination of this problem.

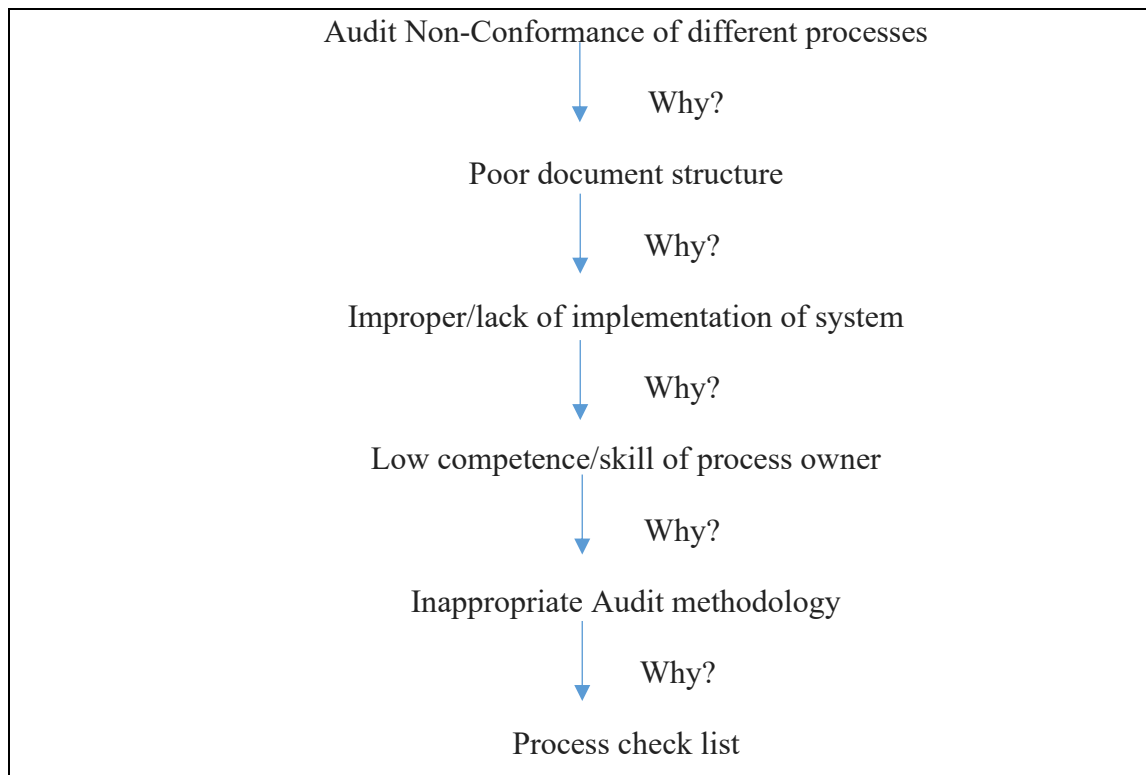


Figure 7.2: Why-Why Analysis of Audit Non-conformance

Process check list is prepared as mistake proofing and will be used by the process owner to carry out the activities of related process. The same check list is referred by the internal auditor to assess the system as per audit cycle to eliminate the audit non-conformance. The design and model are documented in the format.

Sr. No.	Process Check List			Evidence checked	Whether Complying (Yes /No)	NC Reference
	Date: 01-09- 2023	Auditor: ABC	Auditee: XYZ			
1.	Marketing:					
1.	Are all customer requirements determined?			Records	Yes	No NC
2.	Is there any effective system for review of customer requirements?			Records	Yes	No NC
3.	Are customer requirements confirmed to the customer in case of verbal order?			Records	Yes	No NC

4.	Is there a system to measure customer feedback and the data related to customer satisfaction analyzed for continual improvements?			Records	Yes	No NC
5.	Are customer complaints effectively handled as per documented procedures and records of customer complaints maintained?			Records	Yes	No NC
Sr. No.	Process Check List			Evidence checked	Whether Complying (Yes /No)	NC Reference
	Date: 01-09-2023	Auditor: ABC	Auditee: XYZ			
2.	Purchase:					
1.	Is there an initial evaluation process of suppliers in accordance with organizations requirements?			Records	Yes	No NC
2.	Is purchasing information conveyed to the suppliers and adequacy of requirements is ensured before communicated to suppliers?			Records	Yes	No NC
3.	Is routine performance evaluation of suppliers carried out as per scheduled frequency?			Records	Yes	No NC
Sr. No.	Process Check List			Evidence checked	Whether Complying (Yes /No)	NC Reference
	Date: 01-09-2023	Auditor: ABC	Auditee: XYZ			
3.	Stores & Despatch:					

1.	Storage systems/ FG (e.g. proper storage, conditions, authorization, issue system) Storage & handling during production (e.g. WIP storage, handling, etc.) Delivery systems (loading, transport, transportation) Post-delivery (during installation, after sale service etc. as applicable) Packaging (suitable packing, method, marking)			Records	Yes	No NC
Sr. No.	Process Check List			Evidence checked	Whether Complying (Yes /No)	NC Reference
	Date: 01-09-2023	Auditor: ABC	Auditee: XYZ			
4.	Production:					
1.	Are process plans / control plans available?			Records	Yes	No NC
2.	Is effective production-planning system exists?			Records	Yes	No NC
3.	Is validation / revalidation carried out for special processes?			Records	Yes	No NC
4.	Is the product identification available including product status?			Records	No	NC

5.	Are followings available: a) Product specifications, b) Work instructions on relevant machines, c) Suitable equipment’s, d) Master samples, e) Monitoring & measurement equipment’s	Records	Yes	No NC		
6.	Is unique product traceability (as required) is controlled and recorded?	Records	Yes	No NC		
7.	Are tools / dies / fixtures are properly maintained and checked periodically?	Records	No	NC		
8.	Is control exists over customer property?	Records	Yes	No NC		
9.	Are records of change management maintained for the changes in the processes?	Records	Yes	No NC		
10.	Is shop floor maintained adequately for the product / machine / operator safety?	Records	Yes	No NC		
Sr. No.	Process Check List			Evidence checked	Whether Complying (Yes /No)	NC Reference
	Date: 02-09-2023	Auditor: ABC	Auditee: XYZ			
5.	Quality Control:					

1.	Are incoming materials (i.e. raw materials accessories, packing materials & outsourced services) are being inspected / verified and records of this inspection / verification maintained as per the procedure.	Records	Yes	No NC
2.	Are the product parameters (In-process and Final) at appropriate stages in each shift monitored as per the quality plan and records maintained?	Records	Yes	No NC
3.	Does records indicate person(s) authorizing product release?	Records	Yes	No NC
4.	Are deviations authorized in release, if any?	Records	Yes	No NC
5.	Calibration:			
6.	Are required equipment's identified for different monitoring & measuring activities and their calibration / verification carried out at the specified intervals?	Records	Yes	No NC
7.	Are master used for calibration / verification Traceable to international/national or otherwise recorded basis?	Records	Yes	No NC

8.	Are equipment's Safeguarded from adjustments and protected from damage/deterioration?	Records	Yes	No NC		
9.	Are records of calibration & verification maintained?	Records	No	NC		
10.	Control of Non-Conforming product:					
11.	Is non-conforming product identified (e.g. in stores, process areas, finished areas)?	Records	Yes	No NC		
12.	Are responsibilities & authorities defined for dealing with NC products?	Records	Yes	No NC		
13.	Are methods defined to dealt with NC product?	Records	Yes	No NC		
14.	Is corrected product re-verified?	Records	Yes	No NC		
15.	Are action taken for NCs detected after delivery or use?	Records	Yes	No NC		
Sr. No.	Process Check List			Evidence checked	Whether Complying (Yes /No)	NC Reference
	Date: 02-09-2023	Auditor: ABC	Auditee: XYZ			
6.	Maintenance:					
1.	Are the manufacturing machines well maintained (where affecting product quality, environmental and health & safety issues) including utilities (e.g. D.G., etc.)	Records	No	NC		

2.	Are records of preventive & breakdown maintenance maintained?			Records	Yes	No NC
Sr. No.	Process Check List			Evidence checked	Whether Complying (Yes /No)	NC Reference
	Date: 02-09-2023	Auditor: ABC	Auditee: XYZ			
7.	HRD:					
1.	Is there any system for determining of competency needs for personnel affecting product quality, environment, health & safety aspects?			Records	Yes	No NC
2.	Are actions taken on these needs?			Records	Yes	No NC
3.	Is effectiveness measured for the actions taken?			Records	Yes	No NC
4.	Are records maintained of employees for competency related to education, training, skills and experience?			Records	Yes	No NC
5.	Do employees understand the significance and relevance of their work, as well as how it helps to meet quality goals?			Records	Yes	No NC
6.	Are records of required knowledge maintained in the organization?			Records	Yes	No NC
7.	Are the infrastructure requirements identified, supplied, and maintained in order to attain product conformance?			Records	Yes	No NC
8.	Is the required work environment to achieve product conformity determined & managed?			Records	Yes	No NC
Sr.	Process Check List			Evidence	Whether	NC

No.	Date: 02-09-2023	Auditor: ABC	Auditee: XYZ	checked	Complying (Yes /No)	Reference
8.	Management Functions:					
1.	Are systems available in documented form?			Records	Yes	No NC
2.	Are external documents are controlled as per documented system?			Records	Yes	No NC
3.	Are records well maintained and their retention periods defined?			Records	Yes	No NC
4.	Is Quality Policy defined and communicated in the organization and understood by the organization personnel?			Records	Yes	No NC
5.	Is Quality Policy communicated within the organization?			Records	Yes	No NC
6.	Are Quality objectives documented and in line with the Quality Policy?			Records	Yes	No NC
7.	Are there plans to achieve objectives?			Records	Yes	No NC
8.	Are there plans to work for continual improvements?			Records	Yes	No NC
9.	Is the organizational structure defined?			Records	Yes	No NC
10.	Are responsibilities and authorities defined?			Records	Yes	No NC
11.	Is any member of management appointed as MR?			Records	Yes	No NC
12.	Is there any effective system of internal external communication and records available for this internal & external communication?			Records	Yes	No NC

13.	Is there any system of review by top management for critical issues of the organization e.g. Customer feedback / complaints, Product conformity, Status of Corrective / preventive actions, Audit results, Recommendation for improvement?	Records	Yes	No NC
14.	Are there decisions & actions on key results e.g. Improvements in QMS / Process effectiveness, Product improvements w.r.t customer requirements, Resource needs	Records	Yes	No NC
15.	Are internal audits conducted at the defined frequency by the trained auditors?	Records	Yes	No NC
16.	Are responsibilities for planning, conducting, reporting results & maintenance of records defined?	Records	Yes	No NC
17.	Are action taken by auditee to eliminate NCs & causes without delay?	Records	Yes	No NC
18.	Are actions verified & reported?	Records	Yes	No NC
19.	Are monitoring & measurement activities for the key processes implemented?	Records	Yes	No NC
20.	Is data analysed for customer satisfaction, product conformity (rejection/rework), trends for processes and products and supplier performance?	Records	Yes	No NC

21.	Are NCs including potential NCs, customer complaints reviewed, their causes determined, Corrective/preventive actions determined and implemented, their records are maintained and review carried out for action taken?	Records	Yes	No NC
22.	Are management review meetings conducted as per scheduled frequency?	Records	Yes	No NC
23.	Are all agenda points discussed in the meeting and records of Management Review Meeting maintained?	Records	Yes	No NC
24.	Are internal & external issues and risk & opportunities identified by the organization?	Records	Yes	No NC
25.	Are needs & expectations determined for the identified interested parties?	Records	Yes	No NC
26.	Is documentation developed as per the identified risk & opportunities and identified needs & expectations of the interested parties?	Records	Yes	No NC

Table 7.8: Drivers of Quality Management System

S. No.	Drivers	Consequence	Reference
1	Top Management Commitment	Commitment for implementation of management system.	[Perminder Jit Singh, KS Sangwan, 2011]
2	Employee Training	Increase awareness about work practices	[Goyat et al., 2019]
3	Multi Skill Task Force	Ability to perform multifunctional activities	[Kaswan et al., 2021]
4	Preventive Maintenance of Machines and Equipment	Less rate of product defects and manufacturing lead time	[R. Rathi and M. Singh, 2021]
5	Standardization	Improves work practices and productivity	[M. Singh et al., 2019]
6	5'S Methodology	5'S minimizes waste generated in production system and enhances lean manufacturing.	[Veres, et.al. 2018]
7	Internal Audit	Internal audit identifies non-conformity and opportunity for improvement in the manufacturing processes	[M. Singh and R. Rathi, 2019]

7.4 Workplace and 5'S methodology

The concept of this methodology consists of five pillars, which are Sort, Set in Order, Shine, Standardize and Sustain which ensures place of work in better condition.

1S - Sort:

Unnecessary things are removed and desired things are kept in a place where other things are discarded. The 5'S zone layout is outlined and shown in Figure 7.3

2S - Set in order:

All items are properly located with identification. A 2'S philosophy refers to a place for every object and every object in its location.

3S - Shine:

This 3'S relates to maintaining cleanliness in the workplace and indicates of visual control of cleanliness. These practice needs must be followed every day to maintain this system.

4S - Standardization:

Standardization gives the dimension for same type of work to be performed at each and every work station to save the resources. It provides the equal practice at the working operations.

5S - Sustain:

This pillar inform for the maintenance of system is required. By monitoring and audit, sustain of 5'S is ensured. 5'S Audit was conducted in July, 2022 as per the check list and the score obtained was 72%. The minimum target set to achieve was 70%. The key parameters audited were mentioned below:

- Facilities
- Floor and gangways
- Health and Safety
- Environment
- Tools and Fixtures
- Storage of materials
- Machine Guarding



BEFORE



AFTER

Figure 7.4: Stores – Before and After Photograph



BEFORE



AFTER

Figure 7.5: Production Shop – Before and After Photograph

7.5 Conclusion

The conclusion of the study enhanced competence of the researcher and will use the skills in industry. Furthermore, the following benefits were achieved after the successfully implementation:

- The quality management system is successfully studied for implementation with 5'S.
- There has been an improvement in work culture and work flow.
- The implementation of the 5'S technique is studied with an audit score for continual improvement.
- Rejection level was significantly monitored and measured by introducing data tools and Pareto chart. Subsequently, a corrective measure is proposed to control the level of rejection.
- After studying the implementation of quality management system with 5'S wherein an effect of the study indicates that the management of the organization should delegate the responsibility for monitoring the results of effectiveness and report on the same to the management for actions on deviations.

Challenges in Integrating Lean and Green Approach into QMS

The integration of Lean and Green approach within a Quality Management System (QMS) provides organizations with competitive and sustainable advantages. However, the process is complex and presents several challenges:

Cultural and Organizational Resistance

- Challenge: Employees view Lean and Green initiatives as extra work rather than improvements. Resistance to change is common with traditional work practices.
- Impact: Lack of cooperation slows adoption and undermines QMS objectives.

Complexity in Metrics and Measurement

- Challenge: Lean performance is often measured in terms of defect, waste reduction, and cycle time, whereas Green focuses on environmental indicators like carbon footprint, emissions, and resource use.
- Impact: Developing an integrated set of performance indicators for QMS becomes difficult, leading to misalignment in goals.

Knowledge and Skill Gaps

- Challenge: Workers, managers, and other staff lack adequate training in both Lean and Green practices.
- Impact: Misinterpretation of standards and poor implementation reduce the effectiveness of integration.

Short-Term vs. Long-Term Benefits

- Challenge: Lean benefits (like reduced lead time and defects) are visible in the short term, while Green benefits (like reduced emissions) take longer to materialize.
- Impact: Management often prioritizes quick financial results, sidelining environmental aspects in the QMS.

Scalability of Lean and Green Approach for QMS across other Sectors

The Lean and Green approach in Quality Management Systems is not limited to manufacturing, it has significant scalability to a wide range of other sectors. However, the extent and nature of adoption depend on sector-specific characteristics, regulatory frameworks, and organizational maturity.

Scalability of Lean and Green QMS lies in its flexibility. While the principles remain universal as waste reduction, efficiency improvement, and sustainability, the implementation varies sector by sector.

- Manufacturing-based sectors (Automotive, Engineering, Food, Textiles): High scalability due to existing Lean and Green familiarity.
- Service-oriented sectors (Healthcare, IT): Require adaptation of Lean and Green tools to intangible processes like workflows, information flow, and energy usage.
- Large-scale infrastructure and construction: Offer the highest potential impact but face organizational and regulatory barriers.

The biggest challenge across sectors is balancing short-term efficiency gains with long-term environmental goals, as well as aligning regulatory, financial, and cultural aspects to sustain the integrated approach.

7.6 Summary on Lean and Green Approach for QMS

The Lean and Green approach within Quality Management Systems integrates efficiency driven lean practices with sustainability focused green initiatives to create a holistic framework for operational excellence. The tools such as 5S, Kaizen study, Internal Audit and check list reduce process inefficiencies and non–value-added activities, while green practices minimize environmental impacts through resource optimization, energy conservation, and waste reduction. When embedded in QMS, these approaches are reinforced by structured procedures, continuous monitoring, and a culture of continuous improvement, ensuring long-term adoption and measurable results. The synergy not only enhances quality and compliance but also contributes to competitiveness, resilience, and corporate social responsibility by aligning operational performance with environmental and stakeholder expectations.

CHAPTER 8

MANAGERIAL IMPLICATIONS

The current study would support and encourage LG manufacturing practice and industry manufacturers to look forward the practices implementation in their business units effectively and efficiently. As a result, the advantages for decision making to accept LGMPs approach in their conventional manufacturing system to change in sustainable operational system. As employees and financial aspect is involved in implementing LG strategies, so implementation of all MPs at a time is not justified. The strategic manager must consider more relevant to driving LGMPs ahead. The study's findings will assist businesses in improving delivery, efficiency, and waste reduction while boosting employee morale and, ultimately, customer satisfaction. An industry will be able to manage its operations more effectively and efficiently with successful adoption.

Theoretical Implications

This case study makes it easier for MSME manufacturing sectors to successfully and efficiently adopt the lean methodology. The industry can use the lean methodology to minimize process line faults, cut lead times for manufacturing processes, and eliminate waste. The main obstacle to implementation is the lack of knowledge about Lean methodology. As a result, it's critical to map employee skill levels toward lean and train staff to be effectively competent. However, a key obstacle to successfully implementing the lean strategy is the mindset of the shop floor staff. Employees may have the chance to get rewards for their acknowledgment through a specified process. The industry management is further encouraged to continuously conduct corrective action and validate the outcomes of the findings in order to reduce the rate of rejection level in the forging process. To boost their confidence and trust in implementing any new methods for operating systems for continuous improvement, industrial managers and upper management can communicate the study's findings with their internal staff. The suggested methodology's applicability to different industries is that managers and practitioners can utilize the study's lean tools technique to improve process lead times and product defect analysis for remedial action with root cause

identification. The real-time introduction of forging defects, which play a significant role in the process realization, makes this study useful. Lead time reduction also involves value stream mapping, brain storming, training, and a one-minute die exchange. Industrial managers and professionals in the industrial sector greatly benefit from these instruments.

In this research work, a case of engineering industry was studied for green manufacturing in the forging furnace stack emission and implementation of the environment management system. The industry is advised to deploy horizontal implementation of environmental system in the processes of manufacturing. The major barrier identified for adverse impact to the environment is lack of awareness of the shop floor employees. Thus, it is imperative to identify the training needs and provide the training on appropriate subject to enhance the skill level for effective implementation. To minimize the adverse impact to the environment, the environment parameters can be measured within the specified and lower limit. Subsequently, the measurement of the environmental parameters, it is advised to implement the autonomous maintenance plan which will be carried out the machine operator on daily for effective machine and equipment efficiency so that no adverse impact to the environment can release. Secondly for implementation of environment management system, an internal audit is advised at the defined frequency to evaluate the status of environmental objectives and environmental performance. The findings of the audit can be discussed in the management review meeting for sustainable development of green manufacturing.

This study facilitates to the engineering industries to implement the actions and control measures of lean and green waste which were proposed in the future state on both the aspects. The major barrier in the implementation of control of lean and green waste is non awareness of the employees. Thus, it becomes imperatives that skill level of the employees is monitored and provide training on the identified needs to effectively implement the actions. The management of the industry has implemented the actions and validate the data presented on future state of lean and green waste. This validated data horizontally deployed in the other manufacturing processes of lean waste to obtain optimum results. The research work summarizes that the quality management system with 5'S implemented in the industry with the involvement of top management. The

management reviewed this agenda point in the management review meeting and discussed the action results of the review output to the effective implementation of the system.

The integration of Lean and Green principles into Quality Management Systems presents not only improvements to operational excellence but also significant managerial implications. For the organizations to maximize the benefits of this integration, managers must adapt leadership, decision-making processes, and resource allocation strategies.

Strategic Alignment

- Managers must ensure that Lean and Green objectives are aligned with organizational strategy.
- Integrating sustainability targets with quality and productivity goals helps in achieving long-term competitiveness.

Investment and Resource Allocation

- Initial implementation requires investment in technology, training, and eco-friendly infrastructure.
- Managers need to evaluate cost–benefit, considering that environmental initiatives may not deliver immediate returns but provide long-term financial and reputational benefits.

Change Management and Culture Building

- Resistance to new processes is a common barrier. Managers must act as change leaders, fostering a culture of continuous improvement and sustainability.
- Incentive systems, employee engagement programs, and strong communication strategies are vital to implement the strategies.

Performance Measurement

- Traditional QMS metrics focus on quality, and time. Lean and Green integration requires to introduce performance measurement covering both efficiency and environmental sustainability.

Knowledge, Training, and Leadership Development

- Continuous employee training in Lean and Green practices is essential.
- Managers must invest in leadership development programs that promote both

operational excellence and sustainability thinking.

Policy Implications for Lean and Green Approach with QMS

The adoption of Lean and Green practices within Quality Management Systems not only provides operational and strategic benefits at the organizational level but also raises implications for policymakers and industry associations. Managers play a critical role in influencing and adapting to these policy environments.

Managerial implications extend beyond organizational boundaries into the policy ecosystem. Governments can drive adoption through incentives, regulation, and training, while industry associations can support it through benchmarking, collaboration, certification, knowledge sharing and recognition mechanisms. Managers must proactively engage with these policy frameworks, using as enablers to integrate Lean and Green practices into QMS and achieve both operational efficiency and sustainability leadership.

CHAPTER 9

CONCLUSION, LIMITATIONS AND FUTURE RESEARCH DIRECTION

9.1 Conclusion

This study presents the research model and framework by linking the lean practices and sustainability performance. The model explains how the lean practices transform to sustainable development. The areas of linkage between lean, sustainability and operational management system were incorporated in the framework. Further, the chapter explains the research design and constructs in details.

The research will assist in identifying how lean and sustainability are compatible, which will allow the management community persuade various levels of stakeholders to invest in and make the necessary efforts to adopt lean. The reduction in the failure rate of MSMEs, policymakers, and authorities are now working tirelessly to transfer the competence level of MSMEs. In order to address economic growth and fight unemployment, the main focus should be on improving the competence as well as business sustainability of MSMEs. The results of this research provide credence to the need for more focused training and funding for the use of LMPs that increase MSMEs' resilience.

This study identified the root cause and the proposed corrective actions to minimize the rejection rate of forged part due to defects through implementation of lean approach. For this, a case industry was selected from North India and collected the data of around six months during before and after analysis. Before implementing lean approach, it was observed that case industry was having around 1.09% rejection rate of their one hand tool i.e., spanners. Due to the high rejection level of spanner, it was selected as case product from case industry. Further, collected data from industry provided the list of major reason of rejection of product and found the major contributor in rejection as unfilling, cracks, scaling, fold, and twist. Further, critical contributor towards rejection was extracted through Pareto analysis and it was found that cracks, unfilling and scaling are major contributors. Moreover, the cause-and-effect analysis

was conducted to identify the major causes of these contributors. The obtained outcomes reveals that poor heating, improper cleaning of the stock used for forging, and too low working temperature were responsible for unfilling, scaling, and crack, respectively. Based upon this root causes, further solutions were suggested to company personal and they also agreed with them and ready to implement in their running system. After implementing the solutions, further data related to rejection was collected, analyzed, and found that rejection level decrease from 1.09 to 0.85% successfully. Besides, lead time also decrease from 9 to 5 days. The obtained results were also validated through Taguchi analysis and observed that results are in the favour and valid. The outcomes of present case study will facilitate to industrial managers to design the manufacturing system under full capacity utilization of company and minimal rejections, which turns towards operational excellence and quality 4.0. Despite of significant contribution, this study also having few limitations like the present study was carried out only in one manufacturing industry. Moreover, only one forged part was targeted to control the defects and enhance the production rate. In future research, the proposed methodology can be implemented in other type of manufacturing industry like automotive, fasteners and plastics etc. Moreover, researchers can work on other kind of wastages in manufacturing industries in future research direction. The future research scope of the study can be implemented in other type of industry which includes automotive, engineering, plastics, steel manufacturing, railways products and fasteners.

This research work outlined for the study of qualitative implementation for the green manufacturing with respect to quantitative environmental performance of the forging furnace stack emission. The environmental parameters of furnace stack emission were within the specified limit and ANOVA approach was applied for the significance level. The study identified that there was no difference between different cycle of study. To further enhance the environment performance of the furnace stack emission, the autonomous maintenance check list is advised to implement. For the qualitative study of implementation of green manufacturing, the status of environmental objectives was assessed with target and the same was within the limit. The internal audit was carried out to evaluate the effectiveness of implemented system. The identified non-conformities were corrected with root cause analysis and corrective

action. Hence the same system is advised to continue for environmental enhancement of the green manufacturing.

The lean practices followed by organizations worldwide have helped to improve the operational and sustainability performances, especially in the large-scale organizations. Multiple studies have been conducted in different countries for bringing out the benefits of lean practices. This research was aimed to identify the effect of the LGMPs on the sustainability performances of manufacturing MSMEs. The research also focused on identifying the areas of linkage between lean and green with respect to the effect of operating system variables in these areas. To address these aims, initially a thorough literature review was conducted in the subject area and descriptive research was designed.

The constructs and variables for the dependent and independent variables were selected from the previous works. The relevant hypotheses were developed based on the objectives and literature available. The data collection was restricted to the sample frame selected as per the research framework and design.

The data were collected from Victor Forgings, Jalandhar, Punjab, India and was analyzed using various statistical methods like descriptive analysis, ANOVA approach, pareto analysis, rejection trend analysis and qualitative analysis. Finally, the test results were cross validated and analyzed with case studies selected from the sample frame. This chapter presents the main research findings from the study. It also provides the limitations of this study and the directions for the future research. The chapter ends with the conclusions and recommendations arising from the research findings.

According to the current research, lean manufacturing may be a very effective strategy for MSMEs to achieve long-term benefits. The study's findings provide a strong foundation for the connection among sustainability and lean implementation in MSMEs as well as the relationship between sustainability performances. According to the research, LGMPs have a good impact on the environmental sustainability which has a favorable impact on social and economic performance. Both practitioners and the academic community may benefit from the findings of this research. It provides a critical perspective on the significance of LGMPs for MSMEs' sustainability

performance. These findings provide decision-makers valuable information and a significant implication for creating and executing lean approaches in this industry.

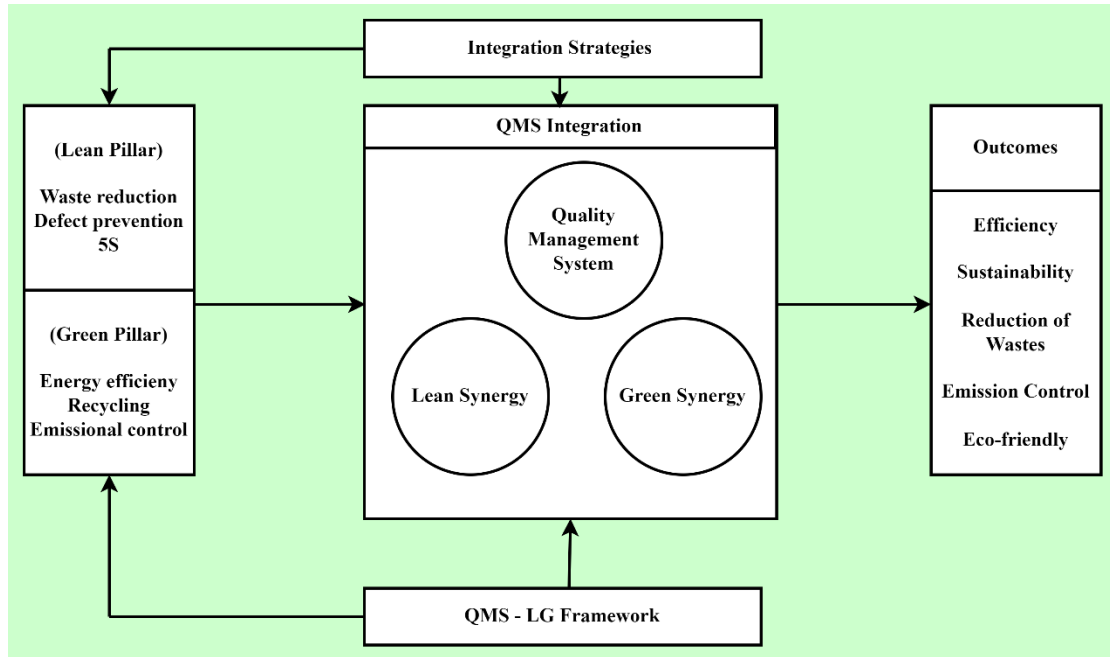


Figure 9.1 – QMS Integration Framework

The objective wise conclusion is summarized as below:

Objective No. 1: To study the manufacturing processes aims to minimize the rejection level.

- For the manufacturing processes aims to minimize the rejection level was implemented for identification of the root cause analysis to the defects and corrective action.
- The Pareto analysis was done to check the major contribution of the defects to take action. After implementing the solutions, further real-time data related to rejection was collected, analysed, and found that rejection level decrease from 1.09 to 0.85% successfully.
- Besides, lead time also decrease from 9 to 5 days. The obtained results were also validated through Taguchi analysis and observed that results are in the favour and valid.
- The overall productivity increased from 10,00,000 pieces to 12,00,000 pieces (20%) after the implementation of actions.

- The outcomes of present case study will facilitate to industrial managers to design the manufacturing system under full capacity utilization of company and minimal rejections.

Objective No. 2: To study the waste elimination to optimize lean manufacturing.

- For the waste elimination to optimize lean manufacturing was identified with lean and green waste.
- Current State of Lean Waste was studied and validated with the future state.
- Similarly, study of green waste was conducted with current state and the same has been validated with future state.
- There has been improvement after the implementation of actions as below:
- Lean Waste:
 - For the corrective action, there is 33% improvement in transportation
 - 60% improved in motion
 - 33% in waiting by introducing SMED
 - Over production improved by 7%
 - 0.2% rejection reduced to control the defects.
- Green Waste:
 - After implementing effective operational control procedures of die design and training, generation of forging flash reduced by 5% (118.75 Ton per month), generation of waste oil reduced to 10% (2.7 Litres) per month and contaminated waste cloth, the quantity reduced by 5 kg (25%) per month.
 - After operational control for filtration process and centralized system, Generation of sludge of cutting oil, the quantity reduced to 10% (5.4 Kg/month)
 - After operational control for spillage and arresting leakages, the generation of hazardous waste oil reduced to 2.7 Litres/month and contaminated waste cloth reduced by 10% (1 Kg per month).
 - After effective operational control for Nickle recovery plant and flow control validation, generation of quantity reduced by 200 Litres/day. Ref. (Consent to Operate – Water)

Objective No. 3: To study the aspect analysis to enhance environment performance.

- The environmental parameters of furnace stack emission analysed and were reduced within the specified limit. After implementation of autonomous

maintenance check list, the stack emission parameters were optimized as below:

- Particulate Matter (Limit Max 150) – 134 mg/Nm³ (Oct 2022) and 63.4 mg/Nm³ (Oct 2023)
- Sulphur Dioxide (SO₂) – 269 mg/Nm³ (Oct 2022) and 40.7 mg/Nm³ (Oct 2023)
- Oxides of Nitrogen (NOX) – 211 mg/Nm³ (Oct 2022) and 139 mg/Nm³ (Oct 2023)
- Carbon Monoxide (CO) – 151 mg/Nm³ (Oct 2022) and 70.6 mg/Nm³ (Oct 2023)
- The internal audit was carried out to evaluate the effectiveness of implemented system. The identified non-conformities were corrected with effective root cause analysis through why-why and corrective action. The findings detail is referred for effectiveness:
 - Internal audit findings – 3 Nos (June 2023) and 2 Nos (June 2024).

Objective No. 4: To study the implementation of Quality Management System with Lean and Green manufacturing.

- Process interaction mapping was prepared to study the operational processes and documentation with process matrix.
- 5S methodology was implementation for workplace orderly with respect to lean optimization. Audit score achieved 72% as per the minimum target of 70%.
- The systematic work flow of quality management system toward lean and green concept of manufacturing was implemented.
- The check list of internal audits was documented and implementation for effective internal audit. There were 50% reduction of non-conformities as compared to April 2022 (4 Nos). Afterward, in April 2023 there were only 2 non-conformities.
- For implementation of Quality Management System with Lean and Green manufacturing was studied effectively.

9.2 Industry Gain

The study for the objectives of research work enhances the competence of core team in the industry as the data obtained for execution of work was real-time. The following advantages to the industry with respect to the objectives are identified:

- For implementation of Quality Management System with Lean and Green manufacturing was studied effectively and systematic work flow of quality management toward green concept of manufacturing was implemented.
- For the waste elimination to optimize lean manufacturing was identified with hazardous and non-hazardous waste. This concept was implemented with 5S at work place and audit was conducted to assess the effectiveness.
- For the manufacturing processes aims to minimize the rejection level was implemented for identification of the root cause analysis to the defects and corrective action. The Pareto analysis was done to check the major contribution of the defects to take action.
- For aspect analysis to enhance environment performance, the aspect-impact study of manufacturing processes was carried out with the core team of Industry and significant aspect identified based on risk classification for operational control. The controls were documented and listed for implementation.

All these advantages are identified which benefitted to the industry for sustainable development in the forthcoming environment.

9.3 Limitations of the Study

The evaluation of the outcomes with the implementation of Lean-Green manufacturing practices within the Indian industrial context is rendered particularly challenging, primarily due to the limited availability of pertinent research models and comprehensive data sets. In light of this limitation, it has become increasingly evident that firms within this sector infrequently manage to integrate the aforementioned concepts in a synergistic manner, which is essential for realizing the overarching social impacts that are often anticipated from such practices. Furthermore, it is critical to underscore that one cannot categorically assert that the outcomes derived from these practices are universally applicable across the entire spectrum of lean manufacturing techniques, as variations in context and execution may lead to divergent results. Nevertheless, a multitude of practical challenges and complexities persist, which significantly hinder the ability to measure these influential factors with any semblance of reliability or accuracy in the field.

This study has made substantial contributions to the theoretical comprehension of how Lean-Green Manufacturing Practices exert influence on performance metrics, while concurrently elucidating the beneficial ramifications these practices can have on both the economic landscape and the environmental sustainability of the region. By advancing this body of knowledge, the research not only highlights the interconnectedness of social, economic, and environmental outcomes but also emphasizes the need for more robust methodologies to assess these interrelationships effectively. Ultimately, a deeper understanding of these dynamics is essential for practitioners and policymakers alike, as it may guide future initiatives aimed at enhancing the efficacy and sustainability of manufacturing practices in India and beyond. However, it is difficult to assess these characteristics with any level of certainty due to many practical challenges. In addition to contributing to LGMP's beneficial impacts on the environment and economy, this study has made substantial theoretical advances in improving our comprehension of how LGMP influences social performances. However, by persuading different stakeholders, these results significantly prepare managers to execute LGMPs in MSMEs. When the social advantages of LGMPs are properly used, the workforce's fear for the loss of jobs which impact the adoption of LGMPs may be reduced. In addition to this, the practitioners may emphasize the importance of lean methods, which are necessary for MSMEs to succeed and survive in a global setting.

Furthermore, research indicates that there are still significant gaps in our knowledge, comprehension, application of sustainability performance and lean-green integration. Using a thorough, specific, straightforward, and broad implementation strategy helps improve lean-green integration and help industries understand the big picture when speaking of sustainability outcomes. There is currently no developed Lean-Green and Sustainability performance toolset because many tools aren't well-known in the manufacturing sector, haven't been used and modified, or haven't reached maturity yet. Resistance to incorporating Lean-Green manufacturing processes and their effects on sustainability performance is exacerbated by the lack of theoretical contribution in this area.

Limitations linked to Methodology Choices

Case Study / Industry Focus

- This study focused primarily on the forging manufacturing sector which may restrict generalizability.
- Methodological choice of sector-specific sampling limits applicability to service industries or other manufacturing sub-sectors.

Data Collection Method

- Reliance on surveys and reported data introduces subjectivity and possible bias.
- Limited observational and real-time data restricts the ability to fully capture waste or environmental impacts.

Measurement of Outcomes

- Selected performance measures of defect reduction, energy use, waste reduction reflect methodological prioritization but may not capture indirect impacts such as supply chain resilience, employee behaviour, and social outcomes.
- Environmental impacts were simplified into measurable indices for emission, and hazardous waste, potentially overlooking broader ecological dimensions.

Timeframe of Analysis

- A cross-sectional approach was adopted rather than a longitudinal study, restricting insight into how Lean and Green integration evolves over time.
- Short-term data may not reflect the full cost savings or cultural changes associated with QMS improvements.

Scalability of Findings

- Methodology centred on a single-site, which may not reflect challenges of scaling Lean and Green QMS across multi-sites operations.

To summarize the study, the following limitations were advised:

- This study was conducted in the hand tool industry of Punjab State; hence the developed model will be implemented in similar kind of industry.
- This model of lean-green with QMS was implemented in MSME industry sector and will apply to these manufacturing MSME only.
- Complexity – Merging lean, green and QMS require co-ordination between multiple departments which can lead to overlapping responsibilities and resistance to change.
- Need for Skilled Manpower – This model requires employees competent and trained. Lack of trained manpower lead to poor implementation and less effectiveness.
- Cultural Resistance – Managers and employees resist the systematic changes which reduces engagement.
- Top Management Support – If management doesn't support and commit to the model, the implementation leads to fail.

Synthesize Insights

The synthesis of Lean and Green approaches within the framework of Quality Management Systems underscores a transformative in organizations of operational excellence. Rather than viewing efficiency and sustainability as parallel but separate goals, the integration demonstrates that both achieved simultaneously with supported by a structured quality framework. Lean tools reduce process inefficiencies, while Green practices minimize environmental impact, and together with QMS, the concept reinforce one another to deliver measurable improvements in performance, cost, and sustainability.

More importantly, this study shows that integration is not limited to operational excellence but extends to organizational culture. A commitment to continuous improvement, proactive leadership, and employee engagement emerges as essential drivers of success. The synergy also promotes decision-making and transparency, ensuring that lean and green metrics are treated with equal importance.

From a strategic point of view, this alignment strengthens competitiveness by enabling organizations to respond to employee satisfaction, market demands, regulatory pressures, and stakeholder expectations without compromising long-term profitability.

Theoretical Framework Integration

The integration of Lean and Green practices within Quality Management Systems reaffirms the relevance of systems theory, which views organizations as interconnected networks where efficiency, quality, and sustainability cannot be optimized in isolation. The findings support the notion that interventions in one subsystem such as waste reduction through lean produce reinforcing effects in others, including resource conservation and quality enhancement. By integrating theoretical framework to academic contribution, the study demonstrates that organizational performance emerges from holistic alignment rather than fragmented initiatives.

At the same time, the results validate the resource based by showing that the combined capabilities of lean efficiency and green innovation through QMS, constitute strategic resources that are valuable, and difficult to imitate. This integration fosters a sustained competitive advantage by embedding environmental responsibility and process excellence into the culture.

By connecting empirical evidence to these theoretical perspectives, the study contributes academically by advancing the discourse on sustainable manufacturing environment. It moves beyond descriptive case findings to demonstrate theoretical integration of lean, green, and quality management systems reframe organizational strategy. This synthesis not only bridges conceptual gaps but also positions as a unifying framework for balancing efficiency, sustainability, and quality in the evolving landscape of industrial competitiveness.

Discussion of Findings align with Prior Research

The findings of this study are largely consistent with prior research that highlights the synergies between lean and green practices. (Kurdve and Bellgran, 2021), highlights that lean-driven waste elimination often leads to reductions in material use and emissions, thereby advancing environmental goals. This study supports their

conclusion by showing that process efficiency and sustainability reinforce each other when structured within a QMS framework. Similarly, earlier contributions by (Garza-Reyes, 2015) and (Dhingra et al., 2014) emphasized that lean and green integration fosters continuous improvement. The alignment is also visible with studies such as (Psomas & Antony, 2017), who highlighted QMS as a mechanism for embedding sustainability into organizational routines. This thesis supports that view, showing that quality management systems provide the governance, measurement, and cultural foundations required for lean and green initiatives to scale effectively.

However, some findings diverge from existing literature. While earlier works often portrayed lean as a straightforward pathway to environmental benefits, this study shows that without managerial commitment, cross-functional collaboration, and reliable data-driven decision-making, the outcomes remain limited. By acknowledging both alignment and divergence, this thesis not only reinforces prior contributions but also adds depth by showing that successful integration depends on organizational readiness, leadership engagement, and strategic intent. This positions the framework not just as an operational toolset, but as a holistic approach that combines efficiency, sustainability, and quality to enhance long-term resilience.

9.4 Future Scope of Study

Although, there is a lot of study being done on the lean and green manufacturing approaches separately, more thorough studies that look at how they perform together when combined into a single framework are desperately needed. Regarding their compatibility, the research currently in publication paints a mixed picture. While some studies warn of possible conflicts, others support their integration as a way to improve sustainability performance.

Lean training and comprehensive instructions, for example, possess the capacity to impart knowledge regarding the methodologies and strategies necessary to effectively minimize lean wastage, which is fundamentally essential in the pursuit of reducing the consumption of inputs while simultaneously enhancing the longevity and operational lifespan of the equipment utilized in various manufacturing processes. Nevertheless, this particular training does not, in a substantial manner, motivate employees and workers to engage in the responsible handling of environmentally

friendly refuse and waste through the processes of disposal, recycling, and the overarching principles of resource conservation that are critical to sustainable practices.

Individuals who participate in this educational practice and acquire the skills to derive integrated value from these two distinct yet interrelated philosophies are able to adeptly apply the mechanisms and tools prevalent within the framework of lean manufacturing paradigms, thereby significantly augmenting social performance and contributing to the broader objectives of organizational efficacy and sustainability.

Therefore, to provide a more comprehensive picture of the effects of combining these two methods, future studies should also try to include the social performance factor. Scholars and industry professionals may get a better understanding of how to combine the advantages of lean and green manufacturing to achieve long-term operational success by filling up these gaps.

The future scope of study can be pertinent to the below area:

- This study can be implemented in the other geographical region of MSME industry.
- Integration with Smart Manufacturing and Industry 4.0 – Digital tools like Artificial Intelligence (AI) and IoT can monitor real-time data of lean-green waste and quality. This can enable predictive maintenance, quality checks and resource optimization.
- Alignment with SDG and ESG – Lean-Green QMS can be used in meeting Sustainable Development Goals (SDGs) and Environment, Social, and Governance (ESG) in many regions.
- Integration with Circular Economy – Lean-Green QMS will support from linear to circular manufacturing through stringent quality system of recycled inputs and minimizing environmental impact.
- Environmental Lifecycle Perspective – Quality and Environmental impact can be managed throughout the product lifecycle from design considerations to disposal.
- Green Certification - Customers and Trade Associations prefer certified sustainable and quality certifications. Lean-Green QMS can be competitive advantage.

- Government Support – Companies with Lean-Green QMS can benefit from tax incentives, carbon credits and export promotions.
- Organizational Learning – This model can foster a culture of learning, sustainability thinking and adaptive quality.
- Sustainable Supply Chain Integration – This model of Lean-Green QMS will focus on upstream and downstream sustainability in the supply chain and manage logistics emissions and eco-friendly environment.
- Development of Global Standards – Harmonization with other standards like occupational health and safety, energy management system, greenhouse gas (carbon foot print) for driving more adoption.

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PUBLICATIONS

- [1] Suresh Kumar Kashyap, Mahipal Singh, Guravtar Singh Mann, Vijay Kumar Singh. (2025). An interactive value stream mapping tool to support the inefficiencies reduction in manufacturing setting. (2025). *International Journal on Interactive Design and Manufacturing (IJIDeM)*, (Indexing: ESCI, Impact Factor: 2.1), <https://doi.org/10.1007/s12008-024-02207-0> (**Published**)
- [2] Suresh Kumar Kashyap, Mahipal Singh, Guravtar Singh Mann, Vijay Kumar Singh. (2024). Towards sustainable development in Indian small-scale industries: A green manufacturing initiative *Journal of Computational Analysis*, 365-376. (Indexing: Scopus, Impact Factor: 0.59) (**Published**)
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- [4] Suresh Kashyap; Guravtar Singh Mann; Vijay Kumar Singh; Mahipal Singh. Waste elimination through Lean and Green manufacturing for sustainable development: A case, *International Conference on Recent Advances in Energy and Materials for Sustainable Development (RAEM-2023)* (**Under Review**)

APPENDIX

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ORIGINAL ARTICLE



An interactive value stream mapping tool to support the inefficiencies reduction in manufacturing setting

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Abstract

As nearly one third of the world's energy usage and carbon dioxide emissions stem from manufacturing, it is becoming increasingly vital to cut down on energy and resource usage in industrial settings. Thus, advancing research and innovation for the future of factories is not just about creating and incorporating new technologies, but also about transforming manufacturing to rely less on energy and operate more efficiently. This entails approaching resource usage with a systematic mindset to ensure optimal exploitation. In this context, this paper aims to propose an interactive value stream mapping to evaluate the resource utilization and minimize the defect reduction in manufacturing setting. The efficacy of proposed model is being checked through case example of forging industry. This study emphasis on defect and lead time reduction, results enhancement of production level in forging industry. Moreover, lean tools like process flow chart, SIPOC (Supplier-Input-Process-Output-Customer), and cause & effect diagram were also adopted in this study. The obtained results reveal that defect rate in hot forging is reduced from 1.09 to 0.85, value added (VA) activities increased by 60%, and the non-value added (NVA) activities reduced by 92% significantly in the forging industry. Also, lead time of forged product is reduced from 9 to 5 days. These results underscore the potential for applying such methodologies to optimize processes in turbo-machinery design and production, ultimately contributing to enhanced performance and cost-effectiveness.

Keywords Smart value stream mapping · Lean · Cause and effect analysis · Lead time · Forging defects

1 Introduction

At present, the industry has embraced the utilization of advanced machinery since the onset of the industrial revolution in the eighteenth century [1]. This era saw the introduction of numerous mechanical facilities on a global scale. To stay competitive in the highly dynamic market and optimize resource utilization, the manufacturing industry

is rapidly evolving [2]. The driving forces in the production environment are the need to keep pace with global competition and make efficient use of resources [3]. Modern companies are raising their standards by increasing awareness and incorporating recent technologies to enhance resource utilization [4]. Small-scale industries like forging industry strive to enhance customer value, production efficiency, and scale, with the goal of evolving into larger organizations [5]. This evolution involves the collaboration of owners, managers, and employees to serve a broader clientele. Given the constantly changing industry landscape, there is a demand for smart tools of continuous improvement approaches to enhance production efficiency.

At this global industrial platform, Lean Manufacturing (LM) has become an emerging approach for improving overall company performance [6, 7]. Numerous studies have recognized the effectiveness of LM initiatives in enhancing company performance and operational excellence [8]. Over the past decade, many organizations have either implemented or planned to implement LM principles and concepts in their running system [9, 10]. Some companies have adopted

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Towards sustainable development in Indian small-scale industries: A green manufacturing initiative

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ABSTRACT

This study explores the impact of green manufacturing practices—specifically green activities, investments, and product types—on the economic performance of firms. Using survey data from Indian small- and medium-sized enterprises (SMEs), the research employs self-determination theory to analyze how the number of green activities, the extent of green investments, and the product type influence economic outcomes. The results reveal that a greater number of green activities enhances economic performance, while the relationship between green investments and economic performance follows an inverted U-shaped pattern. This dynamic is further strengthened when firms offer both green and non-green products. The study advances the understanding of green manufacturing's role in business performance and provides practical guidance for managers seeking to optimize the benefits of green initiatives.

Keywords: Green Manufacturing, Plan Do Check and Act (PDCA), Environment Management System (EMS), Environmental Impact Assessment (EIA).

1. INTRODUCTION

The society's increasing focus on the "green" initiatives of companies stems from rising concerns about environmental issues that pose significant threats globally (Centobelli et al., 2020). Environmental challenges are among the most urgent and unresolved global objectives that need addressing (Cappa et al., 2022). Since it became evident that human activities significantly contribute to environmental degradation and depletion of natural resources, these issues have become a top priority for governments, organizations, and individuals (Michelino et al., 2019). In this context, the Government of India (GOI) has set various emission targets and regulations aimed at reducing the environmental impact of small-scale industries. These targets are part of broader initiatives to combat climate change and improve air quality. As per NCAP-2025 scheme, the aim set by GOI to reduce the particulate matter (PM10 and PM2.5) levels by 20-30% by 2025, compared to 2017 levels (Government of India, 2017).

Due to various factors, manufacturing companies are increasingly adopting green manufacturing practices. These practices aim to benefit the environment, enhance brand image and reputation among consumers (Fercoq et al., 2016), and appeal to customers who favor eco-friendly businesses, ultimately boosting companies' economic performance (Verrier et al., 2016). Green manufacturing involves environmental awareness in production, including the use of renewable energy sources and participation in sustainable supply chains (Dieste et al., 2019).

With the rising interest in green manufacturing, there is growing attention to how these practices impact different aspects of company performance, such as environmental, operational, and financial outcomes (Ye et al., 2023). Previous research indicates that green initiatives positively influence various aspects of economic performance (Li et al., 2021). However, while some green initiatives, such as waste reduction, hazardous material minimization, and reverse logistics, have a positive effect on financial performance, others, such as environmental collaboration with suppliers and eco-friendly purchasing practices, as well as ISO 14001 certification (which certifies effective environmental management systems), do not necessarily lead to improved economic outcomes (Gandhi et al., 2018). Additionally, detailed assessments of the impact of green manufacturing on operations in small scale industries are still limited, and research has yet to fully explore the effects of green initiatives in process and products, which are not designed to minimize environmental impact throughout their life cycle (Liu et al., 2024). This research gap is occupied by conducting the present study towards sustainable development in Indian small-scale industries via green manufacturing initiatives.

RESEARCH ARTICLE | JANUARY 30 2024

Implementation of quality management system with 5'S in a hand tool industry - A case study

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Implementation of Quality Management System with 5'S in a Hand Tool Industry - A Case Study

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Abstract: The implementation of a quality management system (QMS) with 5'S provides working performance at optimum level which helps to achieve the objectives and targets. The aim of the study was to point out the benefits achieved by implementing quality management system procedures with 5'S in the manufacturing industry. The study included a level of documentation structure in accordance with 5'S. For the implementation of the quality management system, a group discussion was held with the process owners. This study was one of the few studies that reported an assessment for this manufacturing industry. During study, manufacturing and inspection processes were evaluated to meet the objectives. Five-S, performance indicators, display management and pareto chart were used. Barriers as well as benefits were also found in industry. The main obstacles in the industry were the lack of understanding of the principles of quality management and the attitude of the workers in the workshops. The main benefits preferred by the industry were a systematic approach to operations, continuous improvement, 5'S cleaning and reduced rejection rates.

Keywords: International Organization for Standardization (ISO), Lean Manufacturing, Plan Do Check and Act (PDCA), Quality Management System (QMS), 5'S.

INTRODUCTION

A quality management system is a systematic approach that is used to implement operational activities and set measurable performance indicators in the industrial sector. [1]

The advantages of the implemented system, which are listed below:

- Increased satisfaction of valuable customers.
- Minimizing rejection rates.
- Adherence to production delivery schedules.
- Minimizing customer complaints.
- Minimization of incidents in production facilities.
- Minimization of electricity consumption, which helps save energy.
- Prevent the depletion of natural resources.
- Control process waste.
- Meet the environmental parameters.
- Comply with legal requirements.

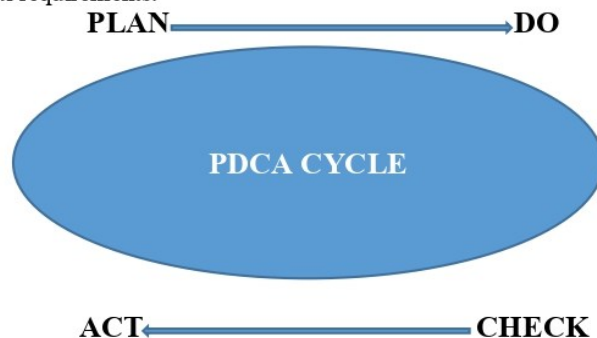


FIGURE 1: P-D-C-A Cycle

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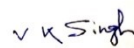
This is to certify that **Prof./Dr./Mr./Ms. Suresh Kashyap** of **Lovely Professional University** has presented a paper entitled **"Implementation of quality management system with 5'S in a hand tool industry - A case study"** in the International Conference on **Advances in Material Science And Technology (ICAMST-2022)** held on **25-26 November 2022** organized by the School of Mechanical Engineering at Lovely Professional University, Punjab.

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