
**EVALUATION OF KEY PERFORMANCE INDICATORS IN SME USING AHP
TECHNIQUE**

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Abstract

Small and medium-sized enterprises (SMEs) play a vital part in a country's socioeconomic well-being. Many businesses today may have underperformed because they lack strong and efficient performance management frameworks. As a result, the majority of SMEs are unaware of their performance in comparison to their peers, as well as the areas in which they are falling short. Performance measurement allows a company to plan, monitor, and regulate its performance using a pre-defined strategy. The Analytic Hierarchy Process is utilised as a multi-criteria decision-making approach for examining performance indicators. The purpose of the article is to examine the performance indicators for assessing the performance of SMEs and rating them against their peers. This study takes a different approach by directly surveying manufacturers to determine the relevance of four main factors and twelve sub factors (performance indicators) using an analytic hierarchy process method. This research presents an analytic hierarchy process-based (AHP) strategy for prioritising performance indicators. The analytic hierarchy technique is used to compute the relative weights of the selected indicators.

Keywords: Analytic Hierarchy Process; Multicriteria Decision Making; Pairwise comparison; Performance indicators; Small and Medium Enterprises.

1. Introduction

The industrial sector has significantly aided global economic progress. It is a net positive to create employment and export cash that can be reinvested in the home economy. It's no secret that economists, scientists, and policymakers are keen to develop measures for assessing industrial success. Although neither the small nor big scale manufacturing sectors witnessed considerable movement in the technical forefront over the research period, they are both very efficient as a consequence of improved operation and management. Scale efficiency benefits large-scale industrial enterprises more than competent operation and administration. The efficiency found in the medium and large-scale industrial sectors, on the other hand, may be the consequence of developments in both operation and management that have enabled them to incorporate new technology and innovations. In any of these industrial sectors, insufficient progress has been achieved in terms of the rate of productivity increase. Manufacturers have been seeking to maximize the use of their present infrastructure and management practices to enhance output.

The performance measurement system serves as the foundation for overall quality management. Normal performance indicators contain measures for both process and outcome. In

today's competitive business world, the single most essential element deciding a company's success or failure is efficiency[1]. One statistic to examine when analysing a company's performance is its efficiency. Productivity is measured by maximizing production, minimizing costs, and maximizing revenues. One sign of a company's technical efficiency is its capacity to maximize revenues from a given set of resources or to minimize the quantity of effort required to create a specified output. Producers strive to be as cost-effective as possible with their produce. Financial measurements like as revenue growth, net income, cash flow, and return on investment have traditionally been the core emphasis of KPIs used for performance assessment[2].

Measuring an organization's success requires both monetary and qualitative metrics. Measuring efficiency is critical since it is a crucial indicator of a company's success. To compete in today's global economy, factories, banks, and private firms of all sizes need exceptional performance[3]. As a consequence, in today's corporate environment, enhancing productivity is a key goal. Every country's government and companies must operate at optimal efficiency for it to prosper. This is the primary issue of any organization since it is the key to attaining its objectives.

Manufacturing has traditionally been a primary engine of economic growth. Countries with a strong industrial foundation tend to create and expand their economies over time. Globally, industries are changing dramatically as a consequence of technical advancements and procedures that have enabled the production of new products and services, as well as new techniques for ensuring regulatory compliance. The manufacturing sector has a significant influence on the overall health of the economy. However, the growth and expansion of this industry are influenced by external factors such as better raw material availability, skilled workers, dependable power sources, cutting-edge technology, a multiplicity of rivals, globalization, and so on.

The debut of new goods is met with more enthusiasm and anticipation than any other aspect of the business. Managers in both well-established sectors such as autos and electrical appliances and freshly developing industries such as computers consider the launch of new goods as a method to obtain a competitive edge. If innovation is revolutionary, it will either establish new industry norms that will make it impossible for other companies to join the market, or it will open up whole new consumer markets.

2. Literature Review

This section of the research demonstrates that for businesses to effectively adopt the lean production paradigm, they must demonstrate the impact of different practices using several performance measurements. Indicators assess progress so far and indicate prospective areas for growth in the face of tough and ever-changing market competition. The AHP approach assists us in prioritizing our efforts by arranging them in order of importance. The authors identified 18 factors/indicators that significantly measure leanness in MSMEs based on a review of the literature and discussions with academics and practitioners and proposed categorizing them into three groups (organizational aspects) based on impact and similarity: financial, operational, and human

resources. Each of these three groups is necessary for a well-executed strategy [4]. Furthermore, these features contribute to the system's evolution and the attainment of our ultimate goal of giving a full and evolving perspective of the deployment process.

Key performance indicators (KPIs) studies have been conducted to bridge knowledge gaps and discover industry expectations for equipment evaluation [5]. These studies examined the industry's cutting-edge energy-use indicators. Job creation, equality, latent resources, the trickle-down effect, social tension insurance, a distributive influence, the construction of a social eco-system, decentralization, and other benefits are all reasons in support of small-scale firms in a country like India. It's easy to underestimate the contributions of small enterprises to economic development. Small and medium-sized company achievement is often celebrated in sections of government budget papers. One of the many advantages of having a small business is the low overhead costs of producing a high-quality product or service in a short period. Businesses in the neighbourhood are doing well, which benefits the whole economy. The small-scale sector's contribution to the national economy may be quantified in a variety of ways, including the number of units, production, employment, and exports.

Despite the broad availability of more modern solutions, small firms in India have not altered their technology; this is likely due to a lack of operational and investment know-how, a reluctance to spend money, an inability to participate in technological research and progress, and so on. Labour productivity falls as a consequence of ICT investment, but the economy gains from higher production. Because of the dynamic character of small businesses, it is hard to undertake once-and-for-all research on the causal link between the components that aid in measuring their success. Because they utilized local resources, high employment creation, and cheap investment costs, MSMEs have become a crucial and dynamic engine/sector for the expansion of economies in developing nations across the globe. According to the International Enterprise Association [6], the vast majority of the world's businesses are micro, small, and medium-sized enterprises (MSMEs). These firms are critical to economies since they account for 60% of all net new job creation.

Aside from commerce and other services, 31% of these firms are involved in manufacturing, which is critical to India's economic and social advancement. Furthermore, this sector provides 32% to GDP growth and 32% to job creation[7]. This statistic emphasizes the importance of these sectors in India's growth and economic success. Nonetheless, they are unable to develop due to several problems, the most important of which are a lack of resources and a paucity of technically trained and managerially proficient staff [8].

Long-term success requires optimizing procedures and resources, making the most of existing equipment, and maintaining excellent relationships with suppliers and customers [9]. These constraints restrict Indian enterprises from attaining their full potential, putting additional pressure on them to constantly innovate and improve their techniques [10]. They are focusing on improving their production procedures to serve their consumers with competitively priced, high-quality goods and services. Businesses should use a lean manufacturing approach to boost efficiency and remain competitive. Finally, the goal of Lean is to provide manufacturers with a competitive advantage in the marketplace by lowering costs and boosting production [11].

The study uses an AHP approach to conduct a systematic analysis of indicators, rankings, and weights to assist industry professionals, practitioners, and researchers in determining which indicators are the least and most significant for MSMEs. AHP enables the selection of the optimal approach in a more scientific manner while preserving integrity and impartiality. The model is clear and simple for the decision maker to understand and use. The Analytic Hierarchy Process calculates the weight of the criteria and the importance of the indicators or alternatives. [12]. Because of its capacity to address issues in both production and service, its groundbreaking gains in manufacturing quality, and the competitive pressure it puts on even the tiniest of organizations, lean manufacturing has become the industry standard [13].

Small and medium-sized enterprises (SMEs) in India claim operational benefits such as greater productivity, customer satisfaction, cost savings, and reduced cycle and lead times as advantages of using lean manufacturing techniques[14]. Implementing lean resulted in considerable gains in inventory management, cooperation, maintenance, layout and handling, supplier relationships, and production, according to the results. TPM, Kaizen, and 5S were cited as three especially beneficial lean tactics in this article, which examined the benefits of lean and green manufacturing practices on SMEs in India[15]. As a result of technical improvements and a paradigm change towards a customer-driven market, production practices have evolved to meet the difficulties of global manufacturing as well as environmental and social concerns. Lean adoption has resulted in strategic improvements in the business and government sectors [16].

Many businesses have reported success with lean implementation, but many more have yet to realize the concept's full potential because they lack the tools to identify success factors, track their progress as they transform into leaner organizations, and compare their progress to that of other businesses [17]. This emphasizes the need to track the outcomes of lean adoption as well as the company's overall progress toward its goals. However, when the goals vary, so does the difficulty of achieving them. This is why businesses must define their performance indicators in their respective economic sectors. The conditions for a successful manufacturing firm vary from those for a successful service company, and vice versa. Businesses of various sizes employ their own set of performance indicators to measure their accomplishments in areas such as product quality, pricing, and delivery timelines.

When reviewing the literature on leanness evaluation, it is obvious that the majority of the case studies concentrate on Indian enterprises, with just a small fraction coming from the United States and the United Kingdom. [18] Despite being the home of the lean concept, Japan has no written literature on the subject. Reduced unproductive processes such as scrap and rework may have a significant impact on a company's bottom line and, as a result, decrease production costs, as outlined in the quantitative study that discovered 21 indicators to measure performance in a lean context [19]. The supply chains of four Indian enterprises were examined using 23 indicators, and their performance was graded using AHP's 36 criteria [20]. According to research conducted at an Indian manufacturing business, using lean evaluation resulted in a quantifiable increase in productivity [21]. If properly implemented, Lean Six Sigma may allow French organizations to

achieve much superior financial and operational results than any of these approaches could accomplish on their own [22]. Thai SMEs are ranked using a supply chain performance evaluation methodology based on cost, speed, and reliability[23].

The leanness levels of Ford and GM were tested and compared using Honda Motor Company as a standard [24]. Although the benchmarking technique holds promise, it is difficult to find the best practices for each unique circumstance. Researchers examined the performance dimensions and the two performance metrics for each dimension, however, they did not evaluate an acceptable weighting approach for the performance meter in the production system. Despite significant advancements in the technique and framework for analyzing leanness, many businesses continue to depend on monetary indicators. These indicators might be quantitative or qualitative. Indicators that are both quantifiable and non-measurable are essential [25]. The question of how these two components may interact in a lean system and what outcomes might ensue emerges. A lack of human resources, a lack of experience, a lack of supporting company culture, and a lack of management commitment to lean methodologies are common barriers to lean adoption by SMEs.

3. Methodology - Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a theory-based method for making multi-criteria judgments in hierarchical situations by building ratio scales from which to do discrete and continuous pairwise comparisons[26]. Thomas Saaty proposed it in the 1970s, and it has been the subject of much research and improvement since then. The AHP technique simplifies decision-making by breaking down the issue into a set of criteria and sub-criteria that can be compared and contrasted using a weighted score. For this technique, Saaty created a comparison method by modeling a hierarchical choice issue framework with several mutually incompatible criteria.

AHP offers a hierarchical approach in which subjective and objective components may coexist. It is an approach that uses both objective evidence and subjective experience to assist individuals in making better choices. [27] The AHP technique offers adequate metrics for assessing and, eventually, enhancing priority setting consistency across decision-makers. Extensive theories for aggregate preference creation promote the deliberate application of collective preferences. Because this study might benefit from group decision-making, the AHP approach could be a viable option for completing the study.

Saaty utilized this approach to create a comparison technique that uses numerous unidirectionally connected criteria to approximate a hierarchical choice issue framework. When considering criteria and picking a winner, AHP prioritizes logical and numerical consistency [28]. To summarise, the AHP is a systematic decision-making process that takes into account previous information, future forecasts, and intuitive leaps, all within the boundaries of a clearly defined approach based on good mathematical theories [29]. AHP is often utilized to handle a certain kind of problem that necessitates prioritizing viable solutions. Multi-criteria approaches provide a useful framework for modelling preferences and collecting, storing, and organizing all relevant data. AHP may be used to make decisions with a broad variety of uncertainties, given a wide range of objectives, criteria, and stakeholders, due to its comprehensive nature. Each set of criteria and

alternatives in the hierarchy is believed to be operationally separate from the other sets (objectives and criteria). The Analytic Hierarchy Process (AHP) is a versatile framework for making decisions with uncertain outcomes that contain several objectives, numerous criteria, and multiple participants[30].

Each level of the hierarchy presupposes that the criteria and options included inside it are operationally separate from those contained in the levels above it. The AHP offers a well-structured, systematic analysis and supports decision making by considering both qualitative and quantitative factors. The AHP model is excellent for disentangling complicated situations since it takes into account multiple linked elements.

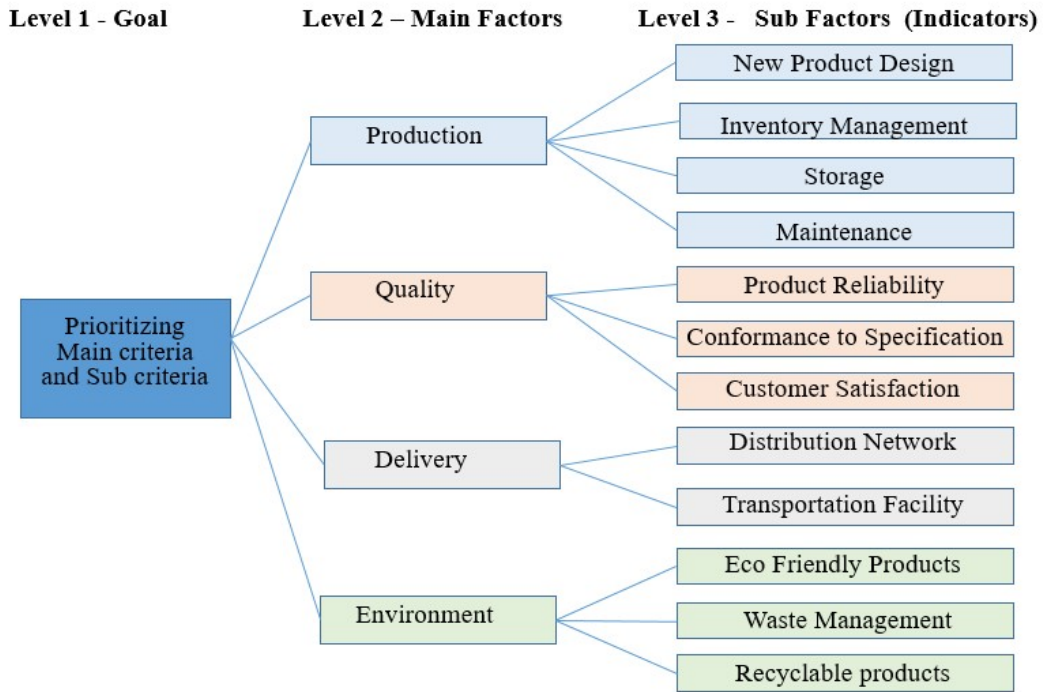


Fig. 1.
Main Factors and Sub Factors(Indicators)

4. Identification Of Key Performance Indicators

Companies are always seeking methods to increase efficiency, particularly in light of increased price competition and market pressure. Supply chain efficiency has a bigger influence on overall company performance as organizations grow more integrated. It's reasonable to say that considering everything, including the supply chain, is critical for top performance. Key performance indicators (KPIs) are commonly used to enhance both networks and businesses. It is significantly more difficult to optimize inter-business value chains when each company bases its KPIs on its objectives, excluding any potential for comparison. KPIs are used in the manufacturing sector for process analysis, monitoring, and improvement. Key performance indicators are an efficient way of monitoring and emphasizing a company's health. They are quantitative indicators of how successfully a business meets its objectives, and they are a kind of performance evaluation

used in the manufacturing sector to evaluate the success of a company or a particular division. Manufacturing firms may utilize KPIs to better understand how to improve customer satisfaction, increase competitiveness, and decrease costs. KPIs enable manufacturers to track their progress toward critical targets and make necessary course changes.

Key performance indicators for lean manufacturing should track efforts to reduce waste and increase production. KPIs are used in lean manufacturing to assess the performance of lean and process improvement programs. KPIs must be adjusted as required, such as while attempting to maintain track of a growing crisis. KPIs should only be used to monitor critical management issues. Too many KPIs may overload management while providing little actual advantage to the organization. A literature review is used in this research to develop the first set of essential performance criteria for measuring sustainable manufacturing inside a manufacturing organization. The basic metrics are a combination of manufacturing performance indicators and measures of sustainable manufacturing. The "triple bottom line" of environmental, economic, and social performance was incorporated in early initiatives. As previously stated, the original measurements consisted of three sections, which were subsequently subdivided into four major elements and a total of twelve minor factors.

Key Performance Indicators

Table 1

Main Factors	Sub Factors - Indicators
Production	1. New Product Design
	2. Inventory Management
	3. Storage Facility
	4. Maintenance
Quality	5. Product Reliability
	6. Conformance to Specification
	7. Customer Satisfaction
Delivery	8. Transportation Facility
	9. Distribution Network
Environment	10. Eco Friendly Product
	11. Waste Management
	12. Recyclable Products

4.1 NEW PRODUCT DESIGN

One of the most important parts of developing a product is the design of a new product. The quality of the design of a product has a significant impact on customers' final purchases. Designers are responsible for developing products that meet the demands of customers while also meeting the requirements of their business. A good product design has significance for the user and solves the problem they face. Although several alternatives and items are essentially the same, product design is what sets a business apart and should highlight any innovative qualities. A lot of obstacles stand

in the way of designers. It is the responsibility of the designer to define the visual language of the product and the company's visual identity throughout the development process. Working together with the engineers, a designer must figure out how to keep prices down via the use of other production methods, materials, or features. Reusing existing designs is another factor that may greatly improve the design process. Although standard components and engineering are the usual focus of reuse discussions, an integrated design platform provides other advantages that may be used by designers. Innovation in design is enabled through adaptability, cooperation, and integration. The form, fit, and function of a design may be brought into harmony with the needs of other disciplines in the concept-to-market process via the use of an integrated and collaborative platform. Improvements in design productivity and quality may be achieved by providing more assistance throughout the preliminary stages of the design process.

4.2 INVENTORY MANAGEMENT

The effectiveness of a company's manufacturing inventory management will depend on how well its inventory process works. Large-scale production makes inventory management in manufacturing even more challenging. Gaining efficiencies in managing production inventories may help manufacturers save both time and money. A company may avoid shortages, duplicate output, and extra carrying costs by enhancing its manufacturing inventory systems. To maintain efficiency and profitability while meeting rising client demands, the vast majority of firms use some kind of inventory management system. Most businesses engage in some kind of inventory management, which involves ensuring there is sufficient stock on hand to meet demand without incurring unnecessary costs. When it comes to production, though, inventory management becomes an even more precarious balancing act. Overstocking of inventory is a major annual cause of financial loss for the industrial sector. Losses may also arise when essential supplies are either misplaced or unavailable, as in the case of understocking. In an industry, inventory management is essential. Not only does this help ensure the smooth operation of the supply chain as a whole, but it also affects the balance sheet and cash flow statement, two key indicators of a business's financial health. To keep operations running smoothly and profits coming in, every business makes it a priority to have just the right amount of inventory on hand at all times. To keep inventory under control, it is necessary to regularly assess both internal and external elements, as well as use a combination of these methods. Planners for stocks of goods need to keep a close eye on stock while also coordinating with the manufacturing, purchasing, and accounting teams.

4.3 STORAGE FACILITY

In a workplace dedicated to manufacturing or heavy industries, storage might be one of the trickiest parts to organize. Problems with stock levels may slow down operations, reduce output, and increase overhead. If the manufacturing sector wants to become more efficient and robust, storage facilities must be upgraded. Industrial storage equipment is used to arrange or store goods, products, and commodities in a designated location temporarily or permanently storing them. The size, weight, and regularity of usage of the stored objects will determine the best kind of static

storage system to utilize. The quantity and nature of the goods to be stored, as well as the nature of the machinery used to transport them, all have a role in the design of the storage system's structure. Items at a warehouse are usually packaged in some way before being kept there. Buffering, or keeping of reserved stock, is a common application of storage systems to ensure there are enough parts or goods on hand to fulfill projected needs. As their businesses expand, many industries find it difficult to keep up with demand in the same footprint. When the economy improves, firms may quickly outgrow their current facilities and need more space. Sometimes industries just can't keep up with rising demand by adding more production space.

4.4 MAINTENANCE

The primary goal of maintenance is to keep all manufacturing gear and equipment running at peak efficiency at all times. In addition, regular maintenance is essential for effective production. The prosperity of a manufacturing company depends on the possession of suitable machinery. Yet, having high-quality machinery isn't enough; it's also important to maintain it effectively. Doing regular maintenance on industrial equipment is essential for keeping production on track. Businesses may save money and time on repairs and downtime by maintaining their machinery regularly. Preventing injuries and accidents that may have been caused by malfunctioning equipment is another benefit of regular equipment maintenance. The lifespan of the equipment is another important benefit of routine maintenance. In the long term, a corporation may save money by extending the life of its equipment via preventative maintenance. The maintenance department of an industry is in charge of keeping all of the equipment, systems, structures, and services necessary for the operation of the other departments running smoothly and at peak efficiency. Preventing failures and maximizing machine performance are the primary goals of preventative maintenance in manufacturing. Nonetheless, there is still a sector of the production industry that considers maintenance to be a waste of production time. Preventing unanticipated downtime due to neglected machinery is as easy as keeping everything in working order. In addition to extending the life of the machine itself, preventing the need for rework or scrap product due to the production of out-of-spec material, routine maintenance, and early detection of worn machine components are essential for minimizing waste and maximizing efficiency.

4.5 PRODUCT RELIABILITY

When production time, quality, and velocity are all in place, we can be confident in our output. As a result of equipment breakdown and subsequent outages, product quality suffers. Constant machine failures slow production, cutting into the available time. Having a dependable outcome as an objective is a good theoretical aim for your staff. As a result, it is very difficult to estimate the dependability of current devices, since most industrial items experience unexpected failure, and only failure information can be acquired. Better manufacturing quality will boost output and shorten the time it takes to go from raw materials to final goods. Improved dependability lays the groundwork for a more efficient and secure production process. Delays in delivery, excess production, Work in Process, and power consumption may all be reduced in this way. Once the

Industrial Revolution began, a flood of new goods began flooding the market. To satisfy customers' loftier expectations, product complexity has skyrocketed. Eventually, used or old products will wear out to the point that they can no longer perform their intended tasks, rendering them useless. Customers want to know that their purchase will last as long as possible while still providing the expected level of performance. Furthermore, the laws enacted to safeguard consumers' rights are becoming increasingly strict.

4.6 CONFORMANCE TO SPECIFICATION

Every manufacturing company has to have final product requirements in place and should be reviewing and updating these standards regularly. They are crucial for assuring the product's viability, legitimacy, and quality. The goals and standards of a firm or organization are reflected in the criteria and specifications established for a product throughout its design phase. Non-conformance may occur when a manufacturer produces an item, but its declaration conflicts with the item's real standards and needs. If it happens, it means the company producing the goods didn't adhere to the required guidelines. Delivering a subpar product is one possible outcome of failing to satisfy and adhere to criteria such as specifications, standards, and guidelines. Errors in products, incorrect configurations, malfunctions, and a negative impact on the end-user experience are all ways in which non-conformance may enhance the organization's exposure to risk and liability.

4.7 CUSTOMER SATISFACTION

Having happy customers is more important to a company's success than almost everything else. Companies all over the globe, and especially those involved in the industrial manufacture of hardware items, are always on the search for innovative methods to better serve their consumers and other important stakeholders. Most manufacturers in the industrial sector serve a small number of clients solely. Commercially viable scenarios often include the creation of volume by Industrial Manufacturing facilities, which in turn results in the generation of income. It's crucial in the year 2023. Eighty-one percent of marketers agree that customer happiness is the most important competitive factor in their sector. Nevertheless, that's not all there is to get a leg up on the competition. Research shows that after only one negative interaction with a firm, 17% of consumers would never return. Maintaining a high level of customer satisfaction is crucial to retaining existing customers and gaining new ones for a business. A quick turnaround time from when an order is placed to when it is delivered is crucial to maintain happy customers. When competition and costs rise, it becomes more challenging for businesses to sustain high levels of revenue and profit over the long run.

One-third of the points for the Malcolm Baldrige National Quality Award, which is administered by the National Institute of Standards and Technology, is dependent on customer satisfaction, therefore the United States government also raises awareness of this problem among its citizens. Publications like Consumer Reports, which claim to be impartial, regularly publish and disseminate ratings of a broad variety of goods and services based on reader feedback on their

performance and satisfaction. Stats on how satisfied customers are often used in auto commercials to convince consumers.

4.8 DISTRIBUTION NETWORK

One of the most important factors in the health of any country's economy is the efficient flow of products and services from manufacturers to consumers. Products must be sent to customers at a fair price and on time. Goods and their titles are recognized to take certain pathways from producer to consumer as part of the delivery function. This network of connections goes under a few other names: distribution channels, trade channels, etc. Academics, professionals, manufacturing enterprises, and distribution agencies have all written extensively on distribution channels and their effects on production costs in the marketing literature throughout the years. The expense of distribution might have a major influence on the bottom line of manufacturing companies. Despite producing high-quality goods, many businesses fall short of their goals because they fail to give distribution the attention it deserves. A company's distribution channel strategy needs to be carefully diagnosed, planned, and implemented to fully realize its profit objectives and to ensure customer satisfaction. In addition, it is worth noting that organizations have huge, often unexplored chances to build distinctive long-term strategic advantages via the design and management of effective and efficient distribution channels. Increasingly, the best way to wow your customers is to put in some serious work to improve the efficiency of your channel operations.

4.9 TRANSPORTATION FACILITY

As well as a greater variety of items being manufactured and sold, mass manufacturing and a broader global market have expanded the scope of commerce in contemporary cultures. Having reliable modes of transportation is crucial for ensuring that industries never run out of raw materials and that finished products reach customers quickly and easily. It helped large-scale enterprises expand by making it easier to get raw materials in and finished products out. The ability to move items around allows business owners to respond to fluctuations in regional demand. As a result, market swings are kept to a minimum. Transport infrastructure improvement is crucial for rapid industrialization. The growth of transportation is essential to the success of mass production and distribution. Logistics support high-volume manufacturing. One of the other kinds of transportation is required whether it's to acquire and deliver raw materials or to move completed items. In doing so, both current and potential new markets benefit. So, there will be a greater need for commodities, and production levels will need to rise to meet that need. Food and other perishable items produced by these sectors need to be transported quickly to reach customers in various time zones. If not, it would be impossible to provide these goods to customers. In the context of the economy, transportation is one of the most important activities. Transportation is a critical business function because it connects a firm to its suppliers and consumers by transferring commodities from their points of origin to their points of demand. It is a critical step in the logistics process that enables location and timing-based economic utilities.

4.10 ECO-FRIENDLY PRODUCT

To achieve ecological, economic, and social sustainability, the manufacturing sector recognizes the need for eco-innovation. Regulation, accountability, and competition are the three key forces that may improve manufacturing's sustainability. Products, procedures, promotions, and establishments all fall under the broad category of eco-innovation. Eco-friendly product creation, however, has emerged as a hot topic for academics in the 21st century. The Organization for Economic Cooperation and Development states that eco-innovation is an "essential pre-requisite for sustainable development" since it has far-reaching, beneficial consequences on a country's economy, society, and environment. Constant attention is paid to the value of eco-innovation by a wide range of public and commercial institutions, including international organizations, research centers, universities, and others. The term "eco-innovation" refers to the creation and implementation of a business model guided by a revised business strategy that integrates sustainability into all aspects of a company's operations using lifecycle thinking and soliciting input from stakeholders throughout the value chain. It comprises a concerted effort to improve a business's performance and competitiveness by implementing a series of adjustments or new solutions across four areas: products (or services), processes (or how they are carried out), the way they interact with the market, and their internal structure. The eco-design method enhances efficiency in manufacturing by minimizing waste. Most obviously, optimization may be seen in the decreased need for energy, the decreased use of raw materials, and the decreased production of pollution and other nuisances. Eco-friendly product design refers to any method used in the creative process to enhance a product's environmental friendliness. The objective of an eco-design is to lessen negative effects on the environment via forethought while keeping the items' use intact.

4.11 WASTE MANAGEMENT

A manufacturer's or manufacturer's commitment to environmental responsibility may be gauged in large part by its handling of industrial waste. Waste from industry has emerged as a major problem in the past two decades, raising serious worries about its global sustainability and environmental implications. Industrial trash is created or used in large quantities in manufacturing facilities; this garbage must be properly handled to avoid posing a threat to human health and the natural environment. The effective management of industrial waste begins and ends with compliance with the law. The Environmental Protection Agency (EPA) is responsible for implementing federal regulations on the proper disposal of hazardous and non-hazardous waste. Waste management regulations are often enacted at the state, county, and municipal levels. Although certain industrial waste is indeed more hazardous than others, there's no denying that any sector, when poorly managed, may cause significant environmental damage. The extraordinary waste output and the contribution to boosting the productivity of natural resources make the chance to improve production sustainability via waste minimization more attractive. Even if all of the materials used are safe, the production process may nevertheless create some hazardous by-products. The industrial sector throughout the world seems to be on the rise. Increases in product demand and manufacturing activity have resulted from globalization,

industrialization, and economic development, leading to a 26% increase in global GDP and a 35% increase in global manufacturing activities between 2001 and 2010. This has increased industrial (material) waste. Concern about the planet's finite resources has been in the spotlight since the term "sustainable development" was first used and the European Union pledged its support to the United Nations Commission on Sustainable Development.

4.12 RECYCLABLE PRODUCTS

It is promising that more and more businesses are considering how they may use recycled materials and reduce their environmental impact throughout the manufacturing process. Instead of just reusing their manufacturing waste, manufacturers are beginning to incorporate recycled materials in their product development and exploration processes. Several of the obstacles may be overcome with sufficient investment in scalable technologies for producing recycled materials, the utilization of high-quality data, and the establishment of sustained demand for greener goods. As the world moves forward in its efforts to construct a circular economy, one approach to recoup the value of garbage is to put it to use in new goods. This might be facilitated by linking upstream and downstream product value chains via the careful reuse of waste-derived materials. This may lead to iterative design changes that make it simpler to salvage usable parts from products. Also, these items may help spread information about new sustainable options and stimulate the growth of environmentally friendly marketplaces. When the recycled or recovered content moves up the supply chain to become a raw material, it might be difficult to keep up with the demand. Careful inventory planning is required to match the supply and demand demands of two supply chains and prevent under or over-supply. Because of this, the price of storing goods rises. The use of recycled materials by manufacturers is increasing in popularity as the sustainable development movement expands. Manufacturers are being forced to assess their procedures and implement environmentally friendly improvements due to increasing demand from community stakeholders, government authorities, shareholders, consumers, and workers to source resources ethically. Using recycled materials introduces additional difficulties for us as producers in terms of material availability, process modification, efficiency, and anticipating customer interest in eco-friendly goods. These challenges may seem insurmountable, yet they are all surmountable.

5. Development Of Sustainable Manufacturing Performance Evaluation

The Analytic Hierarchy Process (AHP), developed by Thomas L. Saaty in 1971, is one of the most extensively utilized approaches for dealing with MCDM-related issues. It is a method of evaluating alternative possibilities and making a decision based on a variety of considerations. For years, it has served as a go-to resource for management and decision theorists in the classroom and in the workplace. The AHP methodology is adaptable and methodical enough to deconstruct a multidimensional problem into its component elements. Breaking down any complex problem into smaller, more manageable ones is an excellent first step toward tackling it.

Second, comparing certain groups of things with one another may assist in eliciting more information from experts or decision makers. Finally, it determines how the weights of the separate elements will be calculated. Fourth, it applies the consistency metric to verify that expert and stakeholder evaluations are correct. The steps below demonstrate how an AHP-based model was created to evaluate the manufacturer's progress toward greener manufacturing processes.

5.1 Construct The Hierarchy

The fundamental performance criteria for green production are used to build a pyramid. We developed a pyramidal structure that included an overarching aim, major components, secondary factors, and tertiary aspects. The hierarchy was established to offer structure to the numerous aspects under consideration. The following level includes manufacturing, quality, shipping, and the local ecology. Only a few of the twelve elements addressed at the third level include product design, stock, dependability, customer happiness, distribution network, transportation, eco-friendly products, storage, maintenance, client specification, and waste management. The alternatives that the decision maker must examine are presented in the last layer of the firm assessment and comparison hierarchy.

5.2 Relative Weights

Once the hierarchy has been defined, the following step is to rank the metrics in order of importance. The AHP approach was employed to accomplish this purpose. The AHP technique was used to calculate the relative importance of many criteria for green manufacturing. Following that, we created a questionnaire that allowed respondents to compare their firms to others in the sector and distributed it to 12 senior executives at the firm. The senior executives were chosen based upon their significant expertise in the appropriate pitch. The Consistency Ratio (CR) was used to evaluate each expert's paired comparisons. Because there are no CR values bigger than 0.1, it passes the consistency test.

If the comparison is still inconclusive, it must be repeated. To estimate the relative weights of the replies to each question, we employed geometric mean averaging. Using Saaty's 1-9 choice scale, a preference matrix was created. The consistency test was applied to all of the combined pairwise comparison matrices. The results show that the CR values are close to 0.03, implying that all pairwise comparisons are credible. This figure is well within Saaty's tolerance range. This outcome implies that the experts were consistent in the significant weights they assigned to the numerous indicators used to assess the sector's overall sustainable manufacturing performance.

Normalized Decision Matrix (Main Factors)

Table 2

	Production	Quality	Delivery	Environment	Weights	Average Weights	Eigen Value
Production	0.27	0.24	0.39	0.27	0.29	1.21	4.13
Quality	0.55	0.50	0.42	0.45	0.48	1.97	4.10
Delivery	0.08	0.13	0.11	0.17	0.12	0.50	4.02

Environment	0.11	0.12	0.07	0.11	0.10	0.42	4.06
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Consistency Index	Random Index	Consistency Ratio
0.03	0.9	0.03

Random Index Table

Table 3

Number of attributes, n	1	2	3	4	5	6	7	8	9	10	11	12
Random Index ,RI	-	-	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54

Normalized Decision Matrix (Sub Factors - Indicators)

Table 4

	NP D	IM	SF	M	PR	CnSp	CS	TF	DN	EcPr	WM	RP	Weights	Average Weights	Eigen value
NPD	0.07	0.04	0.11	0.12	0.07	0.16	0.06	0.11	0.12	0.04	0.12	0.16	0.10	1.3	13.49
IM	0.23	0.13	0.16	0.15	0.09	0.24	0.08	0.19	0.14	0.25	0.15	0.18	0.17	2.3	14.16
SF	0.02	0.02	0.02	0.01	0.04	0.02	0.03	0.02	0.05	0.02	0.04	0.01	0.02	0.3	12.51
M	0.01	0.02	0.05	0.03	0.03	0.02	0.03	0.02	0.06	0.02	0.06	0.02	0.03	0.4	12.39
PR	0.23	0.36	0.14	0.18	0.24	0.10	0.41	0.09	0.13	0.25	0.11	0.15	0.20	2.7	13.72
CnS P	0.02	0.03	0.07	0.08	0.12	0.05	0.04	0.12	0.09	0.03	0.08	0.07	0.07	0.9	12.83
CS	0.22	0.28	0.17	0.18	0.11	0.21	0.18	0.19	0.14	0.25	0.15	0.22	0.19	2.7	14.08
TF	0.02	0.02	0.05	0.05	0.08	0.01	0.03	0.03	0.06	0.02	0.07	0.02	0.04	0.5	12.32
DN	0.01	0.02	0.01	0.01	0.04	0.01	0.03	0.01	0.02	0.01	0.03	0.01	0.02	0.2	12.66
EcPr	0.14	0.04	0.12	0.13	0.08	0.15	0.06	0.16	0.12	0.08	0.11	0.11	0.11	1.5	13.71
WM	0.01	0.02	0.01	0.01	0.04	0.01	0.03	0.01	0.01	0.02	0.02	0.01	0.02	0.2	12.83
RP	0.02	0.03	0.07	0.05	0.06	0.02	0.03	0.06	0.06	0.03	0.06	0.04	0.04	0.6	12.77

Consistency Index	Random Index	Consistency Ratio
0.1	1.54	0.07

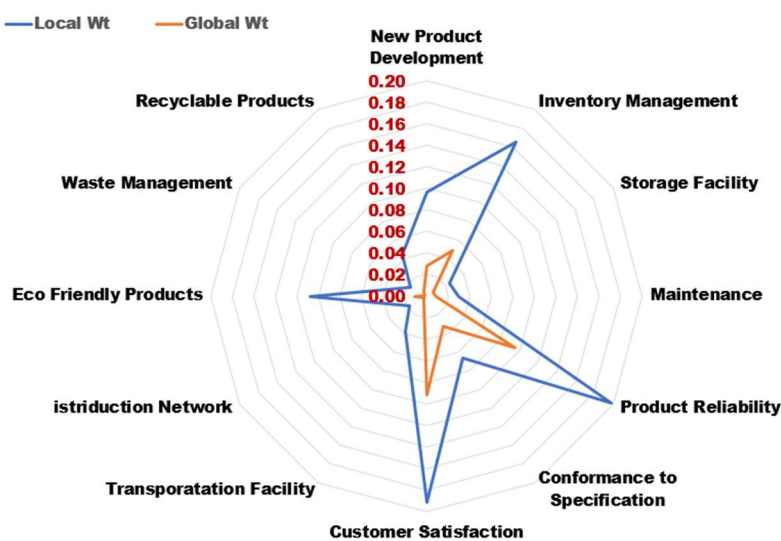
Performance Indicators Ranking

Table 5

Performance Indicators	Local Weights	Global Weights	Overall Ranking
New Product Design	0.10	0.02834	5
Inventory Management	0.17	0.04855	3

Storage Facility	0.02	0.00709	8
Maintenance	0.03	0.00884	7
Product Reliability	0.20	0.09517	1
Conformance to Specification	0.07	0.03208	4
Customer Satisfaction	0.19	0.09187	2
Transportation Facility	0.04	0.00476	9
Distribution Network	0.02	0.00225	11
Eco Friendly Product	0.11	0.0112	6
Waste Management	0.02	0.00178	12
Recyclable Products	0.04	0.00459	10

Performance Indicators Ranking



6. Discussion

The primary goal of this research is to identify and rank the indicators and The analytic hierarchy process approach is used to determine the key performance indicators. The two most crucial factors for accomplishing sustainable manufacturing, with overall rankings of 20% and 19%, respectively, are product reliability and high customer satisfaction. The other significant indications in order of

importance are effective inventory control (17%), product conformity to specifications (7%), and innovative product design in response to market demand (2%).

According to the findings, product reliability is the most significant indicator of the twelve indicators. Improved product reliability is the foundation for a more efficient and secure manufacturing process. In today's cutthroat business environment, continuous evaluation of new product reliability and continual oversight of the reliability of everything supplied are essential requirements. Customer satisfaction is also a significant indicator as maintaining a high level of customer satisfaction is critical for a firm to retain existing customers and win new ones. A short turnaround time from the moment an order is placed to the time it is delivered is critical for keeping consumers pleased. When competition and expenses rise, firms find it more difficult to maintain high levels of revenue and profit in the long run. Inventory management in manufacturing is made more difficult by large-scale production. Gaining efficiency in inventory management may help firms save both time and money. By improving its production inventory processes, a firm may minimize shortages, duplicate output, and excessive carrying costs. Stock planners must keep a check on stock while also cooperating with the production, buying, and accounting departments. Product conformity is critical for ensuring the viability, validity, and quality of the product. Non-conformance may increase the organization's exposure to risk and responsibility through product errors, wrong settings, malfunctions, and a poor impact on the end-user experience.

7. Conclusion

The current study attempts to identify the most helpful performance indicators for process improvements and quantify their benefits. The research might be utilised to assist firms in improving their sustainable manufacturing practices. Businesses may improve their efficiency and competitiveness by using this strategy.

The Analytic Hierarchy Process (AHP) is an approach for prioritizing and weighing distinct criteria. As part of this study, we discuss our ideas for creating an AHP-based model to assess a company's progress toward environmentally responsible production. In accordance with the primary indications of sustainable manufacturing performance evaluation for a manufacturing organization, a hierarchical structure was established. Using the AHP technique, each statistic was then allocated a weight based on its relative value to the others.

The lean implementation method strives to eliminate waste at every level of the process by closely monitoring workers, equipment, and supplies, as well as churning out actual work with fewer errors. The emphasis on characteristics that contribute to or inspire management, as well as the assessment of leanness variables/indicators in decision making during planning, is crucial for the application of the lean concept in organizations. As a result, firms must analyze their performance frequently to guarantee that they remain competitive. Management may use performance evaluation to uncover shifts and chances for development by comparing results before and after applying lean. Overall, it will make consumers happier and enhance business performance and revenues. Because various sectors utilize distinct sets of indicators, little effort has been made to define or even debate lean performance indicators, despite their potential use. Key performance

indicators, in addition to being an effective incentive, aid in the identification of problem areas and the factors that contribute to them.

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