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Implementation of Sustainable Manufacturing in Production Systems: A Systematic Review of Past Decades Data

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Abstract Sustainable manufacturing has been a popular topic of research for quite some time now. Various concepts and ideas, such as lean, green, and agile manufacturing, have claimed to have a substantial impact on the manufacturing industry's sustainability. The goal of this research is to map the current literature on sustainable manufacturing in order to analyse and classify existing methods, as well as highlight the potential benefits and challenges of manufacturing sustainability in production systems. Findings suggest that Sustainability in business and policy refers to the goal of preventing the depletion of natural or physical resources so that they can be used indefinitely. Seventy eight research papers have been reviewed in this paper considering the research contribution, methodologies, year of publication and many pertinent concepts, useful for research exploration. Environmental protection aids in the achievement of other strategic goals such as cost and quality. Holistic solutions based on industrial processes integration must be created in order to give larger industrial solutions that safeguard the environment and society from the negative consequences of production while still being cost effective. The paper also throws light on the new challenges faced by sustainable manufacturing in the production systems and manufacturing sectors.

Keywords: *sustainable manufacturing, sustainability, production systems, environment*

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1. Introduction

Manufacturing industries are forced by increasing challenges such as resource depletion, economic stagnation, human beings pursuing higher life quality, stricter laws and environment protection policies. Sustainable manufacturing is intended to empower the companies to cope with such challenges and help them to stand out in the today's competitive market. As a result, manufacturers are now tending to reset manufacturing processes and products that minimize environmental impacts while considering social and economic dimensions. Manufacturing units, particularly SMEs, have been avoiding any major transformation for a long time [1,2]. Transient analysis of industrial processes has recently become a source of concern. Manufacturing system transients depict the activity of the system until it reaches a steady state, where it is supposed to run at a more coordinated speed. For manufacturing processes, transients occur in a variety of situations. Each component of sustainability has clear goals that must be met in order to build and incorporate an effective sustainability concept. The most important goals of social development are to promote health, protection, quality of life, and ethics. When it comes to environmental protection, clean air, water and soil, as well as the enforcement of legislation and eco-balance quality, all contribute to this aim. Product and process growth, new jobs and large-scale new enterprise markets are the core pillars of economic resilience [3,4]. Reducing a product's environmental effect should be one of our primary goals throughout the whole manufacturing cycle, from the acquisition of raw materials through to the product's eventual disposal. This goal appears to be shared by many reference articles. Various methods used in sustainable manufacturing enables a clear identification of all inputs and outputs that have an impact on the environment, not just on our production line or a specific phase of the cycle, and implement environmental controls throughout the entire manufacturing process [16,19,20]. The major goal of this study is to provide a current state map of sustainable manufacturing research in production systems.

1.1. Sustainable Manufacturing

[5] and [6] reviewed that sustainability has influenced the survival of nations, ethnicity and civilization throughout human history. Manufacturing, being the cornerstone of a civilized lifestyle, is heavily influenced by sustainability challenges and consequently plays a critical role in solving them. [7] stated that manufacturers are working to attain sustainability-oriented goals and creating sustainable manufacturing methods and practices in response to increased environmental concerns, public pressure and harsher regulation. According to [8], goods must be sustainable in and of themselves, as well as the processes used to manufacture the goods and the production systems that coordinate the processes to accomplish the objective of sustainable manufacturing. [9] reviewed that manufacturing sectors have tremendous hurdles in cutting costs, increasing quality, shortening time-to-market, acting and thinking sustainably all at the same time. Selection of the papers for review are searched by keywords, “Sustainable manufacturing” OR “Manufacturing Industry” OR “production systems”. In this paper, a reviewed study of implementation of sustainable manufacturing concepts in production systems presents the ideology and techniques used. According to an examination of industrial case studies, terms and meaning differ based on the source of knowledge and nature of operations.

Sustainable manufacturing is a concept that refers to manufacturing processes that do not affect the atmosphere in any way. Since sustainable production is a big necessity in today's world, there is a pressing need to progress in this area as well. In [10] determined the current state of the literature on Sustainable Manufacturing in production systems, concepts as well as the consequences for future study.

Figure 1. Sustainability in manufacturing

1.2. The Literature

Literature review develops an understanding of existing work in the relevant field. In order to solve these issues and present viable alternatives, industrial production requires the introduction of sustainable structures. The development of sustainable manufacturing concepts took place over several decades with different terminologies like Green manufacturing, Lean manufacturing, Traditional manufacturing and Sustainable manufacturing. First it evolves into 3R (Recover, Redesign, Re manufacturing) approach. After few times modification of 3R in to the 6R (Recover, Redesign, Re manufacturing, Recycle, Reuse, Reduce) approaches. The recover stage is concerned with gathering end-of-life products through post-use activities [11,12,13]. The redesign aspect, on the other hand, offers ample environmental consideration by simplifying future post-use procedures, while the re-manufacture element will increase product efficiency by saving natural capital, electricity, expense and reducing waste. To reach the optimal goal for process, product and device sizes, multiple goals should be considered in terms of architecture for sustainable manufacturing [14]. One part of the paper is to develop and interpret scientific definitions and terminologies, assisting in the compilation of a bibliography or list of the references used and the identification of various methodologies which have been developed by various researchers [15]. [16] explained the key facets of sustainability, according to [17] and [18] are based on the environmental, economic, and social directions, in order to meet better requirements by efficiently using available capital. In manufacturing sector, a lot of things depend on the manufactures who must be focused on innovation of product and proactive about any concern related to environment as well society. The urgency for regulatory enforcement, cost reduction by eco-efficiency, corporate social responsibility programmes and meeting consumer demand are the primary drivers of sustainability [19,20]. Companies must develop products for long life and easy recycling at the end of their useful lives, as well as understand the commercial potential of recycling the recycled products to extract the residual value in their components. ‘New tactics and solutions to improve the overall efficiency of high-tech innovation and manufacturing properties' [21]. Major changes in the design, manufacturing and use of goods and services would be required to make the transition to sustainable production. Efforts to date in the areas of eco-efficiency, eco-innovation, waste management and social justice have been beneficial, but they have been gradual and constrained in their potential to affect systemic change [22,23]. Progress towards sustainability will include new ways of differentiation, as well as operational and growth-related incentives and new market prospects for manufacturing firms [24]. Recent research has also contributed to a better understanding of the value of intangible assets and elements of resilience as a means of competitive advantage [25].

Numeraous key writers have identified the components of a sustainable business model (value proposition, production, distribution and capture) and articulated a business modelling process. Although they do not directly concentrate on providing sustainability, they do offer a comprehensive review of the latest state-of-the-art and state-of-practice [27,28,29,30]. In industrial or manufacturing studies on sustainable business models, principles, and methods. However, more guidance on the sustainable opportunities in business model design framework and supporting mechanisms are also needed to provide businesses with a comprehensive approach for creating, transforming, and implementing of sustainable manufacturing in business models [31-34]. Energy costs have become a larger portion of total output costs for industrial companies and this pattern is likely to continue. Owing to anticipated more strict carbon tax policies as

well as competitively rising energy demands from developed countries, this trend is expected to accelerate and become more pronounced in the future [35,36,37]. They have profoundly inspired research efforts on improving energy production and lowering energy costs of industrial systems in the context to a more carbon-constrained future. Since the manufacturing industry's primary target is benefit maximization, scientific findings that increase energy efficiency and lower energy costs do not come at the risk of production loss [38,39,40]. In the design and implementation of sustainable industrial processes, energy conservation has always been a top priority. To achieve manufacturing sustainability, optimal maintenance solutions have also been extensively researched [11,34,40,41,42] They provided a successful attempt to describe the combined deterministic work shop scheduling problem with system and layout configuration optimization for using a linear programming mathematical model. The benefits and drawbacks of using a rapid solidification process with melt spinning as a sustainable processing technique for bulk metallic glasses are discussed in the article [43]. This work serves as a general guide for incorporating instruments to accelerate sustainable transformations in manufacturing cities, especially in developing countries where local legislative capacity is limited [44]. Businesses' attitudes to the use of goods and services have evolved as a result of the industrial revolution [45]. At present economic models, on the other hand, depend too heavily on resource exploitation and degradation. If remedies are to be sought, businesses, industries, and the general population must be persuaded to change a variety of irresponsible practices. Better Eco-designs, responsible waste disposal and reduction, as well as the reuse and recycle of products, all have the potential to save businesses and customers money and also reducing their environmental effects [46-48]. [49] says that manufacturing industries could benefit from the circular economy's (CE) regenerative processes which slow, close, and narrow material and energy loops to minimize resource inputs, pollution, pollutants, and/or energy leakages. There are a variety of options for local small and medium-sized manufacturing companies to follow such sustainable production principles and allowing them to market their products as eco-designed, eco-friendly, and economically sustainable [50]. Many manufacturing systems and production organizations are moving towards Zero defects manufacturing (ZDM) for getting intelligent and sustainable systems .zdm have m any advantages like less material waste, less scrap in system, low cost, minimum energy consumption, quick deliveries and lead time, improvement in output quality, production system improvement, process capability enhancement etc [12]. New Internet and connectivity infrastructure investments are typically made to reduce costs and improve manufacturing performance, but by looking at the long-term benefits, the payoff is reduced resource demand and increased energy efficiency [51,52]. Many businesses have realized the value of pursuing long-term results. However, owing to a lack of awareness of the equitable elements of those sustainable activities, they have been unable to incorporate them [53]. This paper is focusing on the work related to sustainable manufacturing implantation by different production systems which will develop an understanding of the "sustainable manufacturing" requirements for the present scenario [54].

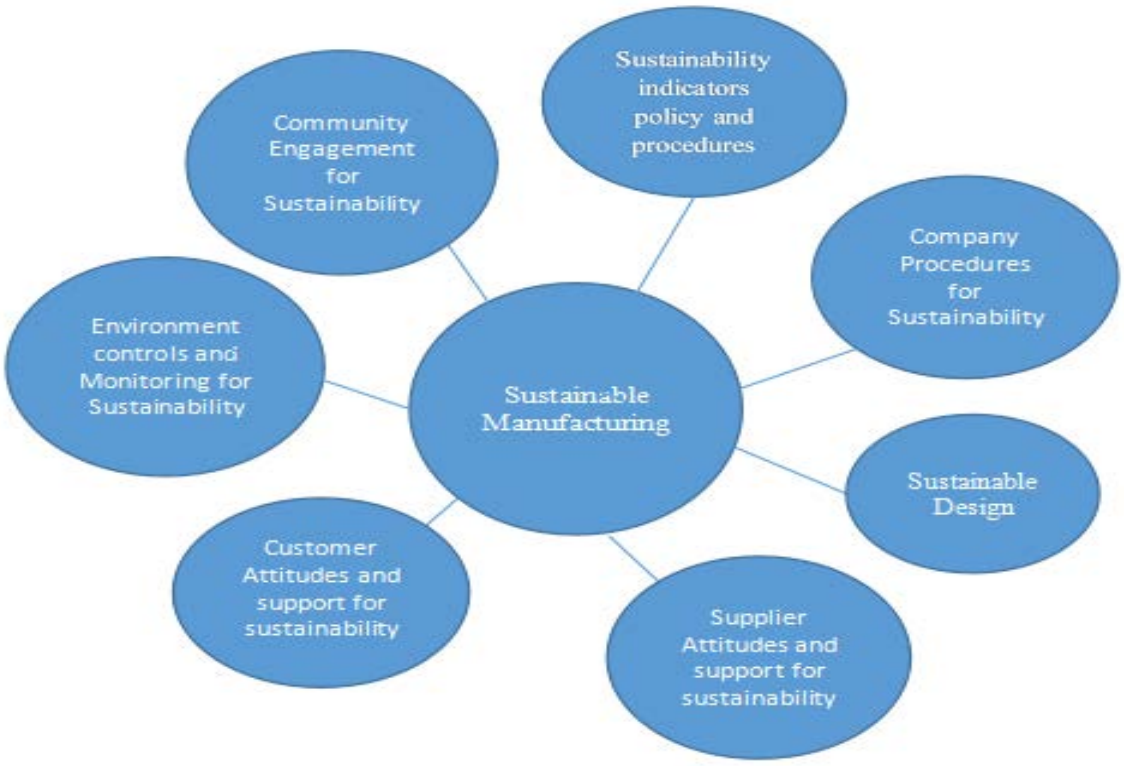

Figure 2. Dependency factors of sustainable manufacturing [26]

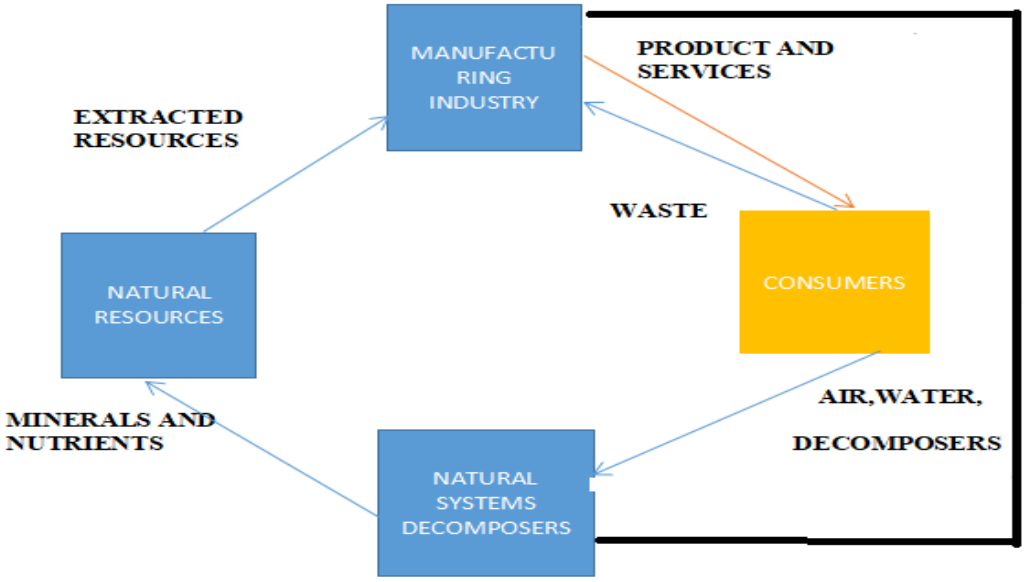

Figure 3. The role of sustainable system in a manufacturing industry [55]

1.3. Fundamentals of Sustainable Manufacturing

Engineers are well-versed in determining the economic importance of engineering strategies for manufacturing since manufacturing is a business function. Measuring environmental and social efficiency is more difficult in terms of engineering and industry. Manufacturing processes and technologies use operations and practices to turn raw resources into marketable goods that have sustainability implications. Material and energy are required as inputs in production processes and systems while wastes and pollutants, which are categorized as outputs, are used as inputs in other industrial and natural systems [20,55] (Figure 3).

2. Review Methodology

2.1. Bibliometric Analysis of Collaborative

Research The relationship between authors and co-authors are find out to use VOSViewer software to analyze the content of published article in the field of "sustainable manufacturing". Cluster linked concepts are used to find the relationship between available data. Total number of Authors and Co-Authors are find out from the articles are 288, clusters made 25 and interrelationship established between authors and co-authors are available links 640. Figure 4 indicates the Overlay visualization of available data.

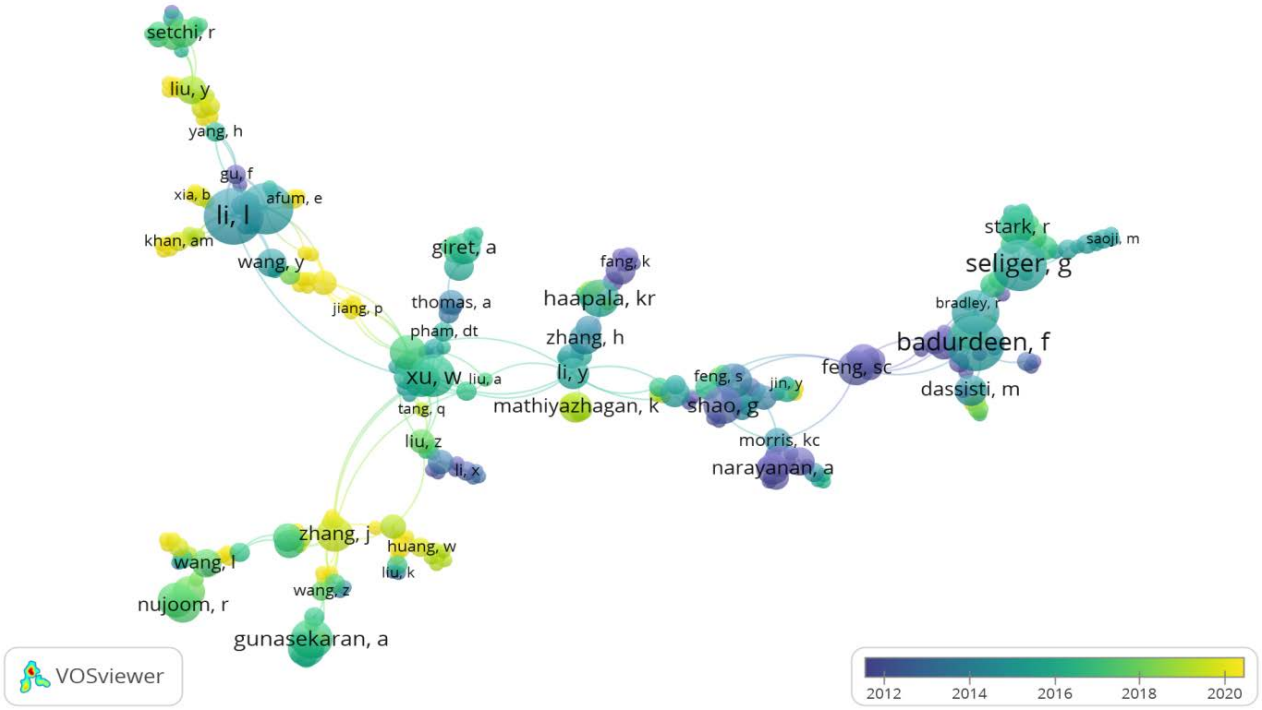

Figure 4. Overlay visualization of relationship between Authors and Co-authors

The most cited articles from the decades are shown in the Table 1, and it shows that six most cited articles have been chosen from 2011 to 2020. Journal of cleaner production paper with the title "Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers" was the most cited journal with a citation of 261. Other articles are also have most citation like Energy journal and applied ergonomics journals.

3. Results

3.1. Quantitative Analysis (Descriptive)

Classification based on number of papers published in the following years shown in Figure 5. The data have taken from 2010 to 2020 strictly. We have reviewed 89 papers for this research which is collected from the google scholar data base strictly follow the titles related to the sustainable manufacturing in production and manufacturing systems. Where the figure shows that the maximum publication is done by the researcher from 2014 to 2020 whereas maximum in 2017.

3.2. Journal Wise Classification

Figure 6 shows the articles that were chosen from various publications and reviewed for writing the paper. Reputed publishers have been considered which includes the Blackwell publisher, Emerald, springer, taylor and francis, inderscience publishing, springer newyork llc, sage publication limited, john willey and sons limites etc. The Figure 6 shows that maximum papers are reviewed from the springer publications.

Some references are shown in the Table 2 that clearly indicates the sector and methodologies used to achieve sustainable manufacturing for the particular sectors.

There are different methods to achieve sustainable environment for the industries like Life cycle assessment (LCA), Modelling and simulation, distribution manufacturing systems etc.

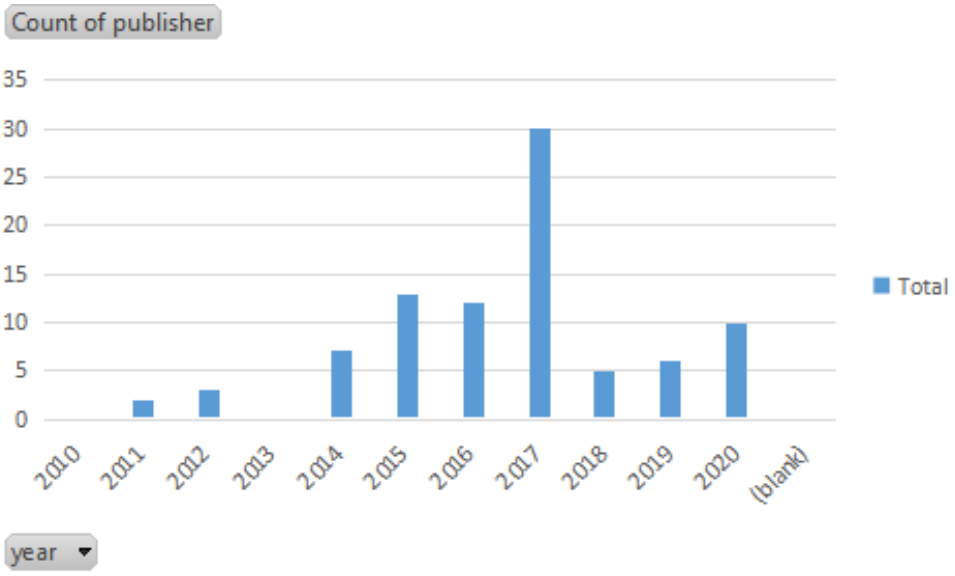

Figure 5. Number of Articles published per year

Table 1. Most cited Articles

Title	Authors	Source Title	Total Citations	Average Per Year
Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers	[20]	Journal of cleaner production	261	43.5
Time-of-use based electricity demand response for sustainable manufacturing systems. Energy	[56]	Energy Journal	181	25.85
Integrating sustainable manufacturing assessment into decision making for a production work cell	[57]	Journal of cleaner production	107	21.4
Sustainable manufacturing and systems ergonomics. Applied ergonomics	[58]	Applied Ergonomics	104	20.8
Sustainable production in emerging markets through Distributed Manufacturing Systems (DMS)	[17]	Journal of cleaner production	93	18.6
Opportunity estimation for real-time energy control of sustainable manufacturing systems.	[15]	IEEE Transactions on Automation Science and Engineering	61	7.62

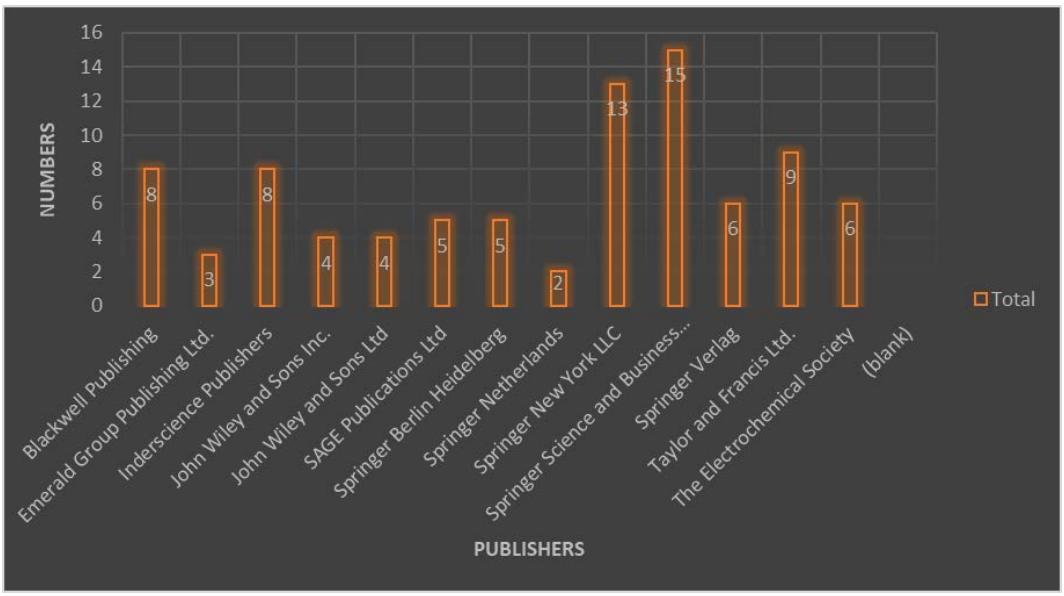

Figure 6. Journal wise classification

Table 2. Sectors and methodologies used by researchers

References	Contribution in sector	Methodology
[52]	System Engineering	life cycle assessment
[13]	System Engineering	Life cycle Engineering
[59]	Factory Modelling	Modelling And Simulation
[59]	Product-service systems	Operation Management
[60]	Manufacturing Systems	Simulation using Economic Index
[61]	sustainability performances business	Sustainable supply chain
[62]	Manufacturing system design	integrated method
[63]	Sustainability in industries	Cross Functional Factory Modelling
[14]	Impeller Manufacturing Industry	impeller manufacturing methods
[64]	Production Systems	Distributed Manufacturing Systems

3.3. Keywords Used in Journals

For finding the articles, there are some keywords which helps the researchers in finding a particular article which is related to specific field. Here a chart of the keywords that are significantly used in the reviewed articles has been prepared. Sustainability, sustainable development, sustainable manufacturing, and sustainable manufacturing capabilities are among the most often used keywords. Figure 7 shows the keywords used during the selection of literature for sustainable manufacturing in different sectors.

Different research tools and techniques are used for Sustainable Manufacturing Concepts in manufacturing and production systems. Pie chart shows the percentage of no. of articles for particular research tool and techniques used in selected articles.

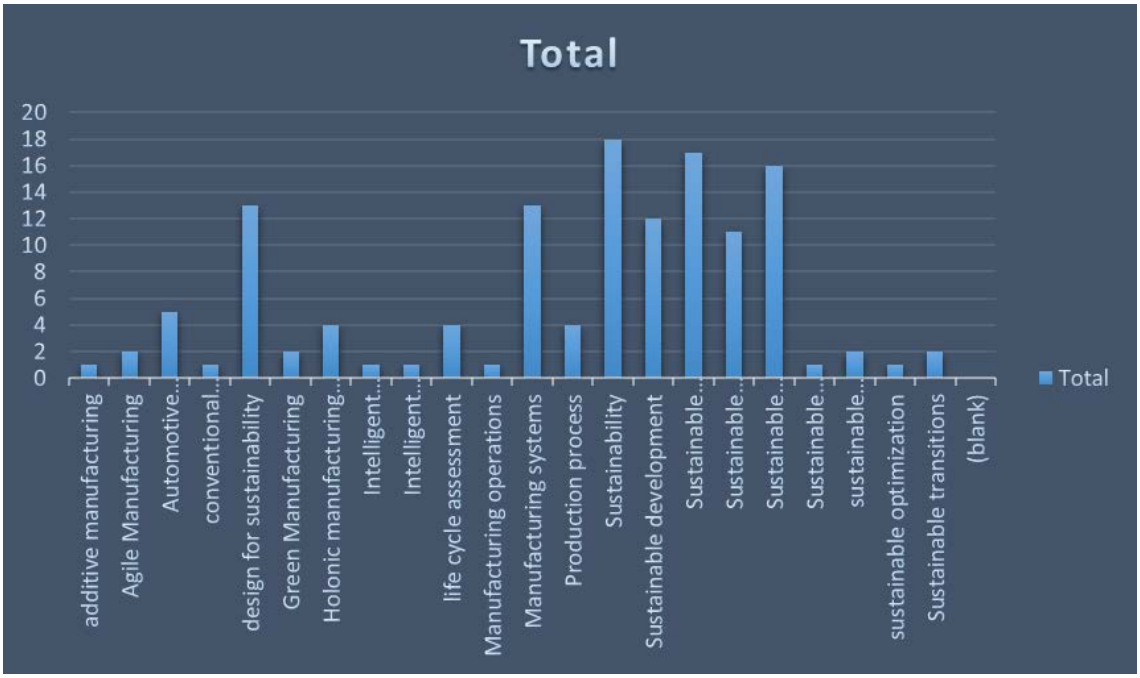

Figure 7. Keywords used during selection of Journals

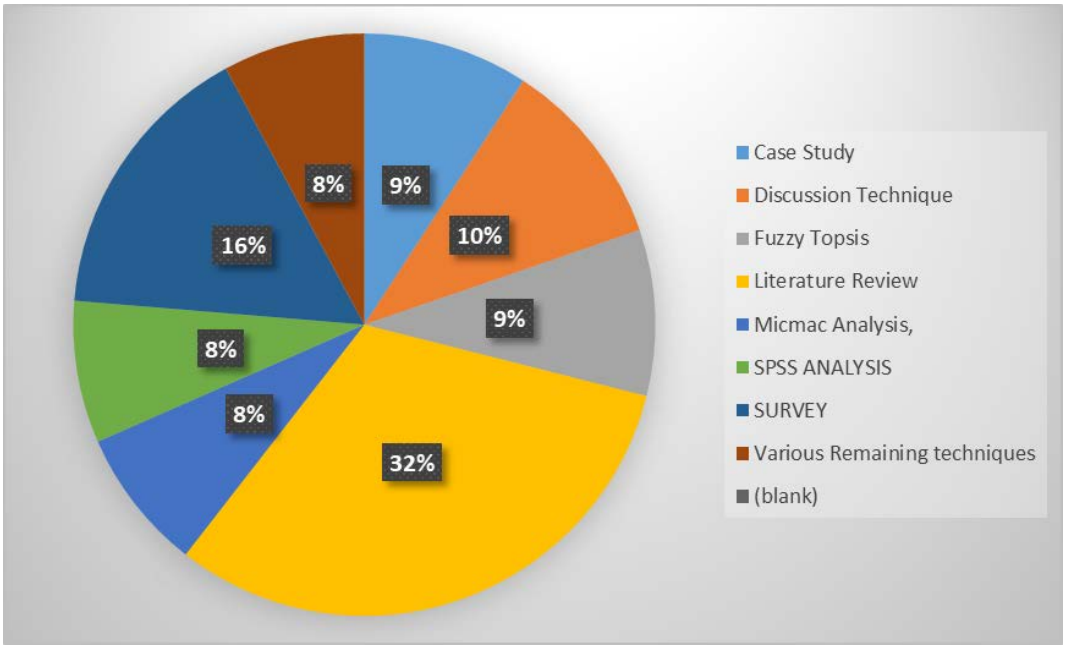

Figure 8. Different Research tools and techniques used for Sustainable Manufacturing Concepts in manufacturing and production systems

As shown in Figure 8, out of total research tools and techniques used, 32% is Literature Review, 16% is Applied Survey, 9% is Fuzzy Topsis method, 9% is Micmac Analysis, 10% is Discussion Technique, 10% is SPSS, 3% is Case Study, and remaining 8% is for Various others techniques as comparison, Dematel Approach, Statistical Analysis etc.

3.4. Tools for Sustainable Manufacturing in Industries

The previous section of the paper presents the understanding of concepts and perspectives of sustainable manufacturing development in production systems. Many child-concepts, such as industrial ecology, have been introduced to promote environmental growth at different levels of interaction and cradle -to-cradle approach [65,66]. Other research areas for industrial sustainability, such as Product-Service Networks and entire supply chain alignment of product and manufacturing system architecture, are emerging and increasingly growing [15,67,68]. Industries can find it difficult to convert these ideas into actionable steps. While it is critical that all organisations have a holistic perspective on goals that are consistent with the concept of sustainable manufacturing, the execution of sustainable manufacturing practises must be tailored to the unique characteristics, circumstances, and actual state of performance of the programmes [69]. Based on the available literature, it has been observed that the evolution and improvement process can be classified into three types of tools [70,71] with the help of the systems performance can check and also improved so that it becomes easier to achieve a sustainable environment for the existing system. Government policies and regulations also affect the decision making process.

[76] and [78] suggested that these tools are useful for supporting changes, but they do not have a functional solution or general institutional structure for consumers through functions to find inefficiencies or resource efficiency enhancement choices. As a result, there is a need for guidance on how to accomplish long-term manufacturing improvement.

Table 3. Tools for Assessment performance and improvement

Types of Tools	Tools Name
Assessment Tools or systems Performance	1. Life cycle Assessment [72] 2. Material flow Analysis [15] 3. Ecological Footprints [16] 4. Sustainability Indicators [69]
Improvement and Design Tools	1. Design For Environment [70] 2. Design for Assembly and Disassembly [74] 3. Design for Recyclying [16]
Enforcement Tools and decision making tools	1. Product Design Devlopment [72] 2. Life Cycle Costing [57] 3. Project Management [70] 4. Value Stream Mapping [73] 5. Sustainable Cloud Manufacturing [74] 6. Dynamic Programming [75]

The literature has emphasised the need to systematise manufacturing development practises by using resources that can assist manufacturing firms in analysing and optimizing their existing results [78]. [77] explained that a variety of methods have been created to evaluate the environmental effects of manufacturing operations and to alter the way goods are made and services are delivered to customers.

4. Conclusion and Discussion

Manufacturing is a critical source of growth and production, as well as a key factor in a country's success. Major key points of the study are mentioned as follows:

1. To stay competitive in the production sector, factories have had to respond to emerging problems and developments on a regular basis, resulting in numerous manufacturing paradigm shifts over the last two centuries.

2. In terms of the research gaps, better implementation of sustainable production demands and deployment strategies is required.

3. A comprehensive guideline is needed to describe the principles and techniques of sustainable production, as well as a production manufacturing systems. Moreover, to gain more benefits for a sustainable production climate, it is important to continue advancing existing sustainable technologies.

4. This study looked at sustainable manufacturing as a concept for academic research and as a compilation of business best practices.

5. The data shows that research on sustainable manufacturing is focused on goods, plants, and processes. Manufacturing, on the other hand, is rarely investigated at the sector level or in terms of its economic impact.

More work is needed to get industries from other regions of the world to fully improve their sustainable manufacturing performance. The outcomes of the study show that sustainable manufacturing is a win-win situation.

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