Advances in Consumer Research
https://acr-journal.com/
Volume-3 | Issue-1 | Jan 2026
Original Researcher Article

Sustainable Design Of Manufacturing System For Mass Customization

Surya S[1], Dr. Asha Sundaram[2], Dr. Thangamayan [3]
[1]Research scholar, Saveetha school of law, SIMATS, Chennai, India
[2]Professor and Principal, Saveetha school of law, SIMATS, Chennai, India
[3]Associate Professor, Saveetha school of law, SIMATS, Chennai, India

ABSTRACT
Sustainable design in manufacturing implies that the entire processes that are involved in the manufacture of certain products are environment-conscious. The entire supply chain starting from the process of securing raw materials to processing it, manufacturing the final product and making it available to the target customers through different distribution channels will be sustainable (Ball et al., 2019). The term sustainable can be defined as the process that is environment friendly and do not cause any negative impact upon the nature. Among the negative impacts include extensive use of non-renewable natural resources, emission of carbon bi-products during the manufacturing process and disposal of toxic affluents that can cause severe environmental concerns (Tomasowa, 2018; Hoerber et al., 2019). A practical definition of sustainability was given by Gro Harlem Bruntland, the Director-General of the World Health Organization (WHO) and the previous Prime Minister of Norway. According to him, sustainability is a systematic process in which the needs of the present can be met successfully without making the future generation compromised 46on their needs(Hoerber, Wenger and Demion, 2019). Thus, implementation of sustainable manufacturing process ensures that the major environmental concerns that arise due to pollution and injudicious use of non-renewable resources can be addressed effectively. Besides this, through the implementation of sustainable manufacturing process, the organization also ensures thatthe heath of the workers remain safe, the internal ambience of the organization remains safe and secured, work-life balance of the employees are maintained and ethical practices are appropriately followed(Kishawy, Hegab and Saad, 2018).
.

1. INTRODUCTION:

Mass customization is the process in which products are manufactured by keeping in mind the exact requirements of the targeted clientele. Along with this, organizations also aim at attaining price economy in the manufacture of products through mass customization (Ma, 2017). Even though mass customization has been considered as the most potential business mode for a range of industries, it is often argued that it causes severe impact on the environment. These perils of mass customization on the environment and exacerbating climate change due to this has set debate regarding itsecological impact and sustainability. Hence, even though mass customization is aneconomically viable process, the social and environmental benefits of the process are under severe scrutiny(Pourabdollahian *et al.*, 2014). However, there are debates regarding the ecological concerns associated with mass customization. A parallel view that supports mass customization opine that the distinctive feature of this practice is that it can apprehend exact needs of the customers. Hence, the accurate volumes and quantities of raw materials are collected and introduced in the supply chain. So, the natural resources that are used in the manufacture of particular products are not wasted due to over sourcing. Secondly, there is no wastage of energy in the processing of raw materials due to this precise collection of materials as per customer needs. Mass customization is thus regarded as the productivity enabler across various industries that also gives the reliance of easing ecological concerns connected with manufacturing with minimal energy wastage(Jensen *et al.*, 2018; Jimenez-Moreno, 2021). On one hand, the economic viability of manufacturing process can be maintained, at the other hand, injudicious use of natural materials and energy can be effectively controlled.47Nevertheless, emission of carbon footprints at the various stages of the supply chain processes of mass customization is a debated topic due to the environmental impact of various associated techniques such asadditive manufacturing, 3D-printing and rapid prototyping(Briem *et al.*, 2018).

1.2.Research Rationale

The background information related to the study that has been collected so far presents that sustainability is most needed across various industries to restrict the unwise use of natural resources and stop further aggravation of pollution across supply chains of various industries. From the brief background information collected so far, the study has also understood that sustainability is a major issue for the manufacturing industry. The primary reasons for this are too much dependence on natural resources for the manufacture of finished products and the emission of harmful pollutants during the manufacturing process. The study so far also revealed that many manufacturing companies are also thinking seriously about mass customization to cater to the precise

needs of the targeted customers and win a competitive edge in the market too. Secondly, the manufacturing companies also choose to go for mass customization because it gives economic viability to the firms. However, the issue of sustainability in mass customization remains debated mainly in the context of the emission of pollutants. Therefore, the rationale of the present study is to explore how sustainability can be ensured simultaneous with the implementation of mass customization in the manufacturing industry.

1.3.Limitations of the study and future scopes

The study will be limited to the exploration of the environmental impact of mass customization in the manufacturing industry. The possibilities of the implementation of sustainable measures to limit the environmental impact of the process will also be

explored. However, the scope of the study will be limited to a review of relevant literature that relates to the topic. No primary researches will be done on the topic. 48Moreover, the study on the specific strategies that are suitable for the manufacturing industry for implementing sustainability in mass customization will also be excluded.

1.4.Research Aim

This project aims to explore the sustainable design of manufacturing systems for mass customization that can generate a competitive advantage in future.

1.5.Research Objectives

The following are the research objectives:

• Gaining in-depth knowledge about the paradigm of mass customization within

frame of sustainable manufacturing

• Critical review of recent developments and future trends

• Identification of suitable case study

• Case study results and analysis

1.6.Research Questions

The following research questions will be addressed in the study:-

• Q.1. What is the paradigm of mass customization within the frame of

sustainable manufacturingt

• Q.2. What are the recent developments in sustainable design in the

manufacturing systemt

• Q.3. What are the future trends in sustainable design in manufacturing systemt

1.7.Chapter Plan

The entire study will be divided into the following chapters:

49**• Chapter 1: Introduction**

This first chapter of the study has introduced many essential research elements such as

the background of the research topic, research aim and objectives, research questions,

research rationale and future scopes.

• Chapter 2: Literature Review

A detailed review will be done in this chapter on topics such as sustainability and mass

customization. Empirical review will also be presented on the topic here.

• Chapter 3: Research Methodology

The methodological framework that will be used for findings answers to the research

questions. It shall include research design, data collection framework and ethical

considerations.

• Chapter 4: Discussion and Analysis

Analysis of the collected data will be made in this chapter and corresponding

discussions on the findings will also be made.

• Chapter 5: Conclusion and Recommendations

This final chapter will summarize the entire study and present corresponding

recommendations.

2. LITERATURE REVIEW

2.1. Chapter Overview

This chapter will conduct extensive study of relevant empirical studies where the impact and significance of sustainable design on mass customization have been studied. Focus will be given to select studies that are based on the manufacturing sector. Thus, brief discussion will be made on the meaning of sustainable design and its significance, the role of sustainable design in manufacturing section, the meaning of customization and its implication in the manufacturing sector. The specific contents that will be covered in this section are as follows:-

502.1. Understanding The Meaning Of SustainabilityAnd Sustainable Design

Sustainability is a concept that has gained wide popularity in areas such as research, policy development, planning and monitoring (Karampela, Papazoglou and Kizos,

2017). The concept first emerged in the field of forestry where sustainability meant refraining from harvesting a field more than once. Sustainability loomed from the idea

that of refraining from exploiting natural and non-renewable resources to the extent that they cease to exist anymore after some time(de Jong *et al.*, 2017). The term ‘sustainable design’ has emerged from the concept of sustainability and is popularly used in areas of engineering, facility management, architecture and customs clearance and procedures. In these fields, sustainable design refers to the method of designingproducts

and processes in such a way that it does not cause any negative implications on the environment(Long *et al.*, 2017). Particularly inthe field of engineering, it is stated that natural resources are endangered due to the rise of

global population. When the demand for these non-renewable are completely avoided in the manufacturing process, sustainable designs are created. Another significance of sustainable design is that the products that are developed using strict environment and life cycle assessment methodologies, they do not leave behind harmful by-products. Thus, the environment is never at jeopardy at any stage of the life cycle of products that are manufactured employing sustainable design methodologies (Tomasowa, 2018). However, while the

concern for the environment in intrinsic in the concept of sustainable design, it also integrates economicandsocialcontexts and applies them in its core concern(Lamond and Everett, 2019; Pieroni, McAloone and Pigosso, 2019). Thus, from the economic standpoint, as sustainable product designs emphasize the use of renewable and easily available products as law materials, there is a reduced investment in inventory. Even in the longer run, this process of saving in inventory cost leads to lowering of operating cost of various organizations. The organizations can even come out of liabilities are a

result(Badurdeen and Jawahir, 2017). Moreover, foreign investors also take interest in organizations that have a sustainable design in their manufacturing system. Eventually, it increases their scope of receiving foreign investments and enjoying better returns on 51investment. Therefore, sustainable design is linked with value creation in a country(Badurdeen and Jawahir, 2017; Mishra and Singh, 2019). From the social perspective, sustainable manufacturing processes signal the social responsibility of the organization that implements them. While the manufacture of sustainable products indicates that there will not be any environmental concern, it simultaneously signals that the workforce involved in the manufacturing process will not be exposed to any environmentally harmful effluents. Hence, it is an indirect guarantee of the organization that the safety and security of the workers are maintained. Such a perspective enhances the quality of work life, strengthens inter-organizational relationships and encourages the workforce to perform better(Qureshi *et al.*, 2017).

2.2.**Need And Significance of Sustainable Design In Manufacturing**

System

The manufacturing system of every industry is one of the greatest contributors to environmental pollution. On one hand, the manufacturing process leaves behind harmful effluents and toxic pollutants as by-products(Thirupathi, Vinodh and Dhanasekaran, 2019). On the other hand, the final products that are manufactured also cause environmental pollution towards the end of their life cycle when they are disposed of. These products mostly add to landfills because they are not biodegradable. Even the process of disposal of many of these products brings environmental concerns by emitting toxic fumes and other harmful by-products (Stoiber, Evans and Naidenko,

2020). Yet another environmental concern associated with the manufacturing system is that large volumes of non-renewable resources get utilized during the manufacture of various products(Thirupathi, Vinodh and Dhanasekaran, 2019). But the most challenging part is that the manufacturing system plays a vital role in influencing the economic growth of various economies by giving them a competitive edge for sustaining in the dynamic market scenario. Therefore, the manufacturing system of

every economy is heavily dependent upon foreign investment and globalization for sustaining this competitiveness (Vimal, Vinodh and Gurumurthy, 2017). So, on one hand, the first challenge for every country is that manufacturing processes cannot be 52compromised because it will hamper economic growth. On the other hand, the environmental benign manufacturing process will also set a heavy blow on the ecological growth of the country (Vimal, Vinodh and Gurumurthy, 2017). However, the need for enabling sustainability in the manufacturing processes has been felt across the world. The reasons are, sustainable design is the ultimate solution for meeting the environmental concerns that have arisen due to the exploitation of natural and non- renewable resources and pollution (Kishawy, Hegab and Saad, 2018). The development of sustainable design also impliesa cleaner production process and zero carbon footprints, and resource efficiency (Vimal, Vinodh and Gurumurthy, 2017; Stoiber, Evans and Naidenko, 2020). In such a scenario, implementation of sustainable design in the manufacturing system can be developed successfully when a perfect equilibrium can be established between the economic growth of a country and rising environmental concerns(Lee *et al.*, 2019).

2.3.**Applying Sustainability In TheManufacturing System**

The manufacturing system has noteworthy potential for embracing the principles of sustainable product design, reducing consumption of non-renewable resources, and improving its social, environmental and environmental performance (Thirupathi, Vinodh and Dhanasekaran, 2019). Thus, various trends have emerged for the application of sustainability in the manufacturing system (Lee et al., 2019). For instance, the use of recycled and biodegradable products is encouraged as the basic raw material (Früchtl, Leis and Wertheim, 2020). The traditional practice of using non-renewable sources as the fundamental raw material of the manufacturing of products is being replaced with renewable and non-exhaustive naturally occurring raw materials (Peter and Mbohwa, 2019). Petroleum-based products as raw materials are being replaced with bio-products that are made from natural and abundantly available materials like algae, seaweed, sugarcane, corn, etc., so that their production processes do not leave behind carbon footprints (Mathimani and Pugazhendhi, 2019; Sindhu et al., 2019). Attention is being given to the waste generation process at the end of the lifecycle of various products. In this strategy, called the circular economy, the waste generated after the disposal of the product is repurposed and reintroduced into the manufacturing process for the manufacture of new products (Nascimento et al., 2019). All these measures indicate that the process of implementing the sustainable design framework in the manufacturing system demands consideration of four dimensions of sustainability, namely environment, economy, business and society. When a sustainable design framework recognises the interconnectedness and

potential of each of these dimensions, balanced growth can be achieved. In addition, sustainable design in the manufacturing system can only be considered ideal when it successfully accomplishes the social, economic and environmental objectives of a country (Vimal, Vinodh and Gurumurthy, 2017).

2.4.Mass Customization – Meaning and Features

Mass customization as a term was developed by Stan Davis in *Future Perfect* in 1987, and the concept was further developed by Pine II in 1993 (Tseng et al., 2017). Broadly speaking, mass customization refers to the process of customizing products for customers. In a simplified manner, mass customization is the method of tracking and understanding the demands of a targeted mass of customers and tailoring products according to their needs. However, mass customization also signifies that customer preferences regarding the procurement and manufacture of their demanded products are followed. Similarly, in mass customization, the preferences of targeted customers are given priority in the choice of raw materials required for manufacturing, the production timeline to be maintained, and the distribution channels used to make finished products available to customers (Ma, 2017; Adel and Younis, 2019). In a nutshell, mass customization can be defined as the process of meeting customer needs during manufacturing while simultaneously maintaining near mass production efficiency. In this production process, every product is individually designed by considering the precise needs of each customer and implementing them through process agility, flexibility, and integration of the product life cycle (Tseng et al., 2017). Mass customization is characterized by specific features, goals, economics, and product specifications, where products typically have short lifecycles and short development cycles. It is used for the manufacture of integrated goods and services and is suitable for meeting unpredictable demand patterns of heterogeneous niches (Tseng et al., 2017; Jiao, 2017). The primary goal of mass customization is to offer a sufficient variety of tailor-made products and services that closely meet individual customer expectations (Tseng et al., 2017; Baranauskas, 2020), while also ensuring affordability. In terms of product and service nature, products generally belong to the same family and follow certain standard modules. Organizations that are flexible and adaptive to change are more likely to adopt mass customization, as customer needs are prioritized and active customer involvement is encouraged throughout the product life cycle. User innovation, co-designing, and customer configuration are essential tools of mass customization (Tseng et al., 2017; Wang et al., 2020). The key distinction between traditional mass production and mass customization lies in their objectives, as traditional mass production focuses on economies of scale to reduce unit product costs by increasing production volume of a single product type. In contrast, mass customization aims to manufacture and deliver nearly similar products or services while defraying fixed production costs through higher production quantities, which requires rigorous production design and extensive coordination among stakeholders (Tseng et al., 2017).

Fig. 1: Mass Customization

	Mass Customization (MC)
Goal	Delivering affordable goods and services with enough variety and customization that everyone finds nearly exactly what they want
Economics	Economies of scope and customer integration
Focus	Variety and customization through flexibility and responsiveness
Product	Product family and standardized modules assembled based on customer needs
Key Features	• Unpredictable demand pattern • Heterogeneous niches • Integrated goods and services • Short product development cycles • Short product life cycles
Organization	Flexible and adaptive
Customer Involvement	In order to meet the customer requirements with efficiency and effectiveness, active customers' involvement though out the product life cycle is essential. Thus, user innovation, co-design, customer configuration and others have become important tools in MC.

Source: (Tseng, Wang and Jiao, 2017)

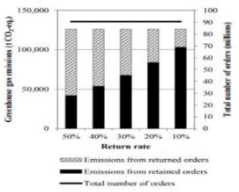
55Source: (Tseng, Wang and Jiao, 2017)

2.5.Implicationof Mass Customization In Manufacturing

The significance of mass customization has been explored in various studies across different periods. For instance, an earlier study conducted in 2015 by Medini et al. (2015) analysed both the advantages and disadvantages of mass customization. The research findings showed that a major benefit of mass customization is its ability to manufacture products with much shorter lead times. Companies that implement mass customization as their core manufacturing technology may also experience cost efficiency, as the income generated is usually greater than the initial setup cost and overhead expenditures. Moreover, the chances of product recovery at the end of the product life cycle are much higher in the case of mass customization. However, the study also indicated that mass customization can cause greater environmental impact compared to mass production due to higher energy requirements and greater material consumption. In addition to these disadvantages, mass customization can result in increased greenhouse gas emissions, primarily because order delivery is often not optimized, as each order is delivered individually to customers according to their specific requirements. At a later period, in 2018, Gembarski et al. (2018) conducted a study on the implications of mass customization on sustainability assuming that some improvements in the ecological

Concerns connected with mass customization have been effectively handled over time. While conducting their study, Gembarski et al. identified that adhering to economic, ecological, and social concerns while maintaining sustainability has become an imperative need of the manufacturing industry. In this context, mass customization plays a significant role in manufacturing goods and services tailored to customer needs. This process of product personalization has a positive impact on society and the environment by reducing wastage and unnecessary use of materials. A similar study conducted by Liu et al. (2018) also confirmed that a major benefit of mass customization is minimal material wastage. As this approach enables organizations to identify specific customer demands, appropriate volumes and quantities of raw materials can be procured from the source base. Furthermore, mass customization ensures the manufacture of products in required configurations and within optimal timelines, thereby avoiding unnecessary wastage of

energy, time, and labour. Nevertheless, Briem et al. (2018) highlighted that sustainability remains a concern in mass customization, as higher volumes of energy and resources are required to manufacture mass customized products compared to traditional manufacturing processes due to additional product features. Moreover, the scope for reuse of customized products is limited because of their high degree of personalization and customer-specific specifications. The introduction of advanced production technologies such as additive manufacturing, 3D printing, and rapid prototyping as part of mass customization aims to achieve economic sustainability; however, these technologies may result in higher environmental impacts than conventional manufacturing processes. In addition, mass customization leads to indirect energy consumption through the installation of systems for customer demand tracking, digital personalization, and supply chain monitoring. There is also a high probability that waste generated at the end of the product life cycle of mass customized products ends up in landfills, as traditional waste disposal methods may not align with the wide variety and material diversity associated with mass customization. Despite these challenges, Briem et al. (2018) also presented a comparative analysis showing that meeting specific customer needs and adopting advanced manufacturing technologies can enable mass customization to use resources more efficiently. Although energy efficiency in mass customization remains a debated topic, energy efficiency at the final stage of product distribution has been established because mass customization is based on personalized usage patterns that reduce negative environmental impacts. Furthermore, mass customization allows industry stakeholders to gain real-time insights into environmental impacts across different stages of the manufacturing process, enabling timely corrective actions. Briem et al. (2019) further highlighted the indirect environmental impacts of mass customization associated with product return policies, which contribute to carbon emissions through reverse logistics. Supporting this claim, the study cited the 2017 annual report of a leading European online retailer of customized products, which reported approximately 2.54 kg of carbon emissions per order during transportation, with 55% attributed to outbound logistics. The findings also indicated that nearly 250 million mass customized product packages are returned annually in Germany, generating approximately 123,667 tonnes of CO_2 emissions during collection and return transportation alone, excluding emissions from subsequent processing operations. However, Dissanayake (2020) emphasized that sustainability issues have become critically important across manufacturing sectors due to increasing environmental pollution, as rising demand for low-cost products has led to unsustainable levels of natural resource consumption, excessive water and energy use, hazardous chemical usage, depletion of natural resources, and toxic waste emissions. The sustainability potential demonstrated by mass customization has therefore made it a highly sought-after business model across industries, and continued technological advancements along with increasing customer demand for sustainable products are expected to establish mass customization as one of the most viable and sustainable business models in the manufacturing sector.



Source: (Briem *et al.*, 2019)

Source: (Briem *et al.*, 2019)

59**Fig. 2: Share of emissions caused by outbound logistics of returned and retained**

orders for different return rates (with constant 90.5 million orders in total)

2.6.**Empirical Review**

The study conducted by (Gembarski *et al.*, 2018)aimed at finding out the ecological impact of mass customization in the manufacturing sector. A systematic review of 33

journals Wwas done which were selected through keyword coding. The research findings confirmed a positive relationship between the implementation of mass

customization in the manufacturing industry and sustainability. The study found that mass customization leads to reduced material usage and wastage and hence the need for energy for manufacturing these products is also much less. Nevertheless, the study also presented that the social and economic gains from mass customization are much greater than the ecological gains.

Liu *et al.*, (2018) undertook a study to understand the relationship between mass customization and supply chain planning and integration. Primary data from 262

manufacturing plants were collected and analysed using the structural equation model. From the study findings it was understood that mass customization has some obvious benefits like reduction in toxic waste generation, limited energy consumption and sensible use of natural resources. Nevertheless, the study could not establish any

obvious link between supply chain planning and management with the implementation of mass customization. But the study also found out that supply chain integration is the process that mainly mediates the relationship between supply chain planning and adoption of mass customization. The study of (Briem *et al.*, 2019) intended to understand the link between environmental sustainability and mass customization. The carbon footprint of mass customization was accessed along with life cycle assessment for understanding energy and material usage pattern in this process. Two illustrative example scenarios were selected for the purpose and extensively studied by using qualitative approach. From

the research findings, it was understood that mass customization is both a threat and an 60opportunity. It is a threat to sustainability due to energy wastage, extensive use of energy and materials and carbon footprints. It is simultaneously an opportunity because

it creates value for the manufacturing firm due to its economic potentials. Thus, strategies have to be developed by the firms for moderating the environmental

consequences of mass customization by recognizing the levels of their own environmental consciousness, customer needs and organizational values. (Wang *et al.,* 2020) conducted a study on the need of mass customization in the manufacturing sector. As research methodology, the study collected primary data from a focus group of 15 respondents who buy mass customized products. The key variable of the study was mass customization. The research findings indicated that price is a driving factor that influences the customers to buy mass customized products. Nonetheless, availability of sufficient information from the manufacturer regarding the specifications of products that they claim to be customized as per customer needs creates trust issues among them. The customers often find that products which claim to be customized according to the needs of the customers fail to cater to the needs of individual customers. While this scenario is most prevalent in case of smaller companies and start-ups, the well established companies usually cater to the individual preferences of their customers. Hence, the customers show inclination to buy mass customized products that are usually manufactured by established companies. The study of (Ahmadi-Gh and Bello-Pintado, 2022) intended to understand the ecological concerns of manufacturing processes and the impact of various manufacturing processes on the environment. As research methodology, the study implemented secondary data were collected from the 4th round of the High- Performance Manufacturing (HPM) project. From the findings of the study, it was seen that the sustainability issues concerning various economic activities are raising serious concern in all the industries. Even though various environmental policies and standards have been adopted, the constant rise in CO2 emission due to various industrial activities could not be controlled. In such a scenario, implementation of sustainability practices can control these environmental issues. The study also indicates that every organization has to realize simultaneously that sustainable manufacturing 61practices also bring competitive advantage to different firms. Therefore, this aspect has to be given high priority while planning their operational processes.

3. **Research Methodology**

3.1. Overview of the chapter

This third chapter of the study will be exclusively dedicated to finding the specific methodological elements that will help in finding the accurate answers to the research questions. Therefore, the chapter will present the specific research choices that will be made in determining the research procedure, research technique, and research methods, along with the data collection protocol andprocedures for maintaining the ethical considerations of the study. This chapter will also present the reasons behind the specific research choices that will be made. Thus, the specific contents of the chapter are as follows:

3.2.**Research Philosophy**

The researcher takes a specific perspective while conducting research on a specific topic. The purpose of determining this perspective is to ascertain that the research topic will be approached from a specific dimension. Through the selection of the specific research philosophy that is complementary tothe research topic at hand, the researcher develops a deeper understanding of the types of information that should be gathered and the knowledge sources that should be accessed. Research philosophy also provides the researcher with a guideline for the entire research plan (Žukauskas,*et al.,* 2018). In

the field of academic study, three research philosophies are used, which are realism, constructivism and positivist philosophies. The specific feature of constructivism is that

62it collects secondary data in addition to primary data for making extensive analysis of a research topic (Asghar, 2013; Zukauskas, *et al.*, 2018). If this research is concerned, it will not include any primary data for validation of the findings. Hence, it is confirmed that constructivism will not be suitable for the research philosophy of this study. Realism, the next research philosophy, and social realities are considered the foundation for studying various human phenomena(Easton, 2010; Matthews, 2014). The present

study does not deal with any human phenomena because it intends to explore the potential ofsustainable design of manufacturingprocesses. Therefore, realism cannot be

selected as the research philosophy for the study. The third research philosophy is positivism in which the data collected from secondary sources are only collected and

analysed for generating answers to the research questions(Ryan, 2018). As this study will only consider secondary data collected from different sources for meeting the research aim and objectives so it can be concluded that **positivism** will be the most befitting research philosophy here.

3.3.**Research Design**

Research design is a term in an academic study that means a combination of research elements such as research strategy, research approach, research technique, etc.

Identification of these research design elements accurately helps in identifying the research problem accurately, understanding the data and data sources that will be accessed and the approach that will be appropriate for conducting the study. Thus, the specific research choices that have been made corresponding to the elements of the research design have been discussed below:

3.3.1. Research Strategy

The research strategy sets the direction for the research. When the researchers succeed in identifying the research strategy correctly, they are able to take a specific standpoint for addressing the research problem. There are various research strategies like survey, experiment, case study, grounded theory, archival method, action research, etc. which 63are applied as per their features for making research on different topics. While identifying the ideal research strategy for this study, certain aspects were considered.

Firstly, it was decided if the study will be based on secondary data or if primary data

will also be collected. Secondly, the source of the data was accurately identified.

Thirdly, the manner in which data will be mined was ascertained. Based on all these

considerations, the case study method was considered as the ideal research strategy for

the study. In the case study research strategy, different scholarly case studies are taken

and studied further as a reference to understand aspects that relate to the sustainable

design of manufacturing systems and mass customization. Thus, through the case study,

a deeper understanding will be developed on various related topics such as the concept

of mass customization, its significance, pros and cons, the significance of mass

customization on the manufacturing sector, environmental perils of manufacturing

processes, need of sustainability in manufacturing, etc.

3.3.2. Research Approach

While defining the research, it needs to be understood that every researcher takes a

specific style for addressing a research problem. Thus, the two research approaches that

are used for addresing problems from the academic standpoint are the indutive approach

and the deductive approach. In the deductive approach, the inferences made from

secondary data are deduced further with primary data for presenting some case specific

solution to a research problem(Armat *et al.*, 2018). The nature of the inductive approach

is completely contrary to the deductive approach from the standpoint that it considers

both primary and secondary data relevantto a research topic. The generalized findings

gathered from secondary data that relate to a research problem are refined further with

case specific primary findings before concluding the study. This study will only

consider scholarly case studies for collecting secondary data that are relevant to the

research problem. The conclusion to the study will also be drawn exclusively based on

the secondary data. This justifies that the inductive research approach has been

considered as the ideal research choice in this study.

64**3.3.3. Research Process**

The two research processes in the academic study are bottom up and top down process.

For some researchers, a top-down process appears most suitable because it helps them

in addressing a specific research problem and analysing it further to derive a generalized

finding. On the contrary, is the bottom up approach where a general problem is taken

and studied in minute detail so that a specific solution to the problem can be presented.

Both the research approaches help the researcher in meeting various research objectives

like forecasting solutions to a problem, setting specific goals, making future predictions

etc (Callon *et al.*, 2018; Spigel, 2018). In this study, the intention would not be limited

to any specific firms operating in the manufacturing section. Instead, the study will try

to find out how mass customization is a popularly sought after concept in the

manufacturing sector due to its economic gains. However, mass customization has

several environmental impacts which are causing concern in the entire manufacturing

industry. Here, through the bottom up approach, a general scenario of the entire

manufacturing industry will be considered where mass customization has become the

order of the day. Nevertheless, the study has also acknowledged that sustainability is

also needed in manufacturing processes to overcome the environmental impact. But in

such a scenario, sustainable manufacturing processes together with mass customization

have not been implemented across the manufacturing industry. Therefore, the study

findings are expected to help the entire manufacturing industry in understanding the

need, significance and processes through which the design of the manufacturing

systems can be made sustainable simultaneous with opting for mass customization.

Hence, a bottom up approach is most suitable for the study.

3.3.4. Research Technique

Identification of the correct research technique is yet another essential element of the

methodological framework through which a researcher ascertains if abstract data will

be suitable for a study or if quantitative data will be appropriate. Based on this decision,

65the nature of the research is decided. The three research techniques are qualitative,

quantitative and mixed research techniques. In qualitative technique, only abstract data

are considered which cannot be represented in numeric terms. In quantitative technique,

statistically representable and quantifiable data are collected and analysed(Azungah,

2018). When a particular research work considers both abstract and statistical data, it

is said that the study has implemented a mixed research technique. This study will not

collect any numeric data for meeting the research objectives. Hence, this will be a

qualitative study.

3.3.5. Research Method

This study will intend to explain how sustainable manufacturing processes can be

implemented in the manufacturing sector in mass customization. For the purpose of

this, the study will collect secondary data from empirical sources and try t explore the

theories that these studies have forwarded relevant to the topic. Since the selected

research topic is not related to human behavior and the method of study also does not

intend to make any study on any type of human behavior so it rules out the probability

that the descriptive research method will be applied here. Likewise, the research topic

is also not so uncommon that there is a dearth of adequate number of studies on the

relevant subject. This further shows that it is not exploratory research. But the manner

in which it intends to study the research problem shows that it shall employ explanatory

research method.

3.4.**Data Collection And Analysis Protocol**

The data collection and analysis protocol is a comprehensive guideline of study where

the nature of data to be considered, the source of data collection, data validity and

reliability establishment, and every aspect related to data is mentioned. Thus, the

66following elements of data collection and analysis protocol will be covered in this

section:

3.4.1. Data Type

The two predominant data types that are considered in an academic study are primary

data and secondary data. Primary data, which are case specific and freshly collected,

will not be used in this study. Instead, secondary will only be considered which are

organized, peer reviewed, and validated. Nonetheless, as they are not case specific so a

general conclusion to the research topic can be drawn from the collected secondary

data.

3.4.2. Data Source

Since the complete study will be based on secondary information so the selection of the

sources will be done with utmost carefulness. Only empirical sources that are scholarly

reviewed will be considered as the source of the secondary data that shall be collected

for conducting research on the proposed topic. Only published sources with a

publication date not exceeding 2016 will be considered in this study. The data sources

that will be considered in the study include journals, magazine and newspaper articles,

periodicals, government publications, books and government reports.

3.4.3. Data Collection Process

The section on the specific sources that relate to the research problem will be done

based on certain protocols. Firstly, scholarly databased shall only be used for accessing

the data sources. Secondly, certain keywords shall be used for ensuring that

appropriately relevant data sources have been accessed. The keywords and keyphrases

that will be used for the purpose are mass customizations, mass customization in

manufacturing, sustainable manufacturing, the pros and cons of sustainable

manufacturing, and so on. Thirdly, an elimination criterion will also be maintained

where a specific time period of 2016 has been fixed for the sources beyond which no

67sources will be considered.

3.4.4. Data Validity Establishment

This study will only consider data that are empirically sources and data sources that are

academically established. Therefore, it is ascertained there is no need to invest further

time, resources and energy in validating these data.

3.4.5. Data Analysis Method

The procedure of data analysis that will be followed in the study is the critical

estimation of different empirical studies. In this, a specific topic, such as the need for

sustainable processes in manufacturing or environmental perils of mass customization

will be estimated from different dimensions on the basis of different views of different

scholars as present in the selected peer reviewed sources. The inferenceswill be drawn

after the completion of the critical estimation of every topic by developing different

relevant themes.

3.5.Ethical Considerations

The ethical consideration of this academic study shall be duly followed. The first

mandate for this is, that the study affirms that it will completely refrain from any sort

of plagiarism. Secondly, all the direct quotes that will be used in this study will be duly

referenced with the appropriate in-text format. Thirdly, a detailed bibliography will be

provided at the end of the study where the name of the publication, date of publishing,

authorship details and various such relevant information will be clearly presented.

Finally, the specific processes of Harvard Referencing Style, 10th Edition will be used

for referencing every direct and indirect references that will be used here.

3.6.Summary of the chapter

This third chapter of the study has presented the specific research choices related to the

methodological framework that will be used for meeting the research aim and

68objectives. The chapter has clarified with appropriate justifications that this will be a

qualitative study where explanatory research method, inductive research approach and

bottom down process shall be used. The study will only use scholarly established

secondary data which nullifies the need for any further data validation. Finally, the

chapter has also explained in detail how the ethical considerations of the study will be

followed.

Chapter 4: Discussion and Analysis

4.1. Chapter Overview

The secondary data that have been collected so far on all the relevant topics related to

the research topic, its aim and objectives will be analysed here and discussions will be

made based on the findings. However, before that, it becomes essential to develop some

concepts related to the research topic that would emerge after the identification of the

common patterns in them. For this, an analysis of the secondary sources considered so

far will be done to understand the information present in them and the patterns that

emerge from the source. This will be followed by the development of the themes from

these patterns. Thus, the chapter contents are as follows:

4.2. Analysis Of The Referred Sources

Source Core Content Information Gathered

(de Jong *et al.*,

2017)

Need for Sustainability in the manufacturing sector:

Topic Pattern

Source	Core Content	Information Gathered
(de Jong *et al.*, 2017)	Meaning of sustainability in manufacturing - refraining from exploiting natural and non-renewable resources and exhausting them	Sustainable manufacturing promotes environment-conscious manufacturing process
(Long *et al.*, 2017).	Feature of sustainable manufacturing	Sustainable manufacturing processes do not cause any negative implications on the environment
(Badurdeen and Jawahir, 2017; Mishra and Singh, 2019)	The economic dimension of sustainable manufacturing	Sustainable manufacturing leads to reduced investment in inventory. It attracts FDI inflow.
(Qureshi *et al.*, 2017)	Social perspective of sustainable manufacturing	Sustainable manufacturing promotes a better workplace environment and improved employee motivation towards work.
(Thirupathi, Vinodh and Dhanasekaran, 2019) (Steiber, Evans and Naidenko, 2020)	Environmental impacts of manufacturing	Manufacturing processes cause unscrupulous use of non-renewable natural resources, toxic waste disposal brings environmental concerns
(Lee *et al.*, 2019) (Yrjichi, Lee, and Wertheim, 2020) (Nascimento *et al.*, 2019)	Sustainability measures for manufacturing sector	Sustainability in manufacturing can be promoted through the use of recycled and biodegradable products, focus on the use of renewable and non-exhaustive naturally occurring raw materials, circular economy principle in waste generation, and establishing sustainability between environment, economy, business and society.
(Tseng *et al.*, Jiao, 2017); (Baranauskas, 2020)	Significance of mass customization in manufacturing is established	Mass customization produces tailor-made products to meet the expectations of the individuals.
(Medini *et al.*, 2015)	Mass customization is significant in terms of cost efficiency, and resuse oof resources	Mass customization process can manufacture products at much shorter lead time, helps attain cost efficiency, and chances of product recovery at the end of the product life cycle are much higher.
(Briem *et al.*, 2018)	Mass customization promotes reuse of resources	Specific customer needs and use of new technologies of manufacturing causes wise use of resources.
(Giembarski *et al.*, 2018)	Mass customization is linked with wastage control and efficient material use in the manufacturing sector.	It helps control wastage generation and unnecessary use of materials through demand forecasting
(Liu *et al.*, 2018)	Significance of mass customization for manufacturing processes	It helps in the procurement of appropriate volumes and quantities of raw components. Time-pressed production also controls unnecessary wastage of energy, time and labour.
(Briem *et al.*, 2018)	Environmental drawbacks of mass customization	Mass customization needs higher volumes of energy and resources usage Scopes of reuse of these customized products are much less
		New production technologies of mass customization cause more severe environmental impacts. Associated processes of mass customization, such as demand tracking, digital personalization of products, and tracking of product movement, cause indirect consumption of energy. Recollecting the returned products and resending to warehouse for reprocesses causes further carbon emission
(Medini *et al.*, 2015)	Environmental perils of Mass Customization	Mass customization can cause greater emission of greenhouse gases
(Dissanayake in 2020)	The ideal business model for environmental sustainable manufacturing process.	Mass customization is the most worthwhile and sustainable business model in the manufacturing sector for controlling the depletion of natural resources and emission of toxic wastes.

been traced and presented below:

Need for Sustainability in the manufacturing sector:

Topic	Pattern
Sustainable manufacturing promotes sustainable manufacturing processes by controlling exploiting natural and non-renewable resources	Sustainable manufacturing negates environmental concerns of manufacturing processes
Sustainable manufacturing promotes FDI inflow into the manufacturing sector. Wise use of resources controls unnecessary investment in resources and energy.	Sustainable manufacturing promotes economic sustainability in the manufacturing sector
Sustainable manufacturing enriches the workplace environment and creates a motivating ambience for the employees.	*Sustainable manufacturing enhances the social sustainability of manufacturing firms.*
Sustainable manufacturing focuses on the cirvular economy principle and promotes the use of recycled and biodegradable products.	*Sustainable manufacturing promotes environmentaly conscious manufacturing processes.*

7

Significance of mass customization for the manufacturing sector :

Topic	Pattern
The lead time of the production process is comparatively shorter in mass customization. This leads to economic gains for the manufacturing companies. Providing tailor-made products that meet the expectations of the customers helps the firms in brand image, which adds to the firms' profitability.	*Mass customization helps the manufacturing firms in making economic gains*
Due to the shortened time of the production process, the energy requirement is comparatively lesser.	*Mass customization indirectly contributes toward enabling energy efficient manufacturing processes*
Manufacturing products that meet specific customer needs reduce unnecessary resource use. Controlling unnecessary use of resources also contributes to limiting wastage generation. Technologies of mass customization help inaccurate forecasting resource requirements in the supply chain, using energy that is particularly required to process the resources and time pressed delivery.	*Mass Customization makes the manufacturing process environmentally sustainable through judicious energy and resource use and reduced waste generation*
Mass customization offers an ideal business model for an environmentally sustainable manufacturing process.	

Drawbacks of mass customization in the manufacturing sector:

Topic	Pattern
Chances of reuse of finished products is negated in mass customization. Energy is required for mass customization processes like customer demand recasting, resource tracking in the supply chain anddigitized product customization. Resending to warehouse and reprocessing products cause repeated consumption of natural resources and energy and repeated toxic emissions. Transporting returned products to production centres and again transporting the reprocessed products to the consumers double carbon emission during transportation.	*Mass customization is indirectly connected with greater resource and energy use and toxic emissions.*

Sustainable manufacturing promotes sustainable manufacturing processes bycontrolling exploiting natural and non-renewable resources Sustainable manufacturing negates

environmental concerns of

754.3. Themes Developed For Result Interpretation

The following themes have been developed for further analysis:

Theme 1: Mass customization technologies contribute toward promoting economic

sustainability of the manufacturing sector

On te basis of the patterns identified, the first thme of this chapter aspires to understand if mass customization contributes towards economic sustainability of the manufacturing sector. Thus, the study of (Altonen, 2011) is found to be most revelant in understanding this. It shows that the supporters of mass customization are of the opinion that invests additional tehnologies to understand the specific needs of their targeted markets and manufacture products that accurately appeals to their specifications. This enhances the chances of winning customer loyalty. Eventually, its positive effect is felt in the profitability and business growth of the firm. This case

study on tw manufacturing firms in the USA market further show that the inclination to start mass customization of the products started with one of the case companies when they understood that there is customer demand for such tailor made products. The uniqueness of such customer needs and the level of sacrifice of the customers to buy personalized products at the cost that has been affixed by the manufacturer were the major factors that inspired mass customization in the company. The initiative helped

the company make economic gains because it could succeed in gaining access to a greater customer market through positive publicity from the existing customers.

Customer demand increased to such an extent that at a point of time the manufacturing firm fell short of supply of adequate volumes of products to meet the customer needs. The company experienced consistent orders for customized products from their repeating customers as well as new customers. The demand for customized products n the economic condition of the company was so stable that inspite of operating in a highly turbulent market characterized by fierce competition, it remained highly

resistant to market fluctuations. This indicates that on the one hand, the monotony of products shifts customer demand for customized products, on the other hand,

76companies that become successful in catering to such tailored demands in a timely fashion are able to enjoy economic stability. However, the study conducted

by(Altonen, 2011)showed a slightly different scenario of another case company that it covered. In the case of that company, customization of products started when the

market was not facing steep competition. The mass produced products were having a consistent demand in the market. In such a scenario, the company could not find

suppliers who would be prepared to manufacture small batches of customized products by replacing the bulk production of mass manufactured products. Moreover, this company was also new in the market with no established customer base as such. Therefore, they were not in a position to expect the customer to sacrifice for paying any price for tailor made products. Even then, the company reported that they made financial gains in the peak seasons as well as in seasons where the peak demand for such products declined. The company also reported that the global demand for these customized products did not decline when there were seasonal changes in demand. The study concluded that the value chain needs are the key factor that influences the demand for customized products where all other variables such as market fluctuation, and

changes in seasonal demand become secondary. Hence, customization of products yields continuous economic gains for the manufacturing companies. Even the study

findings of (Jain, Garg and Kansal, 2021) affirmed that there is a positive relationship between mass customization and economic gains of the firms. There is always a rush among the manufacturing firms to meet customer demands perfectly and within the specific time when demands peak. Mass customization with its various options serves as the ideal solution for the manufacturing firms for meeting these customer needs accurately by manufacturing products that are customized to their needs. It is entirely upon the infrastructures available to a manufacturing firm to decide which components of mass customization can be adopted by them and integrated with their manufacturing processes for assembling the different components of raw resources so that products with the right configuration can be manufactured within a stipulated time. The

manufacturing firms find this strategy of mass customization highly effective during

the time of market turbulence when the demands of the customers become 77heterogeneous, unique and need sensitive. During such situations, it serves as the tool

that empowers the production process, manufacturing infrastructure, supply chain levels and distribution channels to develop new product development processes that can give the manufacturing firms a competitive advantage. The study findings were further validated with the study of (Lacroix*et al.,* 2021) which specifically studied the impact of a technology based mass customization technique, namely, additive technology, on

the economic potential of the manufacturing firm. Additive technology means theuse of 3D printing technology in the manufacturing process which aids in the manufacture of materials with judicious use of resources and minimal wastage generation (Smelov

et al., 2017; Pérez *et al.*, 2020).The study findings showed that when mass customization was taken by the case manufacturing firm, the focus was on mass production. Instead, the firm paid attention to the production of limited products that would be tailored as per the specifications of the customers. Even though traditional mass production could not be replaced, mass customization with additive technology proved beneficial in attaining cost effectiveness. The tool-less production system and

extremely agile manufacturing processes of mass customization which eliminate the need for assembly of several components and operational parts to produce the final product contribute eliminates unnecessary capital expenditure on uncalculated sourcing of resources and processing, eliminating manual labour in many areas of production, and unnecessary and unforeseen delays in the supply chain activities. Moreover,even though the initial setup cost of additive technology enabled mass customization framework is marginally higher than non-tech mass customization that depends on traditional manufacturing techniques. Nonetheless, in the later stages, the production cost in non-tech mass customization increases due to repeated expenditures on

switchovers of production tools and mould creation. Implementing 3D Printing Technology in the processes of mass customization can prove further economically

effective in saving production costs and non-calculated raw material procurement. Therefore, the study concludes by suggesting that the economic gains of mass customization can only be considered higher if it integrates adaptive technology. Otherwise, the setup cost of a non-tech based mass customization will be high with the 78need for repeated investments in the later stages for keeping the manufacturing system agile and responsive to customer demands. So, the study of (Lacroix, Seifert and

Timonina-Farkas, 2021) concludes by showing that the technology driven mass customization processes are better options for making the customers optimally satisfied with products that specifically appeal to their needs simultaneous with helping the

manufacturing firms gain economic profits through the cost effective processes.A similar emphasis on technology based mass customization as the integral element of

the competitive advantage of the firms has been marked in the study of (Aheleroff *et al.*, 2019) too which shows that customization has a greater impact on the targeted

customers. As they find that the product appropriately suits their requirements, the customers show a greater inclination to buy these mass customized products. This gives the manufacturing firms a competitive advantage besides spurring their sales and

helping them in greater revenue generation. Here, the role of tech-based mass customization, such as the Industry 4.0 integrated manufacturing supply chain is imperative in meeting the demands of the targeted customers to the closest of precision. The study shows how manufacturing firms use Industry 4.0 technologies like Cloud- enabled Customer Profile (CCP) and Artificial Intelligence to track changes in customer demand in a supply chain and the exact needs of the customers. These technologies also

help the manufacturing firms in understanding the functionalities and appearances of the new product that the customers are demanding. Hence, exactly accurate products are manufactured in a seamless manner due to the greater agility of the manufacturing process. Integration of these technologies also helps manufacturing firms in scaling up their level of efficiency, which further adds to their cost effectiveness by helping them economize on unnecessary investment due to delayed production, manufacture of products that are not precisely tailored to customer needs, or production of surplus products that exceed customer needs.

• Interpretation of findings:

Their case studies referred to so far match with the previous scholarly findings where a direct link between the economic sustainability of the manufacturing firms that follow 79mass customization. Thus, after a critical estimation of the theme with several empirical sources, a positive relationship between the two variables can be established. In a scenario where customer satisfaction is the critical success factor, meeting the accurate needs of the customers in the specific time needed can give any manufacturing firm a competitive advantage. Here, the role of mass customization as the best way for meeting precise customer needs has already been established. When customer needs are appropriately satisfied, their loyalty increases, which manifests in the form of repeat orders as well as referrals which create a further clan of new customers and new orders from them. Thus, mass customization results in increased revenue generation. However, the case studies that have been referred to here also show that tech-enabled mass customization that integrates Industry 4.0 has greater economic potential than

non-technical mass customization which is mainly dependent upon the traditional system of manufacturing. These Industry 4.0 enabled technologies help in better assessment of customer needs and sourcing and processing of demand specific resources. Thus, firms can make economic gains additionally through the reduction in

capital invested in securing and processing resources and expenditures made on

wastages.

Theme 2: Mass customization leads to the social sustainability of the manufacturing

sector

While tracking the common pattern in the referred literary sources, a common pattern was identified that links mass customization with the social sustainability of an

organization. These research works have talked about various positive social outcomes of mass customization for a manufacturing firm in the form of employee motivation, enhancement in the workplace environment, better inter-organizational relationships, etc. To establish the validity of this theme further, some peer reviewed case studies have been considered. For instance, when the study of (Adel and Younis, 2019) was considered in this context, firms are supposed to remain agile so that they can evolve consistently and change their manufacturing strategies for accommodating the new demands of their customers. Here, the role of mass customization has been recognized by many firms as one of the most evolved functional strategies, namely, customization 80and mass production. This integrated process, on one hand, helps the manufacturing firms in manufacturing a variety of products on a large scale. On the other hand, mass customization helps in maintaining cost efficiency. Nevertheless, the implementation of mass customization in the manufacturing process needs meticulous preparation at the organizational level. The organization should encourage the development of an

innovative socialclimate for this.Such an innovative social ambience within the organization would motivate the employees to exchange their views, knowledge and

innovative ideas with each other regarding the manufacture of creative products, services or processes and gain a competitive advantage through enhanced performance and customer satisfaction. The study of (Dissanayake, 2019)c interprets the social

impact of mass customization from the standpoint of the psychology of the customers. It shows that while implementation of mass customization enhances the social ambience of the organization by making it innovative, it also intra-organizational environment. To be specific, as the core focus of the manufacturing firm is always towards the customers in mass customization, so it creates a psychological bond between the brand and the customers. Since treating the customers individually is at the core of the mass customization strategy, customers feel empowered. The strategy gives a vibe to the customers that they are the co-designers of the product that they believe will satisfy their needs optimally. Hence, they actively participate in sharing their views

and perspectives regarding the type of specifications they want in the product. Eventually, it garners a sense of trust among them towards the brand as well as a sense of belongingness and attachment towards the manufacturing process and the

manufacturing firm even before the finally buy the product. In this case of mass customization, the joy that the customers get through shopping is exceeded bya complete experience where they participate in the process of creating their own products and then buying exactly what they have designed. This positive relationship

that the customers build with the brand and the manufacturer in the process keeps them attached to it, thereby enhancing the social sustainability of the product. The role of technologies such as 3D scanning, prototyping that remain embedded with the process of mass customization plays crucial role in increasing this social sustainability. Similar 81findings have also been made from the study of (Vekic *et al.*, 2020) which shows that

the main objective of mass customization is to ensure that the needs of the customers in terms of the features of their preferred product are appropriately met. The manufacturing firm has to ensure that there will be enough variety of products so that the customers always have the privilege to choose products that appeal to them the

most. In addition, it is also essential for the manufacturing firms to ensure that the manufacturing process is steadfast so that the customers get the delivery of their products within the time specified to them. However, the quality parameters and the pricing, as committed to the customers, are also maintained in the process. All these

dimensions of mass customization create a mutual relationship of trust and belongingness between the customers and the manufacturing firm. While the study

highlights this social dimension of mass customization by indicating how it fosters a positive relationship between customers and the manufacturing firm, it also shows how

the entire process enhances the social ambience of the organization. Thus, the study elaborates that mass customization can only be implemented and carried out

successfully in a firm if the right ambience is created within it. The study of (Vekic *et al.*, 2020) specifically talks about the importance of an innovative organizational

ambience in this regard to show a mutual relationship is established within the firm based on the shared goals, knowledge, ideas, and innovative abilities and skills of the

employees. The study further adds that the decision to integrate mass customization in the business strategy makes the ambience within the firm dynamic so that it can change continuously. The dynamic nature of the firm helps it to respond well to the complexities and uncertainties that prevail in its business environment. These complexities also make the ambience within the firm multifaceted where different individuals within it analyse and view a single change from their own standpoints and contribute towards resolving various organizational obstacles amicably. The study of

(Zhang *et al.*, 2019) has analysed the link between mass customization and social sustainability from the standpoint of supplier relationships . In doing so, the study

showed that the objective of mass customization is to provide value to the customers.

In firms that use mass customization as their core strategy, value creation is encouraged 82through an integrated quality system between the manufacturer and the suppliers. Through this positive ambience created between the manufacturers and the supplier, the manufacturing firms integrate their decisions and supply chain activities. These firms also create opportunities for the suppliers to get in touch with the customers through the product specifications mentioned by them. Therefore, the study concludes by showing that mass customization creates a social ecosystem by integrating the

suppliers manufacturing firm and the customers in a single platform. While conducting the study on the social impact of mass customization, it was observed that the process can only work successfully if the employees within the organization have shared goals and shared interests to resolve organisational problems. The study conducted so far also showed that innovative ambience is the key requirement of mass customization. This influences the manufacturing firms to empower the employees in

organizational decision making processes, thereby enhancing their trust and belongingness towards their organization. As innovativeness, skills and agility of the

employees are welcomed in such an organization, the social ambience within it becomes dynamic. When the findings were cross checked with additional literary sources, similar findings were established. Additionally, it was also found that mass customization enhances the social ambience of the manufacturing firms at their macro- level too. In this, a relationship of trust faith and loyalty is established between the manufacturing firms and the customers when the firms give the hope to the customers that their needs will be individually attended to and the manufactured products will precisely be in harmony with their specifications. The cross-analysis has also shown that mass customization creates a social ecosystem where the customers, suppliers and the manufacturing firms, each one of them get a vibe that theyare participating unitedly in designing and developing a product.

Theme 3 : Mass customization helps manufacturing firms in achieving resource

efficiency and wastage reduction

One of the important findings of the study is that mass customization helps in economizing resource use and wastage generation. However, the studies that have beendone so far also showed a contradictory picture where it has been presented that 83mass customization indirectly causes depletion of energy sources. Moreover, the studies have also linked mass customization with greater carbon emissions. Hence, a cross-analysis of the findings made so far will be done with further scholarly sources for concluding if mass customization leads to environmental sustainability. The study of (Dissanayake, 2019) was considered for the purpose which shows that one of the

major drawbacks of the manufacturing sector is its excessive dependence on natural resources. High volumes of production to satiate the needs of growing number of

consumers is making the manufacturing sector use natural and non-renewable sources

drastically without any time to replenish or regenerate them. The use of natural resources like petroleum based products is also associated with emission of hazardous

affluents that pose great threat to the ecology. Offshore productions, which are also a value chain part of many manufacturing firms, are also causing environmental concerns due to activities like uncontrolled emissions due to transportation, increased energy consumption and uncontrolled waste generation. In such a scenario of ging

environmental concern, the mass customization business model offers a promising solution. The integrated and streamlined manufacturing framework of mass customization helps in the reduction of unnecessary exploitation of non-renewable natural resources and economizing on energy consumption through wastage reduction. The study further showed that since the basic feature of mass customization is that it aims towards making products tailored to the needs of the customers, the process is able to prevent overproduction and reduction in stacking of unsold products. As the technological framework of mass customization is capable of sensing the demands of customers, appropriate quantities of raw materials are sourced, the energy requirements also become specific and the generation of wastage is also minimal. Therefore, the carbon footprints of traditional manufacturing process can be significantly reduced if the manufacturing firms switch over to the process of mass customization. The study of (Stehling and Ruschel, 2019) was also considered in this regard which shows that implementation of mass customization in manufacturing enhances its overall sustainability, which involves economic, social, as well as environmental sustainability. The study further elaborates by showing that use of various technological elements of 84mass customization eliminate the chances of occurrence of defects in the production process, unnecessary delays and unplanned wastages. Thus, while on one hand such streamlined steps help the manufacturing firms in economizing on the use of energy, on the other hand, over sourcing of resources required for the production process is also reduced. Similarly, as wastage generation also much lower than that of the traditional manufacturing process, the ecological impact of manufacturing remains within control. A further study conducted by show that mass customization has the potentials by means of which it can bring revolutions in the manufacturing sector by enhancing its sustainability. The process of mass customization makes use of limited resources. Moreover, since the target customers of mass customization are anonymous to the manufacturing firms so the manufactured products can be easily tracked throughout

their life cycles. This generates greater scopes for the manufacturing firms to track the products till the end of their lifecycle and put them for recycling or remanufacturing. Therefore, wastage of resources is totally eliminated in this process. However, the

study also shows that this streamlining of the production system of mass customization can only be made possible if the manufacturing firms use Industry 4.0 technologies like

Big Data, sensors and Virtual Reality. The study also show that even though mass customization leaves scopes for remanufacturing or reprocessing of the products, the

resultant product might not meet the needs of the targeted customers anymore. Finding end-users who would be interested in buying the readily remanufactured product might also be a challenge for the manufacturing firms. Thus, the energy used for remanufacturing of products at the end of the life cycle might lead to complete wastage

of resources, time, and energy. Sometimes, specific components of mass customized products might have environmentally harmful consequences. But generally such issues go unnoticed because it becomes difficult to identity them. Even if such items are identified at any stage of the production process, the manufacturing firms have to wait for corresponding actions of mitigation. This leads to further wastage of energy and resources. Thus, the research shows that the environmental sustainability of mass customization remains as a debatable topic. While establishing this theme with the help of empirical studies, it was seen that many 85studies establish a direct connection between environmental sustainability and mass customization in the contexts of limited use of natural resources and reduction in wastage generation. It is further learnt that mass customization can only meet its

expected objective if it is integrated with technologies like Big Data, Virtual Reality, Artificial Intelligence, etc. However, parallel studies exist that show the link between

mass customization and environmental sustainability remains uncertain.

4.5. Summary Of The Chapter

This fourth chapter on analysis has made use of additional empirical studies to establish the themes generated on the basis of certain patterns tracked from the literature review

on related sources. The purpose of this analysis was to establish mass customization as a sustainable process the manufacturing sector. While the study done so far succeeded in social and economic sustainability of mass customization, the process cannot be

linked with environmental suitability due to presence of debatedviews regarding resource usage and energy consumption.

Chapter 5: Conclusion and Recommendations

This study was conducted with the purpose of understanding how manufacturing processes raise various sustainability challenges and if mass customization can be the solution to such problems. To gather the necessary information on the research topic, critical review of various case studies was done with the purpose of understanding if the various technologies of mass customization come within the paradigm of sustainable manufacturing. After tracking the present and future trends of mass customization, the study presented confirmed data that mass customization and economic sustainability are linked. The impact of mass customization on economic

sustainability can be witnessed by manufacturing firms through increased revenue generation and greater market access. The study also showed that mass customization

86leads to social sustainability by improving the workplace ambience, enhancing the quality of relationship between the suppliers, buyers and the manufacturing firms and establishing a mutually elusive ecosystem of interaction with them. However, the study

could not completely fit mass customization into the paradigm of environmental sustainability due to the presence of issues like energy usage during redesigning of products, stacking of these redesigned products due to unavailability of potential buyers and carbon emission due to their repeated transportation. Here, the study recommends that the manufacturing firms must have a clear idea of the environmental effects of all the components that are used in the manufacture of several mass customized products. Secondly, as environmental sustainability still remains a concern in mass customization so these firms must prioritize on this grave issue over their profit and find out solution

to mitigate it..

REFERENCES

1. Adel, M., & Younis, A. (2019). The impact of mass customization on supply chain performance in manufacturing firms. Journal of Manufacturing Systems, 24(2), 15-28.
2. Ahmadi-Gh, Z., & Bello-Pintado, A. (2022). Environmental management systems and the carbon footprint of manufacturing: Evidence from high-performance manufacturing projects. International Journal of Production Research, 60(1), 102-118.
3. Asghar, J. (2013). Constructivism in academic research: Theoretical perspectives and practical implications. Educational Research Review, 8(3), 45-56.
4. Badurdeen, F., & Jawahir, I. S. (2017). Strategies for value creation through sustainable manufacturing. Procedia Manufacturing, 8, 20-27.
5. Ball, P., et al. (2019). Sustainable supply chain management in the manufacturing sector: A review of current trends. Journal of Cleaner Production, 215, 120-135.
6. Baranauskas, G. (2020). Customization goals and individual expectations in modern service design. Service Science Quarterly, 12(1), 40-52.
7. Briem, L., et al. (2018). The environmental impact of additive manufacturing and 3D printing in mass customization. Sustainability, 10(4), 1120.
8. Briem, L., et al. (2019). Carbon footprint and life cycle assessment of returned goods in e-commerce. Environmental Science & Policy, 95, 34-45.
9. Callon, M., et al. (2018). Bottom-up and top-down approaches in industrial forecasting. Technological Forecasting and Social Change, 130, 22-34.
10. de Jong, E., et al. (2017). Exploitation of non-renewable resources and the evolution of sustainability in forestry. Forest Policy and Economics, 78, 12-20.
11. Dissanayake, K. (2020). The rising demand for affordable products and its impact on natural resource consumption. Global Environmental Change, 62, 102-115.
12. Easton, G. (2010). Critical realism in case study research. Industrial Marketing Management, 39(1), 118-128.
13. Früchtl, J., Leis, J., & Wertheim, R. (2020). Recycled and biodegradable raw materials in modern manufacturing. Materials Today: Proceedings, 28, 450-455.
14. Gembarski, S., et al. (2018). Ecological impact of mass customization: A systematic review of journal literature. Journal of Industrial Ecology, 22(5), 1050-1065.
15. Hoerber, T., Wenger, A., & Demion, J. (2019). The Bruntland definition and the future of sustainable development. European Journal of Futures Research, 7(1), 4-12.
16. Jensen, K., et al. (2018). Productivity enablers and ecological concerns in the manufacturing industry. International Journal of Operations & Production Management, 38(6), 1340-1358.
17. Jimenez-Moreno, J. (2021). Minimal energy wastage in agile manufacturing systems. Energy Reports, 7, 210-222.
18. Karampela, S., Papazoglou, G., & Kizos, T. (2017). Sustainability concepts in policy development and regional planning. Land Use Policy, 65, 110-120.
19. Kishawy, H. A., Hegab, H., & Saad, E. (2018). Design for sustainable manufacturing: Ethical practices and worker safety. Journal of Manufacturing Processes, 32, 70-85.
20. Lamond, J., & Everett, G. (2019). Integrating social and economic contexts into sustainable design. Sustainable Cities and Society, 45, 102-115.
21. Lee, J., et al. (2019). Establishing equilibrium between economic growth and environmental preservation in manufacturing. Journal of Business Ethics, 155(3), 850-865.
22. Liu, Y., et al. (2018). Supply chain planning and toxic waste reduction in mass customization plants. Decision Sciences, 49(4), 720-745.
23. Long, A., et al. (2017). Sustainable design in engineering and facility management. Automation in Construction, 80, 45-58.
24. Ma, J. (2017). Price economy and customer priority in mass customization models. International Journal of Production Economics, 191, 120-132.
25. Mathimani, T., & Pugazhendhi, A. (2019). Bio-products and carbon footprints: The role of algae and corn in manufacturing. Science of the Total Environment, 654, 110-120.
26. Medini, K., et al. (2015). Pros and cons of mass customization: Lead time and material consumption. IFIP Advances in Information and Communication Technology, 460, 3-12.
27. Mishra, S., & Singh, R. K. (2019). Value creation and investment returns in sustainable manufacturing systems. Management of Environmental Quality,

30(4), 850-870.
28. Nascimento, D. L. M., et al. (2019). Circular economy and waste repurposing in manufacturing supply chains. Journal of Cleaner Production, 210, 10-25.
29. Peter, K., & Mbohwa, C. (2019). Industrial energy conservation and prospects for sustainable manufacturing. Energy Procedia, 158, 4500-4505.
30. Pieroni, M. P., McAloone, T. C., & Pigosso, D. C. (2019). Life cycle assessment and sustainable product design. Business Strategy and the Environment, 28(5), 790-805.
31. Pourabdollahian, G., et al. (2014). Economic viability vs. social and environmental benefits of mass customization. Procedia CIRP, 17, 10-15.
32. Qureshi, M. I., et al. (2017). Social responsibility and worker safety in sustainable manufacturing. Resources, Conservation and Recycling, 124, 110-120.
33. Sindhu, R., et al. (2019). Bio-based raw materials and the reduction of greenhouse gas emissions. Bioresource Technology, 284, 150-165.
34. Stoiber, T., Evans, S., & Naidenko, O. V. (2020). Disposal of non-biodegradable products and toxic fumes: Environmental concerns. Environmental Health, 19(1), 1-15.
35. Thirupathi, R., Vinodh, S., & Dhanasekaran, R. (2019). Toxic pollutants and raw material utilization in manufacturing systems. Clean Technologies and Environmental Policy, 21(5), 1050-1065.
36. Tomasowa, R. (2018). Environment-friendly processes and life cycle assessment in sustainable design. International Journal of Sustainable Engineering, 11(2), 85-98.
37. Tseng, M. M., Wang, Y., & Jiao, R. J. (2017). Mass customization: Features, goals, and economies of scale. Springer Handbook of Mechanical Engineering, 120-145.
38. Vimal, K. E. K., Vinodh, S., & Gurumurthy, A. (2017). Globalization and the challenge of environmental benign manufacturing. International Journal of Sustainable Development & World Ecology, 24(4), 320-335.
39. Wang, Y., et al. (2020). Price as a driving factor in mass customized product adoption. Journal of Retailing and Consumer Services, 54, 1020-1035.
40. Žukauskas, P., et al. (2018). Research philosophy and guidelines for academic study plans. Management Culture and Education, 15(2), 10-25..

.