STUDY OF DESIGN AND MANUFACTURING ISSUES OF MASS CUSTOMIZATION

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In

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By

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DECLARATION

I hereby declare that the thesis work entitled "STUDY OF DESIGN AND MANUFACTURING ISSUES OF MASS CUSTOMIZATION" is an original work carried out by me under the supervision of Prof Suresh Kumar Garg, Department of Mechanical Engineering, Delhi Technological University, Delhi, and Prof Gayatri Kansal, Professor. This thesis has been prepared in conformity with the rules and regulations of the Delhi Technological University, Delhi. The research work presented and reported in the thesis has not been submitted either in part or full to any other university or institute for the award of any other degree or diploma.

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CERTIFICATE

This is to certify that the thesis entitled, “STUDY OF DESIGN AND MANUFACTURING ISSUES OF MASS CUSTOMIZATION” submitted by Ms. Piu Jain to the Delhi Technological University, Delhi for the award of the degree of Doctor of Philosophy in Mechanical Engineering is a bona fide record of original research work carried out by her under our supervision in accordance with the rules and regulations of the institute. The results presented in this thesis have not been submitted, in part or full, to any University or Institute for the award of any degree or diploma.

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Dedicated to my beloved husband

Mr. Vikas Jain,

my adorable son Anirudh and Sanyam

and my loving parents

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ABSTRACT

Consumer markets and purchasing trends are extremely dynamic, and customers today are more demanding than ever. Over the past two decades, mass customization has become more popular as a means of enhancing business due to the growing interest in obtaining customized and increased purchasing power. Mass Customization is a generic business strategy for organizational excellence and organizations striving for competitive advantage are incorporating MC into their business model. A lot of research has been done to improve a single enabler or a bundle of enablers to aid in the improvement process of mass customization. But in certain developing countries like India, mass customization is at its incipient stage, and manufacturing units who desire to implement this production paradigm for competitive advantage require a knowledge of the enablers, drivers, and manufacturing framework to foray into the more competitive arenas of mass customization for getting an edge in the marketplace. Given this need for research, the current study focuses on the enablers, drivers and manufacturing model for mass customization, with special focus on design and manufacturing issues.

Though research has been done to identify enablers of mass customization, there has been an associated degree of study in conceptual papers while theory-building articles are less in number. Also, less study has been done in the Indian market scenario. The literature shows that organizations are apprehensive of their technological potential and are not taking the initiative to transform themselves from conventional mass manufacturing companies to mass customization for emerging market needs. As a response to this research gap, a systematic literature review is conducted on enablers for MC and Total Interpretive Structural Modelling (TISM), and MICMAC analysis is used to develop a framework that illustrates how enablers are placed at different levels and how a particular enabler influences the other or getting influenced. Supporting this insight, a theory for accomplishing mass customization in manufacturing units is established. The theory is verified by

experts by structured questionnaires from three Indian manufacturing companies where Mass customization is being practiced. Practices are suggested to reinforce the attainment of mass customization in organizations aspiring to implement mass customization.

Fostering on the foundation laid by erstwhile researcher Hart, who developed an analytical framework of four pillars of mass customization for organizations, the research was conducted to obtain additional discernments on the nature of the linkage between the four pillars Customer sensitivity, Process Amenability, Competitive environment, and Organizational readiness for attaining mass customization for competitive advantage. Hypothesis developed was statistically verified with the help of structural equation modelling. The analysis of 276 valid responses from Indian professional experts was used to verify and obtain a manufacturing model for MC implementation.

The research applied multiple case study method to verify the manufacturing model framework for mass customization implementation. This study aimed to validate the previous framework with the help of multiple case studies. Production managers, quality managers, sales and marketing personnel, supply chain managers and business heads from three manufacturing enterprises in India were interviewed in-depth. The case companies are diverse in terms of size, ownership, and markets they serve. In businesses striving to implement mass customization, challenges are identified, and strategies are proposed to enhance the accomplishment of mass customization for competitive advantage.

In India, mass customization as a manufacturing approach is a burgeoning concept, and the identification of drivers of mass customization that drive the current market were thoroughly explored. This research work focuses on identifying and ranking the drivers of mass customization adaptation to assist Indian manufacturing companies in strategic planning, encouraging them to take the first step toward a long-term business model in a competitive market and to comprehend strategic goals to build a competitive business structure. Fifteen drivers were grouped into four categories and

ranked based on inputs from industry experts using the fuzzy analytical hierarchy process (FAHP). A fuzzy technique for order performance by similarity to ideal solution (FTOPSIS) was used to rank various manufacturing sectors for mass customization adaptability in the current economic environment. Case studies in four organizations of Indian origin were conducted to uncover the drivers that led them to pursue the more lauded but less explored area of mass customization and verify the proposed framework.

This study will aid managers who are contemplating a transition from mass manufacturing to mass customization in better comprehending the crucial areas where more emphasis is required. Identifying and prioritization of drivers for MC will assist managers and decision-makers in focusing on a few key drivers that will aid in the transition from mass production to mass customization. The case studies will help practitioners to understand the factors/enablers/drivers were practically used by certain companies for MC implementation. Though MC is not an "one size fit" for all companies, it will aid in generating innovative practices for those venturing into this arena.

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LIST OF ACRONYMS

AM	Additive Manufacture
AGFI	Adjusted Goodness of Fit
AMOS	Analysis of Moment Structure
AVE	Average Value Efficiency
CFI	Bentler Comparative Fit Index
BI&A	Business Intelligence and Analytics
CMIN/DF	Chi-square Statistic to Degrees of Freedom
CR	Composite Reliability
CAD	Computer-Aided Design
CFA	Confirmatory Factor Analysis
CR	Construct Reliability
CITC	Correlated Item–Total-Correlation (CITC)
EFA	Exploratory Factor Analysis
FMS	Flexible Manufacturing System
FAHP	Fuzzy Analytical Hierarchical Process
FTOPSIS	Fuzzy Technique for Order Preference by Similarity
GOF	Goodness of Fit
GFI	Goodness-of-Fit Index
IT	Information Technology
ISM	Interpretive Structure Modelling
MC	Mass Customization
MP	Mass Production
MC-IG	MC implementation guidelines
MSV	Mean Shared Variance
NFI	Normed Fit Index
PSS	Product/Service-System
QM	Quality Management
RMR	Root Mean square Residual
SPSS	Statistical Package for Social Science

SEM	Structural Equation Modelling
SLR	Systematic Literature Review
TISM	Total Interpretive Structural Modelling

CHAPTER 1:

INTRODUCTION

1.1 Introduction:

Customers are more demanding in present-day manufacturing than ever, and consumer markets and buying trends are highly dynamic. With the consumers' growing interest in buying customized products and increased purchasing power, mass customization has gained popularity over the past two decades as a way to improve business[1]. A company's ability to offer customized products and services that cater to each customer's individual needs without significantly compromising price, delivery time, or quality is known as mass customization (MC)[2]. Both manufacturers and customers benefit from MC[3]. The manufacturer benefits in terms of profit due to premium prices for customized products[4], increasing the importance of the manufacturer in the marketplace [5], thus leading to business excellence and competitive advantage[6]. Owning a product that is tailored to their likes provides the buyer with satisfaction, a sense of ownership, a unique experience, and fun shopping involvements[7].

Since 1999, Levi Strauss & Co. has successfully built a reputation for itself by providing an 'Original Spin' technique at its retail outlets, a cutting-edge MC method [8]. In recent years, companies including Kraft, M&Ms, Wrigley, Nike, and Zazzle have also used MC with the help of numerous innovative manufacturing technologies[9]. For example, Nike's FlyKnit knitting technique is renowned for its capacity to apply extremely user-generated designs in MC. Mass customization has been used by corporations like Land Rover, Dell, Gateway, Adiamondisforever.com, J.C. Penney, Hallmark, Adidas, Lands' End, Nike, and Shirtcreations in their online operations[10]. Customers can choose from various options provided by these companies to generate a range of customized products. Numerous organizations throughout the world have implemented MC to effectively capitalize on this buying trend of customers. For instance, the regional websites of the automaker Audi provides MC

options across Europe, North America, and Asia. Perspective automobile purchasers can choose a car model and mass-customize wheels, paint color, and interior features[11].

With this growing interest of customers for customized products and services, organizations are moving to MC. This fact was proven through the study of numerous case studies in literature. Way back in 1996, in a study of the National Bicycle Industrial Company (NBIC), in Japan, researchers examined the dynamics of mass customization adoption at a company that engaged in both mass production and mass customization, and they discovered that MC ultimately produced higher profitability[12]. In a research study in the Chinese automobile sector, researchers identified that the manufacturers should "reinvent themselves to survive, "and strategies that address mass customization" can help to enhance the manufacturing infrastructure[13]. They felt that for manufacturing companies to be competitive in the face of supply chain dynamics and uncertainty, mass customization (MC) capabilities are considered essential. In order to investigate the effects of growing variety and customization in the mobile phone sector, researchers conducted a case study on a mass customization program at a leading mobile phone manufacturer in Sweden[14]. They discovered that the increased need for diversity and customization presents a significant opportunity for the sector. These studies and many more established the fact that a lot of research work was conducted globally to identify and ascertain the importance of MC for competitive advantage.

Indian manufacturing enterprises are under tremendous pressure to increase their agility and responsiveness in this age of the global economy. [15]. Upgrading their manufacturing techniques to stay competitive in the international market is the current issue for Indian firms[16]. The manufacturing companies in India must comprehend the aggressive competitive techniques their international competitors use to overcome this problem[17]. Researchers concluded that with the availability of customized products from all over the globe through the internet to meet customers' escalating needs, Indian manufacturers need to adopt MC to satisfy customer demands[15]. According to researchers, Indian businesses that ignore the seriousness of the current market conditions would

face difficult times in the future and risk extinction[3]. Lack of understanding of ideas like product platforms, modularity in product design, co-designing with customers, and flexibility in manufacturing processes has been one of the biggest obstacles for companies in India to put MC into practice[18].

The research focuses on design and manufacturing issues of MC, mainly in the Indian manufacturing segment. This chapter thoroughly explains the background of mass customization, Next, it explains the motivation that instigated the research and explains the need for research. The research gap discussed in chapter 2, which reflects a lack of existing research in that space, explains the research objectives. Finally, the development of the theses is discussed, followed by the conclusion. The flow diagram of the chapter is shown in Figure 1.1.

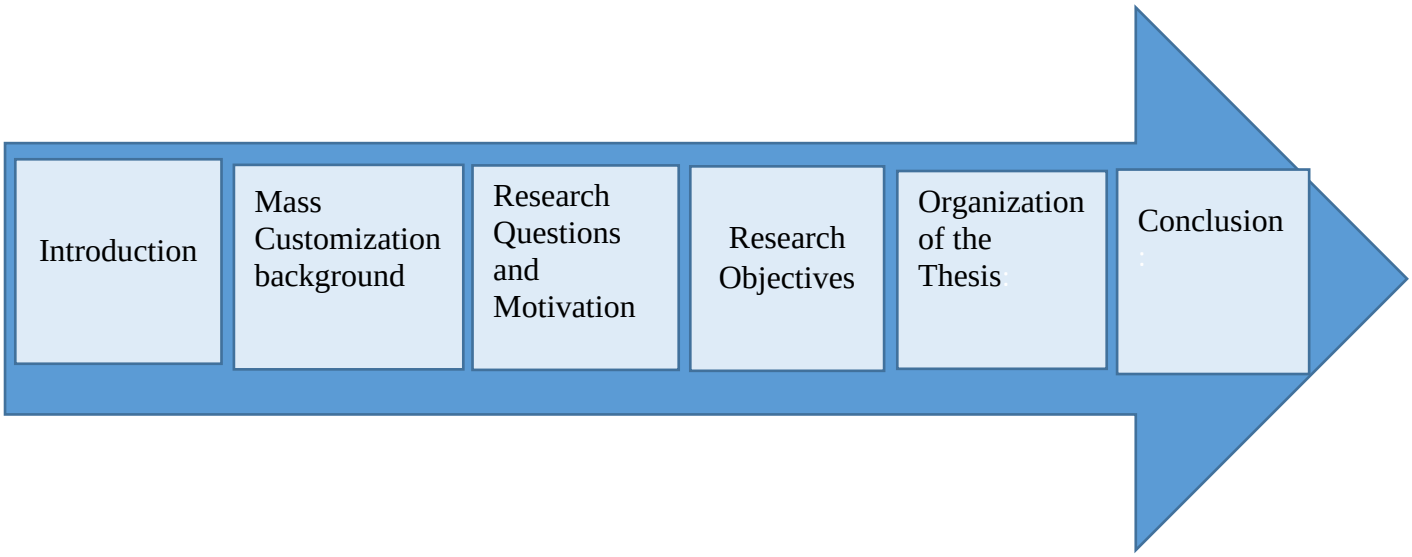

Figure 1.1: Flow of Chapter 1

1.2 Mass Customization Background

The term "mass customization" was initially coined by researcher Stan Davis in Future Perfect[19], and it was later advanced by researcher Pine II[20]. The MC production paradigm is promoted as a management response to a global market that is getting increasingly complicated, competitive, and uncertain[21]. Due to emerging production technologies, there is more competition on the global stage, resulting in shorter product life cycles, and fluctuating consumer preferences, leading to a shift towards

more product variety[22]. MC is viewed as an organised concept that addresses every aspect of product design, manufacture, sale, and logistics, starting with the customer's selection and ending with receipt of the finalized good[23]. This enables manufacturing scale economies to achieve low product prices while preserving product quality[24]. A corporation must cultivate a mindset that values ongoing education, individual and team development, the creation of new capabilities, and the dissemination of standards of excellence throughout all of its plants in order to successfully implement mass customization[25]. Utilizing the market's desire for more varied and customized offerings is the aim of the MC strategy.

The manufacturing sector is facing tremendous competition concerning competitive pricing, quality improvement, marketing strategy, manufacturing flexibility, and product and process innovation. Aggressive competition, reduced product lifecycles, and significant demand volatility are just a few of the issues that globalization and technological innovation have posed to industrial enterprises[26]. The premise of attracting customers has been transformed by the consumer market's perpetual shifts, and traditional strategies are no longer effective[9]. Making the offer more appealing and personalized concerning the tastes and demands of a certain consumer or target group could be a solution to this challenge [27]. To address a volatile and complicated economic landscape as well as shifting consumer preferences, organizations are switching from mass production to mass customization[[26][28]. Even though the Covid-19 problem has presented considerable difficulties for businesses, it has also sparked innovation, enabling better business models that will aid in their ability to adapt, and inspiring organizations to search for new strategic options[29].MC refers to the business strategy to produce customized goods fast and at comparatively low costs[31]. Researchers assert that businesses transitioning from the old paradigm of mass production to the new paradigm of mass customization will have an edge over their competitors [30]. However, MC shouldn't be thought of as a stand-alone solution. Different manufacturing technologies must be incorporated into a structured

framework that can combine human and technology variables to implement MC[1]. The need for mass customization as explained by various researchers are studied in detail.

1.3 Need and Motivation:

Researchers pointed out that it becomes a prime requirement by companies to expand product span and ameliorate product design and concept to endure the aggressive competition in the market segment[31]. MC be a balance between product variety and cost and many researchers found it a strategy manufacturing organizations require to compete globally in terms of cost, quality, and flexibility[32]. The customer's demand for customized requirements is causing organizations to shift from mass production to mass customization [28]**.** Researchers emphasized that persisting dynamic and turbulent environment requires organizations to adopt new strategies that can help them survive in this competitive environment, thus compelling organizations to analyse, evaluate, and reinvent their company strategy[33][34]. Due to the challenges of substantial changes in competitiveness, markets, technology, and demographic situations, the transformation of manufacturing systems to new forms of organization and management approaches has received a lot of research. Multiple internal and external factors influence the success of MC systems. The availability of these elements justifies the use of MC as a tactic for competition and encourages the creation of MC systems [2]. However, further research is needed to determine how to appropriately utilize the MC method when confronted with real-world issues [35].

Over the years, literature has endowed certain guidelines for the implementation of mass customization to help practitioners manage the complexity of MC. The guidelines suggest that two categories of MC implementation instructions exist: (1) Implementation instructions for 'Single Enabler' and (2) Guidelines for 'Bundled Enabler' implementation. Implementation instructions for bundled enablers endeavor to specify the interactions between two or more enablers, while that for single enablers aim to provide accurate implementation instructions for a particular enabler. Most

research works in the mass customization sector aimed at improving the firm's performance by focusing on only a single enabler (aspects) of mass customization [36] [37]. Research focusing on technological aspects in the implementation of MC researched on modularization and postponement [38] [39] [40], e-commerce and knowledge management[41], additive manufacturing technology[42], and Industry 4.0[43]. Research focusing on supply chain area of mass customization researched on supply chain scheduling optimization [44], online supply chain [45], Modularity [23], supply chain quality integration [46], supply chain planning[47]. Research work with bundled enablers included elicitation, process-flexible technology, and logistics[5]. Certain research focused on a firm's strategic orientations like customer, competitor, and innovation[48], while others identified the importance of IT-enabled technology for customer and supplier integration[28]. Such type of research work is effective for organizations that have already implemented MC and need improvement. For organizations transforming from MP to MC requires identifying the enablers and a framework for ithe implementation of the enablers.

Very less work is done on the implementation of MC and providing a roadmap. In a research work, authors used interpretive structure modelling (ISM) methodology to identify MC enablers[15][3], but this failed to explain the interpretation of nodes. Also, research work done are mostly in unorganized sectors like footwear companies in India[15], or specific sector like pigment company in Taiwan[49], and apparel company in Hong Kong[50]. The tailoring of mass customization calls for identification and proper level allocation to enablers[15] and firms implementing MC must identify potential enablers, the order in which these enablers need to be implemented, and the resources that need to be allocated [2].

Research has advanced the awareness of the barriers and challenges that MC adoption faces [18]. The challenge for managers is to create and administer coordinated processes that are able to manage the resulting rise in variety and uncertainty without impacting time to delivery, expenditure, or quality [18]. This issue is made more challenging by the potential need for various techniques

depending on the market type served, the complexity and price and the degree of customization provided. One of the necessities of today is understanding the plans, setups, and operational processes of the various production systems [1]. Because of the complexity and variety of MC, producers must create an implementation framework to match manufacturing with consumer requirements [51]. According to certain researchers, major obstacles to the growth of MC are high costs, a lack of adequate technology, a high degree of client interaction, and ineffective operations[50].

According to researchers, MC is a comparatively new concept in the Indian market[15]. As a result, organizations with Indian roots are wary of their technological potential and are delaying making the switch from traditional mass manufacturing to mass customization to meet the demands of emerging markets. These sectors find it challenging to develop a mass customization adoption roadmap or to put it into practice as a production strategy. Given that many academics believe that mass customization might be an effective way to compete for strategy, it is important to create strategic roadmaps that specify their future trajectories in order to comprehend and ease their transition to mass customization[26]. Manufacturing sectors in India identifying the possibility of moving away from mass manufacturing toward mass customization requires a manufacturing model and framework to guide them in their transition to enhance competitive advantage and reduce the chance of failure. Practitioners need MC implementation guidelines [2]. Manufacturers' ability to use MC is determined by whether they have a system of complementary processes, which explains why only a few companies gain from MC adoption[5]. Organizations that can quickly adapt to changing surroundings have been able to stay afloat and keep their operations running[29]. Diverse industries will require different ways to implement mass customization, since each have different organizational structure. As a result, there are numerous conceptual models, necessitating the identification and description of either the overall strategic approach or a specific common framework[52].

It is required to explore the implementation of mass customization in India, specifically how and why a company distributes its resources and capabilities as it evolves from mass manufacturing to

mass customization with the help of case studies. Empirical research in a specific setting using case studies has yielded data to assist practitioners in the mass customization implementation process with data from Chinese manufacturers[53], factors that influence customization level with data from real pigment company in Taiwan [49]. Using a qualitative, case-based research design, some research offered extensive and evocative information about mass customization, to assist manufacturers in identifying and assessing significant factors[54]. Some studies provided a constructive framework for organization contemplating entry into this dynamic arena [55], but such studies were conducted two decades back and are very limited, especially in Indian market conditions and under the present global scenario. Organizations are still at a crossroads in their transition from mass manufacturing to mass customization considering these research challenges. Identifying and prioritizing MC drivers will help managers and decision-makers concentrate on a few essential factors that will facilitate the change from mass manufacturing to mass customization. Given the circumstances, MC mandates the adoption of procedures and the development of a framework for manufacturing that fosters adaptability, quick customer response, cost-competitive products, product design that meets customer expectations, and achievement of corporate objectives [56]. For businesses employing mass customization to promote market competitiveness, increasing the operational agility of the MC production model is required to increase the flexibility, speed, and efficacy of reacting to specific client requests [57]. Businesses must continuously improve both their cost effectiveness along the value chain and their capacity to respond to shifting client expectations brought on by heterogeneous market demands. The strategy's applicability by the manufacturer and its adaptability to different market conditions are both aspects that impact MC implementation. The employment of proper organisational models and strategies is required for MC to move away from mass production, which may require significant modifications to the organization's physical infrastructure, industrial processes, human resources, and process management. The utilisation of flexible manufacturing technology, responsive human resources, and the development of fresh ideas for both products and processes are also suggested[58].

1.4 Research Questions:

Based on the research gap identified in literature review (Chapter 2), the study questions to pursue in the research work for MC implementation in the Indian manufacturing sector are as follows:

RQ1: *What enablers influence mass customization's adaptation when bulk production gives way to mass customization?* (The answer to this question is provided in chapter 4).

RQ2: *How can an organization implementing MC to compete in the market, especially the manufacturing sector of Indian origin*? (This intriguing question is addressed in chapter 5)

RQ3: *What mass customization strategies are adopted by organizations? (*This is addressed in chapter 6)

RQ4: *When is the right time to mass customize? What drives the MC business approach?*

RQ5: *What types of industries can benefit from the first-mover advantage? What are the challenges faced?* (RQ4 and RQ5 are dealt with in chapter 7)

To find an answer to the research questions, four research objectives were framed. The research objectives are explained in the following section.

1.5 Research Objectives:

The goal of this research is to empirically resolve gaps in MC adaptation, with an emphasis on how manufacturing and design issues affect mass customization capabilities for competitive advantage in India's manufacturing industry. Enablers should be identified for MC implementation and findings need to be verified by experts from case studies who are knowledgeable of the implementation, improvisation, and adaptation of mass customization in the current Indian business conditions. Manufacturing sectors in India identifying the possibility of moving away from mass manufacturing toward mass customization requires a manufacturing model for MC implementation to enhance competitive advantage and tide over competitors. Finding the important drivers for MC implementation is required. Identifying and prioritization of enablers and drivers for MC will assist

managers and decision-makers in focusing on a few key drivers that will aid in the transition from mass production to mass customization. Based on Research gaps (explained in chapter 2), the objectives of this research are:

Objective 1*: To identify the drivers and enablers of Mass Customization (LR and Questionnaire).*

Objective 2*: To develop a model for implementing MC in manufacturing considering design, manufacturing, and customer issues.*

Objective 3*: To develop Case studies in mass customization.*

Objective 4*: To analyse the suitability of a product for a given market for MC.*

1.6 Organization of the Thesis:

The four objectives identified for the research require thorough investigation which is completed and summarized in eight chapters. A brief overview of each chapter is presented below:

Chapter 1: Introduction: The research topic is the main emphasis of this chapter. Background information highlights the necessity for a transition from mass production to MC as well as the design and manufacturing issues connected with mass customization, particularly in Indian manufacturing units. The research gaps identified in Chapter 2, present the motivation for the research followed by the research objectives. The layout of the thesis is presented to provide a basic understanding of the discussions in each chapter.

Chapter 2: Literature Review: The section includes review of literature, which consists of the contribution of mass customization for business excellence. A discussion of manufacturing and design issues related to mass customization, the enablers and driver, is followed by the understanding of the transformation process concerning customer, human resources, manufacturing, and business strategies. The study led to the research gaps. The transformation model is discussed that needs to be understood by practitioners before venturing into the mass customization process. While the concept of mass customization appeals to entrepreneurs in all forms, it has yet to become a global norm. The

challenge of incorporating widespread customization into existing mass production is one reason for this. A discussion of the challenges concerning management, organization, customer, technology, and market is conducted, which is beneficial for practitioners who are at crossroads to venture into the paradigm of mass customization.

Chapter 3: Research Methodology: This chapter describes the philosophical premises that guide any research. The methodology adopted in the research is discussed along with the strategy and approach. This chapter introduces the selected research study and then discusses the investigation's tools and techniques. The creation of the hypothesis and the specific of the questionnaire is discussed and specifics of the procedures for data collecting and analysis have also been covered.

Chapter 4: Enablers of Mass Customization: TISM and MICMAC Methodology: Enablers were determined via the literature analysis in this chapter, and nine experts familiar with the implementation and improvisation of MC in the case study companies provided their interpretation for level partitioning. TISM methodology is used to create connections between the enablers. To ascertain the enabler's driving force, MICMAC analysis is employed. TISM is used to analyse the interaction among twelve potential enablers for building a framework for mass customization implementation. The findings can facilitate organizations in implementation of MC in their industries and understanding the various levels of enablers and their driving and dependence power. This chapter fulfils objective one, i.e., identifying enablers and level partitioning them to form a framework.

Chapter 5: Implementation Model of Mass Customization: Instrument Development, descriptive analysis, and SEM: The chapter comprises establishing the set of constructs for the construction of a manufacturing model for the application of MC and connecting it with competitive advantage along with hypothesis formulation. Based on a literature study, user surveys, comprehensive interviews, discussion forums, and challenging scenarios, a preliminary collection of numerous criteria was created. The content and construct validity of the research model's variables are examined using EFA

and CFA. The path model was validated with Structural Equation Modelling (SEM). SPSS 23 and AMOS Graphics 23 were used for the analysis. This can aid practitioners in the step toward the transition. This chapter discussed the fulfilment of objective two, i.e. – the construction and validation of a bundle of constructs for the development of a manufacturing model.

Chapter 6: Case Studies in Mass Customization: This chapter applied multiple case study methods to verify the framework provided in chapter five for mass customization implementation. This is also aimed at theory extension of the developed framework by identifying additional factors that will contribute to mass customization strategies to be adopted by organizations to comprehend and facilitate their transition. Case studies are necessary when dealing with multidimensional responsive systems [26] and theory extension and refinement are a natural progression from survey-based research to better understand and validate earlier findings [59]. The three manufacturing units analysed are Paint, Cabinets and wardrobes, and apparel industries. Challenges during the implementation process are identified and strategies discussed that were identified by case companies during the implementation of MC. This chapter fulfils objective three, i.e.to study MC implementation in case companies.

Chapter 7: Prioritization of Drivers of Mass Customization by FAHP and FTOPSIS: This chapter identifies the drivers that drive mass customization implementation in manufacturing industries. The drivers are grouped into four categories and ranked based on inputs from industry experts using the FAHP. A FTOPSIS was used to rank various manufacturing sectors for mass customization adaptability in the current economic environment. This chapter fulfils objective four, i.e., identifies the drivers and ranks the drivers and the suitability of industries for mass customization adaptation.

Chapter 8: Conclusion: The research is summarised in the last chapter, with a particular focus on the contribution that this thesis has made to the body of knowledge about the acceptance of mass customization in the context of developing countries like India. Furthermore, addressed are the study's

theoretical and practical consequences. Also highlighted are the study's weaknesses and some recommendations for an additional investigation. The structure of the thesis is presented in Figure 1.3.

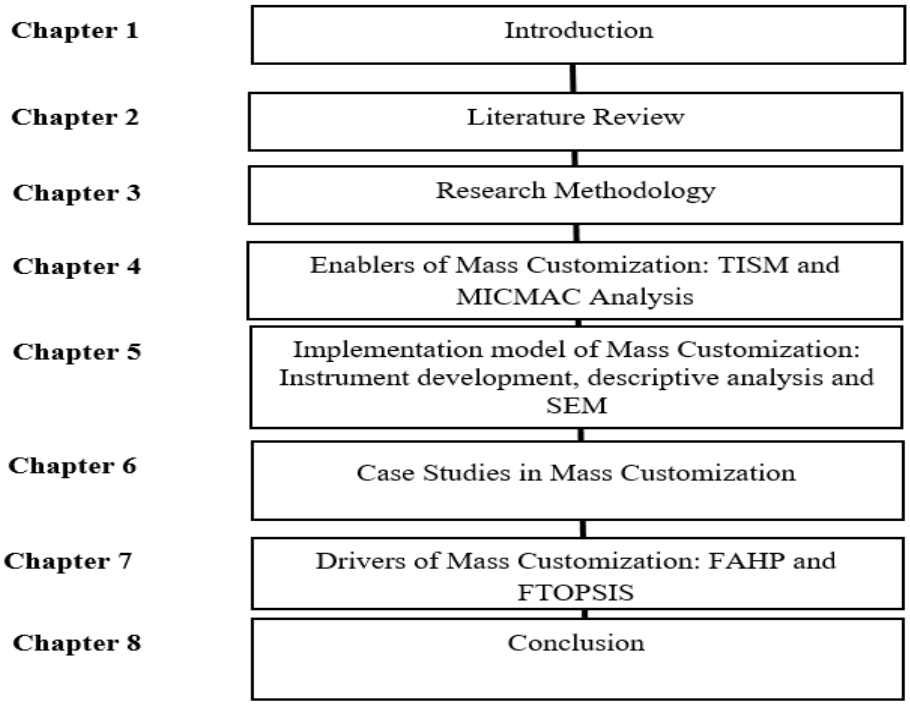

Figure 1.3: Structure of Thesis

1.7 Conclusions:

The chapter introduces the research work carried out in this thesis along with the background to understand the need for the manufacturing sector to implement mass customization for competitive advantage and business excellence. The research motivation is identified in the form of design and manufacturing issues in MC and the identification of the research gap leads to the framing of research questions that form the objective of the research work. In the next chapter, a review of the literature is presented which has formed the backbone of the research.

CHAPTER 2:

LITERATURE REVIEW

2.1 Introduction:

Both industry and academia are becoming more interested in mass customization (MC). Nevertheless, the academic study of MC implementation guidelines has trailed behind other study areas in the MC literature[2]. To identify research areas based on the literature gap, this chapter analyses the literature on MC. The methodology adopted for the LR will be discussed in Chapter 3. While the topic of what enables MC has been well studied, further research is still needed to address several issues. By giving an overview of recent MC literature, this chapter can be considered the basis for the gaps in literature and study of the current research topic. The major research areas concerning design, manufacturing, customer, and the enablers, drivers, barriers, and implementation guidelines will be discussed to identify the potential of these aspects for implementation and identify research gaps. A literature review of methodology will be discussed to comprehend the selection of appropriate methodology for analysis of the findings. The transformation from mass production to MC will be discussed to give an understanding to practitioners of various transformation models before venturing into the mass customization process. The issues and challenges will be discussed to comprehend the potential barriers to MC implementation. Finally, the chapter ends with a conclusion. The flow of the chapter is presented in Figure 2.1.

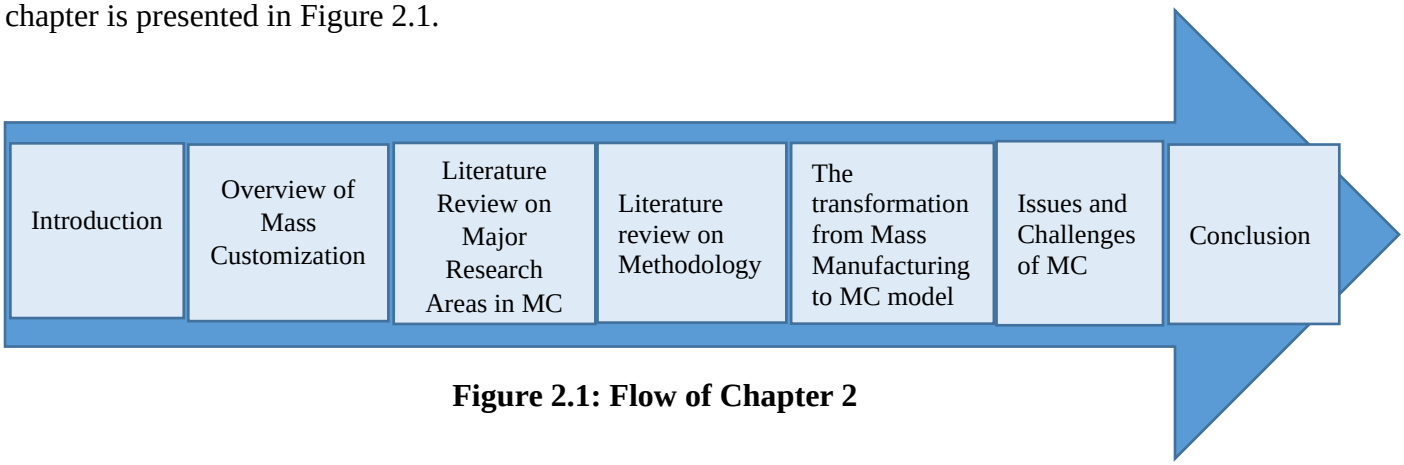

Figure 2.1: Flow of Chapter 2

2.2 Overview of Mass Customization

The previous two centuries have seen a general evolution of manufacturing across three paradigms. The maximum level of customization was achieved before the 20th century when craft production was used to manufacture things completely to the unique specifications of the customers. This kind of production is marked by an infinite variety at a high price. Beginning in the 20th century, there was a paradigm shift that was pushing society towards mass production (MP). Low cost and little variability in the products are the defining characteristics of this manufacturing style. However, the expectations of the modern consumer, who wants customized items at a reasonable price, are not met by these two extremes. Early in the 1980s, manufacturing companies began to build the capacity to offer goods that satisfied customized consumer requirements at a fair price. This marked the beginning of the third manufacturing paradigm, known as mass customization (MC)[15].

Researcher Hart posed the research question, "How powerful a business notion are we talking about here, and in what specific cases is this power most evident"[60] These are very important queries. The business opportunity of the coming millennium is, in his opinion, contained in the answer. "The ability to provide your customers anything they want at any time, in any location, and in any way while still generating a profit" is the creative definition of mass customization [60]. In all honesty, no organization—not even those who are wholly committed to becoming top-tier customizers—will ever succeed in achieving this ambitious goal.MC being an important manufacturing process, more studies are being done to better understand MC and how to utilize MC processes[5]. A solution to the problem of producing customized items is made possible by the synchronization the technology, human resources, and organizational activities. Due to the challenge of mass customization, it is essential to (1) achieve customer satisfaction and (2) optimize the entire process for generating profits [61].Companies are being motivated to reevaluate their business strategies due to the globalization of the market, the introduction of new networked technologies, labour shortages, and individualized client

demands[43]. Mass manufacturing is unable to satisfy the increased requirements of the present[62]. Therefore, customization is a way to cater to client needs.

Organizations view MC capacity as a way for businesses to offer distinctive products that cater to their demands in a timely and cost-effective manner[5]. As a result, customers value MC capability significantly [53]. From the standpoint of the company, MC's capabilities combine value-added customized benefits of pure customization with cost-effective mass manufacturing tactics [5].MC is not a "one-size-fits-all approach"; rather, it is based on the particular desires of the customer, the company's production capacity, and its technological capabilities [63]. As a result, MC's capabilities need to be distinct from and unmatched by competitors. Mass customization has been recognized as a capable strategy to track, develop and add worth to current products and customers, thus contributing widely to enhance product attributes and targeting them to diverse niche markets and customers[3]. The COVID-19 pandemic has triggered vast economic disruption across the world, causing fluctuating customer demand and industry activity[64]. Organizations need to adopt a strategy to cope with the customized demand in health, hygiene, medicine, food, service, and other sectors and prepare themselves for the 'next normal' and build resilience (i.e. the ability to 'bounce back') for future disruptive crises[65]. The intensified disruption in manufacturing has encouraged organizations to upgrade their manufacturing strategy to a dynamic level. MC is a competitive strategy in the market enhancing value to the customer's end-use[66]. Researchers defined MC capability as a continuum and not a contradiction of MP and proposed that MC competence should be developed to a certain extent by every company [48]. Organizations require novel strategies like mass customization to create a niche for themselves in the market to tide over the current dynamic and turbulent business environment [3].MC is a promising strategy that addressed the interest of practitioners and research scholars due to its potential to assist companies in gaining competitive advantage [67].MC has been identified as an important production paradigm and the opinion of various authors to understand the importance of MC is provided in Table 2.1.

Table 2.1: Need for Mass Customization

Sno	Need for Mass Customization	References
1	Mc is the application of adaptable organizational structures and processes to the creation of a wide range of frequently individually customized goods and services at a price that is lower than that of a standardized, mass-production system.	[60]
2	The objective of mass customization is to create enough diversity in goods and/or services so that almost everyone can find what they desire for a fair price	[68]
3	Promoting an attitude that encourages continuous improvement, organizational and individual learning, the development of new talents, and the dissemination of best practices throughout a firm's facilities are essential to the effective application of mass customization.	[25]
4	Given the use of proper enablers across the product, process, and system perspectives, mass customization initiatives at businesses with mass production heritage can be successfully implemented. Proactive customization initiatives might increase efficiency, but they can also result in inefficient product designs and long time-to-market periods.	[69]
5	MC is a business strategy that emphasizes the capacity to create high-value items quickly and at reasonably low costs.	[30]
6	MC is a significant competitive tool that can assist manufacturers in competitive advantage.	[70]
7	Mass customization is a promising strategy that addressed the interest of practitioners and research scholars due to its potential to assist companies in gaining competitive advantage, surge revenue, and moderate waste through on-demand production	[67]
8	The growth of MC will undoubtedly gain more importance as a result of the constant environmental volatility for businesses of all sizes to survive and prosper. By extending their offerings to new and adjacent markets following the unique needs of the clients, businesses must identify and put into action the best strategies in sync with the ones already in place if they are to maximize earnings	[71].
9	The creation of value by the producer and the client together to create a product offering that is better suited to fulfil specific requirements is a characteristic aspect of the mass customization business model.	[72]
10	Mass customization is a business approach that aims to establish a competitive edge by integrating personalization services into product-focused solutions.	[73]

2.3 Major Research Issues in Mass Customization:

The implementation of MC involves various aspects. Every stage, including design, manufacturing, and customer interaction, must incorporate the concept of mass customization[43]. One of the major issues in the existing literature is the dearth of implementation guidelines for MC. Therefore, it is even more essential to create a strategy that is tailored to the realities of the manufacturing industry if they want to differentiate from competitors. The enablers and drivers should be identified with changing business scenarios and a framework for the implementation process must

be looked into. A literature review on certain areas on which the objectives of the research are based is discussed below:

2.3.1 Design Issues: New computational design methodologies, have been applied to mass customization to better utilize the creative potential offered by sophisticated production methods[74]. Companies frequently choose custom-tailored products when clients can influence design at the initial production stage. In the case of a modular design, flexibility can be accomplished by combining numerous previously produced standard modules to create a product that is unique to the user. A set of five MC methods are shown in Figure 2.2[30].

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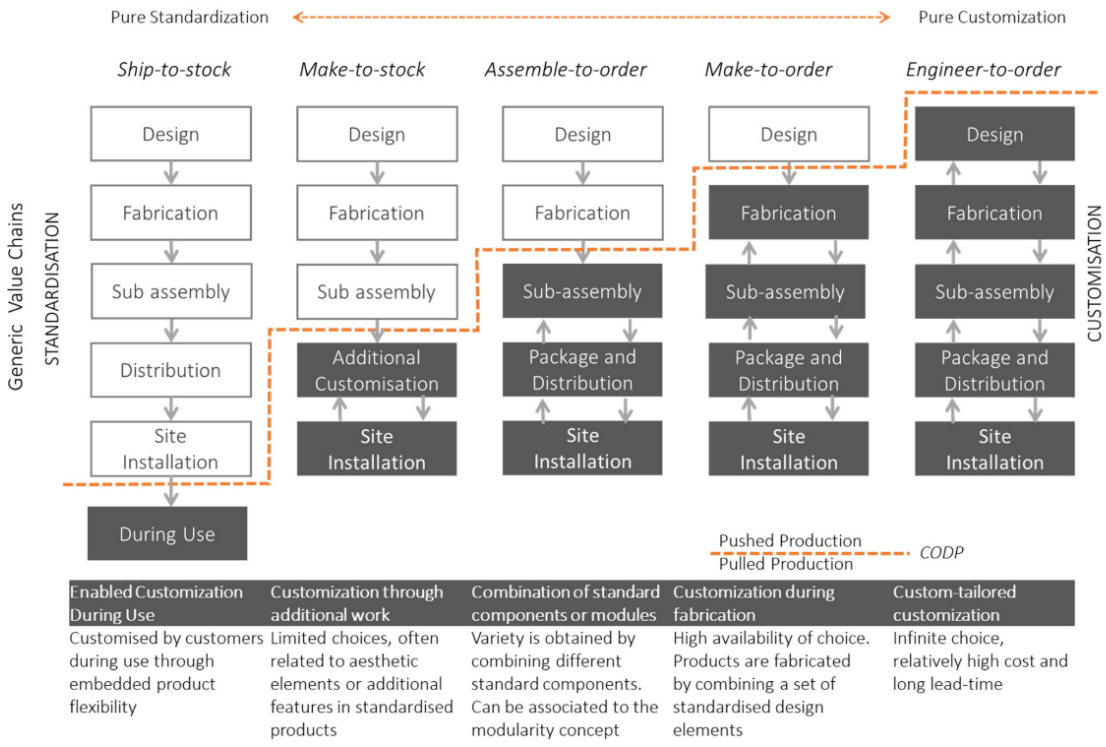

Figure 2.2: Approaches for customization, Source [30]

These methods, which heavily rely on the customer order decoupling point (CODP) position, range from total standardization[30] to pure personalization[11]. Customization of a product may be delayed until the point of sale and accomplished through additional work done after the sale. Customization

may occur throughout use, by incorporating flexibility within the product, or by providing specialized services with standard items[75]. These also determine when customers participate in co-design[72]. It becomes increasingly difficult for manufacturers as the level of customization increases since customers must participate earlier in the co-design process to add value. Adidas, for instance, offers completely customized shoes (in terms of relaxation, fit, and aesthetic), and co-design is originated at the initial stage of ordering, by taking the customer's foot impressions at the customized stores[4]. On the other hand, customers choose alternatives for several characteristics when purchasing a Scion (Toyota's customized vehicles), and the product is manufactured accordingly [72]. The codesign and customer participation for MC product may vary at different stages, which can pose a complication to manufacturer in terms of design issues, to select the best possible option that fits its product type. Based on the level of customization supplied and the manner and timing of consumer interaction, many classification frameworks have been presented in the literature to categorize mass customization tactics used by businesses [30]. Although a fully customized product (such as bespoke tailoring) may be more valuable to the consumer, sacrifices are frequently necessary to achieve an acceptable level of customization for a given product[6]. The risk of product uncertainty is also present when product variety is increased [9]. For MC to be successful, there should be a fair balance between standardization and individualization. To achieve MC, businesses must employ a combination of the deferral idea, modular product design, common procedures, and component platforms. The main areas of focus for adopting modularity for mass customisation should be the ability to assemble products from a set of standardised constituent units, incorporate modularity at the design stage, and product innovation. By providing a wider choice of goods, a shorter time to market, and lower design, manufacturing, delivery, and service costs, product modularity improves MC To understand the design issues associated with the implementation of MC, various research work was studied in detail and some prominent ones that affected the decision during the achievement of the objectives discussed in Chapter 1 are provided in Table 2.2.

Table 2.2: Research Areas of Mass Customization (Design Issues)

Sno	Description	Findings	References
1	A design framework for the mass customization of custom-fit bicycle helmet models	Researchers divided a portion of the Australian population into four categories based on similarity in head shapes for the suggested design framework. Then, brand-new clients were assigned to one of these categories. To ensure that only minor modifications of the helmet liner were used, customization took place within these groups.	[6]
2	Using Product/Service-System Family Design for Efficient Customization with Lean Principles: Model, Method, and Tool	The conceptual design of families of product/service systems (PSSs) is supported by the model, approach, and computerized tool proposed in this article. A computer-aided design (CAD) tool is added as an addition once a PSS family model is first provided. The design approach is then built using a method that builds on the model and lean concepts. Through an industry example of building a family of logistic services, the software and approach are validated.	[76]
3	The "I Designed It Myself" Effect on Mass Customization	Many businesses provide websites that let buyers create personalized goods that the manufacturer can then make to order. To date, preference fit achieved (which should be as high as feasible) and design effort (which should be as low as possible) have been linked to the economic value of items self-designed utilizing mass customization (MC) toolkits. The authors proposed a third element, namely knowledge of being the product designer, based on research on behavioural decision-making.	[77]
4	Data-driven generative design for mass customization: A case study	A promising algorithmic approach for mass product customization is offered by generative design, which boosts both product variety and design effectiveness. The automated program is created manually by the existing designer-driven generative design, which is unable to meet the wide range of needs of people. In this work, researchers offer a data-driven generative design framework that combines various types of data to enhance the automation level and performance of detail design, hence enhancing design effectiveness and user happiness.	[74]
5	Self-design fun: Should 3D printing be employed in mass customization operations?	Researchers examine the application of 3D printing in mass customization (MC) programs in this paper. They take into account the scenario where 3D printing increases consumer self-design enjoyment and alters the cost formula (i.e., the marginal product variety cost) of the MC product, as illustrated in MC practices of the automaker BMW and the furniture maker Poltrona Frau.	[9]
6	Design for mass customization using additive manufacture: case-study of a balloon-powered car	The paper discusses the case study of a balloon-powered car created for a course to illustrate the ability of additive manufacturing for mass customization. This highlights the usefulness of the determined additive manufacturing restrictions and their early application in design to decrease design-print iteration as opposed to as a post-process.	[78]

2.3.2 Manufacturing Issues: Innovative production methods and cutting-edge manufacturing techniques are slowly but surely making their way into architecture, thanks to cutting-edge computational design tools that enhance digital fabrication processes and programming[79]. The implementation of mass customization relates to the possibility of replacing current systems with new ones that may be personalized without increasing their cost and leading to the development of new technologies[80]. One of many manufacturing processes known as additive manufacturing (AM) is recognized as a cutting-edge invention that allows architects unprecedented creative freedom and increases their options for creating cutting-edge architectural forms, construction techniques, and materials[81]. Researchers also emphasized the importance of using Industry 4.0 to preserve or gain a competitive edge in a cutthroat market[82]. The managers' top priorities should be creating cooperative connections with suppliers and establishing adaptable manufacturing expertise[3] for MC implementation.

As product life cycles get shorter and shorter and market trends accelerate quickly, it is getting harder for both producers and consumers to keep up with technological advancements. In light of these new market realities, the methods employed yesterday to produce and distribute goods and services appear rigid and reactive. As a result, the MC firm model must go through significant technological, manufacturing and operational changes. With the availability of various manufacturing processes and technology, researchers acknowledged that the manufacturing issues associated with MC implementation should be thoroughly explored before foraying into this area. Practitioners may argue whether ongoing exposure to recent technologies is quite essential for MC implementation or is required for improving and enhancing the business model considering the development of current technology, such as AR applications, Industry 4.0, and additive manufacturing. Researchers might further investigate whether MC can be accomplished by matching consumers' desire for the MC product considering the incorporation of manufacturing-technology elements into MC interfaces.

Research work of various authors was considered to understand the need of the manufacturing enablers for MC implementation Some prominent research works in this context are explained in Table 2.3.

Table 2.3: Research Areas of Mass Customization (Manufacturing Issues)

Sno	Description	Findings	References
1	Blockchain-based mass customization framework using optimized production management for industry 4.0 applications	Companies are attempting to offer individualized items by eschewing conventional production processes. The adoption of the personal custom manufacturing model is significantly influenced by technologies like blockchain, IoT, and cyber-physical systems. An effective framework for mass customization is suggested in this study.	[83]
2	Industry 4.0: away from mass customization to mass personalization production	This paper provides a framework for mass personalization production based on the ideas of Industry 4.0 to bridge the gaps between mass customization and mass personalization.	[82]
3	Factors that influence Chinese automotive suppliers' mass customization capabilities	This study explores the MC capacities of Chinese automotive suppliers using social dilemma and resource dependency theories. It finds that some, but not all, MC practices are appropriate for the Chinese market.	[13]
4	Operations managers' (OM) individual competencies for mass customization	This article seeks to shed light on the individual competencies (ICs) of an operations manager (OM) that are significant to the mass-customization capability of the manufacturing organization in which the OM is employed.	[54]
5	Supply-chain configurations for mass customization	Most of the study on the application of mass customization strategies has a functional focus, taking various aspects of product design, marketing, manufacturing, or sourcing into account. With the help of this study, a deeper systemic understanding of the mass customization strategy was developed.	[51]
6	Achieving mass customization capability: the roles of flexible manufacturing competence and workforce management practices	The goal of this study is to determine how workforce management practices and flexible manufacturing competency affect the development of mass customization capabilities. The operational practices and the links between them that were found in this research will give businesses guidance on how to succeed in the MC industry.	[71]

2.3.3 Customer Issues: Companies implementing the MC manufacturing paradigm might need to find untapped sources of difference to provide them an advantage over rival mass customizers and increasing the advantages that consumers receive from owning mass-customized products can be one method to do this[45]. Customers' capacity to alter the look and features of items when making judgments about their purchases has evolved into a crucial element in preserving and boosting the

competitiveness of manufacturing firms in a variety of industries. It is suggested that MC is a manufacturing business model that enables the acquisition of a sizable client base while offering the chance to customize the product to satisfy customers' needs[27]. Literature references of MC application can be seen in a various industries, including those in furniture[9], building[30], electronics[84], fashion[50], and machinery industries[54]. Several crucial conclusions were provided: First, the manufacturer should believe that offering customization is always best. They need to understand how the interaction of marketing and production elements affects the ideal level of personalization. Second, the chosen level of customization improves well-being. Third, manufacturer should provide a conventional product at a reduced price. Efficiently facilitating the integration of customers into the production processes is a key mass customization principle. While configuring, defining the product, and co-designing, the client is integrated into value generation. Integration of the customer is frequently viewed as a requirement and a source of additional customization costs. In contrast, researchers contend that customer integration may also be a valuable asset to boost productivity and open the door for a fresh set of cost-saving opportunities[4]. Some purported benefits of MC for businesses that have used it include increasing client loyalty by learning more about their customers[50]

As a result of the mass customisation paradigm, consumer preferences have a big impact on the product design process. To understand customer needs and develop creative products, working with users and customers has become increasingly important in commercial markets. The foundation of MC is the efficient incorporation of distinctive client demands into product and service designs by involving clients in the design process. The success or failure of any corporate organization currently depends on how well it can serve its consumers. The ability of operational processes and suppliers to supply such customized products or services within specified levels of quality, cost, and time is a significant aspect in maintaining a balance between the requirements of customers in terms of customized products or services and their ability to do so. Therefore, it is crucial to understand the

factors that influence the value that customers gain from MC and what level of customer involvement is essential for any company. Literature on MC from the customer's perspective was studied in detail to understand what customer factors are quite essential to implement MC[85]. The prominent works of some authors whose insight influences the research output are discussed in Table 2.4.

Table 2.4: Research Areas of Mass Customization (Customer Issues)

Sno	Description	Findings	References
1	Enhancing the consumer-perceived benefits of a mass-customized product through its online sales configurator: An empirical examination	In business-to-consumer mass customization, uniqueness and self-expression are two new sources of consumer value. This is the first empirical study to provide insights into the qualities that an online Supply Chain should possess to tap into these two value sources.	[45]
2	Personalizing the Customization Experience: A Matching Theory of Mass Customization Interfaces and Cultural Information Processing Emanuel	Consumers are often led step-by-step through the configuration process using mass customization interfaces, concentrating on one product attribute at a time. An increase in "interface fluency"—consumers' subjective impression of ease when using the interface—is what causes these favourable consumer responses to arise. The authors urge companies to use processing-congruent interfaces across consumer markets to personalize the customization experience.	[11]
3	Sustainable value co-creation through mass customization: a framework	Co-design, a major component of mass customization, involves customers and manufacturers jointly deciding on the product's specifications to satisfy client needs. An in-depth analysis of the mass customization model and its potential as a setting for long-term value co-creation is provided in this article.	[72]
4	Company-customer interaction in mass customization	The degree of consumer involvement in a manufacturer's production process is referred to as the level of mass customization in a game-theoretic model of mass customization. Adjusting a product to a customer's tastes individually involves opportunity costs for the customer. Each consumer's trade-off between having a product made specifically for her needs and the expense of her interactions has an impact on the manufacturer's trade-off between diseconomies of scale and larger profit margins.	[86]
5	Understanding the customer value of co-designing individualized products	The goal of the current study is to better understand how the co-design process generates value for customers. A premium shoe individualizer's customers' data were gathered, and analysis was done.	[73]
6	Does mass customization pay? An Economic Approach to evaluate customer integration	The study offers a comprehensive analysis of value generation in manufacturing methods that rely on mass customization. In this paper, researchers make the case that customer integration may also be a valuable tool for boosting productivity and may open up new opportunities for cost-cutting	[4]

2.3.4 Enablers, Drivers, and Barriers, Implementation Guidelines of MC: To help practitioners manage the complexity of MC, academic research has over the years offered various recommendations for MC implementation[2]. Mass customization implementation guidelines (MC-IGs) are being developed as part of academic research projects that are intended to put accumulated MC expertise to use. Unfortunately, prior MC literature assessments have paid little attention to MC-IGs. Some examples of effective MC implementation are provided in the MC literature, including Dell and the National Bicycle Industrial Company[12]. However, according to researchers, "most companies are not textbook examples of best practice," [14]and as a result, "managers need to tailor the [MC] approach in ways that make the most sense for their specific businesses"[51]. This tailoring process is not simple; in fact, paths that are convoluted, uneven, blocked, or interrupted on the way to the MC are not unusual [68]. Companies must go through a difficult transformation process to achieve MC[30].

MC shouldn't be seen as a "one-size-fits-all" answer, though. Therefore, identifying the factors that lead to successful implementation needs to be thoroughly studied. For businesses to more effectively prioritize their resources and implementation efforts, it is necessary to identify MC enablers and demonstrate the interconnections among them[3]. Organizations that want to compete in the MC landscape must identify the enablers that will aid them in achieving MC[15]. Major literature support in this area is provided in Table 2.5.

Based on the study of literature, the following gaps were observed:

Gap 1: Very few references have been found that consider drivers and enablers of mass customization.

Gap 2: Very little work has been done to develop a model which integrates all performance measures of Mass Customization, and which can be used for the implementation of MC in manufacturing.

Gap 3: Research on the case study of mass customization is limited.

Gap 4: The extant literature fails to provide an efficient method to measure the suitability of any product for any given market for MC.

Table 2.5: Research Areas of Mass Customization: Enablers, Drivers, and Barriers, Implementation Guidelines of MC

Sno	Description	Findings	References
1	Analysis of interactions among the enablers of mass customization	To create a clear roadmap for the effective implementation of MC, this article aims to identify the important enablers required to realize the objectives of MC, study the link between them, and prioritize them in order of their importance.	[3]
2	Mass customization in the Hong Kong apparel industry	According to the statistical research, the main obstacles to the growth of MC in Hong Kong are high costs, a lack of adequate technology, a high degree of client interaction, and ineffective operations. There are six suggested managerial implications and recommendations	[50]
3	Operationalizing Mass Customization in Manufacturing SMEs—A Systematic Literature Review	This article seeks to illustrate the various approaches and elements that must be in place for mass customization to be implemented successfully. This study indicates that the characteristics that support the operationalization of mass customization are not prioritized.	[43]
4	Interpretive structural modelling-based framework for mass customization enablers: an Indian footwear case	To investigate the MC enablers, this study has been presented in the context of Indian manufacturing industries, with a focus on the footwear sector. However, to achieve MC, certain supporting technologies and procedures must be in place. This study aimed to identify the most crucial MC enablers using interpretive structural modelling (ISM) and to create a hierarchy of these enablers for the Indian footwear industry.	[15]
5	Analysing the barriers to implementation of mass customization in Indian SMEs using integrated ISM-MICMAC and SEM	This study's goal is to pinpoint the primary barriers to mass customization (MC) adoption in Indian SMEs and look at how they interact with one another to draw critical management conclusions that will help MC adoption in SMEs.	[18]
6	Implementation guidelines for mass customization: current characteristics and suggestions for improvement	To identify possible topics for more investigation, the current work analyses the body of literature on MC implementation guidelines (MC-IGs) and inductively creates a classification scheme for its findings.	[2]

2.4 Literature Review on Methodology:

An organized methodology should be used to tackle the research objectives. The researcher must comprehend not only the how and why of particular research methodologies, but also which of these approaches or methods is appropriate and which is not, as well as what these approaches would imply, support, and mean. Researchers also need to understand the assumptions underlying various methodologies and how to choose the approaches and procedures best suited for a given problem. A literature review to understand the various research methodology undertaken by authors in the

currently available literature to solve similar problems were done. For objective 1, TISM and MICMAC methodology were selected to level partition the enablers and develop a framework along with the driving and dependent power of the enabler. For objective 2, Structural equation modelling (SEM) analysis was selected as an appropriate methodology to evaluate the hypothesized relationships. For objective 3, a Case study analysis was done and for objective 4, FAHP and FTOPSIS were identified to rank the drivers and rank industries for suitability of a product for mass customization. The literature on these mythologies are provided below:

2.4.1 The contribution of TISM and MICMAC analysis for theory building: TISM/ISM in sequence with MICMAC analysis as a dominant medium in determining factors in various research fields [87]. Researchers emphasized that ISM/TISM has been extensively adopted by researchers for theory building, conceptualization, case analysis, and decision-making [88]. TISM is an effective method used to develop a comprehensive systematic model of various criteria and interrelationships[89]. Before introducing practices or implementing them (here mass customization), managers are urged to understand the level of factors/enablers they are researching. This improves the effectiveness of putting numerous factors into practice. The created TISM model and its implementation can also be used to increase the research area's capabilities. This is accomplished by identifying the elements and enablers that improve the research field (in this case, MC) and developing strong relationships with each of them[90]. This is followed by providing interpretation for both substantial and direct transitive relationships in a directed graph(digraph)[87].

The literature survey highlights that TISM/ISM has been practiced in various areas like supply chain, manufacturing, sustainable manufacturing, lean implementation, and six sigma implementations, and some utilization areas are shown in Table 2.6. These eminent research works were studied in detail to understand the applicability of TISM for level partitioning of enablers and build theory. Since the result of TISM solely depends on expert opinion, the type of expert panel considered by the eminent researchers was also studied.

Table 2.6: Select application of TISM and MICMAC analysis

Sno	Area of Application	Expert Panel	References
1	Supply chain knowledge flow enablers	16 Experts from academia and industry	[91]
2	Critical success factors of world-class manufacturing	A team of experts from industry and academia	[16]
3	Enablers of total quality management (TQM)	4 Experts having more than ten years of experience.	[92]
4	Enablers of agile manufacturing Systems (AMS)	Literature and brainstorming with people of industry and academia both.	[93]
5	Enablers of sustainable manufacturing	Literature survey and senior managers from manufacturing organizations	[94]
6	Barriers to green supply chain management	10 Industries, more than five experts from each industry.	[95]
7	Lean barriers for successful lean implementation	5 Lean experts from Indian manufacturing companies, each having more than 5 years of experience	[96]
8	Technological Capabilities and supply chain resilience	3 Supply chain analyst and case evaluation of the proposed model in a firm	[90]
9	Sustainable supply chain management	28 Experts from industries and academia.	[94]
10	FMS performance variables	319 Respondents	[97]
11	Lean six sigma implementations	Committee of 9 experts	[98]

2.4.2 The contribution of SEM for explanatory analysis with statistical efficiency: SEM can assess the related dependency of factors in a single investigation and is valued by researchers. Endogenous and exogenous variables are the two types of variables utilized in SEM[99]. Exogenous variables are the same as the independent variables, while endogenous variables are the same as the dependent variables. The association between improvement initiatives and performance results is examined using SEM. This is a group of statistical methods that enables the analysis of correlations between numerous predictor and response variables. These variables might be either observable (directly measured, also known as manifest variables) or unobservable. SEM is regarded as being more flexible than other statistical techniques since it enables the researcher to concentrate on the structural level. SEM uses two different kinds of models:(1) Measurement model: The measurement model illustrates how the theory is represented by the combination of the measured variables. (2) Structural model: This model represents the theory that explains how different constructs relate to one another[100]. The literature

identified numerous applications of SEM for statistical validation of a research model which is provided in Table 2.7.

Table 2.7: Select application of SEM analysis

Sno	Area of Application	SEM Model	References
1	Measuring the Impact of Lean Implementation on construction safety performance	The research identified 11 components, where 5 components were identified for Lean implementation and 6 components were identified for safety performance.	[101]
2	Lean practices implementation and their relationships with operational responsiveness and company performance in Italy.	5 Latent variables, 23 indicators and 10 Hypothesis were considered in the research work	[102]
3	Analyse barriers to the adoption of green operational practices at Brazilian companies: effects on green and operational performance	5 Latent variables and 49 constructs were considered by researchers. A total o 8 Hypothesis was discussed	[103]
4	Analysis of Sustainable manufacturing factors in Indian automotive component sector	5 enablers (Latent variables) and 18 indicators were considered.9 Hypotheses were discussed.	[104]
5	To investigate the degree to which lean manufacturing (LM) practices are being implemented within Brazilian small and medium enterprises (SMEs),	7 Latent variables and 19 constructs were considered. Two Hypotheses were included in the model.	[105]
6	To analyse sustainable supply chain (SSC) management practices for the Indian automobile industry and to identify the critical factors for its successful implementation	2 Models, the first model has 4 Latent variables, and the Second Model 3 Latent variables. Four hypotheses were developed concerning the first model and 2 research hypotheses for the second model.	[106]
7	Examined the stages involved in the process of utilization of performance measures, i.e. adoption and implementation, and investigated the political, cultural, and rational factors that affect this process.	The model is a first-order factor model consisting of nine latent variables with measured indicators. First, to test H1–H6, was estimated by a model in which the independent variables have a direct effect on implementation.	[107]
8	Analyse the process of implementing JIT methodology in Mexican assembly plants	The research deals with 14 key success factors (KSF) and 22 benefits identified in the literature review.	[108]
9	Analyse lean manufacturing practices in different industries and identify the critical factors for their successful implementation	5 no's Latent Variables and 20 constructs used 10 Hypothesis (discussed)	[109]
10	Studied the relationships among Supply Chain Management practices, Total Quality Management practices	3 enablers (Latent variables) and 12 indicators. 3 Hypothesis (Hypothesis discussed in detail)	[110]

2.4.3 The contribution of Case Studies for testing the framework: The case study approach is a useful tool for promoting process transformation. It helps practitioners with the transitional phase that

allows for the fusion of ideas at various levels of hierarchy. Thus, it not only makes the process of implementation and creating a strategic action plan easier, but also faster [111]**.** The case study was selected as a research method[112] since it focuses on understanding the dynamics that exist within a particular setting since it enables businesses to explore a phenomenon in real situations. It thus not only facilitates but also speeds, up the implementation process and the development of a strategic action Because it allows companies to investigate a phenomenon in actual environments, the case study was chosen as a research technique and focuses on understanding the dynamics that exist within a specific environment. Case study research is a qualitative technique that is regarded to be useful for exploring events in their actual situation and gaining insight via examination of actual practice[113]. New ideas can be generated by researchers that work closely with multiple case studies by conducting field research and being exposed to real-world difficulties, innovative thinking from people at all levels of enterprises, and a diversity of case scenarios [59]. The literature identified numerous applications of Case Studies. Researchers include a multiple case study analysis to illuminate a managerial viewpoint for the implementation of an Industry 4.0 (I4.0) transformation path in the manufacturing value chain. This study seeks to add to this body of knowledge by providing a preliminary but in-depth look into the managerial concerns faced by manufacturing firms as they move towards digitalization, with a particular emphasis on the difficulties they faced and the strategies they used to overcome those difficulties[79]. To demonstrate the application and the advantages of using supply chain scheduling to resolve the main conflict in MC, researchers created a computational industrial case study[44]. A case study of a yacht mass customizer was conducted to show how MC changes how these businesses operate[75]. Researchers identified how significant companies that have embraced mass customization in their six plants—three in the automotive industry and three in the computer sector—formulate their strategies with the help of case studies[69]. Some prominent research work that identified case studies as a research methodology are discussed in Table 2.8.

Table 2.8: Select application of Case Studies.

Sno	Area of Application	Findings	References
1	Moving towards digitalization: a multiple case study in Manufacturing Area	This paper includes a multiple case study analysis to illuminate a managerial viewpoint for the implementation of an Industry 4.0 (I4.0) transformation path in the manufacturing value chain. The research examines three crucial factors to consider when defining the digital transformation path from a managerial perspective	[79]
2	Supply chain scheduling optimization in mass customization based on dynamic profit preference and application case study	The researcher discusses supply chain scheduling optimization in MC based on dynamic profit preference. They also create a unique optimization model to carry out the scheduling. To demonstrate the method's application and the advantages of using supply chain scheduling to resolve the main conflict in MC, they create a computational industrial case study.	[44]
3	Integrating lean and other strategies for mass customization manufacturing: a case study.	The article provides a framework for demonstrating how lean may be combined with other approaches. Then, it uses a case study of a yacht mass customizer to show how MC changes how these businesses operate. To compare pre- and post-improvement performance, simulation modelling is employed.	[75]
4	The manufacturing strategy-capabilities links in mass customization and agile manufacturing – an exploratory study	This research, which is based on longitudinal case studies, examines how significant companies that have embraced mass customization in their six plants—three in the automotive industry and three in the computer sector—formulate their strategies.	[69]
5	Digital readiness assessment of Italian SMEs: case-study research	The goal of this paper is to propose a thorough assessment model suitable for determining the digital readiness levels of small and medium-sized enterprises (SMEs), discuss the findings of an assessment of 20 manufacturing SMEs using the proposed model, and highlight the priorities required to embark on a successful journey towards Industry 4.0.	[26]
6	Business intelligence and analytics value creation in Industry 4.0: a multiple case study in manufacturing.	This study examines elements related to business intelligence and analytics (BI&A) business value development in manufacturing using numerous case study designs. medium-sized businesses going through an I4.0 transformation.	[114]
7	Analyzing Alternatives for green logistics in an Indian automotive organization: A case study	The paper examines organizational goals and green practices choices to give a case study of an Indian automaker. Given that the number of vehicles sold in India over the past few decades has significantly expanded, it is crucial to concentrate on green practices in the context of the country's automotive industry	[115]
8	Agile manufacturing practices: the role of big data and business analytics with multiple case studies	This study set out to investigate the function of big data and business analytics (BDBA) in agile manufacturing techniques. To develop and validate a framework for the role of BDBA within agile manufacturing, researchers focused on qualitative case studies conducted across four UK firms.	[112]
9	Walking the talk? A multiple-case study of quality management implementation in China	The study investigates factors that lead to potential implementation gaps between businesses' current practices and the widely accepted core quality management (QM) practices, with a focus on the manufacturing sector in China. A total of 11 Chinese manufacturing enterprises' production managers, quality managers, and executives participated in in-depth interviews.	[116]

2.4.4 The contribution of FAHP and FTOPSIS for ranking of Drivers and Industries:

The Analytic Hierarchy Process (AHP) is built on a set of axioms that precisely define the parameters of the problem environment [117]. Its foundation is a consistent matrix with a well-defined

mathematical structure and an eigenvector that can produce weights that are either exact or close to the real value [118]. In a natural, pair-wise mode, the analytical hierarchy process compares criteria or alternatives to a criterion[113]. Due to the recent identification of studies employing multi-criteria decision-making (MCDM) methodologies by notable researchers, the Fuzzy AHP-TOPSIS method was taken into consideration for this research job. Certain prominent works of various researchers were studied in detail to get in-depth knowledge about the methodology and application requirements [119].Small and medium-sized businesses (SMEs) are under pressure to adopt sustainable practises in their operations as a result of the escalating environmental problems. Researchers set out to determine and rank the top strategies for overcoming the challenges that SMEs have while implementing eco-design principles. In this research, a framework was proposed to rank the approaches to overcome the obstacles in the implementation of eco-design in SMEs with the help of FAHP/FTOPSIS [120]. Researchers were able to successfully combine AHP and TOPSIS to rank the necessary characteristics for the implementation of agile manufacturing [122]. Based on an fuzzy AHP-TOPSIS methodology, a supplier evaluation and selection model was formed [119], where researchers presented a decision-making model after giving an outline of the supplier evaluation and selection issue. In order to evaluate facility layout design, researchers used an extended fuzzy TOPSIS and fuzzy MCDM technique in Chinese environmental aesthetics to do a preference ranking of the office layout design choices [121]. An integrated Fuzzy AHP-TOPSIS framework was used to standardise the fresh product selection and grading process for increasing quality assurance in perishable food supply chains. This research presents a hybrid strategy for the initial sorting and grading process for procurement, employing TOPSIS to rank various product batches and a fuzzy AHP to determine the weights of evaluation criteria[113]. Researchers intended to define Corporate Social Responsibility (CSR) criteria, recommend, and prioritise various solutions in order to improve an organization's supply chain performance system with FAHP/FTOPSIS techniques. Some research works are provided in Table 2.9.

Table 2.9: Select application of FAHP/FTOPSIS and AHP/TOPSIS

Sno	Area of Application	Findings	References
1	A model for supplier evaluation and selection based on an integrated interval-valued intuitionistic fuzzy AHP-TOPSIS approach	This paper first provides an overview of the supplier evaluation and selection problem, and then presents a decision-making model that integrates interval-valued intuitionistic fuzzy AHP (IVIF-AHP) and interval-valued intuitionistic fuzzy TOPSIS (IVIF-TOPSIS) to solve such problems, and in the end, provides a numerical example to demonstrate the use of the proposed approach	[119]
2	Fuzzy AHP and fuzzy TOPSIS integrated multicriteria decision-making scheme employing Chinese environmental aesthetics for facility layout design evaluation	Researchers performed a preference ranking of the office layout design alternatives using an extended fuzzy TOPSIS and fuzzy MCDM technique.	[121]
3	Standardizing fresh produce selection and grading process for improving quality assurance in perishable food supply chains: an integrated Fuzzy AHP-TOPSIS framework	For the initial sorting and grading process for procurement, this paper suggests a hybrid approach using TOPSIS to rank different batches of products and a fuzzy AHP for determining the weights of evaluation criteria.	[113]
4	A framework based on fuzzy AHP-TOPSIS for prioritizing solutions to overcome the barriers in the implementation of eco-design practices in SMEs	Due to growing environmental challenges, small and medium-sized businesses (SMEs) are under pressure to implement sustainable practices in their operations. The goal of this research was to identify and rank the best ways to get through the obstacles that SMEs face while implementing eco-design practices.	[120]
5	A combined AHP and TOPSIS approach for prioritizing the attributes for successful implementation of agile manufacturing	To successfully deploy agile manufacturing in the Indian manufacturing sector, this research prioritized the necessary characteristics using a combined analytical hierarchy process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach.	[122]
6	Assessment of CSR-based supply chain performance system using an integrated fuzzy AHP-TOPSIS approach	To improve an organization's supply chain performance system, this research sought to identify Corporate Social Responsibility (CSR) criteria and suggest and prioritize alternative solutions. To achieve the goal, first, CSR-based criteria, sub-criteria, and alternatives were determined with FAHP and FTOPSIS approaches.	[123]
7	TOPSIS-AHP Based Approach for Selection of Reverse Logistics Service Provider: A Case Study of Mobile Phone Industry	Businesses, especially those in the white goods and electronics manufacturing sectors, would prefer to concentrate on their core competencies, therefore decisions about outsourcing their reverse logistics operations to third-party reverse logistics providers (3PRLPs) are necessary. The goal of this study is to create a decision support system to help the company's senior management choose and assess various 3PRL service providers.	[124]
8	A hierarchical fuzzy TOPSIS approach to assess improvement areas when implementing green supply chain initiatives	Businesses may have greater potential for growth by putting green supply chain management (GSCM) strategies into practice. To enable such an assessment, this work proposes a fuzzy hierarchical TOPSIS technique. It helps decision-makers comprehend the entire evaluation process and offers a more precise, efficient, and organized decision-support tool.	[125]
9	Analysing the drivers of green manufacturing with a fuzzy approach	To reduce the ambiguity of the results, this research intends to compile these common drivers of green manufacturing from multiple sources and analyse them using the AHP in fuzzy contexts.	[126]

2.5 The transformation from Mass Manufacturing to Mass Customization Model.

The transition of MC from mass production necessitates the use of appropriate organizational models and strategies, which may necessitate substantial changes to the organization's physical infrastructure, industrial processes, human resources, and process management. It also suggests the use of adaptable production technology, responsive human capital, and the creation of novel solutions for both products and processes [18] . By aligning technical needs with the appropriate innovation resources to create flexible customization through modular product development, manufacturing should encourage the emergence of creative ideas and improve innovation efficiency. The various transformation model needs to be understood by practitioners before venturing into the mass customization process.[127].The research works based on the transformation process are discussed below:

2.5.1 Transformation of Customer Model: Adopting the mass customization paradigm, the process of product design is significantly influenced by customer preferences. Working with users and consumers has grown in importance in business marketplaces as a way to learn about client wants and to create innovative products[127]. The effective integration of unique client needs into product and service designs by including clients in the design process forms the basis of MC[8]. Customers' needs are systematically elicited via the customer co-design process by MC providers, who then use this information to create workable product designs[73]. Reduced unit costs of specific products or services due to greater output and faster production process throughput are typically achieved in mass production at the expense of higher overhead expenses through economies of scale. Conversely, low costs in mass customization are typically achieved through economies of scope, or the use of a single process to produce a larger range of goods or services more quickly and affordably [69][24]. Routines, procedures, and tools for sharing information improve the effectiveness and efficiency of customer communications and knowledge gathering in a system with significant customization, enabling firms to fully comprehend market trends and consumer expectations [47][128]. Manufacturers can determine what these clients desire due to close customer relationships[129].

2.5.2 Transformation of Human Resource Model: Every corporate organization is made up of individuals with a variety of abilities, knowledge, and behaviours, so the essential adjustments for flexibility must be made beginning with just these individuals[54]. Organizations need teams of cross-functionally trained and adaptable workers who are committed to accomplishing the organizational goals just as much as they need the right organizational structure and the use of cutting-edge technologies[60]. Businesses with highly trained staff who are allowed to apply their expertise to tasks allocated to them will excel[38]. Due to limited forecasting options, MC concepts demand a very flexible supply chain, with a focus on supplier adaptability[130]. It became clear that coordinating closely with local partners who could move fast owing to shorter supply pathways was the only way to lower the costs associated with, for example, the uneven use of parts on the final assembly line. As a result, respectful cooperation in a manager/supplier relationship is a crucial component of the equation[131].

2.5.3 Transformation of manufacturing Model: The continual, unstoppable phenomena of the fragmentation of the mass market bring down with it the formerly efficient, stable, and controlled industrial system. Along with being tougher to generalize as homogenous marketplaces become less common, individual consumer desires and needs are becoming more and more subject to fluctuations and adjustments. Technology has exacerbated the decline of the mass market. It is becoming more difficult for both producers and customers to keep up with technological improvements as product life cycles are getting shorter and shorter, and market-upsetting trends are accelerating quickly[60]. The methods used yesterday to produce and distribute products and services seem rigid and reactive at best if not entirely doomed to failure when faced with these new market realities. Because MC is based on the pull principle, there are fewer errors in sales forecasting, which results in much smaller markdowns and finished product inventories[131]. The MC company model must therefore undergo considerable modifications in terms of technological, structural, and cultural changes[3]. According to researchers, the paradigms of mass customization and agile manufacturing are not mutually exclusive. Instead, they

contend that mass customization is best understood as a potent illustration of a company's capacity for agility[69]. By reconfiguring common modules, manufacturers may meet specialized requests with the same components, which lowers customization and inventory costs, speed up production, and increases flexibility and responsiveness[5]. Mass customization has made use of cutting-edge computation design methodologies, such as generative design, to fully utilize the design potential offered by new production technologies and increase customer satisfaction[74]. All of this might benefit manufacturers who are willing to use the MC production approach to increase market shares[6].

2.5.4 Transformation of Business Strategies Model: In contrast to the traditional business model, mass customization involves manufacturers contacting customers before they purchase a product so that changes can be made to the product to suit individual preferences [72]. The pressures of a wide range of goods and services combined with the complexity of the marketing environment can be managed by mass customization. Businesses must figure out how to keep their competitive advantages while highlighting their high level of customization and reduced prices in the face of increased competition. As a national industrial IoT platform, COSMO Plat was chosen, for instance, to spearhead the development of international standards for mass customization models in China. This paradigm encourages the modernization and restructuring of the global and Chinese manufacturing sectors[1]**.** Only with the combination of abilities, technologies, know-how, processes, and partnerships with other actors, made possible by strategies in place, can one become flexible and manufacture mass-customized products[132]. Businesses need to consistently increase their ability to respond to changing customer wants to be brought on by heterogeneous market demands, as well as their cost effectiveness along the value chain[4]. The manufacturer's ability to apply the strategy and the strategy's adaptability in various market circumstances are both factors that affect mass customization's limited stage of realization.

The Transformation model is prepared with the research ideas by various eminent researchers{[60][133][69][24][131][5]} and is shown in Figure 2.3.

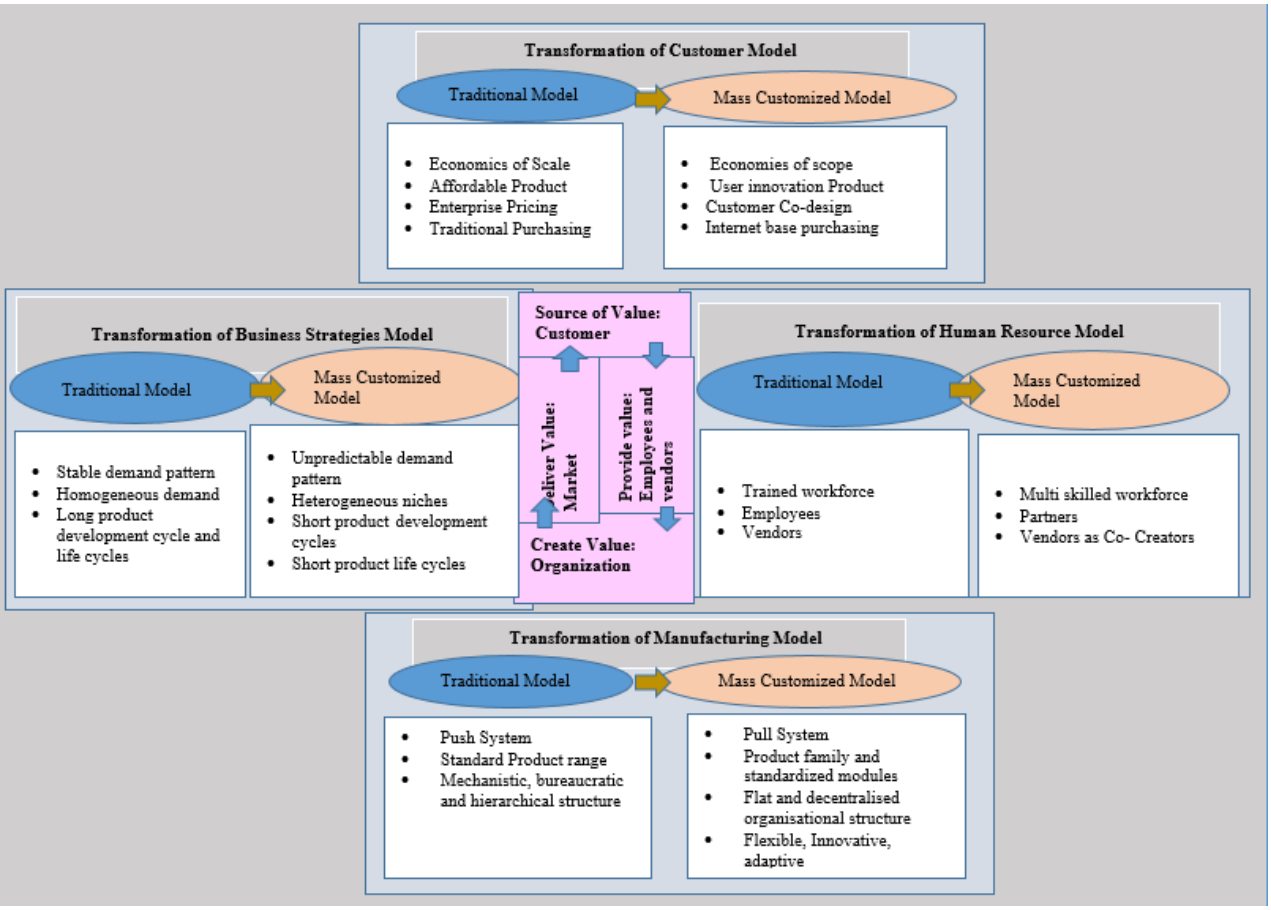

Figure 2.3: Transformation Model of mass production to mass customization, based on {[60][133][69][24][131][5]**}**

2.6 Issues and Challenges of mass customization:

While the concept of mass customization appeals to entrepreneurs in all forms, it has yet to become a global norm. The challenge of incorporating widespread personalization into existing mass production is one reason for this. There is no conventional solution for integrating mass customization into an existing manufacturing line due to the reason that there are still questions about which product, which function, and how many features should or could be personalized [8].

Management Challenges: A mass customization-friendly organization is proactive in recognizing future market opportunities, has proactive managers, and a favourable workplace culture that promotes mass customization, and connects mass customization to core business processes. The major factors of mass customization achievement involve management support for exploring future market

opportunities, engagement to ensure technical, economic, and human support, assistance during obstacles, strategic evaluation of MC initiatives, and appraisal of their development[130]. Managers must tailor the [MC] strategy to the demands of their organizations [51]. This process of tailoring is not simple; convoluted, unequal, blocked, or interrupted paths to MC are not uncommon[54].

Major problems include a lack of commitment from senior management (M1), an inadequate understanding of MC (M2), inadequate strategic planning (M3), and resistance to transformation (M4).

***Organizational challenges*:** The cost of investment is one of the primary barriers to MC as MC demands changes in production systems and work structures, which can be expensive, time-consuming, and labour-intensive [134]. Because MC involves 'small batch' production, production flexibility is essential[135]. MC adopters' manufacturing processes should be adaptable enough to respond to changing market demands. Strategic supplier collaboration is a crucial success driver in MC. Building an alliance, on the other hand, is a challenging undertaking, and if the alliance is inhibited, enterprises will not gain the full benefits of MC. Low cost, vast diversity, and short lead time become increasingly challenging to attain in MC operations, and effective incoming and outbound logistical coordination is necessary [50]. Mass customization is represented throughout a corporation and, as a result, throughout the supply chain. As a result, the manufacturing site must be rebuilt to meet the new challenges. Within and between production lines, transport times must be decreased, which necessitates a high level of machine flexibility, resulting in a higher expenditure that must be carefully planned. Workers must also be able to adapt quickly to specialized demands, necessitating a greater demand for special education programs and equipment[8].

High investment costs, Lack of Flexibility in manufacturing, Lack of know-how and education about MC, Lack of trained workforce, and lack of logistical coordination are the major challenges of mass customization implementation.

***Market Challenges*:** Firms that ignore the present business environment will struggle to survive shortly [71].The greater the market turbulence, the greater the opportunity for variation and customization[60],

which has the potential to motivate enterprises to mass customize their products in response to market demands to survive economic insecurity, where they would otherwise be content to create mass production items under normal circumstances [21]. An efficient system that ties consumer voice to product design, customer relationship management, frequent market surveys, and interpreting customer grievances for product improvement is the cornerstone of quick customer reaction for mass customization deployment[55]. Deploying MC necessitates a significant investment in salesperson training to recognize customer demands and assist the customization process[50]. A sensitive marketing team with a comprehensive business plan is needed to recognize client wants and address emerging market demands[130]. Client requirements must be captured and prioritized in marketing plans, and then translated into configurable attributes[66].

Inefficient customer relationship management, irregular market surveys, the inefficiency of sales personnel, and inefficient marketing strategies possess challenges for efficient mass customization implementation.

Technology Challenges: More mass customization, taking full advantage of the digital world, smart technologies, and AI systems, will be required in the future, as will the formation of a new set of difficulties that will necessitate rapid response and the establishment of an innovation system to enable optimization of all production performance[56]. When confronted with these new market conditions, prior ways of manufacturing and distributing goods and services appear rigid and inadequate, if not doomed to failure. Organizations that adapt, grow, learn to handle and preserve flexibility and improvise in the face of challenges[136]. The adoption of digital technology has a significant impact on business models, resulting in various advantages in terms of mass customization, cost, time-to-market, and new capabilities for reaching out to new clients or developing new products/services[79]. Companies must evaluate how they will identify expenses for specialized technology solutions and digitalization initiatives, how they will cope with changes and obstacles, and how they will coordinate tasks in terms of knowledge exchange within and outside the company's boundaries as they embark on

their digitalization journey[79]**.** Organizations that implement MC are expected to share crucial data in real time, work more efficiently, and exchange information seamlessly. Data collection, processing, and interpretation are challenging problems[37]**.**

The main obstacles to mass customization are a lack of technology and information systems, a lack of data and information availability inside the SC (supply chain), and a lack of technical support.

Customer Challenges: Although mass customization allows customers to personalize items to their demands, increasing customer value, mass customization also comes with additional costs. Researchers argued that if an MC program is organized incorrectly, expanding MC product variation may confuse customers [137]. The product selection process can quickly overwhelm consumers, leaving them unable to decide what they want[138]. Human beings' limited information processing capacity, a lack of product expertise among customers, and potential consumer misunderstanding of their genuine specific demands are all aspects that affect the performance of MC programs [50]. Identifying client desires is challenging since some customers are unsure of what they truly desire; they will become intimidated if presented with a vast number of options, as many MC programs do. As a result, making it simple for clients to select alternatives and providing them with important information during the MC process is critical. [50][138].

Customer ignorance, inefficiency to identify customer needs, and high-priced customized products are the challenges identified for MC from a customer perspective.

2.7 Conclusion

The research objective is justified by the literature review of the need for mass customization for competitive advantage. The broad areas of previous research in the field of design, manufacturing, customer, enabler, driver, barrier, and implementation guidelines are discussed, which are crucial areas for the fulfilment of the research objectives. The methodology for the analysis of the research objectives is discussed to understand their application in recent literature. This chapter forms an

understanding of the transformation process from mass manufacturing to mass customization and gave a critical overview of the transformation process that includes the manufacturing aspects, customer aspects, human resource aspects, and business strategy aspects of manufacturing. The issues and challenges involved in this journey concerning management, organization, customer, technology, and market are discussed. The study of previous research to understand the design and manufacturing issues in mass customization forms the basis of further research. The following chapter discusses the research methodology for the research.

CHAPTER 3:
RESEARCH METHODOLOGY

3.1 Introduction

Research methodology is the study of scientific strategy for logically putting several procedures into action to address the research problem. The method aids in a better comprehension of both the process and the outcomes of scientific investigation. The research methodology's objectives include defining and evaluating methods, clearly stating assumptions and conclusions, and connecting their potential to uncharted terrain at the "frontiers of knowledge." A methodology is a general study plan that specifies the steps to be followed when conducting research. It includes several convictions and philosophical principles that support the approach choice and aid in framing the research questions. A dissertation or thesis needs to have a research approach that helps to keep the methods, tools, and underlying philosophical assumptions consistent.

The focus of this chapter is on the methodology used in this thesis' investigation of mass customization and its application in Indian manufacturing firms. After defining the research objectives in Chapter 1, it was required to develop a research process design, in which it was needed to specify the research design and the framework within which the research will be conducted. This is accomplished in the section on the research process, where the various types of research design a researcher can undertake for completion of the research work and the framework for the research design for the present research are discussed. This chapter's subsequent sections will cover common research technique subjects such as the research instrument, survey design, structure, and data collection, in which various mathematical and statistical tools used in the research are discussed. Also, data interpretation and analysis steps will be discussed. Following this, research steps used in the research will be summarised. Figure 3.1 provides information about the chapter's flow.

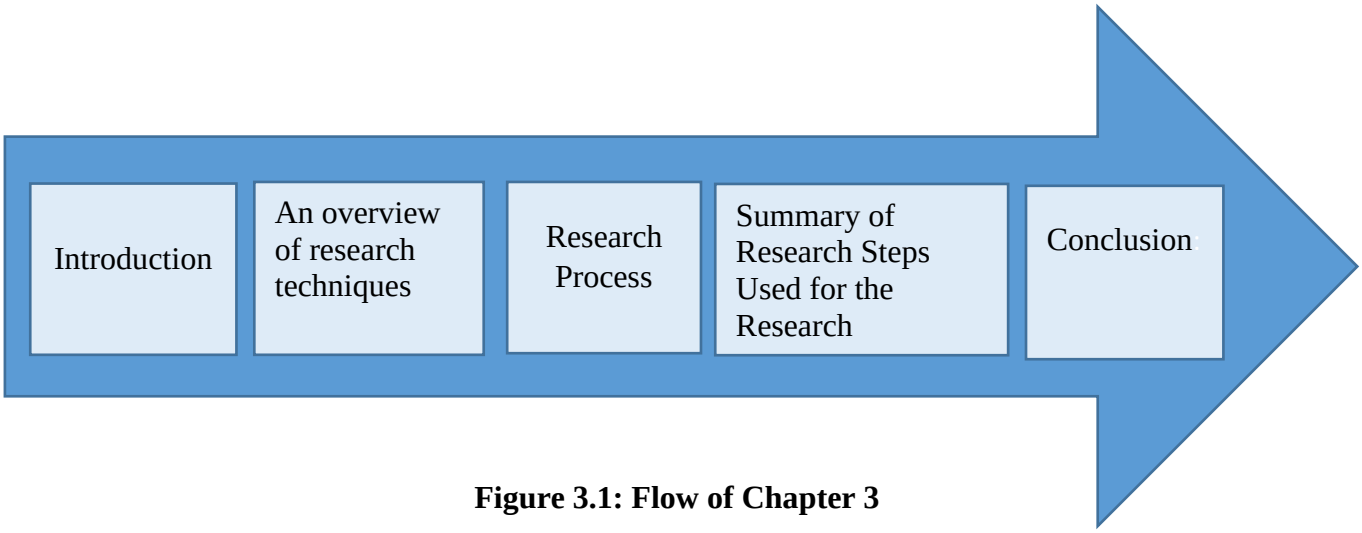

Figure 3.1: Flow of Chapter 3

3.2 An Overview of Research Techniques

Research is the methodical approach that entails generalization and the development of the theory. Therefore, research refers to a systematic process that includes problem definition, hypothesis formation, data collecting, and analysis. A conclusion is reached after presenting the facts, either by providing answers to the specific problem at hand or by making some generalizations based on a particular theoretical formulation It is possible to purposefully approach the research challenge utilizing research techniques. Examining the procedures utilized in scientific research could be seen as a branch of science. Evaluate the various techniques that researchers frequently employ to evaluate the research problem, as well as the arguments that support each technique. Both the plan and the study procedures/methods must be familiar to the researcher. In addition to understanding how to apply particular research methodologies, create particular indices or tests, and distinguish between which of these procedures or approaches are important and which are not, researchers also need to know what they would entail. Research can be categorized according to its duration, aim, settings, setting, location, and methodology. While some studies overlap, others exhibit minor differences. However, each kind of research has a certain relevance. The research objective derived from the research gap is discussed in Chapter 1. The various types of research are discussed below:

Pure Research: Pure research is any study done to expand human knowledge. It is completed to overwhelm the unknowable realities. There is a discussion of generalizations as well as the formation of new theories. Although fundamental research may not offer answers or remedies to the current issue, it does increase our understanding of science.

Basic Research: It is alternatively referred to as "need-based" research or user research. The main objective is to seek solutions to the issues that a group, a neighbourhood, a company, or a government body is now facing. Basic research looks at how processes or concepts work. Information obtained from basic research often creates a foundation for applied studies.

Applied Research: This focuses on research on the qualitative method. It is advantageous for analysing human behaviour. Through observation, it is possible to know about the other someone else's body language, sentiments, opinions, attitude, etc. Both interviewers and psychiatrists will benefit much from it. Among the methods utilized are word association tests, phrase completion tests, picture-sketching tests, and thematic apperception tests. It is frequently referred to as "Motivation Research". Studying social, political, and economic events that have detrimental effects on different industries is one sort of applied research. Usually, secondary data are utilized in this type of research.

Empirical Research: Empirical study is also known as experimental research. Before starting this study, the researcher should offer a working hypothesis and map out the experimental strategies. A researcher should lay out his experimental plans and present a working hypothesis before beginning the investigation. This type of research consists of using primary data for analysing, interpreting, and testing the hypothesis.

Descriptive Research: This study specifically addresses description. It contains a large variety of information, that includes techniques for gathering information and designing surveys. The researcher does not influence the study's variables.

3.3 Research Process: The research process as discussed by researchers [139] consists of the following steps:

3.3.1 Formulating the Research Objective:

A specific difficulty or gap in knowledge that researchers are attempting to fill through their research is referred to as a research problem. Researchers may decide to explore for theoretical challenges aimed at advancing knowledge or practical problems intended at bringing about change. Natural phenomena and relationships between variables are studied in research. The researcher must choose the overall subject of interest, a feature of a subject matter, or the problem that researcher wants to analyse as soon as feasible. Any ambiguities can be clarified after the topic has been introduced broadly first. Before creating a workable formulation of the problem, the viability of a solution must be considered. As a result, the beginning of scientific inquiry is the articulation of a large topic into a specific study problem. The major benefits research can administer are:

- Numerous government policies are formulated with the help of research. Researchers help to formulate and implement nearly all government budgets and programmes. The government develops the monthly and annual budgets, as well as the monetary and economic policies. In order to help the government develop policies, many organisations conduct research.
- It generates a lot of concepts and modifies established truths.
- It is employed in business organizations: Numerous business firms employ researchers to work on a variety of projects. It is utilized to research the market alterations that are occurring. It aids in tax management, cost-cutting measures, and capital budgeting. It fosters creativity and leads to the discovery of novel facts and theories. It supports the growth of the society and its citizens. It gives the researcher the chance to investigate the problem in depth and come up with new solutions.

The research gap that leads to research questions and formulation of research objectives have already been discussed in Chapter 1.

3.3.2 Extensive Literature Survey:

To determine the precise research topics, a summary of the pertinent literature is required. A literature review needs to review and analyse a wide range of materials, including books, articles from scholarly and professional publications, and online resources. The use of the literature search facilitates the recognition and accessibility of relevant documents and other sources. Search engines can be used to look through bibliographic databases and online resources. For learning about a particular subject, conceptual frameworks might be useful. The steps involved in preparing a literature review are: scanning, making notes, structuring the review, writing the review, and creating a bibliography[140]. The research question and design may be informed by a variety of information sources. A very significant issue is the evaluation of these sources. The main source of information for the literature review should be articles from scientific and research journals[140].

To gather and organize current knowledge to fully understand the implementation process, enablers, and drivers of mass customization, a systematic literature review (SLR) technique is used[140]. This protocol included specific goals for the literature review, screening phase, and assessment based on exclusion and inclusion criteria Research papers were looked up using keywords in the databases Science Direct, Emerald, Springer, SCOPUS, and Web of Science. Among the keywords used were "mass customization," "drivers," "factors," Indian industries," and "manufacturing." The goals were to ascertain the extent to which mass customization in manufacturing has been approached holistically and the factors that have influenced its adoption. Articles that fit into a few specific subject categories and were peer-reviewed were the only ones accepted. These study articles were further scanned and examined to find themes and characteristics[141]. 175 papers were

produced by this method, however only 87 of them met the criteria for inclusion in this study. The article searches and selection step is shown in Figure 3.2. Chapter 2 presents an extensive literature review.

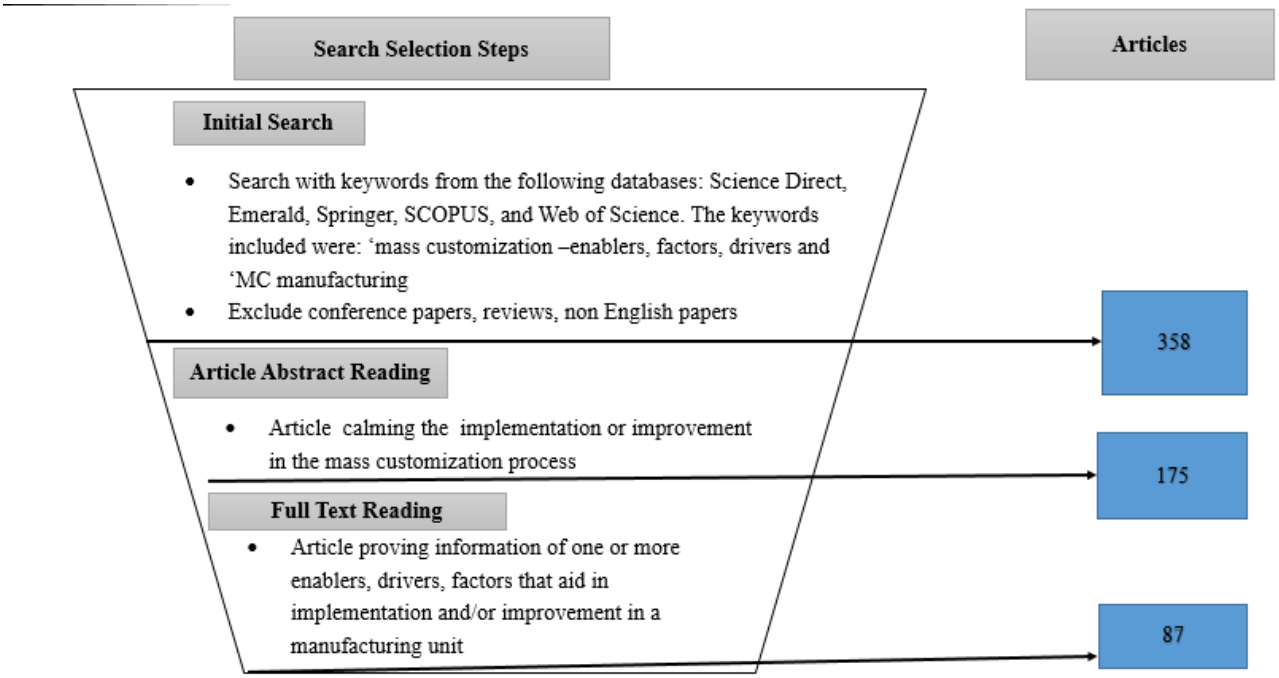

Figure 3.2: Article search and selection step of Literature Review

3.3.3 Preparing the Research Design:

The goal of research design is to define the conceptual framework for the research as well as to make it possible to gather relevant data with the least amount of effort, money, and time. The structure and plan of an investigation taken into account to produce findings in response to research questions is known as the research design, which is the entire plan of the study[139]. The study design is comprised of a summary that covers the results obtained from formulating hypotheses and drawing conclusions from them through doing the final data analysis. The goal of a research design is to ensure that the data collected enables academics to address the research challenge[59]. The conclusions may be weak and unpersuasive if these design issues weren't earlier addressed. Based on their qualities,

research designs can be divided into three categories: explanatory research designs, exploratory research designs, and descriptive types of research designs. The processes and systems to be investigated, the research methodologies to be used, and the research questions should all be considered while designing operations management research. Table 3.1 provides a brief discussion of several research design types[142].

Table 3.1: Comparing Research Design Types

Descriptive Research Design	**Exploratory Research Design**	**Explanatory Research Design**
Descriptive research is described as research that defines features of items, people, clusters, organizations, or surroundings; It tries to show the idea of a given situation	Exploratory research is a methodology approach that explores research questions that have not previously been studied. It is often used when the issue under study is new, or the data	Explanatory research validates causal relationships among variables. The main advantage of this research is to investigate a specific problem to show the relationships among the variables under study

The research methodology utilised in this study, that combines all three categories, is known as a combination study design. The study's initial phase involved exploring the idea of "mass customization" through an exploratory research design. In the instance of a particular segment of the Indian manufacturing industry, this assisted to acquire knowledge of mass customization and different aspects and elements related to it. Exploratory research has been done to develop the study's hypotheses and review the literature. Consequently, this assisted in gathering the necessary information to complete our research activities. In the last stage, explanatory research is carried out to ascertain the relationships between the dependent and independent variables developed in the previous stage. Structured equation modelling has been carried out at this level to describe the relationship between

the components of mass customization practices and competitive advantage. The research gap identified, and the research objectives discussed in Chapter 1 were mapped with research methodology to identify the research design that needs to be adopted for the research.

3.3.4 **Research Instrument, Survey Design, Structure, and Data Collection:**

Exploratory research has been conducted to develop the study's hypotheses and review the literature. A sample design is a present plan chosen before any data are acquired to choose a sample from a certain population. In the data collection design, the technique of data gathering or collecting is planned. Numerous techniques can be used to collect data using primary and secondary data collection techniques. Following the collection of the data was the process of data analysis. The numerical and graphical methods used to organize, present, and interpret the data from responses in the questionnaires are known as descriptive statistics. The amount of measurement that has been employed determines the type of descriptive statistics that are used to describe a variable in a sample. After the data have been analysed as previously described, the evaluation of hypotheses is done. This is to check if any facts contradict the theory or support it. This is often the first query to be answered when testing a hypothesis. For this aim, statisticians have developed several tests, such as the Chi-square test, t-test, and F-test. The hypotheses may be examined via one or more of these techniques, depending on the nature and objective of the research inquiry. The hypothesis will either be accepted or rejected after being tested. If a hypothesis is tested and found to be true several times, the researcher may be able to generalize or build a theory. The ability of research to draw certain generalizations is where its greatest value lie. Exploratory factor analysis (EFA), a statistical technique, is used to reduce many observed variables to a small number of "factors/components," while confirmatory factor analysis (CFA) was utilized to determine a connection between the variables that are seen and the latent construct(s) that underlie them. To test the hypothesis and validate the manufacturing model responses were analysed using structural equation modelling (SEM). Figure 3.3 maps the research

gaps and research objectives with the methodology adopted for the research. There is a thorough description of the research tools employed.

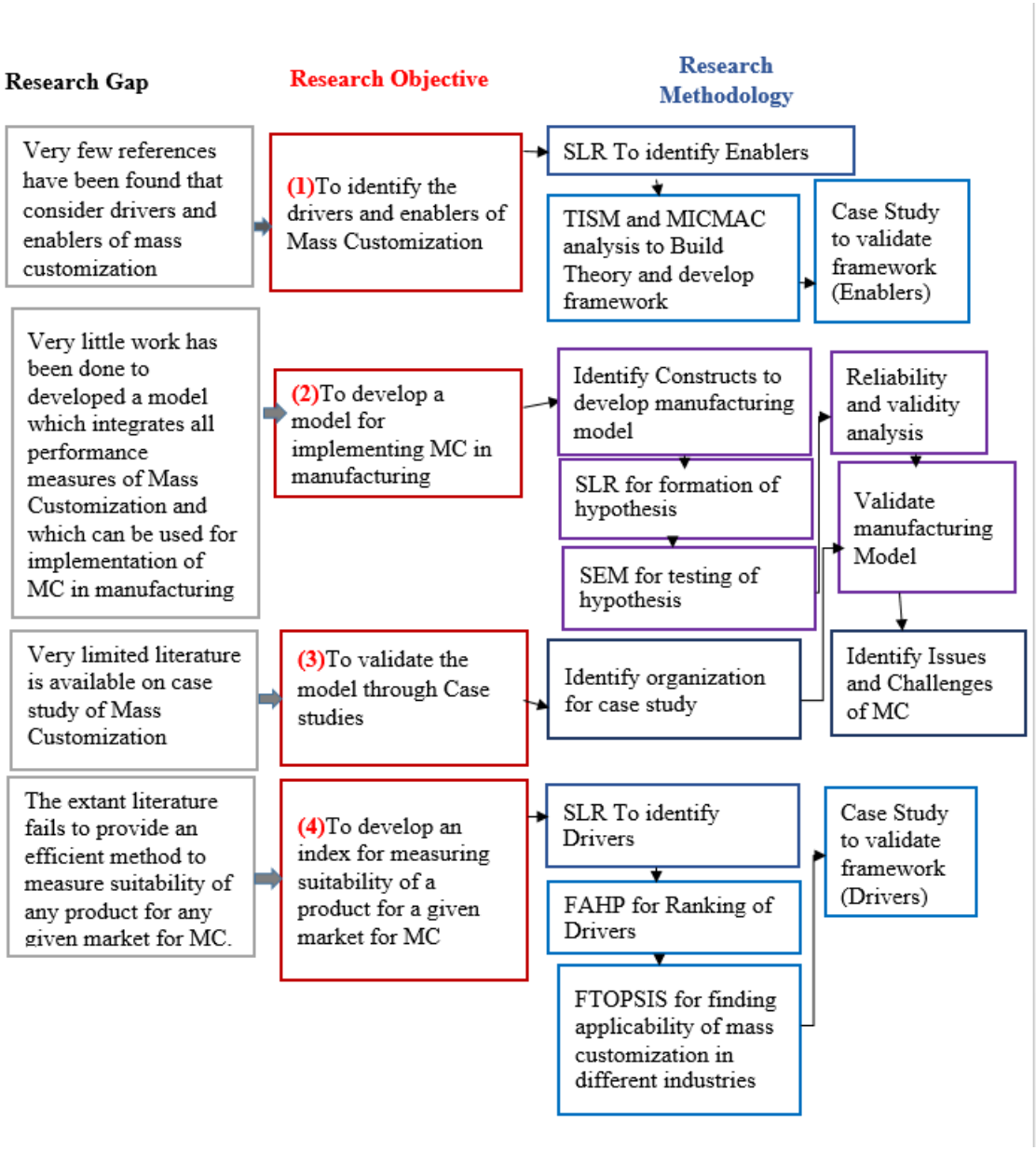

Figure 3.3: Mapping research gap and objective with Methodology

TISM and MICMAC analysis: ISM is in sequence with MICMAC analysis as a dominant medium in determining critical success factors, key variables, enablers, inhibitors, or barriers in various research fields [87]. Researchers emphasized that ISM/TISM has been extensively adopted by researchers for theory building, conceptualization, case analysis, and decision-making[88]. Some researchers felt that TISM is an effective method used to develop a comprehensive systematic model of various criteria

and interrelationships [89]. The literature survey highlights that TISM/ISM has been practiced in various areas [93][143][87][144]. A detailed discussion is provided in Chapter 4.

*SEM as a Statistical technique for analysis***:** SEM is regarded as being more flexible than other statistical techniques since it enables the researcher to concentrate on the structural level. It is also possible to examine the indirect effects of variables by including them in an SEM model. These factors are referred to as mediating or moderating the links between the model's primary variables. SEM theory can be viewed as a collection of connections offering thorough and consistent explanations of the observed events. SEM uses two different kinds of models:

- Measurement model: The measurement model illustrates how the theory is represented by the combination of the measured variables.
- Structural model: The structural model is a representation of the theory outlining the connections between different constructs.

SEM is also known as causal modelling since it examines potential causal linkages. Covariance-based (CB) SEM, PLS-based SEM, and generalized structural component analysis-based SEM are some of the different approaches to SEM. In SEM, observable or non-observable classification is used along with two types of variables, endogenous or dependent variables, and exogenous or independent variables. SEM enables statistical testing of directly unobservable variable hypotheses at the cost of challenging interpretation. It is more adaptable than other statistical techniques since it facilitates structural-level assessment. Each variable under research has its components identified, and a questionnaire is created. For each variable, a minimum of three constructions are identified. A detailed analysis is provided in Chapter 5.

Case Study as a research methodology: A case study method is an effective tool for encouraging process change. It assists practitioners in the transition process which enables the integration of concepts at multiple levels of hierarchy. It thus not only facilitates but also speeds, the implementation

process and the development of a strategic action plan [111]**.** Since the case study enables organizations to examine a phenomenon in actual environments, it was chosen as a research method that focuses on comprehending the dynamics that exist inside a specific context [112]. A qualitative approach known as case study research is recognized as effective for investigating occurrences in their genuine context and gaining understanding via consideration of real-world experience [26]. Qualitative research improves the ability to interpret latent and non-obvious concerns and perform flexible investigation, justifying and evaluating the contents analysed, and establishing existing models in the literature while attempting to ensure that the concept's interpretation continues to remain independent of any prior methodological bias and adaptable to different perspectives. Researchers who closely examine a variety of case studies, perform field research, are exposed to real-world challenges, innovative thinking from individuals at all levels of companies, and a variety of case situations might come up with new ideas [59]. As a result, researchers can observe actual organizational behaviours related to specific themes using the case-study method[59] and should be able to reasonably fully comprehend the "why," "what," and "how" questions. [26]. When interacting with multidimensional responsive processes, case research is needed [26] and theory extension/ refinement is a follow-up to survey-based research to comprehend more thoroughly and verify prior outcomes [59]. Case studies have been progressively prevalent, particularly for theory building [112][145][146][147][148], but very few researchers have used case studies for theory extension, adding novelty to this research work. This is discussed in detail in Chapter 6.

Fuzzy AHP and Fuzzy TOPSIS: To be competitive in the global market, industry decision-makers must constantly rethink their processes. Examining their present manufacturing procedures demands a thorough understanding of a variety of tools and technologies. To achieve significant operational enhancements in increasingly competitive settings, industrial leaders must consider different factors or options in the decision-making process. However, due to algorithmic differences, the outcomes of different MCDM approaches may differ. This puts decision-makers in a bind when deciding on the

best methodology to use[149]. Furthermore, these approaches are unable to examine expert opinions as accurately as fuzzy AHP[120]. While the AHP technique can be used to make judgments on its own, combining it with other decision-support tools, such as TOPSIS, enhances the decision-making process[150]. When dealing with the ambiguity and uncertainty brought on by expert linguistic inputs, a fuzzy-based approach is effective. As a result, a fuzzy AHP-TOPSIS approach was used in this study. Eminent researchers have been recognized for conducting research using FTOPSIS and FAHP. [151][121][120][123] In recent years, hence Fuzzy AHP-TOPSIS method was considered for this research work. This is discussed further in Chapter 7.

Questionnaire Administration: To obtain responses from potential respondents, the questionnaire was distributed both offline and online. Respondents were requested to schedule an appointment ahead of time in offline mode. A soft copy of the questionnaire was then emailed to them, along with a supplemental background note on mass customization, to help them better comprehend the many aspects. A face-to-face interview was used to obtain responses from the respondents. In the instance of an online survey, participants were asked to make their beneficial inputs available. The questionnaire and background note on MC were emailed to 856 respondents from India's manufacturing businesses, representing a variety of industries. The filled-in surveys were examined to see if the respondents gave significant inputs once the online and offline responses were received.

3.3.5 Data Interpretation and Analysis

The questionnaire surveys were compiled, and the outcomes were tallied, using data management tools like Microsoft Excel (2017). The survey results were examined after data classification to identify the crucial mass customization practices and factors that could be embraced. Following data analysis, this step presented the empirical findings and research conclusions that had been reached after extensive deliberation and the use of the proper statistical tools, including SPSS version 23 for exploratory factor analysis and AMOS version 23 for confirmatory factor analysis and structured equation modelling. In

Chapter 5 of this thesis, a thorough analysis of the empirical data, research findings, and related debate has been conducted.

3.4 Summary of Research Steps Used for the Research: The methodology embraced for the research is discussed as under:

1. To investigate more profundity, the mass customization implementation process, and the enablers and drivers of mass customization, a systematic literature review (SLR) method [140], was developed which aimed at encapsulating and sorting the existing literature. The specific objectives for the literature review, the screening procedure, and the assessment based on exclusion and inclusion criteria were specified in a research protocol. Using the terms "mass customization," "enablers," "factors," "drivers," and "manufacturing," researchers were able to find relevant research papers. The goal of this review of the literature was to ascertain how mass customization in manufacturing has generally been perceived and what factors have made it possible. Significant enablers that influence the performance of manufacturing organizations and drivers that drive mass-customized markets were identified via the analysis of the literature.
2. Total Interpretive Structural Modelling (TISM) is utilized to create a framework to ascertain the relationships and interplay among the key enablers for MC implementation and generate a hierarchical link between the enablers. These techniques aid in the transformation of structured mental models into coherent models for conceptualization and theory building[152]. To analyse the relationship between these enablers, top executives from various sectors were consulted. Finally, the TISM model is developed along with the interpretation of links. MICMAC analysis was done to identify the driving and dependence power of enablers.

3. A set of constructs for developing a manufacturing model were formulated with the aid of an LR, and the constructs were classified into four groups—(pillars), and Hypotheses were developed and tested. This work builds on the groundwork established by former researcher Hart [60], who developed an analytical framework of four pillars of mass customization for organizations. Additional insights into the connection between the four pillars and MC were obtained using structural equation modelling (Amos Graphics). 276 legitimate responses from Indian professional experts were analysed.
4. The hypotheses that are described and assessed in the framework are examined using a questionnaire. Structural equation modelling (SEM) is used to test the hypothesis, and the findings are reported. The reliability and validity of the manufacturing framework are obtained with the help of Exploratory Factor analysis (EFA) and Confirmatory factor analysis (CFA).
5. The research applied multiple case study methods to verify the framework for mass customization implementation. This theory extension is aimed at validating and further modifying the above framework and intend to contribute to mass customization strategies to be adopted by organizations to comprehend and facilitate their transition. Production managers, quality managers, sales and marketing personnel, supply chain managers, and business heads from three manufacturing enterprises in India were interviewed in-depth. The case companies are diverse in terms of size, ownership, and markets they serve. In businesses striving to implement MC, challenges are identified, and approaches are suggested to enhance the accomplishment of mass customization for competitive advantage.
6. Drivers were identified and ranked to motivate Indian manufacturing companies in strategic planning, encouraging them to take the first step toward a long-term business model in the form of Mass Customization. Fifteen drivers were grouped into four categories and ranked based on inputs from industry experts using the FAHP approach. FTOPSIS was used to rank

various manufacturing sectors for mass customization adaptability in the current economic environment. Case studies in four organizations of Indian origin were conducted to uncover the drivers that led them to pursue the more lauded but less explored area of mass customization and verify the proposed frameworks. Finally, results were discussed, and the study is concluded with some future scope of research, and limitations. The flow of the research work is presented in Figure 3.4.

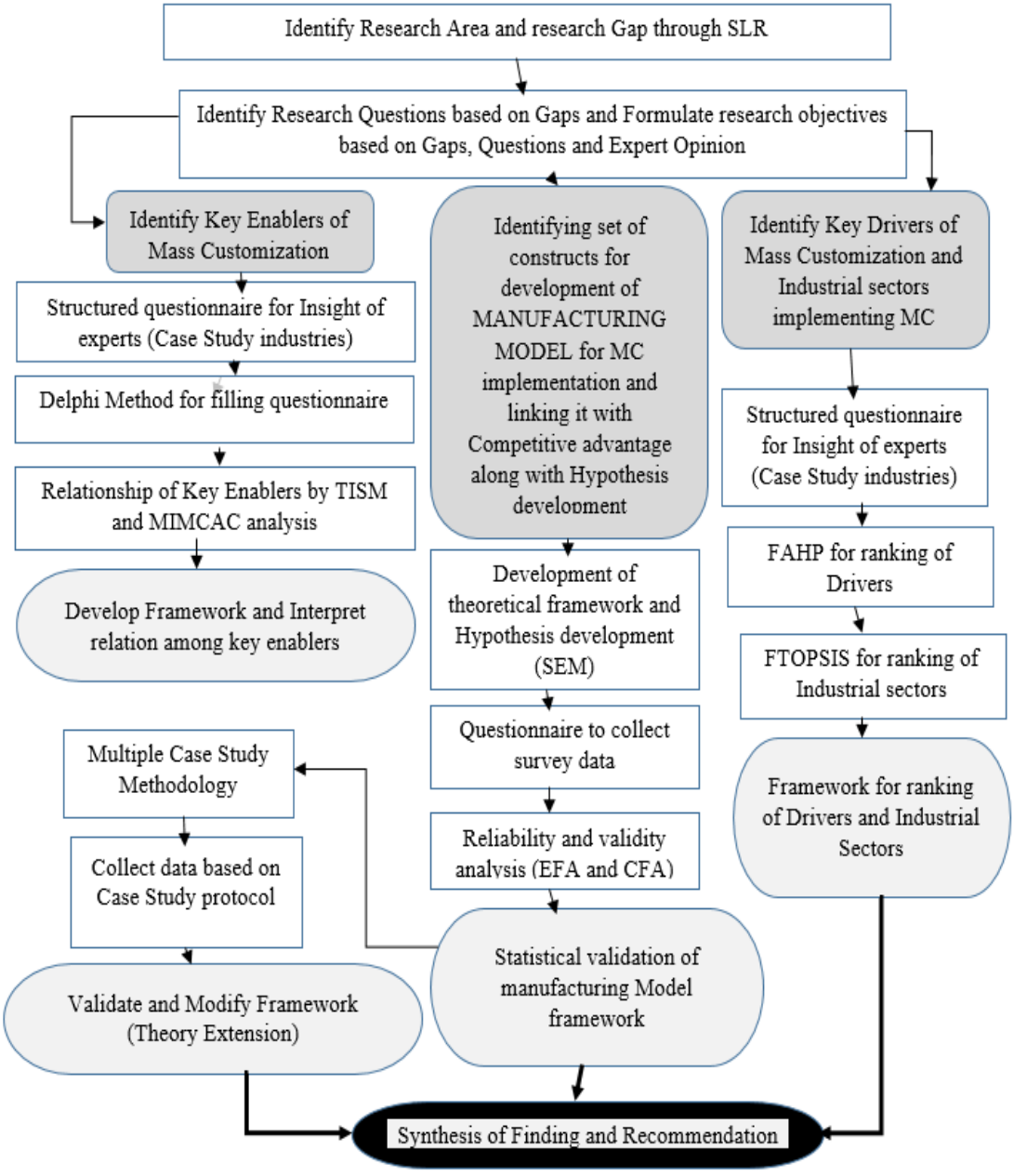

Figure 3.4: Flow of Research work

3.5 Conclusion

The research approach employed in this study was covered in detail in this chapter. The chapter opens with a discussion of the research work's aims and moves on to other research design styles. According to the objectives, the combined research design was selected. After that, the research methodology for this research is discussed, and a process flow of how the work will be carried out in the following chapters is discussed. The research instrument, survey design, and data collection method are discussed followed by the method of data analysis. Finally, the process flow for how the task will be completed in the following chapters is finalized and the research steps are decided. The next chapter identifies the enablers of MC and level partitioning to develop a framework with TISM and MICMAC methodology.

CHAPTER 4:
ENABLERS OF MASS CUSTOMIZATION: TISM AND MICMAC METHODOLOGY

4.1 Introduction

Organisations seeking a competitive edge are adopting mass customization (MC) into their business model. The implementation of mass customization calls for identification and proper level allocation to enablers and firms implementing MC must identify potential enablers, the order in which these enablers need to be implemented, and the resources that need to be allocated [2]. Though research has been done to uncover mass customization enablers, conceptual papers have received more attention than theory-building articles. Very few research article were identified that dealt with MC in Indian manufacturing context[15].The literature further demonstrates that organizations are unable to make the necessary transitions to become MC manufacturer due to the lack of know-how of the potential enablers that can aid in the transition process[3].In answer to research question 1 in Chapter 1, "***RQ1:*** *What enablers influence mass customization's adaptation when bulk production gives way to mass customization?" ,* research to perceive the enablers for the mass customization implementation in an organized sector is required to provide guidelines to the manufacturing sector in India. Also, the findings need to be verified by experts from case studies who are knowledgeable of the implementation, improvisation, and adaptation of mass customization in the current Indian business conditions.

This chapter presents the enablers of mass customization through LR and finalizes the enablers with opinion from experts. Total Interpretive Structure Modelling (TISM) is employed to level partition the enablers to build a framework of mass customization enablers and interpret the links between nodes and internodes. MICMAC analysis is applied to identify their driving and dependence power. This chapter develops a framework for mass customization implementation, which is validated three companies of Indian origin. In the result and discussion section, practices are recommended to

support the attainment of mass customization in organizations desiring to implement it. The flow of the chapter is presented in Figure 4.1.

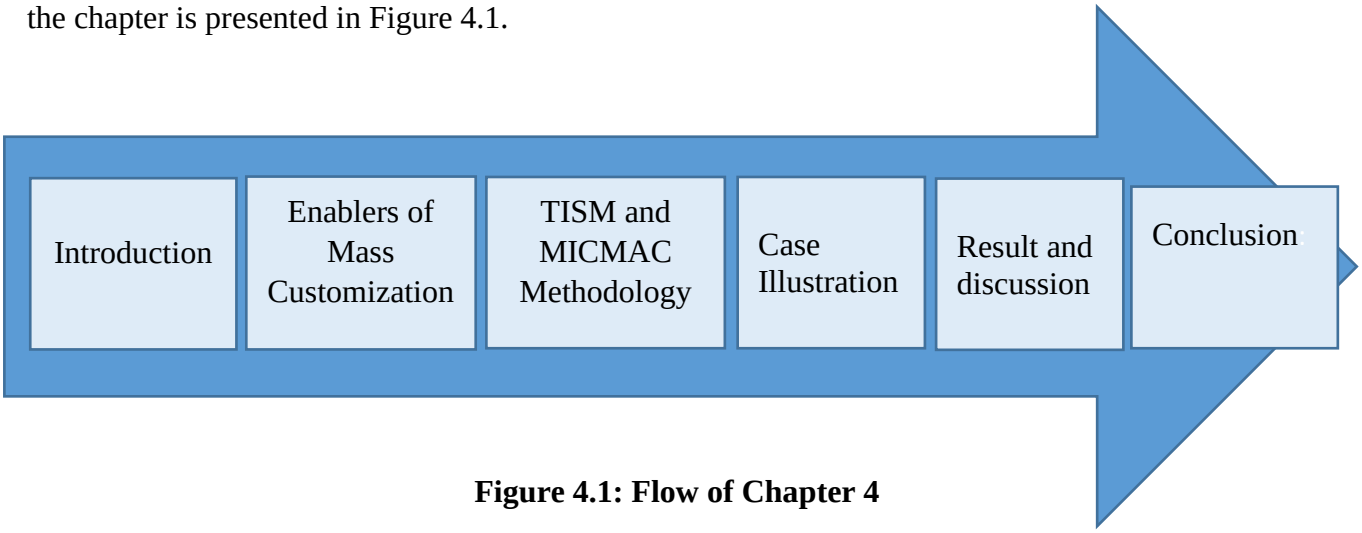

Figure 4.1: Flow of Chapter 4

4.2 Enablers of Mass Customization

Initially, 21 enablers were discovered during the research through literature, but researchers argued that the method's greatest difficulty lies in the need to perform an exponentially growing number of pair comparisons as elements are added[88]. Consequently, 12 enablers were finalized by brainstorming with the experts. Though most research adopted a literature review as a method to identify the enablers, fewer studies considered expert opinion to authenticate the chosen elements [42]. A thorough search for Indian organizations in the organized sector who have already incorporated mass customization as their business strategy was done and finally, after repeated communications, three organizations agreed to participate in this research work. Experts from these organizations were consulted through telephonic interviews and direct visits to the industry. Certain enablers like postponement and modularity were merged to form one enabler and named modularity in design. Similarly, the creative workforce and multi-skilled personnel were combined to form a multifunctional workforce. As per the expert's suggestion, top management supports and organizational readiness was named integrated management system. Experts recommended that a flexible manufacturing system can be considered a broad aspect of the enablers of Inventory management, re-configurable production systems, and changeover time reduction. Supplier flexibility, customer-supplier integration, and

readiness of value chain formed vendor capable of co-development of product. Experts thought that strategic orientation and legality can be eliminated due to its selective effect on the manufacturing process. Thus to simplify the method of pair comparison and easy understanding of enablers, 12 enablers were selected. This section presents a cogent effort to identify enablers of mass customization supported by recently published literature. Twelve enablers of mass customization were selected and are discussed below:

1) *IT Enabled Technology (IT):*

The implementation of MC required certain technologies like the e-Measure system, [50]automated manufacturing systems, IoT technology, cloud computing, and RFID[112] additive manufacturing[6]. Market prediction is considered highly complicated as it encompasses variable customer requirements simultaneously and complicated analysis tools are to be used for analysis[153], and organizations require to incorporate their IT usage for planning, set-up, and operational action for efficient supplier-customer integration[28]. IT solutions to speed up client reaction time require to be incorporated into the manufacturing industries[84]. Internet's capability to link suppliers and customers, online product configuration, and IT-enabled methodologies should be the prime focus for any organization striving to implement mass customization.

2) *Organization Culture and Change Management (OC):*

The concepts of mass customization have gained awareness in the last two decades, but very few organizations have implement MC despite being aware of the advantages of MC. In the companies which have implemented MC, one of the important enabler was the culture of innovation and change management in the organizations[154]. The structure and processes of the organizations were conducive to making changes in the design, manufacturing, and distribution. Organizations need to identify market positions, set their goals, and increase operational efficiency[155]. Also, the organization needs substantial refinements to historic mindsets and practices before it can emerge from

a traditional mass production manufacturer to a successful MC organization [156]. Organizations are required to redesign their organization, products, process, and supply chain to enhance their mass customization capability[157] and prime importance is to be given to the role of organizational structure [36]. Organizational reactiveness in exploring future market opportunities, proactive managers, a positive organizational culture that supports mass customization, and linking MC to core business processes can be considered key factors for a pro-mass customization organization.

3) *Social Media (SM)*:

The key principle of MC is empowering the customer to modify the existing design as per their personal taste. Social media and crowdsourcing should be used as toolkits to assist customers in the co-design of MC products. Companies aspiring for MC implementation should launch e-commerce systems like having a company website and gradually expanding their functionalities[50]. MC implementation requires the digitalization of products and customer demands processing through electronic utilities [84] and should emphasize online customization and purchasing through the Internet [37].

4) *Competitive Pricing (CP)*:

Studies conducted suggest that to be price competitive organizations need to limit their range of customized products [35]. A high range of product escalates the expenses of manufacturing that lead to the high cost of mass-customized products that lack appeal to general customers[42].But in certain cases, customers are will to pay a premium price for a MC product, but these are specialised case [6]. For cost-effective customization in high-volume manufacturing, efficient customization strategies need to be put in place[158]. An intensive study of the market and customers is desired to finalize product price.

5) *Customized Product (CuP):*

The definition of MC is rooted in customized products. Since Davis (1987)[19], researchers like Pine (1993) have emphasized that the concept of MC emerged from the ability of firms to produce customized products, at a specified time, in large quantities, and at the price of mass production. The customer desire is centred on the availability of quick access to MC products [5][159]. Customers are reluctant to buy a customized product at elevated price and hence the challenges of MC should be analysed before any firm ventures into the arena of introducing a customized product in the market[42]. Hence an efficient MC strategy can harness all professional skills and resources of the organization and deliver customized products.

6) *Modularity in design (MD)*:

A process or product should be disintegrated into various groups or modules which can be assorted together in combinations to perform various functions[42]. In order to improve supply chain integration, managers need concurrently deploy MC and product modularity [154]. The flexibility of the production system can be achieved by modularizing the production system[15]. Organizations need to combine the concept of postponement with modular product design [51] and the use of common processes and component platforms[160] to achieve MC. The capacity to assemble products from a set of standardized constituent units, incorporate modularity at the design stage, and product innovation should be the key focus area for incorporating modularity for mass customization. Product modularity enhances MC by enabling a greater range of products, a quicker time to market, and reduced design, manufacturing, delivery, and service costs[38]. Due to the ever-increasing diversity of products, this aids manufacturers in managing in-line complexity.

7) *Multifunctional Workforce (MW)*:

Researchers have referred to employee empowerment which emphasized the need to develop employees to expertise in all fields of manufacturing, marketing, and supply chain for product

innovation and MC implementation[161]. A multifunctional workforce is accompanied by decentralization of decision-making, innovative approach, employee involvement, and participation in managerial decision-making[162]. Hence organizations that consider their employees as potential partners and dynamic assets have more chances of achieving organizational excellence[155]. A creative and supportive workforce, employee involvement in decision-making, on-the-job training, team-building activities, and frequent motivational programs can be effective in creating an effective workforce for MC implementation.

8) *Integrated Management System (MS):*

Top Management Support is necessary to execute MC in the organization with the help of proactive managers. Managers need to interact with customers and suppliers simultaneously to incorporate MC concepts in the design phase[70]. During crises and conflicts, contribution by top management was important in resolving problems[155]. It was required to simultaneously develop production, process, and product on the strategic and operational level during the implementation phase which could be a challenging task for the top management[37]. Top Management Support in exploring future market opportunities, involvement to ensure technical financial and manpower support, assistance during hindrances, strategic review of MC projects, and assessment of their progress are the major factors for mass customization success.

9) *The vendor is capable of Co-development of the product (VD)*:

Vendor development should be accompanied by long-term commitment, trust, and an efficient communication system[28]. Researchers emphasized that the vendor should be encompassed in the primary phase of product design[15]. Reliability and flexibility in supplier development lead to lesser constraints in the supply front for production planning[157]. Supplier selection is an important enabler for MC implementation[37]. Researchers presented a successful MC model where ERP systems are adopted to function with EDI platforms with business partners for successful MC implementation[50].

Under the MC supply chain scenario, optimal pricing, modularity level, return policy, and lead time are the prime decision-making factors[23]. Joint ventures can facilitate an organization's logistics to improve the scheduling arrangement[163]. Supply chain management (SCM) calls for the integration of resources across and within organizations [46]. Willingness and knowledge of vendors to cater to the system's demands, Push-Pull configuration supply chain, inventory management, highly motivated suppliers, and efficiently managed logistics system should be an integral part of the MC system. Effective supplier relationship management, process innovation at the supplier front, inventory management, and just-in-time delivery and joint problem-solving approach should be the prime factors during supplier development.

10) *Quick Customer Response (QCR)*:

In a highly volatile environment, organizations require to respond rapidly to the market. Thus, customization time proves to be an indispensable criterion for mass customization. MC system requires quick responsiveness to deal with market volatility[47]). Some research works have considered response speed to be a prime performance indicator for an organization's mass customization capability[75]. Organizations need to focus on customers and their competitors to compete in the mass customization market[48]. Researchers discussed the need for strategies for customer relationship management (CRM) for translating customer data into customer interaction[156], believing that a customer's unique requirements render the basic essence of MC leads to adding value to a product[4]. Incorporation of the voice of the customer in their design and output is a critical success factor for MC[28]. Research on customers' desires enables a manufacturer to design products effectively[147]. For quick customer response, agility should be incorporated into the mass customization system[84]. Customer feedback help manufacturers determine features and pricing requirement of customized products to fulfil customers' special requirements cheaply and quickly[5]. Investigation into consumer buying patterns can lead to success in this field[37]. The research was conducted on a program called Time to the Customer (TTC,) where every customer's perspective in the critical market situation is

considered for MC implementation[14]. An efficient system to link the voice of the customer to product design, customer relationship management, regular market survey, and understanding customer grievances for product improvement forms the basis of quick customer response for mass customization implementation.

11) *Flexible manufacturing system (FMS):*

Before entering into the mass customization arena, organizations require to research extensively into various flexible technologies and processes[4], and an agile approach can prove a competitive advantage to a firm[132]. This view was supported by other researchers who emphasized the need for integrating agility and mass customization and conceptualized the term agile customization[84]. An agile manufacturing system helps an organization tide over a competitive environment driven by customers' dynamic needs[42].MC requires flexible manufacturing systems to help firms to be first in the market with innovative customized products[112] as it can help manage the complexity of mass customization[164]. Flexible technology and logistics should be simultaneously implemented in an organization[5]. Organizations that are flexible ensure mobility, agility, and adaptability, and are more capable to reduce the response time to demand changes[136]. Flexible manufacturing processes, adequate systems for customer co-design, aggressive marketing modules, and collaborative forecasting and replenishment should be incorporated into the manufacturing system for MC implementation.

12) *Sensitiveness of Marketing team (SM)*:

Market turbulence arises from four major sources-global competition, advancement in technology, and customization of products and solutions for customer desire [112]. Since the market is turbulent and uncertain, a firm should respond as quickly as possible to capture the market[165]. A highly sensitive marketing team is desired with the strategic business plan to identify customer requirements and meet emerging market needs[21]. Marketing strategies require capturing and prioritizing clients' requirements and later translating them into customizable attributes [67]. The sensitiveness of the

marketing team can achieve this by regular market survey[166] for quick response to market demands[75]. They should possess business readiness to meet new challenges[167], and strategic business plans to meet emerging market needs. A description of enablers along with references is provided in Table 4.1.

Table 4.1: Description of enablers of mass customization (MCE)

MCE No	MC Enabler	Description	Literature support
E1	IT Enabled Technology (IT)	Efficiently linked Information network to manage additional complexity of production, supply chain, and service work	[6][37][15][5] [168][28][169][4] [77][41] [170]
E2	Organization Culture and Change Management (OC)	A positive organizational culture that supports mass customization	[157][155][36][156] [75][171][50]
E3	Social Media (SM)	Social media and crowdsourcing as toolkits to assist customers in the co-design of MC products.	[37][50][136][70]
E4	Competitive Pricing (CP)	The capability to yield customized products at a cost comparable to mass production.	[6][42][50][158] [172]
E5	Customised Product (CuP)	Design the product to meet the dynamic demand of the customer.	[6][42] [159][62][14][173]
E6	Modularity in Design (MD)	Capacity to assemble products from a set of standardized constituent units and apply postponement	[42][160][15][51] [158][13]
E7	Multifunctional Workforce (MW)	Creative, supportive, and multi-skilled workforce to effectively cater to the organization's needs.	[162][174][155][75] [38]
E8	Integrated Management system (IMS)	Top Management Support to implement mass customization in the organization with the help of proactive managers.	[8][155][48][54]
E9	Vendor Capable of Co-development of the product (VC)	Develop suppliers capable of handling the additional complexity of MC orders.	[37][15][28][13] [175][158][41]
E10	Quick Customer Response (QCR)	Customers desire to own co-created products and systems efficiency to supply as desired.	[37][15][176][28] [75][156][84]
E11	Flexible Manufacturing System (FMS)	Availability of flexible process technologies to build an integrated manufacturing system capable of delivering MC products	[42][112][37][15] [176][84][75]
E12	Sensitiveness of Marketing team (MS)	A strategic business plan to identify customer requirements and meet emerging market needs	[112][177]

4.3 TISM and MICMAC Methodology

Both interpretive structural modelling (ISM) and total interpretive structural modelling (TISM) consist of pair comparison methods that are used to develop hierarchical relationships among a set of factors. These methods have the advantage of converting ill-structured mental models into well-articulated models which are useful in accomplishing the base for conceptualization and theory building. In addition, TISM has the advantage of providing an interpretation of all the links along with nodes and retaining select transitive links that have meaningful interpretations, while for ISM, all the transitive links are dropped[91].TISM consists of structuring related elements into a comprehensive systematic mode[98]. The limitations of ISM for the limited explanation it provides on transitive links are removed in TISM[178]. The steps for the TISM methodology as per guidelines provided by researchers [97][178][87] are explained in detail.

1) The TISM process consists of identifying enablers that are vital for a manufacturing system.
2) The next step constitutes developing mutual contextual and interpretation relationships among enablers These relationships among enablers are later converted into a SSIM.
3) The next step checks for transitivity.
4) The reachability matrix obtained is then partitioned into different levels.
5) The following stage of level partitioning consists of drawing a digraph and developing an interaction matrix.
6) Next, the TISM model is developed by replacing factor nodes with enablers. Figure 4.2 depicts the structure of TISM and MICMAC methodology.

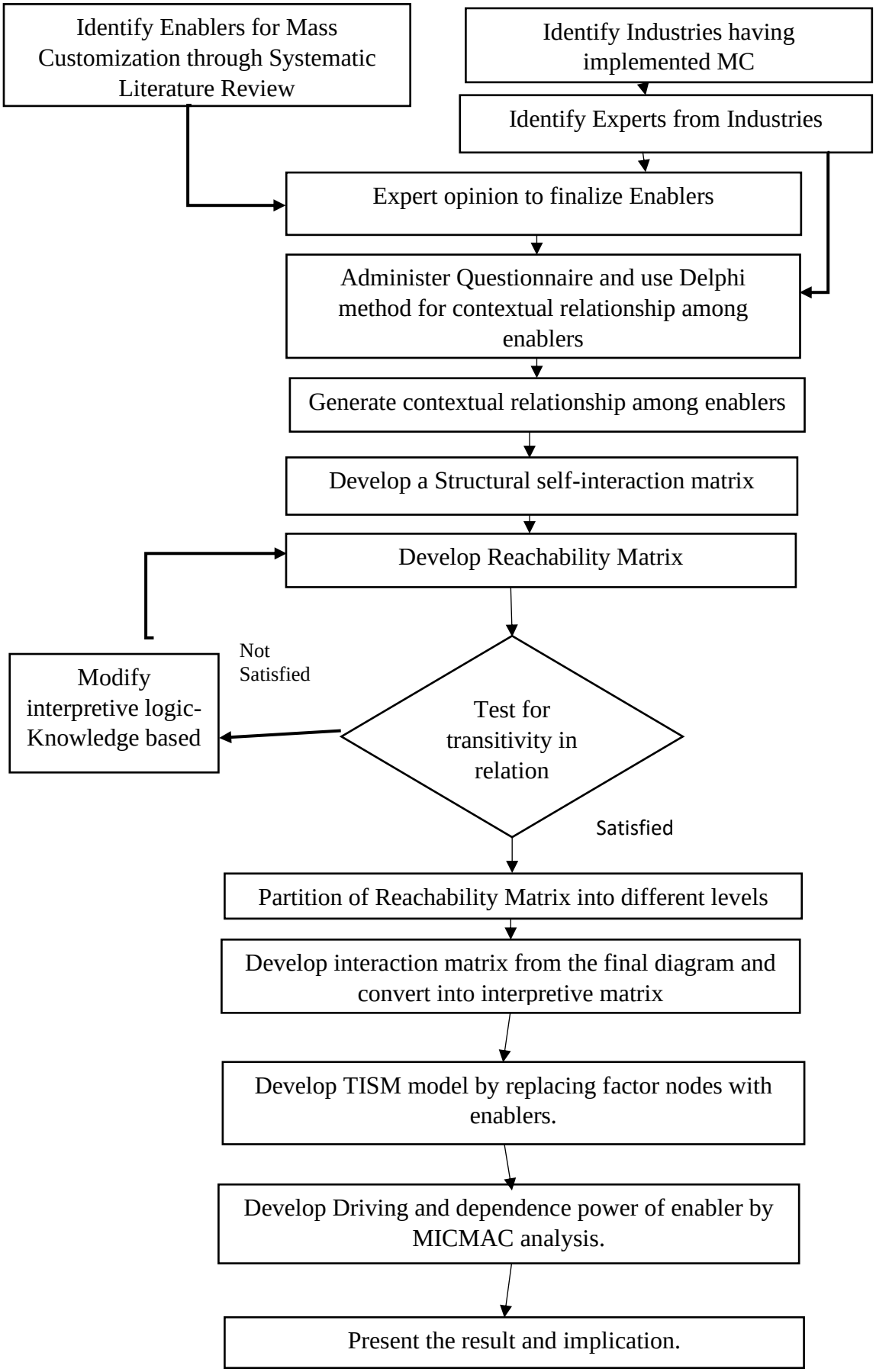

Figure 4.2: **Structure of TISM and MICMAC methodology**

The various steps of TISM are discussed in detail and are provided below:

4.3.1 Self-structured interaction matrix (SSIM)

To establish the relationship and direction between the Mass customization enablers, nine experts from the case organization were consulted consisting of three senior management executives, two production management experts, two knowledge management/ IT experts, one vendor management expert, and one customer relationship management expert. The expert had more than 15 years of experience and was well-versed in the implementation and crisis management of mass customization technology. The Delphi method was applied in three rounds to select the most prominent enablers of mass customization. The Delphi method consists of circulating a questionnaire among experts and gradually working towards mutual consent through a series of rounds where experts are provided feedback of all participants and allowed to modify their answers till the issues were narrowed, responses were focused, and a final solution was reached. Each expert was given sheet for understanding the contextual relationship between various mass customization enablers. Four symbols (V, A, X, and O) were used to represent the relationship between the two mass customization enablers in the final solution summary. The symbols V and A denote a one-way or unidirectional interaction between enablers. V indicates that one enabler leads to the other enabler. For instance, " Organization Culture and Change Management (OC)" (E2) leads to “Sensitiveness of Marketing team (MS)” (E12). But E12 does not lead to E2, which results in selecting V in E2/E12 and A for E12/E2. A two-directional relationship is indicated by the symbol X. “social media (SM)(E3) and “Sensitiveness of Marketing team (MS)” (E12) will strengthen each other, leading to X in E3/E12 and E12/E3. O indicates no relationship, just as in “Quick Customer Response (QCR)” (E10) and “Flexible Manufacturing System (FMS)” (E11) are unrelated, leading to O for E10/E11 and E11/E10. A matrix was created to highlight the contextual relationships between the identified MC enablers. Table 4.2 presents the generated matrix. The interpretation of symbols V, A, X, and O is provided below.

V → Enabler i will aid in the accomplishment of enabler j,

A → Enabler j will aid in the fulfillment of Enabler i,

X → Enablers i and j will strengthen one another,

O → i and j are unrelated enablers,

Where index i correspond to enablers in the i_{th} row and index j to those in the j_{th} column.

Table 4.2: Structural self-interaction matrix (SSIM)

Enabler No	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2	E1
E1	O	A	V	O	A	O	X	O	V	A	A	X
E2	V	V	O	V	V	V	V	O	O	V	X	V
E3	X	O	O	O	O	O	O	O	O	X	A	V
E4	O	A	X	O	O	O	A	O	X	O	O	A
E5	A	O	O	A	A	A	O	X	O	O	O	O
E6	**A**	X	O	O	A	O	X	O	V	O	A	X
E7	O	O	O	V	X	X	O	V	O	O	A	O
E8	V	O	O	V	X	X	V	V	O	O	A	V
E9	A	X	O	X	A	A	O	V	O	O	A	O
E10	O	O	X	O	O	O	O	O	X	O	O	A
E11	A	X	O	X	O	O	X	O	V	O	A	V
E12	X	V	O	V	A	O	V	V	O	X	A	O

4.3.2 Initial reachability matrix

In this stage, SSIM is converted into a binary matrix called the initial reachability matrix. Here, 1 or 0, depending on the relationship, replaces V, A, X, and O. The cell value 0 denotes the absence of a relationship, whereas the value 1 denotes the existence of a relationship between two mass customization enablers. Table 5 displays the initial reachability matrix that was created while achieving this outcome. When constructing this first reachability matrix, the replacement rule was followed. In this stage, SSIM is converted into a binary matrix called the initial reachability matrix. For example, " Organization Culture and Change Management (OC)" (E2) leads to “Sensitiveness of Marketing team (MS)” (E12). Hence E2/E12, V is replaced by 1. But, E12 does not lead to E2, hence

O is replaced by 0. Similarly, “Social Media (SM)(E3)and “Sensitiveness of Marketing team (MS)”(E12) are denoted by X in E3/E12, which is replaced by 1.“Quick Customer Response(QCR)”(E10) and “Flexible Manufacturing System (FMS)”(E11) are un-related, leading to O, which is replaced by 0 in E10/E11 and E11/E10. The initial reachability matrix is represented in Table 4.3.

Table 4.3: Initial Reachability Matrix

Enabler No	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
E1	1	0	0	1	0	1	0	0	0	1	0	0
E2	1	1	1	0	0	1	1	1	1	0	1	1
E3	1	0	1	0	0	0	0	0	0	0	0	1
E4	0	0	0	1	0	0	0	0	0	1	0	0
E5	0	0	0	0	1	0	0	0	0	0	0	0
E6	1	0	0	1	0	1	0	0	0	0	1	0
E7	0	0	0	0	1	0	1	1	1	0	0	0
E8	1	0	0	0	1	1	1	1	1	0	0	1
E9	0	0	0	0	1	0	0	0	1	0	1	0
E10	0	0	0	1	0	0	0	0	0	1	0	0
E11	1	0	0	1	0	1	0	0	1	0	1	0
E12	0	0	1	0	1	1	0	0	1	0	1	1

4.3.3 Transitivity Check

To create the final reachability matrix, a notion of transitivity is offered. Since i is related to j and j is related to k, transitivity demonstrates that i is fundamentally tied to k. The reachability set and antecedent set for each mass customization enabler are identified in the final reachability matrix. The initial reachability matrix is put through a transitivity check. Put another way, it is checked to ensure that each link created in the initial reachability matrix has been properly interpreted. If enabler E_i leads to enabler E_j, and enabler Ej to enabler E_k ((i, j, k = 1, 2, 3... 12), E_i should lead to E_k. A transitivity check is a method used to close these gaps[179] (Thakkar et al., 2008). The initial reachability matrix shows that E2 leads to E1 and E1 leads to E4, which are both equal to 1, hence

E2/E4 must also be 1 and all such transitivity links are marked by 1*.The final reachability matrix thus created is shown in Table 4.4

Table 4.4: Final reachability matrix

Enabler No	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	Driving Power
E1	1	0	0	1	0	1	0	0	0	1	1*	0	5
E2	1	1	1	1*	1*	1	1	1	1	1*	1	1	12
E3	1	0	1	1*	1*	1*	0	0	1*	1*	0	1	8
E4	0	0	0	1	0	0	0	0	0	1	0	0	2
E5	0	0	0	0	1	0	0	0	0	0	0	0	1
E6	1	0	0	1	1*	1	0	0	1*	1*	1	0	7
E7	1*	0	0	0	1	1*	1	1	1	0	1*	1*	8
E8	1	0	1*	1*	1	1	1	1	1	1*	1*	1	11
E9	1*	0	0	1*	1	1*	0	0	1	0	1	0	6
E10	0	0	0	1	0	0	0	0	0	1	0	0	2
E11	1	0	0	1	0	1	0	0	1	1*	1	0	6
E12	1*	0	1	1*	1	1	0	0	1	0	1	1	8
Dependent	9	1	4	10	8	9	3	3	8	8	8	5	

4.3.4 Level partitioning

The reachability and antecedent sets for each enabler are established using the ultimate reachability matrix. The reachability set includes the enablers that could help build mass customization. The antecedent set includes the enabler that might be attained because of another enabler. The intersection set for every enabler is subsequently determined. The enabler whose intersection set and reachability set have been verified to be identical will be given the top-level enabler in the TISM hierarchy. The top-level enablers are then separated from the other enablers, and so on until all enablers have received levels [96].The first iteration results are shown in Table 4.5.E4- Competitive Pricing (CP), E5- Customised Product(CuP), and E10- Quick Customer Response(QCR) are identified as level I enablers.

In the second iteration method, E4, E5, and E12 are eliminated, and the iteration continued. The result obtained is shown in Table 4.6.E1- IT Enabled Technology (IT), E6- Modularity in Design

(MD),E9- Vendor Capable of Co-development of the product (VC), and E11- Flexible Manufacturing System (FMS) are identified as level II enablers.

Table 4.5: First Iteration for Levelling of the Enablers

Variables	Reachability set	Antecedent set	Intersection	Level
E1	E1,E4,E6,E10,E11	E1,E2,E3,E6,E7,E8,E9, E11,E12	E1,E6,E11	
E2	E1,E2,E3,E4,E5,E6,E7, E8,E9, E10,E11,E12	E2	E2	
E3	E1,E3,E4,E5,E6,E9, E10,E12	E2, E3,E8,E12	E3,E12	
E4	E4,E10	E1,E2,E3,E4,E6,E8,E9, E10,E11,E12	**E4,E10**	**1**
E5	E5	E2,E3,E5,E6,E7,E8,E9, E12	**E5**	**1**
E6	E1,E4,E5,E6,E9,E10,E 11	E1,E2,E3,E6,E7,E8,E9, E11,E12	E1,E6,E9, E11	
E7	E1,E5,E6,E7,E8,E9,E1 1,E12	E2,E7,E8	E7,E8	
E8	E1,E3,,E4,E5,E6,E7, E8,E9,E10, E11,E12	E2,E7,E8	E7,E8	
E9	E1,E4,E5,E6,E9,E11	E2,E3,E6,E7,E8,E9, E11,E12	E6,E9,E11	
E10	E4,E10	E1,E2,E3E4,E6,E8, E10,E11	**E4,E10**	**1**
E11	E1,E4,,E6,E9,E10,E11	E1,E2,E6,E7,,E8,E9, E11,E12	E1,E6,E9, E11	
E12	E1,E3,E4,E5,E6,E9, E11,E12	E2,E3,E7,E8,E12	E3,E12	

Table 4.6: Second Iteration for Levelling of the Enablers

Variables	Reachability set	Antecedent set	Intersection	Level
E1	E1,E6,E11	E1,E2,E3,E6,E7,E8,E9,E 11,E12	**E1,E6,E11**	**II**
E2	E1,E2,E3,E6,E7,E8, E9, E11,E12	E2	E2	
E3	E1,E3,E6,E9, E12	E2, E3,E8,E12	E3,E12	
E6	E1,E6,E9,E11	E1,E2,E3,E6,E7,E8,E9,E 11,E12	**E1,E6,E9, E11**	**II**
E7	E1,E6,E7,E8,E9,E11,E1 2	E2,E7,E8	E7,E8	
E8	E1,E3,E6,E7, E8,E9,E11,E12	E2,E7,E8	E7,E8	
E9	E6,E9,E11	E2,E3,E6,E7,E8,E9, E11,E12	**E6,E9,E11**	**II**
E11	E1,E6,E9,E11	E1,E2,E6,E7,,E8,E9, E11,E12	**E1,E6,E9, E11**	**II**
E12	E1,E3,E6,E9, E11,E12	E2,E3,E7,E8,E12	E3,E12	

In the third iteration process, E1, E6, E9, and E11 are eliminated, and the iteration process yields E3- Social Media (SM) and E12- Sensitiveness of Marketing team (SM) as level III enablers. This is shown in Table 4.7.

Table 4.7: Third Iteration for Levelling of the Enablers

Variables	Reachability set	Antecedent set	Intersection	Level
E2	E2,E3,E7,E8,E12	E2	E2	
E3	E3,E12	E2, E3,E8,E12	**E3,E12**	**III**
E7	E7,E8,E12	E2,E7,E8	E7,E8	
E8	E3,E7, E8,E12	E2,E7,E8	E7,E8	
E12	E3,E12	E2,E3,E7,E8,E12	**E3,E12**	**III**

In the fourth iteration process, E3 and E12 are eliminated, and the iteration process yields E7- Multifunctional Workforce (MW) and E8- Integrated Management system (IMS)as level IV enablers. Finally, E2- Organization Culture and Change Management (OC) is identified as a level V enabler. This is shown in Table 4.8.

Table 4.8: Fourth and Fifth Iteration for Levelling of the Enablers

Variables	Reachability set	Antecedent set	Intersection	Level
E2	E2,E7,E8	E2	E2	V
E7	E7,E8	E2,E7,E8	**E7,E8**	**IV**
E8	E7,E8	E2,E7,E8	**E7,E8**	**1V**

4.3.5 Structural model

To establish the final reachability matrix, the structural model (digraph) is obtained. The structural model (Figure 4.1) denotes the enablers in five levels (hierarchical model). The level 1 enablers are dependent on other enablers. The lowest level (fifth level) represents those enablers that lead to level 1 enablers through mediating enablers.

4.3.6 Total Interpretive Structural Modelling (TISM)

Finally, the TISM model is developed and shown in Figure 4.3, and links are also interpreted and shown in Table 4.9.

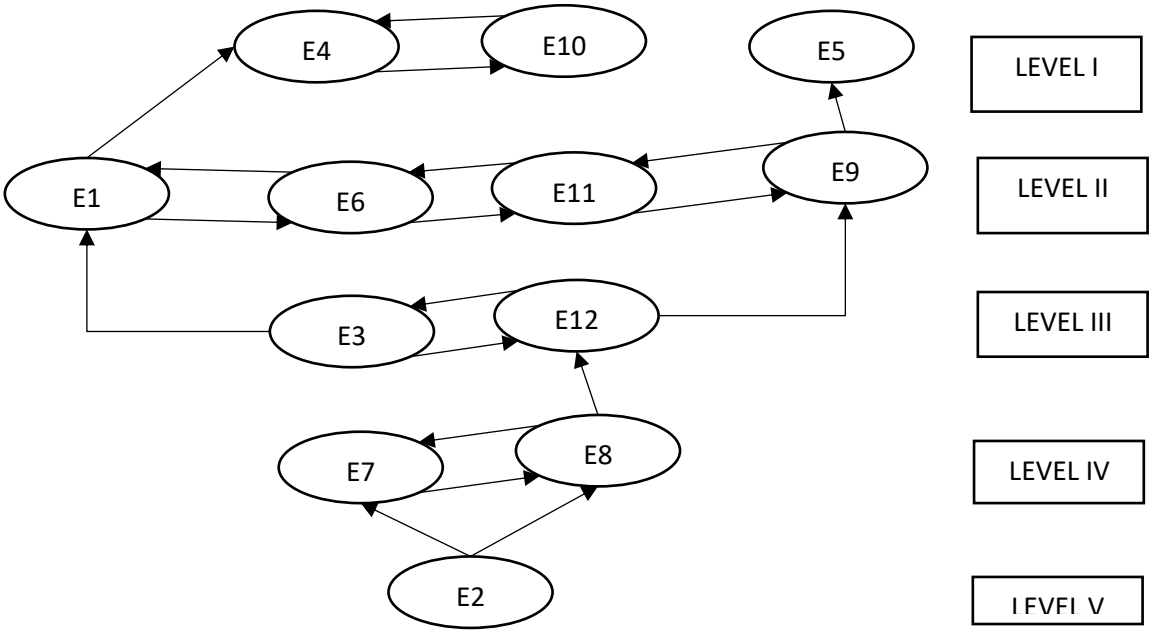

Figure 4.3: The structural model of MC enabler

Table 4.9: Interpretation of Links

Sno	Relation	Interpretation	References
1	E2-E7	Organizational readiness to empower its workforce and train them for change management	[54]
2	E2-E8	Positive organization culture that supports mass customization	[180]
3	E7-E8	Motivating and training employees for mass customization	[36]
4	E8-E7	Proactive Managers and top-quality experts to innovate mass-customized products and services	[54]
5	E8-E12	Top management commitment to understanding customers' needs and linking MC to core business processes	[181]
6	E12-E3	Social media and the internet-empowered system as toolkits to assist customers in the co-design of MC products	Expert opinion
7	E3-E12	Marketing strategies to capture the voice of customers and convert them into product attributes	[21]
8	E3-E1	Brand building and exploring future market opportunities	[156]
9	E12-E9	Competitive pricing strategy by top management	[156]
10	E1-E4	IT enabled the system to reach the market in optimum time and price and desired quality	[169]
11	E9-E5	Supplier involvement in an early stage of product development	[158]
12	E4-E10	Cost-effective customization	Expert opinion
13	E10-E4	The customer is integrated into the design process	[182]
14	E1-E6	Product design modularity IT infrastructure flexibility	[38]
15	E6-E11	Modular design for flexibility	[43]
16	E11-E9	Greater vendor reliability and flexibility for co-development of product	Expert opinion
17	E6-E1	IT-enabled technology for advanced planning and manufacturing integration	[169]
18	E7-E1	Trained employees to implement IT-enabled technology	[33]
19	E7-E10	The management vision of the coevolution of product, process, and production on a strategic and operational level	[183]
20	E6-E1	IT-enabled technology for advanced planning and manufacturing integration	[4]

The TISM framework with five levels of enablers and interpretation of links is provided in Figure 4.4.

Only significant interpretations are considered [179]

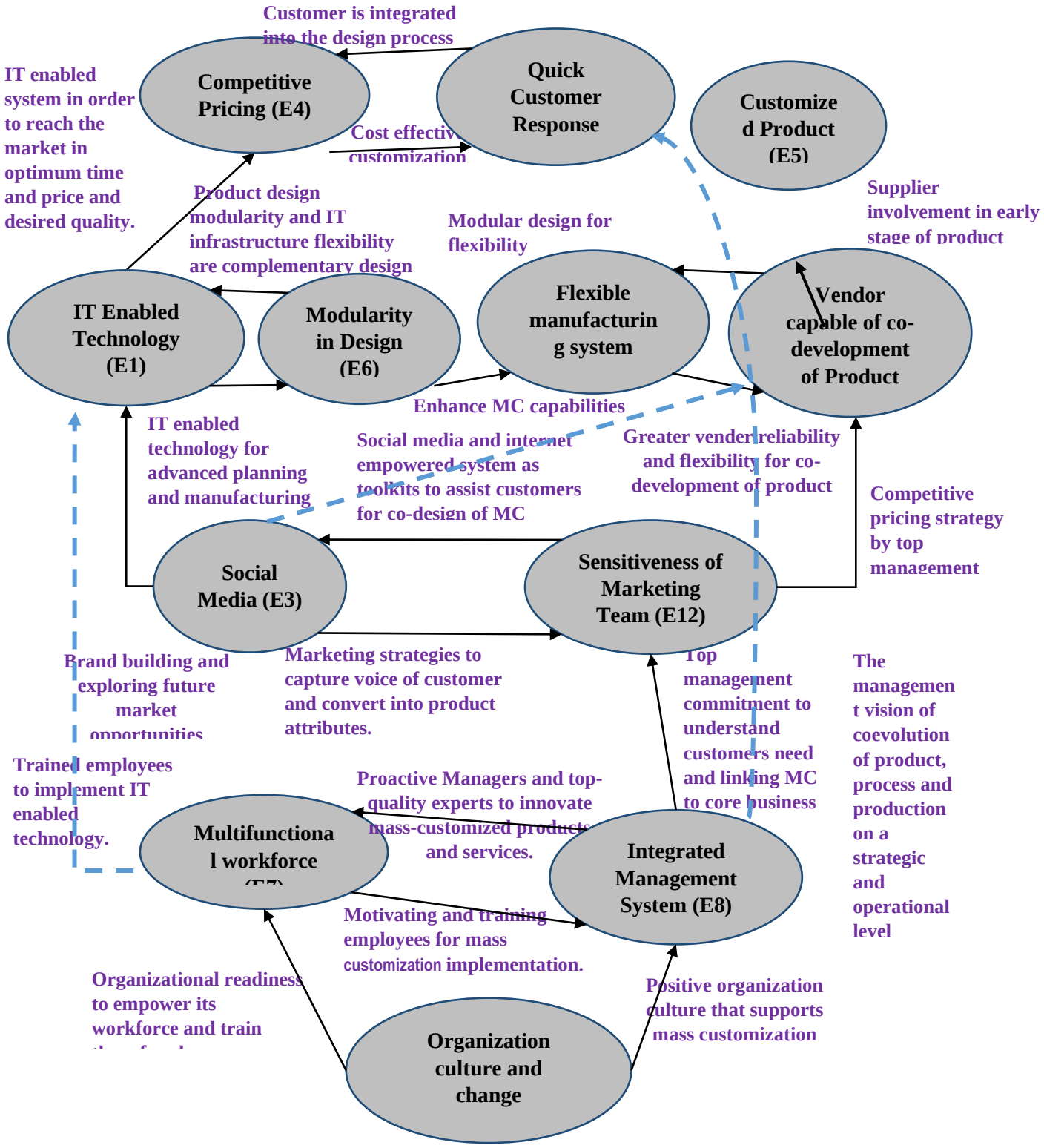

Figure 4.4: TISM-based model for MC Enablers

4.3.7 MICMAC Analysis

The twelve enablers were ranked according to dependence (along the X-axis) and driving power (along the Y-axis) using MICMAC (Cross Impact Multiplication Matrix) analysis, as illustrated in Figure 4.4. The resulting scatter plot has four quadrants. The enablers were classified into four quadrants according to their level of dependence and driving force. The enablers in the top quadrant are known as autonomous enablers. Due to insufficient reliance and inadequate driving power, autonomous enablers are separated from other enablers. There are no enablers in this cluster.

The enablers that make up the second quadrant fall under the category of dependent enablers. High dependency on others and a low driving force are two characteristics of these facilitators. This cluster includes the sites of E1, E4, E5, E9, E10, and E11. Due to their position at top of the TISM hierarchy (see Figure 4.4), they are seen as being crucial for the implementation of MC. All other MC enablers must work together to address the implementation problems with mass customization due to their strong interdependence. The strategy will be beneficial for companies attempting to employ MC. These MC enablers must be accomplished with the utmost priority from high management. These enablers may be obtained with the help of other system enablers.

The enablers in quadrant three are the linkage enablers. These enablers consist of moderate dependence and driving forces. E6 is a part of this cluster. Because these variables are highly unpredictable and each change in them influences others, managers must use adequate caution when managing these enablers.

The enablers in the fourth quadrant are the driving enablers. The driving enhancers have a high driving power and minimum dependence. The genes E2, E3, E7, E8, and E12 are all found in this cluster. The substantial driving power suggests that changes in these driving MC enablers have a considerable impact on the TISM hierarchy. The TISM model places them at the bottom of the TISM

hierarchy, as depicted in Figure 4.2. These MC enablers serve as the cornerstone of all successful MC implementations and are more strategic. The MICMAC analysis is depicted in Figure 4.5.

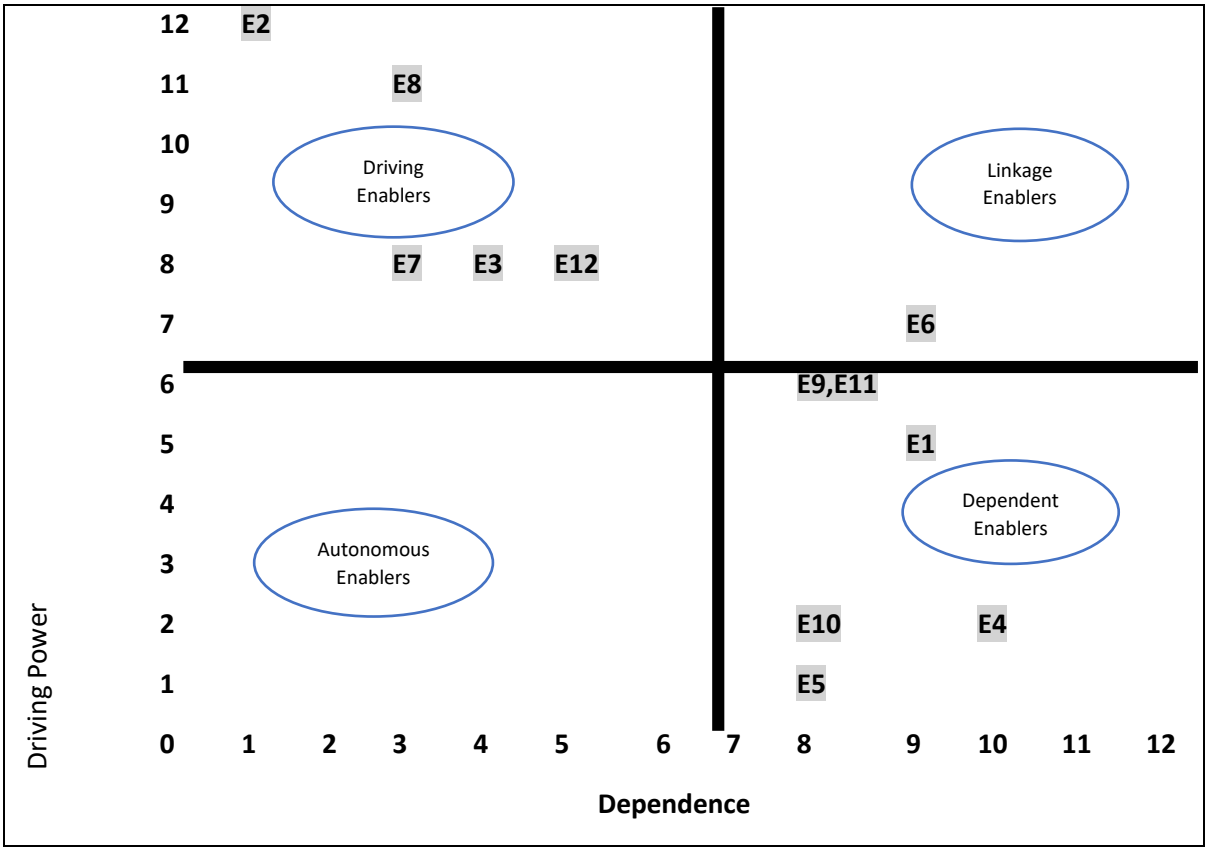

Figure 4.5: MICMAC analysis of MC Enablers

4.4 Case Illustration

A thorough search was conducted to find organizations of Indian origin that have implemented mass customization and finally, three organizations were selected. Case Study Protocol[184], given in Appendix I, is used to conduct the case studies. A questionnaire was used to obtain the feedback from experts mentioned in Table 4.10. The questionnaire for enabler of mass customization (TISM) used is provided in Appendix 2. The mass customization implementation process of these organizations as regards the selected enablers are discussed below:

Company A is a large manufacturer of paints for domestic and industrial use, established in 1942. Until the year 2000, the company was manufacturing paints and decorative coating and then

specializing in modular kitchens, and then expanding its business into the bathroom segment. The company is chosen for the study because it had successfully implemented mass customization in the paint sector. A lot of gradation was done to implement mass customization in the organization. The company then specialized in modular kitchens and then expanded its business into the bathroom segment. The top management's vision to upgrade its IT platform resulted in a 60% reduction in database requirements and development of customer-driven product and marketing outreach and an up-gradation of sales performance. The introduction of the Virtual TSO (Territory Sales Officer) App for the smaller dealers leads to increased interaction among dealers and organizations. A venture into emerging technologies like the IOT, AI, Natural language translation, and 3-D visualization of home décor resulted in delivering value to its customers by keeping the customer at the centre and understanding the unmet needs. The company paid utmost attention to customer grievances and welded a business strategy that helped the company go from strength to strength. The key enablers identified by the company were Organization Culture and Change Management, IT-enabled technology, Sensitiveness of the Marketing team, Vendor Capable of Co-development of products, and Quick customer response. The profile of the companies and experts are presented in Table 4.10.

Table 4.10: Profile of Case Study Company and Experts

Plant Profile	Founded	Major Business	MC Product	Expert Profile	Years of Experience
A	1942	Paint, decorative coating, chemical products	Paint	Senior management executives Production management expert Knowledge management/ IT experts	16 15 16
B	1897	Real estate, consumer and agricultural products, industrial engineering, appliances, and furniture.	Customized wardrobe and furniture	Senior management executives Production management experts Customer relationship management experts	18 16 16
C	1934	Electric Fans, Sewing Machines, Home Appliances, Electric Motors and Pumps, Cooktops Hobs, and Hoods.	Customized fans	Senior management executives Vendor management experts Knowledge management/ IT experts	20 18 15

Company B has diversified its product range in the fields of real estate, consumer products, industrial engineering, appliances, furniture, security, and agricultural products. One of the divisions of the company is engaged in serving the needs of mass customizations for storage requirements due to customer requirements for ready-to-fit storage space and less carpentry work at the site. Its modular design provides to add and modify storage units. The company aims to produce products having the highest design quotient that combines aesthetics, functionality, and technology. The company adopted a multi-channel reach and prioritized its E-commerce activities to maximize its customer engagement. Customer requirement and satisfaction, survey and feedback, and design validation form the basis for customer co-design. Extensive training formed the basis for employer empowerment. Profit protection plans, purchase cost reduction projects and energy conservation initiatives resulted in competitive pricing. Introduction to franchisee stores and e-commerce, vendor development for co-design, branch dealer conferences, priority dealer meets, annual business planning discussions, key supplier meets, new product development meetings at regular intervals, and supply chain enhancement were part of the organization's business strategy. The key enablers identified by the company were the customized product, modularity in design, Quick customer response competitive pricing, and IT-enabled technology.

Company C is a consumer durable company manufacturing Home Appliances, Electric Fans, Electric Motors, Sewing Machines and Pumps, Engines and Pump sets, Cooktops Hobs and Hoods, Water Coolers, and Dispensers, Auto Products. It started its journey of mass customization with the Fans division. The company had wide experience in Digital Commerce. The top management realized the importance of change management culture for MC implementation and with their innovation-led approach, they were passionate about providing value-added services to their customers. The growth strategy consists of the development of ERP systems, arranging effective training modules for the organization, building a distribution structure for products, enhancing its IT-enabled technology, data analysis, and effective e-commerce. For employee empowerment, the company re-trained the entire

organization on competitive marketing approaches. The company focuses on collaborative relationships with its vendors to make them understand their business goals and work closely with them to devise the most efficient strategy mapping with their transformation journey roadmap and implement the best-in-class solutions. The company envisages mass customizing its other products as well shortly. The key enablers identified by the company were the customized product, Management Support, Multifunctional workforce, Quick customer response, social media, Vendor Capable of Co-development of products, and IT-enabled technology.

4.5 Result and Discussion

Theoretical significance: In this research work, enablers have been identified and through a theory-building approach, the interactions and interplay among the strategic enablers for MC implementation have been discussed. The TISM structure depicts the relationships between different enablers. This paper is based on the guidelines of researchers [152][185][94] to build theory.

Theoretically, there are various ways that this research effort adds to the literature on mass customization. The enablers have been ranked by prior academics, but little research has been done to examine the behavioural and practical effects of MC in Indian organizations. The studies done in India fell short of providing a suitable adoption roadmap for MC. In the Indian context, there are few studies that have created a hierarchical structural model for MC enablers and interpreted their transitive linkages.

Managerial implications: The results of this study will help in appropriate decision-making for managers rethinking a change from mass production to mass customization. The hierarchal model provides guidelines to identify the enablers and step-by-step procedures an organization should adopt to successfully achieve mass customization.

The hierarchical model presents a roadmap to current practitioners. Level 5 is the initial step, which would be to generate a cultural move to encourage the MC culture, followed by level 4 where

Top-management support should ensure the linking of MC to core business processes. Simultaneously, the organization should develop proactive managers and top-quality experts to innovate mass-customized products and services. Also, consideration should be provided to motivate and train employees for mass customization implementation, which is a significant capability that empowers the organization to create value. In level 3, top management commitment to understanding customers, marketing strategies to capture the voice of the customer and convert them into product attributes, the management vision of coevolution of the system strategically leads to the sensitiveness of the marketing team and empowers the system with social media and internet as toolkits to assist customers for co-design of MC products. The research of the marketing team on sales revenue, profit, market conditions, and customer preferences, and grievances, competitor's customization strategy provides significant input for MC product design. Level 4 consists of manufacturing strategies that need to be implemented in an organization. Modularity in design leads to flexibility. Flexible technologies need to be responsible for a high degree of market adaptability and in this case, agile methodologies and strategies have a high potential to encounter market fluctuations. MC is inextricably related to the IT-empowered technologies that can share data viably and efficiently, empowering associations to improve dynamic detection and speed. It helps in stock control, transportation, booking, and quality control at the operational level by having progressively exact and auspicious data for settling on the right choices. The association ought to understand that connecting with suppliers and vendors was as significant as contacting end clients. Hence greater vendor reliability and flexibility for the co-development of products and customer integration into the design process are required for better business performance. Integrative and harmonious deployment of IT-enabled technology, modularity in design, flexible manufacturing systems, and vendors capable of co-development leads to level 1, which is competitive pricing that is the success mantra behind a customized product.

The disturbance caused by COVID-19 on manufacturing has severely impacted the operational, social, and financial sectors and hosting challenges to organizations to accelerate the change of global

value distribution models, causing many Indian industries to come to a grinding halt and India's manufacturing sector is now at a crossroads with unmatched consequences for manufactures and supply chains. A new approach is desired to rethink risk management and contingency plans, this mass customization theoretical model can provide manufacturers with a solution to solve the immediate challenges required to keep the business stable.

4.6 Conclusion

In line with objective two of this research, in this chapter, twelve enablers were identified, and a TISM-based framework has been presented that will help organizations understand the potential enablers required to be considered during their transformation from mass manufacturing to mass customization. This chapter demonstrates how enablers are positioned at various levels and how each one influences or is affected by others. MICMAC analysis categorizes enablers as drivers, linking, dependant, and autonomous variables, validates the generated model, and determines their driving and dependence power. The implementation and benefits of the enablers in three case companies will provide insight into the practical effects of MC in Indian organizations. The outcome can contribute by assisting organizations in decision-making during implementation of MC. The following chapter identifies the constructs for MC implementation and statistical analysis to develop a manufacturing model.

CHAPTER 5

IMPLEMENTATION MODEL OF MASS CUSTOMIZATION: INSTRUMENT DEVELOPMENT, DESCRIPTIVE ANALYSIS, AND SEM

5.1 Introduction

Researchers identified mass customization as a promising technique that has grabbed the interest of practitioners and researchers due to its potential to help firms gain a competitive advantage, generate profits and minimize waste through on-demand production. Manufacturing sectors in India identifying the possibility of moving away from mass manufacturing and toward mass customization require a manufacturing model to enhance competitive advantage and tide over competitors and needed to identify operational agility to enhance MC. For organizations to comprehend and facilitate their transition to mass customization, it is required to build strategic roadmaps that specify their future directions[182]. This chapter answers research question, "***RQ2:*** *How can an organization implementing MC to compete in the market, specially the manufacturing sector of Indian origin?"* and is based on research objective 2 which was to identify a set of constructs to develop a manufacturing model .

Based on the above research objective, an extensive LR was undertaken to identify constructs to develop a manufacturing model framework that will facilitate mass customization implementation. A hypothesis was developed to statistically validate the framework. A questionnaire was developed to gather information to test the hypothesis. Every influence-related characteristic was addressed, and the respondents were to indicate their opinions. Descriptive statistics refers to the numerical and graphical techniques used to arrange, present, and analyse the information obtained from questionnaire replies. The kind of descriptive statistics that are used to characterise a variable in a sample depends on how much measurement has been done. Descriptive statistics can be a useful tool for summarising data and characterising the sample, but they cannot provide information for causal analysis. EFA, a statistical

technique, is used to reduce many observed variables to a small number of "factors/components," illuminating similar characteristics within the variable clusters. Confirmatory factor analysis (CFA) was utilized to establish a relationship between the observed variables and the underlying latent construct(s). The manufacturing model was tested against 276 valid responses from Indian professional experts using structural equation modelling (SEM). The statistical tool used for analysis was SPSS 23 (For EFA) and Amos Graphics 23(for CFA and SEM). The flow of the chapter is presented in Figure 5.1.

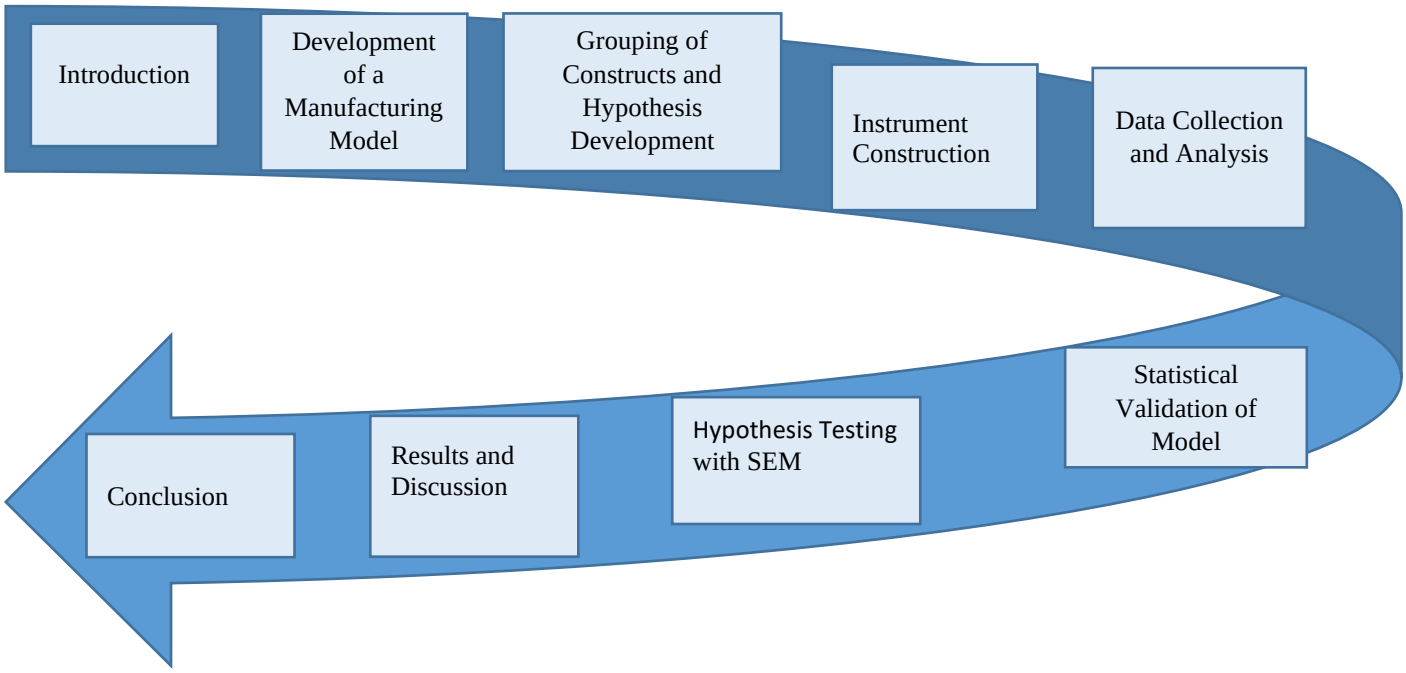

Figure 5.1: Flow of Chapter 5

The model that links observed values to latent variables is the measurement model. The structural model relates latent variables to one another. The measurement model examines relationship between latent variables and their measures. The structural model assesses the interrelationships between latent variables. Typically, to assess the measurement model, researchers analyse the structural model by allowing all latent variables to correlate[100]. In this situation, a SEM application called confirmatory modelling is usually used. The researcher wants to find out how well the model fits the data. The proposed model is said to have been confirmed if a researcher in this case is able to

acquire a satisfactory fit of the offered models. The general approach for conducting a SEM analysis, [100], is provided in Figure 5.2.

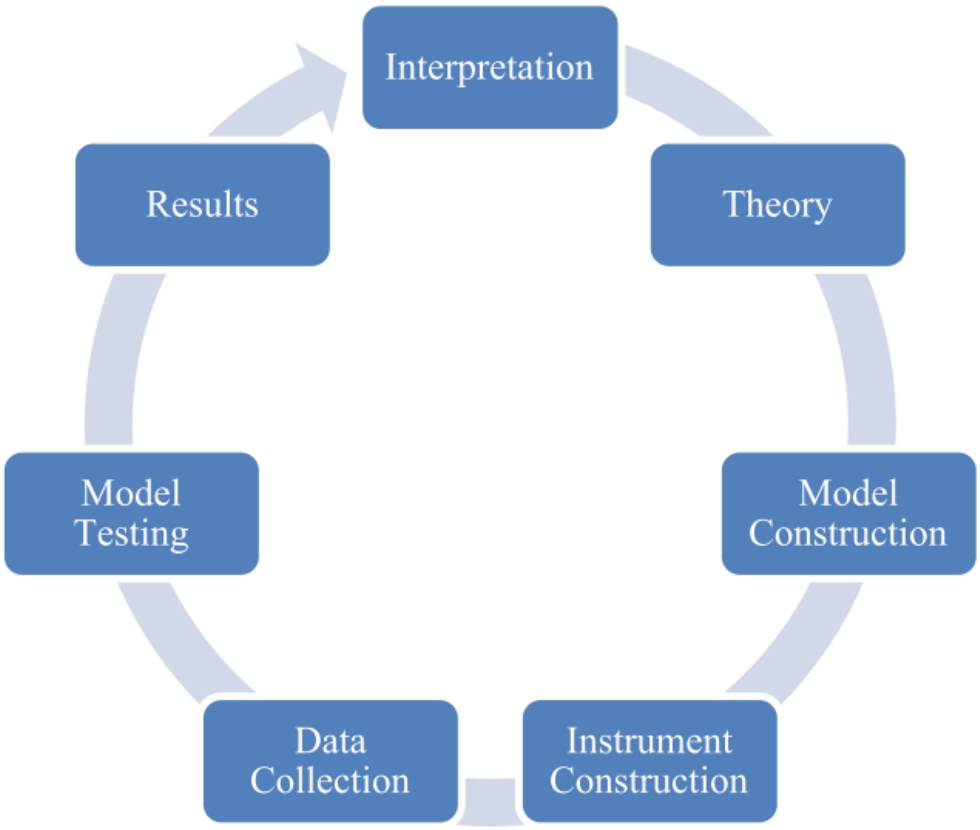

Figure 5.2: General approach for conducting a SEM analysis, Based on [100]

5.2: Development of a Manufacturing Model (Based on Theory)

Developing a manufacturing model that allows for mass customization will require extensive research, as greater coordination and integration of all product design, manufacture, and distribution processes are necessary[151][175]. Managers must enhance mass customization skills using manufacturing and organizational design concepts to address internal and external supply chain quality concerns[46]. A company's agility and flexibility, essential for MC capabilities, are significantly impacted by the combination of suppliers and customers[182]. Hence, the constructs were further explored and identified to be grouped into four groups.

The manufacturing model in this study is based on a theoretical model of the four pillars of mass customization proposed by researcher Hart [60]and is further strengthened by investigating the relationship between MC for competitive advantage from the literature. The four pillars of MC along with constructs are presented in Figure 5.3. The pillars and the respective constructs are explained in the next section along with literature references.

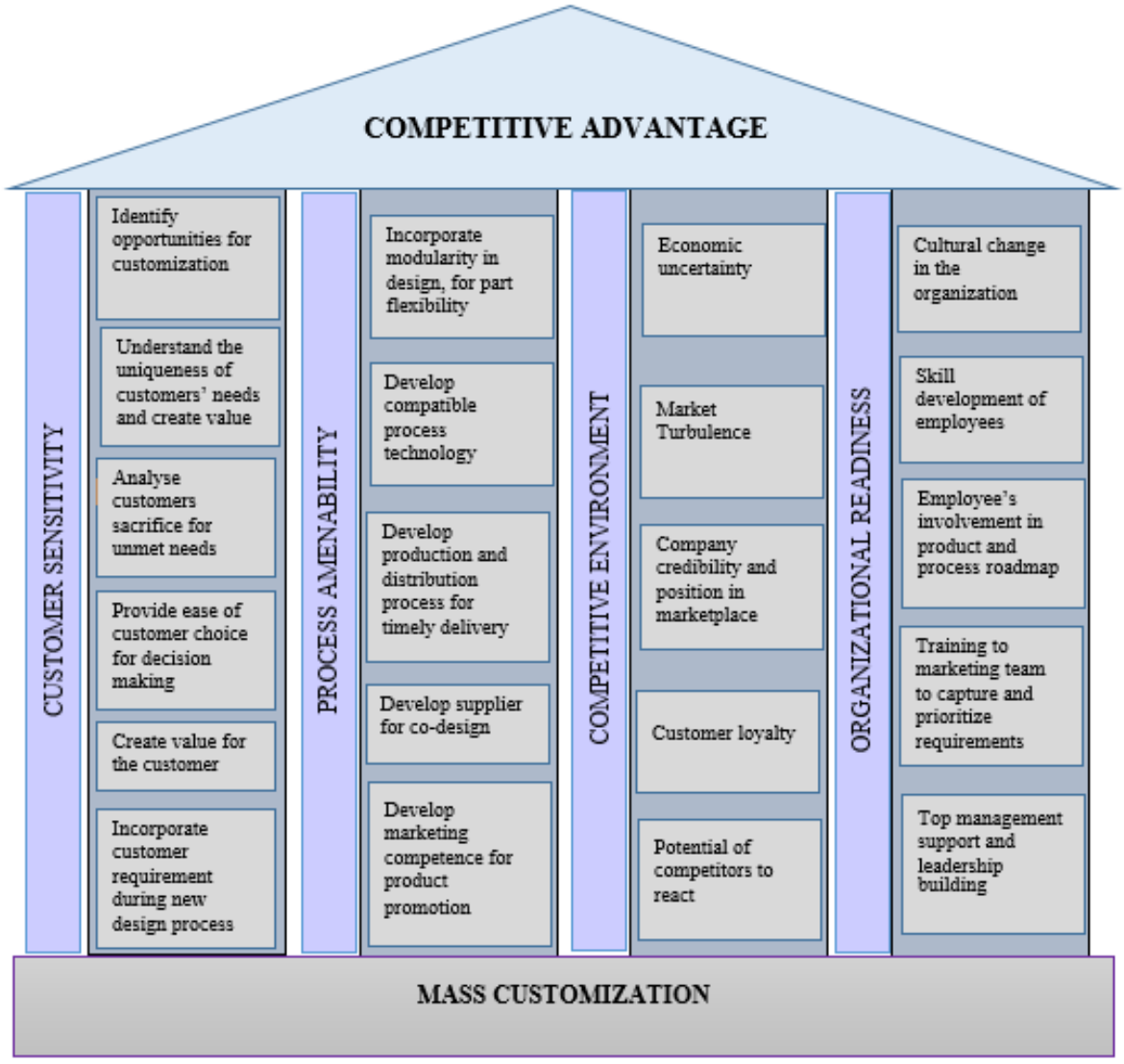

Figure 5.3: Manufacturing model: Four Pillars of Mass Customization

5.2.1 Grouping of Constructs and Hypothesis Development: The hypothesis was developed to explore the empirical indication of the influence of these constructs on mass customization to gain a

competitive advantage. The constructs were grouped into four groups (pillars) as explained by the model in the previous section, namely Customer sensitivity, Process Amenability, Competitive environment, and Organizational readiness. The grouping of the constructs along with hypothesis development on the literature review, are explained in detail:

Customer Sensitivity: The uniqueness of customers' demands and consumer sacrifice for unmet needs are the primary drivers of customer customization sensitivity [60]. To create mass customization capability, organizations must improve their operational efficiency, which necessitates the interchange of information between customers, salespeople, and technical personnel [58]. Customers must transform their wants and demands into particular product requirements [4] by customizing, setting, matching, or altering a solution, limiting the solution space to options already represented in the system's fulfilment, and converting consumer co-design data into customer knowledge for strategic planning and innovation [69][186]. Customer input to establish features and pricing requirements of personalized products to meet consumers' particular requirements cheaply and promptly [70], and a study of consumer buying patterns[37] can contribute to success in this field. Quick customer response for the implementation of MC is built on an arrangement that connects consumer voice to product design, customer relationship management, regular market surveys, and understanding client grievances for product improvement [130].

Identify opportunities for customization (CS1), understand the uniqueness of customers' needs (CS2), Analyse customer's sacrifice for unmet needs (CS3), Provide ease of customer choice for decision making (CS4), Create value for the customer (CS5) and incorporate customer requirement during the new design process (CS6) are the constructs under the head of Customer sensitivity. Thus, the following hypotheses were proposed:

Hypothesis H1: *Customer sensitivity is positively related to MC.*

Process Amenability: This pillar encompasses a wide range of factors, including technology, marketing and strategy, design, production, and distribution[60].For mass customization to be successful, new technology needs to be incorporated and coordinated with individuals and organizations [38]. To assist companies be the first to market with distinctive, customised products, MC mandates flexible manufacturing practices.[112] to manage the complexity of mass customization [187]. Greater product diversity entails greater coordination challenges [175][138], resulting in greater information processing requirements [175].A corporation can better utilise its suppliers' skills and capabilities by involving them in quality improvement and the creation of new products, which reduces component mismatches and reduces lead times and development costs for new products [188][128]. Collaboration with suppliers for new product development and standards by firms is vital since modules rea consistent specification [46]. Modular product design is based on modular components that may be assembled into several end products [189], resulting in increased product volume and variety [40]. Modularity primarily influences the desirability of products by developing tenuously connected modules that may be procured from vendors [27] and merged according to consumer requirements and manufacturing processes [51]. To incorporate values that are significant to clients into the design, it is crucial to stay in continual communication with them and involve them in the design process [27].

Incorporate modularity in design, for part flexibility (PA1), Develop compatible process technology (PA2), Develop production and distribution process for timely delivery (PA3), Develop supplier for co-design (PA4), and Develop marketing competence for product promotion (PA5) are the factors under the head Process Amenability. The following hypotheses are based on the previous reasoning:

Hypothesis H2: *Process Amenability is positively related to MC.*

Competitive Environment: Competitive environment, economic uncertainty, market turbulence, firm credibility and position in the marketplace, as well as consumer loyalty, are all elements to consider in

the journey to mass customization [60]. Researchers have advocated that enterprises that change from MP to the novel paradigm of MC will acquire a competitive benefit [12] due to the growing awareness of mass customization. Organizations require a greater diversity of supply to meet heterogeneous and changeable consumer demand, which upsurges the ambiguity in forecasting demand for each type of product. This causes scarcities, quality concerns, and extended lead times in supplier parts, which causes manufacturing delays and limits a company's capacity to mass customize [175]. To successfully adapt to altering market wants, MC capability development necessitates extraordinary levels of process flexibility and agility inside a company[25], as well as excellent internal integration across multiple roles. Mass customization is a notion that has been put into practice to react quickly to dynamic changes [190]. This method not only improve resilience, preserve operations, and support personnel during economic downturns, but also maintain a competitive advantage and accelerate business growth[130].

Economic uncertainty (CE1), Market Turbulence (CE2), Company credibility and position in the marketplace (CE3), Customer loyalty (CE4), and the Potential of competitors to react (CE5) are the factors in Competitive Environment. The following hypothesis is proposed based on the above research findings:

Hypothesis H3: *Competitive Environment is positively related to MC.*

Organizational Readiness: Organizational readiness demands a thorough examination of the organization's approaches, culture, and resources [41] to determine the extent of similarity between the commercial opportunity offered by mass customization and the organization's capacity to profit from it [60]. For competitive advantage, enterprises must integrate, build, and reconfigure available resources to satisfy the expectations of a continually changing environment [47]. Before transitioning from a conventional mass production setup to a successful MC firm, enterprises must make significant changes to their historical mindsets and practices [156], since mass customization involves true change management initiatives in existing enterprises [69]. To resolve the hindrances faced by organizations

while implementing mass customization, intensification of the training of designers and personnel reassignment needs to be considered for the implementation of MC and enhancing their market competitiveness[57]. A team of employees with cross-functional abilities is necessary for organizational success [3]. The idea of MC is promoted as a marketing strategy that enables the product to be personalized while also attracting a lot of clients [53]. Hence organizations require to bring a cultural change, involve their workforce in all phases of MC implementation, upgrade and train employees for MC innovative ideas, and train their marketing team to understand the desire of customers and market requirements that need to be converted into various MC aspects of design. Such organizational readiness brings about operational agility for MC adaptation and implementation. Organizations have unique operational capabilities with collaborative relationships with the suppliers, flexible, innovative, and adaptive work culture has strong MC [3]. Researchers emphasized that top management's participation in problem resolution was crucial during crisis and conflict, therefore all across the execution phase, it was essential to simultaneously enhance production, process, and product on the strategic and tactical level, which might be a challenging assignment for top management [37]. Effective leadership for analysing future market potential, participation to ensure technical, economic, and personnel support, aid during obstructions, and strategic monitoring of MC projects and appraisal of their progress are the most important criteria for mass customization success[130]. Organizations that are flexible ensure mobility, agility, and adaptability, and are more capable to reduce the response time to demand changes[136]. Companies that are self-sufficient, self-organized, linked with intelligent digitalization and forms of communication, seem to have independent entity management teams, utilize additional supplier networks, guarantee better supply chains' capacity and access to external resources, have a protocol in place and diverse supply alternatives, and facilitate collaboration among supply chains are more ready for MC implementation.

Cultural change in the organization (OR1), Skill development of employees (OR2), Employee’s involvement in product and process roadmap (OR3), Training to the marketing team to capture and

prioritize requirements (OR4), Top management support and leadership building (OR5) are the factors considered under Organizational readiness. Thus, the following hypotheses were proposed:

Hypothesis H4: *Organizational readiness is positively related to MC.*

Mass Customization: MC is becoming a more important strategic goal as competition grows and customers become more assertive[36]. In today's era of globalization and competitive business environment, business excellence is important which needs coordination between business performance and manufacturing strategy. The manufacturing sector is facing tremendous competition concerning competitive pricing, quality improvement, marketing strategy, manufacturing flexibility, and product and process innovation. Mass Customization could be a balance between product variety and cost and many researchers found it a strategy manufacturing organizations require to compete globally in terms of cost, quality and flexibility[175].Persisting dynamic and turbulent environment requires organizations to adopt new strategies that can help them survive in this competitive environment[71]. The mass customization paradigm can prove an efficient tool for achieving business goals.

The product can be customized on a large scale (MC1), Product variety can be enhanced at the same cost and quality (MC2), Product can be designed based on customers' requirements (MC3), Product can be delivered on stipulated time (MC4) are the enabler for Mass Customization. The following hypothesis is proposed based on the previous arguments:

Hypothesis H5: *Mass customization is positively related to competitive advantage*.

5.2.2 Research Model: The four pillars of mass customization developed by researcher Hart [60]were adopted as the manufacturing model based on the research gap, and a preliminary collection of several factors was generated based on a literature review, experience surveys, in-depth interviews, focus groups, and critical incidents [191]. The initial objective is to identify and categorise the network of connections to select the best model for the investigation. The definition will determine whether the

constructs are exogenous or endogenous. Next is to create a path diagram, which provides a pictorial representation of the relationships. Arrows drawn in a straight line show how one building influences another. Estimating the strength of the associations and assessing how well the data fits the model are both aided by a study of this data using SEM. Figure 5.4 illustrates the proposed research model, the hypothesized relationship, and the equivalent which has been previously explained in the hypothesis's development section. The main goals of this study are to see how different constructs stated by researcher Hart[60] affect the ability of an Indian company to mass customize products, which is necessary for competitiveness. The research model consists of five hypotheses. The challenge is determining whether this conceptual or theoretical model is accurate, and then modifying the system so that the theoretical model is suitable for inference.

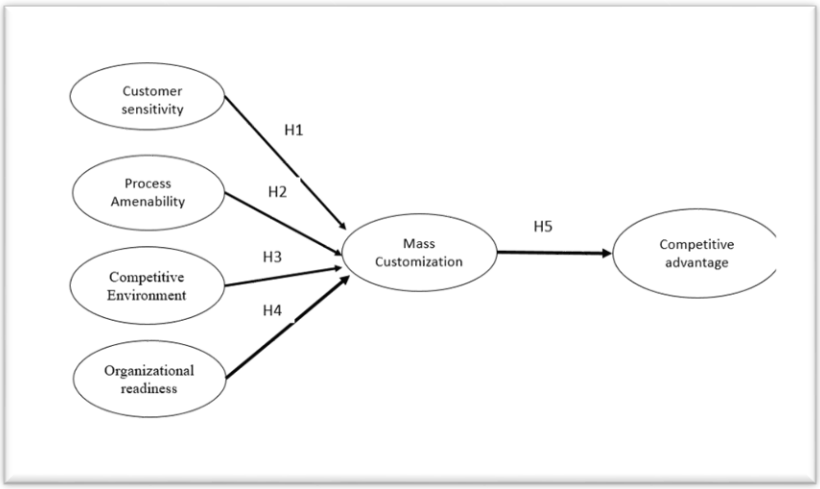

Figure 5.4: A Research Framework

Hypothesis H1: *Customer sensitivity is positively related to MC.*

Hypothesis H2: *Process Amenability is positively related to MC.*

Hypothesis H3: Competitive Environment *is positively related to MC.*

Hypothesis H4: *Organizational readiness is positively related to MC.*

Hypothesis H5: *Mass customization is positively related to competitive advantage.*

5.3 Instrument Construction:

Building the data-collecting tool that will be used to test the model is the next phase. The survey instrument, the target respondents, and the target organizations are all key components of the methodology, and they are all covered in detail in the relevant sections.

5.3.1 Design of Survey Instrument: A questionnaire is used to collect quantitative primary data. Utilizing a questionnaire enables the collection of quantitative data in a consistent manner, resulting in internally consistent findings. The next step was to create a questionnaire based on a literature study, with each latent variable analysed consisting of a set of items to be evaluated. This was done with a detailed understanding regarding elements like creating a questionnaire, and testing it in a pilot study for standardizing the incorrect questions[192]. It was also essential to 'pilot' or pretest' the survey with a small group of participants[100].

There were three sections to the questionnaire. The first component of the questionnaire covers questions about the respondents' demographics, the sort of industry in which they work, and the size of their company in terms of manpower and turnover. The next section contains questions about the respondents' perceptions of their level of MC skill. The final segment contains questions about how respondents feel about various aspects of MC. The response format was a five-point Likert scale, with values ranging from 1 to 5, with 1 indicating strong disagreement and 5 indicating strong agreement [193][194]. Questionnaire for Hypothesis Testing is provided in appendix 3.

The questionnaire was subjected to a panel examination to ensure that it was accurate and clear [33]. This panel consisted of ten experts who were specifically briefed about the research concept and its dimensions and was finalized by engaging individually with six experts from manufacturing firms who were Managers, Vice Presidents, General Managers, Assistant General Managers, and other positions, two consultants from the field with extensive experience, and two academic experts (Ph.D. holders from prestigious universities). The Experts of the decision panel are given in Table 5.1. The

expert screening process was developed in such a way that the panel of evaluators could discover items that were too identically worded [195]. The updated pool of topics was validated with a smaller group of respondents after the questionnaire was validated to ensure that all of the items were clear and understandable to the target audience [196]. The next step was scale purification, which involved using a refined and reduced scale for data collection while adhering to a sampling strategy that was adequately justified in the context of the study.

Table 5.1: Experts of Decision Panel

Expert	Position	Type of Industry/Expertise	Years of Experience
Expert 1	Global Mentor	Supply chain, mass customization consultant	28 Years
Expert 2	Director	Market Research and Innovation, Consultant	27 Years
Expert 3	Deputy General Manager	Product planning, Consumer Electronics	20 Years
Expert 4	Deputy manager	Product planning, Consumer Electronics	15 Years
Expert 5	Chief Mechanical Maintenance Manager	Operation and Maintenance, Furniture Industry	25 Years
Expert 6	Senior Project Manager	Project Expert, Automobile Industry	22 Years
Expert 7	Associate Partner	IT Expert, Textile Industry	25 Years
Expert 8	Vice President	Start-up, Entrepreneurship, Food Industry	20 Years
Expert 9	Academic Expert	Industrial and Manufacturing	17 Years
Expert 10	Academic Expert	Industrial and Manufacturing	25 Years

5.3.2 Target Organizations and Target Respondents: The quality of respondents is an important criterion for empirical research work**.** Respondent lists were obtained from reputable sources such as chambers of commerce and industry, trade organizations, and alumni associations. The most important criteria, limits, and obstacles were to identify respondents knowledgeable in the field of MC [99]. The

survey was conducted in India's manufacturing and processing industries. Respondents were chosen from companies that used or were familiar with such technology and implementation of MC.

5.4 Data Collection and Analysis:

The researchers can concentrate on data gathering in the appropriate format once they have defined relationships and a path diagram [100]. The steps include identifying the data collection method, analysing the respondent's characteristics, analysis of survey data, tests for potential bias in survey data and analysis of survey questions, all of which are explained in detail in the related sections.

5.4.1 Data Collection Method: To obtain responses from potential respondents, the questionnaire was distributed. In the case of offline mode, respondents were requested to schedule an appointment ahead of time. A soft copy of the questionnaire was then emailed to them, along with a supplemental background note on mass customization, to help them better comprehend the many aspects. A face-to-face interview was used to obtain responses from the respondents. In the instance of an online survey, participants were asked to make their beneficial inputs available. The questionnaire and background note on MC were emailed to 856 respondents from India's manufacturing businesses, representing a variety of industries. The filled-in surveys were examined to see if the respondents gave significant inputs once the online and offline responses were received.

5.4.2 Respondent Characteristic: The questionnaire and background note on MC was emailed to 856 respondents from India's manufacturing businesses, representing a wide range of industries. The filled-in questionnaires were examined after the online and offline responses were collected to assess if the respondents made relevant contributions. Out of the 856 surveys distributed, 286 were completed and returned. In the surveys, missing data and outliers were examined[197]. For 10 surveys, outliners were recorded, generating 276 acceptable responses. The final response rate was 32.24 %, which was higher than the minimum of 20 % proposed by Malhotra and Grover[198] to ensure the accuracy of the empirical research

5.4.3 Descriptive analysis of Survey Data: The descriptive analysis of the survey questions were done. The questions in section [A-1] of the questionnaire measure the level of knowledge, specialization, and understanding of the respondent as per the research area. Sample characteristic of respondents exhibits that as per job designation, top management constituted 34.6%, middle management 42.9%, administrative staff 8.3%, technical staff 3.9%, and academician 10.2% (Figure 5.5).

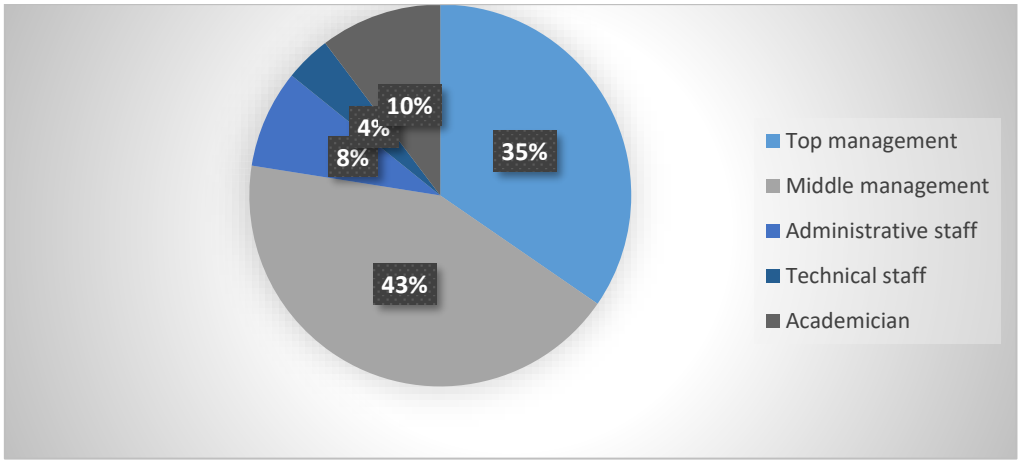

Figure5.5: Respondents' Profile as per Job Designation

This was followed by demographic profile as per job description where marketing professionals accounted for 17.3 % of the respondents, production 16.9 %, procurement 15.4 %, supply chain 11.4 %t, R&D 10.2 %, project management 8.3 %, others accounted for 20.5% (Figure 5.6).

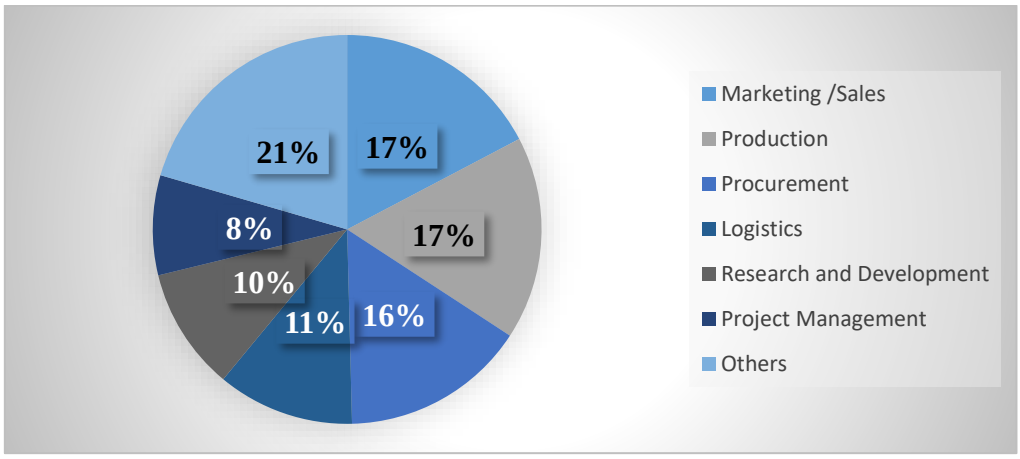

Figure 5.6: Respondents' Profile as per Job Descriptions

In terms of work experience, 7.9% of those polled have worked for their businesses for fewer than five years, 14.3 % of respondents have worked for the company for 5 to 10 years, 28.2 % for 10 to 20 years, and 49.6 % have worked for the company for more than 20 years (Figure 5.7).

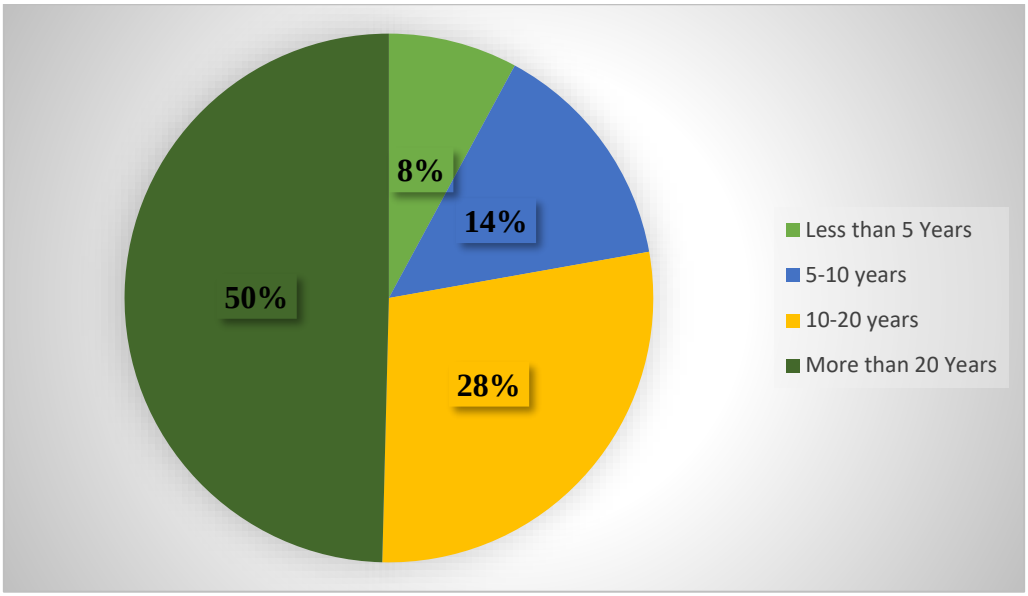

Figure 5.7: Respondents' Profile as per Work Experience

In terms of educational backgrounds, respondents had 3.9 % post-doctoral, 18.5 % Ph.D., 55.1 % postgraduate, 17.9 % graduate, and the rest diploma holders (Figure 5.8).

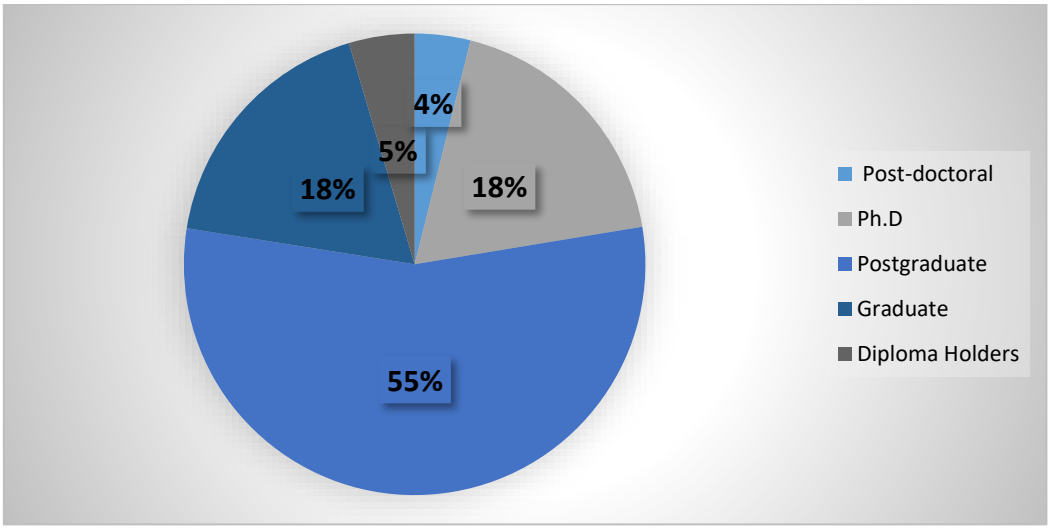

Figure 5.8: Respondents' Profile as per Educational Background

The section A-2 of the questionnaire measure the type of organization that is involved in the study. The Sample characteristic of the surveyed organization consists of consumer electronics 28.5%, interiors, and decors 28.1%, automotive 14.2%, apparel, and footwear 19.5%, Food Industries 9.5%, rest were variable industries (Figure 5.9).

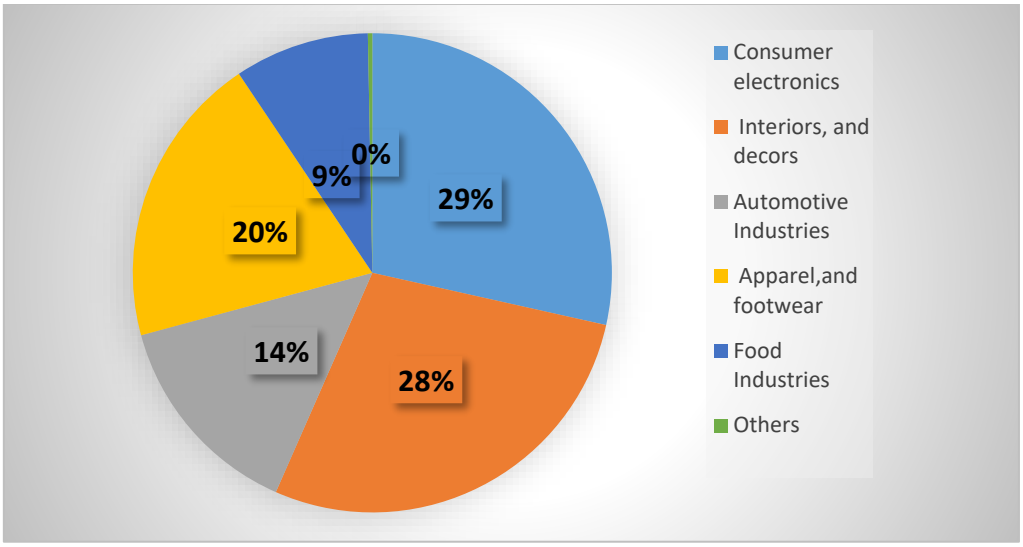

Figure 5.9: Respondents Profile as per Sector

Concerning the strength of workers, organizations with more than 1000 workers were 32.7%, 1000 to 500 was 25.6%, 200–500 was 18.5%, 100–200 was 11%, and less than 100 was 12.2% (Figure 5.10).

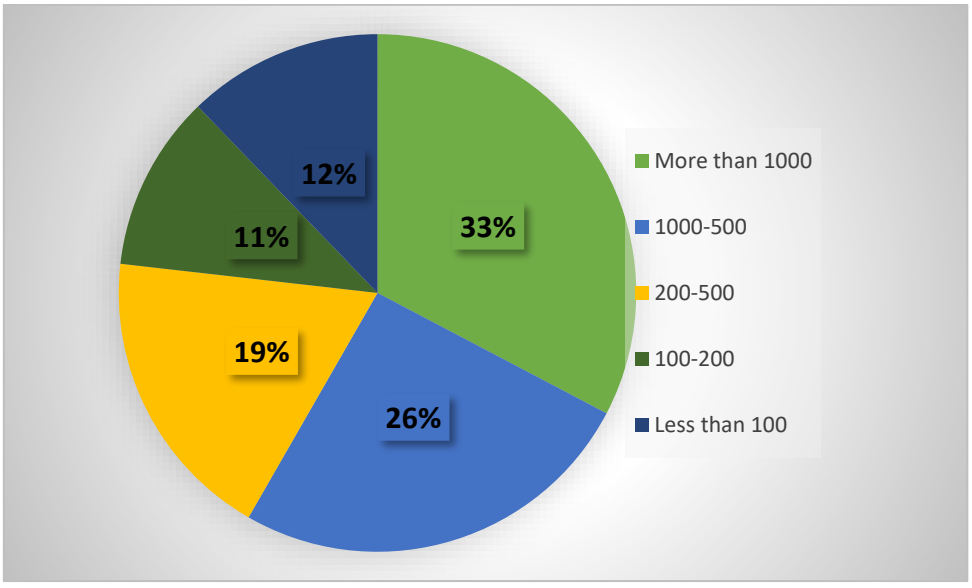

Figure 5.10: Respondents Profile in terms of manpower

Concerning annual turnover in crores, for less than 10 was 21.7%, 10 to 50 was 15.4%, 50 to 100 was 9.8 %, 100 to 500 was 17.3%, and more than 500 was 35.8 % (Figure 5.11).

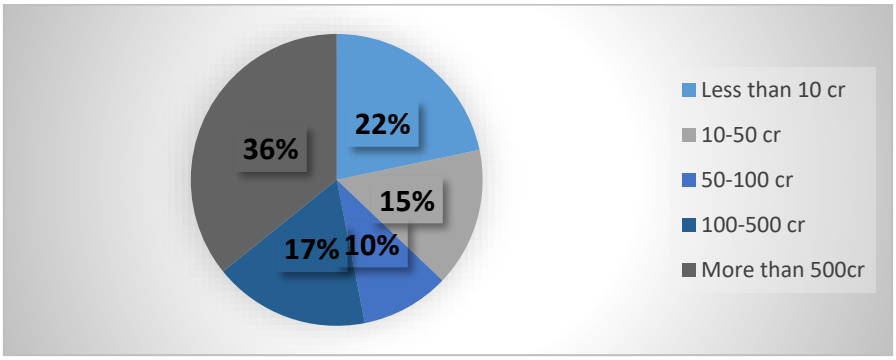

Figure 5.11: Respondents Profile as per Annual Turnover (Crores)

5.4.4 Tests for potential bias in survey data: The mail survey has drawn criticism for not receiving responses the reasons of bias. If respondents significantly differ from non-responders, one cannot infer how the complete sample would have behaved from the data. A crucial step before the selection is applied to the entire population[199]. Statistical bias refers to an error in the design of the experiment or the gathering of the data that leads to outcomes that are not true representations of the population. Here, T-Test is conducted for non-response bias and Harman's single-factor test for common method bias. T-Test method is commonly used by researchers to estimate the risk of late response bias[199]. T-test results show no difference between early and late respondents at the 0.05 level, ruling out response bias. The responses were examined for non-response bias, which might reduce response validity [200]. For this study, 20 survey items were chosen at random for analysis, two groups of 50 surveys were picked at random from the first and last waves of surveys received, and the results of the two groups were compared using t-tests[201] with the help of SPSS program. Using t-tests, there were no statistically significant differences between the 20 survey questions (Table 5.2). These results demonstrate that non-response may not be a problem even though they do not completely rule out the possibility of non-response bias. Scale purification and a confirmatory factor were consequently included in the data analysis. Common method bias may be the result of certain behaviours that

respondents engage in or that regularly influence their responses across various metrics while responding to a survey [202]. Due to the possibility of common method bias and the fact that the data originated from a single survey, the variables were subjected to Harman's single-factor test using SPSS. The results showed that a single component accounted for 48.25%, or less than 50%, of the entire variation. The results show that no one or general factor was present, and common technique bias was not thought to be an issue[202].

Table 5.2: T-tests to analyse Non-response Bias (Paired Samples Correlations)

Paired Samples Correlations Paired Samples Correlations, table, 1 level of column headers and 2 levels of row headers, table with 5 columns and 22 rows				
		N	Correlation	Sig.
Pair 1	Identify opportunities for customization	50	.091	.530
Pair 2	Analyse customer's sacrifice for unmet needs	50	-.261	.068
Pair 3	Provide ease of customer choice for decision making	50	.064	.657
Pair 4	Incorporate modularity in design, for part flexibility	50	-.091	.529
Pair 5	Develop compatible process technology	50	-.145	.317
Pair 6	Develop production and distribution processes for timely delivery	50	-.211	.141
Pair 7	Develop supplier for co-design	50	-.173	.229
Pair 8	Economic uncertainty	50	.178	.216
Pair 9	Market Turbulence	50	.011	.940
Pair 10	Company credibility and position in the marketplace	50	-.042	.774
Pair 11	Customer loyalty	50	-.122	.400
Pair 12	Cultural change in the organization	50	-.105	.470
Pair 13	Skill development of employees	50	-.228	.111
Pair 14	Employees' involvement in product and process roadmap	50	-.131	.364
Pair 15	The product can be customized on a large scale	50	-.012	.936
Pair 16	Product variety can be enhanced at the same cost and quality	50	.009	.953
Pair 17	The product can be designed based on customers' requirements	50	.030	.838
Pair 18	Market share growth/Reaching financial goals	50	-.165	.251
Pair 19	Increased sales volume/ Return on sales/revenue	50	-.094	.517
Pair 20	Reduce waste through on-time production	50	-.072	.621

5.4.5 Analysis of Survey Questions: The survey questions were designed to investigate the importance of elements that influence the performance of mass customization. The analysis of the four pillars is explained below:

Analysis of Dimensions of Customer Sensitivity: The respondents were asked to assign weights to customer sensitivity parameters based on their six characteristics. As shown in Figure 5.12, the most important enabler for customer sensitivity is understanding the uniqueness of customers' needs and creating value for customers, followed by identifying opportunities for customization, providing ease of customer choice for decision making, incorporating customer requirements during the new design

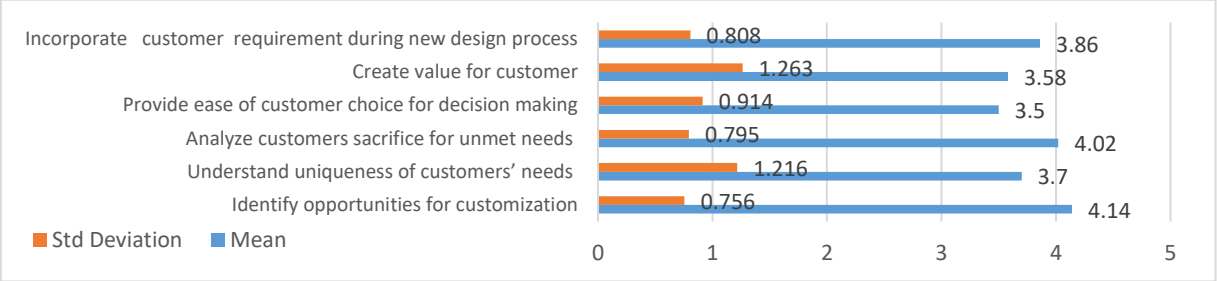

Figure 5.12: Importance of various parameters of Customer Sensitivity

Analysis of the importance of Process amenability: Based on the five aspects of Process amenability, the respondents were asked to provide weights to its characteristics As shown in Figure 5.13, the most important enabler for process amenability is develop production and distribution process for timely delivery, followed by develop supplier for co-design, next is develop marketing competence for product promotion and then incorporate modularity in design, for part flexibility and finally develop compatible process technology.

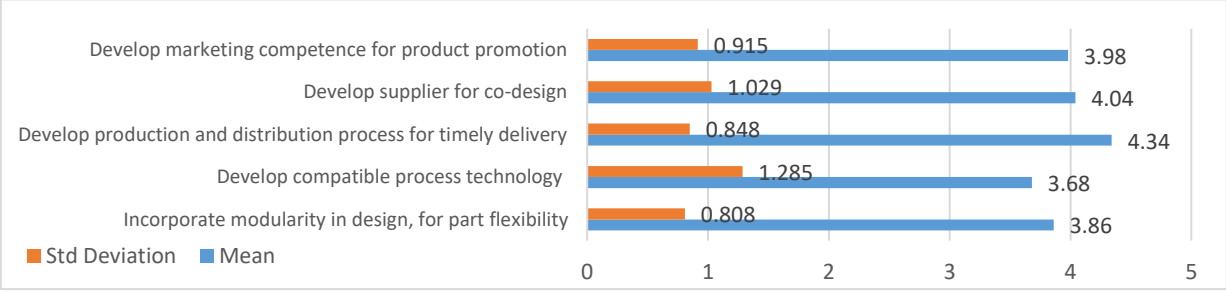

Figure 5.13: Importance of various parameters of Process amenability

Analysis of Dimensions of Competitive Environment: Based on the five aspects of the Competitive Environment, the respondents were asked to provide weights to its characteristics. As shown in Figure 5.14, the analysis showed that organizations should consider customer loyalty and the potential of competitors to react as the prime enabler to venture for mass customization, then further investigate company credibility and position in the marketplace to foray into this challenging paradigm. Economic uncertainty, followed by market Turbulence should be the motivating force for organizations to embrace MC.

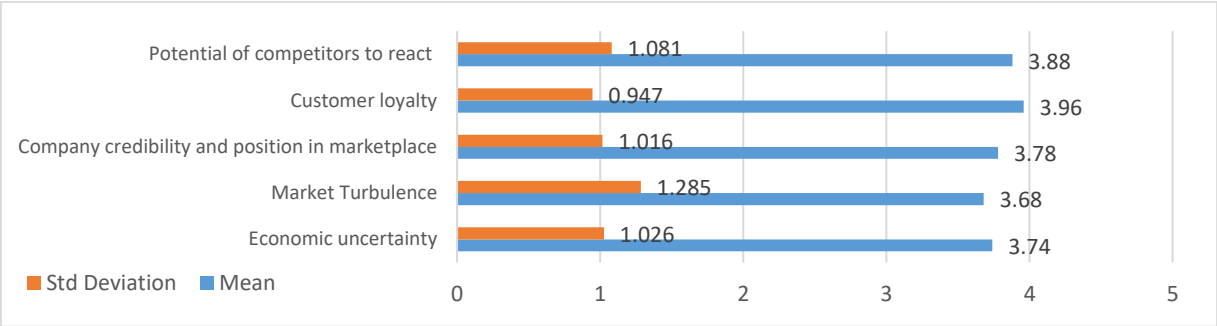

Figure 5.14: Importance of various parameters of the Competitive Environment

Analysis of Dimensions of Organizational Readiness: Based on the five aspects of Organizational readiness, the respondents were asked to provide weights to its characteristics. As shown in Figure 5.15, the analysis depicted that respondents felt organizations should prioritize the skill development of employees as the imperative step to create readiness in the organization for MC implementation, and also instigate top management support and leadership building. This should be followed by training the marketing team to capture and prioritize requirements and then employee involvement.

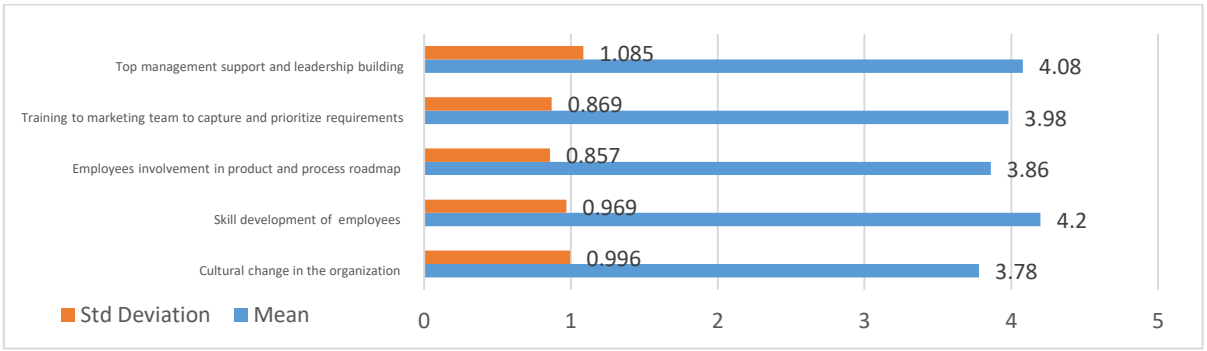

Figure 5.15: Importance of various parameters of Organizational readiness

5.4.6 Means, Standard Deviations, and Correlations: To acquire a thorough grasp of the data, descriptive statistical analysis and bivariate correlation data derived from the Pearson coefficient correlation approaches have been assessed. Table 5.3 reveals that the correlation coefficients for the constructs are greater than 0.40 at the 0.01 level (2-tailed), showing that they are positive and statistically significantly correlated[203]. However, because no relationship is greater than 0.70, multicollinearity is unnecessary[109].

Table 5.3: Descriptive analysis and correlations

	Mean	**SD**	**Customer Sensitivity**	**Process Amenability**	**Competitive Environment**	**Organization Readiness**	**Mass Customization**	**Competitive Advantage**
Customer Sensitivity	3.74	0.96	1					
Process Amenability	3.79	0.88	0.67	1				
Competitive Environment	3.80	0.79	0.59	0.70	1			
Organization Readiness	3.87	0.89	0.45	0.50	0.52	1		
Mass Customization	3.95	0.75	0.44	0.65	0.65	0.49	1	
Competitive Advantage	3.88	0.72	0.45	0.50	0.56	0.55	0.64	1

5.5 Statistical Validation of Model:

It is critical to ensure that the given theoretical framework is reliable and valid before testing it. This next section explains the reliability and validity of the research work. Exploratory factor analysis (EFA) is a statistical technique used to compress many observed variables into a small number of "factors/components," indicating that the variable clusters share some characteristics. In EFA, the connection between several observable variables is found and converted into a few closely related components. EFA, in essence, captures the clusters of observable variables that move regularly in unison[204]. Confirmatory Factor Analysis (CFA) allows the researcher to test the hypothesis that a

relationship between the observed variables and their underlying latent construct(s) exists. The researcher uses knowledge of the theory, empirical research, or both, postulates the relationship pattern, and then tests the hypothesis statistically. Both EFA and CFA are used to test the concept's reliability and validity.

5.5.1 Reliability and Validity Analysis: The rigor of research procedures and the veracity of study findings may be shown and communicated via reliability and validity. If research is to be beneficial, it must not mislead its users. This reliability is dependent on a variety of study elements, including the initial research topic, when and from whom data are obtained, how those data are analysed, and what conclusions are derived. When the scales are expanded to incorporate the field of prediction, the reliability concern increases.

One of the widely used and trustworthy statistics is Cronbach's alpha (Cronbach, 1951). Cronbach's Alpha measures the internal consistency, which is the average correlation of the survey instrument's items, and thus defines the reliability of the survey. Since the Alpha is the ratio of the two variances, its value ranges from zero to one. Alpha calculations, however, can take any value less than or equal to 1, even negative values; only positive values make sense because it depends on the measuring technique utilized. In the analysis, higher alpha values are considerably more preferred. Typically, to be reliable, alpha must have dependability. To examine construct reliability, Cronbach's alpha and composite reliability (CR)[205] are used. The correlated item–total-correlation (CITC) was calculated to do the reliability analysis. A CITC value of more than 0.30 is recommended. As indicate.in Table 5.4, all six constructions had CITC values greater than 0.30[206]. As a result, the scales are determined to be internally reliable, and the construct dependability of the measurement model is not impacted. For each construct, Cronbach's alpha value was calculated, which ranged from 0.90 to 0.95 (Table 5.4), all of which are higher than the recommended threshold value of 0.70.[206].

Table 5.4: Constructs, Measurement items with factor loads.

Constructs	Measurement Items	Factor Loads	Cronbach's Alpha (>0.70)	Item R-Square	CITC (>0.30)
Customer Sensitivity	CS1 Identify opportunities for customization. CS2 Understand the uniqueness of customers' needs and create value. CS3 Analyse customer's sacrifice for unmet needs. CS4 Provide ease of customer choice for decision making. CS5 Create value for the customer. CS6 Incorporate customer requirements during the new design process.	0.902 0.927 0.845 0.883 0.926 0.865	0.958	0.814 0.859 0.714 0.780 0.857 0.748	0.714- 0.874
Process Amenability	PA1 Incorporate modularity in design, for part flexibility. PA2 Develop compatible process technology. PA3 Develop production and distribution process for timely delivery. PA4 Develop supplier for co-design. PA5 Develop marketing competence for product promotion.	0.825 0.765 0.881 0.872 0.863	0.924	0.681 0.585 0.776 0.760 0.745	0.635- 0.784
Competitive Environment	CE1 Economic uncertainty CE2 Market Turbulence CE3 Company credibility and position in the marketplace CE4 Customer loyalty CE5 Potential of competitors to react	0.771 0.758 0.851 0.868 0.873	0.917	0.594 0.575 0.724 0.753 0.762	0562- O.835
Organizational readiness	OR1 Cultural change in the organization OR2 Skill development of employees OR3 Employee's involvement in product and process roadmap OR4 Training to the marketing team to capture and prioritize requirements. OR5 Top management support and leadership building	0.866 0.924 0.869 0.914 0.918	0.954	0.750 0.854 0.755 0.835 0.843	0.754- 0.867
Mass Customization	MC1 Product can be customized on a large scale MC2 Product variety can be enhanced at the same cost and quality MC3 Product can be designed based on customers' requirements MC4 Product can be delivered on the stipulated time	0.848 0.833 0.862 0.830	0.908	0.719 0.654 0.740 0.689	0.647- 0.782
Competitive advantage	CA1 Market share growth and reaching financial goals CA2 Acquiring a new customer CA3 Increased sales volume/ Return on sales/revenue CA4 Increased product variety CA5 Reduce waste through on-demand production	0.815 0.812 0.846 0.783 0.813	0.906	0.664 0.659 0.716 0.613 0.661	0.584- 0.703

5.5.2 Exploratory Factor Analysis of Model: Exploratory Factor Analysis is a multivariate technique that deals with the assessment of the likelihood that a few latent variables will be able to explain a variety of variables. EFA is used to test the scales' unidimensionality, it is therefore employed to assess the nature of the link between the respondent and the variable. The first step in determining if a given set of data is adequate for EFA is to assess two key factors: the sample size (number of samples) and the strength of the association between indicators. Kaiser Meyer Olkin (KMO) is used to evaluate the sampling's adequacy [204], and Bartlett's test of sphericity, which is a measure of the multivariate normality of a set of distributions and evaluated the null hypothesis in SPSS, is used to determine the strength of the relationships between the variables[204]. EFA with principal component analysis and varimax rotation with Kaiser normalization is carried out[70] using SPSS. The Kaiser Meyer-Olkin value of 0.941 is higher than the suggested minimum value of 0.5 [204], indicating that the sample size is sufficient.

SPSS 23 and Amos Graphics is used as a statistical tool because it offers a simple graphical user interface that makes it simple to create models using popular online sketching software. It can employ either an intuitive graphical or programmatic user interface to develop attitudinal and behavioural models that reflect complicated interactions more accurately than with conventional multivariate statistical techniques. It includes an intuitive interface for bootstrapping techniques that may be used for parameter estimation, effect estimation, sample means, sample variances, sample covariances, correlations, model comparisons, and comparisons of estimation techniques.

Table 5.5 shows how six EFA components affect the loadings of measuring scale variables. It meets the requirement of clarifying the factors and the hypothesized model based on theory, because components 1, 2, 4, and 5 correspond to the four pillars of mass customization, namely Customer Sensitivity, Organizational Readiness, Competitive Environment, and Process Amenability, and components 3 and 6, correspond to Competitive Advantage and Mass customization.

Table 5.5: Rotated Component Matrix

Measurement Items	Component					
	1	2	3	4	5	6
Create value for the customer	.880	.156	.140	.113	.218	.084
Understand the uniqueness of customers' needs	.840	.161	.171	.211	.200	.167
Provide ease of customer choice for decision making	.832	.162	.196	.150	.201	.082
Identify opportunities for customization	.832	.128	.160	.208	.216	.110
Incorporate customer requirements during the new design process	.818	.092	.150	.164	.268	.043
Analyse customer's sacrifice for unmet needs	.794	.185	.167	.220	.164	.087
Skill development of employees	.156	.865	.206	.140	.164	.132
Employees' involvement in product and process roadmap	.134	.855	.173	.075	.135	.128
Training the marketing team to capture and prioritize requirements	.213	.851	.200	.134	.129	.123
Cultural change in the organization	.100	.848	.185	.178	.109	.110
Top management support and leadership building	.181	.843	.213	.129	.174	.158
Increased sales volume/ Return on sales/revenue	.189	.164	.822	.119	.094	.152
Market share growth/Reaching financial goals	.189	.264	.765	.135	.083	.128
Reduce waste through on-time production	.139	.183	.758	.154	.188	.217
Acquiring new customers/Perceived customer value	.180	.138	.753	.177	.217	.190
Increased product variety	.159	.242	.753	.127	.016	.186
Market Turbulence	.178	.084	.129	.834	.202	.169
Economic uncertainty	.211	.065	.135	.792	.195	.166
The potential of competitors to react	.190	.250	.160	.742	.241	.197
Customer loyalty	.301	.214	.178	.679	.203	.218
Company credibility and position in the marketplace	.217	.196	.246	.677	.313	.205
Develop marketing competence for product promotion	.250	.152	.168	.279	.765	.158
Develop production and distribution processes for timely delivery	.317	.208	.121	.203	.746	.235
Develop supplier for co-design	.268	.173	.145	.295	.735	.206
Incorporate modularity in design, for part flexibility	.332	.149	.060	.267	.715	.217
Develop compatible process technology	.286	.176	.196	.182	.686	.188
The product can be customized on a large scale	.096	.183	.174	.245	.165	.817
Product variety can be enhanced at the same cost and quality	.078	.168	.192	.236	.224	.786
The product can be designed based on customers' requirements	.161	.159	.266	.211	.227	.761
The product can be delivered on the stipulated time	.158	.157	.398	.154	.249	.684

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

5.5.3 Confirmatory Factor Analysis of Model: Following an exploratory factor analysis, a confirmatory factor analysis (CFA) is utilized to ascertain the structure of the study dataset. CFA is a confirmatory approach with a theoretical foundation[97]. The researcher might utilize this study to analyze the theoretical connections between the measured outcomes and the latent variables or factors. To assess the population covariance matrix using CFA, the researcher utilizes a hypothesized model. Through the confirmatory procedure, the main goal is to lessen the discrepancy between the observed

and anticipated variables. The number of constructs/factors and the manner of loading of the indicator factor are predetermined in CFA. Several goodness-of-fit indices are calculated for each hidden variable. Figure 5.16 shows a CFA model with the AMOS 23 program. Each item in the model is associated with a construct, and the covariance between those constructs is computed. The data were examined for skewness, kurtosis, and normality. There was no major violation found. According to the modification indices, no major changes were required for this model.

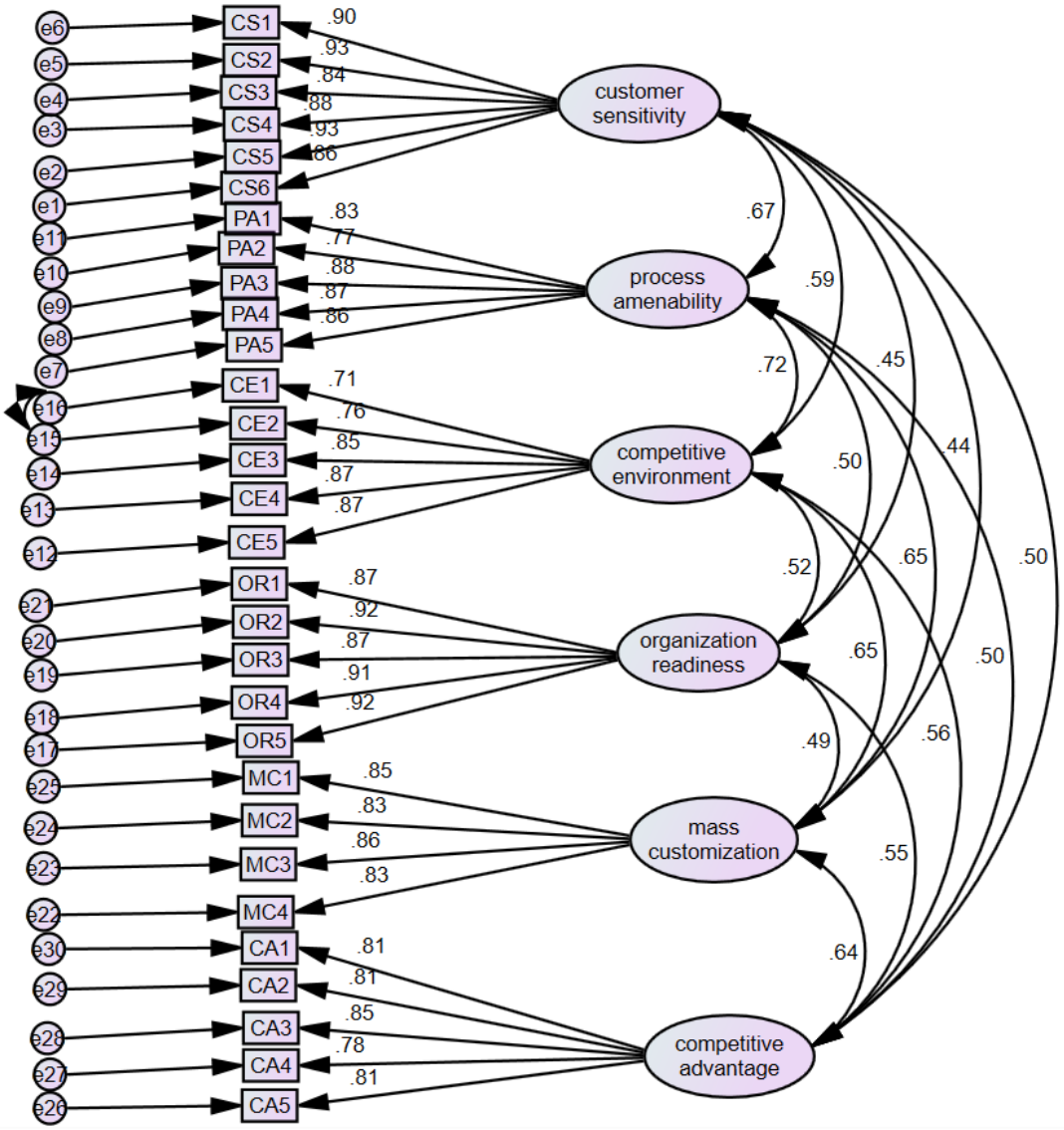

Figure 5.16: Path diagram showing the regression weights and the correlation between the constructs

After the factors are extracted using EFA and the quality of fit is confirmed using CFA, validation is done in two steps. Expert opinion is used to assess content validity and construct validity is divided into two parts: convergent validity and discriminant validity. The values of CR (Construct Reliability) and AVE (determine convergent validity (Average Value). The CR and AVE values should both be more than 0.7 and 0.5, with CR always being bigger than AVE[207]. Discriminant validity is determined using MSV values (Mean Shared Variance)[208]. The AVE value should always exceed the MSV value. Table 5.6 backs up the findings, and both convergent and discriminant validities exist.

Table 5.6: Assessment of Discriminant Validity and Convergent Validity

	CR	**AVE**	**MSV**	**ASV**	**Customer Sensitivity**	**Process Amenability**	**Competitive Environment**	**Organizational Readiness**	**Mass Customization**	**Competitive Advantage**
Customer Sensitivity	0.96	0.80	0.45	0.28	**0.89**					
Process Amenability	0.92	0.71	0.52	0.37	0.67	**0.84**				
Competitive Environment	0.91	0.66	0.52	0.37	0.59	0.72	**0.81**			
Organizational Readiness	0.95	0.81	0.27	0.25	0.45	0.50	0.52	**0.90**		
Mass Customization	0.90	0.71	0.42	0.33	0.44	0.65	0.65	0.49	**0.84**	
Competitive Advantage	0.90	0.66	0.41	0.30	0.45	0.50	0.56	0.55	0.64	**0.81**

Analysis of the model's validity should be accomplished by evaluating the construct validity of the measurement model and GOF indices[100]. A researcher can specify a structural model if the measurement model is valid by the established ranges of GOF and construct validity[209]. The CMIN/DF ratio, AGFI, GFI, RMR, NFI, CFI, and root mean square error are all indicators of acceptable fit.[208] and the adequate fit suggested for models is shown in Table 5.7. All the

measurement models have acceptable fit indices, and consequently signify the unidimensionality of the constructs.

Table 5.7: Model Fit Indicators for CFA

Indicators of Model Fit	CMIN/DF	AGFI	GFI	RMR	NFI	CFI	RMSEA
Result	1.73	0.83	0.86	0.032	0.91	0.96	0.050
Default Value	Less than 2	Greater than 0.8	Greater than 0.8	Less than 0.05	Greater than 0.9	Greater than 0.9	Less than 0.06

5.6 Hypothesis Testing with Structural Equation Modelling (SEM)

Structural equation modelling (SEM) the link between observable variables and latent constructs, it combines multiple regression analysis and factor analysis. Path diagrams are used in SEM to show the connections between observable and unseen variables. Both endogenous and exogenous variables are used in this analysis. Rectangles or squares are computed variables, but ovals or circles are latent variables. The data collection (or a combination of data sets) is modelled as the actual values of a collection of potential joint distributions that have a common probability distribution for a group of random variables. Using AMOS 23, SEM analysis was used to analyse the associations between each pair of postulated components. Figure 5.17 shows a path diagram created with the AMOS software., which portrays the results of the analysis derived from the SEM. Model fit indices values show good fit (CMIN/DF = 1.83; GFI = 0.85; AGFI=0.83, NFI=0.91, CFI=0.95, RMSEA = 0.05). All these values are satisfactory for the recommended range values.

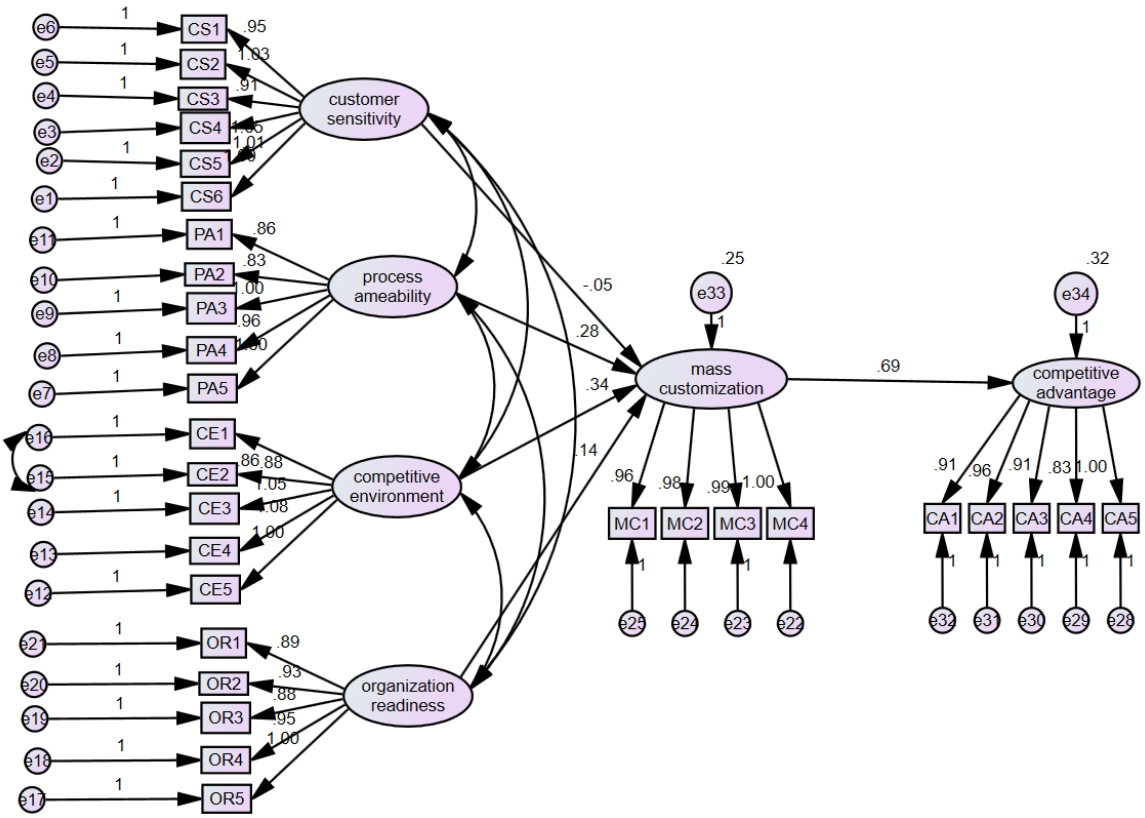

Figure 5.17: Path diagram of structural equation model

5.7 Results and Discussions:

The result of SEM analysis shows that in terms of the impact of customer sensitivity on MC , the SEM results do not support H1, the path coefficient is β =-.05, t= -.096, thus disagreeing with the suggestions of Hart (1995) that the customers' needs and wants, and his sacrifice for unmet needs require to be considered by any organization before shifting from mass production to mass customization. The result is surprising, but it may be because the analysis was carried out in India where mass customization is at its nascent stage, and respondents' ability to analyse the gap between products provided and products desired by the customer gives rise to mass customization was crucial. As hypothesized, a significant relationship between Process Amenability and mass customization is observed (β = 0.28, t= 4.07, significant at p<0.00), thus supporting H2. This concurs with the research by Hart (1995) that organizational enablers, marketing competence, supportive production and distribution team, and design aspects can enhance the mass customization of a firm. Hypothesis H3 is

supported (β = 0.34, t= 4.32, significant at p<0.00), acceding to Hart's research theory that a competitive environment promotes mass customization. Hypothesis H4 showing Organizational Readiness leads to mass customization is supported (β = 0.14, t= 3.12, significant at p<0.002), harmonizing with research by Hart (1995) that organizations need to identify the fit between business opportunity and organizations' ability to capitalize on this opportunity before venturing into mass customization. Finally, H5 is supported (β = 0.69, t= 10.23, significant at p<0.000), emphasizing that MC-capable manufacturing plants may dynamically modify their resource/skill mix to adapt to individual client demands, gaining a competitive advantage [175]. The result are shown in Table 5.8.

Table 5.8: Result of Hypothesis testing

	Hypothesis	**B**	**C.R(β)**	**p-value**	**Supported**
H1	Customer sensitivity is positively related to MC	-0.05	-0.096	0.33	Not Supported
H2	Process Amenability is positively related to MC	0.28	4.07	0.00	Supported
H3	The competitive environment is positively related to MC	0.34	4.32	0.00	Supported
H4	Organizational readiness is positively related to MC.	0.14	3.12	0.002	Supported
H5	Mass customization is positively related to competitive advantage	0.69	10.23	0.00	Supported

Theoretical Implication: During customer demand in a certain period, a manufacturing company must choose the best acceptable product configuration from a wide range of options to achieve effective MC, which in turn relies on the firm's capacity to effectively grasp client wants and obtain the necessary mix and quantity of components for timely assembly of the needed product configuration. Researcher Hart's [60]four pillars of mass customization were used to identify constructs, which are then followed by a systematic literature review to identify measurement items. The study used this

information to describe the links between mass customization and competitive advantage, as well as give empirical evidence for the proposed research technique.

COVID-19 had a considerable influence on operational, social, and financial sectors, as well as posing challenges to organizations attempting to accelerate the change of global value distribution models, effectively halting many Indian industries. The manufacturing sector in India is now at a crossroads with unprecedented consequences for manufacturers and supply chains[130]. A new method is required to limit the impact of COVID-19 and rethink risk management and contingency plans. This empirical model of mass customization can provide manufacturers with a solution to the pressing issues that must be addressed to make the business as stable as possible. This strategy will not only improve resilience, protect operations, and support people during the crisis, but it will also help businesses maintain a competitive advantage and accelerate growth after the economy recovers.

***Managerial Implications*:** The practical goal of the research is to provide strategic instructions to top-level manufacturing executives to encourage mass customization for business excellence. According to the findings of the study, the competitive environment has a significant impact on mass customization, which is consistent with Hart's (1995) research findings that organizations should shift from mass production to mass customization only when market turbulence occurs, resulting in homogeneous versus heterogeneous customer demand. However, the first-mover advantage can only be guaranteed if there is customer loyalty and a good reputation in the market. Because of the turbulence that has disrupted the mass market, mass customization should be regarded as an organizational approach. Firms should view market volatility as an opportunity rather than a hindrance or a threat to which they should escape [60]. For a diverse country like India, organizations need to consider the diverse and individualized needs of consumers, variable human choices, and inconsistent economic levels of customers for identifying what to mass customize. An organization should focus on setting up the product vision for the business unit while maintaining a big picture focus; evaluating

competitor offerings technically & commercially and identifying gaps to deliver according to human needs with close control on time to market.

Once the organization had identified its potential to venture into mass customization, it needs to strengthen the other three pillars simultaneously. Customer sensitivity that identifies the uniqueness of customer needs and sacrifices for unmet needs should be deciding factor for the type of mass-customized product, which should cogitate the voice of the customer during the new design process. The other pillar Process Amenability needs to empower production, process, distribution, the vendor for co-development, and the marketing team to be 'market ready' for mass customization. The fourth pillar, requires firstly, top management involvement (highest factor loading) and employee empowerment to ensure a cultural change, followed by skill development of employees for the successful attainment of mass customization goals.

5.8 Conclusion

The study has contributed to creating a manufacturing framework for mass customization deployment for competitive advantage. This will make it easier for Indian manufacturers to use MC as a business strategy. This model will assist the managers in identifying and prioritizing the variables that are crucial for the change from mass production to mass customization analysis is first performed to assess and validate the constructs. All of the items underwent the Cronbach alpha reliability test. The importance of the dataset was additionally confirmed using the KMO and Barlett's Test. Scales for various objects under the factors were then produced following the factor analysis. Convergent and discriminant validity results, together with the constructs, were considered in the CFA analysis. Each of the constructs included in the study's evaluation had its Composite Reliability assessed. All of the constructs turned out to be suitable for the values. The constructs' convergent and discriminant validity were assessed using the values of AVE and MSV. Structural equation modeling was used to test each of the five hypotheses. All the hypotheses except H1 was supported. The surprising outcome may be

due to the capacity of the respondents to understand how the distinction between the products given and those wanted by the client results in mass customization being a nascent concept since the analysis was carried out in India, where mass customization is still in its infancy. This is followed by verification of this manufacturing model with the help of case studies in the next chapter.

CHAPTER 6

CASE STUDIES IN MASS CUSTOMIZATION

6.1 Introduction

The manufacturing model created in chapter 5 and statistically validated requires further validation with the help of case studies, as per objective 3. The case study method is an effective tool for validation of theory or theory extension to encourage process change. This chapter will answer the research question "***RQ3:*** *What mass customization strategies are adopted by organizations?"* and explore the steps that Indian manufacturing companies have taken to implement mass customization and overcome the challenges faced. For conducting the case studies, three organizations of Indian origin were approached who have implemented mass customization. A questionnaire was established on the manufacturing model structure conversed in the previous chapter for the initial round of interviews, which was later modified, based on input from the interviewees. A case study protocol to conduct the interviews and discussions in the case companies was framed. Structured questionnaires were used to collect data during interviews and group discussions. Later, data analysis was done to find the validity of the manufacturing model framework. The MC implementation strategy and the challenges faced by the case companies are elaborated in result and discussion section. This is followed by the conclusion of the chapter. Figure 6.1 depicts the chapter's structure.

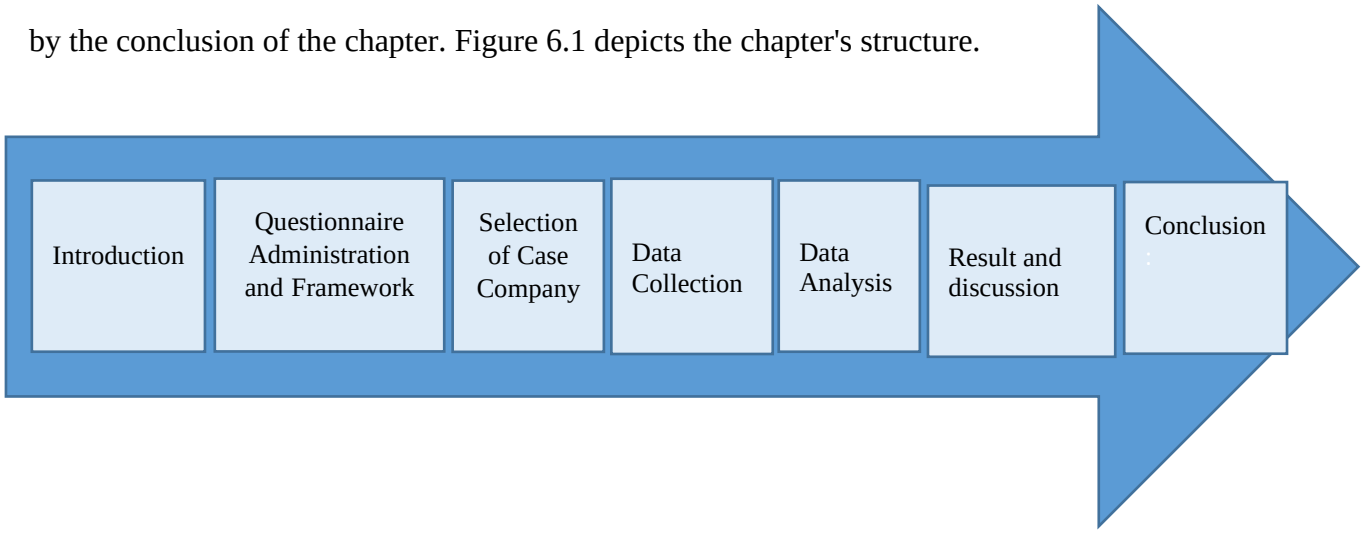

Figure 6.1: Flow of Chapter 6

6.2 Questionnaire Administration and Framework

The design of theory-building research with case studies benefits from a prior factor specification since it allows researchers to assess the factors more precisely. If these factors demonstrate to be significant as the study develops, the emergent theory will have a stronger empirical foundation[210]. Developing a conceptual framework will allow the researcher to meticulously and methodically explore the variables that will be a part of the analysis [59]. The framework developed in chapter 5 was identified to frame the questionnaire. The factors in the framework were further categorized under pre implementation, implementation and post implementation phase. This was done after discussion with experts from case study companies. The framework that was used to develop questionnaire during interview and discussion is depicted in Figure 6.2.

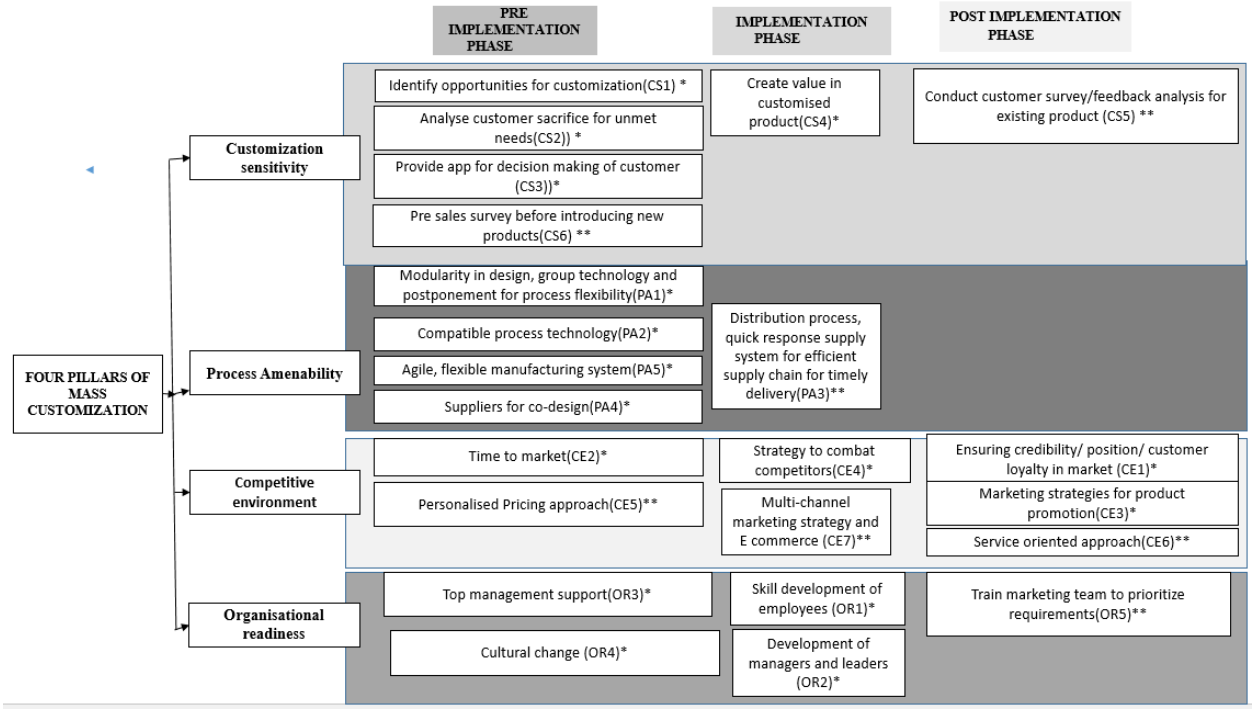

Figure 6.2: Conceptual Framework for mass customization

Here, in the framework expressed in Figure 6.1, (*) is considered the initial framework. These were used to develop a questionnaire for the initial round of interviews, which was later modified,

based on input from the interviewees and expressed as (**). The four pillars on which the framework is based, and the factors were discussed in detail to the interviewees. The discussion is provided bellow. Some more factors were added after discussion.

Customization sensitivity is the first pillar. Customer's customization sensitivity is driven by the individuality of individuals' demands and consumer compromise for unfulfilled wants [55]. Organizations must increase their operational efficiency to achieve mass customization capabilities, which necessitates the exchange of information between customers, salespeople, and technical workers [58]. By customizing, setting, matching, or altering a solution, restricting the solution space to alternatives already represented in the system's fulfilment, and converting consumer co-design data into customer knowledge for strategic planning and innovation[132],Customer feedback to create features and pricing criteria [70], as well as a study of consumer buying patterns [37], can help in this field.

Identifying opportunities for customization, analysing customer sacrifice for unmet needs, providing apps for the decision-making of customers, create value in customized products were identified as major factor of this pillar. Later, conducting customer analysis/feedback for existing products and–sale surveys for the new product were identified as two other factors after discussion with case study firms.

The second pillar, *Process Amenability*, covers enablers, branding and strategy, innovation, manufacturing, and distribution[60]. Across many industry segments, the competitive landscape is one of enduring and intensified levels of competition, which necessitates adaptability, timely delivery, and innovation. Only by integrating abilities, technological advancements, technical expertise, processes, and supplier partnerships, all of which are aided by strategies, can one produce mass-customized products and become agile[[84] [132][5]. A corporation can benefit at crucial stages of the manufacturing process by using modularity, which can increase the effectiveness of flexible

production systems Modularity can improve the efficiency of flexible production systems [46][13][38]. Postponement and mass customization tactics can help organizations achieve this flexibility[39].

Hence modularity in design, group technology and postponement for process flexibility, compatible process technology, agile, flexible manufacturing system, and supplier for co-design was identified as the primary factor for this pillar. Later, the distribution process, and quick response supply system[75] was added to this pillar, based on discussion with case studies firms and accessing literature support.

The *competitive environment*, the third pillar, must be stable. On the road to mass customization, the competitive landscape, economic instability, market turbulence, organizational credibility and positioning in the market, as well as customer retention, are all factors to consider.[55]. Customer bargaining is used to modify the price of things sold from enterprise pricing to customer negotiating[154]. Customers' knowledge enables producers to ascertain the specifications and pricing of new or customised products as well as localise imported goods and technology to quickly and affordably satisfy customers' specific needs[70].

The factors considered for this pillar were ensuring credibility, position, customer loyalty, time to market, marketing strategies for product promotion, and strategies to combat competition. Later, personalized pricing approach and multichannel marketing strategy were added, based on practices observed in case study firms.

The evaluation of the organization's attitudes, culture, and resources is necessary for the fourth pillar, *organizational readiness*[60]. To improve the flexibility of the manufacturing process and respond swiftly to discrete consumer needs, effective workforce management practices must be implemented[71]. For a manufacturing organization to be capable of mass customization, negotiation, knowledge seeking, performance orientation, critical thinking, and pattern recognizing are essential managerial skills[54].

Skill development of employees, development of managers and leaders, top management support, and cultural change were the factors identified for this pillar. Later, train the marketing team to prioritize requirements was added, based on the case study.

6.3 Selection of Case Company

Building theory from case studies necessitates careful case selection[210]. The research was conducted using a theoretical sampling strategy across several industries, to develop propositions and theories that could be applied to a wide range of enterprises [145]. Existing research suggests that the size of a organization has an influence on its operations and outcomes[116]. A thorough search for organizations of Indian origin that have implemented mass customization was conducted. Since mass customization is at its nascent stage in India, very few organizations were found who have successfully implemented mass customization and had a business model. Firms in the unorganized sector and service sector were excluded from the study, as the study aimed at identifying a framework for mass customization in Indian manufacturing sector. Out of the organizations shortlisted, only three organizations agreed to participate. The profile of the companies are presented in Table 6.1.A small enterprise, one medium-sized regional company, and one multinational with global activities were included in the research.

Table 6.1: Profile of Case Study Company

	Type of Industry	**Mass Customized Product**	**Turnover**	**Size of Enterprise**	**Profile of Expert**
FA	Furniture and Storage	Customised Storage	300 cr	Large	I_1-Product expert, I_2-Marketing and sales expert, I_3-IT expert, I_4-Head, Production planning
FB	Home Appliance	Customized Fans	100 cr	Medium	I_1- Production planning expert, I_2- IT expert, I_3- Marketing strategy Expert I_4- Operation Head, Fans Division
FC	Garment Industry	Fashion apparels	50L	Micro	I_1- Design expert, I_2- IT expert,I_3- Marketing Expert,I_4- Business Strategy Expert

Company FA is a large-scale enterprise with turnover of 300 crores and has diversified its product range in the fields of real estate, consumer products, industrial engineering, appliances, furniture, security, and agricultural products. One of the divisions of the company is engaged in serving the needs of mass customizations for storage requirements due to customer requirements for ready-to-fit storage space and less carpentry work at the site. Its modular design provides to add and modify storage units. The company had wide experience in Digital Commerce.

Company FB is a consumer durable company manufacturing Home Appliances, Electric Fans, Electric Motors, Sewing Machines and Pumps, Engines and Pump sets, Cooktops Hobs and Hoods, Water Coolers, and Dispensers, Auto Products. In is a medium scale enterprise with turnover of around 100 crores. It started its journey of mass customization with the Fans division.

Company FC is a small-scale enterprise with turnover around 50 lacs. It mass customizes women fashion clothes and is a fashion-forward digital company that uses technology and artificial intelligent solve the most common problem with garment fit. Their business model is to provide inspiring fashion that is also innovative and environmentally friendly. They offer the best fit in garments with 3D body scanning and digital personalization because they are a tech-based design firm (in store and online). Since not every client fit into the typical retail clothes chain, the firm feels that each body form should be honoured in its own unique way. The heart and soul of the firm reflects their respect for their customers and their choices. They strive towards a zero-waste policy and environmentally friendly practises.

6.4 Data Collection

Senior personnel were contacted, and the study's goals and objectives were explained, as well as providing relevant comments on the findings and ensuring anonymity (Nachmias and Nachmias 1992). The essential data for the study was gathered through focused interviewing, observations, and the compilation of accessible published works[211] resulting in data collection from numerous sources

rather than just one, allowing for data triangulation [212]. Most of the interviews were performed on-site, but a few were conducted over the phone. The researchers interviewed 12 production managers, quality managers, and business leaders at 12 separate times for an average of 90 minutes per session, with structured interviews serving as the primary data collection method. The profile of the interviewees are provided in Table 6.1. Understanding the mechanisms involved becomes achievable by investigating relevant process events[116],and by tackling critical challenges, new and emerging sectors can be explored[59]. As a result, interviewees were chosen following the mass customization implementation needs, beginning with important employees who know the most about all phases and can share many process-related descriptions. Proposals, newspaper articles, and books, as well as pilot projects, presentations, documents, and meeting minutes, were evaluated and analysed. These documents were assembled and reviewed to map and/or authenticate information. A large portion of the time spent acquiring information was spent assessing the consistency of the evidence from various sources. Guidelines from the most recent research on increasing retrospective data accuracy were used in the data collection procedure. The empirical part of the case study was investigated by the organization's lead interviewees after all of the materials had been examined and an initial case study narrative had been written[146]. Based on the frequency of incidences, the data were categorized into several groups. By comparing each episode to earlier occurrences in the same category, the researchers were able to build theoretical features of categories and the dimensions of these properties [146].

The interview process was based on methods adopted by eminent researchers [114]. The interviews were categorized into two sections. The first was an unrestricted conversation regarding their environment, operational methods, mass customization evaluation, and performance evaluation. The purpose of this interview was to learn more about their situation. A structured questionnaire was used in the second interview, the performance indicators on which questions were based are presented in Figure 1. At this stage, questions were modified according to inputs received from the interviewee. The data was collected using a case study protocol as presented in Table 6.2, based on [212].

Table 6.2: Case study protocol, based on [212]**.**

Source 1: Personal interview /telephonic interview/ Online meeting- as some interviewees were not available due to COVID-19 protocol (4 interviews and at least one and half hours per case)	
General information	Brief description of the interview: products that were mass customized, role performed by the interviewee in the department, and contribution to mass customization implementation.
Pre-Implementation Phase	What were the primary drivers behind the company's decision to install a mass customization system? How did the company's business processes get revised by the managers? What steps were taken to design a mass-customized product? What steps did the executives take to prepare the company for the MC business model? What were the most difficult challenges faced? What steps did the company take to overcome these obstacles? How were the company's suppliers or consumers prepared?
Implementation Phase	Did the implementation of MC require any special skillset in employees? What steps were taken by a firm to develop the skills in employees? What steps were undertaken to add value to the product? Did the organization redefine its supply chain and marketing strategy to combat competitors?
Post Implementation Phase	What steps were taken by organizations to ensure customer loyalty and increase the sale of mass-customized products? What marketing strategy was adopted for promoting mass-customized products in the market?
Source 2: Direct observations (at least one hour per each case) Plant tour	
Plant Visit	Examine the marketing, technology, manufacturing processes, sales, production, and functional areas from a broader viewpoint, and inquire about the products and processes from management.
Source 3: Official documents	
Company's website, News, and press. National database	Product offering; general information about the organization (background, vision, mission, product types, product features, technical data, applications, etc.). Details on new product developments, sales, financial information, employee details, etc.
Source 4: Internal documents	

6.5 Data Analysis

The research employed grounded theory and takes a qualitative methodology. When a researcher considers examining the opinions and perspectives of participants in order to construct a theory, the grounded theory appears to be a plausible alternative[213]. A data-driven analytical technique known as "open coding" clarifies concepts' characteristics and dimensions. In the open coding procedure, the text of each interview was examined phrase by phrase, step by step, and paragraph by paragraph. The main ideas were taken out and put into abstract categories based on the impression. Once the concepts have been retrieved and the categories have been chosen, the critical categories are grouped around the major areas' centre and connected using the axial coding [213].

The process flow chart of company FA is mapped with the four pillars of the manufacturing model along with potential factors that aided in the implementation stages. The process starts with the site supervisor inspecting and measuring the area. On-site, a member of the design team discusses 2D and 3D designs in the context of the customer's requirements. The final features and costs are offered after a discussion with the customer at the retail location. At the installation location, all electrical, plumbing, and mechanical work is finished. Following that, AutoCAD software is used to build the digital developing design. The collaborative customised design system, which may integrate all product kinds, serves the cabinet product agile manufacturing mode with small quantities and a range of needs. This is shown in Figure 6.3.

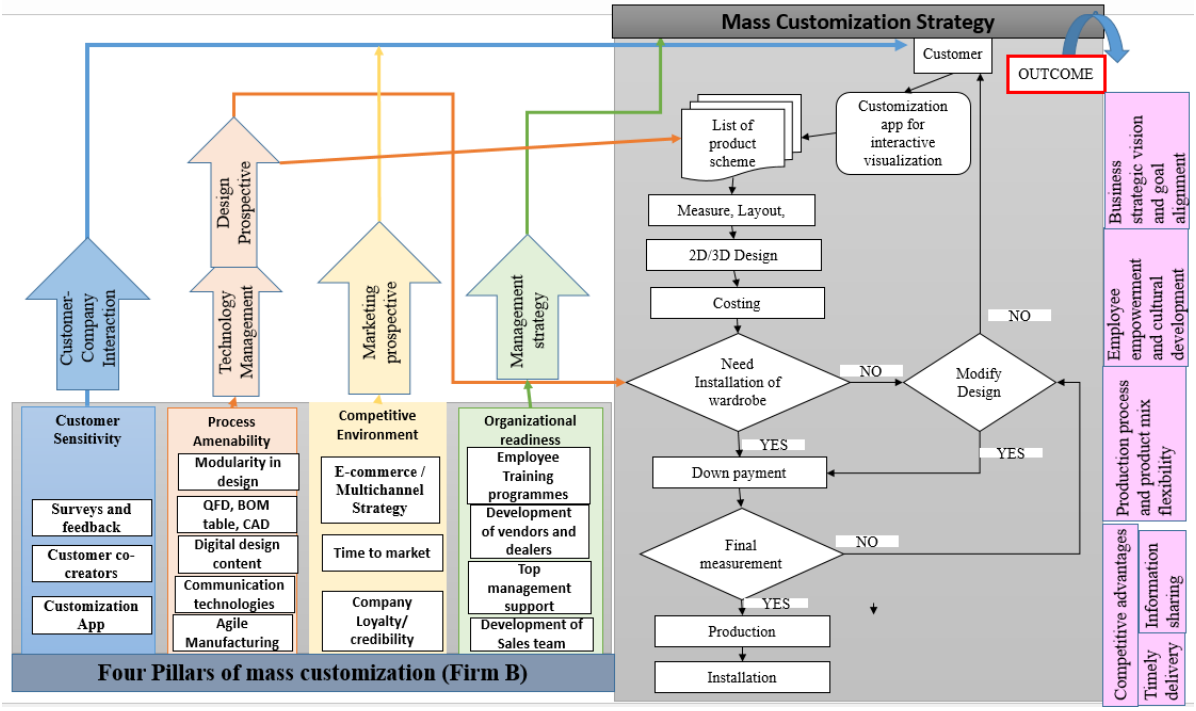

Figure 6.3: Mass customization process flow chart (FA, Customized storage manufacturer)

The four pillars of the manufacturing model are depicted in the process flow chart of firm FB, along with any relevant factors that may have aided in the implementation stages. The Company's new online Custom Configurator helps customers express their design vision by graphically guiding them through the process of designing their own custom ceiling fan, complete with motor, light, control, style, and finish that are ideally customised to the style of their room. The online tool is simple to

utilise and incorporates the company's whole line of mass Customized ceiling fans, resulting in over 800 possible combinations. Consumers may build a ceiling fan in four easy steps using the Configurator. Firstly, determine if the fan will be used inside or outside, then choose the motor's style and finish, direct drive motors that are ENERGY STAR® certified are available, as well as bespoke paint finishes including brushed chocolate, aged bronze, and cottage white. Last choose the colour and shape of the blade. For both indoor and outdoor use, there is a vast assortment of superior blade designs. Finally, choose from several light fixture styles and glass colours, such as LED bowls and outdoor four-light fixture. This is shown in Figure 6.4.

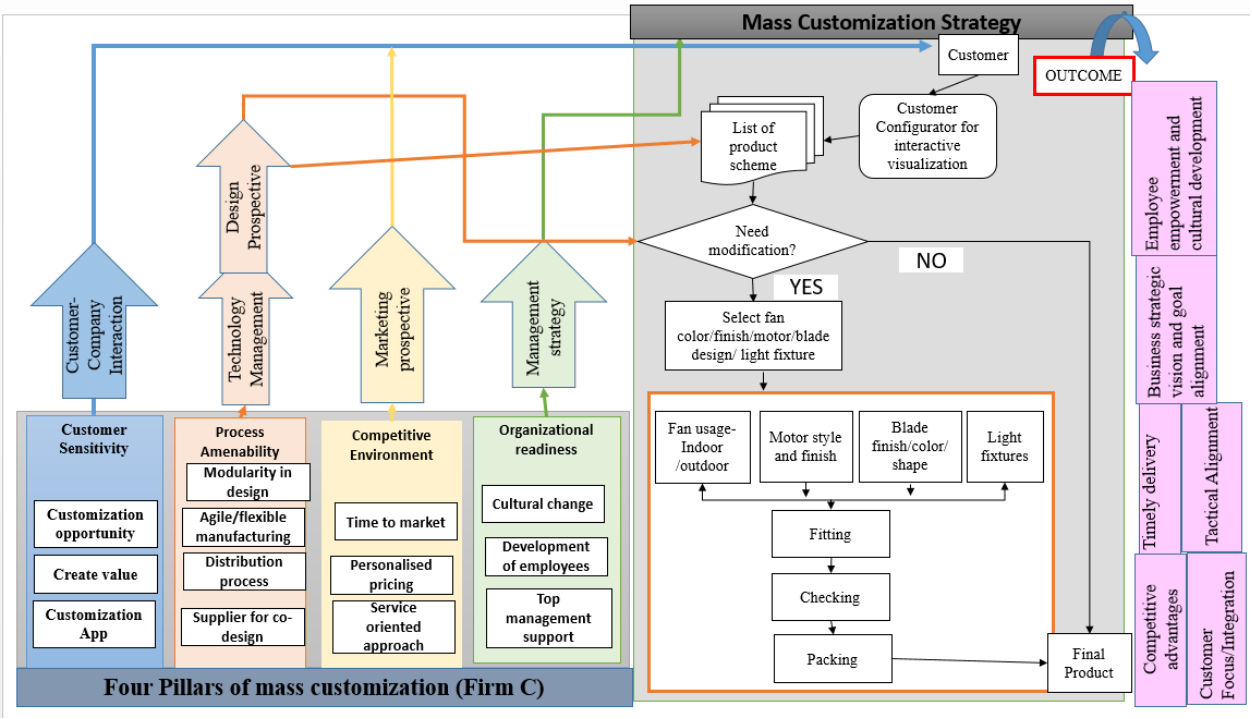

Figure 6.4: Mass customization process flow chart (FB, Customized fan manufacturer)

The process flow diagram of firm FC includes the four elements of the manufacturing model as well as any other pertinent elements that may have aided in the implementation process. Here, customer get a completely tailored outfit for around the same price as a store-bought one. Even though the retailer must acquire and maintain the measurement gadget, the purchase will result in a large increase in sales per square foot. Only samples of a certain species should be kept in the outflow. End-of-season discounts,

which stores must give to clear away unsold merchandise, become obsolete. Given that clothes store normally only sells 50 percent to 60 percent of its inventory at full price, eliminating such discounts can result in a significant increase in earnings. Furthermore, the modular process architecture considerably decreases inventory risks for apparel producers. Manufacturers can stock relatively low-cost raw textiles that are only transformed into finished products in response to actual orders, rather than stocking high-cost finished things that may or may not sell. Customers can provide dimensions, styling details, and fabric designs for apparel items that can be mass-produced quickly using mass customization methods and technologies. The is depicted in Figure 6.5.

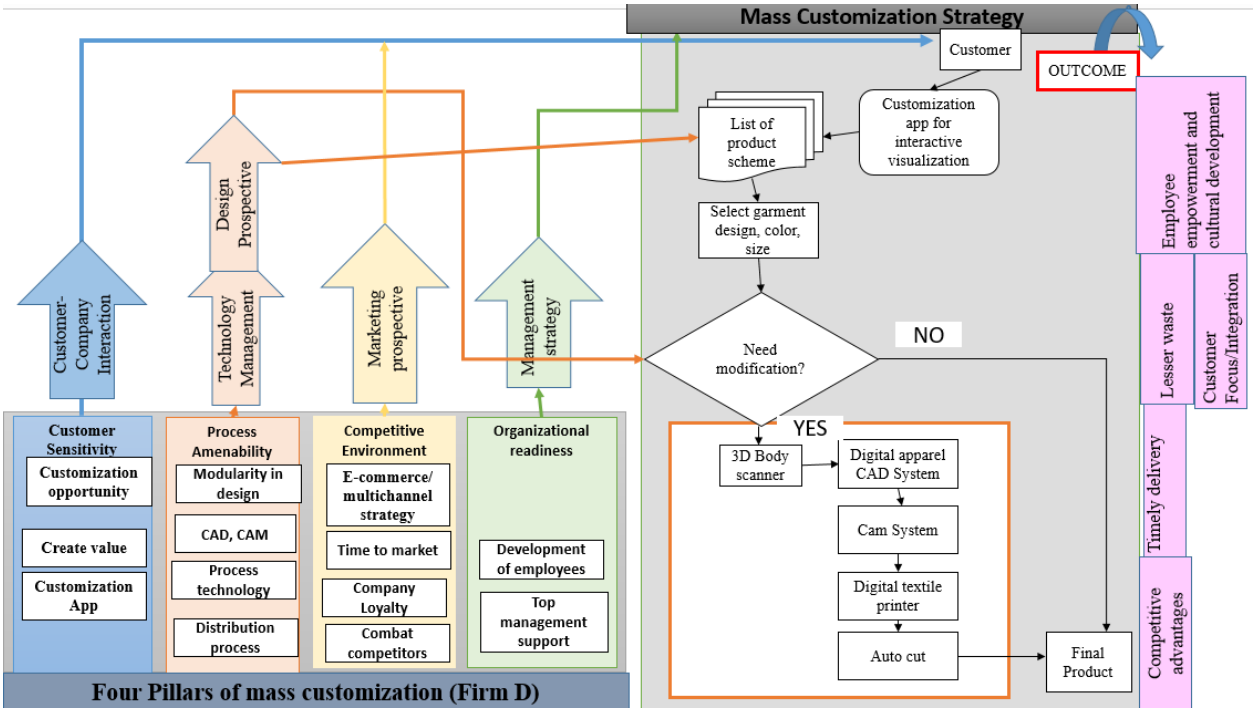

Figure 6.5: Mass customization process flow chart (FC, Customized garment manufacturer)

Figure 6.6 clarifies the information flow in the mass-customized system. The major segments identified are marketing and sales, management, Research and development and IT department, process management and vendor. The information flow was summarised after understanding the common process in all the three companies.

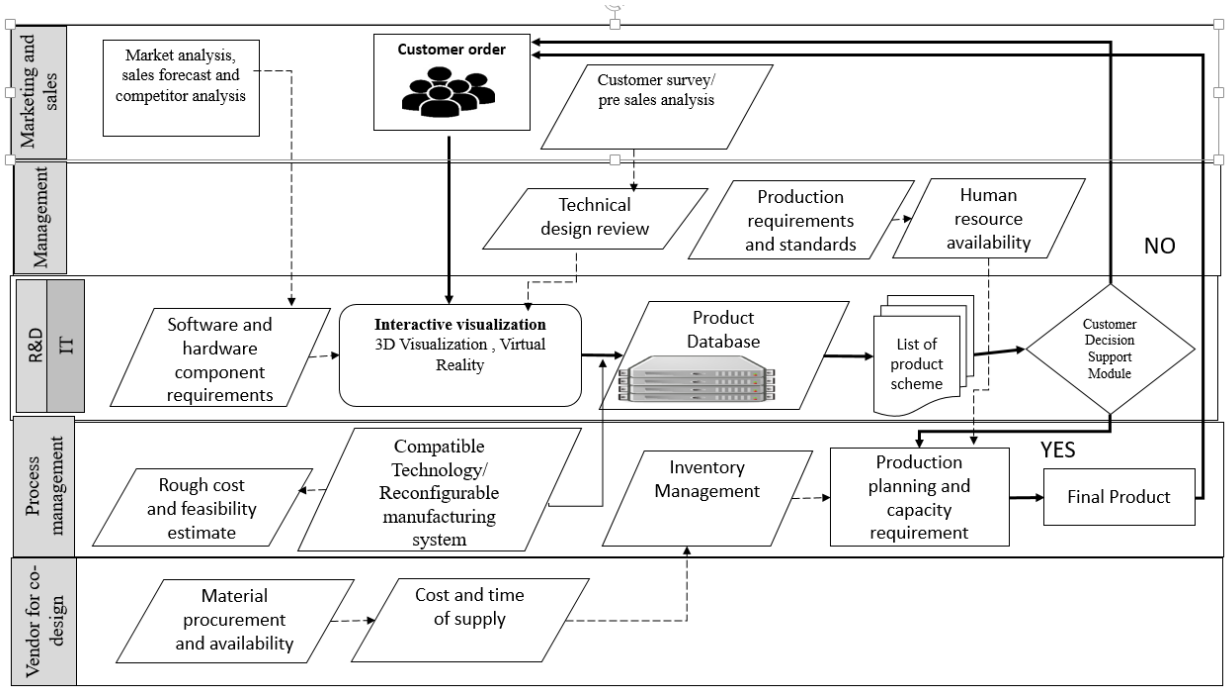

Figure 6.6: Information flow in a mass customization system

6.6 Results and Discussion:

The mass customization implementation strategy was discussed to understand the factors responsible for pre implementation, implementation, and post implementation stages of MC and how these factors helped the organizations to implement mass customization. Additional factors were also identified for extension of the manufacturing model. Organizational competitive strategies and challenges faced were summarized to understand the barriers for implementation. The academic and managerial implications of this study is also discussed in the relative section.

6.6.1 Mass customization implementation strategy: All the enterprises surveyed claimed to have implemented mass customization in their businesses. Interviewees were asked open-ended questions about MC methods and strategies during the interviews. If the interviewee admitted to having a certain category of MC practices in place, more specific activities relevant to that category were requested.

Following that, the interviewees' responses were classified into the appropriate categories during the analytic phase, in accordance with the manufacturing model framework.

Customer sensitivity: To address *customer sensitivity,* according to FA, mass customization needs were developed to address customers' unmet needs for less carpentry work at the site. For FA, transforming the customer experience by providing personalized, automated life assistance, and empowering self-service to enable stakeholders to collaborate in the design process, virtual reality, and artificial intelligence are helping to improve everyday experiences for customers. By navigating the company website, customers can select from 500 plus range, selecting the material type (5 choices), no of doors (4 choices), category (3 choices: steel wardrobe, wooden wardrobe, combination wardrobes), and various colour choices that the firm keeps on updating, depending on market trends. The company designed green and sustainable products to create value for customers. Customers can also purchase things on the company's official website. It also has ties to other shopping websites, resulting in quick sales. Creative thinking, an integrated research-development-innovation framework, advancements in R&D, a dedicated core innovation department, as well as an in-house development facility, all contribute to maximizing consumer value. FB believes in promoting consumer satisfaction rather than selling actual goods. The Company’s new online Custom Configurator helps customers express their design vision by graphically guiding them through the process of designing their custom ceiling fan, complete with motor, light, control, style, and finish that are ideally customized to the style of their room. The online tool is simple to utilize and incorporates the company's whole line of mass Customized ceiling fans, resulting in over 800 possible combinations. Consumers may build a ceiling fan in four easy steps using the Configurator. Firstly, determine if the fan will be used inside or outside, then choose the motor's style and finish, direct drive motors that are ENERGY STAR® certified are available, as well as bespoke paint finishes including brushed chocolate, aged bronze, and cottage white. Lastly, choose the colour and shape of the blade. For both indoor and outdoor use, there is a vast assortment of superior blade designs. Finally, choose from several light fixture styles and glass

colours, such as LED bowls and outdoor light fixtures. To make consumers' lives easier, the company has always endeavoured to develop newer and more innovative products that better meet their demands. FC feels that the Indian retail industry's largest pain points are sizing and fit, as most women don't fit into mainstream retail clothing that follows international sizing charts. Firm FC has achieved an extraordinary level of customization while eliminating textile waste by introducing 3D body scanners at the retail level for the first time in India. This retail solution conveniently allows customers to virtually modify items both online and offline, at no additional cost and with an agile delivery timeline. They strive towards a zero-waste policy and environmentally friendly practices. New technology in the fashion business has effectively divided the physique dimension and stitching procedures into two modular processing steps. In the storefront, a device that works identically to a tailor uses digital and optical devices to take a client's dimensions. The computer sends the measurements to the clothes vendor, who creates and stitches the garment. Even though the retailer must acquire and maintain the measurement gadget, the purchase will result in a large increase in sales per square foot. Only samples of a certain species should be kept in the outflow. End-of-season discounts, which stores must give to clear away unsold merchandise, become obsolete. Given that clothes store normally only sells 50 percent to 60 percent of its inventory at full price, eliminating such discounts can result in a significant increase in earnings. Furthermore, the modular process architecture considerably decreases inventory risks for apparel producers. Customers can provide dimensions, styling details, and fabric designs for apparel items that can be mass-produced quickly using mass customization methods and technologies.

During the transition from mass manufacturing to mass customization, all firms examined the possibilities for customization and unmet customer needs, according to the findings. IT systems for modelling and maximizing product features have been proven to be highly integrative, assuming that they give a consistently observable reference for all consumers. Customer survey analysis, which provides useful insight for the company to stay competitive was found deficient in firm FB and FC. As a result, the grievances of customers and continual improvements and innovations as per market

need was lacking in their business model. Analysis revealed that the pre-sales survey was conducted only by the firm FA. For the sales team to understand how to position their product or service solution and generate a proposal that best solves the customer's problem, pre-sales must research to establish exactly what the customer is looking for and their specific challenges.

Process Amenability: A lot of work was put in to improve *Process Amenability* for mass customization. For FA top management's desire to strengthen the company's IT platform led to a reduction in database requirements, the creation of customer-driven goods and marketing outreach, and an increase in sales performance. Exploration of emerging technology IOT, AI, and Contextual Learning, as well as 3-D visualization of interior decoration, led to the company adding benefit to its clients by putting the customer first and acknowledging unmet needs. Group Technology, Module supplier capability analysis, and quick response supply system ensured the timely delivery of the product. FA introduced modularity in design so that customers can design modular storage cabinets, and consumers can participate in product design, fully illustrating the movement in customer status from "willful ignorance" to "make the first move to select" in the purchasing process. The method necessitates the use of communication technologies and networks to promptly produce items that clients demand. According to the system's implementation method, the digital design content of the storage cabinet product is divided into two parts: concept design and system architecture. The corporation believed in expanding its operations and enhancing its factories' growth capacities by investing in cutting-edge machinery and making smart IT investments. To be able to respond to continually changing consumer demand patterns, the company is constantly focusing on making its manufacturing distribution and shipping processes more adaptable. The foundation of process amenability is establishing specialized digital groups, escalating e-commerce, utilizing global collaborations, developing the innovation infrastructure, expanding technological infrastructure, producing consumer-generated media, exploring, and expanding reach. For FB, modular design is achieved by categorizing all components into variations and common modules that are built onto a core platform. The next step is to create a

flexible and agile manufacturing system for the ordered product's production ease, as well as a vendor to aid in co-designing parts. In addition, the organization established a distribution system to ensure prompt delivery. FC offered the highest quality goods on time. Since they operate in a niche market, hence they aim to provide the greatest services in terms of exchange, quality, and delivery time to ensure that customers are satisfied and come back.

All firms agreed that process flexibility and modularity allow for the development of multiple product types (modularity product design) while maintaining a low cost of production for each module (modularity process design). The combination of modularity types enables businesses to readily communicate various product variants to customers and to promptly fulfil orders. Postponement is a method for deferring final product customization to as close to customers as feasible until a real order is placed so that organizations' supply chains can meet customer requests swiftly while keeping operating costs low. Postponement brings the entire supply chain together to reduce total cost. FA and FB insisted that the prerequisite for the entire firm to engage suppliers for co-design, fostered targeted discussions across divisions about product design and production management, resulting in timely delivery. FA and FC emphasized that excess inventory, stock-outs, wrong projections, insufficient scale efforts, and even poor customer service were decreased because of proper significance to the distribution process and quick response supply system for an effective supply chain, leading to tactical alignment.

Competitive Environment: In terms of *the Competitive Environment*, the firm FA's decision to change from mass production to mass customization was prompted by the emergence of new competitors and the danger of a foreign market. Its focus on service rather than goods provided the organization with the necessary competitive advantage. The marketing strategy of the companies is to offer a selection of goods at various price points based on the income levels of the customers they are targeting. The segment is based on demographic and geographic factors such as location, income levels, and so on, then target each segment with things customized to their needs and price themselves properly. They

effectively use both traditional and digital media in their marketing. The organization has maintained a competitive and personalized pricing approach. It has maintained a strategy that aids in market penetration, building and maintaining market needs, and establishing monopolies for some of its products, thus ensuring the company's credibility in the marketplace and ensuring customer loyalty. To maximize customer interaction, FA implemented a multi-channel strategy and prioritized E-commerce activities. For FB, the presence of a largely unorganized sector poses a major threat to the Indian fan business, as such companies accounted for 55-60% of the market but rarely followed industrial unit legislation or paid their fair share of taxes. But demand for premium fans has increased as consumers' spending power has increased. The firm has expanded its modern trade market network to penetrate with better space. It has also introduced fans at low rates, impacting the growth rate of the unorganized sector. According to the organized market, economy fans price less than Rs. 1500, regular fans cost between Rs. 1500 and 2500, and premium fans price more than Rs. 2500 for a single fan. Premium fans are finding a distinct niche in the Indian market as people's lifestyles evolve and their disposable income rises. For FC, the company specializes in Western attire and provides customization. Since very few brands offer such a wide range of customizing options in India, hence there is less rivalry in Western clothing. On the other hand, the market for traditional clothing is large, but it is becoming saturated. The firm feels that India's young population is more contemporary and receptive to Western culture. The ratio of Western to ethnic acceptability used to be 25:75, but it has since risen to 40:60. As a result, the market for Western clothing has shown steady growth.

According to the findings of researchers [60], when market turbulence arises, businesses should move their focus from mass manufacturing to mass customization, resulting in uniform rather than diverse client demand, causing all businesses to assume that the competitive environment has a substantial impact on mass customization. A first-mover advantage, on the other hand, necessitates consumer loyalty and a positive market reputation. Mass customization should be regarded as an organizational approach in light of the turmoil in the mass markets[55]. The expansion strategy

includes technologies as well as data analysis. Market volatility should be viewed as an opportunity rather than a hindrance or a threat that needs to be addressed. Multichannel strategy and e-commerce by FA resulted in a more cohesive, integrated approach to a larger audience and generated new demand for products or services, while also increasing brand awareness and conversions. According to FA and FC, a personalized pricing approach and service-oriented approach can provide a competitive advantage to firms in mass customization.

Organizational readiness: In response to *organizational readiness*, the company FA encourages and supports its employees in their efforts to improve their skills and expertise. There are training resources accessible based on the needs. There are also policies in place for continuing education to ensure that people develop their abilities in preparation for further responsibility and overall competitiveness. It held leadership development programs to prepare future leaders. In each location, a trained sales team is on hand to assist customers by providing guidance on the storage solutions they need. The distribution network of the company extends from the manufacturer to warehouses, sales offices, dealers, retailers, and customers. To market its newer and innovative items, the corporation creates several marketing campaigns. Employer empowerment was built on a foundation of extensive training. Profit management techniques, purchasing cost savings efforts, and energy efficiency activities were used to achieve competitive pricing. The organization's business strategy included incorporating franchisee retail locations and e-commerce, as well as supplier development for co-design, branch reseller conferences, priority dealer training workshops, annual financial planning deliberations, strategic supplier conferences, and new product development discussions at regular intervals, as well as supply chain enhancement. FB's top management recognized the importance of a change management culture for MC implementation and was committed to providing clients with value-added services through their innovative solutions. The development of ERP systems, the implementation of effective training modules, the creation of a product distribution structure, and the advancement of IT-enabled technologies are all part of the growth strategy. The corporation re-trained the organization,

including new techniques for selling in a competitive global environment, to empower employees. Employee talent is developed and invested in by the company, which improves the overall functionality of the organization and generates a more productive and collaborative work environment for all employees. Employees were given milestones to work toward, and realistic and measurable KPIs were used to track their progress. By monitoring their employees' performance and growth, managers can motivate and continuously improve their performance. The goal is to create collaborative partnerships with its suppliers to ensure that they completely understand their company objectives and that they collaborate closely with them to establish the most appropriate approach that maps to their transformation journey roadmap and includes best-in-class solutions. The company is also planning to mass-customize its other products soon. Firm FC facilitated revenue growth by predicting future market position, adapting product strategy to industrial requirements, and through product enhancements & effective product positioning. It built mission-critical solutions that increased the organization’s top-line growth and market share. In FC, through digital personalization and artificial intelligence, the company strives for zero inventory and sustainability to eliminate textile waste. It is one of the first brands in India to develop a 3D body scanner, which can take 110 measures in under five seconds.

Analysis revealed that FC requires to make cultural changes in the organization and train managers and leaders as it evolves. Also, extensive training provided to the marketing team by FA should be considered by other firms. It was observed that awareness of mass customization goals is primarily attained at the management level, particularly senior executives and department heads, since management believes that understanding long-term goals and policies is not necessary for front-line employees. As a result, there is a lack of thoroughness in new product evaluations, clarity in product requirements and procedures, cost or schedule targets, and manufacturability considerations, despite collaboration across design, quality, manufacturing, and purchasing departments.

6.6.2 Organizational competitive strategies and challenges faced: The competitive strategy of FA involves expanding its range in the economy segment and consolidating its position in the market. The company's aggressive pricing policy is used to acquire market share while retaining a solid operating margin and aims to be significantly more agile than its global competitors. The entire competitive edge is built on adaptability. A lot of the firm's strategy revolves around how it can remain adaptable as it develops. This entails interaction with team members for faster decisions. The first and most important task is to keep and expand leadership, the second factor is innovation, and the third step is to set up the systems and technology. There's also the broadening of distribution in both urban and rural areas, thus leading to competitive advantage and business sustainability. The competitive strategy of FB is organized around four key areas of attention. These include identifying specific products to cater to different customer needs while keeping in mind different tastes in different parts of the country; implementing state-of-the-art ERP systems, which will be followed by various other systems such as CRM, SEM, and so on; and, finally, constructing a vastly superior distribution structure. To provide world-class items to Indian consumers, the company is also pursuing overseas sourcing. To satisfy needs of the rural customers, the company is also offering specific models of fans. The firm FC build its strategy on the belief that India's culture is diverse and rich, and its customs are diverse as well. However, most of the India's population is in their mid-to-late twenties, and they are both traditionalists and modernists, willing to accept new items. As a result, the product must be localized while keeping its unique selling proposition. To segment the target demographic for its product, the corporation needed to localize its marketing plan.

Any project should start with a thorough review of the current infrastructure and a thorough cost–benefit analysis of future expenditures, which should include detailed descriptions of demands, goals, to-be situations, and task management. Companies must identify and train professionals who have the necessary abilities to implement their mass customization strategy and new business models. Company credibility and brand images in the market are other factors organizations should consider

before venturing into mass customization. For a diverse country like India, organizations need to consider the diverse and individualized needs of consumers, variable demographic and geometrical choices, and inconsistent economic levels of customers for identifying what to mass customize. The organization should focus on setting up the product vision for the business unit while maintaining a 'big picture' focus; evaluating competitor offerings technically & commercially and identifying gaps to deliver according to domain needs with close control on time to market. Creating business plans/cases and go-to-marketing strategies for businesses for sustained revenue growth and monitoring commercial success and overall product performance and competitiveness in the marketplace is an essential factor for success. Establishing consumer-centric brand architecture & repositioning the product offering, evangelizing multiple product launches through value-centric messages and pre-launch market conditioning; conceptualizing & designed go-to-market plans, messaging tools, collaterals, and product demos should be considered as strategies for mass customization.

The challenges faced by case study companies along with organizational learnings and outcomes summarised in Table 6.3 will facilitate managers to analyse their as-in situation and provide guidance to take the road forward for mass customization. The challenges in terms of company-customer interaction, design, management, marketing and technology were considered the primary challenges by the organizations. The major learnings were customer involvement where organizations learnt tp monitor and fulfil client requirements, communicate with customers, and build a connection based on trust and expertise. Innovation was required for creating value and taking measures toward competitors to provide a unique product. Organizational capabilities development for performance management, self-maintenance, marketing department multifunctional training, and fostering behavioural responses are all ways to deal with unpredictable demand volatility.

Table 6.3: Challenges and Organizational Learnings

	Challenges faced during mass customization implementation	Organizational learning to overcome challenges	Outcome
Customer—Company Interaction	Due to a variety of considerations, determining customers' willingness to invest in their ideal product was challenging. User experience with the organization to alter the product to client preferences is exacerbated by the mass customization process. Customization, according to the organization, causes economic inefficiencies.	**Customer Involvement** - Monitor and fulfil client requirements, communicate with customers, and build a connection based on trust and expertise. **Customer Feedback**-Building a strong customer feedback system by addressing their concerns and suggestions.	Customer Focus/ Integration, Lesser pre-consumer waste., Brand image, Business sustainability
Design perspective	Customize products that are one-of-a-kind and challenging for competitors to replicate. Customers' unique preferences should be addressed and incorporated into product designs. Defining generic, variant, and distinctive modules for a mass-customized product family, encompassing both present and emerging derivative commodities for a product platform Developing product variants from a set of product components and modules	**Innovation** - for creating value and taking measures toward competitors to provide a unique product. **Collaboration-** with suppliers to generate truly creative goods by incorporating unique knowledge and experience from another source. Technical collaboration on product design and development with experts. **Information acquisition**- stakeholders in the supply chain (i.e. suppliers and customers)	Tactical alignment Adaptability
Management strategy	Managers and corporate engineers are resistant to change. Estimation of human, financial, technical, and generic resources required for mass customization implementation and development of such resources The absence of a well-defined mass customization case analysis model makes it difficult for company managers to make timely judgments.	**Training and skill development programs -** **Knowledge acquisition** - the ability of the organization to locate and obtain externally generated information that is vital to operations, such as customer requirements, supplier operations data, and new technological advancements. **Knowledge exploitation** - transferring knowledge into practical use **Knowledge management**- provide operational efficiencies and critical competitive advantages, as well as enhance production flexibility	Business strategic vision and goal alignment Integral management Sustainable leadership development Cultural development Employee empowerment
Marketing perspective	Forecast the market demand to plan these–finished standard item's inventory in advance. Identify variable geometrical and demographic choices Co-ordination with dealers and another distribution channel for timely delivery	**Organizational capabilities development**- Performance management, self-maintenance, marketing department multifunctional training, and fostering behavioural responses are all ways to deal with unpredictable demand volatility.	Competitive advantages Broadening of distribution, Decrease in Time- to Market
Technology Management	Incorporating the desired technology changes required accordingly to the specific business and needs Incorporating internal IT infrastructure and automation Control of product flow and reduction of cycle time Understanding how the company business model changes after technology adoption	**Process enhancement**- Deployment of Information technology, as well as specific software, to increase process productivity (e.g., software for quality control, planning, project-based accounting, etc.). Among the software applications used are enterprise performance systems (ERP) and customer relationship management (CRM).	Information Sharing Data-enabled decision-making processes Production process and product mix flexibility

6.6.3 Academic and Managerial Implications: In theory, this research contributes to the mass customization of literature in several ways. Although prior studies have ranked enablers, there has been little research into the practical and behavioral implications of MC in the Indian manufacturing sector. In India, research on MC uptake lacked a clear roadmap. There are very few studies in the Indian context where researchers propose frameworks that are tested in case study companies that have already implemented mass customization[130].The findings of the study can help firms make better decisions about how to establish distinctive operational capabilities and transform existing mass production systems into competitive mass customization ones.COVID-19's manufacturing disruption has had a significant impact on the functional, environmental, and financial realms, as well as posing challenges to firms aiming to accelerate the transformation of global value modeling approaches, affecting a variety of Indian businesses[55]. The manufacturing industry in India stands at a crossroads, with far-reaching implications for companies and supply chains. This framework for mass customization can present firms with a solution to the current concerns that must be addressed in ensuring the success of their enterprise.

6.7 Conclusion

The study has contributed to validating the manufacturing framework for mass customization deployment for competitive advantage with the help of case studies. Some major factors that contribute to mass customization during implementation phase, which were not considered in literature, were identified and added to the framework. The challenges faced by case companies and the organizational learnings along with outcome provides a prominent picture to understand MC as a business strategy. The managers will be helped by this model to identify the factors that are essential for the shift from MP to MC. The following chapter identifies the drivers of MC and rank them with FAHP and analyses the suitability of industry with FTOPSIS.

CHAPTER 7

PRIORATISING OF DRIVERS OF MrankssCUSTOMIZATION BY FAHP AND FTOPSIS

7.1 Introduction

Indian organizations are still at a crossroads in their transition from mass manufacturing to mass customization, and three intriguing study questions to pursue in the future for the Indian manufacturing sector are ***RQ4:*** *When is the right time to mass customize? What drives the MC business approach?*

RQ5: *What types of industries can benefit from the first-mover advantage? What are the challenges faced?*

This chapter is based on objective 4 of the research work and focuses on identifying and ranking the drivers of mass customization adaptation. Since the ease of mass customization adaptation may differ as per the manufacturing sector, therefore, it is desirable to rank the various sectors to understand their ease of adaptability. A hybrid framework based on a fuzzy analytical hierarchy process (FAHP} was used to prioritize the drivers for MC adaptation, and a fuzzy technique for order preference by similarity to the ideal solution (FTOPSIS) was used to rank different industrial sectors for ease of adaption. Four case studies are carried out to show the applicability of the proposed framework, all of which are cantered on the Indian manufacturing industry. Figure 7.1 provides the chapter's flow.

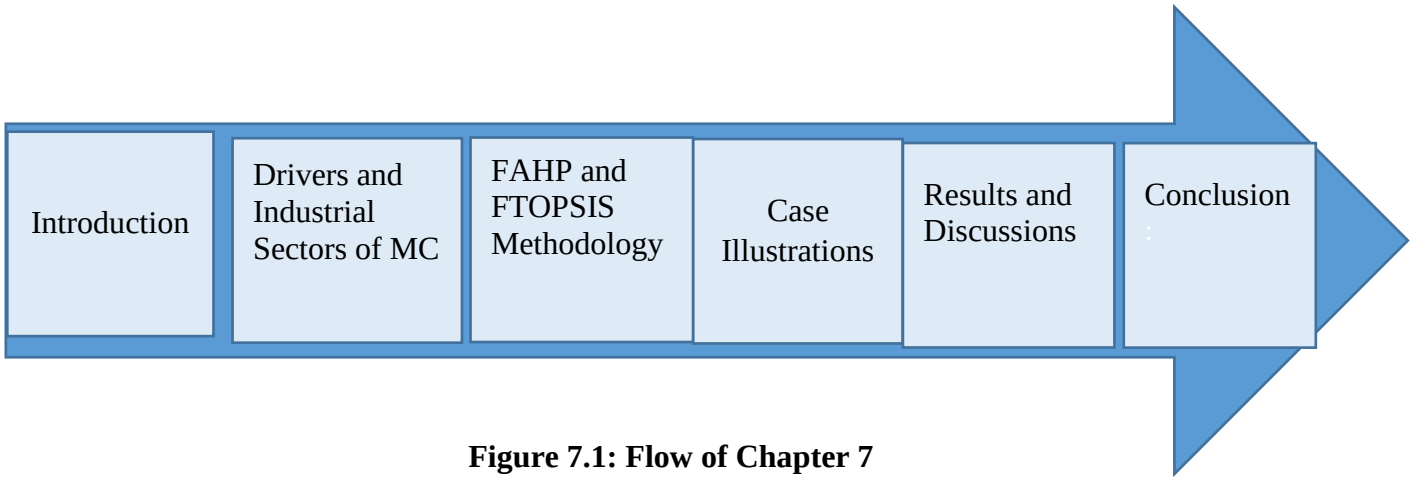

Figure 7.1: Flow of Chapter 7

7.2 Drivers and Industrial Sectors of Mass Customization

A systematic literature review (SLR) method was conducted for encapsulating and sorting current literature to identify the mass customization drivers and the industrial sectors that have already implemented MC. Four industries were identified and ten experts from these industries were contacted for ranking of drivers. Identification of drivers, industries, and formation of expert panel are provided bellow:

7.2.1 Identification of Drivers: Fifteen primary drivers of MC were identified for this research, which was categorized into four categories of Organization, Customer, Market, and Technology .The Drivers are discussed below:

Organization perspective (D1): At the corporate level, competitive strategies represent an organization's desire to integrate its goals with the limitations of its surroundings to pave the path to competitiveness[214]. It is concerned with how a corporation determines to operate in a business, specifically with how the firm positions itself concerning competitors to establish a profitable and long-term position.[32]. During and after the COVID-19 pandemic, decision-makers were forced to redefine their corporate goals in terms of realistic objectives [215], and businesses are turning to a demand-driven paradigm for managing their supply chains[170]. To survive a pandemic catastrophe, organizations may need to re-invent business goals to modify products according to market needs, emphasizing customer, product features, product demonstrations, and competencies, as well as the connections between these issues [167]. When mass customization methodologies are integrated with other resources, such as human resources, their interactions can generate important knowledge and skills, leading to the creation of better mass customization capabilities[71]. When compared to mass production, MC capacity is being viewed as a developing approach for businesses looking to generate value-added customized products while also increasing profitability [21], leading firms to market benefits. [53]. A company's ability to establish pricing based on a balanced evaluation of prices, market, and consumer requirements is known as manufacturing cost control[175] and enterprises with

greater pricing flexibility can provide the best value for money relative to its rivals[216] ,hence makes mass customization possible without much increase in price.

Corporate strategy and goals (D11), financial benefits (D12), Manufacturing cost control (D13) and skilled human resource (D14) are identified as drivers from an organization perspective.

***Customer Perspective (D12)*:** Customer fluctuating needs and the demand paradigm has led the industries to get dependent on the voice of end user and customer satisfaction, therefore driving them to seek suitable organizational strategies which aim at creating consistent customer involvement[21]. Instead of discovering potential markets/clients for new products, manufacturers and practitioners focus on developing desirable and preferred products for customers [217]. The desire of the customer to own a product as per their need tends to drive today's market and MC strategy desires to align manufacturers with customer needs[187][166]. Social distancing and other mitigating activities during COVID-19 have resulted in new habits and behavioural patterns, such as a rise in telework, and changes in work and school schedules, [218] giving rise to several Mass customization opportunities. Several firms are implementing work-from-home and telecommuting solutions on a large scale. [219], giving rise to requirements of IT-supported platforms for teleworking and digital conferencing mass customized as per business needs. The socio-cultural changes in the eco-system drive organizations to fulfil mass customized products and services to deal with the disruptions arising due to COVID-19 situations.

Requirements of the customized product (D21), Customer purchasing capacity (D22), Customer dependency on Brand Image (D23), and Demographic and sociocultural differences (D24) are the drivers considered from Customer's perspective.

***Market Perspective (D3)*:** Supply chain management has recently become the key success criteria due to the pressures of increasingly competitive markets, where every organisation must be able to react

swiftly to external stimuli**.**Firms that ignore the importance of the current business scenario will struggle to survive soon. [18]. The greater the market turbulence, the greater the opportunity for variation and customization [60], making it capable of driving firms to mass customize their products in response to market demands to survive economic uncertainty, where they would otherwise be content to produce mass production goods in normal circumstances [21]. Manufacturers aim to protect themselves from new competition by providing innovative goods that are suited to particular client needs [158]. The most significant potential of MC is its ability to help manufacturers compete in a rapidly evolving global economy marked by the diversity of customer requirements, and the rapid development of products [47]. It can also be used as a market positioning strategy that contributes to the customer's end-use [66].

Market Turbulence and globalization (D31), Introduction of customized products by competitors (D32), and new product development/shortened life cycle (D33) are acknowledged as drivers from a market perspective.

Technology perspective (D4): In the future, there will be a greater need for mass customization, which will fully utilise digital technologies, intelligent systems, and AI systems. Additionally, there will be a fresh set of tasks that will call for quick responses and the setting up of an innovation framework to enable the optimisation of all production performance [56]. Organizations that adapt, evolve, learn to handle and maintain flexibility and improvise in the face of adversity while utilizing prior expertise will not only keep their firm afloat but will also re-invent themselves and thrive as they establish post-crisis strategies[136]. The core premise of MC is empowering the client to change the design of the product as well as add new features and functions. Crowdsourcing and social media should be used as toolkits to aid customers in the co-design of MC products[130]. Design ideas are generated from the public which increases customer engagement [50] and digital technology is commonly used to allow users to actively engage and design a product.[10]. The success of the MC process depends on the

presence of "Digital Consumers", because today's "digital customers," who are young and knowledgeable about computers, typically use digital technology for their buying activities (Fiore, 2008), and is considered the most preferred digital technology among women aged 16 to 24 years [10]. Customers can now witness the final prototype of their mass-customized product online thanks to the advancement of interactive product websites [41]. Customers may easily read, explore, and research their desires at different venues before deciding to buy in the age of e-commerce marketing [220]. The internet is a great communication tool as well as a potent sales avenue, and hence developing an e-commerce system is a vital step in MC deployment. High costs are a major impediment, however many of these costs can be decreased by judicious use of the internet, making MC a more appealing initiative.

Social Media and crowdsourcing (D41), Penetration of mobile and internet (D42), User interface and website/ Omni channel distribution and e-commerce (D43), and Technology advancement and innovation (D44) are the drivers considered from a technology perspective. The drivers of mass customization adaptation along with category and subcategory and literature references are provided in Table 7.1.

7.2.2 Identification of industrial sectors : A diversity of industrial sectors embrace mass customization as a methodology that enables the retention of a lot of customers while also allowing for the customization of the product to satisfy the demand of the clients[18]. When confronted with fierce competition, several firms prefer to enhance their MC abilities to outperform their adversaries[22]. A thorough analysis of the literature was conducted to determine the types of industries that have successfully adopted mass customization. In the electronics sector, researchers [221] determined that MC deployment considerably reduced overall delivery time for a complete system as well as production costs. In the automotive sector, researchers determined that MC adoption resulted in a significant reduction in overall delivery time for a complete system as well as a reduction in production costs [11],. Researchers concluded that connecting MC interfaces to cultural information processing can result in several positive consequences for customers. "Real-world examples include

General Motors, Ford, and Toyota in the automobile industry, Nike iD, mi Adidas, Puma, Lands' End, Louis Vuitton, Burberry, and Brooks Brothers in the fashion sector, including luxury and sportswear companies, and Proctor & Gamble in the pharmaceutical industry"[35]. In the fashion sector, mass customization processes are well-established. [50][35][170] and also in footwear[134] [15]. So the next sector identified as suitable for mass customization was Apparel and footwear. The limited application was observed in the food industry [156]. Case studies in the pigment industry[49], furniture, [130], and door industry[27] were categorised as interiors and decors sectors. All the five sectors identified were also considered major industrial sectors in Indian manufacturing and studied for their ease of adaptation to MC implementation.

Table 7.1: Literature reference of Drivers of mass customization adaptation

Category Code	Category	Subcategory Code	Subcategory	Reference
D1	**Organization perspective**	**D11**	Corporate strategy and goals	[132], [22]
		D12	Financial benefits	[5]
		D13	Skilled human resource	[40],[180]
		D14	Manufacturing cost control	[50], [35],[40], [130]
D2	**Customer Perspective**	**D21**	Requirements of customized product	[86][180],[25],[22]
		D22	Customers purchasing capacity	[86],
		D23	Customer Dependency on Brand Image	[222]
		D24	Demographic and socio-cultural differences	[11]
D3	**Market Perspective**	**D31**	Market Turbulence and globalization	[22],[37]
		D32	Introduction of customized products by competitors	[48], [25],[47],[27]
		D33	New product development/shortened life cycle	[37]
D4	**Technology Perspective**	**D41**	Social Media and crowdsourcing	[50],[35][130]
		D42	Penetration of mobile and internet	Expert opinion
		D43	User interface and website/ Omni channel distribution/ E-commerce	[50], [35],[11],[220]
		D44	Technology advancement and innovation	[35], [42],[48], [223][3][27]

7.2.3 Formation of Expert Panel: The MC drivers reported were tabulated and presented in the form of a questionnaire to an expert group consisting of 10 experts. The specialists were chosen depending on their knowledge of adopting mass customization in their respective Indian-based companies. Following the finalization of the drivers, the experts were tasked with categorizing the drivers and providing the initial inputs for the fuzzy AHP[224]. The MC driver weights were calculated using the fuzzy AHP technique.

The experts had extensive experience in supply chain management, business management, and production planning (at least 15 years), and belonged to the different manufacturing sectors-electronics, automobiles, interiors and decors, food industry, apparel, and footwear. A questionnaire to rank the industrial sector suitable for mass customization adaptation in the Indian scenario based on drivers was presented to each exert. A three-round Delphi procedure was used until a consensus decision was reached[225]. This result was later used for ranking the various sectors using fuzzy TOPSIS to understand their ease of adaptability.

7.3 FAHP and FTOPSIS Methodology

Fifteen drivers were grouped into four categories and ranked based on inputs from industry experts using the fuzzy analytical hierarchy process (FAHP). A fuzzy technique for order performance by similarity to ideal solution (FTOPSIS) was used to rank various manufacturing sectors for mass customization adaptability in the current economic environment. The difficulty of evaluating drivers is characterized as a multi-criteria decision-making task due to the complexity and lack of transparency in the data [34]. It needs the use of fuzzy-based strategies that can deal with the uncertainty and imprecision that comes with interpretability. It was proposed to use fuzzy set theory to eliminate the inherent ambiguity[119].

7.3.1 Fuzzy AHP Research Methodology: The researchers used the experts' paired comparisons and double-checked their consistency to ensure high-quality inputs for calculating the driving weights. Questionnaire for ranking of drivers of mass customization for FAHP calculations is provided in

appendix 6. The experts were contacted and asked to compare the pairwise drivers, based on guidance provided in questionnaire. Questionnaire for ranking of manufacturing sector as per drivers of mass customization for FTOPSIS calculation is provided in appendix 7. The complete approach for these steps is described further below.

Step 1: *MC driver identification and finalization*. The specialists were tasked with finalizing the MC drivers discovered in the literature review that influenced its acceptance, as well as grouping the drivers into subgroups with functional commonalities.

Step 2: *Construct paired comparisons and the fuzzy comparison matrices*: This stage makes use of data from paired comparisons derived from expert decisions. During this phase, all MC drivers in a specific group were compared using the scale [151] presented in Table 7.2. The experts were asked to rate the comparisons among every two drivers, in such a way, that it critically defined how much a particular driver influences the other driver in the pair. A=[aij], where-i,j=1,2,3…..n

The linguistic evaluation received by the experts is transferred to the corresponding triangular fuzzy numbers (TFN). TFNs are used to improve the original nine-point scale of Saaty [117]1977) based on linguistic variables illustrated in Table 7.2 to determine the fuzzy weights for the pair-wise comparisons.

Table 7.2: Scale of Pairwise comparison

Intensity of importance	Linguistic variables	Triangular Fuzzy Number assigned
1	"Ai" is equally important to "Aj"	(1,1,1)
2	"Ai" is equally to moderately more important than "Aj"	(1,2,3)
3	"Ai" is moderately more important than "Aj"	(2,3,4)
4	"Ai" is moderate to strongly more important than "Aj"	(3,4,5)
5	"Ai" is strongly more important than "Aj"	(4,5,6)
6	"Ai" is strong to drastically more important than "Aj"	(5,6,7)
7	"Ai" is drastically more important than "Aj"	(6,7,8)
8	"Ai" is drastic to extremely more important than "Aj"	(7,8,9)
9	"Ai" is extremely more important than "Aj	(8,9,10)

Based on TFNs, the pairwise comparisons matrices for the main criteria and sub-criteria are constructed[151]:

$$\acute{A} = \begin{Bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{Bmatrix} \quad (7.1)$$

Where: $\tilde{a}_{ij} = \begin{cases} \tilde{9}^{-1}, \tilde{8}^{-1}, \tilde{7}^{-1}, \tilde{6}^{-1}, \tilde{5}^{-1}, \tilde{4}^{-1}, 3^{-1}, \tilde{2}^{-1}, \tilde{1}^{-1}, \tilde{1}, \tilde{2}, \tilde{3}, \tilde{4}, \tilde{5}, \tilde{6}, \tilde{7}. \tilde{8}, \tilde{9}, i \neq j \\ 1, i = j \end{cases}$

The rate of the importance of the barrier "Aj" in comparison to "Ai" is derived by the rate of "Ai" in comparison to "Aj" by $1/\tilde{a}_{ij}$ (Saaty, 1977).

Step 4: Calculate the weights of criteria and sub-criteria using the extent analysis proposed by Chang (1996). The corresponding fuzzy synthetic extent would be represented as

$$S_{i=} \sum_{j=1}^{m} \tilde{a}_{ij} \otimes \left(\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{a}_{ij} \right)^{-1} \quad (7.2)$$

In addition, to consider the minimum and maximum values for fuzzy numbers, the degree of possibility for two fuzzy synthetic extents Si is presented as follows: -

$$V(S_1 \geq S_2) = sup_{x \geq y} \left[min, \left(\mu_{S_1}(x) \mu_{S_2}(y) \right) \right] \quad (7.3)$$

Where the membership degree of possibility can be expressed as:

$$V(S_2 \geq S_1) = hgt(S_1 \cap S_2) = \begin{cases} 1, m_2 \geq m_1 \\ 0, l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \end{cases}, \quad (7.4)$$

Assuming that

$d(A_1) = minV(S_i \geq S_k)$ For k=1, 2,….,n;k≠i, (5) (7.5)

Then the weight vector is given by$W` = (d`(A_1), d`(A_2), \cdots, d`(A_1)^T)$, where A_i (i=1,2,….,n) for all categories and subcategories of Drivers. RI is a normalized factor depending on the matrix size.

After normalization, the normalized weight vectors of each barrier can be defined as follows:

$$W = \left(d(A_1), d(A_2), \cdots . d(A_n)\right)^T \quad (7.6)$$

Step 5: The final step focused on the check of consistency by the calculation of the normalized consistency ratio (CR). When the crisp comparison matrix A is consistent, it means the fuzzy comparison matrix Ã is also consistent. The consistency rate (CR) can be calculated as follows: • Calculation of the largest Eigenvalue of the matrix by solving the following equation:

$$A\omega = \lambda_{max}\, \omega \quad (7.7)$$

Where ω is the Principal Eigenvector of the matrix.

• Computation of the CR as:

$$CR = \frac{CI}{RI} \quad (7.8)$$

7.3.2 Fuzzy TOPSIS Research Methodology

Step 1: *Construction of fuzzy evaluation matrix*: Following the identification of weights of drivers, three sets of experts from different industrial sectors were consulted to create a fuzzy evaluation matrix using the linguistic scale [151] shown in Table 7.3. This is accomplished by comparing alternatives to each driver. The fuzzy evaluation matrix was then constructed by converting the linguistic concepts into assigned (triangular fuzzy number) TFNs.

Table 7.3: Linguistic scale for solution rating

Linguistic variables	Very low	Low	Medium	High	Very High
TFNs assigned	(0,1,3)	(1,3,5)	(3,5,7)	(5,7,9)	(7,9,11)

2nd Step: *Computation of aggregate fuzzy ratings for the solutions*. The steps followed as [150].). If the fuzzy rating of the Nth decision maker is X_{abN} = (l_{abN}, p_{abN}, u_{abN}) where a = 1, 2, 3, . . ., m, b = 1, 2, 3, . . ., n then the fuzzy aggregated fuzzy ratings X_{ab} of solutions concerning each criterion is given by X_{ab} (l_{ab}, p_{ab}, u_{ab}), where

$$a = \min_{N}(l_{abN})$$

$$b = \frac{1}{N}\sum_{N=1}^{N} p_{abN}$$

$$a = \max_{N}(u_{abN}) \qquad (7.9)$$

3rd step: *Normalized fuzzy decision matrix.* Data is normalized to achieve a comparable scale when using linear scale transformation. It is given by B where:

$$\check{B} = \left[p_{ij}\right]_{m\times n}$$

Where i=1.2.3……, m and j=1, 2, 3,….., n

$$\check{p}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}\frac{c_{ij}}{c_j^*}\right) \; and \; c_j^* = max c_{ij} \text{(Benefit criteria)} \qquad (7.10a)$$

$$\check{p}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}\frac{a_j^-}{a_{ij}}\right) \; and \; a_j^- = \min a_{ij} \; (cost \; criteria) \qquad (7.10b)$$

Step 4: The weighted normalized matrix is constructed by using the given Equation:

$\check{V} = \left[\check{v}_{ij}\right]_{m\times n}$ Where i=1, 2, 3,…….., m and j=1,2,3,……, n

$$\check{v} = \check{p}_{ij} \otimes w_j \qquad (7.11)$$

Step 5: The ideal and fuzzy negative ideal solution (FNIS) and positive ideal solution (FPIS) are determined as follows respectively:

$$A^+ = (v_1^+ \cdots \cdots v_n^+), where \; v_j^+ = max\left[v_{ij}\right] if j \in J: min\left[v_{ij}\right]$$

If $j \in j^{`}\}j = 1, \cdots\cdots, n$

$A^{-} = (v_1^{-} \cdots\cdots v_n^{-}), where\ v_j^{-} = min\left[v_{ij}\right] if j \in J: max\left[v_{ij}\right]$

If $j \in J^{`}\}$ j=1,……,n (7.12)

Step 6: The distance of each alternative from FPIS and FNIS is computed as follows

$$d_i^{+} = \left\{\sum_{j=1}^{n}\left(v_{ij} - v_{ij}^{+}\right)^2\right\}^{1/2}, i = 1,2, \ldots\ldots\ldots, m$$

$$d_i^{-} = \left\{\sum_{j=1}^{n}\left(v_{ij} - v_{ij}^{-}\right)^2\right\}^{1/2}, i = 1,2, \ldots\ldots\ldots, m \quad (7.13)$$

Step 7: The closeness coefficient (CCi) of each alternative is calculated by using Eq.

$CC_i = \frac{d_i^{-}}{d_i^{-} - d_i^{+}}$, i=1,2,……..,m.$C_i \in (0.1)$ (7.14)

Step 8: The alternatives as per closeness rating by using CCi are ranked in descending order.

The framework of the research methodology is provided in Figure 7.3

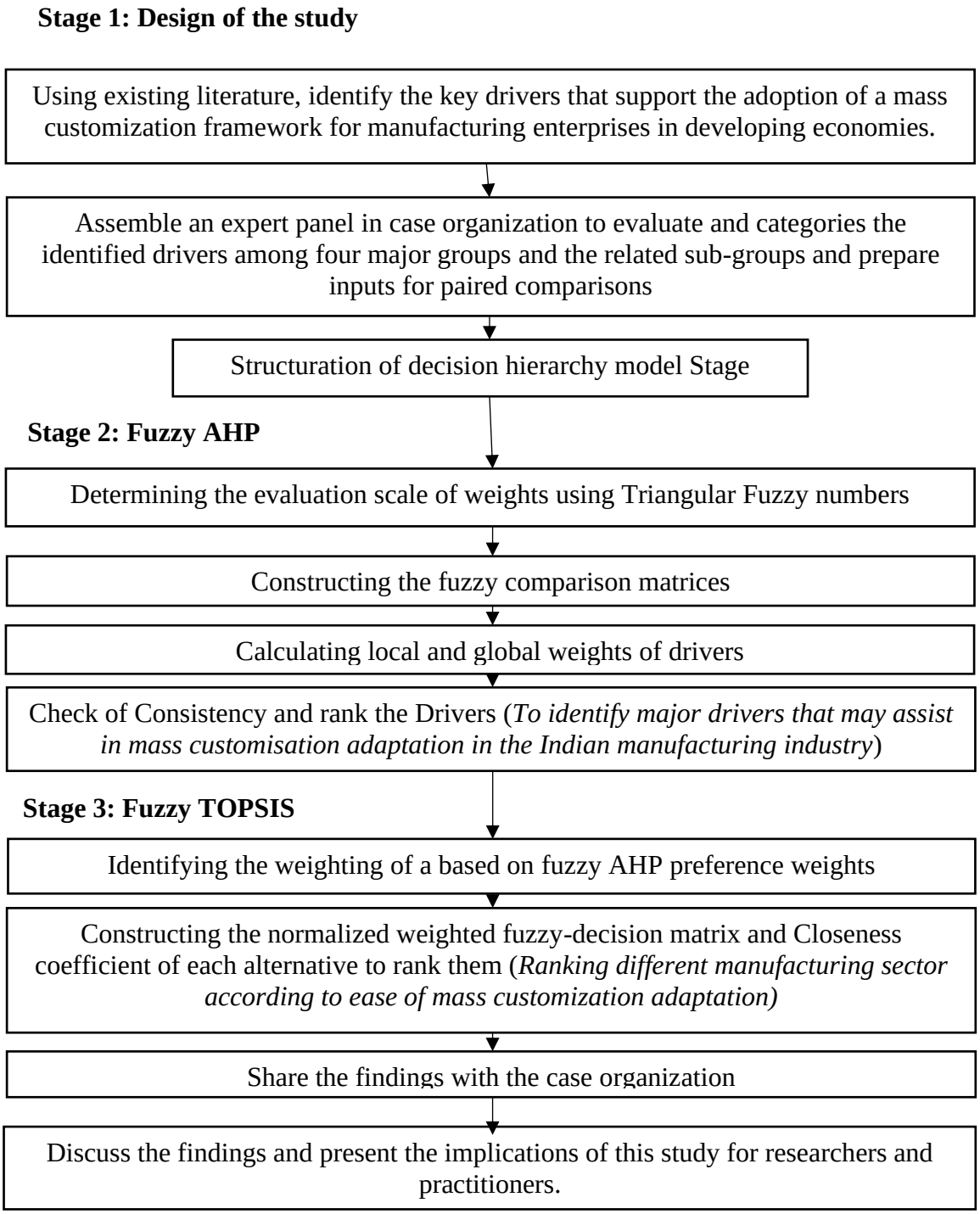

Figure 7.2: A proposed three-phase methodology for prioritizing the drivers of mass customization (Adopted from [151][224]**)**

The proposed framework for prioritizing the Industrial sectors for mass customization adaptation. is provided in Figure 7.3.

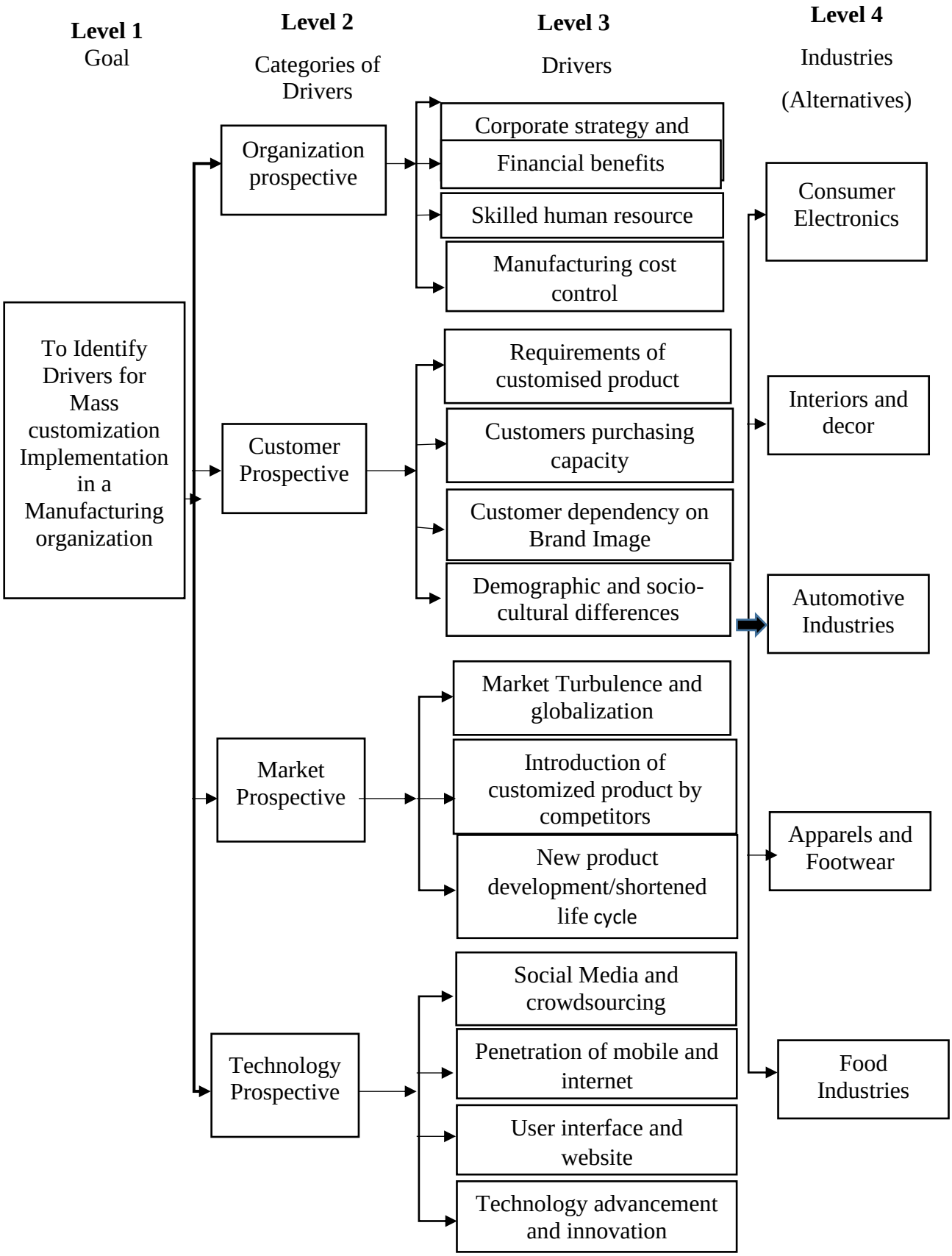

Figure 7.3: Proposed framework for prioritizing the Industrial sectors for mass customization adaptation: (Based on [151] [224]

7.3.3 Application of Proposed Framework

*Application of Fuzzy AHP***:** In this part, the fuzzy AHP technique was used to compute the weights of the MC drivers examined for this study. The pairwise comparisons were gathered from the group of experts stated in the preceding part, as shown in Table 7.2. Comparisons of the main criteria drivers and sub-criteria drivers were established based on expert opinion. Organization, Market, Customer, and Technology prospects were among the main criteria drivers. Table 7.4 contains the thorough comparisons conducted by the experts for the important criteria.

- Following the experts' decisions, the research methodology mentioned in the previous section was followed. The linguistic evaluation received by the 10 experts was transferred to the corresponding fuzzy numbers.
- In the next step, the elements of the synthetic pairwise comparison matrix were then calculated by using the geometric mean method as

$$\tilde{a}_{ij} = \left(\tilde{a}^{1}{}_{ij} \otimes \tilde{a}^{2}{}_{ij} \otimes \cdots \otimes \tilde{a}^{10}{}_{ij}\right)$$

For eg: For D12, 10 experts ranked intensity of importance as 4, 3,…..,1

They were then converted to TFNs(Table 7.3) as (3,4,5),(2,3,4),…,(1,1,1),Taking the geometric mean of TFNs,

$\tilde{a}_{12} = (3,4,5)\otimes(2,3,4)\otimes,\cdots\otimes(1,1,1) = (3\times 2\times\cdots 1)^{\frac{1}{10}}, (4\times 3\times\cdots 1)^{\frac{1}{10}}, (5\times 4\times\cdots 1)^{\frac{1}{10}} =$ (2.08,2.78,3.42) (Refer table 7.4, for D1-D2).Similarly , other values were calculated.

- Thereafter, the local weight vector is calculated using Chang's Extent Analysis method as follows. The associated Si values can be calculated through Eq. (7.2) as follows:

$$S_1 = (4.61,5.94,7.27)\otimes\left(\frac{1}{24.42}, \frac{1}{19.41}, \frac{1}{15.31}\right) = (0.19,0.31,0.47)$$

Similarly, S2-S4 are calculated: S2 = (0.09, 0.13, 0.20), S3 = (0.16, 0.27, 0.46), and S4 = (0.19, 0.29, 0.46)

Using Eq. (7.3), the degree of possibility for two fuzzy extents numbers is given as:

$$V(S_2 > S_1) = \frac{0.19 - 0.20}{(0.13 - 0.20) - (0.31 - 0.19)} = 0.056$$

Similarly, $V(S_i \geq S_k)$ are calculate:

$V(S_3 \geq S_1) = 0.887, V(S_4 \geq S_1) = 0.958$

$V(S_1 \geq S_2) = 1, V(S_3 \geq S_2) = 1, V(S_4 \geq S_2) = 1$

$V(S_1 \geq S_3) = 1, V(S_2 \geq S_3) = 0.210, V(S_4 \geq S_3) = 1$

$V(S_1 \geq S_4) = 1, V(S_2 \geq S_4) = 0.05, V(S_3 \geq S_4) = 0.03$

Using equation 7.4, we obtain:

$d`(A_1) = minV(S_1 \geq S_2, S_3, S_4) = \min(1,1,1) = 1$

$d`(A_2) = minV(S_2 \geq S_1, S_3, S_4) = \min(0.056,0.210,0.050) = 0.050$

$d`(A_3) = minV(S_3 \geq S_1, S_2, S_4) = \min(0.887,1,0.03) = 0.03$

$d`(A_4) = minV(S_4 \geq S_1, S_2, S_3) = \min(0.958,1,1) = 0.958$

Hence $W` = (1,0.050,0.03,0.959)^T$ and After normalizing, W=(0.491,0.025,0.015,0.470)T.This is provided in Table 7.4 for main categories of drivers.

Table 7.4: Pair-wise comparison matrix and local weights calculation for categories of Drivers

	D1	**D2**	**D3**	**D4**	**Local Weight**	**Rank**
D1	1	(2.08,2.78,3.42)	(1.05,1.57,2.11)	(0.48,0.59.0.74)	0.491	1
D2	(0.29,0.36,0.48)	1	(0.38,0.54,0.79)	(0.44,0.59,0.78)	0.025	3
D3	(0.47,0.64,0.95)	(1.89,2.88,4.06)	1	(0.57,0.76,0.98)	0.015	4
D4	(1.35,1.69,2.07)	(1.28,1.69,2.27)	(1.02,1.32,1.75)	1	0.470	2

The local weigh value thus calculated helped to rank the main drivers, where organization is ranked first, followed by technology, customer and market. Similar calculation is done for organization perspective. The local weight calculation ranked corporate strategy and goals (D11) as first, financial benefits (D12) as second, followed by skilled human resource (D14) and manufacturing cost control (D13). The result of calculation is provided in Table 7.5.

Table 7.5: Pair-wise comparison matrix and local weights calculation for categories of Drivers of Organization perspective

Organizational (D1) Drivers	D11	D12	D13	D14	Local Weight	Rank
D11	1	(0.84,1.16,1.52)	(0.90,1.23,1.94)	(1.94,2.55,3.12)	0.386	1
D12	(0.66,0.86,1.2)	1	(1,94,2.55,3.12)	(0.62,0.86,1.09)	0.332	2
D13	(0.64,0.81,1.11)	(0.32,0.39,0.51)	1	(0.57,0.79,1.10)	0.084	4
D14	(0.32,0.39,0.51)	(0.92,1.16,1.60,)	(0.91,1.26,1.77)	1	0.198	3

Likewise, the fuzzy comparison matrix for customer perspective is calculated and shown in Table 7.6. The local weight calculation ranked requirements of the customized product (D21) as first, customer purchasing capacity (D22) second, demographic and sociocultural differences (D24) third and customer dependency on brand Image (D23) fourth driver to drive MC implementation.

Table 7.6: Pair-wise comparison matrix and local weights calculation for categories of Drivers of Customer Perspective

Customer Drivers(D2)	D21	D22	D23	D24	Local Weight	Rank
D21	1	(1)	(1.40,1.90,2.43)	(1.06,1.41,1.68)	0.445	1
D22	(0.45,0.56,0.71)	1	(1.20,1.49,1.81)	(1.16,1.44,1.71)	0.258	2
D23	(0.41,0.52,0.71)	(0.55,0.67,0.83)	1	(1.01,1.34,1.69)	0.072	4
D24	(0.59,0.71,0.95)	(0.58,0.70,0.86)	(0.59,0.79,0.99)	1	0.225	3

Based on the above process of calculation, the fuzzy comparison matrix for market prospective is calculate. The local weight calculation of W (0.553, 0.417, 0.013) ranked market turbulence and globalization (D31) of rank one, followed by introduction of customized products by competitors (D32), and new product development/shortened life cycle (D33). This is provided in Table 7.7.

Table 7.7: Pair-wise comparison matrix and local weights calculation for categories of Drivers of Market Perspective

Market Drivers(D3)	D31	D32	D33	Local Weight	Rank
D31	1	(1.45,1.93,2.44)	(0.98,1.25,1.55)	0.553	1
D32	(0.41.0.52,0.69)	1	(1.69,2.06,2.40)	0.417	2
D33	(0.64,0.80,1.02)	(0.42,0.49,0.59)	1	0.013	3

Similarly, the fuzzy comparison matrix for technology perspective rank is calculated and shown in Table 7.8. Technology advancement and innovation (D44) is ranked first, penetration of mobile and internet (D42) second, social media and crowdsourcing (D41) third, and user interface and website/ omni channel distribution and e-commerce (D43) fourth.

Table 7.8: Pair-wise comparison matrix and local weights calculation for categories of Drivers of Technology Perspective

Technology Drivers(D4)	D41	D42		D44	Local Weight	Rank
D41	1	(0.90,1.13,1.41)	(0.88,1.10,1.34)	(0.34,0.47,0.64)	0.139	3
D42	(0.71,0.89,1.11)	1	(2.23,2.96,3.60)	(0.44,0.52,0.63)	0.368	2
D43	(0.75,0.91,1.14)	(0.28,0.34,0.45)	1	(0.86,1.02,1.21)	0.055	4
D44	(1.57,2.13,2.96)	(1.58,1.92,2.29)	(0.82,0.98,1.16)	1	0.438	1

The experts' matrix comparisons were double-checked for consistency. The λ_{max} and consistency indexes were determined first, and then the consistency index CI was validated. For weight calculation,

only matrices with a CI value of less than 0.1 were considered. If any of the matrixes were found to be inconsistent, they were sent back to the experts for a second opinion [121]. In the present case, all the matrix comparisons made by the experts were found to be consistent. The final rank of all drivers is provided in Table 7.9.

Table 7.9: Weights and ranking of all categories and Drivers of Mass Customization

Ref	Categories of Drivers	Weight	Ref	Drivers	Local Weights	Global Weight	CR	Rank
D1	Organization perspective	0.491	D11	Corporate strategy and goals	0.386	0.096	0.041	**5**
			D12	Financial benefits	0.332	0.083		**7**
			D13	Manufacturing cost control	0.084	0.021		**12**
			D14	Skilled human resource	0.198	0.050		**10**
D2	Customer Perspective	0.025	D21	Requirements of customized product	0.445	0.111	0.045	**2**
			D22	Customers purchasing capacity	0.258	0.064		**8**
			D23	Customer Dependency on Brand Image	0.072	0.018		**13**
			D24	Demographic and socio-cultural differences	0.225	0.056		**9**
D3	Market Perspective	0.015	D31	Market Turbulence and globalization	0.553	0.138	0.098	**1**
			D32	Introduction of customized products by competitors	0.417	0.104		**4**
			D33	New product development/shortened life cycle	0.013	0.008		**15**
D4	Technology Perspective	0.470	D41	Social Media and crowdsourcing	0.139	0.035	0.078	**11**
			D42	Penetration of mobile and internet	0.368	0.092		**6**
			D43	User interface and website/ Omni channel/E commerce	0.055	0.014		**14**
			D44	Technology advancement and innovation	0.438	0.109		**3**

*Application of Fuzzy TOPSIS***:** After determining driving weights, the MC experts were required to develop a fuzzy evaluation matrix based on the language scale displayed in Table 7.3(To prevent an excessive number of tables, just the fuzzy evaluation matrix provided by expert 1 is shown in tables 7.10.) This is performed by comparing each driver's MC adaptation in various industrial sectors.

Table7.10: Linguistics variables rating matrix for the Industrial sectors (expert 1)

	D11	D12	D13	…	…	D42	D43	D44
I1	VH	M	L	…	…	H	M	H
I2	M	L	L	…	…	VH	M	VH
I3	L	M	VH	…	…	H	M	M
I4	H	H	L	…	…	H	VH	VH
I5	L	L	H	…	…	L	H	M

Then after, the fuzzy evaluation matrix was created by transforming the linguistic concepts into TFNs (As per Table 7.3). To prevent an excessive number of tables, just the fuzzy evaluation matrix provided by expert 1 is shown in tables and 7.11.

Table7.11: TFN evaluation matrix for the Industrial sectors (expert 1)

	D11	D12	D13	…	…	D42	D43	D44
I1	(7,9,11)	(3,5,7)	(1,3,5)	…	…	(5,7,9)	(3,5,7)	(5,7,9)
I2	(3,5,7)	(1,3,5)	(1,3,5)	…	…	(7,9,11)	(3,5,7)	(7,9,11)
I3	(1,3,5)	(3,5,7)	(7,9,11)	…	…	(5,7,9)	(3,5,7)	(3,5,7)
I4	(5,7,9)	(5,7,9)	(1,3,5)	…	…	(5,7,9)	(7,9,11)	(7,9,11)
I5	(1,3,5)	(1,3,5)	(5,7,9)	…	…	(1,3,5)	(5,7,9)	(3,5,7)

.

Drivers are used as a criterion in this study, and industrial sectors are used as alternatives. Aggregate fuzzy weights are obtained by taking the arithmetic mean of the inputs obtained from the three sets of experts using Equation (7.9). It is shown in Table 7.12

Table7.12: Aggregate fuzzy decision matrix for Industrial sectors

	D11	D12	D13	…	…	D42	D43	D44
I1	(5,8.33,11)	(1,4.33,7)	(5,8.33,11)	…	…	(3,5.67,9)	(3,6.33,9)	(5,7.67,11)
I2	(3,5.67,7)	(1,3.67,7)	(1,3.67,7)	…	…	(5,7.67,11)	(3,5,7)	(7,9,11)
I3	(1,3.67,11)	(1,4.33,7)	(1,3,11)	…	…	(5,7.67,11)	(3,5,9)	(3,6.33,9)
I4	(5,7.67,11)	(5,8.33,11)	(5,7.67,9)	…	…	(5,8.33,11)	(5,8.33,11)	(5,8.33,11)
I5	(1,5,7)	(1,3.67,5)	(1,3.67,5)	…	…	(1,4.33,9)	(5,8.33,11)	(3,6.33,9)

Because the study's purpose is to maximize the criteria (i.e., drivers), the drivers are regarded as benefit criteria. As a result, the normalized fuzzy matrix (shown in Table 7.13) is obtained using Equation (7.10b). The normalized entry for solution I1 about driver D11, for example, is calculated as

$p_{ij}= (\frac{5}{11}, \frac{8.33}{11}, \frac{11}{11})$; $c_{max=11}$= (0.45, 0.76, 1.00), For 1I1-D11 calculation.

Table 7.13: Normalized fuzzy decision matrix for Industrial sectors

	D11	D12	D13	..	D42	D43	D44
I1	(0.45,0.76.1	(0.09,0.39,0.6	(0.45,0.76.1.0	..	(0.27,0.52,0.8	(0.27,0.58,0.8	(0.45,0.
I2	(0.27,0.52,0	(0.09,0.33,0.6	(0.09,0.33,0.6	..	(0.45,0.70,1.0	(0.27,0.45,0.6	(0.64,0.
I3	(0.09,0.33,1	(0.09,0.39,0.6	(0.09.0.27.1.0	..	(0.45,0.70,1.0	(0.27,0.45,0.8	(0.27,0.
I4	(0.45,0,70,1	(0.46,0.76,1.0	(0.45,0.70,0.8	..	(0.45,0.76.1.0	(0.45,0.76,1.0	(0.45,0.
I5	(0.09,0.45,0	(0.09,0.33,0.4	(0.09,0.33,0.4	..	(0.09,0.39,0.8	(0.45,0.76,1.0	(0.27,0.

In the next step, a weighted normalized matrix is calculated using Eq. 7.11, and shown in Table 7.14.

Table 7.14: Weighted normalized fuzzy decision matrix for Industrial sectors

	D11	D12	D13	..	D42	D43	D44
I	(0.45,0.76.1.0	(0.09,0.39,0.6	(0.45,0.76.1.0	..	(0.27,0.52,0.8	(0.27,0.58,0.8	(0.45,0.
I	(0.27,0.52,0.6	(0.09,0.33,0.6	(0.09,0.33,0.6	..	(0.45,0.70,1.0	(0.27,0.45,0.6	(0.64,0.
I	(0.09,0.33,1.0	(0.09,0.39,0.6	(0.09.0.27.1.0	..	(0.45,0.70,1.0	(0.27,0.45,0.8	(0.27,0.
I	(0.45,0,70,1.9	(0.46,0.76,1.0	(0.45,0.70,0.8	..	(0.45,0.76.1.0	(0.45,0.76,1.0	(0.45,0.
I	(0.09,0.45,0.6	(0.09,0.33,0.4	(0.09,0.33,0.4	..	(0.09,0.39,0.8	(0.45,0.76,1.0	(0.27,0.

Fuzzy positive-ideal solution FPIS (A+) and fuzzy negative-ideal solution FNIS (A-) are calculated using Eq. (7.12-7.14) as shown in Table 7.15.

Table 7.15. Closeness coefficient (CCi) and the final ranking of Industrial sectors

Ref	**Industrial Sector**	d_i^+	d_i^-	CC_i	**Rank**
I1	Consumer Electronics	0.0129	0.0135	0.510	**3**
I2	Interiors and decors	0.0116	0.0145	0.555	**2**
I3	Automotive Industries	0.0171	0.0113	0.397	**4**
I4	Apparels and Footwear	0.0032	0.0466	0.936	**1**
I5	Food Industries	0.0213	0.0046	0.117	**5**

7.4 Case Illustration

Four companies were selected after a thorough search for organizations of Indian origin that had implemented mass customization. A study was carried out to determine the drivers that prompted them to venture into the more touted and less explored realm of mass customization. The businesses profiles of the organizations are provided in Table 7.16. Questionnaire for Drivers of Mass Customization to understand opinions of expert regarding drivers is provided in appendix 5.

Table 7.16: Company and Expert Profile

Company Name	Type of Industry	Mass Customized Product	Expert Profile	Years of experience
A	Interior and décor section	Sheesham wood furniture	Sales and Marketing expert Production management expert IT experts	20 15 17
B	Food Industry	Mass customized nutritional foods (semi prepared)	Business analyst Production Head Marketing expert	15 15 17
C	Apparels and Footwear	Shoes	Senior management executives Social media expert	20 15
D	Apparels and Footwear	Fashion garments	Customer relationship management experts Vendor management experts	15 16

Thorough discussions with experts from the case companies of Indian origin were done to understand the drivers that motivated them for mass customization. The discussion avenues are provided bellow:

Company A, qualifying for the interior and décor section, is a major e-commerce portal, that recently debuted a new line of Sheesham wood furniture with more than 8700 products across 82+ product categories, as per the global furniture trends. The products featured on their website are expertly crafted and accessible at a reasonable price, keeping in view an important driver, customers purchasing capacity. Considering user interface and website/ omni channel/E commerce as an imperative driver, the company provided several search options to help customers find exactly what they're looking for, like down comforters, storage chests, bookshelves, and a simple yet elegant

housewarming present. They provide a customized solution that meets individual needs, resulting in high-quality furniture that is tailored to the preferences of customers, thus identifying requirements of customized products as a major driver. To ensure the individuality of their designs, they perform considerable study before handcrafting the components that create a beautiful appearance to space. Companies stay updated on the current developments and latest trends in the industry, because of the introduction of customized products by competitors as a significant driver and disseminate information as soon as possible on the web platform to stay ahead of the competition. As a result, they can mix the best of their craft with their skilled craftsman and design and furniture development team, driven by skilled human resources, with cutting-edge concepts to give their customers the most cutting-edge modern furniture. The firm is quickly adopting new technology, keeping abreast with major drivers, technological advancement, and innovation, to boost its visibility and provide immediate support to consumers looking for furniture solutions in the market and aimed at providing class apart furniture that is a perfect fusion of creativity and modernism. Corporate strategy and goals emphasize adopting a clear, accurate, straightforward policy for refunds, returns, and shipping tracking, resulting in a convenient and interactive furniture purchasing procedure.

Company B, mass customizing food products, has its recipes based on the preferences of their customers, and all recipes are seasonal and made with 100 percent local ingredients sourced from small farmers who grow things naturally, considering the requirement of healthy customized food and free from harmful preservatives as a major driver(Requirements of customized product). They have over 130 handcrafted delicacies for all age groups, starting as early as the 6th month, and over 7000 recipes that can be mass customized, considering demographic and socio-cultural differences of customers in India as the driver for the same. The company increased its revenue more than four times in the current year, thus motivated by financial benefit as a driver for change. During the pandemic, market turbulence and globalization drove the firm to accept the challenge of persuading new customers who were apprehensive about safety. The company provided the facility to customers to see their orders

being made life on social media, made possible due to the penetration of mobile and the internet. Because of its remote location, the company had no way of selling or exposing its work at first, but Omni channel and e-commerce marketing eventually propelled it forward.

Company C, a start-up company, manufactures affordable mass-customized shoes to cater to an urban audience, considering customers purchasing capacity a prominent driver. The firm created a ground-breaking 3D interactive design tool, technology advancement, and innovation being the driver that allows users to customize more than five different aspects of a shoe, comprehending the requirements of customized products for comfort and fit. Customers can choose from a variety of materials or submit their own, considering demographic and socio-cultural differences in India as a prime driver for mass customization. Firms ensure that the gross margins are sufficient to cover marketing and other expenses, identifying financial benefits as a major driver for success. They seek up-and-coming designers who need a platform to show off their work on a commission basis, leading to manufacturing cost control. Identifying the importance of customer dependency on Brand Image, they are in the process of tactical alignment with popular brands for their product. Identifying penetration of mobile and internet as an important driver of change, their unique selling point (USP) lies in the user experience on its website, which is extremely simple and easy to use. As part of corporate strategy and goals, they aspire to develop the operation and eventually build an e-commerce business and brand in India by engaging customers on social media.

Company D, mass customizing fashion garments, is a fashion-forward tech brand that uses technology and artificial intelligence to solve the main problem with garment fit, identifying requirements of customized products and technology and advanced innovation as the major drivers. Their business model aims to provide inspiring fashion that is also innovative and sustainable. They offer the best fit in garments through 3D body scanning and digital modification as a tech-based fashion firm (in-store and online). To reduce industrial waste, the company maintains digital inventory, manufacturing cost control being a foremost concern. The firm had to personalize its

marketing strategy to segregate the target demographic for its product, owing to the rich culture and tradition of India. The firm finds the clothing e-commerce sector fiercely competitive, and online clients unpredictable. Customers prefer to shop where they can find the best deals, affecting online businesses, classifying market turbulence and globalization, and introduction of customized products by competitors as the drivers. The corporate strategy and goal are to offer high-quality products on schedule, and the greatest services in terms of exchange, quality, and delivery time to ensure that customers are satisfied.

7.5 Results and Discussions:

No research has been done to date, to the best of the researchers' awareness, on identifying and prioritizing the drivers of mass customization. Concerns about the transition in business practices toward internet purchases and customization must be addressed cost-effectively for firms to remain competitive and provide value in the current global landscape. This study aims to motivate and encourage practitioners to foray into the more competitive arenas of mass customization for getting an edge in the marketplace by identifying the drives that drive the industry from mass production to mass customization and gain a better understanding of the primary drivers that tends to drive the adoption of MC in the Indian context, as well as to provide important managerial consequences.

The result in fuzzy AHP ranks market turbulence and globalization as the major driver that drives mass customization, in agreement with researchers that businesses that fail to recognize the severity of the competitive landscape will suffer [71]. This is followed by the requirement of customized products (ranked 2^{nd}) since customers' requirements, preferences, and expectations alter with developing trends and fads[27]. Technology advancement and innovation (ranked 3^{rd}) drive organizations to be far more flexible in their manufacturing processes and to customize conventional products to alter and reinforce qualities that are more important to customers [27]. Introduction of the customized product by a competitor ranks 4^{th}, in view that entrepreneurs must pay close attention to their competitors' expanding activities[27] followed by corporate strategy and goals(ranked 5^{th}) since

many industries encounter a rapidly escalating competition that is referred to as "hyper-competition." and a shift would necessitate a strategic restructuring, strategy formulation and planning of how corporations administer the strategy process [132]. Penetration of mobile and internet ranks 6th, though it is observed that in India, mobile phones have a high penetration rate, however, mobile Internet penetration is still low[226], hence it is advisable to implement MC in areas where there is greater reach. To mitigate the consequences of COVID-19 and reassess risk assessment and contingency measures, manufacturers require a new approach, such as MC, that can provide a solution to the pressing issues that must be addressed to keep the organization financially viable [130], ranking financial benefits of organization 7th. Customers purchasing capacity (8th) should be considered before the company decides to go for a high level of mass customization or a low degree of MC. Demographic and socio-cultural differences rank 9th, given the wide socio-cultural diversity in India, matching MC interfaces to customers' culture-specific thinking methods can provide considerable benefits[11]. Skilled human resource ranks 10th, implying that firms should not view mass customization adaptation as a difficult goal, but rather as a process that necessitates thorough consideration and application of appropriate techniques such as employee attitudes, team processes, and employee participation [71]. India has a highly qualified workforce as well as a large number of English-speaking scientists, researchers, and engineers, making it well-suited to assist high-tech industries[227]. Social Media and crowdsourcing(11th) should be used as toolkits to assist customers in the co-design of MC products[130] to generate unprecedented options for the customer to select the brand he needs[228]. Manufacturing cost control comes in at number 12, indicating that even though an MC system might raise manufacturing complexity, it is still vital to discover chances for customisation that provide value for the client and reach a reasonable cost for the producer [35].Customer dependency on Brand Image ranks 13th , accentuating companies that specialise in mass customization, need to have devoted customers, or have a strong brand to thrive in rapidly growing and profitable markets [222].User interface and website/ Omni channel/E commerce ranks 14th , it is essential to take a proactive stance,

comprehend multiple barriers, and analyse potentials by establishing a dynamic Omni channel marketing method and strategy in India, where it offers customers an interactive online presence, an engaged mobile interaction, and a vibrantly integrating website to provide a seamless shopping experience[220]. Increased "interface fluency"—consumers' perceived experience of simplicity while using the interface—as well as the need for businesses to adapt the customisation perspective by delivering handling interfaces across consumer marketplaces result in positive consumer responses[11]. Growing demands for product variety and shorter product life cycles create a slew of challenges for the product lifecycle, necessitating the development of methodologies and tools to meet product–service customisation. As a result, new product development/shortened life cycle ranked 15th.

MC is no longer a concept, but rather a reality that can be observed in a range of industries, particularly in the fashion industry, with apparel and footwear (29 percent) and food and beverages (29 percent) being the most popular categories for acquiring customized products in China [35]. According to Fuzzy Topsis, the simplicity of adapting MC in apparel and footwear rates first. According to certain research, the footwear sector in India has adapted to MC [15]. Interiors and Decors are ranked second, with literary support in the Indian context [54] and highlight MC in the wardrobe and pigment business. Electrical and Electronics stands 3rd, finding literature support for mass customization of fans in India[55]. The automobile industry ranks 4^{th,} and the Food industry ranks 5th. Though literature support of mass customization in these industries was unavailable from the Indian context, a study from the global context suggests and case study (Company B) supports the possibility of the adaptability of MC in these fields. Customer dependency on Brand Image should be considered by the automotive industry before venturing into the arena of MC. The focus of customers on health and hygiene issues due to Covid 19, can provide new arenas of mass customization in the food industry, but drivers like demographic and socio-cultural differences and customers' purchasing capacity should be considered.

7.5 Conclusion

This chapter focuses on identifying and ranking the drivers of mass customization adaptation to assist Indian manufacturing companies in strategic planning, encouraging them to take the first step toward a long-term business model in a competitive market and to comprehend strategic goals to build a competitive business structure. The major drivers identified are market turbulence and globalization, requirements of customized product, technology advancement and innovation and introduction of customized products by competitors. Identifying and prioritization of drivers for MC will assist managers and decision-makers in focusing on a few key drivers that will aid in the changeover from mass production to mass customization. The different manufacturing sectors for ease of adaptability according to identified drivers are prioritised. Case studies in four organizations of Indian origin were conducted to uncover the drivers that led them to pursue the more lauded but less explored area of mass customization and verify the proposed framework. The next chapter concludes the research work.

CHAPTER 8

Summary, Limitation, and Scope

8.1 Introduction

The research is summarised in the last chapter, focusing on the contribution that this thesis has made to the reservoir of knowledge about the acceptance of mass customization in the context of developing countries like India. Also addressed are the study's theoretical and managerial ramifications. The study's limitations are also discussed, along with some suggestions for further research. The chapter ends with the main findings of the investigation. The flow of the chapter is presented in Figure 8.1.

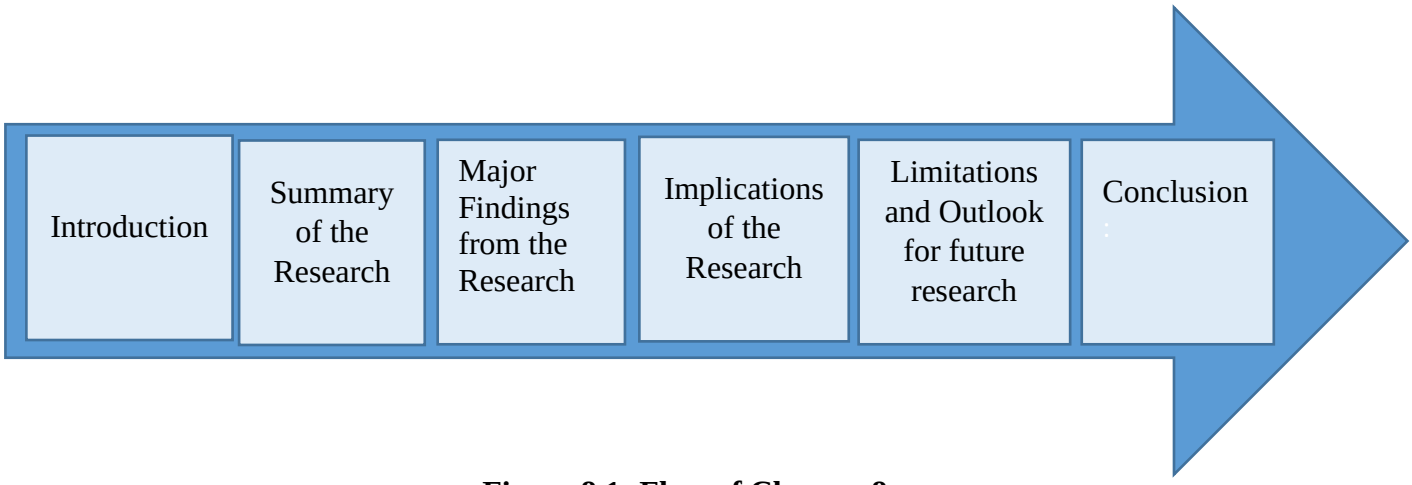

Figure 8.1: Flow of Chapter 8

8.2 Summary of the Research: In this section, the research work is summarised as follows:

Mass customisation has emerged as a significant topic of research in the quickly changing economic world of today. Various authors' points of view have been reviewed to determine the requirement for the study work in Chapter 2's literature review, which also identifies the research gap and examines the necessity for mass customization as a manufacturing paradigm for excellence. To comprehend the significance of the subject for further research, the design and manufacturing difficulties described in the literature have been highlighted. The transformation model must first be

understood by practitioners before they can take on the difficult paradigm, notwithstanding the theory's soundness. With the help of a literature analysis, this study examined and proposed a model for the mass customization transformation that occurs when an organization switches from mass manufacturing to MC in terms of manufacturing, customers, human resources, and business strategies.

In fulfilment of objective one, twelve enablers were identified with the help of LR and expert opinion and presented in chapter 4. The level partitioning of the enablers in five levels with TISM, led to developing of a theoretical framework which depicted how enablers are positioned at various levels and their influence on each other. The analysis of achieving the enablers is shown by the interpretation of their transitive links. The driving and dependence power of the enablers is determined using MICMAC analysis. Thus, a theory for MC for manufacturing units is created. This theory is then validated using the expert judgment of three Indian manufacturing organizations with the help of structured questionnaires. Practises to facilitate the attainment of mass customisation are advised for organisations wishing to implement it.

In chapter 5, for attaining objective two, constructs were identified for creating a manufacturing model for MC implementation. The manufacturing model created was based on the theoretical model of the four pillars of mass customization identified by researcher Hart. and five research hypotheses generate a set of research hypotheses. To gather feedback from business professionals, a questionnaire was created and disseminated. The survey responses provided insight into how the market views major model elements influencing the use of mass customization for competitive advantage. To test the developed hypotheses, the study used a sample of 276 Indian enterprises and the structural equation modelling (SEM) method. The responses received was examined using the content and construct validity, reliability, descriptive statistics, and statistical analysis. The manufacturing model was statistically validated.

The research applied multiple case study methods to verify the manufacturing model framework developed for mass customization implementation in Chapter 6. This helped in the

attainment of objective 3. The case studies were carried out in three Indian manufacturing companies. This theory extension is aimed at validating the framework, that will contribute to understanding strategies to be adopted by organizations to comprehend and facilitate their transition. Production managers, quality managers, sales and marketing personnel, supply chain managers, and business heads from three manufacturing enterprises in India were interviewed in-depth. The case companies are diverse in terms of size, ownership, and markets they serve. In businesses striving to implement mass customization, challenges were identified, and strategies were proposed to enhance the accomplishment of mass customization for competitive advantage. While earlier studies on mass customization in India focused on framework for implementation, the current research expanded on Hart's four pillars of mass customization and empirically tested the framework to identify the connections between the constructs for competitive advantage.

In India, mass customization as a manufacturing approach is a burgeoning concept, and the identification of drivers of mass customization that drive the current market was thoroughly explored in chapter7. This research work focused on identifying and ranking the drivers of mass customization adaptation to assist Indian manufacturing companies in strategic planning, encouraging them to take the first step toward a long-term business model in a competitive market and to comprehend strategic goals to build a competitive business structure. A systematic literature review (SLR) method was conducted for encapsulating and sorting current information to identify the mass customization drivers. Fifteen drivers were grouped into four categories and ranked based on inputs from industry experts using the FAHP. FTOPSIS was used to rank various manufacturing sectors for mass customization adaptability in the current economic environment. Case studies in four organizations of Indian origin were conducted to uncover the drivers that led them to pursue the more lauded but less explored area of mass customization and verify the proposed framework. Thus, objective four was achieved.

8.3 Major Findings from the Research: The major findings of the research work are summarized below:

A framework is developed in chapter 4, with the help of TISM to level partition twelve major enablers that will aid in the implementation process of mass customization. Five levels are identified in the framework and the driving and dependence power of enablers calculated with the help of MICMAC methodology. Organization Culture and Change Management was identified in level 5, that led to Management support and Multifunctional Workforce in level four. In level 3, was social media and sensitiveness of marketing team. Level 2 had four enablers, IT enabled technology, modularity in design, vendor capable of co-development of product and Flexible Manufacturing system. Finally, the driven enablers in level 1 were competitive pricing, quick customer response and customised product. The framework was validated in three companies who have already implemented mass customization, Company A, mass customizing Paints, Company B, mass customizing wardrobes, and Company C, mass customising ceiling fan.

The research, in chapter 5, was able to obtain discernments on the nature of the linkage between the four pillars and MC, leading to competitive advantage. The empirical evidence identified that process amenability, competitive environment, and organizational readiness all have a major impact on mass customization. The study, on the other hand, did not support customer sensitivity, which could be because mass customization is a new manufacturing paradigm in India.

The research applied multiple case study methods to verify the above framework for mass customization implementation in chapter 6. This not only validated the manufacturing model framework, but also added seven more factors during discussions with case study companies. The process flow chart of three companies and the mapping of the manufacturing model factors to the process flow will help practitioners to understand different mass customization strategies to be adopted by organizations to comprehend and facilitate their transition. The organizations considered for the study specialised in mass customization of wardrobe, ceiling fans and fashion clothing.

According to the literature analysis, fifteen drivers were found, and in chapter 7 they were divided into four categories: Organisation perspective, Customer perspective, Market perspective, and Technology perspective. The drivers were ranked with the help of FAHP methodology. This can serve as the motivating factor for mass customization adaptation in the Indian manufacturing industry. Five manufacturing sectors were identified for ease of adaptability according to identified drivers. Since the ease of mass customization adaptation may differ as per the manufacturing sector, therefore, it was desirable to rank the various sectors to understanding their ease of adaptability. FTOPSIS result suggested that the simplicity of adapting MC in apparel and footwear rates first, Interiors and decors is ranked second, Electrical and Electronics stands 3rd, Automobile industry ranks 4th and Food industry ranks 5th.Four case studies in companies mass customizing furniture, shoes, fashion clothes and semi cooked food validated the framework.

8.4 Implications of the Research: The research utilised various methodology and developed framework for enablers, manufacturing model for mass customization implementation and framework for drivers and industrial sectors for ease of adaptability of mass customization. The implication of the research for academicians and managers are provided below:

8.4.1 Implication for Academics

The research has several important implications for academics.

- The research discussed the various review of literature on mass customization, with emphasis on design and manufacturing issues in chapter 2. This can form the base for future researchers to identify research gaps and explore other realms of MC.
- The research identified important methodologies and their importance and application in literature in chapter 3. Researchers can apply these methodologies in other aspects of their studies.
- Future studies on manufacturing organisations in other nations can be based on the enablers mentioned in this thesis.

- The questionnaire produced in this study could be utilized to conduct other empirical studies in manufacturing organizations.
- The case study protocol used in chapter 4 and chapter 6 can be used by academicians in future research in case studies.

8.4.2 Implications for Managers: The research has several important implications for managers:

- There has been minimal research regarding MC in the Indian manufacturing industry. • Businesses can use the study's findings to help them make decisions about creating distinctive operational capabilities and changing their present mass production systems to competitive MC ones.
- The findings of this study will aid managers who are contemplating a transition from mass manufacturing to mass customization in better comprehending the crucial areas where more emphasis is required. The TISM model offers recommendations for the enablers and the sequential process a company should use to properly implement mass customization.
- Identifying and prioritization of drivers for MC will assist managers and decision-makers in focusing on a few key drivers that will aid in the transition from mass production to mass customization.
- The case studies will help practitioners to understand hoe the factors/enablers/drivers were practically used by certain companies for MC implementation. Though MC is not an “one size fit” for all companies, it will aid in generating innovative practices for those venturing into this arena.
- The interplay of the components of the manufacturing model will assist the management in determining the causal associations between the constructs and their influence on overall operation for competitive advantage.

8.5 Limitations and Outlook for future research

A significant limitation of this study was the fact that mass customization is still a novel idea in India. Although management is aware of the issue, it is still early in the process of deciding the appropriate course of action. This study's objective was to learn more about the factors that influence the Indian economy's shift from MP to MC, and its methodology. The limitations are as follows:

The TISM technique has been used to develop theory in chapter 4. The TISM technique calls for the opinion of professionals, whose prejudice could skew the results of the study and prevent the technique from succeeding at the adoption stage. There is a chance that the outcomes will vary, as the organised sector and manufacturing environment of India served as the basis for this research's inputs, both for other industries and other geographical areas. This concept is only applicable to sectors of organised production. In the context of MSMEs, studies can be done to determine the mass customization enablers and their hierarchical relationships. The service industry is another area where mass customization is advancing, thus researching its success characteristics can be useful. Additionally, estimation of these enablers and their interrelationships could be communicated using other methodology. The current study can also make use of Fuzzy-MICMAC to ascertain the binary digits' current bounds.

In view of chapter 7, as with any empirical study, some limitations demanded further investigation. This framework should be tested in another country in the future to ensure that it works in other markets. Second, the research concentrates on the manufacturing sector. To assess the model presented in this study in other industries, a cross-industry comparison study could be conducted in the future. In the service sector, the approach can also be put to the test. Future research could include elements not included in this study, such as financial concerns. This framework is best suited for companies with a solid technical foundation. A comparable framework for MSMEs and start-ups may be investigated for the use of mass customization in a variety of businesses. Furthermore, the concept was put to the test for mass customization to edge over the competition. It is possible to test the same

model to see if it is profitable for other business prospects. Although mass customization, which employs modularization to improve product variety while maintaining mass production (MP) efficiency, has been popular in recent years, it does have some drawbacks. To begin with, clients do not fully participate in the design process. Second, designers have predetermined possible combinations. Due to multiple challenges faced, partial mass customization can be considered since the scope of operation and organizational readiness required is simpler. Automobile, furniture, and apparel industry can apply partial customization of standard products at the assembly or delivery stages.

The data gathered and outcomes of FAHP and FTOPSIS in chapter 7 for drivers of mass customization are mostly dependent on manufacturing enterprises in India's region. It limits the findings' generalizability from the perspective of the realm of industries of various geographies, types, and sizes. However, the findings might be analysed for applicability using wide and diverse sample sets. To evaluate the outcome of this study with those of other developing/developed countries, more research may be done. Other decision analysis approaches like TISM and MICMAC may be used to build theory and Structural equation modelling applied to test the theory. Also, future researchers can identify the drivers of mass customization for MSMEs and start-ups because these industries are finding it difficult to survive amidst COVID-19 economic turbulence.

8.6 Conclusion

With ever-increasing economic instability, MC will inevitably become more crucial for businesses of all sizes to survive and prosper. Given this scenario, businesses preparing to transition from MP to MC will require a framework for execution. The achievement of research objectives and the frameworks will aid in this process. The studies were able to complete all research objectives and draw inferences of the research work. The academic and managerial implications fulfil the research's desire for practical implacability.

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Appendix 1: Case Study Protocol

Section	Content	Purpose
Preamble	The identity of the organization and the person involved will be kept confidential. The data received from persons in the organization will be used for the sole purpose of research work and not used for any other purpose. The data received will be the property of the researchers and only the outcome of the data will be published in research journals.	Encloses information regarding the purpose of the protocol, guidelines regarding the storage of data, and document and publication.
General	• This research is based on identifying the enablers required to implement mass customization in a manufacturing unit and finding out their hierarchal structure The experts from the different organizations involved in this research work will be required to give their expert opinion regarding the importance of enablers, their interplay, and their role via a questionnaire prepared by the researcher. The hierarchical model will be developed by TISM and MICMAC analysis and experts will be required to validate the model as per the business strategy used in their organization.	Provides a brief overview of the research project and the case research method
Data analysis guidelines	• For analyzing the contextual relationship among different mass customization enablers, a structural self-interaction matrix sheet without notation was administered to each expert. • The final solution was summarized using four symbols (V, A, X, and O), to signify the relationship between the two Mass customization enablers. •	Guidelines for data analysis

Appendix 2: Questionnaire for Enabler of mass customization (TISM)

Delhi Technological University,

Department of Mechanical Engineering,

Shahbad-Daulatpur, Bawana Road,

Delhi-110042

Research Supervisors: Prof S.K Garg Mobile: 9873339015

Prof Gayatri Kansal

Subject: "**Enablers to enhance operational agility of an organization for Mass customization"** for a research-based study on Design and Manufacturing Issues of Mass Customization

Dear Sir/Madam

The goal of this research is to explore how enablers are placed at different levels and how a particular enabler influences the other or gets influenced. The enabler category, code, and description are provided for proper understanding. In the questionnaire provided, write V, A, X, or O as per the symbol description

V → Enabler i will help in achieving enabler j,

A → Enabler j will help in achieving enabler i,

X → Enabler i and j will improve each other and

O → Enabler i and j are unconnected

Note: The identity of the organization and person involved will be kept confidential

The data received will only be used for research work and not used for any other purpose.

The data received will be the property of the researchers and only the outcome of the data will be published in research journals.

Enabler code	Mass Customization Enabler	Description
E1	IT Enabled Technology	Efficiently linked Information network to manage additional complexity of production, supply chain, and service work
E2	Organization Culture and Change Management	A positive organizational culture that supports mass customization
E3	Social Media	Social media and crowdsourcing as toolkits to assist customers in the co-design of MC products.
E4	Competitive Pricing	The capability to yield customized products at a cost comparable to mass production.
E5	Customized Product	Design the product to meet the dynamic demand of the customer
E6	Modularity in Design	Capacity to assemble products from a set of standardized constituent units and apply postponement
E7	Multifunctional Workforce	Creative, supportive, and multi-skilled workforce to effectively cater to the organization's needs
E8	Integrated Management system	Top Management Support
E9	Vendor Capable of Co-development of product	Develop suppliers capable of handling the additional complexity of MC orders
E10	Quick Customer Response	Customers desire to own co-created products and systems efficiency to supply as desired
E11	Flexible Manufacturing system	Availability of flexible process technologies to build an integrated manufacturing system capable of delivering MC products.
E12	Sensitiveness of the Marketing team	A strategic business plan to identify customer requirements and meet emerging market needs

Questionnaire-Answer V/A/X/ or O as per your interpretation

Enabler Relationship	**Interpretation of Relationship between Factors**	**V/A/X/or O**
E1-E2	IT Enabled Technology helps in achieving Organization Culture and Change Management	
E1-E3	IT Enabled Technology helps in achieving Social Media	
E1-E4	IT Enabled Technology helps in achieving Competitive Pricing	
E1-E5	IT Enabled Technology helps in achieving Customised Product	
E1-E6	IT Enabled Technology helps in achieving Modularity in Design	
E1-E7	IT Enabled Technology helps in achieving Multifunctional Workforce	
E1-E8	IT Enabled Technology helps in achieving an Integrated Management system	
E1-E9	IT Enabled Technology helps in achieving Vendor Capable of Co-development of product	
E1-E10	IT Enabled Technology helps in achieving Quick Customer Response	
E1-E11	IT Enabled Technology helps in achieving a Flexible Manufacturing system	
E1-E12	IT Enabled Technology helps in achieving Sensitiveness of the Marketing team	
E2-E3	Organizational Culture and Change Management Help in Social Media	
E2-E4	Organization Culture and Change Management help in achieving Competitive Pricing	
E2-E5	Organization Culture and Change Management help in achieving Customised Product	
E2-E6	Organization Culture and Change Management help in achieving Modularity in Design	
E2-E7	Organization Culture and Change Management help in achieving Multifunctional Workforce	
E2-E8	Organization Culture and Change Management help in achieving an Integrated Management system	
E2-E9	Organization Culture and Change Management help in achieving Vendor Capable of Co-development of product	
E2-E10	Organization Culture and Change Management help in achieving Quick Customer Response	
E2-E11	Organization Culture and Change Management help in achieving a Flexible Manufacturing system	
E2-E12	Organization Culture and Change Management help in achieving the Sensitiveness of the Marketing team	
E3-E4	Social Media helps in achieving Competitive Pricing	
E3-E5	Social Media helps in achieving Customised Product	
E3-E6	Social Media helps in achieving Modularity in Design	

E3-E7	Social Media helps in achieving Multifunctional Workforce	
E3-E8	Social Media helps in achieving an Integrated Management system	
E3-E9	Social Media helps in achieving Vendor Capable of Co-development of product	
E3-E10	Social Media helps in achieving Quick Customer Response	
E3-E11	Social Media helps in achieving a Flexible Manufacturing system	
E3-E12	Social Media helps in achieving Sensitiveness of the Marketing team	
E4-E5	Competitive Pricing helps in achieving Customised Product	
E4-E6	Competitive Pricing helps in achieving Modularity in Design	
E4-E7	Competitive Pricing helps in achieving Multifunctional Workforce	
E4-E8	Competitive Pricing helps in achieving an Integrated Management system	
E4-E9	Competitive Pricing helps in achieving Vendor Capable of Co-development of product	
E4-E10	Competitive Pricing helps in achieving Quick Customer Response	
E4-E11	Competitive Pricing helps in achieving a Flexible Manufacturing system	
E4-E12	Competitive Pricing helps in achieving Sensitiveness of the Marketing team	
E5-E6	Customized Product helps in achieving Modularity in Design	
E5-E7	Customized Product helps in achieving Multifunctional Workforce	
E5-E8	Customized Product helps in achieving an Integrated Management system	
E5-E9	Customized Product helps in achieving Vendor Capable of Co-development of product	
E5-E10	Customized Product helps in achieving Quick Customer Response	
E5-E11	Customized Product helps in achieving a Flexible Manufacturing system	
E5-E12	Competitive Pricing helps in achieving Sensitiveness of the Marketing team	
E6-E7	Modularity in Design helps in achieving Multifunctional Workforce	
E6-E8	Modularity in Design helps in achieving an Integrated Management system	
E6-E9	Modularity in Design helps in achieving Vendor Capable of Co-development of product	
E6-E10	Modularity in Design helps in achieving Quick Customer Response	
E6-E11	Modularity in Design helps in achieving a Flexible Manufacturing system	
E6-E12	Modularity in Design helps in achieving the Sensitiveness of the Marketing team	

E7-E8	Multifunctional Workforce helps in achieving an Integrated Management system	
E7-E9	Multifunctional Workforce helps in achieving Vendor Capable of Co-development of product	
E7-E10	Multifunctional Workforce helps in achieving Quick Customer Response	
E7-E11	Multifunctional Workforce helps in achieving a Flexible Manufacturing system	
E7-E12	Multifunctional Workforce helps in achieving the Sensitiveness of the Marketing team	
E8-E9	Integrated Management system helps in achieving Vendor Capable of Co-development of product	
E8-E10	Integrated Management system helps in achieving Quick Customer Response	
E8-E11	An Integrated Management system helps in achieving a Flexible Manufacturing system	
E8-E12	An Integrated Management system helps in achieving the Sensitiveness of the Marketing team	
E9-E10	Vendor Capable of Co-development of the product helps in achieving Quick Customer Response	
E9-E11	Vendor Capable of Co-development of the product helps in achieving a Flexible Manufacturing system	
E9-E12	Vendor Capable of Co-development of product helps in achieving Sensitiveness of Marketing team	
E10-E11	Quick Customer Response helps in achieving Flexible Manufacturing system	
E10-E12	Quick Customer Response helps in achieving Sensitiveness of Marketing team	
E11-E12	Flexible Manufacturing system helps in achieving Sensitiveness of Marketing team	

Appendix 3: Questionnaire for Hypothesis Testing

Delhi Technological University,

Delhi Department of Mechanical Engineering,

Shahbad-Daulatpur, Bawana Road,

Delhi-110042

Research Supervisors: Prof S.K Garg Mobile: 9873339015

Prof Gayatri Kansal

Subject: "**Manufacturing model to enhance operational agility of an organization for Mass customization "** for a research based study on Design and Manufacturing Issues of Mass Customization

Dear Sir/Madam

Mass customization (recent nomenclature is Multi Product Variability –MPV) relates to the ability to provide customized products or services in high volumes and at reasonably low costs. A research to study the impact of various factors for successful implementation of mass customization is being conducted. A small questionnaire has been prepared where it is needed to rate different factors which can later be used as an assessment tool for prioritizing factors for achieving mass customization in manufacturing organizations The survey should take 10-15 minutes and your response will be confidential.

Please respond genuinely and in case you are uncertain, you may answer with your first intuitive response.

SECTION A

Kindly Provide the information regarding your background details

- *Name (optional)*
- *Level of education*

i)Doctorate ☐ ii) Post Doctorate ☐

iii)Graduate ☐ iv) Diploma ☐

v)Intermediate ☐

- *Designation*

i) Top Management ☐ ii) Middle management ☐

iii) Technical Staff ☐ iv) Administrative personnel ☐

v) Academician

- *Department*
  - i) Marketing/Sales ☐ ii) Production ☐
  - iii) Procurement ☐ I v) Logistics ☐
  - v) R& D ☐ v) Retailer ☐
  - vi) Project Management ☐

- *Years of Experience*
  - i)More than 20 ☐ ii) 15-20 ☐
  - iii) 10-15 ☐ iv) 5-10 ☐
  - v) 0-5 ☐

Kindly Provide the information regarding organizational details

- *Organization name (optional)*
- *Type of Industry*
  - i)Apparels and Footwear ☐ ii) Food ☐
  - iii) Consumer electronics ☐ iv) Automotive ☐
  - v) Interiors and Decors ☐ vi) Others, if any ☐

- *No of workers*
  - *i)* More than 1000 ☐ ii) 500-1000 ☐
  - iii) 200-500 ☐ iv) 100-200 ☐
  - v) less than 100 ☐

- *Annual Turnover(In rupees crores)*
  - i) Less than 10 ☐ ii) 10-50 ☐
  - ii) 50-100 ☐ iv) 100-500 ☐
  - v) More than 500 ☐

- Location of your organization
  - i) North India ☐ ii) South India ☐
  - iii) East India ☐ iv) West India ☐
  - v) Outside India ☐

- *Type ofBusiness*
  - *ii)* Government ☐ ii) PSU ☐
  - iii) Private Listed ☐ iv) Private Unlisted ☐
  - v) MSME ☐ v) Startups ☐

Given bellow are various factors that will affect successful Implementation of Mass Customization. Please indicate the extent to which you agree with each statement

S.No.	1. Customer sensitivity					
	Please rate the importance of following factors for improving customer sensitivity	**Very High**	**High**	**Medium**	**Low**	**Very Low**
A	Identify opportunities for customization					
B	Understand uniqueness of customers' needs					
C	Analyse customers sacrifice for unmet needs					
D	Provide ease of customer choice for decision making					
E	Create value for customer					
F	Incorporate customer requirement during new design					

S .No.	2. **Process amenability**					
	Please rate the importance of following factors for improving Process amenability	**Very High**	**High**	**Medium**	**Low**	**Very Low**
A	Incorporate modularity in design, for part flexibility					
B	Develop compatible process technology					
C	Develop production and distribution process for timely					
D	Develop supplier for co-design					
E	Develop marketing competence for product promotion					

S .No.	3. Competitive environment					
	Please rate the impact of following factors for gaining Competitive advantage due to mass customization implementation.	**Very High**	**High**	**Medium**	**Low**	**Very Low**
A	Economic uncertainty					
B	Market Turbulence					
C	Company credibility and position in marketplace					
D	Customer loyalty					
E	Potential of competitors to react					

S.No.	4. Organizational readiness					
	Please rate the importance of following factors for incorporating Organizational readiness	**Very High**	**High**	**Medium**	**Low**	**Very Low**
A	Cultural change in the organization					
B	Skill development of employees					
C	Employees involvement in product and process roadmap					
D	Training to marketing team to capture and prioritize requirements					
E	Top management support and leadership building					

S.No.	5. **Mass customization**					
	Please rate the importance of following factors to measure firm's capability to customize and deliver products	**Very High**	**High**	**Medium**	**Low**	**Very Low**
A	Product can be customized on large scale					
B	Product variety can be enhanced at same cost and quality					
C	Product can be designed based on customers' requirements					
D	Product can be delivered on stipulated time					

S.No.	**6. Competitive advantage**					
	Please evaluate the business growth of an organization compared to competitors on account of	**Very**	**High**	**Medium**	**Low**	**Very**
A	Market share growth					
B	Acquiring new customer					
C	Increased sales volume/ Return on sales/revenue					
D	Increased product variety					
E	Perceived customers value					
F	Reduce waste through on demand production					
G	Reaching financial goals					

Please provide the information as per your expertize

1) What are the major reasons that encourage you to implement Mass Customization in your esteemed Organization?

2) What were the major challenges you faced, or you may face during the implementation phase?

3) What were the major measures adopted by your organization to move from mass production to mass customization?

Appendix 4: Questionnaire for Drivers of Mass Customization

Subject: "**Identify Drivers of an organization for Mass Customization implementation**" for a research-based study on Design and Manufacturing Issues of Mass Customization

Dear Sir/Madam

The goal of this research is to explore the drivers that lead to implementation of mass customization in India as an organization evolves from mass manufacturing to mass customization. The questionnaire is based on fifteen major drivers identified from thorough search criteria of research literature. Kindly answer as per the implementation process identified in your organization. You may choose not to answer any particular question if you are unsure of the methodology adopted by your organization. This research will contribute to mass customization in comprehending the major drivers that drives the mass customization market.

Note: The identity of organization and person involved will be kept confidential

The data received from persons in organization will be used for sole

purpose of research work and not used for any other purpose.

The data received will be the property of researchers and only outcome of data will be published in research journals.

Criteria Code		Sub Criteria	Drivers that drive the current mass customization(MC) market(Answer in Brief)
Organization perspective D1	D11	*What Corporate strategy and goals drive the MC market?*	
	D12	*Did Financial benefits motivate you to implement MC?*	
	D13	*How Skilled human resource drive the MC market?*	
	D14	*How did Manufacturing cost control have any major role to drive MC implementation?*	
Customer Perspective D2	D21	*How Requirements of customised product effect MC implementation requirement?*	
	D22	*How Customers purchasing capacity effect MC implementation requirement?*	
	D23	*How Customer dependency on Brand Image drive MC implementation process?*	
	D24	*How Demographic and socio-cultural differences are addressed during MC implementation?*	
Market Perspective D3	D31	*How Market Turbulence and globalization effect MC requirement?*	
	D32	*How Introduction of customized product by competitors drive MC implementation requirement?*	
	D33	*How New product development/shortened life cycle effect drive for MC product?*	
Technology Perspective D4	D41	*How social media and crowdsourcing drive MC requirement?*	
	D42	*How Penetration of mobile and internet drive MC market?*	
	D43	*How does User interface and website/ Omni channel distribution/ E commerce drive MC implementation?*	
	D44	*How Technology advancement and innovation drive MC market?*	

Appendix 5: Questionnaire for Ranking of Drivers of Mass Customization

Delhi Technological University,

Department of Mechanical Engineering,

Shahbad-Daulatpur, Bawana Road,

Delhi-110042

Research Supervisors: Prof S.K Garg Mobile: 9873339015

Prof Gayatri Kansal

Subject: "**Ranking of Drivers of an organization for Mass Customization implementation**" for a research based study on Design and Manufacturing Issues of Mass Customization

Dear Sir/Madam

The goal of this research is to rank drivers of mass customization. The driver category, code and description is provided for proper understanding. In the questionnaire provided, write any number 1-9, as per your understanding of interpretation of relation of driver with other in terms of importance, For eg , if you feel **"Ai" is equally to moderately more important than "Aj", assign the no 2.**

Intensity of importance	**Linguistic variables**
1	"Ai" is equally important to "Aj"
2	"Ai" is equally to moderately more important than "Aj"
3	"Ai" is moderately more important than "Aj"
4	"Ai" is moderate to strongly more important than "Aj"
5	"Ai" is strongly more important than "Aj"
6	"Ai" is strong to drastically more important than "Aj"
7	"Ai" is drastically more important than "Aj"
8	"Ai" is drastic to extremely more important than "Aj"
9	"Ai" is extremely more important than "Aj

Note: The identity of organization and person involved will be kept confidential

The data received from persons in organization will be used for sole purpose of research work and not used for any other purpose.

The data received will be the property of researchers and only outcome of data will be published in research journals.

Drivers	Subcategory Code	Subcategory Drivers
Organization perspective (D1)	D11	Corporate strategy and goals
	D12	Financial benefits
	D13	Skilled human resource
	D14	Manufacturing cost control
Customer Perspective (D2)	D21	Requirements for customized product
	D22	Customers purchasing capacity
	D23	Customer dependency on Brand Image
	D24	Demographic and socio-cultural differences
Market Perspective (D3)	D31	Market Turbulence and globalization
	D32	Introduction of the customized products by competitors
	D33	New product development/shortened life cycle
Technology Perspective (D4)	D41	Social Media and crowdsourcing
	D42	Penetration of mobile and internet
	D43	User interface and website/ Omni channel distribution/ E-commerce
	D44	Technology advancement and innovation

Questionnaire-Assign any number (1,2,3……9) as per your interpretation

Driver Relationship	Interpretation of Relationship between Drivers	Rate comparison between two drivers								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
D1-D2	Relative importance of Organization perspective over Customer Perspective									
D1-D3	Relative importance of Organization perspective over Market Perspective									
D1-D4	Relative importance of Organization perspective over Technology Perspective									
D2-D3	Relative importance of Customer perspective over Market Perspective									
D2-D4	Relative importance of Customer perspective over Technology Perspective									
D3-D4	Relative importance of Market perspective over Technology Perspective									
D11-D12	Relative importance of corporate strategy and goals over financial benefits									
D11-D13	Relative importance of corporate strategy and goals over Skilled human resource									
D11-D14	Relative importance of corporate strategy and goals over Manufacturing cost control									
D12-D13	Relative importance of financial benefits over Skilled human resource									

D12-D14	Relative importance of financial benefits over Manufacturing cost control									
D13-D14	Relative importance of Skilled human resource over Manufacturing cost control									
D21-D22	Relative importance of Requirements for customized product over Customers purchasing capacity									
D21-D23	Relative importance of Requirements for customized product over Customer dependency on Brand Image									
D21-D24	Relative importance of Requirements for customized product over Demographic and socio-cultural differences									
D22-D23	Relative importance of Customers purchasing capacity over Customer dependency on Brand Image									
D22-D24	Relative importance of Customers purchasing capacity over Demographic and socio-cultural differences									
D23-D24	Relative importance of Customer dependency on Brand Image over Demographic and socio-cultural differences									
D31-D32	Relative importance of Market Turbulence and globalization over Introduction of the customized products by competitors									
D31-D33	Relative importance of Market Turbulence and globalization over new product development/shortened life cycle									
D32-D33	Relative importance of Introduction of the customized products by competitors over new product development/shortened life cycle									
D41-D42	Relative importance of social media and crowdsourcing over Penetration of mobile and internet									
D41-D43	Relative importance of social media and crowdsourcing over User interface and website/ Omni channel distribution/ E-commerce									
D41-D44	Relative importance of social media and crowdsourcing over Technology advancement and innovation									
D42-D43	Relative importance of Penetration of mobile and internet over User interface and website/ Omni channel distribution/ E-commerce									
D42-D44	Relative importance of Penetration of mobile and internet over Technology advancement and innovation									
D43-D44	Relative importance of User interface and website/ Omni channel distribution/ E-commerce over Technology advancement and innovation									

Appendix 6: Questionnaire for Ranking of Manufacturing Sector as per Drivers of Mass Customization

Delhi Technological University,

Department of Mechanical Engineering,

Shahbad-Daulatpur, Bawana Road,

Delhi-110042

Research Supervisors: Prof S.K Garg Mobile: 9873339015

Prof Gayatri Kansal

Subject: "Rank various manufacturing sectors for mass customization adaptability in the current economic environment based on drivers of Mass Customization" for a research based study on Design and Manufacturing Issues of Mass Customization

Dear Sir/Madam

The goal of this research is to Rank various manufacturing sectors for mass customization adaptability in the current economic environment based on drivers of Mass Customization. The driver category, code and description is provided for proper understanding along with five manufacturing sector. In the questionnaire provided, write any number 1,3,5,7,9, as per your understanding of interpretation of importance of driver with industry type in terms of importance.

Note- Kindly rate only the industry with which you have been associated.

Linguistic scale

Importance of driver with respect to industry	**Very low**	**Low**	**Medium**	**High**	**Very High**
Rating value	**1**	**3**	**5**	**7**	**9**

Please fill the questionnaire based on your understanding of how the drivers D11 to D44 drive the mass customization market and rate with number 1,3,5,7 or 9, based on linguistic scale

	Type of Industry(Rate 1,3,5,7 or 9)				
Drivers of Mass customization	**Electrical and Electronics**	**Interiors and decor**	**Automotive Industries**	**Apparels and Footwear**	**Food Industries**
Corporate strategy and goals (D11)					
Financial benefits (D12)					
Skilled human resource (D13)					
Manufacturing cost control(D14)					
Requirements for customized product(D21)					
Customers purchasing capacity(D22)					
Customer dependency on Brand Image(D23)					
Demographic and socio-cultural differences(D24)					
Market Turbulence and globalization(D31)					
Introduction of the customized products by competitors (D32)					
New product development/shortened life cycle (D33)					
Social Media and crowdsourcing (D41)					
Penetration of mobile and internet (D42)					
User interface and website/ Omni channel distribution/ E-commerce (D43)					
Technology advancement and innovation (D44)					

Appendix 7: Questionnaire for Case Study

Subject: "**Manufacturing model to enhance operational agility of an organization for Mass customization ”** for a research based study on Design and Manufacturing Issues of Mass Customization

Dear Sir/Madam

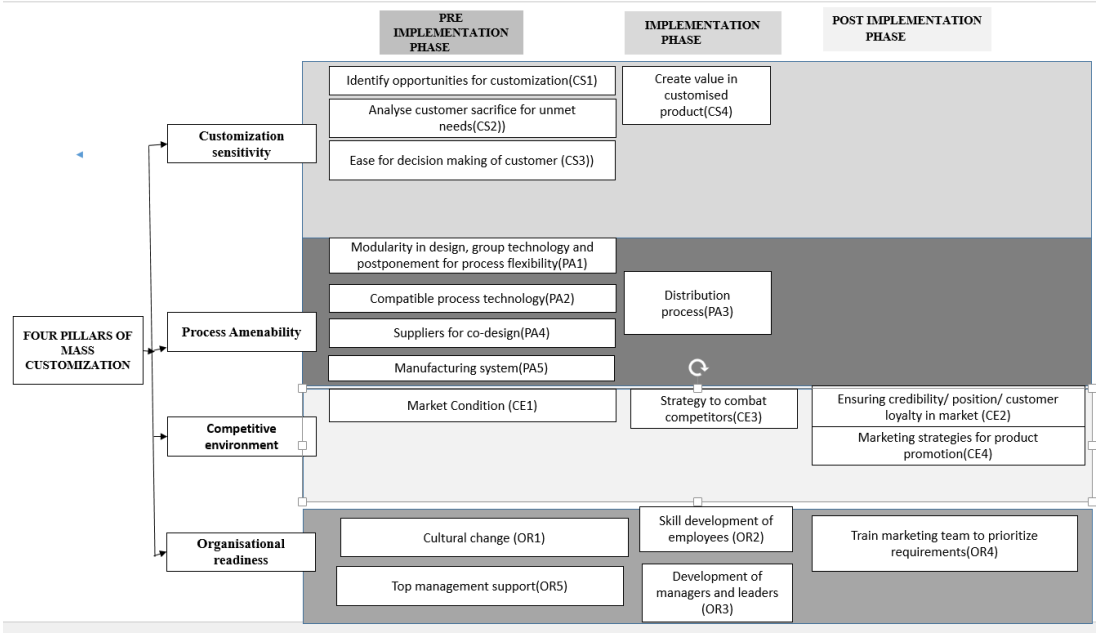
The goal of this research is to explore the implementation of mass customization in India, specifically how and why a company distributes its resources and capabilities as it evolves from mass manufacturing to mass customization. The research will apply multiple case study method to verify the framework provided by eminent researcher Hart[60] for mass customization implementation. This theory extension aims to developing a framework that will contribute to mass customization strategies to be adopted by organizations to comprehend and facilitate their transition.

Note: The identity of organization and person involved will be kept confidential

The data received from persons in organization will be used for sole purpose of research work and not used for any other purpose.

The data received will be the property of researchers and only outcome of data will be published in research journals

Research Framework



Case Study Protocol: The data will be collected using a case study protocol as shown in Table adopted from [212]

Source 1: face-to-face interview /telephonic interview as some interviewees not available due to COVID-19 protocol (4 interviews and at least one and half hour per case)	
General information	Brief description of the interview: products that were mass customized, role performed by interviewee in department and contribution to mass customization implementation.
Pre-Implementation Phase	What were the primary drivers behind the company's decision to install mass customization system? How did the company's business processes get revised by the managers? What steps were taken to design a mass customized product? What steps did the executives take to prepare the company for the MC business model? What were the most difficult challenges faced? What steps did the company take to overcome these obstacles? How was the company's suppliers or consumers prepared?
Implementation Phase	Did implementation of MC require any special skillset in employees? What steps were taken by firm to develop the skills in employees? What steps were undertaken to add value to product? Did the organization redefine its supply chain and marketing strategy to combat competitors?
Post Implementation Phase	What steps were taken by organizations to ensure customer loyalty and increase sale of mass customized product? What marketing strategy was adopted for promoting mass customized product in the market?
Source 2: Direct observations (at least one hour per each case) Plant tour	
Plant Visit	Examine the marketing, technology, manufacturing processes, sales, production, and functional areas from a broader viewpoint, and inquire about the products and processes from management.
Source 3: Official documents	
Company's website, News and press. National database	Product offering; general information of the organization (background, vision, mission, product types, product features, technical data, applications, etc.). Details on new product developments, sales and financial information, employee details etc.
Source 4: Internal documents	

Constructs	Question Code	Interview Questions	Mass customization implementation process by organization (Answer in Brief)
Customer Sensitivity	CS1	What prompted organization to identify opportunities for customization	
	CS2	What was the organizations understanding about the uniqueness of customers' needs	
	CS3	How the company analyse customers sacrifice for unmet needs	
	CS4	How the organization provide ease of customer choice for decision making	
	CS5	What step organization took to create value for customer	
	CS6	How the organization incorporate customer requirement during new design process	
Process Amenability	PA1	How modularity in design was incorporated for part flexibility	
	PA2	What compatible process technology was developed by the organization	
	PA3	What distribution process was developed for timely delivery	
	PA4	How supplier for co-design was developed	
	PA5	What marketing strategies for product promotion was developed	
Competitive Environment	CE1	What factors prompted organization to adopt mass customization?	
	CE2	How Company ensures credibility and position in marketplace	
	CE3	How firm ensured Customer loyalty?	
	CE4	How firm ascertain its position to combat potential of competitors to react?	
Organizational readines s	OR1	How firm ensures cultural change in the organization	
	OR2	How firm ensures skill development of employees	

	OR3	How is training to marketing team provided to capture and prioritize requirements	
	OR4	How firm ensures top management support and develops leadership building skills.	
Mass customization	MC1	How firm mass customized on large scale	
	MC2	How firm mass customize product variety at same cost and quality	
	MC3	Hoe does firm design products based on customers' requirements	
	MC4	Does firm has any measure to deliver product on stipulated time	
Competitive advantage	CA1	Has mass customization helped firm in market share growth and reaching financial goals	
	CA3	Has mass customization helped firm in increased sales volume/ Return on sales/revenue	
	CA4	Has mass customization helped firm reduce waste through on demand production	

LIST OF PUBLICATIONS

International Journals:

1) Piu Jain, Suresh Garg & Gayatri Kansal (2022): "Implementation of mass customization for competitive advantage in Indian industries: an empirical investigation." *International Journal of Advanced Manufacturing Technology* **121**, 737–752. https://doi.org/10.1007/s00170-022-09324-8

2) Piu Jain, Suresh Garg & Gayatri Kansal (2021): "A TISM approach for the analysis of enablers in implementing mass customization in Indian manufacturing units", *Production Planning & Control*, 34:2, 173-188, DOI: 10.1080/09537287.2021.1900616

International Conferences:

1) Piu Jain, Suresh Garg & Gayatri Kansal (2022): "Road to Mass Customization: A Review" at the International Conference on Mechanical, Industrial and Production Engineering (ICMIPE), held in Salem, India on 19 August 2022 by International Institution for Science Technology Engineering and Management.

2) Piu Jain, Suresh Garg & Gayatri Kansal (2022): "Issues and challenges of Mass Customization", 3rd International Conference on Recent Advances in Materials Manufacturing and Thermal Engineering (RAMMTE-2022), July 8-9, 2022, by Delhi Technological University, Delhi, India.