ORGANIZATIONAL CAPABILITIES TO ADOPT MASS CUSTOMIZATION IN SELECT INDIAN INDUSTRIES

Submitted by

JAYANT KISHOR PUROHIT

(2012RME9042)

Under the supervision of

Dr. Murari Lal Mittal
Associate Professor

Submitted in fulfillment of the requirements for the award of
the degree of
DOCTOR OF PHILOSOPHY
to the

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

November, 2017

Respectfully Dedicated to
My Mother, My Wife, My Son,
My Teachers
&
The Beautiful Soul of
My Father, My Sister & My Nephew

Certificate

This is to certify that the thesis entitled **"Organizational Capabilities to Adopt Mass Customization in Select Indian Industries"** being submitted by **Mr. Jayant Kishor Purohit (ID No. 2012RME9042)** to the **Malaviya National Institute of Technology Jaipur** for the award of the degree of **Doctor of Philosophy** in **Mechanical Engineering** is a bonafide record of original research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirement for the submission of this thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted in part or full, to any other University or Institute for the award of any other degree or diploma.

Date:

Dr. Murari Lal Mittal
Associate Professor
Department of Mechanical Engineering,
M.N.I.T. Jaipur, INDIA

Declaration

I hereby certify that the work which is being presented in this thesis entitled **"Organizational Capabilities to Adopt Mass Customization in Select Indian Industries"** in fulfillment of the requirement of **Doctor of Philosophy** and submitted to the Malaviya National Institute of Technology, Jaipur is an authentic record of my own work carried out at the Department of Mechanical Engineering under the supervision of **Dr. Murari Lal Mittal**, Associate Professor, Department of Mechanical Engineering, Malaviya National Institute of Technology, Jaipur. The results contained in this thesis have not been submitted in part or full, to any other University or Institute for the award of any degree. The content of the thesis has been checked for plagiarism and has been found under acceptable limit.

Date:

Jayant Kishor Purohit
ID No. 2012RME9042
Department of Mechanical Engineering
MNIT, Jaipur, India

Acknowledgements

It is difficult for me to know where to begin because there are so many people that I want to thank. First, I want to thank the Lord for all the blessings in my life and for giving me the opportunity to follow my dreams. Next, thanks should go to my supervisor, **Dr. Murari Lal Mittal** for giving me the opportunity to undertake this **Ph.D.** and for introspective guidance with constructive suggestions, deliberative discussions, encouragement and all the last minute editing.

I feel indebted to **Dr. G.S. Dangayach** (Head, Mechanical Engineering Department), **Prof. A.P.S. Rathore** (Professor, Mechanical Engineering Department) and **Prof. M. K. Sharma**, JNV University, Jodhpur for their unreserved help and suggestions during the period of study. I express my sincere words of gratitude to DREC members, **Prof. Awadhesh Bhardwaj** and **Dr. Gunjan Soni** for their help, constructive inputs, and research insights given during Ph.D. progress presentations.

My family members deserve special mention for their inseparable support and prayers. I wish to express my heartfelt reverence to my mother **Smt. Saraswati Purohit**, wife **Anjali Purohit**, son **Madhavan** and siblings for their constant support. Their presence is the most precious blessing in my life and it is not possible for me to express my love and gratitude to them in few words.

I wish to pay overwhelming thanks to my friends **Avanish Singh Chauhan, Gaurav Badhotiya, Sameer Mittal, Rahul Jain, Surya Prakash, Manish Kumar, Dheeraj Joshi and Vinod Yadav** for constant moral support and generous help. I also extend sincere thanks to other fellow Ph.D. scholars of MNIT.

I am also grateful to all those people, whom I have not mentioned, but they had helped me directly or indirectly during the work.

Abstract

Current business and economic environment render both big opportunities and scaring challenges for manufacturing organizations. In order to be competitive, the manufacturing organizations should work on a long term proactive business policy and develop new assets and capabilities. Organizations can accomplish and sustain their competitiveness by providing either cheaper products with lesser manufacturing costs or differentiated products compared to contenders. From a strategic decision making viewpoint, Mass Customization (MC) tenders a mix policy by offering distinguished (i.e., customized) products with low price (Kaplan et al. 2006). Mass customization takes into account the merits of both the earlier systems of production, i.e. mass production and craft production as craft production satisfies the personalized demands of customers while the mass production produces a limited variety of products at lower cost. In the early 1980s, the manufacturing organizations started developing the capabilities to provide products satisfying personalized customer requirements at an affordable price. This started the third paradigm in manufacturing termed as mass customization.

The organizations aspiring to be in the landscape of MC and to be competitive need to find the enablers that can help them in achieving MC. Researchers have put efforts to identify and classify these enablers. Currently available literature normally considers mass customization in terms of its effect on firm's performance, i.e. the concurrent accomplishment of product customization, lesser price, flexibility in production system and quality. The significance of enablers of mass customization and its effect on firms' performances has been stressed by a number of investigators but, to the best of our knowledge, the linkage involving mass customization enablers, organizational capabilities and achievement of competitive advantage through mass customization adoption has not been tested empirically. The suggested framework promotes the level of research by specifying mass customization in forms of its enablers and firms specific organizational capabilities like operational and knowledge management capabilities.

Operational capabilities symbolize the organization skills to operate on attributes of quality of product, delivery schedules, flexibility in product design & processes and cost compared to its direct rivals in the target markets. In this study,

operational capabilities refer to the firms aptitude to deliver high quality customized products to the customers with low price, resulting into large number of customers compared to contenders. An organization's aptitude to efficaciously adapt to varying circumstances will be superior when it has an intense knowledge management potentiality. Knowledge based resources (tangible and/or intangible) coupled with other capabilities lead to competitive advantage. This study employs four criteria of competitive advantage i.e. innovativeness in products and processes to adopt mass customization strategy, market position, availability of wide array of products with low cost compared to competitors and complexity to replicate the mass customization strategy for rivals.

There are four distinct focus of this research. First deals with the enabling factors that are required to be implemented successful mass customization into manufacturing. This is important because of the excessive importance is given to the enabling factors to achieve MC. There is a scarcity of literature on the discussion as how these enablers were taken to enhance capabilities of the firm and eventually affect firm's competitive advantage. In this part, literature review and interpretive structural modeling (ISM) are used to attain a hierarchical structure of dominating MC enablers. The second part is an extension of ISM to accommodate organizational capabilities with MC enablers to develop a framework of a firm's competitive advantages through adoption of mass customization. The third part is responsible to empirically test the impact of MC enablers on organizational capabilities and also the effect of organizational capabilities on firm's competitive advantage and demonstrating its relevance to theory and practice. Finally, three case studies of Indian manufacturing firms are provided to demonstrate the practical applicability of the proposed model to redesign its resources to achieve mass customization. We believe that the proposed mass customization adoption model should improve a manufacturer's competence in the new dynamic business environment.

In beginning, preliminary frameworks of dominating mass customization enablers have been explored for Indian organizations through literature review and application of ISM technique. The results of ISM establish the theoretical framework of the research and the hypotheses have been constituted on the finding from the literature. To achieve competitive advantages two views have been put forward in the literature-Resource Based View (RBV) and Dynamic Capability View (DCV).The RBV advocates that organizations attain the competitive advantage by obtaining assets and resources that diverse from those of competitors. The DCV literature, however, debated that beyond the resources and assets; it is ultimately the unique capabilities produced by organizations that shape sustained competitive advantage . While the foundation of DCV literature is rooted in RBV with its establishment on competitive advantage, the DCV theory has argued that resources per se may not render competitive advantage except it is used to do something. It suggests that an organization acquire capabilities by which its idiosyncratic resources can be directed to fit with varying market environment. This study follows both the approaches for developing the conceptual research model to play up the significance of resources and capabilities to achieve competitive advantage.

The conceptual model has been developed to investigate the relationship among MC enablers, Firm's capabilities and competitive advantage, which is validated through quantitative analysis (i.e. Structural Equation Modeling). Extensive survey was conducted among Indian manufacturing organizations to gather data appropriate for empirical evaluation of the theoretical framework. Data examination approaches were employed to analyze the gathered data. Descriptive data analyses part of study were subsequently carried to render a general idea of the sample, summarizing statistical details related to demography of select firms and responders. Study suggests that all of the six variables fit the data fairly well. In the end, structural equation modeling (SEM) was applied to investigation the conceptual model. Reliability and validity have also been investigated with single/multi factor analysis of measurement models in SEM. The test results adequately confirm the model for the hypotheses testing via path model investigation. The relationships are positive and significant which implies that hypotheses are strongly supported (except one hypothesis).

The proposed integrated research approach is applied to three Indian manufacturing industries. The manufacturing units of analysis are from modular kitchen manufacturing, apparel manufacturing and jewelry manufacturing. Assessment of capabilities of the case firms regarding mass customization implementation is presented with the help of analytical network process (ANP) method. In the end, relevant recommendations derived from the case results are discussed.

Contents

Certificate……………………………………………………………………………iv
Declaration…………………………………………………………………..………...v
Acknowledgement…………………………………………………………………...vi
Abstract…………………………………………………………………………...vii-ix
Contents……………………………………………………………...………...x- xiv
List of tables ……………………………………………..…………..…………xv - xvi
List of figures……………………………………...………...………..xvii-xviii
Abbreviations ………………………………………………………………… xix-xx

Title		**Page No.**
CHAPTER 1: INTRODUCTION		**01-08**
1.1	Background	01
1.2	Research motivation	03
1.3	Research questions and objectives	04
1.4	Research process overview	05
1.5	Thesis outline	06
CHAPTER 2: THEORETICAL BACKGROUND & LITERATURE REVIEW		**09-50**
2.1	Origins of mass customization	10
2.2	Defining mass customization	11
2.3	Mass customization approaches	13
2.4	The Mass customization process	18
	2.4.1 Development sub-process	18
	2.4.2 Interaction sub-process	18
	2.4.3 Purchasing sub-process	19
	2.4.4 Production sub-process	19
	2.4.5 Logistics sub-process	20
	2.4.6 Information sub-process	20
2.5	Mass customization challenges	20
	2.5.1 External complexity	21
	2.5.2 Internal complexity	22
2.6	Mass customization benefits	23
2.7	Success factors for mass customization	25
2.8	Enablers of mass customization	28
	2.8.1 Supplier integration	29
	2.8.2 Customer integration	30
	2.8.3 Internal integration	31
	2.8.4 Concurrent engineering	32

Title		Page No.
	2.8.5 Collaborative design	32
	2.8.6 Modularity-based practices	33
	2.8.7 Postponement	33
	2.8.8 Lean manufacturing practices	35
	2.8.9 Agile manufacturing practices	35
	2.8.10 Leagility	36
	2.8.11 Enterprise resources planning	36
	2.8.12 Digital manufacturing practices	37
	2.8.13 Web-based interactive systems	38
	2.8.14 Electronic commerce	39
	2.8.15 Agent based systems	39
2.9	Operational capability	47
2.10	Knowledge management capability	48
2.11	Competitive advantages	49
2.12	Chapter summary	50
CHAPTER 3: DEVELOPMENT OF CONCEPTUAL FRAMEWORK & HYPOTHESES		**51-78**
3.1	Three phase research methodology	51
3.2	Finding the dominating enablers of MC: An Indian experience	52
3.3	ISM methodology	55
3.4	ISM-based model for MC enablers	58
	3.4.1 Self-structured interaction matrix	58
	3.4.2 Reachability matrix	59
	3.4.3 Level partition	60
	3.4.4 The ISM model	60
	3.4.5 Cross-impact MICMAC analysis	63
	3.4.6 Discussion of ISM outcomes	65
3.5	Combining & refining the idea	66
3.6	Modeling process	68
3.7	Research hypotheses development	71
CHAPTER 4: RESEARCH DESIGN		**79-89**
4.1	Introduction	79
4.2	Survey based methodology	80
4.3	Preliminary study	81
4.4	Questionnaire design	81
4.5	Pilot survey	82

Title		Page No.
4.6	Sample design	83
4.7	Questionnaire administration	83
4.8	Data analysis techniques	84
	4.8.1 Goodness-of-Fit assessment	84
	4.8.1.1 Absolute fit measures	84
	4.8.1.2 Incremental fit measures	86
	4.8.1.3 Parsimony fit measures	86
	4.8.2 Unidimensionality and construct validity	87
	4.8.3 Structural model testing	88
CHAPTER 5: DESCRIPTIVE ANALYSIS		**89-102**
5.1	Introduction	89
5.2	Data coding and screening	89
	5.2.1 Missing data analysis	90
	5.2.2 Outliers	91
	5.2.3 Normality of data	91
	5.2.4 Reliability of scale	93
5.3	Descriptive analysis	94
	5.3.1 Response rate and demographic profile of industries	95
	5.3.2 Response of Indian industries on MC enablers and capabilities	99
	5.3.2.1 Response analysis to mass customization enabler	99
	5.3.2.2 Response analysis to firm's capabilities & competitive advantage	100
CHAPTER 6: INVESTIGATION OF MASS CUSTOMIZATION MODEL		**103-126**
6.1	Introduction	103
6.2	Development of model constructs	104
6.3	Choice of model estimation methods	105
6.4	Model indices	105
6.5	Two-phase approach in structural equation modeling	106
	6.5.1 Development of measurement models for mass customization	107
	6.5.1.1 One factor measurement model for modularity based practices	108
	6.5.1.2 One factor measurement model for big data and information technology enabled supply chain integration	109
	6.5.1.3 One factor measurement model for digital manufacturing	109
	6.5.1.4 One factor measurement model for firm's operational	110

Title	Page No.
capabilities	
6.5.1.5 One factor measurement model for firm's knowledge management capabilities	111
6.5.1.6 One factor measurement model for firms competitive advantage on mass customization adoption	112
6.5.1.7 Analysis of multifactor measurement model for mass customization enablers	113
6.5.1.8 Analysis of multifactor measurement model for firm's capabilities	115
6.5.2 Reliability and validity of measurement models	115
6.5.3 Development and testing of structural model for MC	119
6.5.3.1 Model analysis using estimations	120
6.6 Discussions on research objectives and hypotheses testing	120
6.6.1 Hypotheses between mass customization enablers, firm's capabilities and competitive advantage	121
6.6.1.1 Relationship between MC Enablers	123
6.6.1.2 Relationship between MC enablers and firm's critical capabilities	123
6.6.1.3 Relationship between firm's capabilities and competitive advantage	126
CHAPTER 7: CASE STUDIES	**127-153**
7.1 Introduction	127
7.2 Case firm A: Stainless steel modular kitchen manufacturer	128
7.2.1 Introduction	128
7.2.2 Product	129
7.2.3 Working procedure	129
7.2.4 Process overview	130
7.2.5 Plant characteristics	131
7.2.6 Capability assessment to adopt mass customization (Case Firm A)	131
7.3 Case firm B: Made to Measure customized clothing manufacturer	134
7.3.1 Introduction	134
7.3.2 Product	134
7.3.3 Working procedure	134
7.3.4 Process overview	135
7.3.5 Plant characteristics	136
7.3.6 Capability assessment to adopt mass customization (Case Firm B)	136
7.4 Case firm C: Custom jewelry manufacturer	139

Title	Page No.
7.4.1 Introduction	139
7.4.2 Product	139
7.4.3 Working procedure	139
7.4.4 Process overview	140
7.4.5 Plant characteristics	140
7.4.6 Capability assessment to adopt mass customization (Case Firm C)	140
7.5 Comparative analysis	143
7.6 Lessons learned from case studies	144
7.7 Capability assessment to adopt mass customization strategy in case firms	144
7.7.1 Introduction	144
7.7.2 Pair-wise comparisons	146
7.7.3 Relative weights of elements and consistency ratio of matrices	147
7.7.4 Supermatrix and the limit matrix	147
7.7.5 Discussions	150
CHAPTER 8: CONCLUSION	**151-161**
8.1 Introduction	151
8.2 Summary of the research	151
8.3 Theoretical contribution	152
8.4 Managerial implication	154
8.5 Limitations of the study	155
8.6 Future research	156
REFERENCES	**159-178**
Appendix-I: List of publications	179
Appendix-II: Biographical profile of researcher	181

List of Tables

Table No.	Title	Page No.
2.1	Mass Production vs. Mass Customization	13
2.2	Definitions of mass customization	14
2.3	Internal and external success factor	27
2.4	Research article composition across years on mass customization enablers	44
2.5	Journal wise overview of articles reviewed on mass customization enablers	45
2.6	Comprehensive literature review on mass customization enablers	46
3.1	Structural self interaction matrix for MC enablers	60
3.2	Initial reachability matrix	61
3.3	Final reachability matrix	61
3.4	Results of partitioning (Iterations I to VI)	63
3.5	Results of partitioning (Iterations altogether)	64
3.6	Clusters and its features	65
3.7	Table for final constructs	71
3.8	Summarized hypotheses	78
4.1	Summary of absolute fit indices and their characteristics	86
4.2	Summary of incremental fit indices and their characteristics	87
4.3	Summary of parsimony fit indices and their characteristics	88
5.1	Coding of measurement scale and their description	92
5.2	Descriptive statistics of all research variables	94
5.3	Descriptive statistics and assessment of reliability	96
5.4	Summary of responses	97
5.5	Demographic profile for the respondents	98
6.1	Phases of structural equation modeling	106
6.2	Description of model construct	107
6.3	Summary of model fit indices	109
6.4	Summary of one factor congeneric models	116
6.5	CR and AVE for MC enablers	121
6.6	CR and AVE for organizational capabilities	121
6.7	Summarized results of hypothesized relationships	124

Table No.	Title	Page No.
7.1	Plant characteristics for case firm A	134
7.2	Mass customization practices in case firm A	136
7.3	Plant characteristics for case firm B	139
7.4	Mass customization practices in case firm B	141
7.5	Plant characteristics for case firm C	144
7.6	Mass customization practices in case firm C	145
7.7	Comparison of adoption of mass customization practices in case firms	146
7.8	Fundamental comparison scales	149
7.9	Super- matrix for the ANP decision model	151
7.10	Limit matrix for the ANP decision model	152
7.11	Final out put report from ANP model	153

List of Figures

Figure No.	Title	Page No.
1.1	Chapter outline	9
2.1	Classification of literature for present research	11
2.2	Changes in manufacturing paradigms	12
2.3	Mass customization approaches	17
2.4	Customer involvement and modularity in MC manufacturing cycle	18
2.5	Article count for each mass customization enabler	42
2.6	Percentage of articles for MC enablers	43
3.1	Methodological overview of proposed research	54
3.2	ISM methodology flowchart	59
3.3	ISM-based model for mass customization enablers	62
3.4	Driver-Dependence diagram for MICMAC analysis	65
3.5	Proposed research framework	70
3.6	Proposed hypotheses framework	72
5.1	Type of sector / industry	99
5.2	Annual sales in INR	99
5.3	Number of employees	100
5.4	Position of respondent in the organization	100
5.5	Responses on supply chain integration	101
5.6	Responses on modularity based practices	102
5.7	Responses on digital manufacturing practices	102
5.8	Responses on operational capabilities	103
5.9	Responses on knowledge management capabilities	103
5.10	Responses on competitive advantage	104
6.1	CFA results for modularity based practices	111
6.2	CFA results for supply chain integration	112
6.3	CFA results for digital manufacturing practices	113
6.4	CFA results for firm’s operational capabilities	114
6.5	CFA results for firm’s knowledge management capabilities	115
6.6	CFA results for firm’s competitive advantage	115
6.7	First order measurement model for mass customization enablers	117
6.8	First order measurement model for firm’s critical capabilities	119

Figure No.	Title	Page No.
6.9	Complete standardized structural model for hypotheses testing	125
7.1	Basic modular kitchen components	133
7.2	ANP model for capability assessment of case firms	148

Abbreviations

ABS	Agent based system
AGFI	Adjusted goodness fit indices
AHP	Analytical hierarchical process
AMOS	Analysis of moment structure
AMP	Agile manufacturing process
ANP	Analytical network process
AVE	Average variance extracted
CAD	Computer aided design
CAE	Computer aided engineering
CAM	Computer aided manufacturing
CAPP	Computer aided process planning
CCE	Concurrent engineering
CFA	Confirmatory factor analysis
CFI	Comparative fit indices
CII	Confederation of Indian industries
CIM	Computer integrated manufacturing
CMIN/DF	Normed fit index
CNC	Computer numeric controlled
COA	Competitive advantage on mass customization adoption
COD	Collaborative design
CR	Composite reliability
CSI	Customer integration
DCV	Dynamic capability view
DFM	Design for manufacturability
DMP	Digital manufacturing practice
DOF	Degree of freedom
ECM	Electronic commerce
EDI	Electronic data interchange
ERP	Enterprise resources planning
FMS	Flexible manufacturing system

GFI	Goodness fit indices
GLS	Generalized least square
GOF	Goodness of fit
INI	Internal integration
ISM	Interpretive structural modeling
IT	Information technology
KM	Knowledge management
KMC	Knowledge management capability
LMP	Lean manufacturing process
MADM	Multi attribute decision making
MBP	Modularity based practices
MC	Mass customization
MICMAC	Impact matrix cross-reference multiplication applied to a classification
MLE	Maximum likelihood estimation
MTM	Made to measure
NFI	Normed fit indices
OPC	Operational capabilities
POS	Postponement
RBV	Resource based view
RFID	Radio frequency identification
RM	Rapid manufacturing
RMR	Root mean square residual
RMS	Reconfigurable manufacturing system
RMSEA	Root mean square error of approximation
SCI	Big data enabled supply chain integration
SEM	Structural equation modeling
SPI	Supplier integration
WIS	Web-based interactive system

Chapter-1
Introduction

Chapter-1

Introduction

1.1 Background

Today's economic situation is characterized by properties such as worldwide presence of business activities coupled with more rapid technological development. This has headed to degradation of conventional resources of competitive advantage (Jacome et al. 2002), necessitating organizations to noticeably be aware of the varying character of business contest and take up new balancing strategically significant approaches (Jackson et al. 2003).

Furthermore, it is debated that business firms working in emerging economies like India are faced with supplementary dubieties and business turmoil associated to a multiplicity of elements like transforming financial and societal circumstances (Ramamurti, 2000). These circumstances render both big prospects and scaring challenges for companies, particularly concerning to manufacturing. To outlive and grow, manufacturing organizations should work on a long term proactive business policy towards new assets and capabilities to accomplish a competitive advantage. As per Porter (1985), "organizations can accomplish and sustain their competitive advantage by providing either cheaper products with lesser manufacturing costs or differentiated products" compared to contenders.

Manufacturing has evolved broadly through two paradigms during the last two centuries. Before the twentieth century the products were produced through craft production in which products were manufactured solely as per the personalized requirements of the customers indicating the highest level of customization. This type of manufacturing is characterized by unlimited variety but at a high unit cost. A paradigm shift was observed in the beginning of twentieth century towards mass production. This type of manufacturing is characterized by low product cost with limited variety. These two extremes of manufacturing system continuum however fail to satisfy the needs of modern consumer requiring customized products at an affordable price. In the early 1980s, the manufacturing organizations started developing the capabilities to provide products satisfying personalized customer requirements at an affordable price. This started the third paradigm in manufacturing termed as mass customization (MC).

Mass customization is about developing a customized product on demand for a particular customer after receiving a real order and producing it with the similar operational efficiency as one would anticipate from a mass-produced product. It takes into account the merits of both the earlier systems of production, i.e. mass production and craft production.

In order to able to produce customized products the manufacturer has to pursue each customer individually in an interactive manner with the objective to earn accurate knowledge about their specific requirements, converted into real product specifications. The continuing improvements in manufacturing technologies, as well as availability of advanced information and communication technology have established mass customization a viable alternative for a broader array of products. The ability of world wide web has already been recognized for its chances in linking customers, manufacturers and suppliers in every phase of the manufacturing value chain. Cyberspace tools and computerized production systems are allowing customers to custom-make almost everything from cars, gadgets, appareling, ornaments to cakes and confectioneries.

There are some developed countries where mass customization has been practiced in industries such as automobile, electronics, furniture, jewelry, footwear, and apparel to a varying degree. Mass customization is still an incipient conception in the Indian manufacturing industry, aimed to furnish custom-made products in bulk at fairly low prices through adjustable production processes.

As firms shift from bulk manufacturing to MC they are compelled to put together some necessary modifications in their relationship with customers and suppliers as well as in their manufacturing processes. Firms will undergo a demanding situation like less effective integration among supply chain partners, methodological alterations in product as well as in manufacturing process, digitalization of manufacturing process to enhance responsiveness and many more. Firms will moreover be introduced to new level of enabling practices such as integration among these partners with the increased degree of information sharing, applications of modularization in product and process development helps the customers and suppliers to become unified in the progression of developing the customized goods.

There are several restraints to MC implementation noted by Kumar et al (2004). There is scarcity of assessment making tools for MC implementation. Additionally, there is dearth of studies that help in assessing the impacts of these tangible/Intangible enabling practices on firm's capabilities to attain mass customization implementation. For a manufacturing organization it is difficult to handle the swing from product centric mass production strategy to client-based MC strategy (Piller 2004). Bardakci and whitelock (2003) assert that the "execution of a MC strategy calls for different capabilities than for mass manufacturing." Broekhuizen and Alsem (2002) stress that it is principally organizational capabilities that establish the ability of a firm to take advantage on customers' needs.

1.2 Research motivation

The organizations aspirant to be in the landscape of mass customization need to find the enablers that can help them in achieving mass customization. Researchers have put efforts to identify and classify these enablers. Kotha (1996) consider inter-connected information network with retailers as most important external factors while investments in advanced-manufacturing technologies as most important internal factors to successfully pursue mass customization. Da Silveira et al.(2001) puts forward six enablers of mass customization, viz. lean manufacturing, supply chain management, agile manufacturing, design and manufacturing driven by the customer, advanced processing technologies and communication and networking. They also categorizes the MC enablers into methodologies, processes like order evocation and supply chain coordination with the need of online configurators to involve customer in design of the products.

Rudberg and Wikner (2004) considered Customer order decoupling point as the base for mass customization implementation. Salvador et al. (2004) mentions different supply chains for different degrees of mass customization.

Up till now little published empirical support provides recommendations about which organizational capabilities companies require to attain MC and how these capabilities are achieved by the enablers of mass customization (Salvador et al. 2008). Implementation of mass customization isn't an unquestioned achievement, due to some inner and outer circumstances.

In accordance with the resource based views (Grant, 1991) organization's core capabilities make the most substantial efforts to achieve competitive advantage. The preferred conclusion of this research is to offer an indication and review the distinguished enablers that require consideration when carrying out MC. The firms need to evaluate cautiously about their existing internal capabilities and the external market environment, whether and up to what level they require mass customization.

We are considering two such organizational capabilities i.e. firms operational capabilities and knowledge management capabilities. If satisfactorily developed, these capabilities can be potent sources of competitive advantage (Barney 1991). Yet modest available empirical support puts forward recommendations concerning nature of capabilities the manufacturing companies require to achieve MC (Moser 2007; Salvador et al. 2008).

Currently available literature normally considers mass customization in terms of its effect on firm's performance, that is, the concurrent accomplishment of product customization, lesser price, flexibility in production system and quality. The significance of enablers of mass customization and its effect on firms' performances has been stressed by a number of investigators (e.g., Tu et al. 2001**;** Liu et al. 2006; Huang et al. 2010). But, to the best of our knowledge, the linkage involving mass customization enablers, organizational capabilities and competitive advantage through mass customization adoption has not been tested empirically. The current study is an attempt to this end.

1.3 Research questions and objectives

We suggest framework as an alternative to promote the level of research by specifying mass customization in forms of its enablers and firms specific organizational capabilities. This study hence objectives to develop the structure of the enablers of mass customization and organizational capabilities and anticipate their business effect, with a powerful guidance on describing causative relationships.

The current study is based on deducible approach; which involves deducing propositions from concept and then examining the concept. For this reason, big empirical studies and statistical investigation using structural equation modeling are the methods of choice. To this end the present study seeks to answer the three critical research questions given below:

- *Which enablers/factors are needed to implement mass customization effectively into manufacturing?*
- *Which organizational capabilities are strategically relevant for mass customization adoption?*
- *Which enablers are positively related to these organizational capabilities?*
- *How these capabilities affect firm's competitive advantage through mass customization adoption?*

To respond to the above research questions, this research has the following objectives

1. To establish the relationships between mass customization enablers and firms critical capabilities that a firm must possess to adopt mass customization.
2. To develop a framework of a firm's competitive advantages through mass customization adoption.
3. To test empirically the impact of firms organizational capabilities on firm's competitive advantages and demonstrating its relevance for theory and practice.
4. To validate the research findings among different manufacturing firms operating in India.

An integrated framework has been developed in this research that fulfils above mentioned objectives. The integrated framework shall be discussed in detail in Chapter 3 of this research.

1.4 Research process overview

To meet the objectives of the study a three phase research methodology is adopted. The research methodology is based on survey of Indian manufacturing firms to assess the extent of adoption of MC enablers and their impact on firm's capabilities and eventually competitive advantage.

The three phases of research are as follows:

- First, preliminary framework for dominating mass customization enablers have been explored for Indian organizations through literature review and application of Interpretive Structural Modeling (ISM) technique.
- Second, the conceptual model has been developed for Indian organizations to investigate the relationship among MC enablers, firm's capabilities and competitive advantage which is validated through quantitative analysis (i.e. Structural Equation Modeling)
- Third, capability assessment of select Indian firms to adopt mass customization strategy through Analytical Network Process (ANP) method.

1.5 Thesis outline

Succeeding this opening chapter, this thesis delivers six core chapters and a concluding final chapter. Figure 1.1 give an outline of sections included in the thesis.

Chapter 2 deals with the existing literature allied to the extent of this study. In this chapter the concept of MC is defined. Further, the benefits, challenges and characteristics of different level of the mass customization strategy are addressed. Achieving mass customization, however, require certain enabling technologies and processes in place. Several such enablers have been identified from the research literature; special concentration is given on the enablers for mass customization. Finally, literature related to organizational capabilities and competitive advantage are discussed

Chapter 3 keys out significantly important enablers for mass customization using interpretive structural modeling (ISM). This chapter also sets up the conceptual framework of the research and the research hypothesis based on the finding from the literature and ISM method.

Chapter 4 summarizes the research design followed to accomplish current study. Several usable research schemes like experiments, surveys and case studies were assessed and it was detected that combining survey and case studies is most suited to deal with the issues like mass customization implementation in Indian industries. A brief explanation is offered to make acquainted with suggested methodology to address the research objectives.

Chapter 5 presents preliminary data analysis and examines the various enablers of mass customization and organizational capabilities. It also includes descriptive analysis of data collected from survey and response analysis of all research variables. This chapter also includes test of data normality and analysis of demographic profiles.

Chapter 6 presents a two-phase method to structural equation modeling (SEM) employed for analysis. The validity of construct and measurement model fit was evaluated at the beginning via confirmatory analysis to confirm that the measurement model. The path model was then formulated and applied to carrying out the final step of SEM.

Chapter 7 presents three case studies to obtain information about the practical implementation of mass customization and to get deeper insights of the findings of research. The manufacturing units of analysis are from modular kitchen, apparel and jewelry industries. Assessment of manufacturing units regarding mass customization implementation is presented with the help of analytical network process (ANP) method. A cross case comparison is also presented and discussed.

Chapter 8 concludes the thesis. All the results are coalesced in conclusions. The limitations of the research are commented and some thoughts for future research are presented. Lastly the chapter concludes with the practical implication for the Indian manufacturing industries.

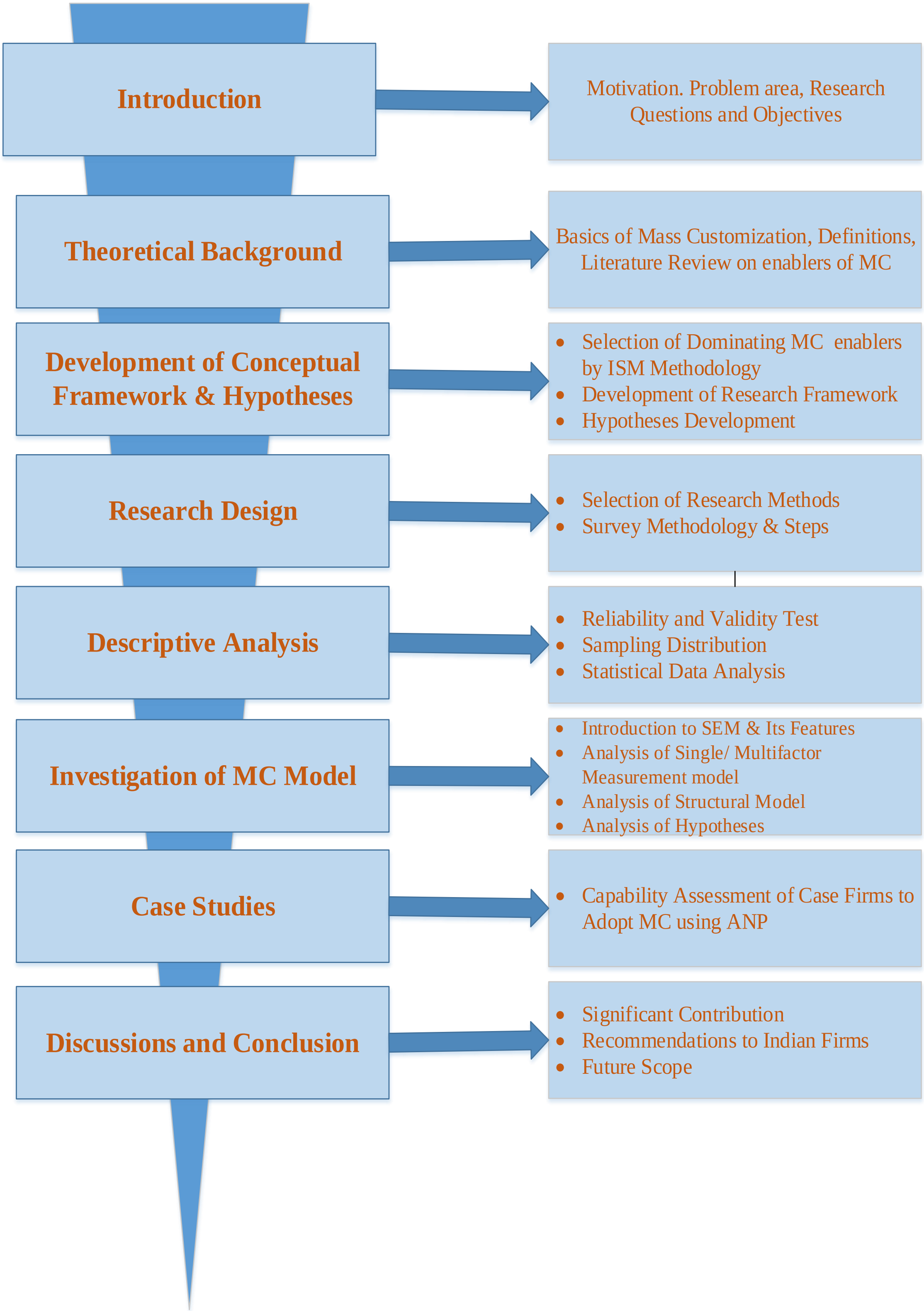

Figure 1.1 Chapter outline

Chapter-2

Theoretical Background & Literature Review

Chapter-2

Theoretical Background & Literature Review

This section establishes the background linked to the aim of this research. The chapter summarizes past work on the conception of MC, besides the definitions and diverse approaches that a firm can take with the objective of making tailor made products. Further, the benefits and challenge of the mass customization adoption are covered in addition to the key success elements. Attention is focused on the enablers for MC, which adds to the proposed research model of this thesis. In the end, on the basis of strategic firm perspective, some insights are furnished about organizational capabilities and achievement of competitive advantage after successful adoption of MC strategy. The literature classification is provided in a diagrammatic view in Figure 2.1

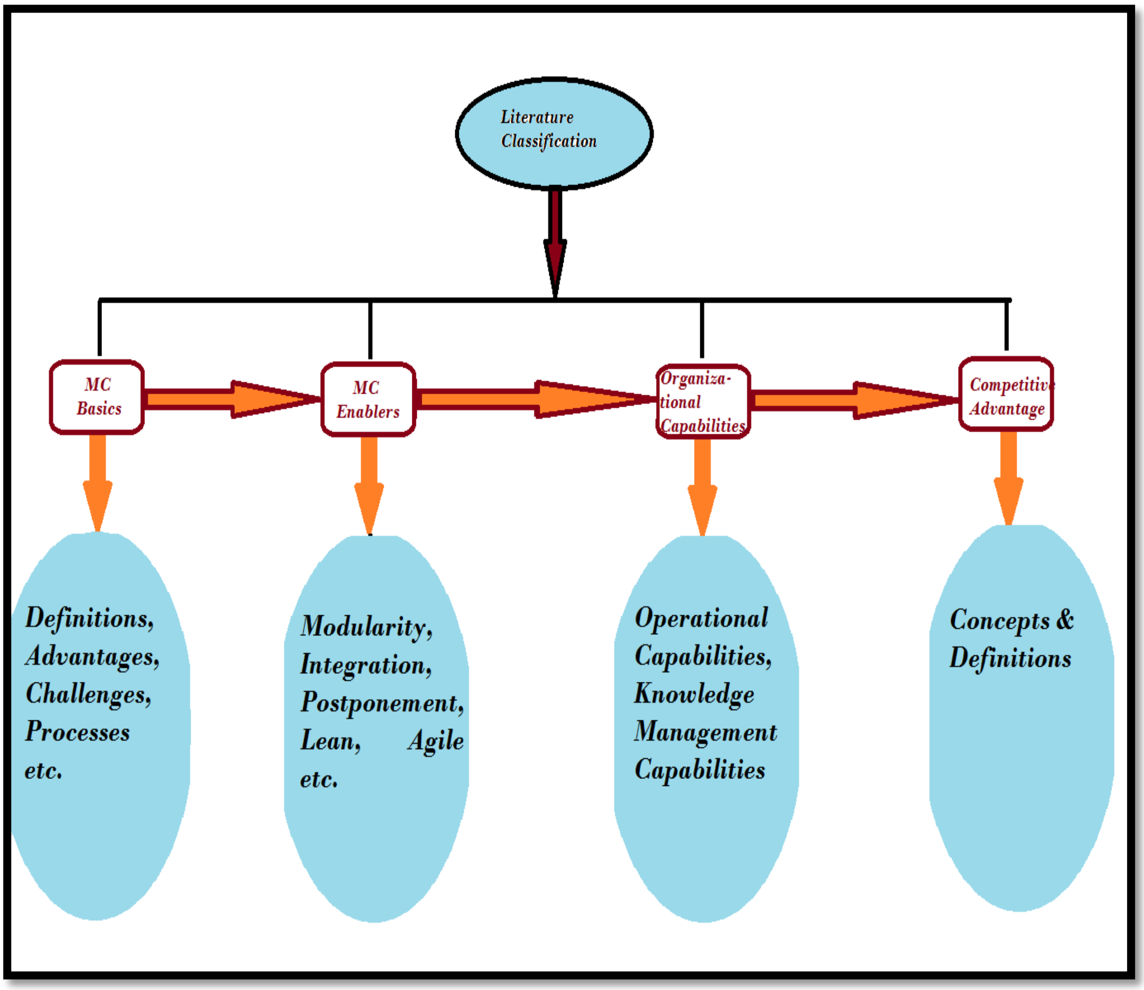

Figure 2.1: Classification of literature for present research

2.1 Origins of mass customization

Manufacturing has progressed through broadly three paradigms during the last two centuries. Before the twentieth century only the craft production was prevalent in which the products were manufactured as per the individualized demands of the customers signaling the utmost level of customization. This type of manufacturing is characterized by unrestricted variety at high product cost. A paradigm shift was witnessed with the beginning of twentieth century that leads the world towards mass production. This type of manufacturing has characterized by low product cost with limited variety. The strategy of mass production has actuated industrialization that lead to gain in financial strength of many manufacturing organization and countries.

The craft production and mass production as two extremes of manufacturing systems were failing to satisfy the needs of modern customer asking for customized products at an affordable price. In the early 1980s, the manufacturing organizations started developing the capabilities to provide products satisfying personalized customer requirements at an affordable price. As mentioned in Figure 2.2 this change started the third paradigm in manufacturing termed as mass customization (MC). Table 2.1 shows the detailed comparison between mass production and MC.

MC takes into account the merits of both the earlier systems of production, i.e. mass production and craft production. The craft production satisfies the personalized demands of customers and the mass production produces a limited variety of products at lower cost.

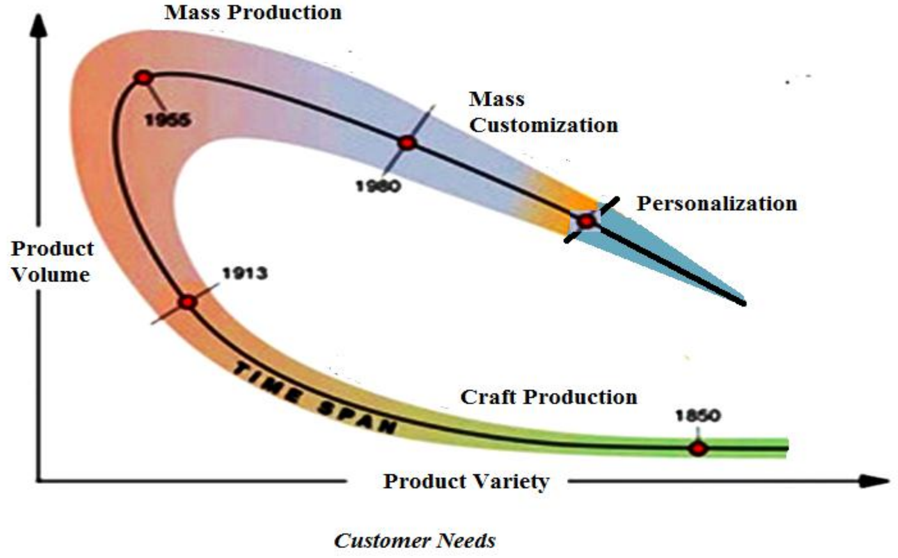

Figure 2.2: Changes in manufacturing paradigms. (Adapted from Koren Y. 2010)

Table 2.1: Mass Production vs. Mass Customization (Adapted from Pine, 1993)

	Mass Production	Mass Customization
Emphasize	Achievement of production efficiency via manufacturing stability and control.	Attainment of product variety through flexible product architecture and manufacturing system.
Objective	Designing, making and transporting products at low prices.	Designing, making and transporting products with such variety that almost all people gets what exactly they want.
Main Features	Stationary requirement	Separated requirement
	Identical markets	Assorted niches
	Less-price, better-quality, similar product features	Less-price, better-quality, custom-made product features
	Lengthy product development/life cycles	Short product development/life cycles

2.2 Defining mass customization

The concept of mass customization was primarily introduced in the late 1980s, as a manufacturing strategy centered upon the extensive supply of individualized goods (Davis, 1989; Pine et al., 1993), typically with the help of modularization and flexibility in production processes. MC aims at forwarding exclusive personalized products at efficiency approximately equal to mass production (Blecker and Abdelkafi, 2006).Several authors have defined MC with a variety of perspective as given in Table 2.2.

Davis (1989) refers to mass customization when the number of customers can be huge as in marketplaces of the industrial economy, although at the same time dealt personally similar to the markets of prior to industrial economies. Pine (1993) declared the mass customization as a way to offer immense variety, at prices comparable to standard products.

In more naturalistic way, Hart (1995) has defined MC as a business strategy that employ information technology and flexibility in manufacturing processes to facilitate custom-make goods and services to a particular customer with a cost that is nearly equal to the cost of standard products.

Duray et al. (2000) put forward that “the application of MC does not fit with the traditional pattern of the production planning and control”. Earlier, manufacturing firms favored processes that supported either purely crafted products or identical products. In counterpoint to this conventional paradigm, mass customization has emerged.

The aim of MC strategy is to present the customer centric products at a lesser price with customers specific requirement with bulk manufacturing efficiency (Tseng and Jiao, 2001).

According to Piller (2004) mass customization pertains to customer’s involvement in development procedure of products to match the demands of every single customer in relation with definite product characteristics. Blecker and Abdelkafi, (2006) consider MC as a business strategy having the aim to put forward exclusive personalized products at efficiency approximately equal to mass production

Table 2.2: Definitions of Mass Customization

Sr.no.	Name of Authors	Year	Definition of MC
1.	Davis	1989	“MC is a capability of manufacture to offer personalized products to all customers with economies of scale.”
2.	Kotler	1989	“MC is an application of economies of scope, through modular production system, offering remarkable array of products and services, at prices similar to standardized products and services.”
3.	Pine	1993	“MC offering incredible range of goods, at prices equivalent to usual goods that almost every person finds accurately what they wish for.”
4.	Kay	1993	“MC utilizes information technology enabled manufacturing system to achieve specific customer requirement proficiently at price of standardized products.”
5.	Lau	1995	“MC is a ability of firms to quickly design and manufacturing of goods as per the customer’s demand at prices of standardized products.”

7.	Hart	1995	“MC is a system that utilize information technology and flexible processes to attain customization of products to individual customers with a cost that is matching to the cost of mass produced products.”
8.	Duray et al.	2000	“MC as making products to customer requirement utilizing modularity in product architecture to accomplish economies of scale.”
9.	DaSilveira et al.	2001	“MC is seen as a organized plan concerning all aspects of product sale, development, production, and delivery, full-circle from the customer option up to receiving the finished product.”
10.	Tu et al.	2001	“If we take MC as a capability, its basic law to meet up specific customer demands at the cost comparable to mass production.”
12.	Broekhuizen and Alsem	2002	“Mass customization as the capability to offer customized products to individual customers employing information technology at optimum manufacturing efficiency and cost.”
13.	Piller and Kumar	2006	“Mass customization refers to a customer co-design process of products and services, which meet the needs of each individual customer with regard to certain product features.”

2.3 Mass customization categorization

Though researchers have consensus on producing customized products and services at an affordable price as the core concept of MC; there exists a systematic categorization of MC strategy primarily based on the level of customer involvement in complete value chain (Duray et al. 2000; Lampel and Mintzberg, 1996).The customers participation in a particular stage of value chain generally referred to as the “Customer order decoupling point". Pragmatically, the level of the customization of product is enhancing when the engagement of the customer is getting in the upper level of manufacturing cycle.

On the basis of participation of customer in the value chain, Lampel and Mintzberg (1996) outlined a scope of approaches. They modified the conversion process in to very basic form and considered only most important phases like product development, manufacturing, assembly and delivery. They specified five core strategies on the basis of lowest to highest customer participation in the value chain. They argued that the existing propensity is not concentrated on pure customization, but on around intermediate type of customization, that they describe as customized standardization.

Gilmore and Pine (1997) identify four basic levels of customization: (1) collaborative customization (when the product development team discuss the actual wants of the customers to key out their demands), (2) adaptive customization (standard module of products can be reassembled by customers all through the utilization of product), (3) cosmetic customization (standard products are delivered in aesthetically different fashion to every customer) and (4) transparent customization (products are adapted regarding individual demands, even without customers' knowledge).

As per Gilmore and Pine (1997) collaborative customization is worthy for industries whose clients can't convey their requirements in a simple manner and get frustrated when are called for to pick out from the plethora of choices, while adaptive customization is desirable for companies whose customers desire for the product to behave in special fashion in specific circumstances, and current technological render the opportunity for them to modify the product by themselves, with very less effort. The cosmetic way of customization is appropriate when consumers exercise the product in identical way but exclusively alters the manner the product is exhibited to them. Finally, the transparent customization is originated to be suitable when the wants of the customers are simple to be anticipated, and this approach is especially worthy for clients that do not want to convey their requirements. Transparent customizers supervise the activities of their potential customers without any direct customer participation. Figure 2.3 show these four approaches symbolize a model for organizations to develop customized goods and firms functional activities. Aggregated together it can deliver an awesome profitable offer (Gilmore and Pine, 1997).

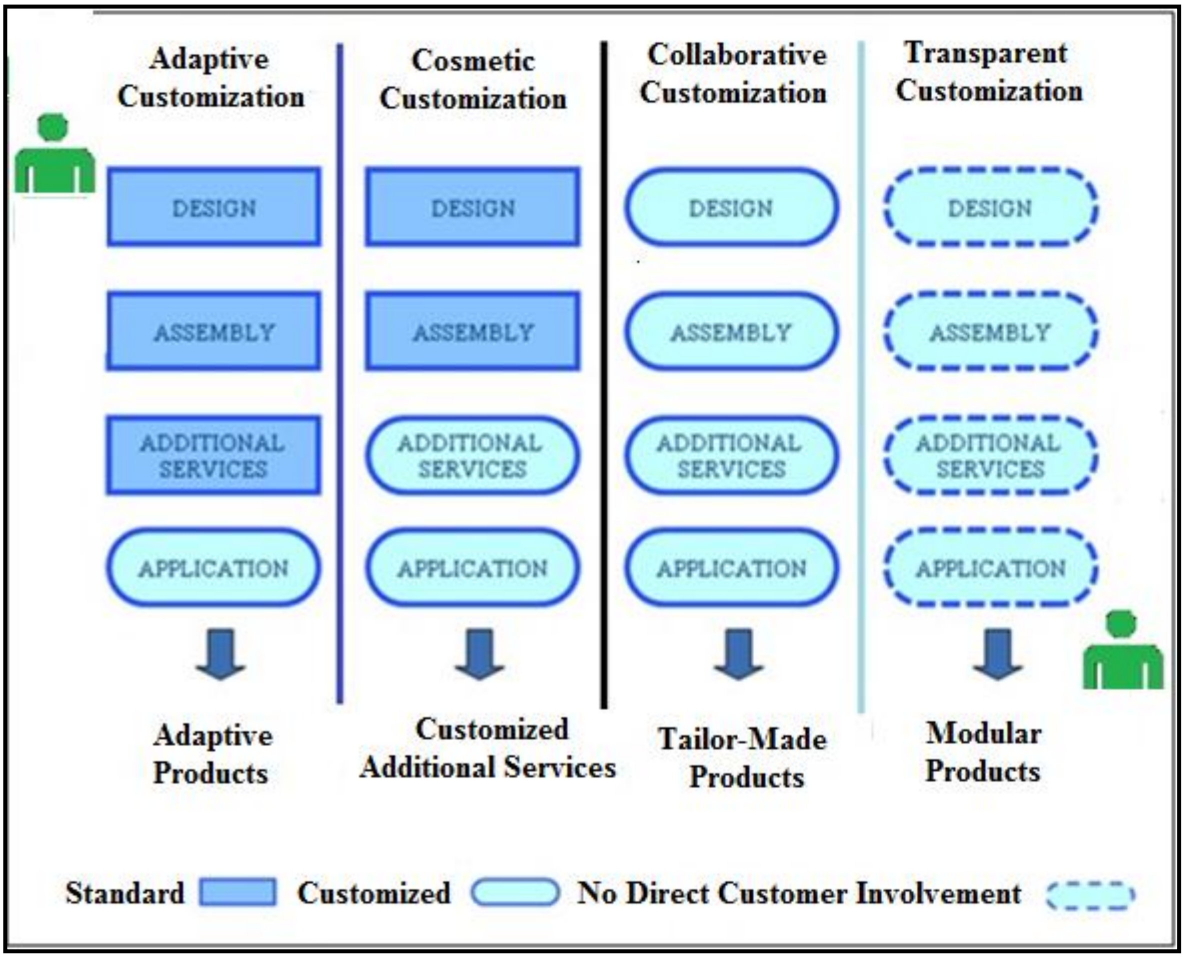

Figure 2.3: Mass Customization Approaches (Adapted from Broekhuizen and Alsem 2002)

It is not mandatory for mass customizers to permit customers to modify the manufacturing process at its very initial phase. Managers should find proper equilibrium, among extra value raised for customer and the funds essential to furnish customization for high volume (Broekhuizen and Alsem 2002).

In addition to customer involvement in value chain; modularity is also considered to be essential element of mass customization (Duray et al. 2000). The literature advises that application of modularity in product design helps to raise the potential number of available product variants, while simultaneously lowers the costs. Pine et al. (1993) also supports that the modularization is the most vital component of mass customization because it can provide the opportunity to produce the components on mass scale which eventually reduces cost per piece. Also, it facilitates few of the product constituents to be manufactured in masses as standard units and the customized identity of the product to be attained by mixing and matching of these units. Thus, modularity is believed to be the most critical criteria for accomplishing the scale factors in mass customization.

The point at which a manufacturer connects the customer in the development of customized products and the application of modularity in product design & production system defines level of customization. Duray et al. (2000) adopted the classification made by Ulrich (1994) and included it into a framework of the production cycle, as shown on the Figure 2.4. They used the design/production process as a starting point, and assigned the distinct types of modularity to different stages of production cycle. At the design and fabrication stages, the modules can be changed or supplementary parts for the standard modules can be produced in order to meet the customer specifications, regarding the uniqueness of the product requirements. During assembly and use stages, standard modules are structured and integrated in a way to satisfy the customer special requirements, but no components can be produced, nor can new modules be modified.

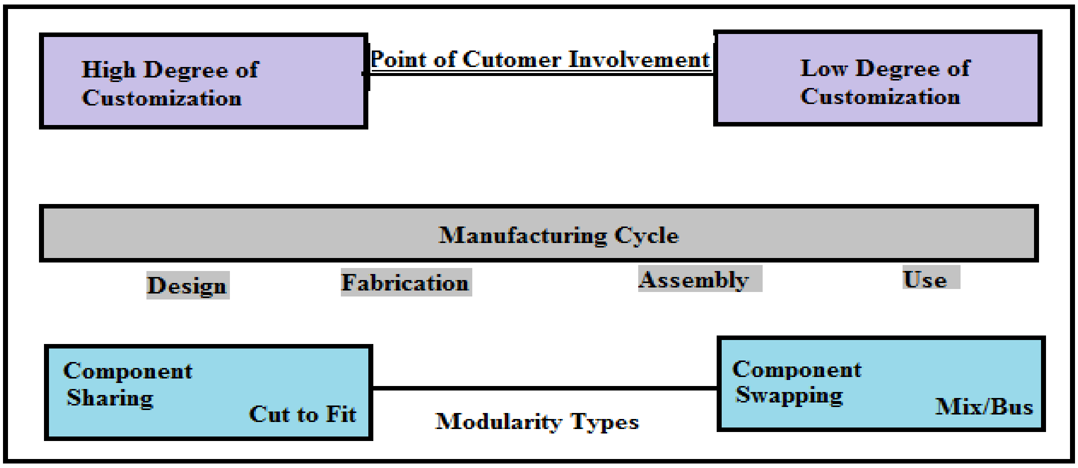

Figure 2.4: Customer Involvement and Modularity in MC Manufacturing Cycle

When Cut-to-fit and component sharing modularity is applied, it is necessary that the components be freshly developed or altered thus this forms of modularization need to be utilized during design and assembly phases of the manufacturing cycle. Cut to fit modularity stands that all the elements, concerning substantial dimension of the product, are altered by the particular proportions called for by the customer. This alteration necessitates fabrication of usual components of specific measurement as per the customer request. Component sharing modularity is also taking place throughout design/ production stages. Despite the fact that standard base unit is utilized in the end product, substitute parts are developed with the aim to offer particular end customized product.

Component swapping modularity, sectional modularity, mix modularity, and bus modularity incorporate standard parts that cannot be modified. Standard modules are aggregated to construct the end product, custom-made for personal requires of the customer. In their archetype form above mentioned modularity provide customization by allowing customers to choose among a mixture of standard components with hardly any opportunity to be modified.

Duray et al. (2000) linked two concepts of customer involvement and modularity among components together and suggested four mass customization models, with substantial deviations on the basis of process assortment, process supervision and engineering, together with design, production and management technologies .

(1) Fabricators carry out collectively the concepts of customer participation and modularity in very initial stage of design and fabrication of the manufacturing cycle. Fabricators follow system to achieve complete customization, but also include the concept of modularization through sharing common attributes of components.

(2) Involvers combine both concepts of customer involvement and modularity similar to fabricators except the utilization stages. They permit the customer participation in the early stage of initiation of the design and fabrication process, but employ the concept of modularity when assembly and delivery phases are coming about. Involvers include customers engagement in the production cycle at the very early stage, however for these clientele no fresh parts are manufactured. Involver's practices achieve higher degree of economies of scale in comparison to fabricators as they do not manufacture customized components.

(3) Assemblers propose mass customization by employing the concept of modularity to facilitate a huge variety of alternatives for the client and act in almost equal manner to mass producers. This class of mass customizers carries out customer involvement and modularization in the assembly and use phases.

(4) Modularizers imitate manufacturing methods similar to mass producers, but not exactly in an exact manner as assembler. Modularizers let in the customer at the later phases of assembly and use, but utilization of modularity concept earlier in the

manufacturing cycle, in the design and fabrication stages. As per the above discussion to this Modularizers behave in similar fashion to Assemblers except that the late participation of the customers.

Based on this model, Duray (2000) differentiates producers that are mass customizers and those that are not. According to her, the manufacturers are not considered mass customizers if they are not involving the customer in the early stage of product design or are not utilizing the concept of modularity.

2.4 Mass customization process

Mass customization can efficaciously be attained by the procedure of interconnected operations that are essential to acquire customers personal requirements. The mass customization process is comprised of many sub-processes as well as the main phases of the value chain. Blecker et al. (2005) has keyed out six sub-processes as follows:

2.4.1 Development sub-process

The purpose of the development sub-process is to translate several customer requirements into standard product architecture, where the outcome can be large number of product versions. The introduction of product variety is accomplished by mixing & matching of the modules into different arrangements. Moreover, the conceptions like component commonality and product platform schemes substantially enhance the capability of producers to reuse the components within mass customization (Blecker et al., 2005). The objective here is to adopt aforesaid concepts to facilitate reduction in utilization of particularly manufactured parts which usually guide to raise the scope for product variants and production costs. Together component commonality and modularity define the product platform strategy.

2.4.2 Interaction sub-process

In order to furnish offers that fulfill customer’s demands; organizations incline to formulate a broad solution space with many product options. This needs a sub-process that satisfies the customer’s anticipation from the real product. The intention of this interaction sub-process is to collect and describe customer wants and deliver the highly appropriate product as per the requirements. Zipkin (2001) mentioned this interaction sub-process as order-elicitation process. He discovers four types of elicitation information in the mass customization –recognition, such as capturing knowledge about the name or address of the customer; knowledge about customer's preference from catalog of choices; actual sizes; and reactions to working models. This synergistic coordination among the manufacturer & the client can be channeled via different mediums like from point of sale or through web based interactive system.

2.4.3 Purchasing sub-process

Since the buying division of organization plays critical role to connect the firm with its upstream suppliers, it has enormous importance in the whole value chain. In mass customization environment, the organizations greatly believe on highly developed set-up of suppliers which deliver raw material and parts as a prominent share of the entire value of the product. Hence, to facilitate MC, purchasing department of the producer is believed to assure that suppliers have the requisite reactivity and flexibleness in furnishing extensive scope of possibilities for mass customization (Blecker et al., 2005).

2.3.4 Production sub-process

All the firms aspiring to be a mass customizer must produce heterogeneous products in an effective and efficient manner. Thus the operations that are crucial to modify parts, equipment, tooling, instruments and software programming from one product to another, have to be realized (Anderson, 1997). The application of flexible production systems and the modularity in product design and production system are usually accepted as elements that regulate the realistic achievement of mass customization. There are usually two types of mass customization manufacturing that can be separated based on the category of flexibility. The first depends on the flexibility as an integral part of product design through the application of modularity, and the second considers the flexibility rooted in the manufacturing systems and processes. The kind of customization presented by the mass customizer is ascertained by the receiving stage of the customer's order in the manufacturing cycle, mentioned as customer order decoupling point or differentiation point. This point can be regarded as the specific stage in the manufacturing process till the products get their typical features as requested by the customer. The responsibility of manufacturer is to ensure the scope of product variety at an affordable cost as desired by the customers.

2.4.5 Logistics sub-process

Logistics sub-processes incorporate the upstream logistics with the providers (transfer and storage of raw materials and parts) as well the downstream logistics with customers (wrapping and delivery of finished goods). The upstream logistic has a task for all the raw material and parts of the products to be transported to the manufacturer as per the production schedule. The downstream logistic has a job to ensure delivery of each individual item of the product right away to the customer. Customized packaging, like gift wrap or personal delivery time are few examples illustrating the participation of logistics in the procedure of customization.

2.4.6 Information sub-process

The aim of information sub-process is to gather and incorporate all significant information concerning custom-made product and to ascertain smooth and continuous information flow (Blecker et al. 2005). Effective information system for mass customization has a capability to incorporate the customer's wants, construct a list of product necessities, and having decisiveness according to the unicity of the products. It has to be able to decide the product order status, set up the manufacturing system and organize the shipment of the ultimate product.

Radio frequency identification (RFID) is hopeful technology that makes recognition and supervision of the personalize goods along the supply chain (production and transportation). Application of Enterprise resource planning (ERP) system at manufacturing location, aids to integrate all functional units of the organization viz. from purchasing to the final delivery eventually increases the agility and ability to change to unanticipated happenings.

2.5 Mass customization challenges

Two approaches to classify the challenges in mass customization environment are considered as external complexity and internal complexity. External complexities are the doubts confronted by the clients when they are involved in product customization, as well as the outside market conditions. Then again, the troubles came across inside the firms manufacturing are treated as internal complexity (Blecker & Abdelkafi, 2006).

2.5.1 External complexity

According to Piller (2004), the comprehended (net) worth has the largest effect on the customer's mind on their readiness to purchase mass customized product, and it is illustrated as the distinction between customer's usefulness for the product (value) and the product cost. From the consumers' standpoint, disbursements of mass customization can be specified as direct and indirect costs. The direct costs correspond to the price premium paid for customization of product, compared to its non-customized usual alternative. Indirect costs result from the comprehended risk of involvement in co-creation (Xie et al. 2016), which can be inferred as the anticipations of customers to make a loss.

Few researchers emphasize the negative aspects of the co-creation practices for the customer, especially in the perspective of toolkits for user innovation and co-design (Piller, 2004; Zipkin, 2001). They debate that the vigorous role of the customer as a designer may result to "mass confusion" (Piller, 2004).

Piller (2004) acknowledged three dissimilar trouble phases, explaining the sources of mass confusion from the customers' standpoint:

(1) **Burden of choice**. The excessiveness of alternatives of mass customized products is frequently emphasized as main limitation that contributes to an external complexity (Piller, 2004). The excessiveness of option scan results in information surplus, since humans have limited capability to analyze the information.

(2) **Matching needs with product specifications**. One more complexity comes along if customers don't have the correct knowledge and know-how related to the product. They generally may lack the know-how and proficiency to make "suitable" preference and to convert their own wants into definite product requisites (Piller et al.2004).

(3) **Information gap regarding the behavior of the manufacturer**. The process of formulating custom-made products is nevertheless strange work for many customers still there is a well present doubt regarding the potential conduct of the provider (Piller, 2004). This issue is more common for ordering via online retailers and the customers buying customized products have bigger difficulties to announce that they do not like the product once received.

According to Piller & Kumar (2006) customer purchases mass customized products, only if the comprehended worth of product for the customers is positive. They argue that setting the optimal degree of co-design options is essential competence for managing mass customization.

Customers need to be offered a well support through the interaction process, in order to facilitate the identification of customers' objective requirements. In the effort to serve the product exploration project, organizations offer web based tools to their customers called configuration systems. This configuration system automatically seizes the customers' requests and creates a product specification without any intermediaries. Well configured and managed configuration systems can help companies to decrease the level of external complexity so the implementation of the mass customization is done in a more effective way (Blecker and Abdelkafi, 2006).

In summary, the challenges that customers face when they get involved in mass customization (external complexity for the provider) can be addressed as: (1) Paying price premium (direct cost); (2) Complexity of design and specification (indirect cost); (3) Time and effort spent in design and specification; (4) Burden of choice - information overload, increased uncertainty (indirect cost); (5) Knowledge lacking to translate personal needs in product specification (indirect cost); (6) Longer waiting time for the finished product (indirect cost); (7) Need to trust supplier to deliver exactly as specified (indirect cost).

2.5.2 Internal complexity

Internal complexity exists generally as a result of the large number of product diversity that negatively influences the manufacturing processes by increased costs and decreased speed of the supply chain which is experienced within production and distribution operations (Blecker et al. 2006).

According to Kotha (1995) the cost may rise due to the amount spent in sophisticated manufacturing methods and information technologies. Similarly, Zipkin (2001) argues that MC anticipates an extremely flexible manufacturing and implementation of such methods can be overpriced and prolonged. Cost may rise also due to investments in computerized information systems to collect and monitor information about customer needs (Kotha, 1996). It requires a complex system for extracting customers' requirements. To build something exclusive for someone necessitates exclusive information. Eliciting this knowledge can be more difficult than it appears (Zipkin, 2001). There is also an increment in labor cost due to hiring of trained and experienced manpower.

The wide product diversity in MC cannot be obtained without losing operational efficiency to some extent. The direct effects of variety involve product and process flexibleness, large number of set ups, bulk inventory, excessive material handling and complex production planning. On the other hand, the indirect effects essentially refer to cost, quality and distribution consistency. Despite the fact that modularity decreases product complexity and reduces the amount of used components, the challenge in mass customization systems primarily relates to production planning and scheduling.

In order to deliver individual products, complex distribution networks are crucial (Blecker and Abdelkafi, 2006). Same argument is used by Zipkin (2001), who points out that strong direct-to-customer logistics system is required.

In summary, the internal complexity for the provider of MC offerings can be addressed as: (1) Producing customized products may cost more; (2) Finding right amount of offered customization is necessary; (3) Increased information management required; (4) Organizational and cultural changes are needed (5) Troubles in accomplishing the essential flexibility in product as well as process; (6) May require expensive investments in flexible machinery and acquiring highly-skilled staff; (7) Agile and complex supply networks.

2.6 Mass customization benefits

Kotha (1996) listed possible benefits from applying mass customization in a manufacturing industry aiming to reduce cost of production are:

- Mass customization manufacturing systems hardly transmitting finished product inventories and substantially declining amount of work-in-process inventory;
- Mass customization manufacturing systems considerably abolishes issues like product obsolescence as an outcome of frequent modifications in model and launching of fresh product;
- Mass customization manufacturing eliminates the difficult statistical methods of demand prediction implemented for mass-production systems;

Similarly, Anderson (1997) describes the benefits that the companies will gain if the strategy of the mass customization will provide the required effect including

- Conforming to customer requirements for variety and customization;
- Making out in advance about the customer's necessitates, by means of customer relationships;
- Opportunity to familiarizing customers for premium pricing;
- Look into fragmentized markets and niches;
- Attaining operational efficiency with the aid of advanced manufacturing technology; and
- Eliminating carrying costs of finished goods inventory.

Huffman and Kahn (1998) classified the approach by which mass customization cuts down the operating cost of high-variety strategies as either by economies of scale or by economies of scope. In economies of scale, standard product modules are ordered in a customized manner. Economies of scope result from the benefits of employing an exclusive procedure to achieve higher variety of products.

According to Jiao and Tseng (2003), mass production strategy is advantageous in bulk-volume manufacturing where the huge volume can recover the costs of high investments in equipment, machines and technology. But satisfying the individual needs of every customer typically can be transformed into superior value, in which little production quantity cannot be neglected and consequently cannot give good reason for the big investment. The authors debate that mass customization is capable to reduce the operating cost and lead-time scale by repetitive manufacturing.

Mass customization can substantiate higher allowances leading to added benefit. The availability of amplified flexibleness imbedded within highly developed flexible manufacturing systems and application of digital technology in communication and manufacturing technologies, firms with small or medium production volumes can accomplish competitive advantage by carrying out mass customization. Noticing from an economical standpoint, mass customization promises better characteristic concerning the producers' capacity and customer needs (Jiao and Tseng, 2003).

In summary, the benefits for the company implementing MC business model can be seen as:

(1) Effective approach to carry out a broader scope of customer wants;

(2) Customer's real participation in product development & design;

(3) Reduction in finished good and in process inventories;

(4) Reduction in product model being superannuated, fashion risk reduction;

(5) Reduction in operating costs by means of economies of scale or economies of scope;

(6) Anticipating what customers' needs via real know-how about customer interaction;

(7) Opportunity for premium pricing.

The most important profit for the clientele from involving in mass customization practices is to improve product that meets their demands (Pine, 1993). In total, the feel of engagement in the design and development, the customers perhaps view it as pleasurable (Huffman and Kahn, 1998), which can as well increase the happiness with the end product (Bardacki and Whitelock, 2003).

2.7 Success factors for mass customization

Broekhuizen and Alsem (2002) describe the success of MC as the "capability to offer greater customer satisfaction, on contrary to standardized product (on the shelf) offerings, by customization on a mass scale". Additionally, they contend that mass customization has the potentiality to get better customer commitment by founding associations utilizing customer know-how, which can only be accomplished if the buying are often repetitive. The success of mass customization depends upon the manner clients comprehend the tradeoff involving the additional costs and the profits of the proposed customization. The conjunction of opportunities coming from the outside and the internal abilities of the firm have control over the success of mass customization. Established on literature reviews, various researchers have attempted to deal with the "vital success factors" for mass customization, and have classified them by internal or external views. For instance, Kotha (1996) compares the internal and external aspects of success (Table 2.3).

Table 2.3: Internal and External success factor

External Conditions	***Internal Conditions***
Success is more likely if • There is hardly any entrenched contender already engaging in MC. • The firm has an advantage of availability of related supplier base within reach. • The firm has interlinked data network with supply chain partners.	Success is more probable when a firm • Has made long term investment in digital manufacturing technology, data driven integration among functional domains. • Has access to extensive in house technical expertise and operational capabilities. • Manages knowledge creation and sharing.

In a parallel approach, Da Silveira et al. (2001) summed up what they find to be the most important elements for successful mass customization implementation. As per their recommendation, the accomplishment of mass customization strategy is hinged upon group of organizational factors, as well as market-related factors. In the subsequent, the first two elements are mostly market-related factors, whereas the remainders are chiefly relating to an organization.

1. **Customer demand for customization must exist.**

   The critical explanation for MC is the existing requirement to deal with the rising requirement for innovative and tailor-made products. Mass customization attainment is based on the equilibrium among the possible loss that clients agree for getting customized products (like price and delivery time) and alternatively, the prospective of the firm to create and distribute personalized products contained by a satisfactory time frame at reasonable cost.

2. **Market conditions must be appropriate.**

   According to Kotha (1996), the capability of a firm to convert mass customization capability into competitive advantage depends on whether the firm will be the foremost in the marketplace to provide a mass customization products or not. It might offer significant benefit over rivals because the organization with improved position in the market will be regarded as inventive and customer-focused firm.

3. **Value chain must be ready**

   The success of MC too relies upon the conformity and willingness of all units in the value chain, such as the suppliers, distributors and retailers to take action to the requirements of the whole system. The supply network need to be capable to proficiently allocate the raw materials and has to be within the close proximity to the firm. It is also very important that manufacturers, suppliers, distributors and logistics providers and other participants in the value chain have to be an element of an efficiently associated information system.

4. **Availability of technical know-how**

   The accomplishment of highly developed flexible production methods is primary factor to facilitate the progress of MC strategy. The conception of MC came forth as a result of the potentiality to effectively put together a progression of information and manufacturing process flexibility technologies. Mass customization uses the offered opportunities promising from corresponding realization of superior production technologies and knowledge throughout the value chain.

5. **Products should be customizable.**

   Products for MC must be standard, adjustable and continually enhanced. Furthermore, mass customization procedures should be qualified by quick product development and novelty due to customary short product life cycles.

6. **Knowledge must be shared.**

   The vibrant nature of MC system depends on the capability of the system to transform novel customer desires into novel products. To realize this situation, the weight is put on the organizational culture towards knowledge creation and allocating that knowledge throughout the value chain.

According to Da Silveira et al. (2001), if these elements exist, a firm is warranted in the use of mass customization as a competitive weapon, and the growth of such arrangements will have the essential support. These factors show the practical implications of mass customization. They support the idea that mass customization cannot be considered as best strategy for every company, but it must correspond to particular market and type of customers.

2.8 Enablers of mass customization

The organizations aspiring to be in the landscape of MC and to be competitive need to find the enablers that can help them in achieving MC. Researchers have put efforts to identify and classify these enablers.

Kotha (1996) consider inter-connected information network with retailers as the most important external factors while investments in advanced-manufacturing technologies as the most important internal factors to successfully pursue MC. Da Silveira et al. (2001) puts forward six enablers of MC, viz. lean manufacturing, supply chain management, agile manufacturing, design and manufacturing driven by the customer, advanced processing technologies and communication and networking. Fogliatto et al. (2012) categorizes the MC enablers into MC methodologies, MC processes like order evocation and supply chain coordination with the need of online configurators to involve customer in design of the products.

Jiao et al. (2005) develops a mechanism considering the variety handlers, a coding system for variant management has also been proposed. Potter et al. (2004) has focused on unified taxonomy approach to achieve MC. Rudberg and Wikner (2004) considered Customer order Decoupling Point as the base for MC implementation. Salvador et al. (2004) mentions different supply chains for different degrees of MC.

Information technology (IT) can be considered as a link to unite external information i.e. from customer and supplier to manufacturer and it is viewed as a budding way to implement mass customization (Helms et al., 2008). IT-enabled resources may make the company's competitive performances sustainable as it is dynamic and is tough to copy by rivals (Prajogo et al. 2012).

IT-enabled sharing capableness is an antecedent for improving flexibilities in producers supply chain including suppliers and customers which is successively linked with competitive advantage. Apart from the material and monetary flow in the supply chain there is another very important flow to be considered: the information flow. It is becoming more and more important these information and knowledge flows and their effect on the other flows of the supply chain (Warkentin et al. 2000). Sanders (2014) and Akter et al. (2016) suggest big data and analytics as an ingredient to connect the supply chain activities (e.g. Buy, Make and Sell) to create remarkable prospects & competitive advantage.

Before advancing with the literature review it is important to understand mainly the difference between cooperation and integration with different actors of the supply chain. Although both are used under and sometimes a synonym for relationships they usually denote to different types of associations between actors.

In coordinative and cooperative situations the actors are centered on common objectives reducing duplicate activities for increasing value added activities (Pan and Holland, 2006; Zhang and Huang, 2010). This is created through information sharing across the supply chain.

Integration is a more rigorous concept which aims to integrate the actors in both ends (downstream and upstream) with the internal functions to achieve an optimal supply chain process. This includes integrating processes, activities, locations etc. to optimize the performance of all actors as a whole (Jitpaiboon et al. 2009; Lau et al. 2010). Lau et al. (2010) argues that integration decreases uncertainties, increases flexibility and quick response.

Detailed discussion on these identified enablers is as follows:

2.8.1 Supplier integration (SPI)

Major percentage of cost of the typical mass customizable product accounts for purchased items as compared to operational or distribution cost. Therefore, the suppliers need to be integrated cautiously. To achieve MC a manufacturer need to have a trusted delivery system for the supply of components and subassemblies to their assembly line. This requires seamless integration with its suppliers and thus SPI is considered to be an important enabler for achieving MC.

In an empirical study Devaraj et al. (2007) found a direct correlation between SPI and functional performance of the manufacturer. According to Zhao et al. (2011) SPI can be accomplished by information exchange, formation of speedy ordering system and participation of key supplier in the design phase of product development. Liao et al.

(2011) suggest that a high level of mutual trust can lead to open information allocation among suppliers and manufacturer, which successively guide to better MC capabilities.

Designer and manufacturing engineer can share the data with the suppliers around the world to quickly create simulations of different designs, test and selection of product component as well as supplier itself.

Moser & Piller (2006) state the data coming from customers and forecasting can also be an important input for a supplier. Integration facilitates this data to be assigned across parties resulting in a more efficient supply chain.

Lau et al. (2010) states that integration with suppliers reduces uncertainties and hence it can promote integrated inventory systems .The information systems are important to provide a platform for the integration which will help optimizing the supply chain (Wang et al. 2007).

2.8.2 Customer integration (CSI)

Wang & Lin (2007) states that, parallel to mass customization definition, customer information should be well accumulated and understood by manufacturer. Constructing semi permanent interaction among the supply chain members is essential to build supply chain integration (Alfalla-Luque et al. 2013). Integration with customers is an essential factor to design and develop customer centric products (Ninan and Siddique, 2006).

Customer integration is making customers a part of the early product lifecycle, similar to the case with the suppliers, integrating them in design or engineering stages which help the customization aspect of mass customization (Pan and Holland 2006). It assists the manufacturer not only in getting information on requirements of the customers but also to capture customer preferences dynamically. Capturing customer preferences dynamically helps the manufacturer in designing the manufacturing system and managing the inter-organizational activities.

Duray et al. (2000) explains the importance of customer involvement in achieving MC. Jitpaiboon et al. (2009) consider CSI as manager's view of the keenness of a customer to correspond and allocate information with the manufacturer.

Piller et al. (2004) consider CSI as a significant way to gain efficiency by its cost saving potentialities. Budding technologies like 3D-printing serving the manufacturer to make solid objects from the software design. This technology makes desktop manufacturing achievable and it scarcely requires any economies of scale.

2.8.3 Internal integration (INI)

INI recognizes that diverse functions like purchasing, manufacturing, logistic, marketing and other supportive internal services within a firm should not act as operational units, but as part of a unified process. This integration can be achieved by sharing relevant business/operational information among different functional units.

Flynn et al. (2010) opine that INI forms the basis on which customer and SPI builds without which companies are unable to achieve MC. Zhao et al. (2011) refer INI as functioning together across different functions in process betterment. Kumar et al. (2015) consider the importance of enterprise integration along with creation of exact product using well-organized production system.

In mass customization environment, applications of big data analytics are very important to integrate inventory management to other functional domains of organizations. RFID tags communicate data to analyze stock levels in transit inventory & automatic reorder quantity. To fulfill customer requirements companies have to have a sound quality monitoring system to identify the defects in real time of their occurrence. According to Sanders (2014) companies can captured data from sensors and tags attached to the production equipment that can monitor the operational performance in real time. These sensors can capture the data of machine characteristics like heat, vibration, sound and wear–tear to early detection of the problem related to machine break down. This way, companies can reduces the cost of equipment failure and reduces production lead time by making alternative arrangement of machine with the help of proper investigation of information gathered by the sensors.

Use of internet-of-things is granting producer to utilize real time information from sensors & tags to track the machinery and assembly with their exact location, administration of the machine functioning & wellness, and supervising of ailing areas in entire manufacturing process.

2.8.4 Concurrent Engineering (CCE)

Concurrent engineering takes the linear, traditional product management process and transforms it into a partly simultaneous, integrated process. It links different stages of product development and production. The most common used concurrent engineering processes are design for cost, lifecycle (inspect ability, maintainability and reliability), manufacturability, enabling technology and quality (Kincade et al. 2007). They believe that with using concurrent engineering the companies can become more consumer-centric, a better mass customizer and focuses on especially apparel industry. They used a survey to assess the frequency of using the seven different concurrent engineering processes (design for cost, lifecycle etc.) at three different companies in the apparel industry. They used different operational statements to understand deeply the usage of these processes. The results show that the operational statements based on concurrent engineering represent their different product development processes.

The design for cost processes are used by product development activities which are cost-related. Design for enabling technologies is used by activities based on information and decision making. Design for inspect ability covers activities related to colors and specifying the products while for maintainability covers fabric testing based on performance. For reliability includes the activities of designing different prototypes. Design for manufacturability take in activities which encompasses close to mass production efficient production processes of mass customization and finally for quality are activities which consumer-centric such as goals, consumer demand data to determine the customer needs.

2.8.5 Collaborative design (COD)

Collaboration can be simply explained as different people in a system working together without the constraints of the physical world around them. Throughout the literature different methods, like over the internet or multi-agent systems, are proposed to make this possible (Trappey and Hsiao 2008).

The study of Trappey and Hsiao (2008) focuses on implementation of an advanced production quality hub (APQP) which will make collaboration between different actors on the supply chain possible. The authors describe the current model as lacking collaboration in design phase; all designs are done independently from each other. Also due to lack of collaboration, the design changes which are needed to keep up with the changing demand cannot be shared on-time and effectively, also pointing out the lack of visibility between different supply chain actors.

2.8.6 Modularity-based practices (MBP)

Modularity in products/processes has been used by the manufacturing organizations to achieve faster production at low cost. Blecker and Abdelkafi (2006) define modularity as "… an attribute of the product system that characterize the capability to mix and match independent and interchangeable product units with standardized interfaces in order to make product varieties."Product customization can come about either based on a common platform with extra alternatives or based on combining and mixing and matching modules to accomplish dissimilar product features. By means of modular design, MC firms becomes capable of attaining manufacturing efficiency nearly adequate to mass production.

Duray et al. (2000) emphasizes that the type of modularity employed in the production systems determines the extent of MC. Droge et al. (2012) develop a relationship between modularity in design/process and supply chain integration. The modular architecture of product and modular production system thus has been considered to be one of the ways to achieve flexibility and responsiveness in manufacturer's production system to enhance MC capabilities.

Ro et al. (2007)'s focus is how modularity alters the processes in the supply chain, how it affects supplier buyer relationships. They identified different kinds of modularity strategies used throughout automotive industry history. DaCunha et al. (2007) propose a mathematical model to optimize the supply chain to find the configurations of modules with lowest cost in an assemble-to-order system.

2.8.7 Postponement (POS)

To ensure the application and the efficiency of mass customization on the supply chain different types of postponement strategies can be used. Graman (2010) defines postponement as "the capability of a supply chain to delay product differentiation, or customization, until closer to the time that demand for the product is known." Baozhuang et al. (2008) defines postponement only on postponement of manufacturing until the receiving of customer orders while Su et al. (2005) emphasizes on the delaying distribution until the arrival of customer orders and also delaying differentiation in the supply chain.

Different companies adapt different types of postponement strategies which are best fit for their operations and market. The literature agrees on three different categories of postponement strategy is present: time, form and place postponement. With the integration of these different categories a full postponement strategy is created.

Time postponement denotes the delaying type created by the holdup of delivery of the product until the orders are received from the customer. In manufacturing, the production of the final good is started after the receiving of the customer order also known as the make-to-order approach. This postponement strategy results in lower inventory levels while it increases service by fulfilling the customized demand (Suet al.2005; Kisperska and Swierczek 2011).

In the case of form postponement, production of the product is completed to a certain point, (Su et al. 2005; Graman 2010; Trentin and Forza 2010; Kisperska and Swierczek 2011). The semi-finished products are in generic form when they are shipped out of the manufacturing process and customized further on the downstream supply chain after the customer order is received.

The last type of postponement is the place or location postponement. This category is based on moving of the inventories in the upstream supply chain in selected centralized locations where manufacturing or distribution activities occur. In these inventory-keeping points downstream shipment is delayed until the customer order is received, resulting in postponement of the progress of the products towards the customer. Trentin and Forza (2010) focus on designing, or rather redesigning, for form postponement. The analysis on the five case studies on machinery industry aims to reveal different approaches in product architecture, supply chain and production processes

Feitzinger and Lee (1997**)** is probably the first to report the ability of postponement. They report a case as how postponing the fitting of country-specific power supply unit in a LaserJet printer, from assembly to distribution stage in the supply chain, could reduce total manufacturing, shipping and inventory costs. Van hoek (2001) define postponement '… as an organizational concept whereby some of the activities in the supply chain are not executed until customer orders are obtained. Firms can then finalize the out-put in accordance with customer tastes and even customize their products'. It involves in detaining the final manufacturing till a concrete customer order is received and is commonly regarded as one of the key pillars of any MC effort (Skipworth and Harrison 2004; Forza, Salvador, and Trentin2008). Brun and Zorzini (2009) demonstrate the relationships between postponement and modularization.

2.8.8 Lean manufacturing practices (LMP)

Lean manufacturing tries to minimize all wastes produced in all facets of manufacturing. In this perspective, waste is defined as any activity, which employs resources, but does not add any value. Tu et al. (2001) contend that lean manufacturing is an essential factor that facilitates MC. Though, lean manufacturing may not directly facilitate product variety but it support MC by increasing operational efficiency.

According to Panizzolo et al.(2012) companies in developing countries are also looking for ways to raise efficiency of their production system by removing unneeded procedures and uneconomical practices from their production systems.

2.8.9 Agile manufacturing practices (AMP)

A mass customizer should be responsive to the varied needs of individual customers. Barutcu (2007) consider agile manufacturing to be a technology that a firm can employ to attain flexibility and reactivity that entail responsiveness. Squire et al. (2006) introduced a tool based on criteria that may help in taking decision in a production system. Vinodh et al. (2010) and Felipe et al. (2016) consider agile manufacturing and MC to be complimentary to each other and argue that these two strategies may lead to improved competitiveness of the firm.

Narasimhan et al. (2006) consider the production to be agile if it expeditiously alters working states in answer to unsealed and varying demands placed upon it. Mishra et al. (2013) use grey relational approach to assess the most suitable agile system for carrying out MC strategies.

2.8.10 Leagility (LEA)

When considering the connection between agility and leanness there are great amount of separated beliefs. Few researchers debate that lean is a precondition for agility, and also appropriate for MC (Narasimhan et al., 2006).

To affirm their statement of leanness being a qualification for agility, Narasimhan et al. (2006) argues that in order to move towards agility a company must have the features of leanness, reducing waste and cost efficiency. Also (Brown and Bessant, 2003) backs this view, as they propose that agility depends on a set of profound Lean factors and thus makes lean an antecedent for agility.

The model offered by (Naylor et al., 1999; Yao & Carlson 2003), shows how the location of the customer order decoupling point should signal where and to what level both lean and agility should be employed.

2.8.11 Enterprise resources planning (ERP)

In order to attain MC in a firm there should be a seamless data and information flow among various business functions such as sales, purchasing, manufacturing planning, and control without any time lag which can be achieved by integrating these business functions. This flow of information right away affects production system planning and, inventory control therefore; organizations must employ a strategy to integrate internal business function as well as external supply chain partners (Jain et al.2009).

One of the enabling technologies used for this integration is Enterprise resources planning. ERP should further be incorporated tightly with other enterprise data system, particularly data management systems for tracking and controlling the data related to especial product, data related to interaction of company with customers and supply chain management system to gain competitive advantage.

Modern enterprises relying on cloud based ERP system to handle their business data. An integrated intelligence system is achieved via integration of ERP and Big data analytics. The ideal future of such system is where real time sales data generated for one product can be used to predict future demand for another apparently unconnected product. In a Delphi study conducted by Akkermans et al. (2003) ERP has been seen as an important contributor to customize products and services.

2.8.12 Digital manufacturing practices (DMP)

A production system with MC capabilities is required to be sufficiently flexible to react to varied customer needs. This flexibility can be attained by flexibility in product design wherein the customer is facilitated to design/configure products as per per-sonalised needs. Realization of these products without losing its economic advantage is possible with flexible production system. Further, product design and manufacturing should be carried out in synchronized way so that the total lead time is minimized.

Computer-aided engineering (CAE), computer-aided design (CAD), computer-aided manufacturing (CAM), cellular manufacturing, reconfigurable manufacturing system (RMS), rapid manufacturing and radio frequency identification techniques (RFID) are some of the technologies being considered in literature as the enabling technologies for achieving flexibility in design and manufacturing.

According to Chu et al. (2006) CAD and CAE are drivers to achieve flexibility in product design and manufacturing leading to reduced product development time, bettered productivity and decreased costs.

The research conducted by Romero et al. (2011) aims to present state of the art computer aided tools and characteristics which help the mass customization process. Joergensen (2011) contemplate RMS as potential enabler of MC which facilitates to achieve less quantity and more variety of products with the help of reconfigurable production system. In this regard production system asks to be not only flexible enough, but also responsive enough in product bringing.

Automated identification with the application of RFID assures to aid with the mechanization of mass customized manufacturing processes by the retrieval and tracking of specific components (Brusey and McFarlane 2009).
Manufacturing organizations now integrate isolated datasets generated from digital manufacturing techniques like CAD, CAM, CAPP, and FMS for efficient production. This type of data integration would ultimately reduce development time, improved quality and optimize resource utilizations for all supply chain partners.

The study Tuck et al. (2008) focuses on the concept of rapid manufacturing and mass customization. According to the study, rapid manufacturing can aid mass customization mainly in two ways. The first one is aesthetically and the second level is by capturing the body shape of the customer to create a better fit. Rapid manufacturing could offer truly customized products.

2.8.13 Web-based interactive systems (WIS)

WIS is a key enabler to MC strategy, establishing the interface among customer and players in the supply chain that are sitting at physically distant locations. Configurators can be used as interface between manufacturer and customer wherein manufacturer provide online information regarding product options using which the customer can design products matching their needs. The product information captured though configurators are shared online with the suppliers to let them enable for the timely delivery of the raw material, components and sub-assemblies. Coronado et al. (2004) demonstrates a three level Internet-enabled supply chain to assess the driving feasibility of a production system.

Jiao et al. (2005) has considered a WIS for the better acquisition of information at different levels of production systems. Through these systems customers can acquire creative achievement and hedonic benefit of co-designing (Merle et al. 2010; Trentin et al. 2014)and customer's willingness to pay (Franke et al. 2010). Yassine et al. (2004) describes the importance of information technology in custom-design products to achieve MC. Chen and Li (2010) advice the firms to fully adopt information technology for new product development processes and devote themselves to building up design customization capability.

Son et al. (2012) identify the perceived benefits offered by a collaborative customer co-design websites and its authority on consumer adoption of this technology.

Now days, companies increasingly rely on outside input to drive innovation and development of the product to fulfill customer needs. These outside agencies may be consumers, suppliers and other third parties to submit their ideas and even collaborate on product development via web based platforms. This technique reduces the time taken to identify a potential idea.

WIS offers better interaction among supply chain partners. These partners can contribute huge amount of data to support decision making.

2.8.14 Electronic commerce (ECM)

In the research of Turowski (2002) e-commerce is defined as businesses in any form which take place electronically over computer networks between supply chain actors. These interactions between actors resulted in different types of e-commerce activities among business, consumer and administration (Ghiassi et al. 2003).

The study of Helander et al. (2002) focuses on e-commerce and its use as an enabler of mass customization in the new product development phase (in other words e-product development (ePD) and present a research program. According to the authors, mass customization is one of the pillars of ePD along with supply chain management and integrated product lifecycle along design, engineering, manufacturing, assembly, distribution, sales and marketing.

The fundamental issues to be considered are identified as human-computer interaction in customization, customer decision making process especially based on internet and mass customization, product platforms, electronic catalogs, product family modeling, virtual teaming of supply chain actors, web-based workflow management and architecture of the system. Ruohonen et al. (2006) establish the relationship between e-business and mass customization.

2.8.15 Agent based systems (ABS)

Multi-agent systems are artificial intelligence systems which are composed of intelligent agents (Dietrich et al. 2006). The agents are autonomous units within the system which can perform different tasks without the need of human interaction (Turowski, 2002; Ghiassi et al. 2003; Dietrich et al. 2006). These agents have the ability to choose the tasks to work on (Dietrich et al. 2006) and they can use data from different environments.

This capability results in agents using different resources and know how within a network (Ghiassi et al. 2003). They also can detect changes in the environment (Dietrich et al. 2006). Apart from these another important characteristic of these systems is the cooperative nature of the agents. Different agents communicate, interact and share information to complete tasks and solve problems (Ghiassi et al. 2003; Dietrich et al. 2006).

In the mass customization context the agents can be used for communication and coordination of activities within the supply chain. They can efficiently and effectively handle data exchanges between actors, as an example supplier and manufacturers. This can be a cost efficient and flexible way to ensure these processes are working effectively (Turowski, 2002)

In the study of Dietrich et al. (2006), the aim is to understand mass customizations effect on business information systems using agent technology. The focus on Turowski (2002) is in a different aspect of multi-agent systems; the e-commerce and electronic data interchange (EDI) applications connected with agent technologies. For a mass customization supply chain they propose to implement an agent system based on contract net paradigm where all actors (manufacturer and suppliers) are represented by different agents. These agents negotiate on the offer until an acceptable offer is reached and the ERP system creates an offer. In the case of failure again agents negotiate to create suitable conditions like shipment times or amounts. As a result of these systems Turowski (2002) argues that the mass customizing company would be more flexible, efficient and more responsive to the needs of the customers.

Ghiassi et al. (2003) studies a software system that satisfies the needs resulting from the changing supply chain and the environment it is in due to mass customization. It explains IT enablers for mass customization, especially object oriented (Java), intelligent agents and e marketplaces and using these technologies to create a synchronized supply chain model.

Figure 2.5 shows article count for each mass customization enabler where percentage of articles for MC enablers mentioned in Figure 2.6.

Table 2.4 shows research article composition across years on mass customization enablers where journal wise overview of articles reviewed on mass customization enablers shows in Table 2.5.Table 2.6 presents comprehensive literature review on mass customization enablers.

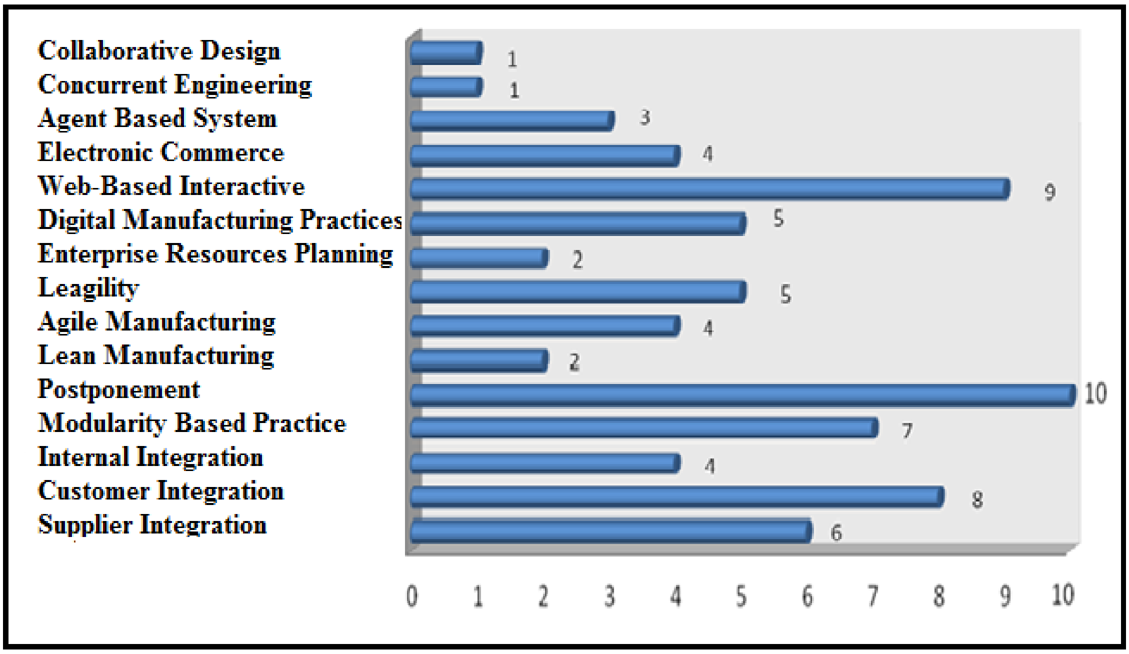

Figure 2.5: Article count for each mass customization enabler

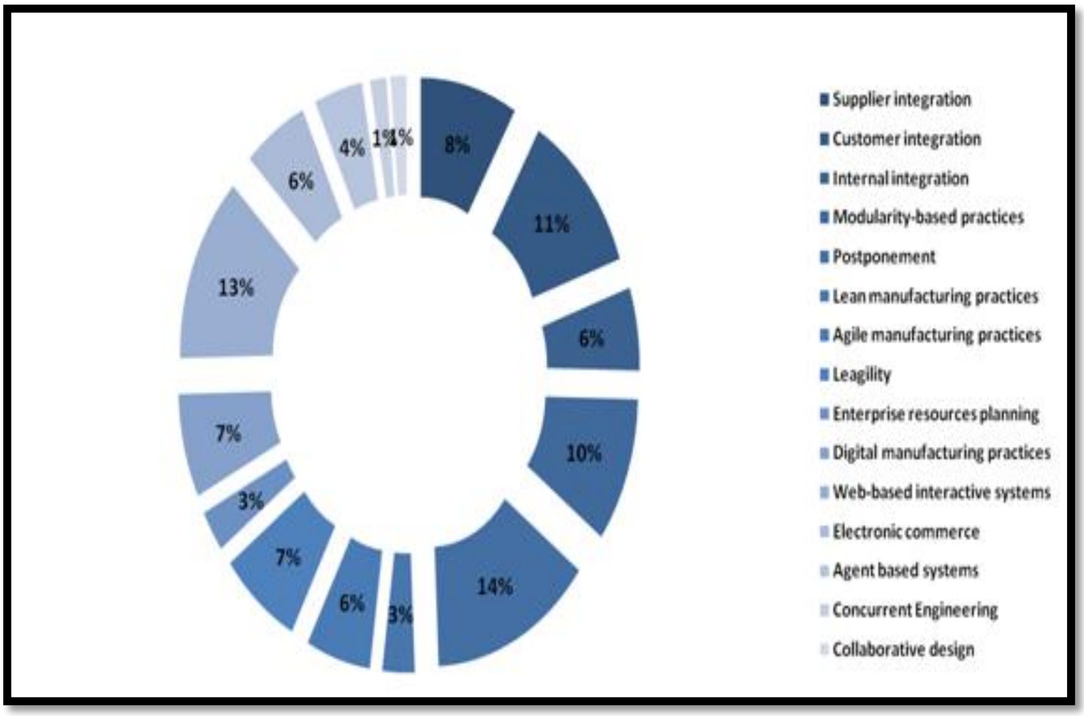

Figure 2.6: Percentage of articles for MC enablers

Table 2.4: Research Article Composition across Years on mass customization enablers

MC Enablers → / Years ↓	Supplier integration	Customer integration	Internal integration	Concurrent Engineering	Collaborative design	Modularity-based practices	Postponement	Lean manufacturing practices	Agile manufacturing practices	Leagility	Enterprise resources planning	Digital manufacturing practices	Web-based interactive systems	Electronic commerce	Agent based systems	<u>Grand Total</u>
1997	*	*	*	*	*	*	1	*	*	1	*	*	*	*	*	2
1998	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0
1999	*	*	*	*	*	*	*	*	*	1	*	*	*	*	*	1
2000	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0
2001	*	1	*	*	*	*	1	1	*	*	*	*	*	*	*	3
2002	*	*	*	*	*	*	*	*	*	*	*	*	*	2	1	3
2003	*	*	*	*	*	*	*	*	*	2	1	*	*	1	1	5
2004	*	2	*	*	*	2	1	*	1	*	*	*	2	*	*	8
2005	*	*	*	*	*	*	1	*	*	*	*	*	1	*	*	2
2006	1	2	*	*	*	1	*	*	1	1	*	2	*	1	1	10
2007	2	1	*	1	*	2	*	*	1	*	*	*	*	*	*	7
2008	*	*	*	*	1	*	1	*	*	*	*	*	*	*	*	2
2009	*	*	*	*	*	*	1	*	*	*	1	1		*	*	3
2010	1	*	1	*	*	*	3	*	*	*	*	1	3	*	*	9
2011	2	*	1	*	*	*	1	*	*	*	*	1	1	*	*	6
2012	*	*	*	*	*	2	*	1	*	*	*	*	1	*	*	4
2013	*	1	*	*	*	*	*	*	1	*	*	*	*	*	*	2
2014	*	1	1	*	*	*	*	*	*	*	*	*	1	*	*	3
2015	*	*	1	*	*	*	*	*	*	*	*	*	*	*	*	1
<u>Total</u>	6	8	4	1	1	7	10	2	4	5	2	5	9	4	3	71

Table 2.5: Journal wise Overview of articles reviewed on mass customization enablers

Journal Name	Number of Articles
Production Planning & Control: The Management of Operations	11
Journal of Operations Management	9
International Journal of Production Economics	8
International Journal of Operations & Production Management	6
International Journal of Mass Customisation	4
Computers in Industry	3
Automation and Logistics-IEEE International Conference	2
Concurrent Engineering	2
Pearson Education Book	2
Engineering Management-IEEE	2
Harvard Business Review	2
European Journal of Operation Research	2
International Journal of Computer Integrated Manufacturing	2
Computers & Industrial Engineering	2
Management Research Review	1
Management Research News	1
Journal of Fashion Marketing and Management	1
Journal of Manufacturing Technology and Management	1
Springer Book	1
International Journal of Production Research	1
Ege Academic Review	1
Benchmarking -An International Journal	1
International Journal of Industrial Engineering and Management	1
Production and Operations Management	1
Management Science	1
International Journal of Electronic Business	1
Journal of Research in Interactive Marketing	1
Technovation	1
Grand Total	**71**

Table 2.6: Comprehensive Literature Review on Mass Customization Enablers

MCEs No.	MCEs	Sub Criteria of MCEs	Description of MCEs	Literature support
EN1	Supplier Integration (SPI)	SPI & Manufacturer Performance, Information Exchange, Mutual Trust, Quick Ordering System	The degree to which a firm can collaborate strategically with its suppliers to manage inter-organizational activities.	Devaraj et al. (2007); Zhao et al. (2011); Moser et al. (2006); Lau et al. (2010); Liao et al. (2011); Wang et al. (2007)
EN2	Customer Integration (CSI)	Customer Centric Products ,Involvement in NPD, Cost Saving Potentials	The consumers take part in activities and processes which used to be seen as the domain of the companies.	Wang et al. (2007); Ninan et al. (2006); Pan et al.(2006); Jitpaiboon et al. (2009); Piller et al. (2004); Alfalla-Luque et al. (2013); Sanders(2014)
EN3	Internal Integration (INI)	Cross-Functional Practices, Organizational System Visibility	The degree to which the different internal functions of firms are able to strategically coordinate.	Flynn et al. (2010) ; Zhao et al. (2011) ; Kumar et al. (2015); Sanders (2014)
EN4	Modularity Based Practices (MBP)	Product Modularity,Coupling Interface,Modularize PFA	The ability to mix and match independent and interchangeable product building blocks with standardized interfaces in order to create product variants.	Mikkola et al. (2004); Blecker et al. (2005); Droge et al. (2012); Duray (2000); Fogliatto et al.(2012); Ro et al. (2007); Cunha et al. (2007)
EN5	Postponement (POS)	Time postponement, Place postponement &Form postponement	Delaying activities in the supply chain until customer orders are received.	Van hoek (2001); Skipworth et al.(2004); Forza et al.(2008); Trentin et al.(2010); Graman (2010); Baozhuang et al.

MCEs No.	MCEs	Sub Criteria of MCEs	Description of MCEs	Literature support
				(2008); Kisperska et al. (2011); Brun et al.(2009)
EN6	Lean Manufacturing Practices (LMP)	Increased operational efficiency ,Supply chain IT and lean practices	The efficient use of resources through the minimization of waste.	Tu et al. (2001); Panizzolo et al. (2012)
EN7	Agile Manufacturing Practices (AMP)	Agility in Product Design, Agility in Manufacturing Processes	Efficiently changes operating states in response to uncertain demands.	Barutçu (2007) ; Squire et al. (2004) Narasimhan et al.(2006); Mishra et al. (2013)
EN8	Enterprise Resources Planning (ERP)	ERP & Information Flow , ERP with Lean Production	Management systems which are designed to integrate the data and processes of an organization into a system.	Akkermans et al.(2003); Jain et al.(2009)
EN9	Digital Manufacturing Practices (DMP)	CAD/CAM/CAE,RMS, Concurrent Engineering, Cellular Manufacturing, Rapid Manufacturing	Application of computer tools considered as enabling technologies for achieving flexibility in design and manufacturing.	Joergensen et al. (2010); Brusey et al. (2009); Chu et al. (2006) ; Romero et al. (2011); Tuck et al.(2008);
EN10	Web Based Interactive Systems (WIS)	Product Configurators, Interface among SC partners	WIS establishing the interface among customer and players in the supply chain that are sitting at physically distant locations.	Merle et al., (2010); Trentin et al., (2014); Franke et al., (2010); Peng et al. (2011) ; Yassin et al. (2006); Jiao et al. (2006) ; Chen et al. (2010) ; Coronado et al. (2004); Son et al. (2012)

MCEs No.	MCEs	Sub Criteria of MCEs	Description of MCEs	Literature support
EN11	Leagility (LEA)	Lean to Agility, Position of the CODP	Agility relies on a set of fundamental Lean elements and thus makes Lean a precursor for agility.	Narasimhan et al.(2006); Naylor et al.(1999); Brown et al.(2003); Feitzinger et al.(1997); Yao et al.(2003)
EN12	Electronic Commerce (ECM)	E-product development , Human-computer interaction	E-commerce is defined as businesses in any form which take place electronically over computer networks between supply chain actors.	Turowski (2002) ; Ghiassi et al. (2003); Helander et al. (2002); Ruohonen et al. (2006)
EN13	Agent Based Systems (ABS)	Autonomous agents, Intelligent agents	Agents can efficiently and effectively handle data exchanges in a cost efficient and flexible way to ensure these processes are working effectively for mass customization	Dietrich et al. (2006); Turowski (2002) ; Ghiassi et al. (2003)
EN14	Concurrent Engineering (CCE)	Design for cost, Design for enabling technologies	Concurrent engineering takes the traditional product management process and links different stages of product development and production.	Kincade et al. 2007

MCEs No.	MCEs	Sub Criteria of MCEs	Description of MCEs	Literature support
EN15	Collaborative Design (COD)	Collaboration between supply chain partners	Collaboration can be simply explained as different people in a system working together without the constraints of the physical world around them.	Trappey et al. (2008)

2.9 Operational capability

In this study, Operational capabilities refer to the firms aptitude to offer customized products with specific features demanded by customers with low price resulting into large number of customers compared to contenders. As customer likings are really hard to forecast and the marketplace is extremely dynamic several researchers stressed the need for flexibility in design and marketing of tailored products for firm's success (Krishnan et al., 2002). Boyer et al.(2002) establish the tradeoffs between that quality, delivery, cost and flexibility. However, grounded on the experience of Japanese industries, business firms can concurrently realize several operational capabilities by the implementation of digital manufacturing practices and early involvement of customer and supplier (Rosenzweig, 2004).

Olavarrieta et al. (1997) define operational capability as "complex packets of person skills, assets and collected knowledge implemented via organizational processes that permit organizations to align activities and applications of available resources". Operational capabilities symbolize the organization's skill to operate on attributes of quality, delivery, flexibility and cost comparative to its direct rivals in the target markets (Rosenzweig et al. 2004). It is typically evaluated along the dimensions of cost, quality, flexibility and delivery (Devaraj et al., 2004). Enhanced operations capability has shown to improve effectiveness in the delivery procedure, reduced costs of operations and attain competitive advantage (Tan et al., 2007).

2.10 Knowledge management capability

According to Davidson et al. (2002) purposeful information is called as Knowledge. Knowledge is an awareness and intellect acquired from a combining of data, information, experience and observation (Bollinger et al.2001). Knowledge can be arranged in to two different classes as explicit and tacit knowledge. Explicit knowledge is knowledge that is able to be documented and can channelized easily to other people as manifestations, presentation and further types of communication. By contrast, tacit knowledge is hard to transfer to another individual by means of any document or articulating it. (Debowski, 2006).

Knowledge management (KM) can be considered a trade practice where precious information is recognized, accumulated, aligned, stored, administered, and finally utilized to attain the firm's objectives. According to Walters (2002), KM may be viewed as a aggregations of processes of gaining as well as employing knowledge to realize outcomes such as competitive advantage.

James (2005) puts forward that KM can perk up efficiency and effectiveness of business processes as well as receptiveness and flexibleness to external business fluctuations. In addition, KM can also be utilized to enhance efficiency of activities like new product development, creation and product and process quality management (Davenport et al.1998; Hauschild et al. 2001).

An organization's aptitude to efficaciously adapt to varying circumstances will be superior when it has an intense knowledge management potentiality. An organization's Knowledge management capability is characterized as power to actuate and establish knowledge based resources combining with other capabilities, heading to competitive advantage (Chuang 2004). These resources may be tangible and/or intangible. Barney et al. (2007) suggest that firms strategies grounded on intangible resources surpass those with plans based exclusively on actual resources. Firms want to concentrate on the knowledge acquired through supply chain integration to raise association with customers and other supply chain partners for product development. Properly planned investments in big data and analytics techniques can enhance the knowledge management capabilities within the supply chain by assisting managers to effectively manage the knowledge resources and transform those resources into firm's knowledge management capabilities. Gold et al. (2001) argue that firms can be distinguish from the rivals with the help of precious resources to built distinctive knowledge management capabilities which are difficult to obtain and hard to replicate, thus, attaining competitive advantage.

From the above discussion it can be assumed that KMC is a dynamic capability which concentrates not simply on the utilization of knowledge capitals but also to create a flow of the firm's knowledge stored in its repository, backing the formation, renovation and utilization of organizational capabilities.

2.11 Competitive advantages

Competitive advantage is the level to which a firm can be weighed superior than its rivals. It is an evaluation of strength comparative to firms' competitors in accomplishing targets of financial gain, and productivity (Lall, 2001). According to Li et al. (2006) competitive advantage of a firm is its capacity to keep a defendable situation over the competition. Porter (1985) correlates firms secure market status with sustainable competitive advantage and opines that firm's dominations on either cost effectiveness or distinction plays a significant role in ascertaining the competitive advantage. Ma (2000) makes use of counter illustrations to show that neither cost advantage nor differentiation is enough and essential for better performance. Instead, better performance could also be achieved from other types of competitive advantage such as speed & flexibility (Sanchez et al. 1995, Dangayach et al. 2000) or possibly, an amalgamation of various competitive advantages.

A firm's competitive advantage can be marked in many attributes like novelty, market position, mass customization, and complexity in replicating (Byrd et al., 2001). This study employs four criteria of competitive advantage (1) innovativeness in products and processes to adopt mass customization strategy, (2) market position (3) availability of wide array of products with low costs compared to competitors and (4) complexity to replicate the MC strategy for rivals.

A number of enablers have been identified in literature with different authors towards achieving MC. There is, however, no study in the literature that prioritize enablers for adoption of MC. There is a large research gap in the identification of authoritative enablers for adoption of MC practices. The present study aims to fill this gap.

2.12 Chapter summary

In this chapter the concept of MC is defined. Further, the benefits, challenges and characteristics of different level of the mass customization strategy are addressed. Achieving mass customization, however, require certain enabling technologies and processes in place. In total fifteen such enablers have been identified from the research literature; special concentration is given to the literature on mass customization enablers. Finally literature related to organizational capabilities and competitive advantage also discussed.

Chapter-3

Development of Conceptual Framework & Hypotheses

Chapter-3

Development of Conceptual Framework & Hypotheses

The previous chapter of literature review helped in understanding the basics of the mass customization from the academic point of view. Literature review was made covering 118 articles on the concerned subject. The following key contributions pertaining to the present research from the literature are summarized as:

a) Identification of literature on mass customization basics, definitions, approaches etc.
b) Identification of mass customization enablers as a key area of research.

To meet the objectives of the study a three phase research methodology is adopted.

3.1 Three phase research methodology

The three phases of research are as follows:

- First, preliminary task is to attain dominating mass customization enablers explored for Indian organizations through literature review and application of Interpretive Structural Modeling (ISM) technique. Development of conceptual framework and research hypotheses also get established in this phase.
  All the MC enablers do not necessitate the similar intensity of attention on the part of decision-makers. There is, thus a need to prioritize the MC enablers for adoption by the organizations aspiring for the mass customization To this end, Interpretive Structural Modeling (ISM) has been adopted to study key enablers of mass customization systematically. The methodology adopted for the development of research framework from ISM model is shown in Figure 3.1.
  The main outcome of this phase is structural framework of key constructs of the research.
- Second, the testing of developed of conceptual model and hypotheses for Indian organizations to investigate the relationship among MC enablers, organizational capabilities and competitive advantage. Data collection through survey of Indian manufacturing organizations producing customizable products is conducted to offer validity to research. The validation is focused on testing the

relationship among key variables through quantitative analysis (i.e. Structural Equation Modeling)

- Third, Capability assessment of select Indian firms to adopt mass customization strategy through Analytical Network Process (ANP) method.

The next sections will describe the ISM methodology to find the dominating MC enablers.

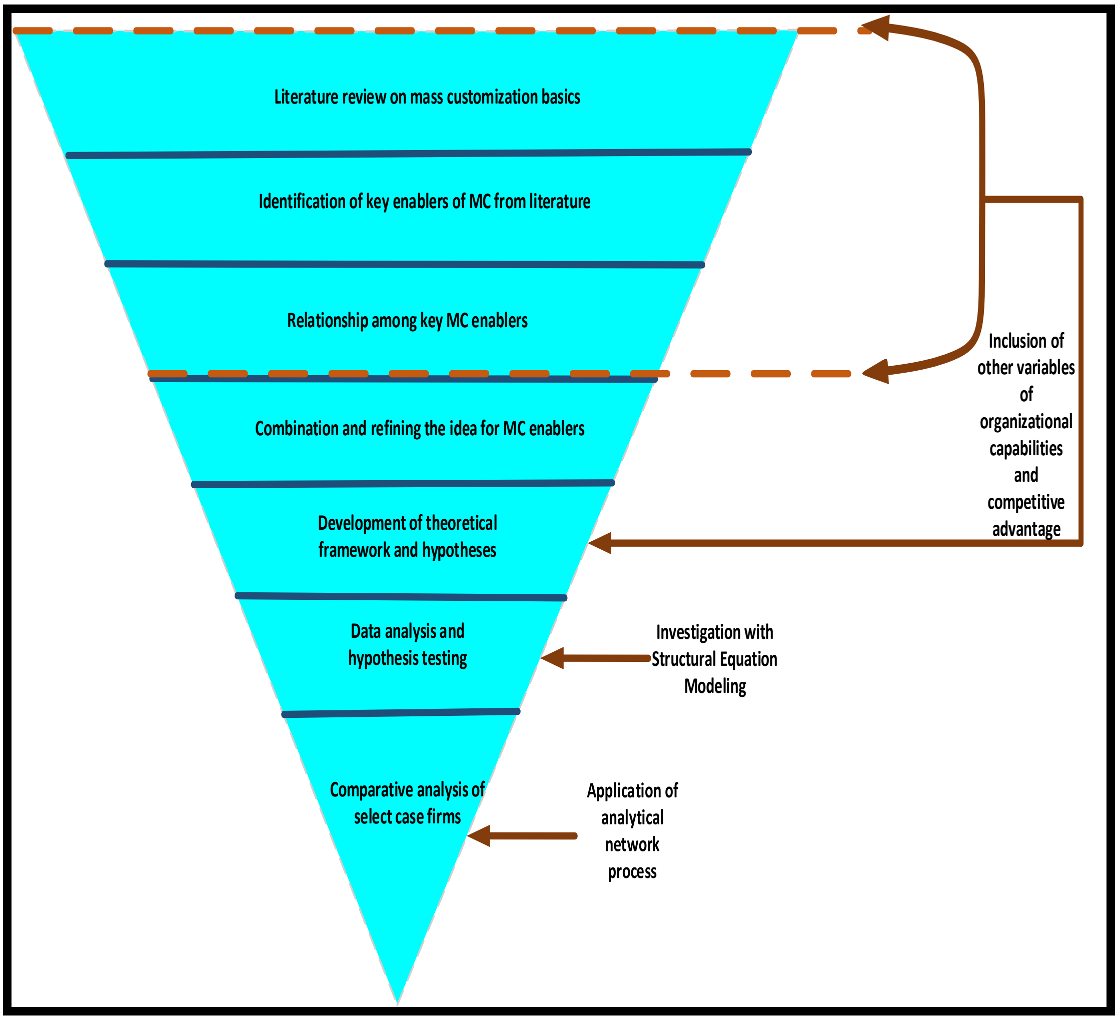

Figure 3.1: Methodological overview of proposed research

3.2 Finding the dominating enablers of mass customization: An Indian Experience

Mass Customization (MC) is observed as an important strategy by the firms to provide products exactly as per customer need and adapt themselves internally to provide these products efficiently. It is useful to make out several MC enablers which can be placed conjointly to establish the firm profitable one in the marketplace. Altogether the MC enablers do not necessitate the similar intensity of consideration on the part of managers. To attain this, Interpretive Structural Modeling (ISM) has been accepted to study enablers of mass customization analytically. The ISM method delivers a hierarchical model that describes the straight and indirect relationships between several elements in a system established on dominance, priority, and relation throughout and between each other. The main enablers for accomplishment of mass customization have been identified in an Indian context.

Mass customization enablers take the firm to a new level in answer to the firm's capability. This rises to re-examine the firm's policy and rebuild it as per the mass customization strategy. It is usually experienced that persons or group of managers come across troubles in treating with difficult systems. The complication of the systems is due to the existence of a huge quantity of factors and their linkages. The existence of directly or indirectly linked factors causes difficulties in the development of the arrangement of the system in a well-defined manner. It turns out to be tough to address with such ill-defined structure of system. Therefore, it requires the formation of a tactic which helps in placing a structure for a system.

ISM is such a technique which imparts an improved understanding of a system structure and describes valuable instruction in producing a graphical illustration of the structure. Thus a hierarchical model proposed here to categorize the MC enablers and aids the managers to extract the realistic relationship among them to implement MC strategy. This ISM approach can aid in determining the priority to implement the practices proactively in achieving these enablers.

In this Chapter, the enablers of MC are first selected from the literature and then key out important enablers with the help of expert opinion. Contextual relations among these enablers are then identified using interpretive structural modeling (ISM). MICMAC analysis is performed subsequently to categorize the MC enablers. ISM as a soft computing technique contains verdicts of individual's special knowledge in a organized way and demonstrates causative associations among variables (Warfield 1974; Sage 1977; Diabat and Govindan 2011). Based on many advantages of ISM methodology, it has been growingly employed by several investigators to signify the interrelations among respective factors related to the matter (Attri et al.2013).

This section of research classifies the entire research design process in three stages from selection of case companies and experts to the final stage of identification of MC enablers for the Indian manufacturing industry.

In the initial stage of research design more than 80 manufacturing industries (producing customizable products) located mainly in northern, western and southern part of India were included, and hence we selected Indian states of Delhi, Uttar Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Maharashtra, Karnataka and Tamil Nadu for current research. Indian manufacturing industries Database' was accessed and down-loaded from the websites like NIIR Project Consultancy Services, Indian manufacturer directory, trade India and Confederation of Indian Industry (CII) database.

After this, 80 manufacturing industries were sent an email. The mail comprised of the aims and the requisite for research. Documents related to literature on MC and implementation of MC in manufacturing industries and relevant case studies of global mass customizers like Nike and Dell (brand-driven mass customizers, have only partial flow of revenue through MC) and companies like shoes of Prey and Zara (product-driven mass customizer have complete flow of revenue generation is happening through MC) were attached with the mail.

Following repeated phone calls and emails, we received a response from twenty six industries (from Apparel, Furniture, Automobile, Footwear and Bicycle manufacturing) after three weeks. Finally, based on the profile and availability of the experts, 13 industries from those 26 industries were shortlisted. As strategic decisions are made by top/senior management they were found to be suitable respondents for this study. All the respondents were well-versed with their companies existing manufacturing, technological and supply chain-related capabilities and were familiar with competitive advantage of international brands using mass customization strategies. Four experts from each company participated as a member of the expert panel, making the overall strength of panel as fifty two, and all these fifty two members participated in the second round of the research design.

In the middle stage of research design this survey was mailed to identify common enablers of the MC. To find the common enablers of MC all 52 experts were asked to rate the importance associated with each MC enabler, that can enhance the organization's ability to adopt MC.

The responses were recorded on a five-point likert scale (1 – Not important at all; 2 – Not very important; 3 – Somewhat important; 4 – Moderately important and 5 – Extremely important) to rate the importance of each enabler.

There were 15 enablers that were sorted with the help of research literature on MC, and from this list, 5 enablers obtained an average lower than 3.0 and remaining 10 received an average between 3.0 and 5.0. These 10 enablers were categorized between moderate and extreme importance. Finally, these 10 enablers (i.e. SPI, CSI, INI, MBP, POS, LMP, AMP, ERP, DMP and WIS) qualified as the 10 most dominant enablers in the context of Indian Manufacturing industries and they were recommended for this research.

In the final stage of research design, a one-day workshop for each industry was carried out to develop a contextual pair wise relationship among these enablers and later on the authors collectively analyzed the data to developed mutual relationships between enablers based on with the aid of brainstorming and nominal technique.

For analyzing enablers, a contextual relationship of 'leads to' type is taken. This means that one enabler of MC leads to another. Based on this, a contextual relationship between pairs of enablers was developed in the form of self-structured interaction matrix (SSIM) which guides to identification of contextual relationship among enablers using ISM.

3.3 ISM methodology

The methodological steps (Govindan et al. 2012; Talib et al. 2011; Mathiyazhagan et al. 2013) involved in the formulation of ISM model are described in this section.

Step 1: List the enablers examined for the system under considered.

Step 2: Develop a SSIM with the help of discussion with expert showing contextual relations between pairs of variables identified in Step 1.

Step 3: Develop initial reachability matrix (RM) using appropriate relationship involving the variables established in SSIM.

Step 4: Develop final RM considering transitive property of relation between variables. The transitivity of the relationship is a constatation made in ISM. It expresses that if a variable A is related to B and B is related to C, then A is inevitably related to C.

Step 5: Develop partition table consisting of reachability set and antecedent set consisting a set of variables driving the variables in question.

Step 6: Determine the levels of variables in the hierarchal framework using following steps.

- 6.1 Identify variables at level I for which the reachability and intersection set are the same.

- 6.2 Remove all the level one variables from the reachability and the antecedent set and determine level two variables of the hierarchy as done in 6.1.

- 6.3 Repeat 6.2 till the level of all the variables is decided.

Step7: Based on the above relationship, a directed graph is drawn and transitive links removed.

Step8: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.

Step9: Finally, the ISM-based model developed in step 7 is reviewed for inconsistency and modifications are incorporated through expert opinions.

Figure 3.2 depicts a flowchart as the steps are explained in this section.

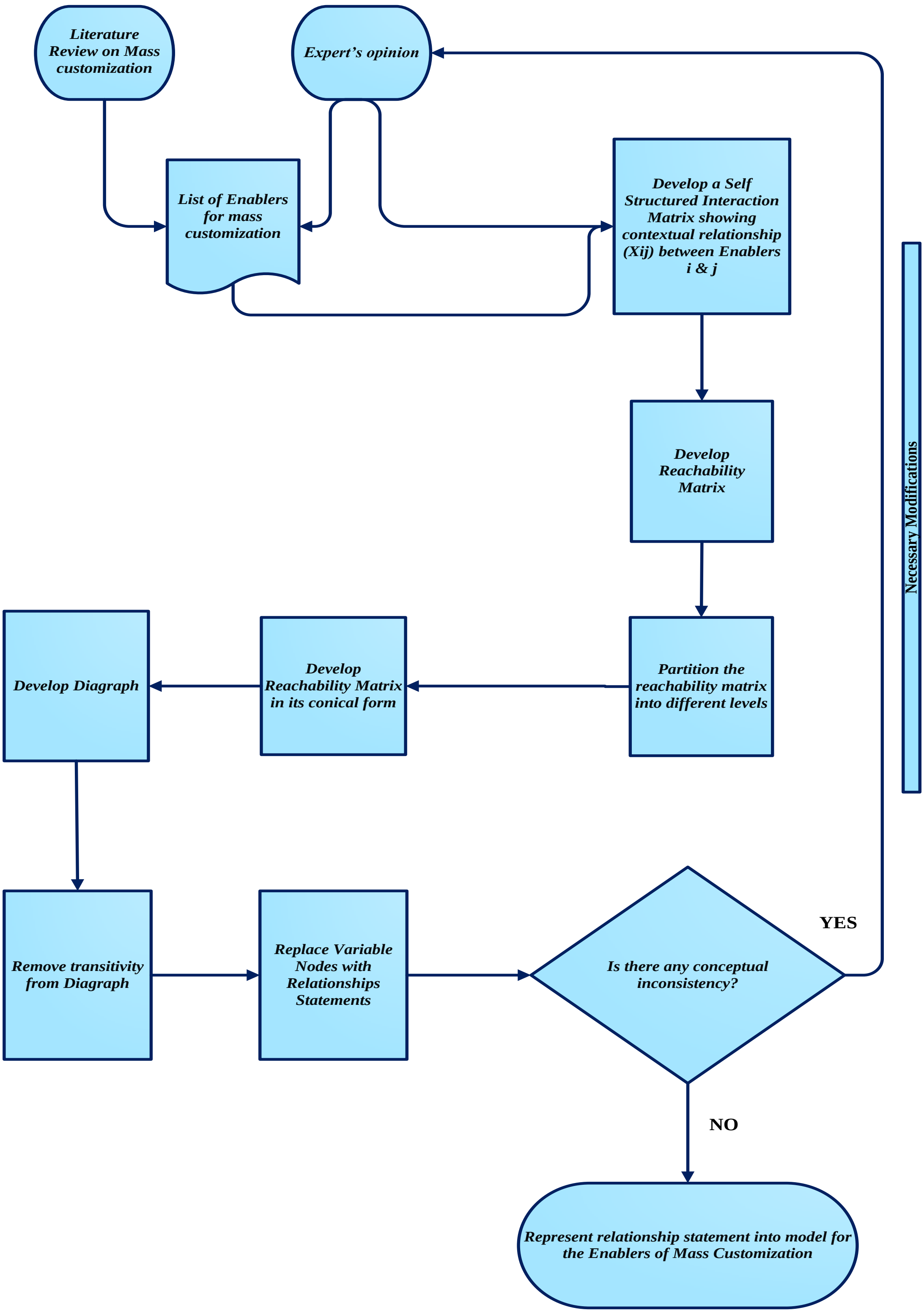

Figure 3.2: ISM methodology flowchart

3.4 ISM-based model for MC enablers

This section provides the details of application of ISM for development of a hierarchical model of MC enablers. The MC enablers considered in this research were taken from literature as well as emanated from the discussion with a panel of experts consisting of 40 experts from different Indian manufacturing industries. These experts corroborated with each other to establish contextual relationships among the enablers of MC in the context of their functional areas. The various steps in development of ISM model are described below:

3.4.1 Self-structured interaction matrix (SSIM)

As a first step we develop a SSIM to show the contextual relations among all the MC enablers identified earlier. The resulting matrix is shown in Table 3.1. The symbols in the table corroborate the 'leads to' type of relationship between a pair of enablers with

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

Where index i is for enablers in row and j is for enablers in column.

Table 3.1: Structural Self Interaction Matrix for MC enablers

SSIM		EN10	EN9	EN8	EN7	EN6	EN5	EN4	EN3	EN2	EN1
		WIS	DMP	ERP	AMP	LMP	POS	MBP	INI	CSI	SPI
EN1	SPI	X	A	X	V	X	V	X	X	V	X
EN2	CSI	A	A	X	X	V	V	O	A	X	
EN3	INI	A	O	X	V	V	V	O	X		
EN4	MBP	V	X	V	V	V	V	X			
EN5	POS	A	A	A	X	V	X				
EN6	LMP	A	A	A	X	X					
EN7	AMP	X	A	A	X						
EN8	ERP	X	A	X							
EN9	DMP	X	X								
EN10	WIS	X									

3.4.2 Reachability matrix (RM)

In this step, the RM is formulated from SSIM. Firstly, an initial RM is developed by converting the value in each cell of SSIM into binary value. The conversion is done as per the following rules: If the entry (i, j) in SSIM is V, then corresponding entry in RM is 1 and entry (j, i) becomes 0. If the entry (i, j) in SSIM is A, then corresponding entry in RM is 0 and entry (j, i) becomes 1. If entry (i, j) in SSIM is X, then corresponding entry in RM is 1 and entry (j, i) becomes 1. If the entry (i, j) in SSIM is o, then the corresponding entry in RM is 0 and entry (j, i) becomes 0.

The resulting initial RM is shown in Table 3.2. Second, the final RM for the enablers is developed by incorporating the transitivity as enumerated in Step 4 of the ISM methodology. Table 3.3 shows the final RM.

Table 3.2: Initial Reachability Matrix

IRM		EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10
		SPI	CSI	INI	MBP	POS	LMP	AMP	ERP	DMP	WIS
EN1	SPI	1	1	1	1	1	1	1	0	0	1
EN2	CSI	0	1	1	0	1	1	1	1	0	0
EN3	INI	1	1	1	0	1	1	1	1	0	0
EN4	MBP	1	0	0	1	1	1	1	1	1	1
EN5	POS	0	0	0	0	1	1	1	0	0	0
EN6	LMP	1	0	0	0	0	1	1	0	0	0
EN7	AMP	0	1	0	0	1	1	1	0	0	1
EN8	ERP	1	1	1	0	1	1	1	1	1	1
EN9	DMP	1	1	0	1	1	1	1	0	1	1
EN10	WIS	1	1	1	0	1	1	1	1	1	1

Table 3.3: Final Reachability Matrix

FRM		EN1 SPI	EN2 CSI	EN3 INI	EN4 MBP	EN5 POS	EN6 LMP	EN7 AMP	EN8 ERP	EN9 DMP	EN10 WIS	Driving Power
EN1	SPI	1	1	1	1	1	1	1	0	0	1	8
EN2	CSI	0	1	1	0	1	1	1	1	0	0	6
EN3	INI	1	1	1	0	1	1	1	1	0	0	7
EN4	MBP	1	1*	1*	1	1	1	1	1	1	1	10
EN5	POS	0	0	0	0	1	1	1	0	0	0	3
EN6	LMP	1	0	0	0	0	1	1	0	0	0	3
EN7	AMP	0	1	0	0	1	1	1	0	0	1	5
EN8	ERP	1	1	1	0	1	1	1	1	0	1	8
EN9	DMP	1	1	1*	1	1	1	1	1	1	1	10
EN10	WIS	1	1	1	0	1	1	1	1	1	1	9
Dependence Power		7	8	7	3	9	10	10	6	3	6	69 / 69

Note: 1* indicates indirect relationship through transitive property.

3.4.3 Level partition

As per the steps 5 and 6 of the ISM methodology, detailed in Section 3.3, levels partitioning is performed to decide the levels of variables in the hierarchical model. In the current study levels of all the enablers have been decided in six iterations (Table 3.4). The results of partitioning after all six iterations are shown in Table 3.5.

3.4.4 The ISM model

As a result of the level partitioning all the enablers have been classified into six levels. These levels show the antecedent–precedent relations between the enablers with level VI enablers are antecedent of level V enablers and level V enablers are antecedent of level IV enablers and continuing in the same way. The final ISM model for the enablers of MC showing the levels is shown in Figure 3.3.

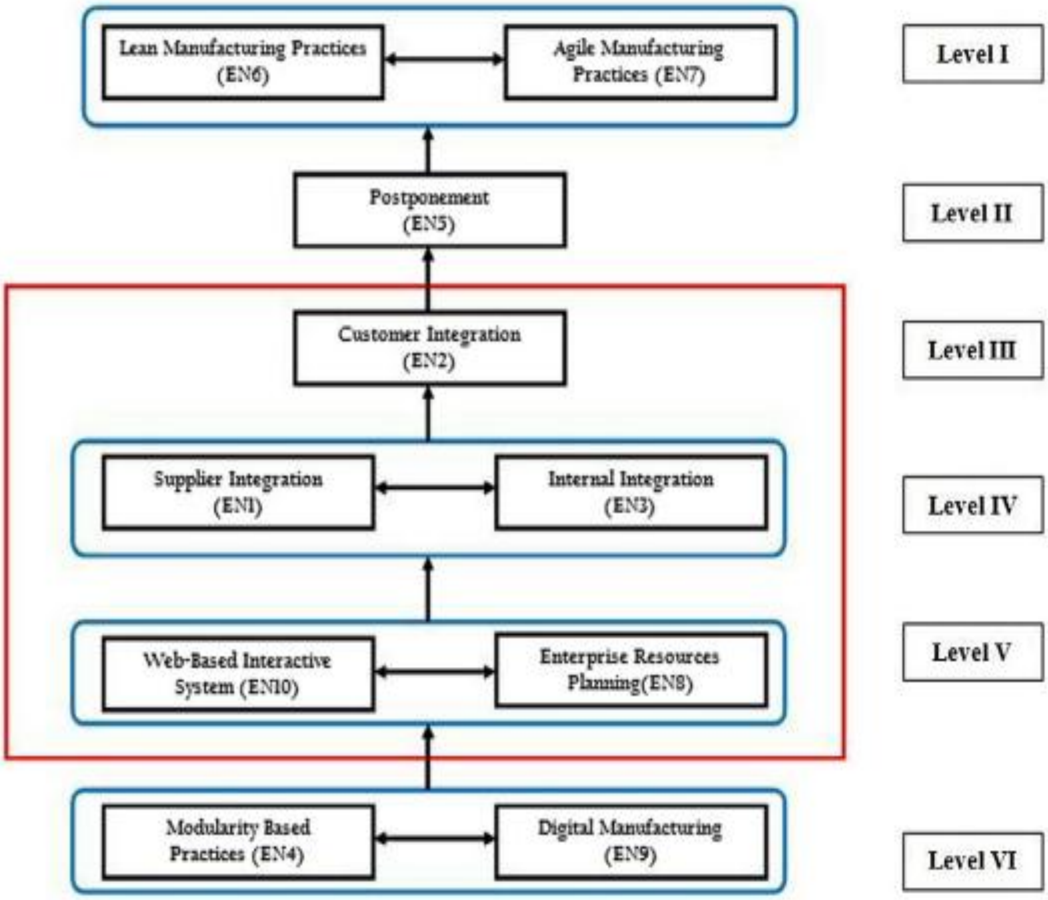

Figure 3.3: ISM-based model for mass customization enablers

As can be seen in Figure 3.3, MBP and DMP emerges out to be the lowest level (Level VI) enabler out of the ten enablers considered in the study indicating that these are the most important enabler and would drive all other enablers. ERP and WIS are placed at Level V. SPI, INI and CSI placed at Level IV/Level III of the structure.

Table 3.4: Results of Partitioning (Iterations I to VI)

Iterations	Enabler Code	Reachability set	Antecedent Set	Intersection Set	Level
I	EN1	1,2,3,4,5,6,7,10	1,3,4,6,8,9,10	1,3,4,6,10	
	EN2	2,3,5,6,7,8	1,2,3,4,7,8,9,10	2,3,7,8	
	EN3	1,2,3,5,6,7,8	1,3,4,8,9,10	1,3,8	
	EN4	1,2,3,4,5,6,7,8,9,10	1,4,9	1,4,9	
	EN5	5,6,7	1,2,3,4,5,7,8,9,10	5,7	
	EN6	1,6,7	1,2,3,4,5,6,7,8,9,10	1,6,7	I
	EN7	2,5,6,7,10	1,2,3,4,5,6,7,8,9,10	2,5,6,7,10	I
	EN8	1,2,3,4,5,6,7,8,10	2,3,4,8,9,10	2,3,8,10	
	EN9	1,2,3,4,5,6,7,8,9,10	4,9,10	4,9,10	
	EN10	1,2,3,5,6,7,8,9,10	1,4,7,8,9,10	1,7,8,9,10	
II	EN1	1,2,3,4,5,10	1,3,4,8,9,10	1,3,4,10	
	EN2	2,3,5,8	1,2,3,4,8,9,10	2,3,8	
	EN3	1,2,3,5,8	1,3,4,8,9,10	1,3,8	
	EN4	1,2,3,4,5,8,9,10	1,4,9	1,4,9	
	EN5	5	1,2,3,4,5,8,9,10	5	II
	EN8	1,2,3,4,5,8,10	2,3,4,8,9,10	2,3,8,10	
	EN9	1,2,3,4,5,8,9,10	4,9,10	4,9,10	
	EN10	1,2,3,5,8,9,10	1,4,8,9,10	1,8,9,10	
III	EN1	1,2,3,4,10	1,3,4,8,9,10	1,3,4,10	
	EN2	2,3,8	1,2,3,4,8,9,10	2,3,8	III
	EN3	1,2,3,8	1,3,4,8,9,10	1,3,8	
	EN4	1,2,3,4,8,9,10	1,4,9	1,4,9	
	EN8	1,2,3,4,8,10	2,3,4,8,9,10	2,3,8,10	
	EN9	1,2,3,4,8,9,10	4,9,10	4,9,10	
	EN10	1,2,3,8,9,10	1,4,8,9,10	1,8,9,10	
IV	EN1	1,3,4,10	1,3,4,8,9,10	1,3,4,10	IV
	EN3	1,3,8	1,3,4,8,9,10	1,3,8	IV
	EN4	1,3,4,8,9,10	1,4,9	1,4,9	
	EN8	1,3,4,8,10	3,4,8,9,10	3,8,10	
	EN9	1,3,4,8,9,10	4,9,10	4,9,10	
	EN10	1,3,8,9,10	1,4,8,9,10	1,8,9,10	
V	EN4	4,8,9,10	4,9	4,9	
	EN8	4,8,10	4,8,9,10	4,8,10	V
	EN9	4,8,9,10	4,9,10	4,9,10	
	EN10	8,9,10	4,8,9,10	8,9,10	V
VI	EN4	4,9	4,9	4,9	VI
	EN9	4,9	4,9	4,9	VI

Table 3.5: Results of Partitioning (Iterations altogether)

Enabler Code	Reachability set	Antecedent Set	Intersection Set	Iterations No. & Level
EN6	1,6,7	1,2,3,4,5,6,7,8,9,10	1,6,7	**I**
EN7	2,5,6,7,10	1,2,3,4,5,6,7,8,9,10	2,5,6,7,10	**I**
EN5	5	1,2,3,4,5,8,9,10	5	**II**
EN2	2,3,8	1,2,3,4,8,9,10	2,3,8	**III**
EN1	1,3,4,10	1,3,4,8,9,10	1,3,4,10	**IV**
EN3	1,3,8	1,3,4,8,9,10	1,3,8	**IV**
EN8	4,8,10	4,8,9,10	4,8,10	**V**
EN10	8,9,10	4,8,9,10	8,9,10	**V**
EN4	4,9	4,9	4,9	**VI**
EN9	4,9	4,9	4,9	**VI**

3.4.5 Cross-impact MICMAC analysis

The MICMAC theory is based on multiplication attributes of matrices (Sharma and Gupta 1995). MICMAC was formulated by Duperrin and Godet (1973) to study the dispersal of impacts through response paths and loops for developing hierarchies for members of an element set. MICMAC analysis can be used recognize and examine the elements in a complex system (Warfield 1974) with an objective of taking apart the driving power and the dependency power of the variables (Faisal et al. 2007).

In this research, MICMAC analysis is used to categorize MC enablers into four categories namely, autonomous enablers, dependent enablers, linkage enablers and driver or independent enablers based on their driving power and dependence power. The driving power and the dependence of each one of the enablers as derived in final RM (Table 3.3) are used to classify the enablers into above four categories. The resulting driver-dependence diagram is shown in Figure 3.4.Table 3.6 provides more details about clusters and its features.

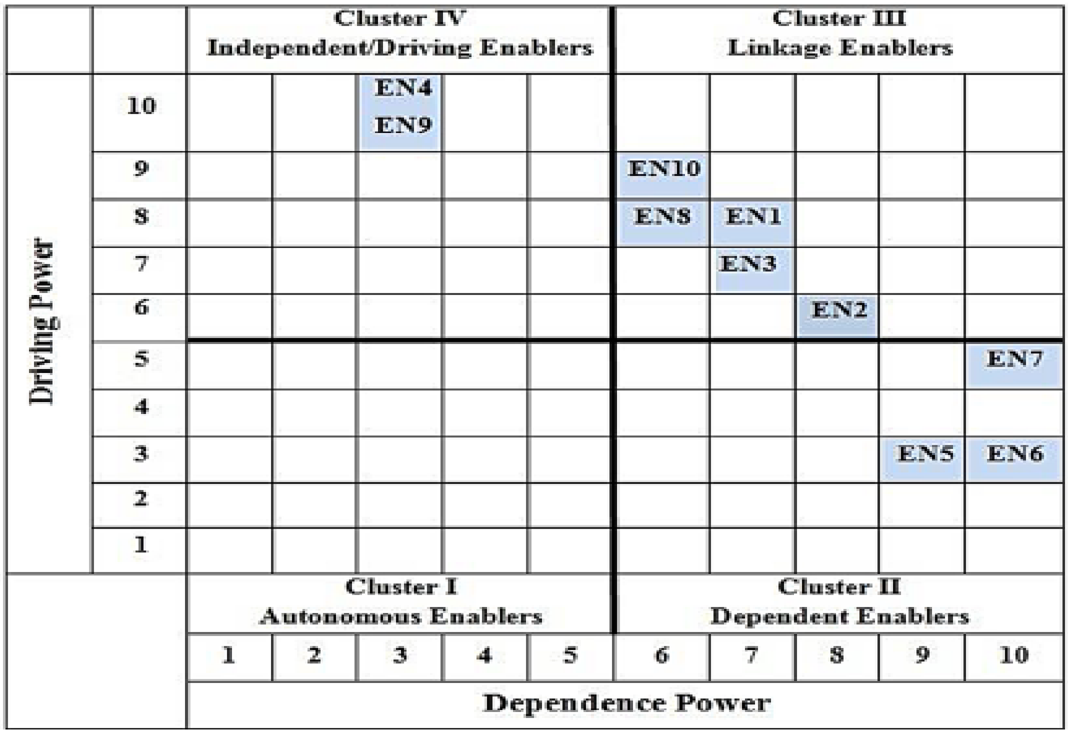

Figure 3.4: Driver-Dependence diagram for MICMAC analysis

Table 3.6: Clusters and its features

Cluster no.	**Clusters Name**	**Cluster's Features**	**Driving Power**	**Dependence Power**	**MC Enablers**
I	Autonomous Enablers	These enablers are comparativelydisjointed from the arrangement.	Weak	Weak	No Enabler Found
II	Dependent Enablers	These enablers are the automatic followers of other enablers.	Weak	Strong	AMP ;LMP;POS.
III	Linkage Enablers	These enablers are unsteady. Any activity on these will have aconsequence on another enablers and also a reaction on themselves.	**Strong (Key Enablers)**	Strong	SPI; INI ;CSI; ERP; WIS.
IV	Independent Enablers	These enablers are the key factors for achieving MC practices. Firms have to give utmost concern to these enablers to get instant results.	**Strong (Key Enablers)**	Weak	MBP; DMP.

3.4.6 Discussion of ISM outcomes

As can be seen in Figure 3.3 MBP and DMP are placed at the lowest level of ISM hierarchy meaning that these enablers are antecedent of other enablers' namely SPI, INI, CSI, ERP and WIS. Internet-based technologies like ERP and WIS help to achieve integration among different functional domains of the manufacturing organization as well as among the partners of supply chain. SPI, INI and CSI placed at the middle level of hierarchy help to achieve upper level enablers such as POS, LMP and AMP, respectively.

The observations from driver-dependence diagram in Figure 3.4 are as follows:

- MBP (EN4) and DMP (EN9) appears in the fourth cluster (driver variable cluster) having the lowest degree of dependence power and most prominent driving power. The high driving power of these enablers shows its capability to affect other enablers of MC thus these enablers should be in place for other enablers to ascertain an appreciable change. Modularity in product/process is a major concern for every organization trying to implement MC and the degree to which firms use WIS-like product configurators depends strongly on modular product architecture. DMP facilitates responsiveness, efficiency and accuracy in product design and manufacturing by allowing designer to manage design and drawing of product/components over the computer rather than real drawings over the paper. This enabler also helps to structure a product design into interchangeable modules and formulate standardized interfaces among these modules (Bourke et al. 1999). Information processing abilities of tools like CAD/CAE helps the designer to dig into broad range of design variable to satisfy customer's demand of vast product range where tools like CAM help the organizations to respond quickly to customer's demands. It shows that these two enablers strongly influence other enablers.
- The enablers viz. SPI (EN1), INI (EN3), CSI (EN2), ERP (EN8) and WIS (EN10) appears in the third cluster (Linkage variables cluster also highlighted in Figure 3.4) have high dependence power as well as high driving power thus they are of unsteady character and act as a link between other enablers and a feedback to themselves thus should be taken seriously.

- POS, LMP and AMP appear in the II cluster (dependent variable cluster) with high dependence power and moderate driving power showing stability than the linkage variables.
- No enabler has been observed in the first cluster (autonomous cluster), which means no enabler can be believed to be disengaged from the whole system meaning that the manufacturing organization has to concentrate on all the enablers of MC considered in the present study.

3.5 Combining & refining the idea:

The essence of this chapter is to identify and prioritize the enablers of MC with respect to their importance towards implementation of MC in the Indian Manufacturing industries. Salient contributions of this section are as follows:

- Ten enablers namely SPI, CSI, INI, MBP, POS, LMP, AMP, ERP, DMP and WIS have been identified from literature.
- Based on the inputs from experts from Indian Manufacturing industries a hierarchical model is developed using ISM-MICMAC analysis performed to categorize the enablers on the basis of their driving and dependence power.
- It is observed that all of the ten enablers considered in the study are important and thus the companies trying to achieve MC capabilities should concentrate on them.
- MBP and DMP emerge out to be the most important enablers of MC with highest independence. Thus, in order to be able to provide mass customized products to the customer modularity in product/process and application of digital manufacturing technology in product design and manufacturing should be in place.
- Huge amount of data collected from the enablers like ERP and WIS would improve integration in whole supply chain as these enablers enhance realization of other enablers such as INI SPI and CSI. In this chapter we have combined these five enablers as big data and information technology enabled supply chain integration. Supply chain integration cites to managerial procedures to connect suppliers, customers and internal functional areas so as to enhance the aggregate outcomes of all supply chain collaborators (Flynn et al. 2010; Lau et al. 2010).

In a volatile business scenario, practices such as enterprise resource planning and online interaction of partners in supply chains have turned out to be very vital for firms to efficaciously handle its flow of data, material and funds (Baihaqi et al. 2013; Prajogo et al. 2012). In this research, SCI is conceptualized as a three-dimensional variable including internal integration, customer integration and supplier integration. By exercising so, such work can allow worthy guidelines for operations managers to choose how to use their big data analytics resources to supervise a supply chain integrating all supply chain partners in real time.

To realize mass customization a producer requires a committed logistics arrangement for the raw material and/or parts supply to their manufacturing unit. This necessitates seamless co-operation with its suppliers and hence supplier integration is regarded as an important enabler for accomplishing mass customization.

Proper coordination with clients is a necessary element to plan, develop and distribute customer based products (Ninan et al. 2006). It helps the manufacturer in acquiring data on necessities of the consumers but to catch customer likings in real time as well.

Flynn et al. (2010) signifies that inner integration among the organization's functional units makes the foundation on which external integration shapes lacking which organizations are incapable to attain mass customization. Sanders (2014) suggest big data as an ingredient to connect the supply chain activities (e.g. Buy, Make, and Sell) to create remarkable prospects & capabilities to the organization to achieve competitive advantage. The phrase big data (BD) especially named to huge data sets whose quantity is so large then inner useable memory of computer currently employing (Manyika, et al., 2011) (Havens, et al. 2012). BD is defined as high volume, velocity, and variety data property that assert profitable, new classes of information for superior decision making (Dubey et al. 2015).

Finally from the above discussion we have finalized three enablers as resources for the organizations to implement mass customization i.e. Big data enabled supply chain integration (for simplicity using SCI as abbreviation), Modularity based practices (MBP) and digital manufacturing practices (DMP).

3.6 Modeling process

To achieve competitive advantages two views have been put forward in the literature- Resource Based View (RBV) and Dynamic Capability View (DCV).The RBV advocates that organizations attain the competitive advantage by obtaining assets and resources that diverse from those of competitors (Porter 2011; Skinner 1985 and Roth 1990). The DCV literature, however, debates that beyond the resources and assets; it is ultimately the unique capabilities produced by organizations shape sustained competitive advantage (Mata, 1990; Bharadwaj, 2000). While the foundation of DCV literature is rooted in RBV with its establishment on competitive advantage, the DCV theory has argued that resources per se may not render competitive advantage except it is used to do something. It suggests that organization acquire capabilities by which its idiosyncratic resources can be directed to fit with varying market environment (Eisenhardt, 2000). This study follows both the approaches for developing the conceptual research model to play up the significance of resources and capabilities to achieve competitive advantage (Wernerfelt,1984; Teece,1997).

The conceptual research model presented in Figure 3.5 includes three parts: first part suggests that firm's operational and knowledge management capabilities are influenced by the firm's resources like MC enablers i.e. big data and information technology enabled supply chain integration, Modularity based practices and digital manufacturing practices. These enablers facilitate building a production system that is receptive to varied customer requirements. Operational Capability has a direct effect on competitive advantage of adoption of mass customization. Empirical studies (Kotha 1996) indicate that custom-made products provide competitive advantages than identical products produced on mass level. The six constructs used in the model are Big data enabled supply chain integration (for simplicity using SCI as abbreviation), Modularity based practices (MBP), digital manufacturing practices (DMP), firms operational capabilities (OPC), knowledge management capabilities (KMC) and competitive advantage (COA) as described in Table 3.7 .

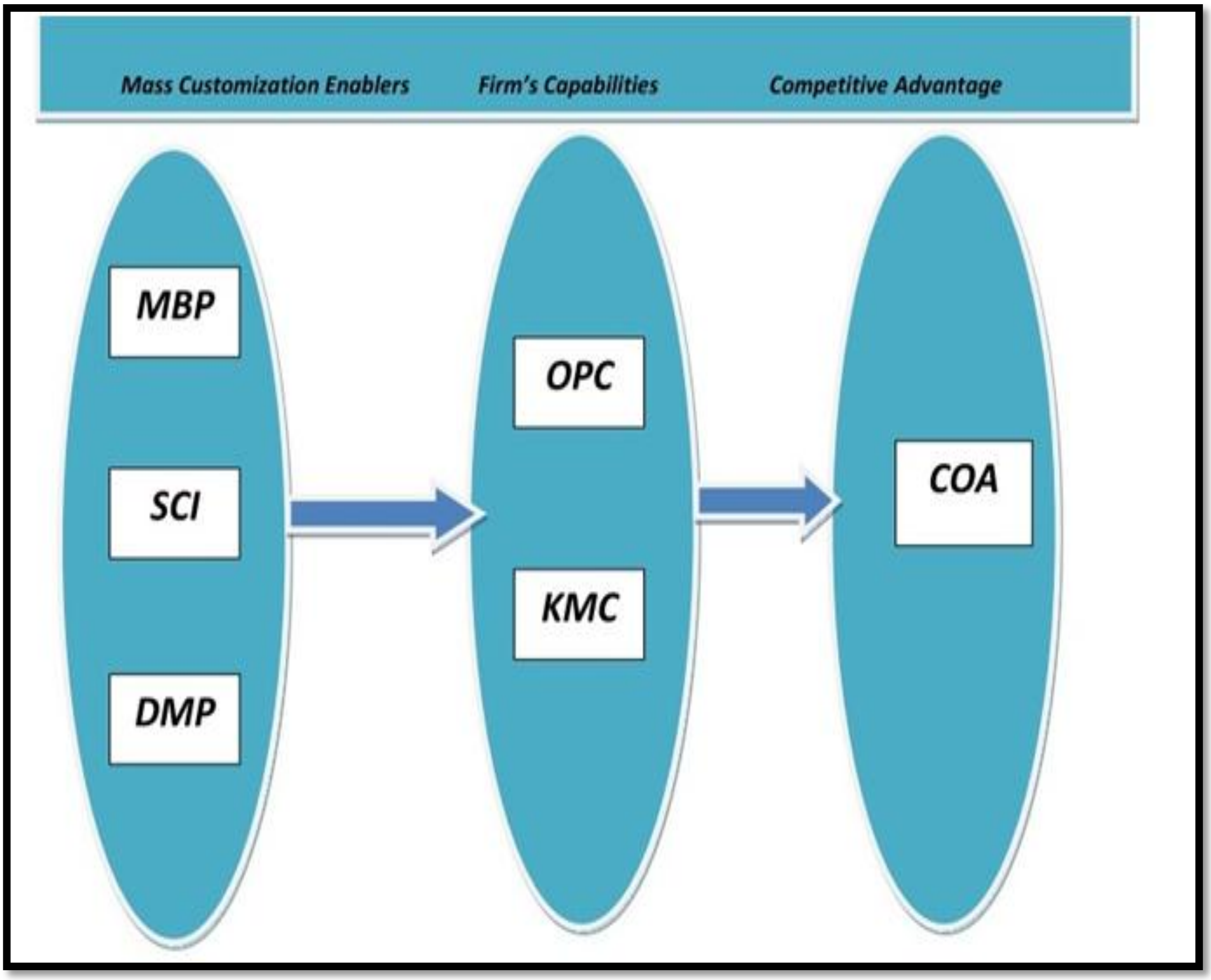

Figure 3.5: Proposed Research Framework

MBP: Modularity based practices

SCI: Big data enabled supply chain integration (for simplicity using SCI as abbreviation)

DMP: Digital manufacturing practices

OPC: Operational capabilities

KMC: Knowledge management practices

COA: Competitive advantage

Table 3.7 Description of constructs used

SN.	Variable	Operational Definition	Literature sources
1	Big data enabled supply chain integration (SCI)	Supply chain integration can be accomplished with collecting and examining big amount of data in concurrent manner for different supply chain process. big data may be consider as an ingredient to connect the supply chain activities (e.g. Buy, Make, and Sell) to achieve remarkable competitive advantage.	Sanders 2014; Mishra et al.2016; Chae et al.2014; Huang et al. 2007
2	Modularity Based Practices (MBP)	An dimension of the product system that describes the capability to mix and match autonomous and exchangeable product with standardized interfaces to create product variants	Blecker et al. (2005) ;
3	Digital Manufacturing Practices (DMP)	To react promptly for varied customer needs, application of computer hardware and software tools considered as enabling technologies for achieving flexibility in design and manufacturing.	Joergensen et al. (2010);
4	Operational Capabilities (OPC)	Operational capabilities refer to the firms aptitude to offer customized products with specific features demanded by customers with low price resulting into large number of customers compared to contenders.	Olavarrieta et al. (1997); Krishnan et al. (2002); Rosenzweig et al. (2004); Tan et al. (2007)
5	Knowledge Management Capabilities (KMC)	An organization’s Knowledge management capability is characterized as power to actuate and establish knowledge based resources combining with other capabilities, heading to competitive advantage.	Chuang (2004); Walters (2002); James (2005) ; Gold et al. (2001)
6	Competitive Advantage (COA)	Competitive advantage is the scale to which a firm can be counted superior than its rivals. It is an assessment of strength relative to firms’ contenders in attaining aims of financial gain and	Porter (1985); Barney (2001); Hoffman (2000); Priem et al. (2001); Li et al. (2006); Ma (2000)

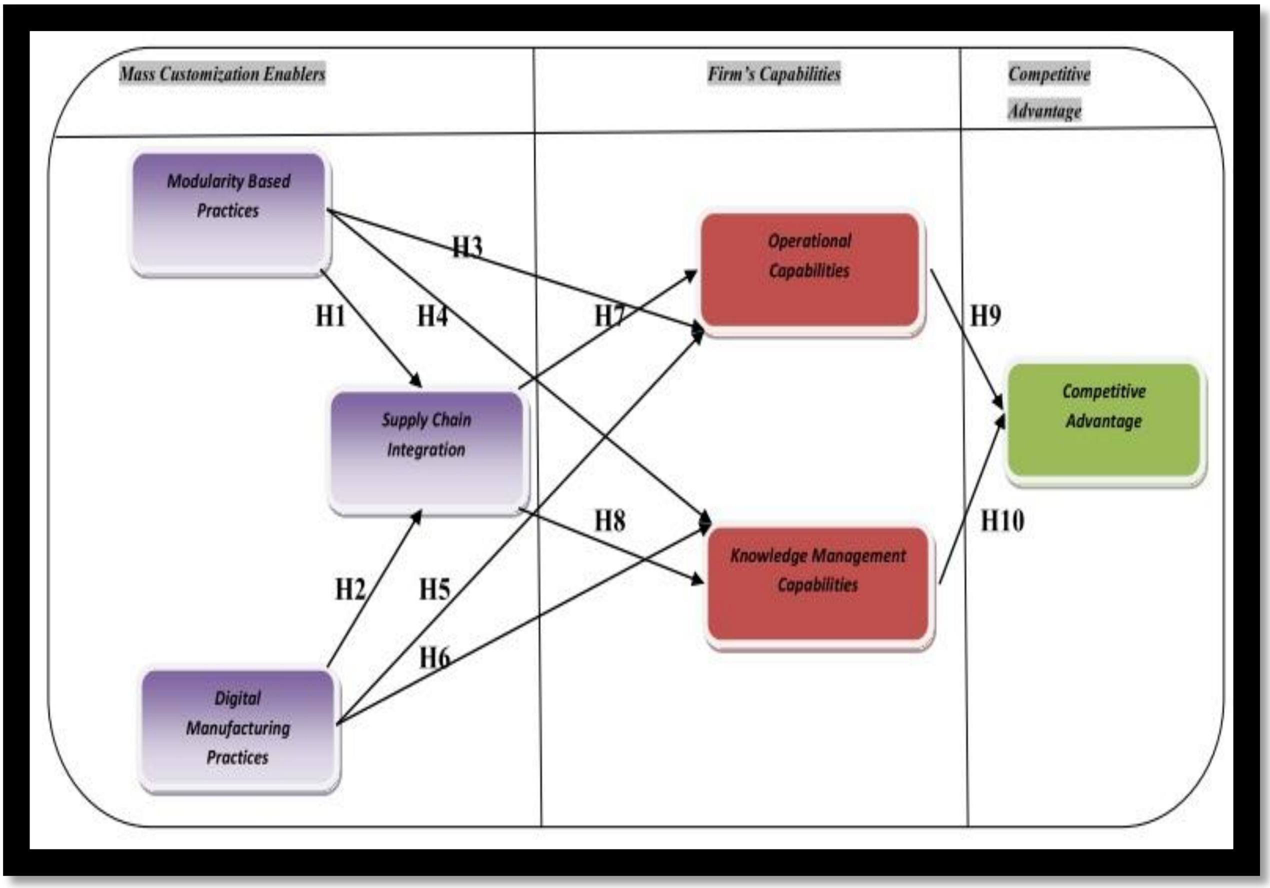

Figure 3.6 Proposed hypotheses framework

3.7 Research hypotheses development

In order to address the research model following hypotheses are specially examined in this research. Figure 3.6 shows the relationship and direction of various research hypotheses. Each of the hypotheses is described next.

In previous sections of ISM methodology we have found that modularity based practices and digital manufacturing practices emerge out to be the most important enablers of MC with highest independence and drive the other combination of enablers represented as big data and information technology driven supply chain integration. As modularity becomes an important concept on mass customization supply chain the supplier-manufacturer relationships became more collaborative (Lin et al. 2009). Due to this reason part of the research focuses on supply chain integration and how modularity affects these relationships (Howard and Squire 2007; Lin et al. 2009; Lau et al. 2010) Droge et al. (2012) also suggested that product modularity and process modularity are both related to supplier integration and customer integration, suggesting that they engender integration across a supply chain. Modular product architectures facilitate increased communication and interaction with customers (Sanchez and Mahoney, 1996). It promotes a customer focus, which is indicative of a partnership mentality (Koufteros et al., 2005). Lau et al. (2011) showed that product modularity is related to supply chain integration in both large and small manufacturers. Therefore, we propose the following hypothesis:

H01: Modularity based practices are positively associated with supply chain integration.

Manufacturing organizations now integrate isolated datasets generated from digital manufacturing techniques like CAD, CAM, CAPP, and FMS for efficient production. This type of data integration would ultimately reduce development time, improved quality and optimize resource utilizations for all supply chain partners. The application of RFID assures to aid with the mechanization of mass customized manufacturing processes by the retrieval and tracking of specific components (Brusey and McFarlane 2009). Wamba (2012) empirically support the enabling role of RFID technology in allowing supply chain integration. RFID systems may translate into better quality control and enhanced data security. They can increase supply chain integration by providing improved stock management and throughput (Asif, 2005).Advances in 3D technologies such as CAD facilitate the closeness of both the customer and manufacturer. The exploitation of CAD/CAM systems together with the development of body scanners has brought the offer of mass customization in clothing industry. Therefore, we propose the following hypothesis:

H02: Digital manufacturing practices are positively associated with supply chain integration.

Modularity is a premeditated product design alternative to improve the product array without disturbing manufacturing cost in proportion (Salvador et al. 2002).Remaking a product based on a conventional architecture grants a firm to reconfigure the parts into custom-made products (Schilling, 2000). Therefore, modular product architecture cuts the total costs and develop the economy of scale when modules are reprocessed (Lau Antonio et al., 2010).Modularization can undertake the tradeoffs between production costs, manufacturing lead-time and customization (Tu et al., 2001). Sanchez et al. (1996) suggest that standardizing interfaces in modular product architectures of many types maybe a new dominant way for achieving increased flexibility in manufacturing. Product development time can be reduced by modularity in production system (Nepal et al., 2005). Greater degree of modularity has an encouraging affect on capacity usage, operational efficiency and as profitability (Cheng 2011). Therefore, we propose the following hypothesis:

H03: Modularity based practices are positively associated with Operational capabilities

Firms that create new products through modular product development are likely to place increasing emphasis on knowledge sharing at the architectural level. Nguyen (2010) said that modular products enable knowledge management activities in an organization. Modular architectures to source more components through loosely coupled networks of component suppliers growing strategic use of modularity as a framework for more effective strategic learning and knowledge management may result in increasingly dynamic product markets. Therefore, we propose the following hypothesis:

H04: Modularity based practices are positively associated with Knowledge management capabilities

Kotha (1995) pointed out that proper utilization of CAD/CAM system enhanced responsiveness against customer order in National bicycle industrial company. Tu et al.

(2001) suggested that digital manufacturing practices like CIM and CNC machines make it possible for the firms to switch between production lines with minimum cost penalties so they can increase product variety while maintaining high volume of production. Qiao et al. (2006) proposes Flexible Manufacturing System as an enabling technology for mass-customization manufacturing systems enhances flexibility in volume as well as in variety. Digital manufacturing technologies which includes tools like design for manufacturability (DFM/A) helps to improve operational capabilities of manufacturer for product development in mass customization environment. On the basis of above discussion we propose the following hypothesis:

H05: Digital manufacturing practices are positively associated with firm's Operational Capabilities

The study Tuck and Hague (2006) focuses on the concept of rapid manufacturing and mass customization. According to the study, rapid manufacturing can aid mass customization mainly in two ways. The first one is aesthetically and the second level is by capturing the body shape of the customer to create a better fit. El Ghazali et al. (2012) suggest that RFID enhances the management, sharing, and transfer of knowledge. On the basis of above discussion we propose the following hypothesis:

H06: Digital manufacturing practices are positively associated with firm's Knowledge Management Capabilities

Boyer et al. (2002) establish the tradeoffs between that quality, delivery, cost and flexibility. However, grounded on the experience of Japanese industries, a business firms can concurrently realize several operational capabilities by early involvement of customer and supplier in product development (Rosenzweig, 2003). Lau et al. (2010) states that integration with suppliers reduces uncertainties and hence it can promote integrated inventory systems for more responsive manufacturing. The advancement of big data and analytics provides a novel view of customer integration. Companies however needs to synchronize their operations to the marketing to ensure production of customized products; where sourcing needs to ensure supplies in timely and cost effective manner. (Kauffman et al. 2012). There are number of organizations using big data enabled supply chain integration for product development, inventory management, stock level optimization and quality control. Data provided from enterprise resource planning module help the companies to analyze operational performances on a daily basis by a specific location. Data integrates the operational part of the company by enabling higher efficiency in product design & development. It helps to reduce product development time considerably and eliminates defect through simulation & testing even prior to the production of specimen. On the basis of above discussion we propose the following hypothesis:

H07: Supply chain integration is positively associated with operational capabilities

Firms want to concentrate on the knowledge acquired through supply chain integration to raise association with customers and other supply chain partners for product development. Properly planned investments in big data and analytics techniques can enhance the knowledge management capabilities within the supply chain by assisting managers to effectively manage the knowledge resources and transform those resources into firm's knowledge management capabilities. Knowledge management (KM) is a critical practice assists in mass customization implementation. In mass customization environment customers and suppliers collaborating on products design via a web based interactive system (Purohit et al. 2016). Effectual co-design demands companies to process deep knowledge on preferences of customer and feasibility of product manufacturing (Helms et al. 2008). Integration of major supply chain partners via big data analytics often provides huge amount of information which stimulates knowledge management guiding to the innovative mass customized products. The experience collected via supply chain integration points both in-house and outside activities have to be sleek and unlined. KM stresses the significance of integration with key manufacturing and marketing practices, like product design and quality improvement along with customer preference tracking for achieving mass customization. Therefore, we propose the following hypothesis:

H08: Supply chain integration is positively associated with knowledge management capabilities

Porter (1985) opines that firm's dominations on either cost effectiveness or distinction plays a significant role in ascertaining the competitive advantage. Ma (2000) makes use of opposite illustrations to show that neither cost advantage nor differentiation is enough and essential for better performance. Instead, better performance could also be achieved from other types of competitive advantage such as speed & flexibility. Operational capabilities symbolize the organization's skill to operate on attributes of quality, delivery, flexibility and cost comparative to its direct rivals in the target markets (Rosenzweig et al. 2004). It is typically evaluated along the dimensions of cost, quality, flexibility and delivery (Devaraj et al., 2004).Enhanced operations capability has shown to improve effectiveness in the delivery procedure, reduced costs of operations and attain competitive advantage (Tan et al., 2007).In this study, Operational capabilities refer to the firms aptitude to offer customized products with specific features demanded by customers with low price resulting into large number of customers compared to contenders. Helfat et al. (2011) argue that a organization's competitive advantage is established on operational capabilities i.e. few sets of resources bundled into valuable, rare and difficult to imitate capabilities (Barney et al., 2007). Hence, on the basis of above discussions, we develop the following hypotheses.

H09: Operational Capabilities are positively associated with firm's Competitive advantage.

Knowledge management (KM) can be considered a trade practice where precious information is recognized, accumulated, aligned, stored, administered, and finally utilized to attain the firm's objectives. According to Walters (2002), KM may be viewed as a aggregations of processes of gaining as well as employing knowledge to realize outcomes such as competitive advantage. An organization's Knowledge management capability is characterized as power to actuate and establish knowledge based resources combining with other capabilities, heading to competitive advantage (Chuang 2004).Gold et al. (2001) argue that firms can be distinguish from the rivals with the help of precious resources to built distinctive knowledge management capabilities which are difficult to obtain and hard to replicate, thus, attaining competitive advantage. From the above discussion it can be assumed that KMC is a dynamic capability which concentrates not simply on the utilization of knowledge capitals but also to create a flow of the firm's knowledge stored in its repository, backing the formation, renovation and utilization of organizational capabilities. On the basis of above discussion we propose the following hypothesis:

H10: Knowledge Management Capabilities are positively associated with firm's Competitive advantage

Table 3.8 shows summary of hypotheses with description and literature support**.**

Table 3.8: Summarized Hypotheses

SN	Hypothesis Number	Hypothesis Description	Literature Support
1	H01	*Modularity based practices are positively associated with supply chain integration.*	Lin et al. 2009;Howard and Squire 2007; Lau et al. 2010;Sanchez et al.1996;Koufteros et al., 2005
2	H02	*Digital manufacturing practices are positively associated with supply chain integration.*	Brusey et al. 2009;Wamba 2012;Asif, 2005;Apeagyei et al. 2007
3	H03	*Modularity based practices are positively associated with Operational capabilities*	Salvador et al. 2002; Schilling, 2000; Tu et al., 2004; Nepal et al., 2005;Lau et al., 2007; Cheng 2011
4	H04	*Modularity based practices are positively associated with Knowledge management capabilities*	Sanchez et al. 1996; Nguyen 2010
5	H05	*Digital manufacturing practices are positively associated with firm's Operational Capabilities*	Kotha 1995;Tu et al. 2004;Qiao et al. 2006;Peng et al. 2011
6	H06	*Digital manufacturing practices are positively associated with firm's Knowledge Management Capabilities*	Tuck et al.2006; Ghazali et al.2012
7	H07	*Supply chain integration is positively associated with operational capabilities*	Boyer et al. 2002; Rosenzweig, 2003; Lau et al. 2010; Kauffman et al. 2012
8	H08	*Supply chain integration is positively associated with knowledge management capabilities*	Helms et al. 2008; Purohit et al. 2016
9	H09	*Operational Capabilities are positively associated with firm's Competitive advantage.*	Porter 1985;Ma 2000; Rosenzweig et al. 2004; Devaraj et al. 2004; Helfat et al.2011;Tan et al. 2007;Barney et al. 2007
10	H10	*Knowledge Management Capabilities are positively associated with firm's Competitive advantage*	Walters 2002;Chuang 2004; Gold et al.2001

Chapter-4

Research Design

Chapter-4

Research Design

4.1 Introduction

Chapter 3 keyed out a gap in the present literature about the relationships among mass customization enablers, organizational capabilities and competitive advantage of the firm achieved through adoption of mass customization. A theoretical framework was also proposed. The framework is made up of six first-order latent factors namely big data enabled supply chain integration, modularity based practices, digital manufacturing practices, firms operational and knowledge management capabilities and competitive advantage. Ten hypotheses were suggested to serve research questions and accomplish an empirical study of Indian manufacturing organizations.

This chapter concentrates on the particulars of research design followed to take on the objectives of the research. The research is instituted on survey of Indian firms to evaluate the degree of adoption of MC enablers and their effect on organizational capabilities and eventually competitive advantage. The research design process has two phases:

- First, the conceptual model has been developed to investigate the relationship among MC enablers, firm's capabilities and competitive advantage, which is validated through quantitative analysis. (i.e. Structural Equation Modeling)
- Second, Comparative analysis of adoption of MC enablers by select Indian firms through case studies.

The research design dealing with the research questions authentically, precisely and with objectivity enhances the capabilities of research programs to reveal empirical verifications to investigate the research issue (Sekaran, 2003). Primary data are collected through questionnaire survey in the Indian manufacturing industries. Research problem was selected based on gaps identified in literature and through field visits. Information of relevant manufacturing organization was captured from industrial database and a questionnaire was devised.

The questionnaire was distributed in more than 1000 manufacturing companies from six major sectors like: automobile, footwear, apparel, modular kitchen, furniture and jewelry.

4.2 Survey based methodology

In first step, practical perspectives on MC enablers were acquired by an ordered framework. The model establishes a conceptual condition on identifying & selection of MC enablers through a literature and expert opinion.

With the help of an empirical work established on survey in Indian manufacturing firms, the hypotheses and relations among variables like MC enablers, firm's critical capabilities and their competitive advantage on adoption of mass customization are examined using structural equation modeling (SEM). The literature available in the field of the MC brought out that very inadequate attempts have been made concentrating on the implementation of MC practices in Indian industries. No existing studies were found that directly/indirectly address as the MC enabling factors, firms' capabilities and competitive advantage. To fill these gap MC enablers were identified through literature survey and then semi-structured interviews were conducted with ten managers of Indian industry and academicians.

The unrestricted questions were raised associated to their awareness on conception of mass customization, market requirement of mass customized goods, challenges, complexities, benefits and enabling factors, existing capabilities of Indian manufacturing firms to implement mass customization and competitiveness. Grounded on the results of literature review and introductory discussions, the questionnaire was devised to probe the research objectives. This analysis helped in identifying the interaction of MC enablers, firm's critical organizational capabilities and their impacts on the firm's competitive advantage. Employing Resource based view of the firm combined with operational and knowledge management capability based approaches, the research builds up a set of theories to examine a model empirically in the Indian perspective . Hence, descriptive research was undertaken in this study.

Descriptive research is "devised to identify the features of a population" (Zikmund 2003), demonstrating "a image of the precise information of a state of affairs or relationship" (Neuman 2006). It is less confusing and expects more integrated plan than exploratory research. According to Davis (2004) survey questionnaire based technique is usually employed for descriptive research.

Neuman (2006) asserts that constructs and associations between them are the fundamental thoughts in quantitative study. Quantitative investigators mainly pursue a deductive path proceeding from conceptual thoughts or constructs to particular data collection methods (measurement process) and to accurate statistical information.

4.3 Preliminary study

The objective of this introductory part of research is to raise the know-how regarding implementation of MC practices and to measure the association amongst them, and to make sure an acceptable vocabulary and functioning of the survey questionnaire. Eight trips of relevant industry were carried out. These visits were broad and constituted of formal interviews with managers for a better understanding of MC enabling factors. As the field of study is fairly new particularly for Indian manufacturing organizations, it turns out to be necessity to attain preliminary data for the farther evolution of assessing tools. Lastly, the questionnaire items were modified as per the outcomes of industrial visits and interviews.

4.4 Questionnaire Design

The main goal of the large scale survey was to gather data appropriate for empirical evaluation of the theoretical framework presented in Chapter 3. Questionnaire surveys have been frequently applied in modern research areas of supply chain management and mass customization (Sarkis, 2003; Tu et al.2001) but for mass customization adoption research especially in Indian context the area is not yet explored. Thus, based on the result from preliminary research and literature review a questionnaire survey technique with ordered and closed questions was designed. Several matters related to MC enablers, firm’s capabilities and competitive advantage have been incorporated relevant to Indian context.

Questionnaire divided in to two parts i.e. Part A and Part B. Part A (11 questions in total) designed to gather background and demographic information about the respondents. Part B contains 34 questions (Numbers reduced from 48 questions) within six parts.

- Part B.1, (SCI01 to SCI07) designed to gather information about big data and information technology enabled supply chain integration enablers.
- Part B.2, (MBP01 to MPB04) designed to gather information about modularity based practices.
- Part B.3, (DMP01 to DMP07) designed to gather information about digital manufacturing practices.
- Part B.4, (OPC01 to OPC07) designed to examine information about firm's operational capabilities.
- Part B.5, (KMC01 to KMC04) designed to examine information about firm's knowledge management capabilities.
- Part B.6, (COA01 to COA05) designed to measure respondent's view about competitive advantages on the adoption of mass customization strategy.

Constructs in this research are evaluated using interval scales in which, answers measure the conceptions by grading them on a seven point Likert scale. Responders were inquired to respond from strongly disagree to strongly agree on a seven-point Likert rating scale, ranging from 1 = strongly disagree and 7 = strongly agree in section B.

4.5 Pilot Survey

After being devised, the draft questionnaire should be pre-tested. The major intention of performing a pilot survey is to find and cure any potential mistakes in questionnaire blue print former to distributing the large scale survey (Cavana et al. 2001; Diamantopolos et al. 2001; Malhotra 2004; Polit, 2005) and by and large, to purify and modify the questions in addition to make it more easy to use. Nevertheless, the pre-test can also be employed to approximate response rates for the questionnaire and decide the sample size of the large scale survey (Green et al. 1988).

As the scale has not been adapted from any already existing literature, the draft questionnaire was pretested. A pilot survey was carried out with a sample size of 40 to make clear the complete structure of questionnaire and investigative some details like: series of the questions, quantity of the questions, and words of questions and awareness with responders. The responders furnished remarks on simplicity of a few items and affirmed face validity of questions. In combination with this qualitative judgment, quantitative evaluation was also done for farther cleansing of survey items at this degree. For this, the approved item-to-total correlation was calculated. Item-to-total correlation equal to or greater than 0.6 is considered.

There is difference between validity and reliability. The main task of reliability analysis is to checking the consistency of the result on repeated measurement. According to Hair et al. 2006, the measurement of reliability is done with the help of alpha coefficient; also known as Cronbach's alpha. Reliability of measure considered acceptable over the values of 0.7.

4.6 Sample Design

The sample design process mostly requires following steps:

(1) Selecting the set of the particular population applicable to the study.

(2) Identification of list of population constituents from which the sample may be drawn.

(3) Choosing the procedure of sampling

(4) Ascertaining the size of sample

According to Joreskog et al. (1996) and Raykov et al. (1995) in order to attain best outcomes from structural equation modeling, the large size of the sample is a prerequisite. Hair et al. 2006 advocated that number of survey respondents must be five times to the questionnaire items, to apply SEM for the analysis.

4.7 Questionnaire Administration

In recent times to conduct survey over the web few web sites are very popular i.e. Survey Monkey and Google survey. In this study email survey method was adopted to communicate questionnaire to the potential respondents. Moreover, to accomplish prominent responses from the respondents, follow-up reminders were sent after pre-decided time frame.

4.8 Data Analysis Techniques

Detailed data analysis schemes were employed just after the completion of the survey data collection. Investigation must be held to examine the data accuracy and missing values in forms. Application of SPSS helps to analyze some basic statistical information like demography of participating organizations and respondents. Latest available software version SPSS 20.0 was employed to investigation of distribution of variables. At the end of the analysis SEM software AMOS version 22.0 was employed to test the theoretical model

4.8.1 Goodness-of-Fit Assessment

Goodness-of-fit (hereafter referred to GOF) indicates 'how well the specified model reproduces the covariance matrix among the indicator items' (Hair et al. 2006,). Chi-square (χ 2) is the fundamental measure of fit used in SEM to quantify the differences between the observed and estimated covariance matrices. In addition, there are a number of alternative GOF measures, including (1) absolute fit indices, (2) incremental fit indices, and (3) parsimonious fit indices (Hair et al. 2006).

4.8.1.1 Absolute Fit Measures

Absolute fit indices are a direct measure of how well the model specified by the researcher reproduces the observed data (Kenny et al. 2003). The indices and their characteristics are summarized in Table 4.1.

Table 4.1 Summary of Absolute fit indices and their characteristics

Name	Symbol	Acceptable level	Comments
Chi-square statistic	χ^2	p>0.05 (insignificant) p<0.05 (N>250, m>12)	Sensitive to sample size and model complexity. Likely to be greater when sample size or the number of observed variables increases even if the difference between the observed and estimated covariance matrices are identical.
Goodness of fit index	GFI	> 0.90 (N>250, m>30) >0.95 (N>250, m<12)	Less sensitive to sample size. Range of values is 0 (poor fit) to 1 (perfect fit). Higher values indicate better fit. No absolute threshold level for acceptability.
Root mean square residual	RMSR	Set by researcher, difficult to compare	An average of the residuals between individual observed and estimated covariance and variance terms. Lower values represent better fit (badness-of-fit measures)
Standardised root mean residual	SRMR	<0.08 (m>12) Biased (m<12)	A standardised value of root mean square residual (RMSR). No statistical threshold level for acceptability.
Root mean square error of approximation	RMSEA	Between 0.03 and 0.08	Used to correct the impact of sample size or model complexity on χ^2. Lower values indicate better fit (badness-of-fit measures).Values over 0.10 indicate poor fit.
Normed Chi-square	Normed χ^2	3:1 or less	A simple ratio of χ^2 to the degrees of freedom for a model.
Expected cross validation index	ECVI	Not applicable	An approximation of the GOF the estimated model would achieve in another sample of the same size. More useful in comparing the performance of one model to another.
Actual cross-validation index	CVI	Not applicable	Using the computed covariance matrix derived from a model in one sample to predict the observed covariance matrix taken from a validation sample.
Gamma Hat		Between 0.9 and 1.0.	Used to correct the impact of sample size or model complexity on χ^2.

4.8.1.2 Incremental Fit Measures

According to Hair et al. (2006) comparative fit measures (incremental fit) evaluate the fineness of particular model fits compared to some baseline model substitute.

A summary of these fit indices and their characteristics are displayed in Table 4.2 below

Table 4.2 Summary of Incremental fit indices and their characteristics

Name	Symbol	Acceptable level	Comments
Normed fit index	NFI	>0.90 (N>250, m>30) >0.95 (N>250, m<12)	A ratio of the difference in the χ^2 value for the fitted model and a null model divided by the χ^2 value for the null model. Range of values is 0 (poor fit) to 1 (perfect fit).
Comparative fit index	CFI	>0.90 (N>250, m>30) >0.95 (N>250, m<12)	An improved version of NFI. Relatively insensitive to model complexity. Values range between 0 (poor fit) and 1 (perfect fit). Higher values indicate better fit.
Tucker Lewis index	TLI	>0.90 (N>250, m>30) >0.95 (N>250, m<12)	Values can fall below 0 and above 1. Higher values suggest a better fit. Conceptually similar with CFI and so provide very similar values.
Relative non-centrality index	RNI	>0.90 (N>250, m>30) >0.95 (N>250, m<12)	Values range between 0 (poor fit) and 1 (perfect fit). Higher values represent better fit.

4.8.1.3 Parsimony Fit Measures

Parsimony fit measures employed exclusively, to furnish knowledge about the best model among a set of contending models, believing its fit compared to its complexity

(Hair et al. 2006). Table 4.3 below draws the acceptable level of fit of the model with indices.

Table 4.3.Summary of Parsimony fit indices and their characteristics

Name	Symbol	Acceptable level	Comments
Parsimonious goodness of fit index	PGFI	Not applicable	Adjusts GFI by using the parsimony ratio. Values range between 0 and 1. Used in comparing one model to another.
Parsimonious normed fit index	PNFI	Not applicable	Adjusts NFI by multiplying it times the parsimony ratio. Higher values represent better fit. Used in comparing one model to another.

4.8.2 Unidimensionality and Construct Validity

To attain the concept of unidimensionality of measures, a combination of measurable variables i.e. survey questionnaire items must only be related to one latent variable only (Hair et al. 2006).

Hair et al. (2006) defined construct validity is 'the degree to which a group of questionnaire items truly represents the conceptual latent construct .It has three main significant factors: convergent validity, discriminant validity, and content validity.

Convergent validity is "the magnitude to which items of a particular factor converge a high ratio of variance in common" (Hair et al. 2006). Confirmatory factor analysis provides a scope of information employed in assessing the proportional quantity of convergent validity among indicators like factor loadings and variance extracted.

According to Hair et al. (2006) discriminant validity is 'the degree to which a factor is actually different from other factors. It also means that individual measured items should represent only one latent construct and thus, the existence of significant cross-loadings show a lack of discriminant validity. Confirmatory factor analysis provides two common ways of assessing discriminant validity.

The content validity refers to the meaning of every indicator which must be established prior to any theoretical testing using CFA (Hair et al. 2006).

To restate, the procedure used to assess trait validity is as follows:

- Compute the Cronbach's alpha.
- Run a confirmatory factor analysis (CFA). Evaluate individual items through modification indices and item loading. Evaluate the overall model with fit indices
- Using the result from the CFA, evaluate discriminant and convergence validity

4.8.3 Structural Model Testing

Testing of the validity of path model as well as its consequent hypothesized relations are prime task after completing measurement model testing (Gerbing et al.1988; Hair et al. 2006). In the beginning, the general fit of the path model is evaluated employing the identical standards as applied in the measurement model. Following, the parameter figures that symbolize each explicit hypothesis are tested. If the model demonstrates well fit and if the hypothesized paths are significant and in the direction hypothesized, then the structural model is supported.

Chapter-5

Descriptive Analysis

Chapter-5

Descriptive Analysis

5.1 Introduction

Previous chapter has outlined the methodology and design of the research. In this chapter, data analysis is taken as a main affair. The investigation of the data gathered from the large scale survey comprises of a descriptive statistical analysis, management of missing records, data normality examination, investigation about the outliers, reliability and validity of the variables.

The descriptive analysis is carried out to investigate the broad notices about the data gathered concerning the enablers of mass customization and capabilities of Indian manufacturing industry.

In addition to this analysis next chapter will continue with related analysis utilizing structural equation modeling (SEM) to study the research hypotheses.

5.2 Data coding and screening

Codification of the data and its entry in appropriate software database is a prerequisite of any inferential statistical computation. The systematic method of data codification incorporates few steps like the appropriate numbering of constructs, their stages and values (Coakes et al., 2007).

The data codification of measurement items are accomplished principally for items of section B of the survey questionnaire. This section has six sub-sections including thirty four questions. The coding of every item is required for descriptive analysis.

Table 5.1 describes the main factor, constructs, item details and their codes. After codification, screening of data is commenced looking at the common assumptions which are generally entailed in a variety of statistical analyses.

Table 5.1: Coding of measurement Scale and Their Description

Main Factor	Constructs	Item Details	Item Code
Mass Customization Enablers	Supply Chain Integration	**With the aid of Big data and information technology**	
		We remain in touch with our customers to know about their exact requirement.	SCI01
		Our customers can participate during product design stage.	SCI02
		Our organization can configure the product exactly as per customer needs.	SCI03
		Our top management emphasizes the importance of good inter-functional relationship.	SCI04
		The top managers of our organization are able to get information about all functional dept.	SCI05
		We interact with our suppliers to customize components for final product .	SCI06
		Our organization deploys information technology to integrate with our suppliers in new product development.	SCI07
	Modularity Based Practices	Our products are designed as detachable module	MBP01
		Our product components are standardized	MBP02
		Our manufacturing system is designed as adjustable module for changing production needs in terms of volume	MBP03
		Our manufacturing system is designed as adjustable module for changing production needs in terms of variety	MBP04
	Digital manufacturing Practices	Our firm employs numerically controlled machines	DMP01
		Our organization have flexible manufacturing system	DMP02
		Our organization deploy computer aided technology that plan and controls shop floor material requirement	DMP03
		Our organization use computer aided technology that provides rapid prototyping in product design process	DMP04
		Our firm employs automated inspection and testing equipment	DMP05
		Our firm has automated storage and retrieval system	DMP06
		Our organization have automated guided vehicles that delivers parts and tools	DMP07
Firm's Capabilities	Operational Capability	Our manufacturing system flexible enough to add product variety without sacrificing overall production volume	OPC01
		Our manufacturing system flexible enough to be operated at different output levels	OPC02
		We respond well to changing customer choices regarding products	OPC03
		We are capable enough to alter our delivery schedule for each customer's requirements	OPC04
		Our capability of adding product variety without increasing cost is excellent	OPC05
		Our capability of changing set up for a different product at low cost is excellent	OPC06
		We maintain quality production with high variety in demand	OPC07
	Knowledge Management Capability	Our company is able to identify and acquire internal and external knowledge	KMC01
		Employees can easily access the information that they want	KMC02
		Our company can successfully exploit internal and external information and knowledge into concrete applications	KMC03
		All employees have generalized knowledge regarding this firm's objectives	KMC04
Competitive Advantages on Mass Customization Adoption	Competitive Advantage	as compared to our major competitors ,It is perceived that my firms cpabilities would….	
		….source product and process innovation to adopt mass customization strategy.	COA01
		….source strong market position by making barriers other companies to enter.	COA02
		….source to widen the array of products without increasing cost.	COA03
		….source mass customization strategy in my organization that would be difficult and expensive for rivals to duplicate.	COA04
		….source capability to identify the gap between current product offerings and customers actual desire.	COA05

5.2.1 Missing data analysis

The data imputation technique is employed to manage missing data problem. Data imputations deals with substituting the missing data, and then continue with a formal investigation suitable for entire data set. IBM AMOS 22 software presumes that a data value that is missing entirely at random allows approximates that is effective and logical.

5.2.2 Outliers

An answer of respondent is called uttermost if there is a significant deviation from the other responses. The existence of outliers in survey data may considerably influence on the model estimations for model fit and reliability (Leech et al., 2005). Mahalanobis distance (D2) which is the distance of a particular case from the centroid of the remaining cases is used as the measure of outliers.

Hair et al. (2006) proposed that the critical levels for the measure D2/Df should less than 3 or 4 in larger samples (more than one hundred). In this study, no evidence of outliers is observed when tested with SPSS 20.0 software, as the measure D2/Df did not exceed the threshold value of 3 or 4.

5.2.3 Normality of data

Numerous statistical tests presuppose that certain constructs in study abide by the condition of normality at least at approximate level. It can be noticed by frequency distribution which resembles like bell shaped with majority of the data in middle-range and lesser number of data in extreme ranges (Coakes, et al., 2005).

The skewness and kurtosis are regarded as the measurement of approximate normality of the data distribution. Skewness is a measure of symmetry while the kurtosis tests the peakness or flatness of the distribution (Hair et al., 2006). For absolutely normal distribution of the data these values will be zero. The skewness and kurtosis should be within the +2 to-2 range when the data are normally distributed (Lewis-Back et al. 2003).In the research, most values of skewness and the kurtosis of parameter are found between -1 to 1 or near to zero, which indicates that the items of the main survey are approximately normally distributed and comply the conditions for statistical tests employed in this research. The highest value of skewness is 1.06 and for kurtosis is .931 which is again near to 1. Table 5.2 presents the outcomes of skewness, kurtosis and initial statistics of various constructs studied.

Table 5.2: Descriptive Statistics of all research variables

Item Code	N	Mean	Std. Deviation	Skewness	Kurtosis
SCI01	206	3.9709	1.29129	.453	-.068
SCI02	206	4.1311	1.40983	.166	-.533
SCI03	206	3.8981	1.35945	.328	.123
SCI04	206	4.3641	1.39982	-.057	-.726
SCI05	206	4.3689	1.48810	-.115	-.827
SCI06	206	4.4126	1.48147	-.110	-.860
SCI07	206	4.1990	1.40875	.075	-.524
MBP01	206	3.8786	1.52694	.124	-.670
MBP02	206	4.7282	1.46966	-.451	-.856
MBP03	206	4.9272	1.54590	-.661	-.326
MBP04	206	5.3155	1.32975	-1.061	.541
DMP01	206	5.3786	1.50522	-.995	-.221
DMP02	206	5.3689	1.39330	-.814	.203
DMP03	206	5.3883	1.35958	-.920	.166
DMP04	206	5.5922	1.06782	-.899	.815
DMP05	206	5.4175	1.34000	-.848	.408
DMP06	206	5.5922	1.14710	-.620	-.413
DMP07	206	5.8981	1.01419	-.757	-.355
OPC01	206	5.0097	1.47496	-.487	-.584
OPC02	206	5.0194	1.45489	-.610	-.293
OPC03	206	5.1311	1.45411	-.827	.154

Item Code	N	Mean	Std. Deviation	Skewness	Kurtosis
OPC04	206	5.2864	1.23388	-.986	.529
OPC05	206	4.9272	1.42779	-.307	-.718
OPC06	206	5.3058	1.35383	-.940	.517
OPC07	206	5.4272	1.31485	-.828	-.096
KMC01	206	5.2330	1.10170	-.606	-.931
KMC02	206	5.5097	1.09429	-.871	-.345
KMC03	206	5.5825	1.16890	-.988	.341
KMC04	206	5.3932	1.23989	-.954	.260
COA01	206	5.4126	1.16017	-.893	-.022
COA02	206	5.5777	1.21426	-.959	.163
COA03	206	5.5291	1.17562	-.871	.050
COA04	206	4.6165	1.39809	-.069	-.659
COA05	206	5.3786	1.16549	-.702	-.111
Valid N (listwise)	206				

5.2.4 Reliability of scale

The study has carried out a reliability test and item-total correlation analysis. ‘Cronbach’s alpha, test is regarded as the parameter of the reliability which evaluates internal consistency, that represents the closeness of items as a group. Nunnally and Bernstein (1994) recommended alpha value larger than 0.60 establishing acceptableness.

Table 5.3 expresses the outcome of reliability analysis of various variables of the research. The reliability for all the variables are noticed higher than recommended limit

(>0.6), the alpha values are 0.90, 0.68, 0.82, 0.91,.84 and 0.81, while the inter-item correlations are 0.440-0.818, 0.423-0.714, 0.412-.0610, 0.430-0.746,0.440-0.724 and 0.464-0.879 for SCI, MBP, DMP,OPC,KMC and COA, respectively.

The high values of Cronbach's alpha (>.60) and of the item—total correlation coefficients (>0.40) of the all six variable for study suggest that all of the six factors fit the data reasonably well.

Reliability and validity will be farther examined in succeeding chapter with the measurement models in SEM approach.

Table 5.3: Descriptive Statistics and assessment of reliability

Constructs	Number of Items	Mean	Cronbach alpha Index	Range of correlation
Supply Chain Integration (SCI)	7	4.192	0.906	0.440-0.818
Modularity Based Practices(MBP)	4	4.71	0.685	0.423-0.714
Digital Manufacturing Practices(DMP)	7	5.52	0.822	0.412-.0610
Operational Capability (OPC)	7	5.16	0.915	0.430-0.746
Knowledge Management Capability(KMC)	4	5.43	0.844	0.440-0.724
Competitive Advantages on Mass Customization Adoption (COA)	5	5.32	0.81	0.464-0.879

5.3 Descriptive analysis

Descriptive analysis is valuable to investigate the data gathered and it is predominantly helpful if one concentrated to illustrate the general characteristics of sample like demographic matters, distribution, percentage, mean, range, standard deviation and skewness (Leech et al., 2005). The descriptive analysis is carried out with two key motivations: first, to test the rate of response, respondent's profile and second to examine the mean and standard deviation which will further aid to statistical analysis.

5.3.1 Response rate and demographic profile of industry

The fraction of obtaining completed questionnaire is regarded as the response rate of survey. A high survey reply rate assists to make sure that the survey outcomes are illustration of the whole population. The online mailing, two follow-ups and personal visits generate 206 usable responses out of 1120 questionnaires, yielding the response rate of about 18.39% which deemed acceptable for further analysis (Table 5.4).

Table 5.4: Summary of response

Status of response	Total number	Total %
Total number of questionnaire Delivered	1120	100
Responses received	220	19.64
Incomplete/Inappropriate responses	14	1.25
Useful responses for analysis	206	18.39

The data has been collected from 206 Indian organizations including small-sized, medium-sized and large-size organizations which are apparel, automobile, furniture, modular kitchen, footwear, eyewear, jewelry, bicycle manufacturer and steel fabrication. Since these firms don't like to make public their names, seek to preserve anonymity. Table 5.5, Figure 5.1, Figure 5.2 Figure 5.3 and Figure 5.4 are shown demographic data for the respondents in various manufacturing organizations.

Table 5.5: Demographic profile for the respondents

Demographic data for the respondents (sample size 206)	
Type of Sector/ Industry	**Percentage of Total sample**
Apparel manufacturing	19
Automotive or Parts	18
Furniture	15
Modular kitchen & Kitchenware	9
Footwear	8
Eyewear	6
Jewellery manufacturing	6
Bicycle manufacturing	6
Plastic products	5
Fabricated metal products	4
Blanket manufacturing	4
Annual Sales in Rs.	**Percentage of Total sample**
<10 Crore	23.3
10–50 Crore	36.3
50-100 Crore	25.3
100 Crore and above	15.1
Number of employees	**Percentage of Total sample**
<75	5.7
76–299	46.6
300–500	28.5
>500	19.2
Position of the respondent in the organization	**Percentage of Total sample**
Owners/Proprietors	13.7
CEO/COO/GM	29.2
VP/AVP/AGM	32.8
Any other senior position	24.3

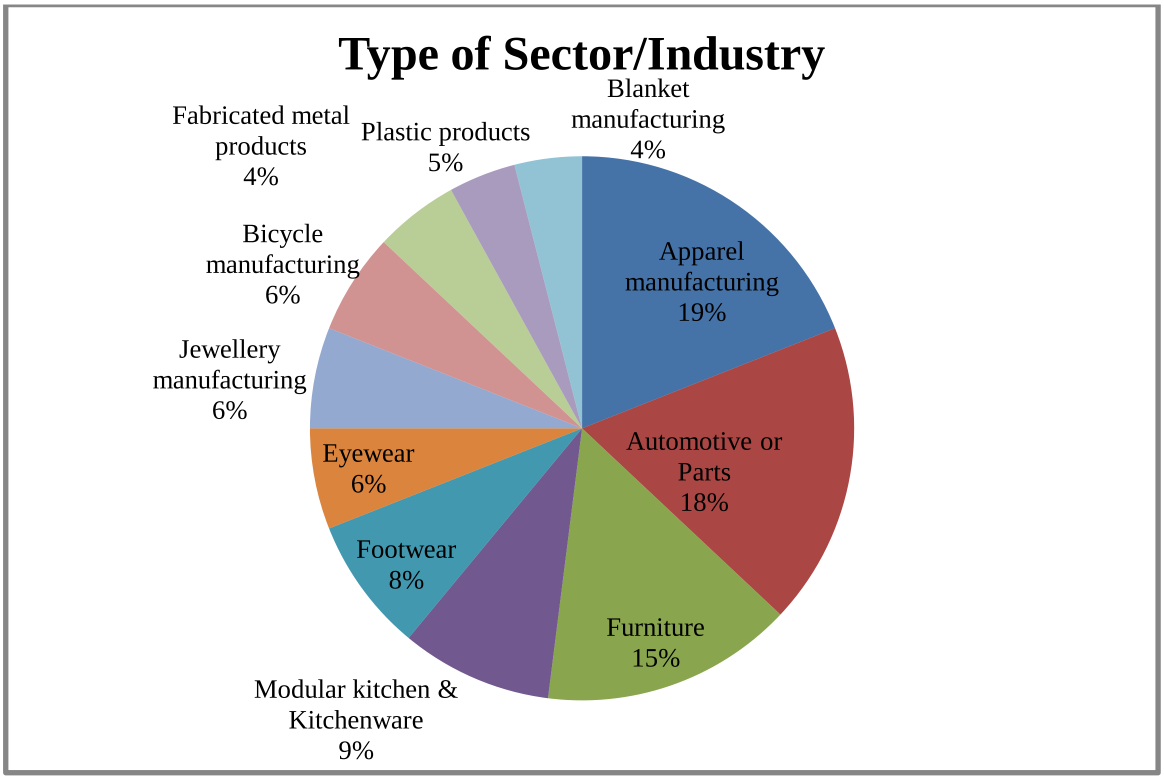

Figure 5.1: Type of Sector / Industry

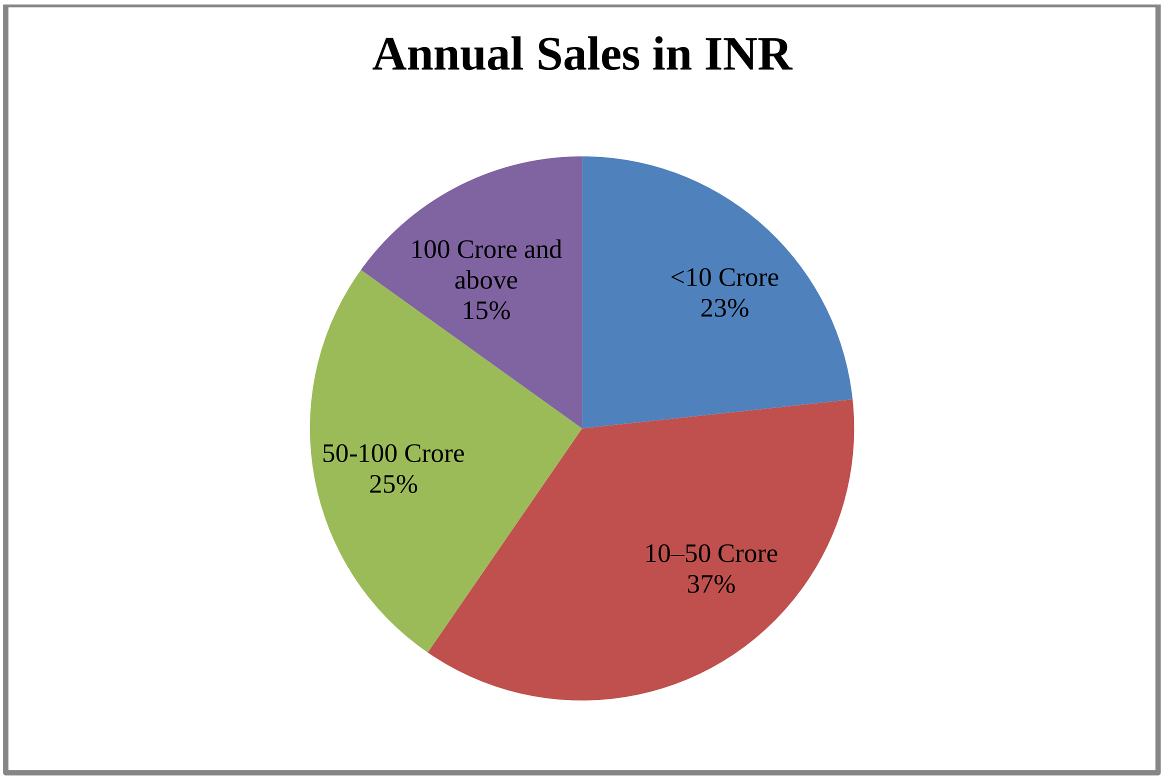

Figure 5.2: Annual Sales in INR

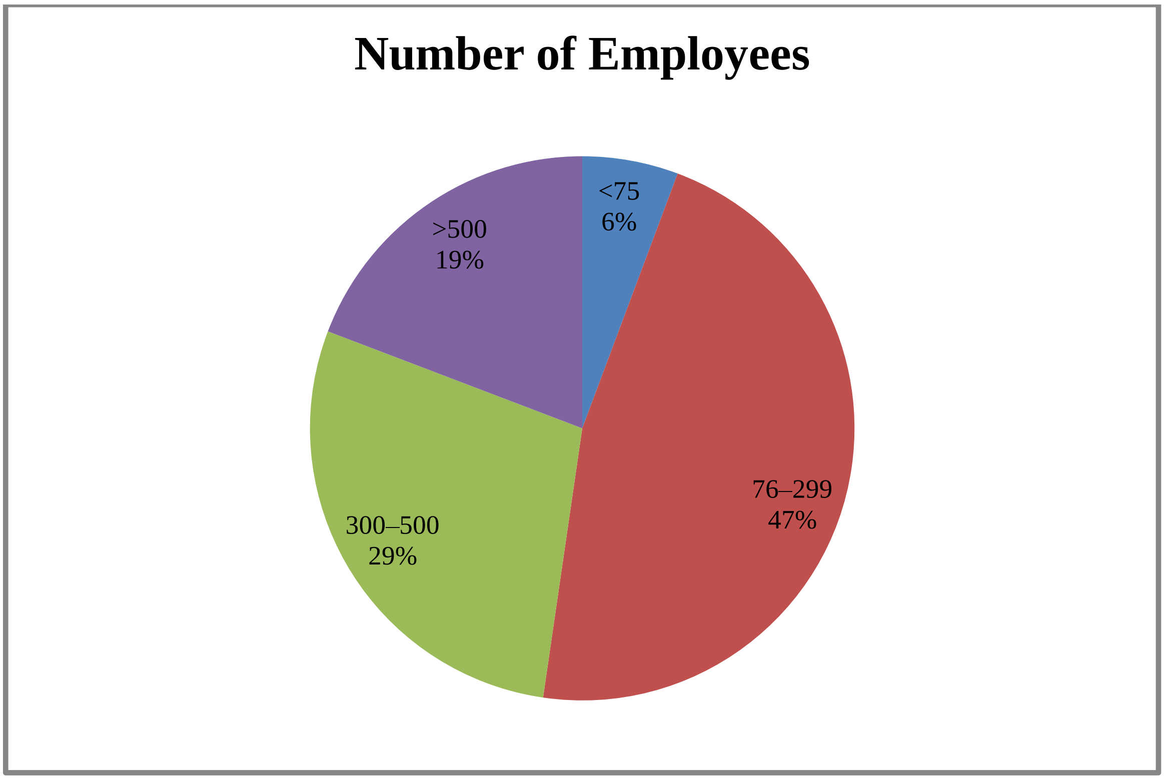

Figure 5.3: Number of Employees

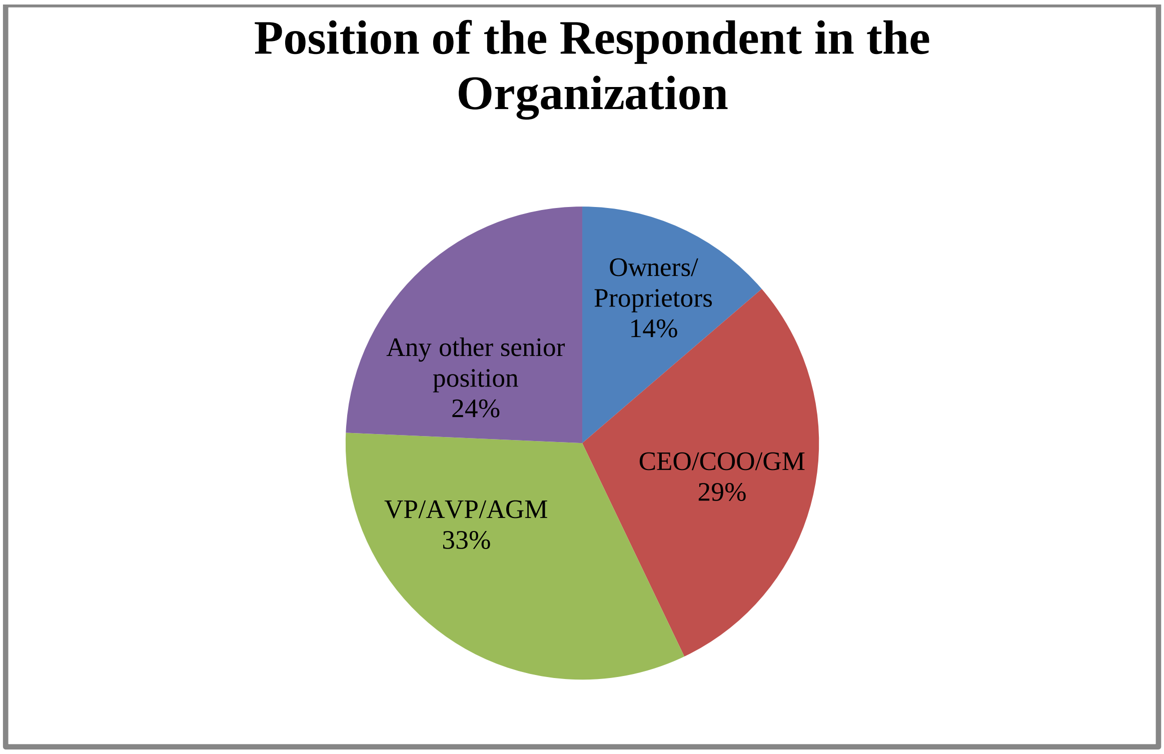

Figure 5.4: Position of Respondent in the Organization

5.3.2 Response of Indian industry on MC enablers and capabilities

The response of industries for the mass customization adoption is collected by the questions inquired in section B of survey questionnaire. In this study the MC enablers and its effect on firm's capabilities to achieve competitive advantage are examined by comparing the view of respondents concerning the practices and perceptions on implementing MC strategy.

5.3.2.1 Response analysis to mass customization enabler

Based on analysis of data relating to section B.1, B.2 and B.3 of the questionnaire of the various enablers of mass customization, the result under the individual categories are summarized in subsequent Figures5.5, 5.6 and 5.7.

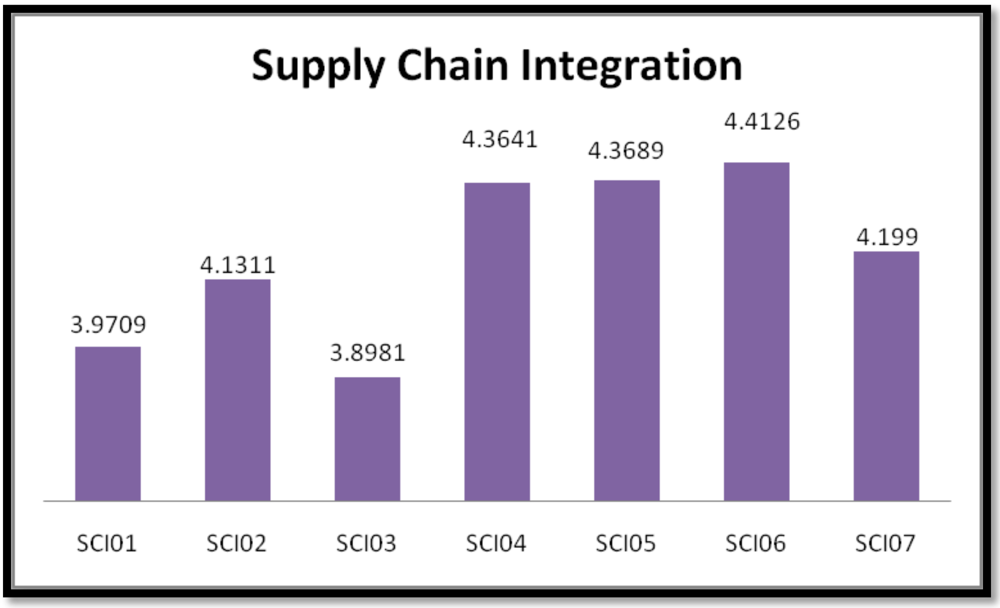

Figure 5.5: Responses on Supply Chain Integration

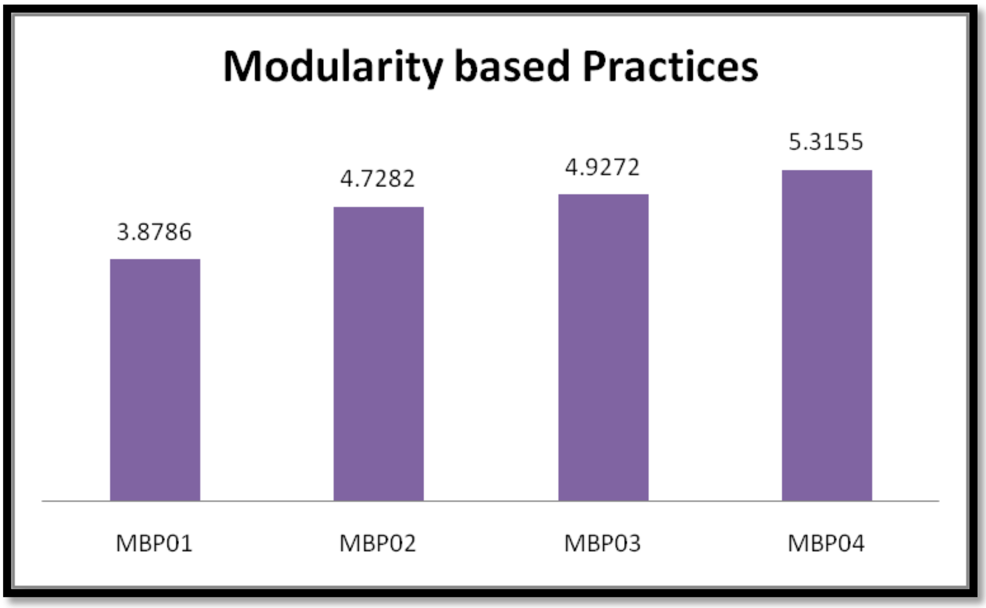

Figure 5.6: Responses on Modularity Based Practices

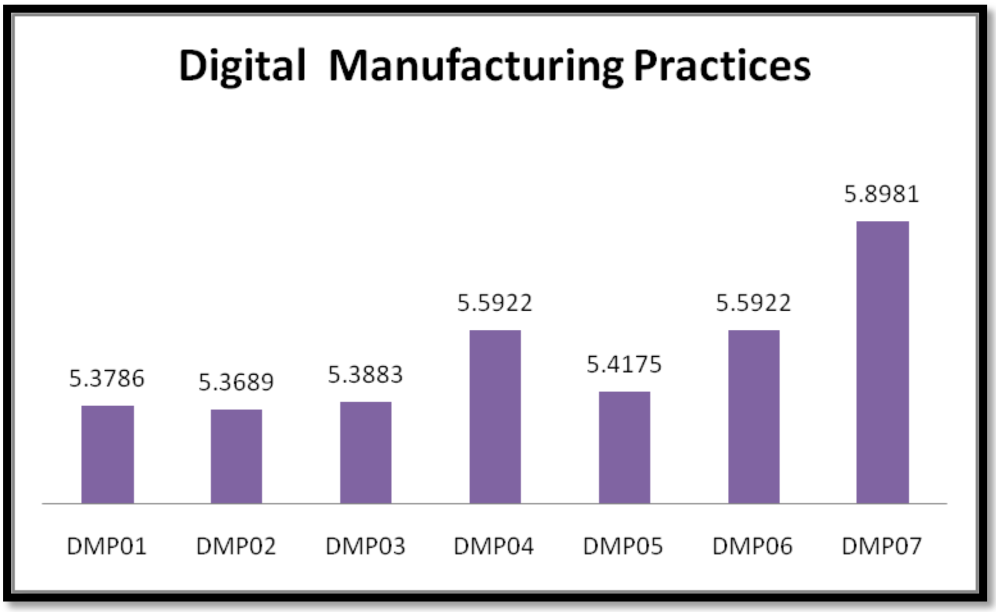

Figure 5.7: Responses on Digital Manufacturing Practices

5.3.2.2 Response analysis to firm's capabilities and competitive advantage

Based on analysis of data pertaining to section B.4, B.5 and B.6 of the questionnaire of the firm's capabilities and competitive advantage, the result under the individual categories are summarized in subsequent Figures 5.8,5.9 and 5.10.

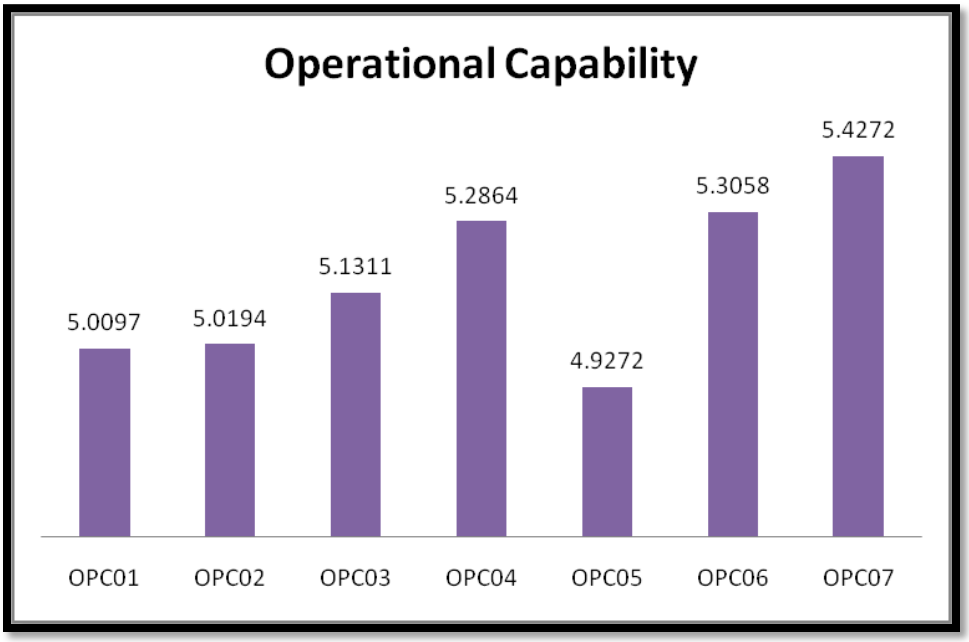

Figure 5.8: Responses on Operational Capabilities

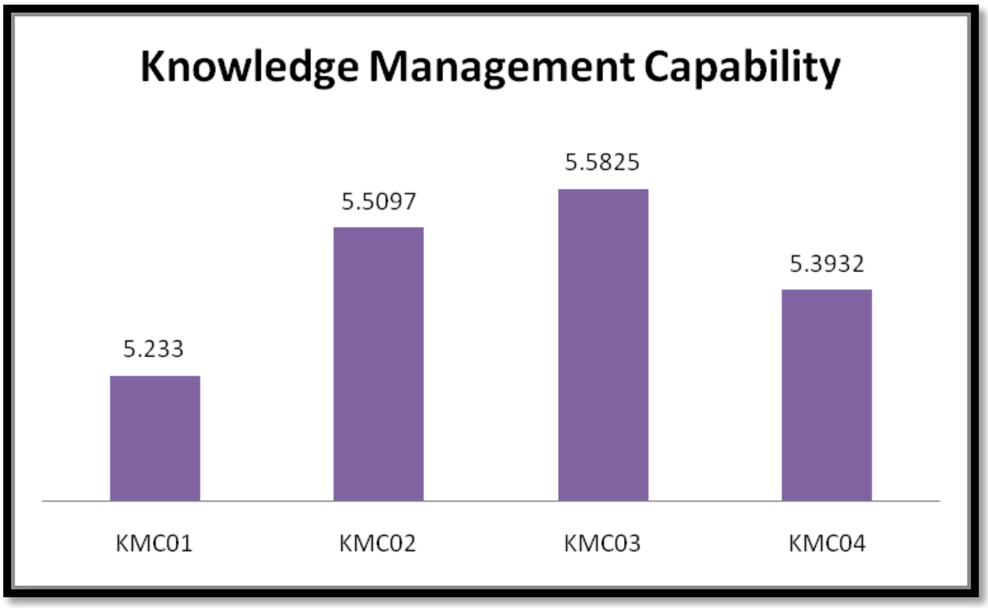

Figure 5.9: Responses on Knowledge Management Capabilities

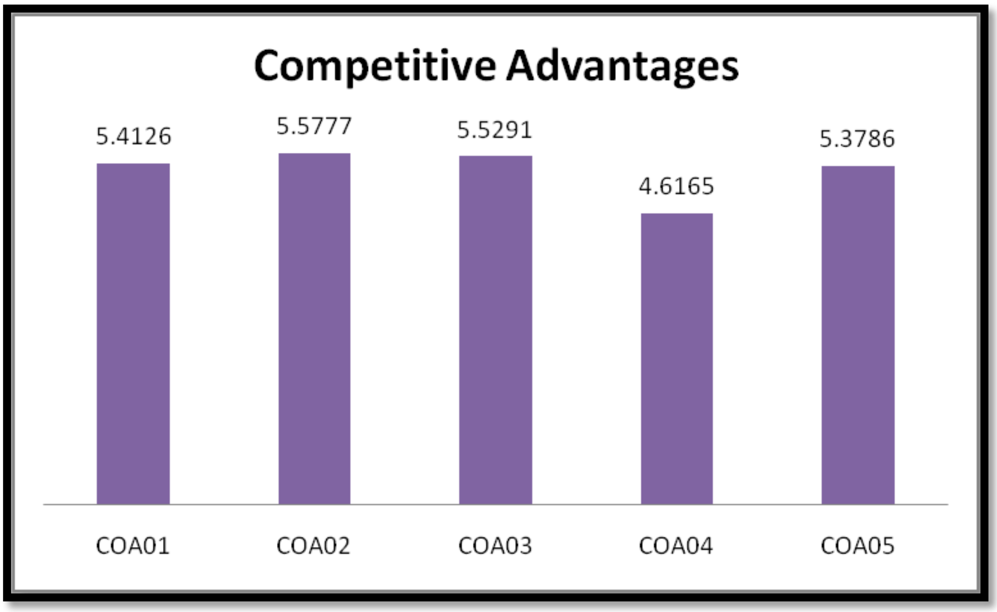

Figure 5.10: Responses on Competitive Advantage

Chapter-6

Investigation of MC Model

Chapter-6

Investigation of MC Model

6.1 Introduction

The descriptive analysis is carried out to get familiar with the sample features (Mean, Std. deviation, Normality, and Reliability) in the previous chapter. In this chapter, the major thrust is given to examine the MC adoption framework for Indian firms and check the hypotheses (Relationship between MC enablers, Firms capabilities and competitive advantage) which are defined in previous Chapters. This chapter concentrates on the objective to investigate and validate the MC adoption model for Indian organizations. The causal relationships among mass customization enablers, capabilities and competitive advantage are investigated with Structural Equation Modeling (SEM). Byrne (2013), Kline (2005), Schumacher and Lomex (2004) have recommended the subsequent phases for accomplishment of SEM which are shown in Table 6.1.

Table 6.1: Phases of structural equation modeling

Phases No.	Description of SEM Phases	Details
1	Development of conceptualized model	• Measurement models • Structural models
2	Model evaluating elements	• Choice of estimation method • Choice of model fit indices • Model identification
3	Measurement of model specification and evaluation	• Single and multifactor approach • Model based reliability and validity measurement
4	Structural model modification and rectification	• Estimating the coefficient and hypotheses testing

6.2 Development of model constructs

SEM holds a mixed framework with several indicators (observed variables) for every latent construct (unobserved variable) (Byrne. 2013). The observed variables (items in questionnaire) in the study help the unobserved variable (Latent constructs) to be operational to attain the research objectives.

Latent construct includes all dependent, mediating and independent unobserved factors. Exogenous variables are autonomous factors and free from any previous causal variables whereas the endogenous variables are on the receiving side of the causal link and plays as a pure dependent factors. Mediating factors symbolize a particular type of endogenous factor affected by exogenous factors and other mediating factors and also turns out to be the causes to the further pure factors. The illustration of latent factors based on their associations with observed indicators (items in questionnaire) in one of the promising characteristics of SEM.

As given in Table 6.2 the suggested research framework including the latent factors and the items of each factor is backed by theoretical framework represented accurately by the literature review and preliminary studies. Three groups of research constructs are considered having three constructs in MC enablers as exogenous variables except supply chain integration (Endogenous/ mediating variable), two firms critical capabilities as the mediating variable (Endogenous variable), and one construct as competitive advantage on mass customization adoption factor as the endogenous constructs.

Table 6.2: Description of model construct

Main Factors	Latent Constructs	Items	Nature of Variable
Mass Customization Enablers	Modularity Based Practices	MBP01 toMBP04	Exogenous
	Supply Chain Integration	SCI01 to SCI07	Endogenous
	Digital Manufacturing Practices	DMP01 to DMP07	Exogenous
Firm's Capabilities	Operational Capabilities	OPC01 to OPC07	Endogenous
	Knowledge Management Capabilities	KMC01 to KMC04	Endogenous
Competitive Advantage	Competitive Advantage on Mass Customization Adoption	COA 01 to COA 05	Endogenous

6.3 Choice of model estimation methods

In this phase of SEM; evaluating the model is to recognize the type of data and choose the estimation methods. Structural coefficients in SEM may be calculated with numerous manners. AMOS 22.0 software supports Maximum likelihood (ML), Generalized least square (GLS), Un weighted least square (ULS), Scale free least square (SLQ) and asymptotically distribution free (ADF) methods of coefficient estimations.

Maximum likelihood estimation (MLE) is undoubtedly the most frequent method of estimation. ML is the iterative estimation method that estimates the fairly accurate value for each parameter (Kline, 2005). It establishes estimates supported on maximizing the probability (likelihood) that the observed covariance are drawn from a population presumed to be the similar as that reflected in the coefficient estimates (Ullman, 2003).

When condition of normality is not satisfied weighted least square (WLS) or asymptotically distribution free (ADF) approach can be employed. But these estimation methods need large sample sizes (Byrne, 2013). Generalized least square (GLS) is also an extremely familiar estimation method when MLE is not suitable. This also necessitates the requirement of large sample size (more than 2000) recommended by Byrne (2013).

As examined in previous chapter, the distribution of research constructs realize the term of approximate normality, furthermore, the sample size is not very large, thus, MLE method ascertained suitable for parameter estimations in this study.

6.4 Model Indices

It is significant to carry out the model-fit analysis as it specifies the goodness of the fit of research framework. It mainly suggests that how substantially the items are jointly reflecting the latent factor and how well the items are dependable to their - factor (Arbuckle, 2007).

AMOS 22.0 supports number of goodness of fit indices but the preference of selection of model fit examination diverges throughout in literature. It is also debated that there is no single fit that can best identify the strength of framework to describe the framework expectedness (Arbuckle, 2007). Yet, it is observed that the chi-square ($\chi2$) test, linked with p value with test statistic ($\chi2$) is extensively acknowledged statistical measure, employed to compare the observed and estimated covariance matrices (Byrne, 2013; Arbuckle, 2007).

Researchers recommended to applying at least one test of each class (each class of tests has its own specific abilities to evaluate the model) to speculate the various measures. Kline (2005) exclusively proposed minimum four tests like chi square ($\chi2$), goodness of fit index (GFI), normed fit index (NFI) or comparative fit index (CFI) and root mean square residual (RMR) for dealing with the spreaded statistical prospects.

The most frequent suggestion to study the fit indices advises the chi square ($\chi2$) and root mean square error of approximation (RMSEA) tests. Incorporating the suggestions of several researchers, we study the fit indices as remarked in Table 6.3.

Table 6.3: Summary of model fit indices

Fit Indices	Abbreviation	Description	Range
Chi square ($\chi2$) with degree of freedom	($\chi2$),df,p	Absolute fit test	$p>0.05$
Normed chi square	CMIN/DF	Absolute fit and model parsimony test	$1.0<CMIN/DF<3.0$
Root mean square residual	RMR	Absolute fit test	$RMR<0.10$
Goodness of fit index	GFI	Relative fit test	$GFI\geq0.90$
Adjusted goodness of fit index	AGFI	Relative fit test	$AGFI\geq0.90$
Comparative fit index	CFI	Relative fit test with baseline comparison	$CFI\geq0.90$
Normed fit index	NFI	Relative fit test with baseline comparison	$NFI\geq0.90$
Root mean square error of approximation	RMSEA	Parsimony test	$.05\leq RMSEA\leq.08$

6.5 Two-phase approach in structural equation modeling

The two-phase structural equation model constructing method is applied for the study as advocated by Anderson and Gerbing (1988).

The first phase is the investigation of the measurement model, which determines the associations among the observed factors and latent factors or hypothetical constructs.

Three main groups of constructs are considered in this study as follows the MC enablers, organizational capabilities and competitive advantage on MC adoption. The outcomes of this investigation make out the measurement attributes of the observed and latent factors. This is done individually prior to fitting a structural path model to check out the link between the latent factors. Measurement models were specified for all the autonomous and endogenous latent factors.

The second phase of the SEM determines the associations between the latent factors as provided in the research framework, is prepared and confirmed.

This methodical two-phase process allows the researcher to key out origins of poor fit, of a model and also to recognize whether this poor fit is the result of to the measurement or path model.

Kline (2005) debated that the examining of the structural model is pointless except it is first proved that the measurement model holds good for the given data. Hence, the measurement model must be tested former to the structural relations being accomplished.

6.5.1 Development of measurement models for mass customization

The phrase confirmatory factor analysis (CFA) is employed to denote to the measurement framework testing. CFA method undertakes to check the feasibility of chosen model and structures, which are generally based on theory or prior knowledge or as the research objectives, and to study whether or not offered data are reliable with a suggested research framework having restrained configuration.

The work evaluates two types of measurement models that are the one-factor congeneric models and multi-factor models. One-factor congeneric measurement model is utilized to assess item reliability, construct validity whereas multifactor measurement models are more prone to investigate the discriminant validity of the individual scales in the construct.

To build up a measurement model for the accomplishment of MC practices, the researchformulated18 number of measurement items on MC enablers and 16 for firm's capabilities and competitive advantage inclusively. The measurement items were developed on the basis of inputs from literature review, industry experts, academics persons and practitioners from the field of mass customization, supply chain management and strategic management.

One factor congeneric model

Anderson and Gerbing (1988) said that a one-factor congeneric measurement model is a model of single latent variable (factor) which is measured by several observed variables (items/indicators). Observed variables are those variables that are directly observable like the items in a survey.

This study contains three constructs models for MC enablers and three for capabilities and competitive advantage.

The following section presents the results of the CFA assessment of the goodness-of-fit and validity of the six individual first-order latent constructs and the two multi-factor latent constructs followed by the final overall measurement model. In particular, the fit indices, factor loadings and construct reliability are examined.

6.5.1.1 One factor measurement model for Modularity Based Practices (MBP)

The latent variable of MBP holds four indicators MBP01 to MBP04. The ratio of chi square to degree of freedom test (CMIN/DF) is 1.147 (p>0 .05) suggesting the good fit to the data. The values of other indices such as GFI = 0.999, AGFI = 0.972, CFI = 0.999, NFI=0.996, RMR = 0.02 and RMSEA=.03 are well within standard limits. These result recommended that the measurement model of modularity based practices presented a good fit as shown in Figure 6.1.

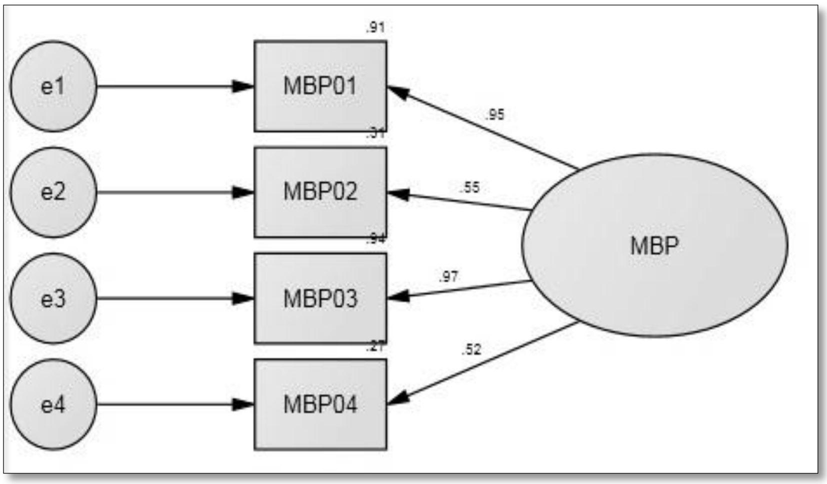

Figure 6.1 – CFA Results for Modularity Based Practices

6.5.1.2 One factor measurement model for big data and information technology enabled Supply Chain Integration (SCI)

The latent variable of SCI holds seven items SCI01 to SCI07. The ratio of chi square to degree of freedom test (CMIN/DF) is 2.479 (p>0 .05) which specify the good fit to the data. The values of other model -fit indices like GFI = 0.964, AGFI = 0.909, CFI = 0.981, NFI=0.969, RMR = 0.06 and RMSEA=.08 are well within standard limits. These outcomes recommended that the measurement model of supply chain integration found statistically good as shown in Figure 6.2.

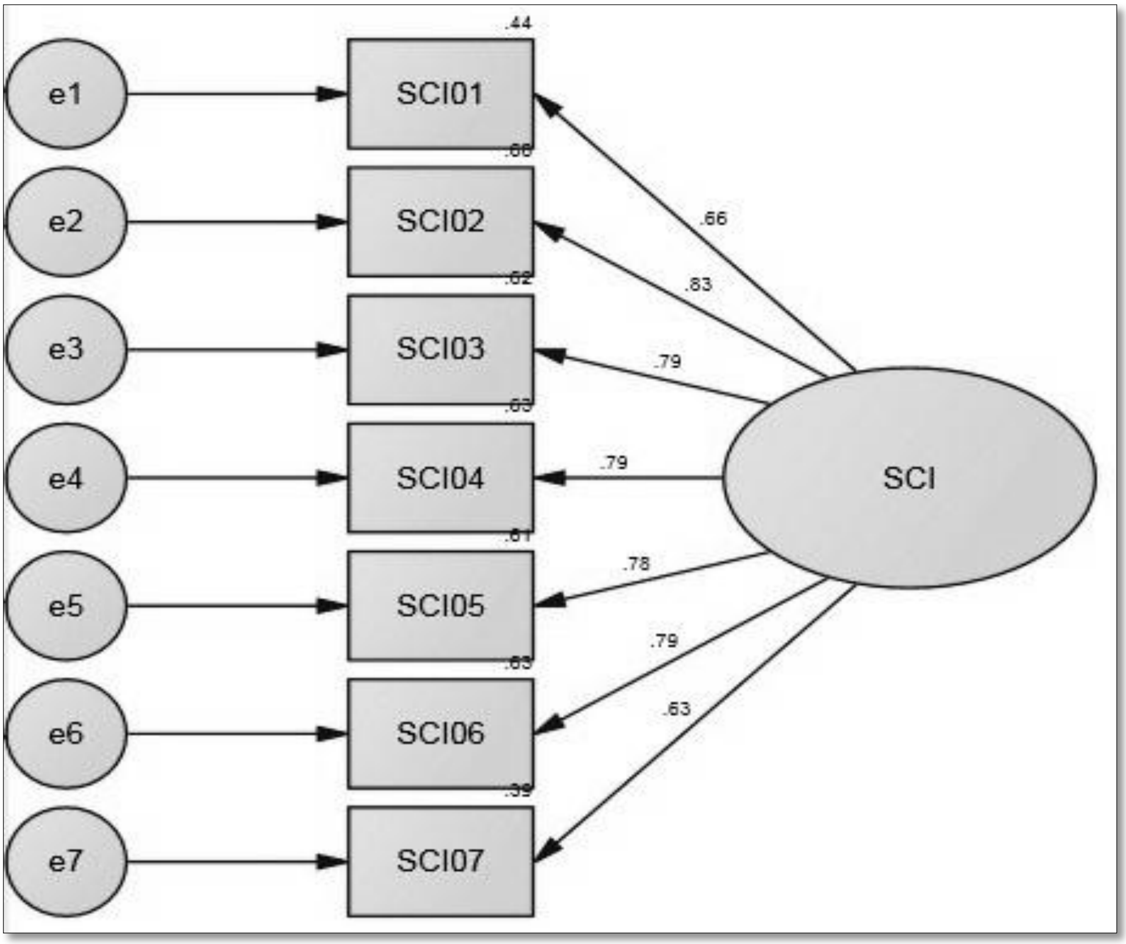

Figure 6.2 – CFA Results for Supply Chain Integration

6.5.1.3 One factor measurement model for Digital Manufacturing Practices (DMP)

The variable of DMP has seven indicators DMP01 to DMP07. The ratio of chi square to degree of freedom test (CMIN/DF) is 2.089 (p>0 .05) which could indicate the good fit to the data. The values of other indices such as GFI = 0.971, AGFI = 0.926, CFI =

0.974, NFI=0.953, RMR = 0.05 and RMSEA=.07 are well within standard limits. The model was found statistically fine as shown in Figure 6.3.

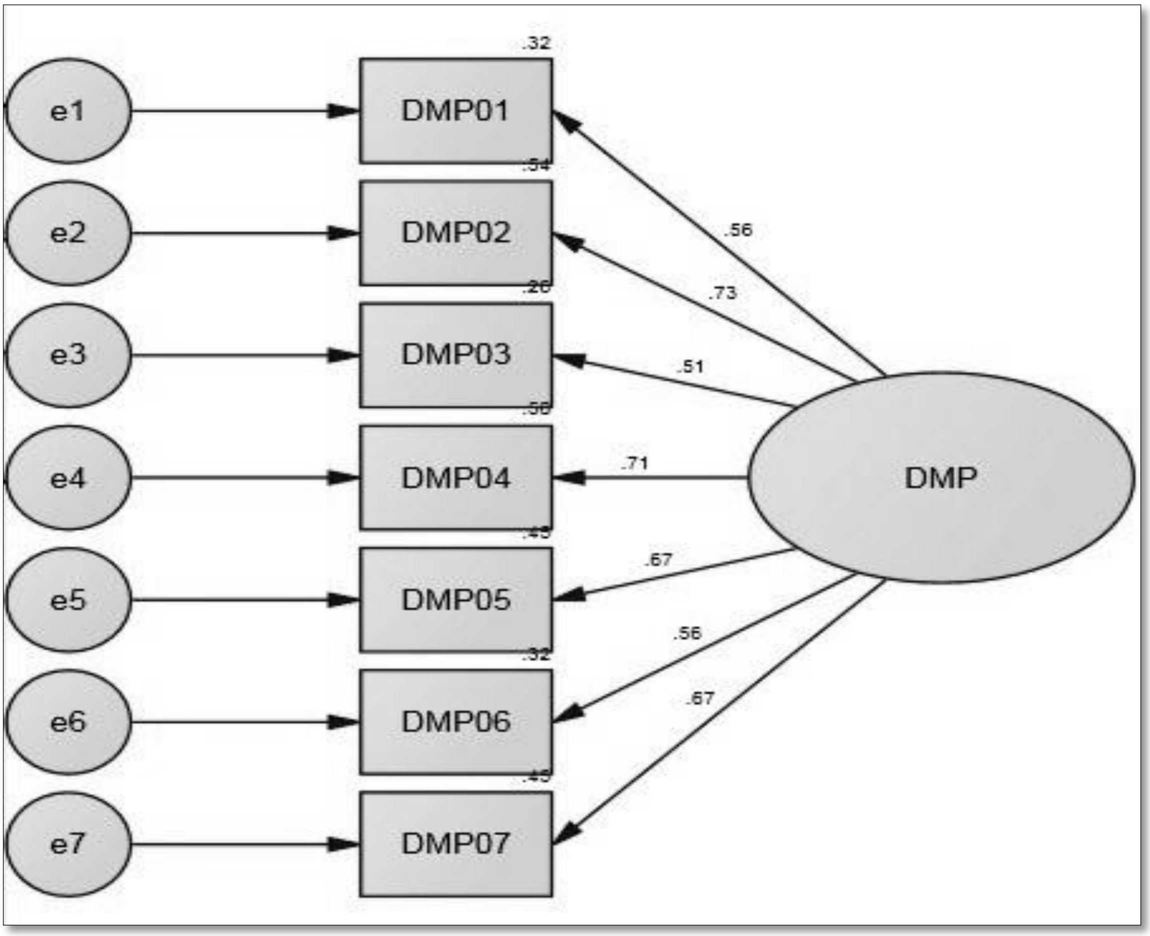

Figure 6.3 – CFA Results for Digital Manufacturing Practices

6.5.1.4 One factor measurement model for firm's Operational Capabilities (OPC)

The latent variable of OPC connected with seven observable survey items OPC01 to OPC07. The model was found statistically good as shown in Figure 6.4. The ratio of chi square to degree of freedom test (CMIN/DF) is 1.647 (p>0 .05) which could indicate the best fit to the data. The values of other indices such as GFI = 0.972, AGFI = 0.934, CFI = 0.992, NFI=0.979, RMR = 0.04 and RMSEA=.06 are well within standard limits.

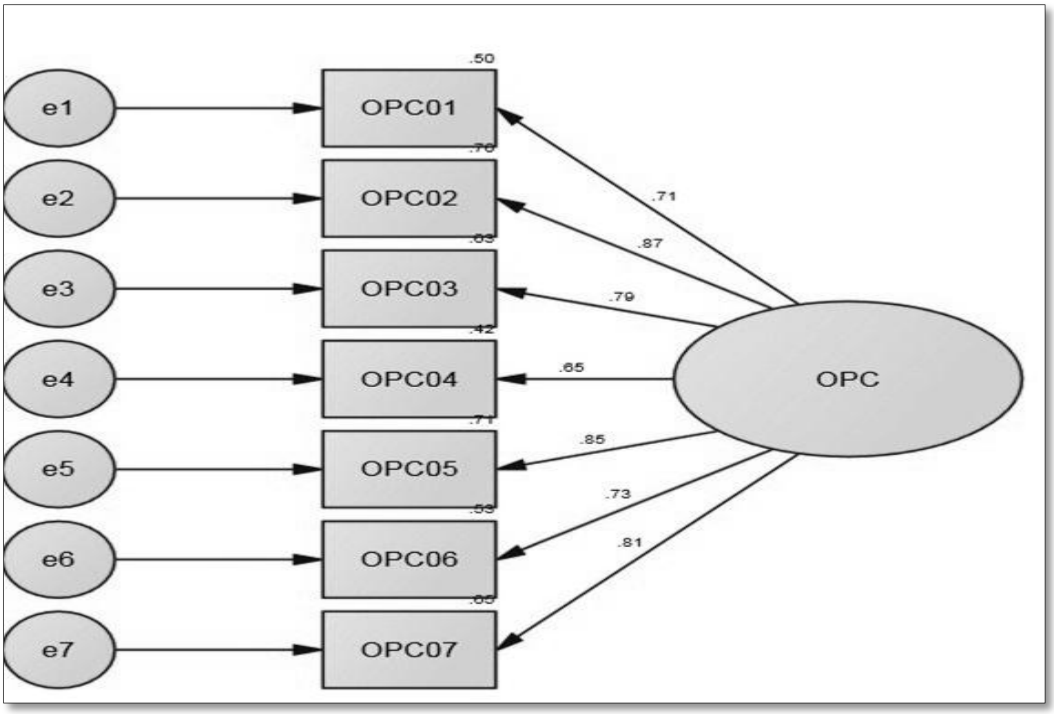

Figure 6.4 – CFA Results for Firm's Operational Capabilities

6.5.1.5 One factor measurement model for firm's Knowledge Management Capabilities (KMC)

The latent construct of KMC carries four items mentioned as KMC01 to KMC04. The ratio of chi square to degree of freedom test (CMIN/DF) is 0.961 (p>0 .05) which could indicate the best fit to the data. The values of other indices such as GFI = 0.995, AGFI = 0.977, CFI = 0.990, NFI=0.979, RMR = 0.01 and RMSEA=.01 are well within standard limits. The model was found statistically good as shown in Figure 6.5.

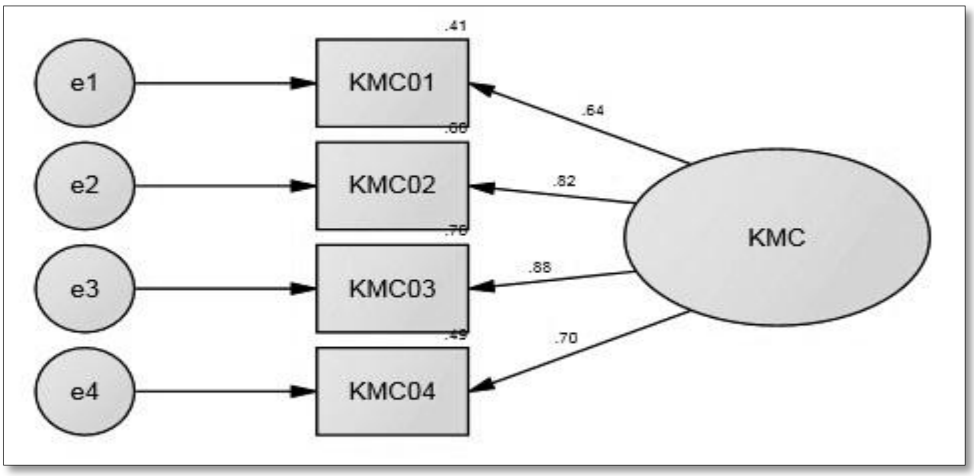

Figure 6.5 – CFA Results for Firm's Knowledge Management Capabilities

6.5.1.6 One factor measurement model for firms Competitive Advantage on mass customization adoption (COA)

The latent variable of COA carries four survey items named as COA01 to COA05. The ratio of chi square to degree of freedom test (CMIN/DF) is 3.425 (p>0 .05) which could indicate the best fit to the data. The values of other model -fit indices such as GFI = 0.981, AGFI = 0.903, CFI = 0.985, NFI=0.980, RMR = 0.07 and RMSEA=.09 are well within standard limits. These out comes recommended a good model fit as shown in Figure 6.6.

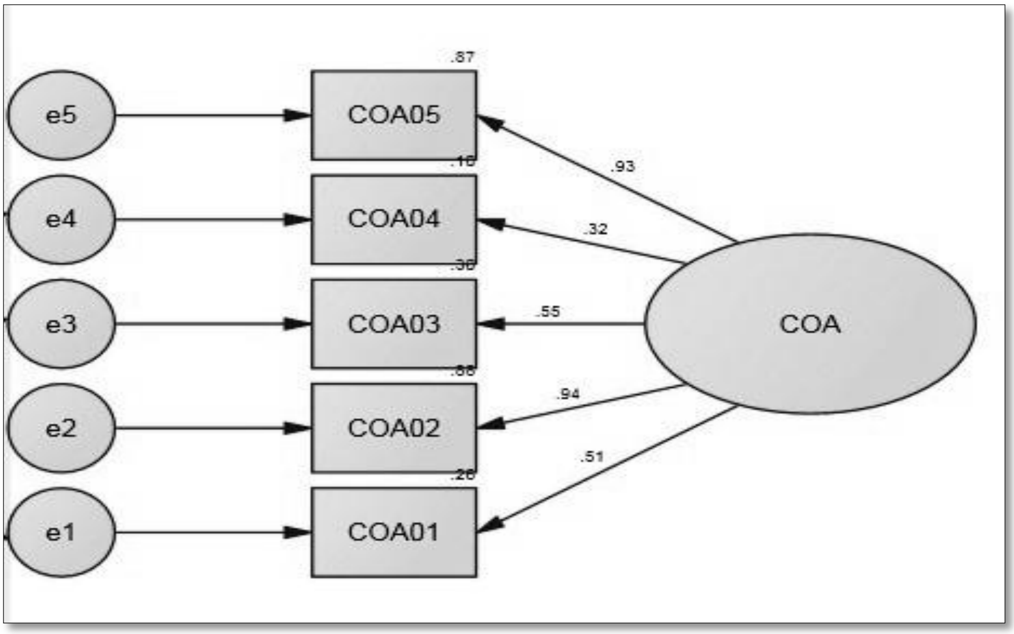

Figure 6.6 – CFA Results for Firm’s Competitive Advantage

The summarized report of all one factor measurement models is shown in Table 6.4. The ratio of chi square to degree of freedom test (CMIN/DF) with p-value and the values of other model fit indices such as GFI, AGFI, CFI, NFI and RMR are well within standard limits except CMIN/DF value for construct COA but according to Schumacher and Lomax (2004) the value even as high as 5.0, can also be considered a reasonable fit.

Table 6.4: Summary of one factor congeneric models

Construct	CMIN/DF	GFI	AGFI	CFI	NFI	RMR
Recommended Range	**≤3.0**	**≥0.90**	**≥0.90**	**≥0.90**	**≥0.90**	**<0.10**
Modularity Based Practices (MBP)	1.147	0.997	0.972	0.999	0.996	0.02
Supply Chain Integration (SCI)	2.479	0.964	0.909	0.981	0.969	0.06
Digital Manufacturing Practices (DMP)	2.089	0.971	0.926	0.974	0.953	0.05
Operational Capabilities (OPC)	1.647	0.972	0.934	0.992	0.979	0.04
Knowledge Management Capabilities (KMC)	0.961	0.995	0.977	0.99	0.979	0.01
Competitive Advantage (COA)	3.425	0.981	0.903	0.985	0.98	0.07

Multifactor measurement model for confirmatory factor analysis

The multifactor measurement models are further developed with prime objective to investigate the discriminant and construct validity as confirmatory factor analysis for the prior specification of items to their respective latent construct and uniqueness of constructs.

6.5.1.7 Analysis of multifactor measurement model for mass customization enablers

To investigate the behavior of factors related to mass customization enablers (i.e. modularity based practices and digital manufacturing practices) an analysis is performed as first order measurement model. The value of CMIN/DF is 1.733 with p-value is .003 which indicates the best fit to the data. The values of fit indices such as GFI = 0.949, AGFI = 0.912, CFI = 0.986, NFI=0.969, RMR = 0.11 and RMSEA=.06 are well within standard limits.

An analysis of inter-correlations between the two variables of mass customization enablers (Figure 6.7) depict the estimate to be considerably lower than standard value of 0.80 as recommended by Ullham (1996), that is 0.31, meaning distinctness in construct content. Likewise the substantial factor loadings of the indicators to their construct symbolize the construct validity of the model. Therefore the measurement model for mass customization enablers demonstrates adequate discriminant as well as constructs validity of underlying constructs. The model was found statistically good as shown in Figure 6.7.

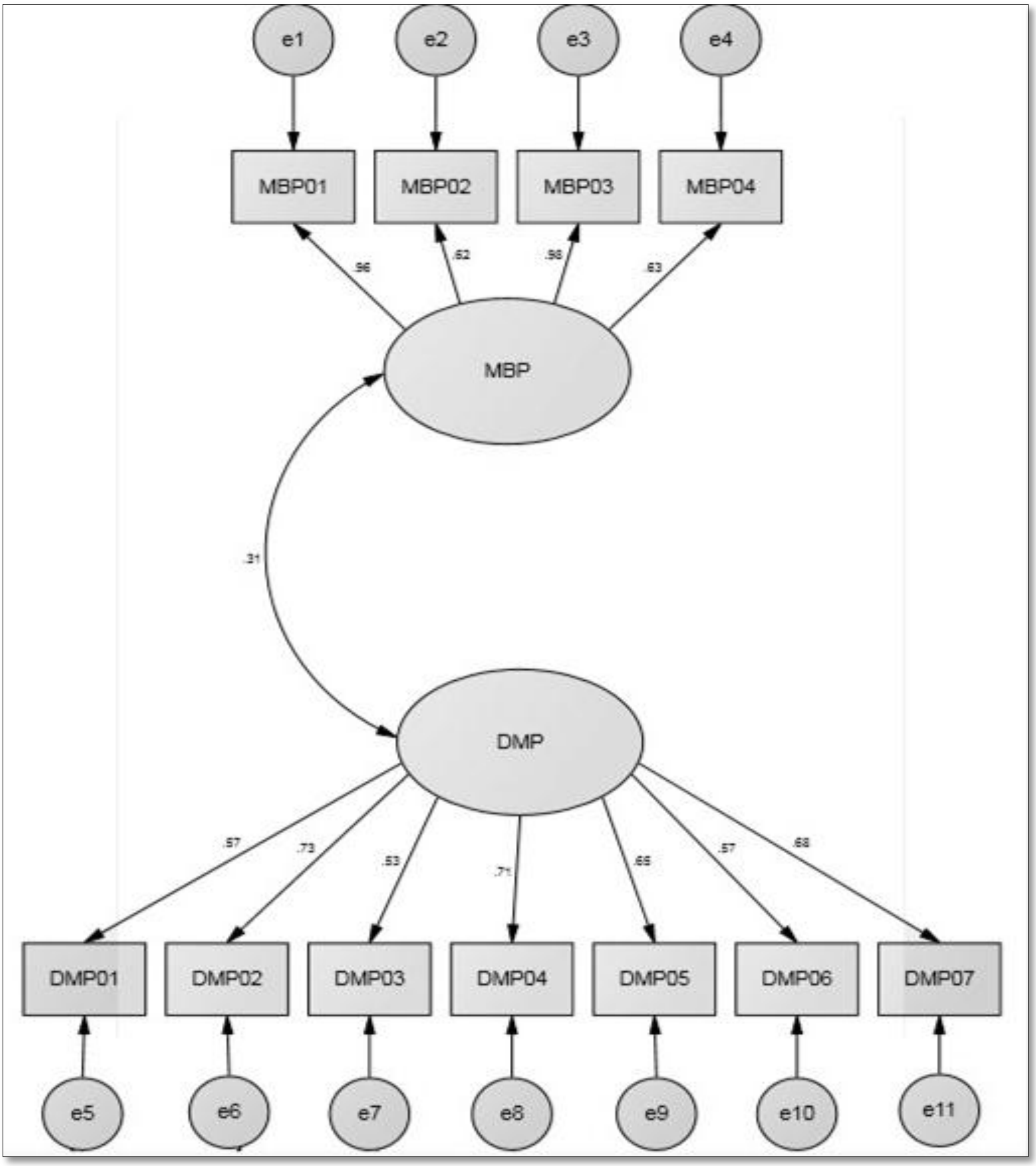

Figure 6.7 – First order measurement model for Mass Customization Enablers

6.5.1.8 Analysis of multifactor measurement model for organizational capabilities

To investigate the behavior of factors related to firm's critical capabilities (i.e. operational capabilities and knowledge management capabilities) study is performed as analysis of first order measurement model. The value of CMIN/DF is 1.738 with p-value is .002 which could indicate the best fit to the data. The values of other indices like GFI = 0.936, AGFI = 0.899, CFI = 0.976, NFI=0.946, RMR = 0.07 and RMSEA=.06 are well within standard limits. These results suggest that the measurement model for firm's critical capabilities provide a reasonably good fit. The model was found statistically good as shown in Figure 6.8.

A testing of inter-correlations between the two attributes of organizational capabilities (Figure 6.8) demonstrated considerably lower than standard value of 0.80 proposed by Ullham (1996), that is 0.34, implying discriminant validity. Also the considerable factor loadings of the indicators to their variable symbolize construct validity of the model. Therefore the measurement model for organizational capabilities demonstrate sample discriminant and constructs validity.

6.5.2 Reliability and validity of measurement models

The CFA with single and multifactor measurement model provides sufficient evidence for acceptability of the model in terms model fit, model validity and reliability. But still to get better insights further assessment is carried out for construct validity of the model including of composite reliability, convergent validity and discriminant validity as the prime concern.

Content validity was established through literature review, questionnaire design and pre-survey interviews. Convergent validity demonstrates whether the set of alternative measures accurately measure the construct under consideration (Hair et al. 2006). After establishing the CFA model for each of the construct we assess the convergent validity based on level of significance of factor loadings.

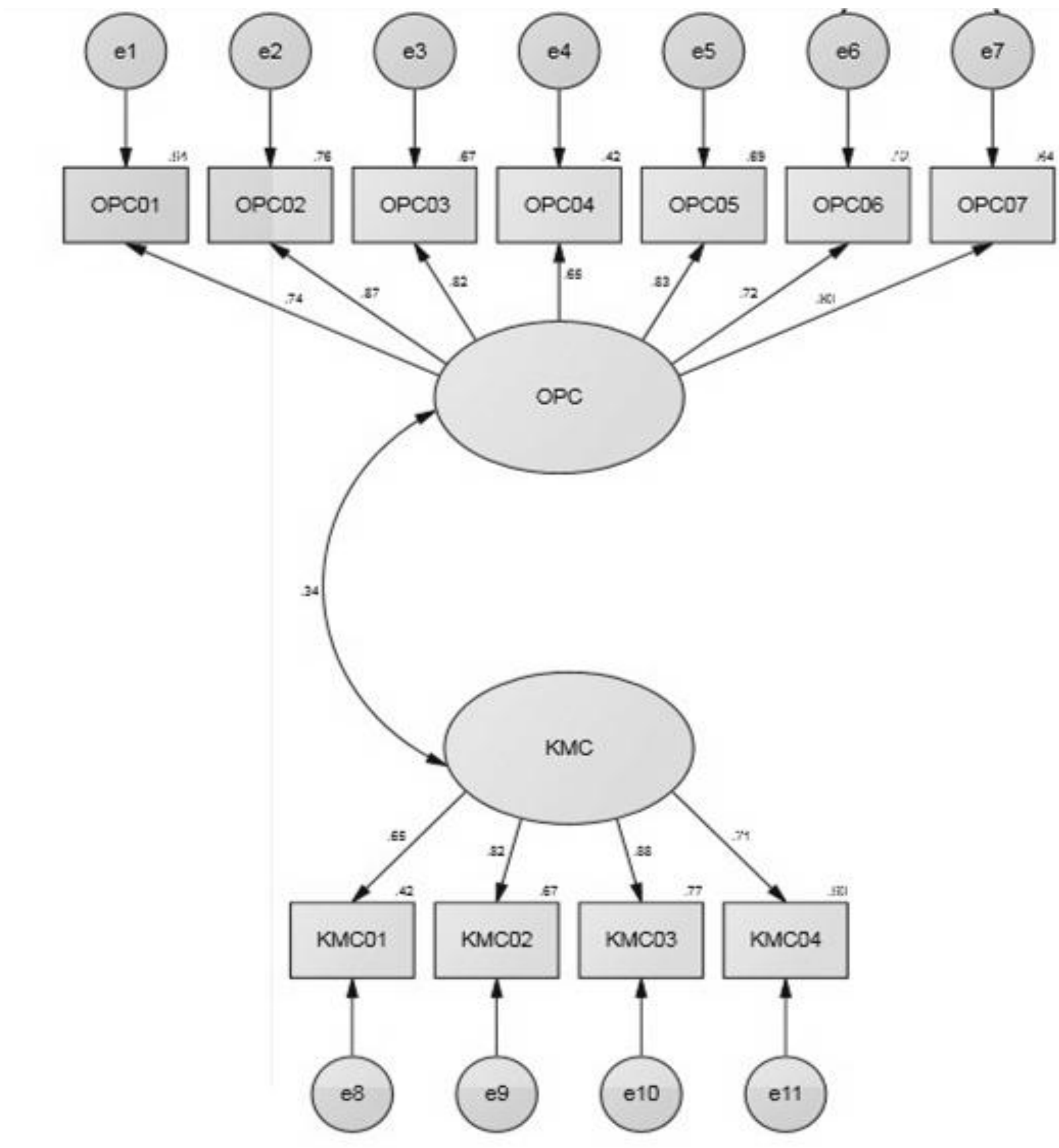

Figure 6.8 – First order measurement model for Firm's Critical Capabilities

The significant path loading depicts that the indicators are effectively converging to the same construct. The large and significant path loadings of indicators exhibit the strong evidence of convergent validity (Table 6.5, 6.6).

Average variance extracted (AVE) reflects the measure of convergence among a set of indicators representing a latent construct. The relation (See Equation 6.1) to estimate the AVE is given as:

$$\textbf{Average varience expected}(\textbf{AVE}) = (\textstyle\sum_{i=1}^{n} \lambda i)^2/n \ \ldots(6.1)$$

Here λ is the standardized factor loading of items to their construct; n is the number of items associated to particular construct.

The above relation is applied for the measurement of AVE of the constructs. The results are reported in Table 6.5 and 6.6. The value of AVE is suggested around 0.5. It is observed that for all constructs such as MBP, DMP, OPC and KMC the AVE is found satisfactory to their recommended value.

Anderson and Gerbing (1988) suggested that for path analysis composite reliability is better option than Cronbach's alpha reliability index. The relation (See Equation 6.2) for composite reliability is given as:

$$\textbf{Comosite reliability}\ (\rho) = (\textstyle\sum_{i=1}^{n} \lambda i)^2/[(\sum_{i=1}^{n} \lambda i)^2 + (\sum_{i=1}^{n} 1 - \lambda i2)] \ldots (6.2)$$

Here, λ represents the standardized factor loading of items; and n represents the number of items associated to particular construct

Hair et al. (2006) recommend the acceptable value of composite reliability ρ> .7. But for new scale the value > 0.6 can also be accepted. The estimation of composite reliability indicates the mixed response. The results show that the set of indicators are all stable and a reliable measure of their individual constructs (See Table 6.5 and 6.6). These values indicate the acceptable convergence of the model.

Table 6.5: CR and AVE for MC enablers

Items in study	Modularity Based Practices	Digital Manufacturing Practices
MBP01	0.95	
MBP02	0.55	
MBP03	0.97	
MBP04	0.52	
DMP01		0.56
DMP02		0.73
DMP03		0.51
DMP04		0.71
DMP05		0.67
DMP06		0.56
DMP07		0.67
AVE	**0.604**	**0.47**
CR	**0.849**	**0.823**

Table 6.6: CR and AVE for organizational capabilities

Items in study	Operational Capabilities	Knowledge Management Capabilities
OPC01	0.72	
OPC02	0.878	
OPC03	0.79	
OPC04	0.65	
OPC05	0.85	
OPC06	0.73	
OPC07	0.81	
KMC01		0.64
KMC02		0.82
KMC03		0.88
KMC04		0.7
AVE	**0.606**	**0.59**
CR	**0.914**	**0.848**

Taken together, the evidence supports the convergent validity of the measurement model, although few of the constructs failed the test on AVE. All Standardized loadings estimates are found well above 0.5 values except for few items. Many, in fact, exceed the 0.7 value. Also, more importantly, composite reliability (ρ) is greater than 0.7 for all cases. In addition, the model fits relatively well based on the goodness of fit indices.

Since the requirements for convergent validity, composite reliability and discriminate validity are moderately fulfilled that support the acceptability of proposed model. Thus reliability and validity analysis and model fit indices indicates that model is fairly acceptable to proceed further to analyze the structural model.

6.5.3 Development and testing of structural model for MC

SEM has a tremendous capacity to simultaneously measure the item to construct relationships as well as relationships between various latent constructs. It also provides the assessment of predictive validity and amount of explained and unexplained variance in the model (Kline, 2005). Maximum likelihood estimation (MLE) approach is employed in this study to fit the SEM to the data with AMOS 22.0 software package.

In this study constructs for MC enablers and organizational capabilities, utilizing a survey instrument administered to Indian industry, are examined. Measurement scale for evaluating the different facets of MC practices implementation is tested for its validity and reliability. The measurement items in the scale for evaluating MC enablers are classified into three dimensions: MBP, SCI and DMP. The construct of MC enablers appears to adequately fit the data collected. The validity and reliability of the scale for evaluating the implementation of MC enabling practices are established with the systematic and scientific procedures used in this study.

MC enablers and capabilities model both are found to be fit and can be used for further analysis. The estimated parameters (MBP, SCI, DMP, OPC, KMC and COA) are found to be significant in both the models. Thus, it implies that all the variables are important and have significant impact on adoption of mass customization practices.

Practically, manufacturers should strive to improve on multiple dimensions of MC enablers, to arrive at the improvement of firm’s capabilities to adopt mass customization which may include achievement of competitive advantage for the organizations compared to contenders.

6.5.3.1 Model analysis using estimations

After the verification of structural model with underlying assumption the model coefficient estimations are examined to test the hypothesis. Path coefficients and level of significance (p-value) is employed to test the hypothesized relationships between MC enablers, firm's capabilities and determinant related to firm's competitive advantage. The hypothesized relationships of mass customization adoptions are presented in Table 3.9 (Chapter 3) which is further verified by structural equation modeling.

The hypothesized model permits to examine the direct relations between MC enables like MBP & DMP with SCI and further with firm's critical capabilities like OPC & KMC. The models also permit direct relationships between firm's critical capabilities and determinant related to firm's competitive advantage. The model comprising ten hypotheses is tested and results are presented in Table 6.7.

Figure 6.9 represents the structural paths with respective statistics and Table 6.7 shows the hypotheses under the influence of impact of MC enablers on firm's capabilities to adopt MC practices in an organization and impact of these capabilities on organization's competitive advantage.

6.6 Discussions on research objectives and hypotheses testing

In this section the results of hypothesis testing will be discussed in the light of research objectives, as discussed in chapter 1. In coming sub-sections the relationships are investigated empirically and discussions on hypothesis testing are provided. The Figure 6.9 shows complete standardized structural model for hypothesis testing.

The model outcome in term of CMIN/DF = 1.606 is less than the 3.00 maximum recommended by Kline (1998), GFI = 0.83, AGFI=0.80, CFI =.945, NFI = 0.88, RMR = 0.1 and RMSEA = .054. The fit indices suggest an acceptable fit for the model. The GFI is 0.83 which is near to acceptance limit 0.90, while the NFI is 0.88 which also near to 0.90. Furthermore, the CFI is .945, RMR is 0.1 and RMSEA is .054 are well within acceptable limits. In sum, the test results acceptably support the model for the hypotheses testing for MC enablers, organizational capabilities and competitive advantage construct. Hypothesis test results are shown in Table 6.7.

6.6.1 Hypotheses between mass customization enablers, organizational capabilities and competitive advantage

There are ten hypotheses between MC enablers, organizational capabilities and competitive advantage.

Table 6.7 Summarized results of hypothesized relationships

H. No.	Hypotheses Path			Estimate	S.E.	C.R.	P	Result
H1	SCI	←	MBP	0.146	0.046	3.194	0.001	Supported(+)
H2	SCI	←	DMP	0.349	0.111	3.136	0.002	Supported(+)
H3	OPC	←	MBP	0.418	0.046	8.991	0.001	Supported(+)
H4	KMC	←	MBP	0.05	0.046	1.078	0.281	Not Supported(-)
H5	OPC	←	DMP	0.245	0.095	2.582	0.01	Supported(+)
H6	KMC	←	DMP	0.551	0.124	4.458	0.001	Supported(+)
H7	OPC	←	SCI	0.442	0.084	5.287	0.001	Supported(+)
H8	KMC	←	SCI	0.196	0.085	2.301	0.021	Supported(+)
H9	COA	←	OPC	0.156	0.046	3.375	0.001	Supported(+)
H10	COA	←	KMC	0.873	0.086	10.17	0.001	Supported(+)

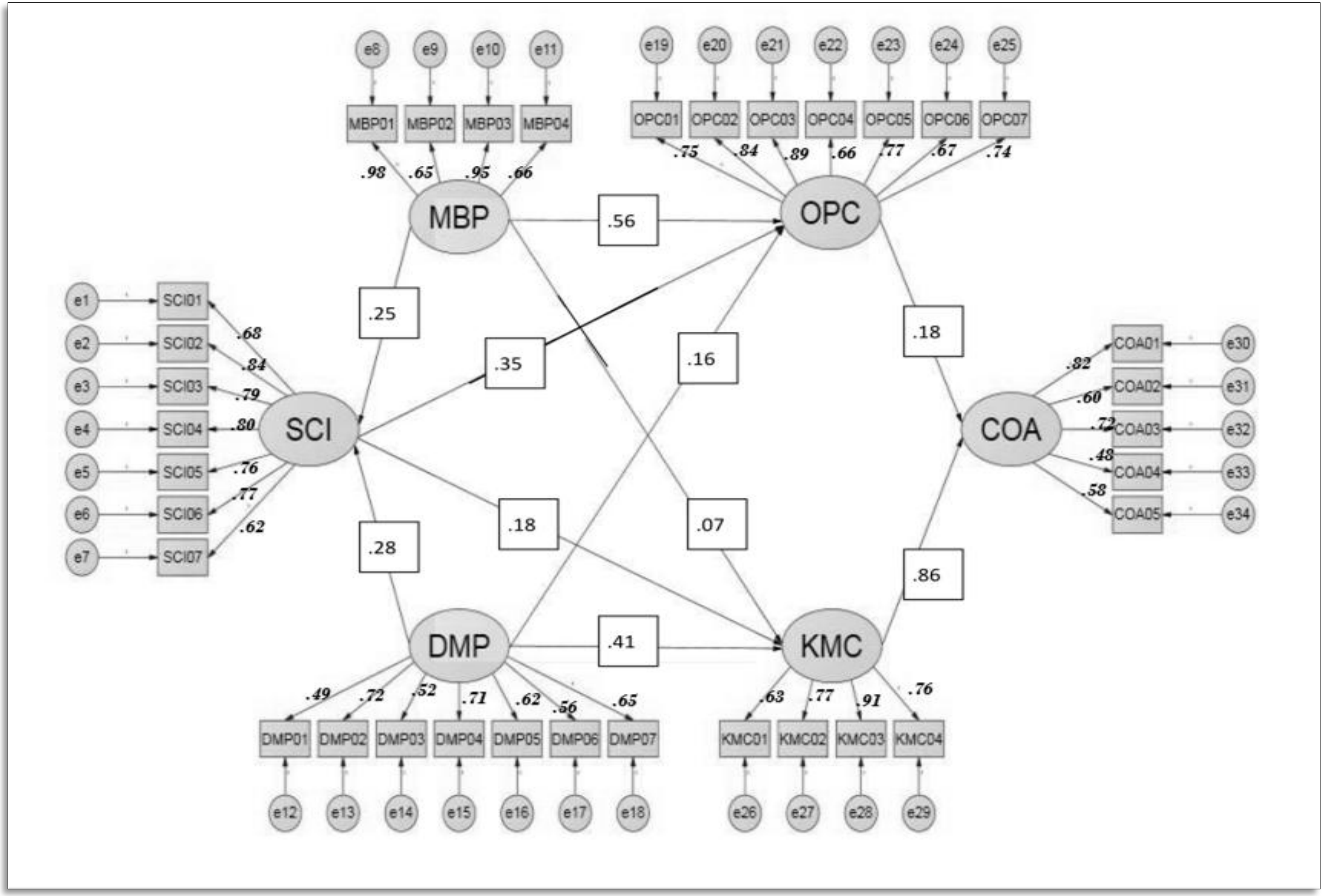

Figure 6.9 Complete standardized structural model for hypotheses testing

6.6.1.1 Relationship between MC Enablers (Hypothesis H1 and H2)

H1 and H2 are specially considered to analyze the role of independent enablers like modularity based practices (MBP) and digital manufacturing practices (DMP) on enabler related to big data and information technology driven supply chain integration (SCI) in an organization. To provide the detailed analysis, the impacts of MBP and DMP on SCI, the following hypothesis are suggested as:

H1 SCI….$^{+}$←….MBP

H2 SCI….$^{+}$←….DMP

As shown in table 6.7 the critical ratios (CR) are found as 3.194 and 3.136 which are greater than 1.96 for 95% confidence level. The relationship are positive and significant at the $p<0.001$ level (2-tailed) which implies that hypotheses H1 and H2 are strongly supported. Further the standardized path coefficients are examined for the above shown hypothesized path for MBP, DMP and SCI. This represents that when MBP and DMP goes up by 1 standard deviation, SCI goes up by 0.247 and .279 standard deviations respectively. The above analysis shows that constructs MBP and DMP positively affects one of the key enabling factor of mass customization i.e. SCI. This analysis also validates the results found in ISM hierarchical framework as mentioned in chapter 3.

6.6.1.2 Relationship between MC enablers and Firm's critical capabilities (Hypothesis H3 to H8)

To provide the detailed analysis, the impacts of MBP on OPC and KMC, the following hypothesis are suggested as:

H3 OPC….$^{+}$←….MBP

H4 KMC….$^{-}$←….MBP

H3 and H4 are specially considered to analyze the impact of mass customization enabler like modularity based practices (MBP) on critical capabilities like operational capabilities (OPC) and knowledge management capabilities (KMC) of an organization.

As shown in table 6.7 for hypothesis H3 the critical ratio (CR) is found as 8.991 which is greater than 1.96 for 95% confidence level. The relationship is positive and significant at the $p<0.001$ level (2-tailed) which implies that hypothesis H3 is strongly supported the statement i.e.*Modularity based practices are positively associated with Operational capabilities*. Further the standardized path coefficient is examined for the above shown hypothesized path for MBP and OPC. This represents that when MBP goes up by 1 standard deviation, OPC goes up by 0.561 standard deviations.

As shown in table 6.7 for hypothesis H4 the critical ratio (CR) is found as 1.078 which is lesser than 1.96 for 95% confidence level. The relationship is not significant at the p<0.05 level (2-tailed), In other words, the regression weight for MBP in the prediction of KMC is not significantly different from zero at the 0.05 level (two-tailed) which implies that hypothesis H4 is not supported the statement i.e. *Modularity based practices are positively associated with Knowledge management capabilities.* Further the standardized path coefficient is examined for the above shown hypothesized path for MBP and KMC. This represents that when MBP goes up by 1 standard deviation, KMC goes up only by 0.07 standard deviations.

To provide the detailed analysis, the impacts of DMP on OPC and KMC, the following hypothesis are suggested as:

H5 OPC…. $^{+}$←….DMP

H6 KMC…. $^{+}$←….DMP

H5 and H6 are specially considered to analyze the impact of mass customization enabler like digital manufacturing practices (DMP) on critical capabilities like operational capabilities (OPC) and knowledge management capabilities (KMC) of an organization.

As shown in table 6.7 for hypothesis H5 the critical ratio (CR) is found as 2.582 which is greater than 1.96 for 95% confidence level. The relationship is positive and significant at the p<0.001 level (2-tailed) which implies that hypothesis H5 is strongly supported the statement i.e *Digital manufacturing practices are positively associated with firm's Operational Capabilities*. Further the standardized path coefficient is examined for the above shown hypothesized path for DMP and OPC. This represents that when DMP goes up by 1 standard deviation, OPC goes up by 0.155 standard deviations.

As shown in table 6.7 for hypothesis H6 the critical ratio (CR) is found as 4.458 which is greater than 1.96 for 95% confidence level. The relationship is positive and significant at the p<0.001 level (2-tailed) which implies that hypothesis H6 is strongly supported the statement i.e. *Digital manufacturing practices are positively associated with firm's Knowledge Management Capabilities*. Further the standardized path coefficient is examined for the above shown hypothesized path for DMP and KMC. This represents that when DMP goes up by 1 standard deviation, KMC goes up by 0.407 standard deviations.

To provide the detailed analysis, the impacts of DMP on OPC and KMC, the following hypothesis are suggested as:

H7 OPC…. $^{+}$←….SCI

H8 KMC…. $^{+}$←….SCI

H7 and H8 are specially considered to analyze the impact of mass customization enabler like big data and information technology driven supply chain integration (SCI) on critical capabilities like operational capabilities (OPC) and knowledge management capabilities (KMC) of an organization.

As shown in table 6.7 for hypothesis H7 the critical ratio (CR) is found as 5.287which is greater than 1.96 for 95% confidence level. The relationship is positive and significant at the p<0.001 level (2-tailed) which implies that hypothesis H7 is strongly supported the statement i.e. *Supply chain integration is positively associated with operational capabilities*. Further the standardized path coefficient is examined for the above shown hypothesized path for SCI and OPC. This represents that when SCI goes up by 1 standard deviation, OPC goes up by 0.351 standard deviations.

As shown in table 6.7 for hypothesis H8 the critical ratio (CR) is found as 2.301which is greater than 1.96 for 95% confidence level. The relationship is positive and significant at the p<0.001 level (2-tailed) which implies that hypothesis H8 is strongly supported the statement i.e. *Supply chain integration is positively associated with knowledge management capabilities* Further the standardized path coefficient is examined for the above shown hypothesized path for SCI and KMC. This represents that when SCI goes up by 1 standard deviation, KMC goes up by 0.181 standard deviations.

6.6.1.3 Relationship between Firm's critical capabilities and Competitive advantage (Hypothesis H9 to H10)

To provide the detailed analysis, the impacts of firm's critical capabilities on competitive advantage achieved by firm on adoption of mass customization strategy as compared to contenders, the following hypothesis are suggested as:

H9 COA ….$^{+}$←…. OPC

H10 COA ….$^{+}$←…. KMC

As shown in table 6.7 for hypothesis H9 the critical ratio (CR) is found as 3.375 which is greater than 1.96 for 95% confidence level. The relationship is positive and significant at the p<0.001 level (2-tailed) which implies that hypothesis H9 is strongly supported the statement i.e. *Operational Capabilities are positively associated with firm's Competitive advantage.* Further the standardized path coefficient is examined for the above shown hypothesized path for OPC and COA. This represents that when OPC goes up by 1 standard deviation, COA goes up by 0.18 standard deviations.

As shown in table 6.7 for hypothesis H10 the critical ratio (CR) is found as 10.179 which is very greater than 1.96 for 95% confidence level. The relationship is positive and significant at the p<0.001 level (2-tailed) which implies that hypothesis H10 is strongly supported the statement i.e. *Knowledge Management Capabilities are positively associated with firm's Competitive advantage.* Further the standardized path coefficient is examined for the above shown hypothesized path for KMC and COA. This represents that when KMC goes up by 1 standard deviation, COA goes up by 0.866 standard deviations.

Chapter 7

Case Studies

Chapter 7

Case Studies

7.1 Introduction

To get deeper insight of the findings of the survey discussed in previous chapters, a case study approach was employed. In this chapter three case studies from Indian manufacturing industries are discussed. All three case studies were carried out with the objective of better understanding of mass customization adoption in Indian manufacturing industries which will help in interpretation of propositions formulated in present study.

The cases were selected in such a way as to maximize the variation on dimensions that are of potential importance for the degree of mass customization implementation according to extant literature. The cases were selected that were expected to be different with regard to heterogeneity in manufacturing dimensions such as raw material and final product, type of manufacturing processes, integration among supply chain partners, applications of advanced machining and technologies etc. which are important regarding mass customization implementation.

Cases were selected on the basis of product architecture i.e. customizable product. To keep anonymity the names of the case firms are not disclosed.

The case firms are:

Case firm A: Stainless steel modular kitchen manufacturer

Case Firm B: Made to Measure customized clothing manufacturer

Case Firm C: Gold and fabricated diamond/gem stone studded jewelry manufacturer

The cases in the following are presented in a largely descriptive format. First the common characteristics of the plant are discussed. Subsequently the firm is discussed on the dimensions such as product, size, geographical location, market and process. Capability assessment to adopt mass customization is also discussed for each case firm. The multi-attribute decision-making (MADM) is suggested to be a viable method for assessment of firm to adopt mass customization strategy. The analytic hierarchy process (AHP) can be used as a tool for MADM. However, AHP can only be employed in hierarchical decision models. For complicated decision problems with interdependencies, the analytic network process (ANP) is highly recommended. ANP can evaluate multidirectional relationship among decision elements.

Sections 7.2 to 7.4 illustrate the observation of each case respectively. Section 7.5 discusses cross case comparison, section 7.6 employed ANP to assess the capability of case firms to adopt mass customization and section 7.7 describes the important findings of case studies.

7.2 Case firm A: Stainless steel modular kitchen manufacturer

7.2.1 Introduction

Case firm A has taken the initiative to promote Stainless steel (SS) products and technology solutions to cater to the emerging market of stainless steel modular kitchen in India. The company particularizes in complete design, fabrication and installation of high quality stainless steel modular kitchen with an in-house design team comprising of architects, product designers and engineers to provide the clients with a flexible and creative approach in achieving spectacular and unique design solutions. The manufacturing facility is strategically located near Delhi (Gurgaon, Haryana), equipped with state-of-the-art CNC (Computer Numerical Control) machineries commissioned in March 2004 for fabrication and machining of specialty components in stainless steel. Firm has been set up with the objective of creating exclusive stainless steel lifestyle products, which are synonymous with quality, beauty and functionality. In-house design team is dedicated to exploring the frontiers of design and the product range. The range encompasses tableware, serving ware, gifts and home and office accessories.

As almost all international luxury modular kitchen brands manufacture wooden kitchen whereas case firm manufactures stainless steel modular kitchen. The firm is one of the firsts in India with such a wide range of products and solutions in stainless steel which is completely recyclable. The firm is wholly owned subsidiary of India’s largest stainless steel producer & with strong export markets in over 40 countries including US, Europe, Middle-East and South Asian region, explains our prompt access to the raw material required.

The firm has annual turnover of Rs. 350 Crore (2015-16) where more than 300 employees working in its plant at Gurgaon. The firm has retail outlets in major cities of India like New Delhi, Mumbai, Bangalore, Chennai, Gurgaon, Jaipur, Ahmadabad, Pune and Indore.

7.2.2 Product

Attentive to the needs of customers and the market, firm offer a wide range of styles and models to Indian market. Understanding the requirement of the Indian consumer firm's design team provides customized solution to suit customer's requirement. Firm produces kitchen variants like gallery kitchen, island kitchen, U-shaped kitchen and L-shaped kitchen on the basis of available space and customer desire.

All types of Kitchens made by case firm are made of high quality stainless steel grades like 202 and 304. Stainless Steel 202 is recommended for utensils where stainless steel 304 is recommended by government of India for commercial kitchens. It has a higher capacity to resist corrosion than stainless steel 202. They are eco-friendly, easy to maintain, fungus resistant and hygienic. For stainless steel modular kitchen in North India, SS 202 is recommended. SS 304 Grade is recommended in coastal areas.

7.2.3 Working procedure:

It starts with site visit & actual site measurement by site supervisor. Design team member at site discusses 2 dimensional and 3 dimensional designs according to customer's requirement. Final features and cost offered after discussion with customer at retail outlet. Production starts with a tentative delivery date given by customer. At installation site all electrical, plumbing and tiling markings done by site execution team. After completion of civil work at customer's location final measurement taken. Before dispatching the kitchen on site, firm pre install kitchen in trial room of their showroom to prevent any possible error. Once final inspection (Demo of Kitchen) cleared by the customer, delivery and installation starts from the next day.

7.2.4 Process Overview:

A basic kitchen consists of the following modules:

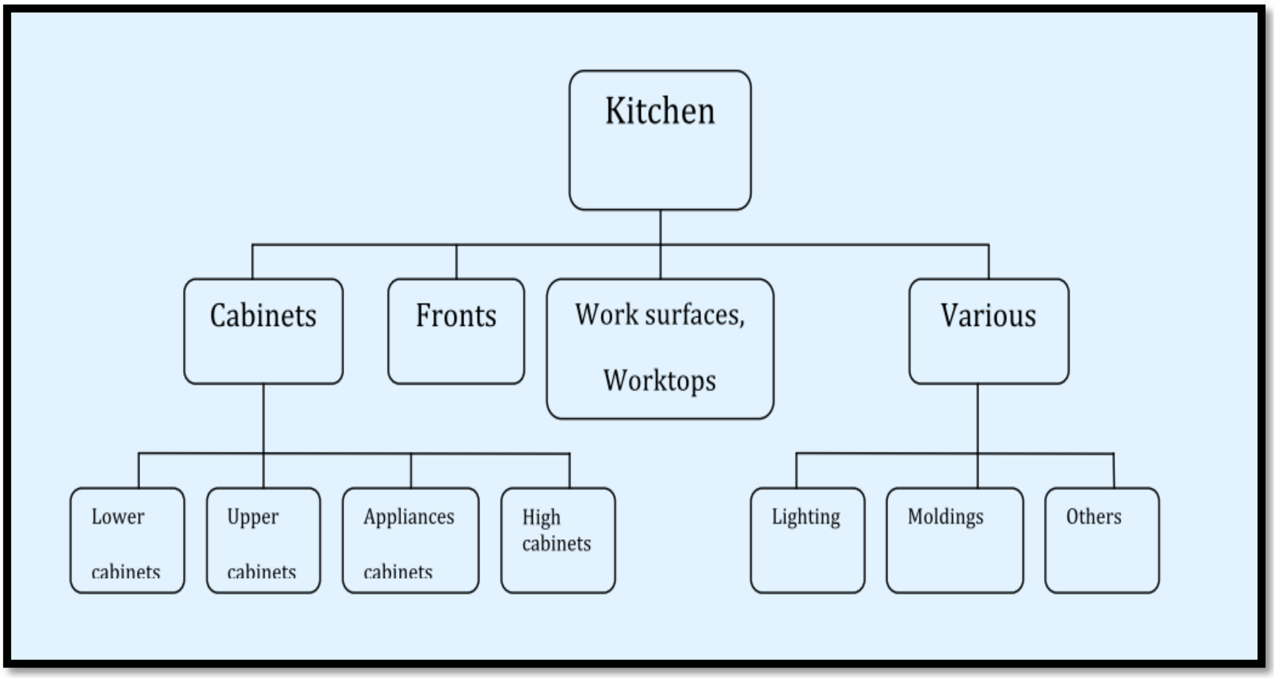

Figure 7.1: Basic Modular Kitchen Components

After assessing manufacturing feasibility, production planning personnel schedules following manufacturing processes for various components (See Figure 7.1) of a complete modular kitchen (i.e. Panel Cutting, Carcasses edging, drilling, mounting, internal parts mounting etc.)

- Sheet metal component cutting (for panels, cabinets & drawers)
- Grinding for smooth finish.
- Pressing & Bending
- Assembly
- Packing/Dispatch
- Installation at client site

7.2.5 Plant Characteristics:

Different plant characteristics are shown in Table 7.1

Table 7.1: Plant characteristics for Case Firm A

Plant Characteristics	Case Firm A
Product variety	Very High
Operational strategy	Make to Order
Equipment type	General Purpose/Specialized
Number of major operation	5
Main operations	Cutting, Grinding, Pressing & Bending, Assembly, Packing
Labor skill input	Moderate
Process flexibility	Moderate
Raw material Inventory	High
WIP	High
Finished goods Inventory	low
Best practices	ISO 9001,ISO 3834-2,ASME section VIII, TUV Rheinland

7.2.6 Capability assessment to adopt mass customization (Case Firm A)

Capability assessment (visibility of MC practices) of case firm A is illustrated in Table 7.2.As case firm A getting major portion of raw material from parent organization therefore managers are least concerned about supplies.

The firm offers modular kitchens solutions only after getting concrete sales order from the customer. Managers are more concerned about customer satisfaction. Retail staff members communicate to the customer about the benefits of application of stainless steel in modular kitchens compared to wooden alternative. They transfer the knowledge about the available grades/finishes of stainless steel and try to capture customer's preferences too. Design team involves customers in very early stage of product design to achieve more customization as per the customer needs. Team finalizes the product design only after cross functional feasibility analysis for product and production system.

Modularity is one of the key enabler to achieve MC. Modular kitchen manufacturing is completely based on mixing and matching of standard modules. Product modularity practices are present up to a great extent in case firm. Main operations like cutting, grinding, pressing, bending and assembly are executed at different sections of shop floor therefore firm showcase only a moderate amount of process flexibility. All the machinery and workers are associated with the particular section of operations so they are least flexible to work in another section.

Subassemblies and components are dispatched to the customer location and final form of finished product achieved only at customer site therefore criteria of form postponement is exist up to a great extent.

Case firm practices just in time supplies to very small extent. Firm schedules partial receiving of raw material (specific grade of stainless steel from overseas market) for few specific projects only.

Enterprise resource planning was kicked off by Accenture software services in their Gurgaon plant in December 2007. The firm successfully exercising SAP from last nine years in production planning, materials management, project management and finance modules.

Firm is also utilizes digital manufacturing practices up to a considerable extent. Plant’s cutting section employing laser cutting machine and turret punching machine for cutting of stainless steel sheets of different thicknesses. For best possible utilization of SS sheets design personnel of shop floor employing component nesting techniques with the help of CAD software. Visibility of mass customization practices in Case FirmA mentioned in Table 7.2.

Table 7.2: Mass customization practices in Case Firm A

Mass Customization Practices	Case Firm A					Degree to which practices are present
	1	2	3	4	5	
Supplier lead time reduction						To a small extent
Collaborative product design with supplier						To a considerable extent
Customer learning						To a considerable extent
Customer knowledge acquisition						To a considerable extent
Collaborative product design with customer						To a considerable extent
Data Integration						To a small extent
Cross functional teams for process improvement						To a considerable extent
Cross functional teams for product development						To a considerable extent
Product modularity						To a great extent
Process modularity						To a considerable extent
Dynamic teaming						To a small extent
Form postponement						To a great extent
Just in time supply chain						To a considerable extent
Preventive maintenance						To a great extent
Enterprise resources planning						To a great extent
Applications of CNC machines						To a considerable extent
Automated inspection & testing						To a small extent
Automated material handling						To a small extent
Computer aided manufacturing						To a great extent
Computer aided design						To a great extent
Online product configurators						To a small extent
Electronic commerce						To a considerable extent

7.3 Case firm B: Made to Measure customized clothing manufacturer

7.3.1 Introduction

The case company was established in year 2003. It is India's first made to measure (MTM) clothing manufacturer. Subsidiary of India's largest branded fabric and fashion retailers. Company manufactures customized suits and formal trousers at their manufacturing plant located in Karnataka. It has 70 retail outlets and 25 exclusive made to measure outlets around the country. Gross revenue of case company is Rs. 400 Crore. It has annual capacity to produce one million suits & jackets and two million trousers. Around 500 employees are working at its Karnataka plant. Customized clothing sewn from standard size base pattern. The concept behind made to measure is to provide the customer a tailored fit garment with high quality fabric, trims, designs (cuff, collar, pockets) & styles (lapels) according to customer preferences. Mass customized garments are more expensive and superior to ready to wear garments but cheaper than bespoke one.

7.3.2 Product

Case firm B manufacture suits, jackets and trousers. The firm is a niche service that allows a discerning customer to customize his garment from start to finish. Suits, shirts and trousers are crafted with great detail and precision, and to fit better than ever, because of a unique computerized process newly introduced. The service is only offered through exclusive outlets.

7.3.3 Working procedure:

In made to measure practices, the case firm shows similar processes of in-store activity in the following way. When customers enter the store, with the help of trained sales people, their sizes are taken by hand, and the styles and fabrics they prefer are selected by sample swatches and displays. After that, information about customer's size is recorded and stored in the computer system by trained sales people. With the computer system, every bit of information about the customer with photographs of different angles in order to capture the details of his fit, posture and walk is communicated to the manufacturing unit. In every process, sales people help the customer to choose what styles she/he desires as specifically as possible. Then a base pattern is selected that most closely corresponds with the customer's measurements. This base pattern is altered to match the customer’s measurements. The garment is constructed at the plant from this altered pattern.

The primary benefits to the customer of MTM clothing are that the garments will be well fitted to the customer's body and the customer may have the opportunity to customize the fabric and detailing.MTM also requires fewer fittings than bespoke, resulting in a shorter wait between customer measurement and garment delivery. The primary disadvantage of MTM is that the customer must wait up to several weeks for the garment to be sewn and delivered. A typical price markup for a MTM item is 15% over the price of its ready-to-wear counterpart. Unlike bespoke garments, which traditionally involve hand sewing, MTM manufacturers, use both machine- and hand sewing.

7.3.4 Process Overview:

For mass customization as such, advanced computer technology is being utilized extensively in the apparel industry from product planning to manufacturing and marketing. Particularly for fast and accurate production in the apparel manufacturing process, flexible computer-aided manufacturing systems are being applied to apparel manufacturing processes such as apparel pattern making, grading, and marker making.

The whole process starts with order receiving with customer measurement data and recorded photographs of the customer from different angles, from retail outlet. Base pattern alteration, marker preparation, fabric cutting, fusing and sewing are key processes. Facility personal needs to add allowance with net dimension of approved samples. Process of marker making executed on a thin paper which contains all the components of all sizes of a particular style. Just before the step of cutting, fabric is unfold in lay form. Special types of cutters are employed to cut fabric according to the exact dimension required. Sewing is done by different types of machines and quality inspection is also done at the same time. For ironing and finishing garments are treated by steam. The final inspection should meet specs given by buyer. After packing the garments are placed in a hard paper box to minimize damages during the transportation. The cartoons contain all the information over the box according to buyer specification.

7.3.5 Plant Characteristics:

Different plant characteristics are shown in Table 7.3

Table 7.3: Plant characteristics for Case Firm B

Plant Characteristics	Case Firm B
Product variety	High
Operational strategy	Make to Order
Equipment type	Specialized
Number of major operation	5
Main operations	Pattern alteration, Marker making, Fabric cutting, Fusing, Sewing
Labour skill input	moderate
Automation level	High
Process flexibility	low
Raw material Inventory	High
WIP	Moderate
Finished goods Inventory	Low
Best practices	ISO 9001,ISO14001

7.3.6 Capability assessment to adopt mass customization (Case Firm B)

To perform capability assessment to adopt mass customization by case firm B, visibilities of mass customization practices illustrated in Table 7.4. In case firm managers are least concerned about supplier integration/collaboration as the parent organization providing all raw material in bulk with almost all available grade of fabrics as displayed to the customer at retail outlet as sample swatches.

The base pattern which is most closely corresponds with the customer's measurements taken at retail store, is altered to match the exact dimensions. The garment is constructed at the plant from this altered pattern. Production planning team plans for scheduling and loading for the specific product. The type of cutter and sewing machine also got selected at the time of initial planning. Product modularity practices are present up to a considerable extent in case firm as parts of the final product with different sizes, shapes and styles produced at the different work station as per the marker preparation. All the processes and labors are associated with the particular section of operations so they are stiff to work in another section of manufacturing.

To integrate all functional departments the case firm utilizing ERP software with all core modules since year 2009. Company prefers more automation during raw material to finished product conversion steps .To achieve this firm largely relies on automated material handling systems and automated inspection equipments. To reduce production lead time and to improve quality of product firm utilizing application of CNC machines up to a great extent.

Case firm produces mass customized products according to individual body measurements using CAD system. Computer aided manufacturing also playing an important role for mass customization in the case firm. Firm is employing several different types of dedicated MTM CAD systems for textile industry including brands like Gerber, Lectra and Investronica etc. to enhance customer responsiveness and operational efficiency. Visibility of mass customization practices in Case Firm B mentioned in Table 7.4.

Table 7.4: Mass customization practices in Case Firm B

Mass Customization Practices	Case Firm B					Degree to which practices are present
	1	2	3	4	5	
Supplier lead time reduction						To a small extent
Collaborative product design with supplier						To a small extent
Customer learning						To a considerable extent
Customer knowledge acquisition						To a considerable extent
Collaborative product design with customer						To a considerable extent
Data Integration						To a considerable extent
Cross functional teams for process improvement						To a small extent
Cross functional teams for product development						To a considerable extent
Product modularity						To a considerable extent
Process modularity						To a small extent
Dynamic teaming						To a small extent
Form postponement						To a small extent
Just in time supply chain						To a small extent
Preventive maintenance						To a great extent
Enterprise resources planning						To a great extent
Applications of CNC machines						To a great extent
Automated inspection & testing						To a small extent
Automated material handling						To a considerable extent
Computer aided manufacturing						To a considerable extent
Computer aided design						To a great extent
3 D Body scanner						To a considerable extent
Online product configurators						To a small extent

7.4 Case firm C: Custom Jewelry manufacturer

7.4.1 Introduction

Case Firm C manufactures gold, silver and other metal and fabricated diamond/gem stone studded jewelry. The firm established in year 2006 at Jaipur, Rajasthan. It has employee strength is around 60 and Annual turnover Rs.80 Crore. The firm is producing personalized jewelry to their local customers as per their specific requirements. For the metallic raw material like gold, silver etc. the firm relying on local supplier base but procuring diamond and other precious stone from abroad. The firm is utilizing the pool of skilled labor and designers available in western part of India. To maintain trust among customers, the firm achieved BIS certification for hallmarking of gold jewelry from the beginning of establishment.

7.4.2 Product

Product mix includes rings, ear rings, chains, pendants/sets, necklaces, bracelets, tanmaniyas and bangles etc. the case firm also deals in traditional jewelry with unique and innovative designs produced specifically for bridal collection. Products are also classified on the basis of type of raw metal i.e. gold, silver, white gold and platinum. Even further as per the requirement of customer, company provides almost all variants of raw material on the basis of its purity i.e. from 18 Carats to 24 Carats. Apart from the purity of raw material, the product also classified on the basis of characteristics of diamond and precious stones namely cut clarity, carat, and color.

7.4.3 Working procedure:

Customized jewelry requirements of the customers are handled by the designers of the case firm. The process is start with a concept, and then it is converted into rough sketch by the designer. The prime objectives of the design team are to educate the customer on the available combination of metals, diamonds and precious stones. Once the basic requirement of the customer is captured final drafting and designing process starts in collaboration with the customer. The designer’s concept and drawings are employed by the model maker to create original piece of jewelry. All other processes like molding, casting, polishing, embellishment/setting, finishing, rhodium plating, quality check and packaging are performed at different section of manufacturing unit.

7.4.4 Process Overview:

Jewelry manufacturing process is a composite process undergoing a long and slow process. Each product undergoes a series of procedural steps like molding, casting, polishing, embellishment/setting, finishing, rhodium plating, quality check and packaging.

Professional molders turn the sketch into a master mold which sets the final outcome rests on the master mold. The wax replicas are placed in steel containers which are then occupied with investment powder Liquefied metal is then poured into the flasks, allowed to cool, then demolished to reveal the jewelry in casting form. Every part must be polished while the mount is being made. After the product has passed from the polishing and finishing departments, it has to undergo for embellishment process. Most plating is done by electro- deposition, rhodium or other metals being practiced by passing an electric current through a solution and then channelizing the plating metal from the piece of pure metal to the object set aside in the solution.

The process of quality checking is done by very experienced workers; it is then forwarded for final packaging and labeling.

7.4.5 Plant Characteristics:

Different plant characteristics are shown in Table 7.5

7.4.6 Capability assessment to adopt mass customization (Case Firm C)

The supply chain for the jewelry industry is complex and fragmented. Raw materials may come from many different types of sources in many different countries; they may be sold several times, mixed, and converted into new products before being sold to the end consumer. Case firm procure raw material, diamonds and other precious stones from local traders as well as from global supplier. Particularly in case of raw material like gold, all purchases being executed on the basis of weekly or monthly cycles depends on the consumption trends. Remaining parts are purchased on the basis of customer requirement. One of the core competences of case firm to provide customized jewelry is the collaboration with customer during initial design stage. Sales people are well capable to acquire customer knowledge as well as to educate them on technical feasibility of jewelry manufacturing with different combination of metal and stones. The designers and customer examines about the manufacturing feasibility of required product with skilled persons, from all sections like molding, casting, polishing, setting and plating.

Table 7.5: Plant characteristics for Case Firm C

Plant Characteristics	Case firm C
Product variety	High
Operational strategy	MTO/MTS
Equipment type	General & Specialized
Number of major operation	6
Main operations	Designing, Molding, Casting, Polishing, Embellishment, Rhodium plating
Labour skill input	High
Automation level	Low
Process flexibility	High
Raw material Inventory	Moderate
WIP	High
Finished goods Inventory	Low
Best practices	ISO:9001, BIS Hallmark

Product modularity is one of the key enabler to achieve mass customization in jewelry manufacturing. Case firm utilizes the concept of modularity in product manufacturing specifically in the items like studded jewelry. For entirely new concept design, firm hardly able to utilize product modularity. Production system of case firm also employed a fix route of processes however to enhance capacity case firm outsources few jobs like mould making and casting. A pool of dedicated skilled and semi-skilled workforce has been employed for different sections of manufacturing. Dynamic teaming practices are almost invisible in the firm. Daily maintenance activities (tools and equipment cleaning, maintaining, modest modification, etc.) are necessary to prevent the deterioration of facilities. Furthermore, case firm performed regular check on the deterioration status of tools utilizing in polishing and testing process. The repair/replacement of parts and tools, as well as the preparation for spare items are conducted according to the scheduled plan.

For the purpose of management information system the firm is using legacy software system installed from the establishment of the firm. There is hardly any type of automation practices are employed in the domain of material handling, inspection and testing. Case firm has very little knowledge about the application of the 3D printing in jewelry manufacturing and online applications like web based product configurators to collaborate with customer located at distances. However firm extensively employing computer aided design practices during design stage of manufacturing. Visibility of mass customization practices in Case Firm C is mentioned in Table 7.6.

Table 7.6: Mass customization practices in Case Firm C

Mass Customization Practices	Case Firm C					Degree to which practices are present
	1	2	3	4	5	
Supplier lead time reduction						To a small extent
Collaborative product design with supplier						To a considerable extent
Customer learning						To a considerable extent
Customer knowledge acquisition						To a considerable extent
Collaborative product design with customer						To a considerable extent
Data Integration						To a small extent
Cross functional teams for process improvement						To a considerable extent
Cross functional teams for product development						To a considerable extent
Product modularity						To a considerable extent
Process modularity						To a small extent
Dynamic teaming						To a small extent
Form postponement						To a small extent
Just in time supply chain						To a small extent
Preventive maintenance						To a considerable extent
Enterprise resources planning						To a small extent
Applications of CNC machines						To a small extent
Automated inspection & testing						To a small extent
Automated material handling						To a small extent
Computer aided manufacturing						To a considerable extent
Computer aided design						To a great extent
Online product configurators						To a small extent
3 D Printing						To a small extent

7.5 Comparative analysis

The study involved multiple case studies to better relate and interpret the finding of quantitative analysis carried out in previous chapters. The firms selected for case studies show diverse characteristics on several important dimensions mentioned in the literature. Table 7.7shows the comparison among case study firms regarding adoption of mass customization practices. Different colors show different levels of implementation of mass customization practices among case firms.

Table 7.7:Comparison of adoption of mass customization practices in Case Firms

S.No.	Mass Customization Practices	Case Firms		
		A	B	C
1	Supplier lead time reduction			
2	Colloborative product design with			
3	Customer learning			
4	Customer knowledge acquisition			
5	Colloborative product design with			
6	Data Integration			
7	Cross functional teams for process			
8	Cross functional teams for product			
9	Product modularity			
10	Process modularity			
11	Dynamic teaming			
12	Form postponement			
13	Just in time supply chain			
14	Preventive maintenance			
15	Enterprise resources planning			
16	Applications of CNC machines			
17	Automated inspection & testing			
18	Automated material handling			
19	Computer aided manufacturing			
20	Computer aided design			
21	Online product configurator/3 D Printing			
22	Electronic commerce			

No Implementation → **Complete Implementation**

7.6 Lessons learned from case studies

The important outcomes on mass customization adoption in select Indian firms can be summarized as follows:

Consistent and extensive adoption of mass customization practices like customer learning, customer knowledge acquisition, preventive maintenance and application of computers in product design are widely used in select Indian industries. These findings from the cases strengthen the survey findings. It has been observed that case firm A has adopted mass customization practices formally and extensively and case firm B has also adopted these practices to a considerable extent. However case firm C has implemented only a few mass customization practices. Major cause of not adopting mass customization practices as mentioned by case firms is unfamiliarity with these practices. Practices related to customer integration are widely implemented to all selected case firms whereas practices like ERP have been adopted by all case firms except firm C.

7.7 Capability assessment to adopt mass customization strategy in case firms (Analytic Network Process Technique)

7.7.1 Introduction

The multi-attribute decision-making (MADM) is proposed to be a feasible technique for assessment of firm to adopt mass customization strategy. The analytic hierarchy process (AHP) can be applied as an instrument for MADM. Yet, it can only be utilized in hierarchical models. For complex decision issues with interdependencies, the analytic network process (ANP) is highly recommended. ANP can assess multidirectional linking among decision variables (Saaty, 1996).

Figure 7.2 exemplifies the model being framed of four stages. At the apex level is the problem itself (Goal i.e. capability assessment of case firm to implement mass customization strategy), while the bottom level constitutes three decision alternatives (i.e. Case Firms).The criteria (Dominating mass customization enablers) and sub-criteria (Mass customization Practices) represent the middle two levels.

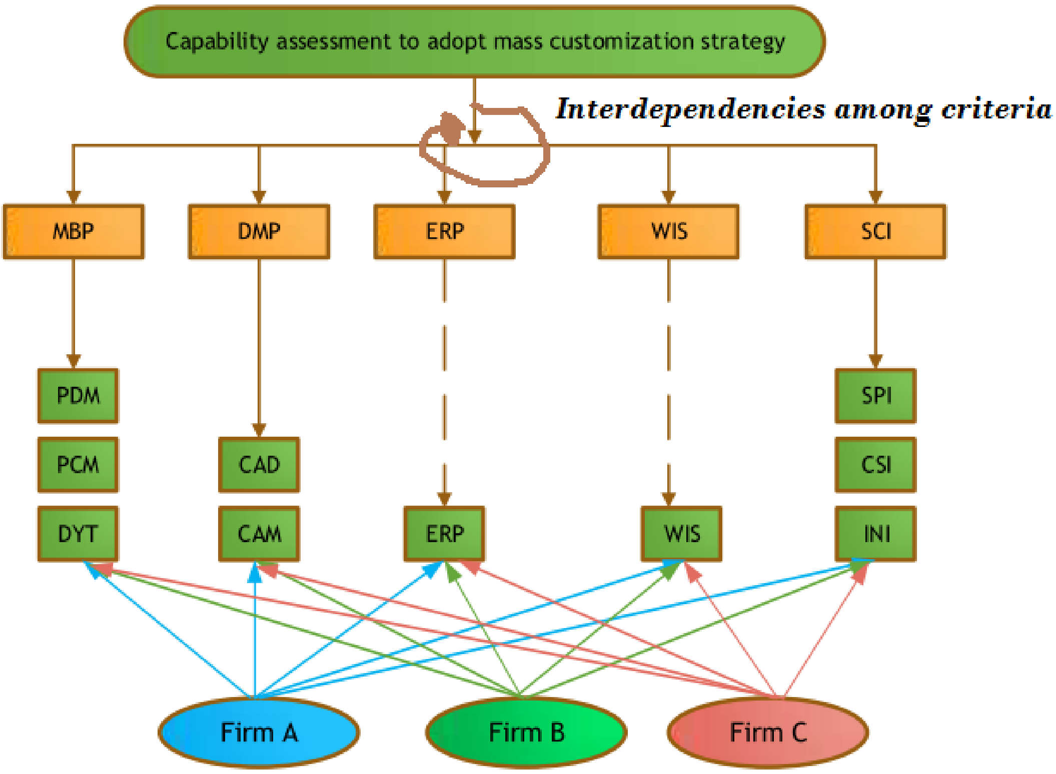

Figure 7.2: ANP Model for capability assessment of case firms

In this study, we employed a group of 16 experts to assign a priority to five criteria (i.e. modularity based practices, digital manufacturing practices, enterprise resource planning, web based interactive system, supply chain integration) for assessment of case firm's capability to adopt mass customization. These five criteria are interrelated to a definite extent. For instance, web based interaction enhances integration among supply chain partners. Where modularity based practices helps to enhance the interaction between customers and manufacturer over the internet. Hence, ANP is more helpful to be engaged in this interdependent relationship.

According to Sarkis (1999), ANP comprises four main steps:

(1) carried out pair-wise comparisons on various decision levels;

(2) Identifying the relative weight in sub-matrices contained by the super-matrix;

(3) Conforming the values in the super-matrix;

(4) Advancing the super-matrix to limiting powers.

7.7.2 Pair-wise comparisons

The usual modus operandi of a pair-wise comparison is to request experts to compare two sub-cluster's elements with respect to their respective cluster's element. Saaty (1996) has developed a 9-point priority scale of measurement. Table 7.8 provides an example of the role of the fundamental comparison scale.

Table 7.8: Fundamental comparison scales

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

After having consulted with five supply chain professionals, the pair-wise comparisons in this study are of three bases. First, this study adopts the original pair-wise comparison results in the criteria and sub-criteria for the three case firms. Second, this study adjusted part of the original relative weights of the criteria with respect to the top goal and those of the sub-criteria with respect to their respective criteria. Third, for synthesizing the relative weights among the criteria, other pair-wise comparisons have to be made for this study.

7.7.3 Relative weights of elements and consistency ratio of matrices

After the pair-wise comparison matrices are developed, a vector of priorities (i.e. a proper or eigen vector) in each matrix is calculated and is then normalized to sum to 1.0 or 100 per cent. This is done by dividing the elements of each column of the matrix by the sum of that column (i.e. normalizing the column); then, obtaining the eigen vector (eVector) by adding the elements in each resulting row (to obtain 'a row sum') and dividing this sum by the number of elements in the row (to obtain 'priority or relative weight'). Moreover, for ascertaining the consistency of the judgment matrices, Saaty (1994) suggested three threshold levels: (1) 0.05 for 3-by-3 matrix; (2) 0.08 for 4-by-4 matrix; and (3) 0.1 for all other matrices.

7.7.4 Super matrix and the limit matrix

The system that consists of cluster and sub-cluster matrices must translate to a Super-matrix. This can be achieved by entering the local priority vectors in the super-matrix, which in turn obtains global priorities. Table 7.9 shows the super- matrix for the ANP decision model. After entering the sub-matrices into the super-matrix and completing the column stochastic, the super-matrix is then raised to sufficient large power until convergence occurs (Saaty, 1996; Meade and Sarkis, 1999). Table 7.10 presents the final limit matrix.

Table 7.9 Super- matrix for the ANP decision model

	Goal	Case Firm A	Case Firm B	Case Firm C	DMP	ERP	MBP	SCI	WBIS	cad	cam	csi	dyt	ini	pcm	pdm	spi
Goal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0
DMP	0.24	0.00	0.00	0.00	0.00	0.13	0.14	0.06	0.06	0	0	0	0	0	0	0	0
ERP	0.12	0.40	0.33	0.33	0.05	0.00	0.06	0.20	0.05	0	0	0	0	0	0	0	0
MBP	0.43	0.00	0.00	0.00	0.15	0.13	0.00	0.06	0.28	0	0	0	0	0	0	0	0
SCI	0.08	0.00	0.00	0.00	0.09	0.13	0.09	0.00	0.11	0	0	0	0	0	0	0	0
WBIS	0.13	0.10	0.17	0.17	0.21	0.13	0.21	0.18	0.00	0	0	0	0	0	0	0	0
cad	0.00	0.04	0.08	0.10	0.38	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0
cam	0.00	0.08	0.10	0.02	0.13	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0
csi	0.00	0.07	0.13	0.04	0.00	0.00	0.00	0.12	0	0	0	0	0	0	0	0	0
dyt	0.00	0.02	0.03	0.08	0.00	0.00	0.07	0.00	0	0	0	0	0	0	0	0	0
ini	0.00	0.08	0.04	0.05	0.00	0.00	0.00	0.31	0	0	0	0	0	0	0	0	0
pcm	0.00	0.02	0.02	0.05	0.00	0.00	0.12	0.00	0	0	0	0	0	0	0	0	0
pdm	0.00	0.16	0.08	0.14	0.00	0.00	0.31	0.00	0	0	0	0	0	0	0	0	0
spi	0.00	0.03	0.03	0.02	0.00	0.00	0.00	0.07	0	0	0	0	0	0	0	0	0
Case Firm A	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.15	0.26	0.56	0.30	0.30	0.49	0.54	0.54	0.53
Case Firm B	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.27	0.41	0.32	0.54	0.16	0.31	0.16	0.30	0.33
Case Firm C	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.08	0.33	0.12	0.16	0.54	0.20	0.30	0.16	0.14

Table 7.10 Limit matrix for the ANP decision model

	Goal	Case Firm A	Case Firm B	Case Firm C	DMP	ERP	MBP	SCI	WBIS	cad	cam	csi	dyt	ini	pcm	pdm	spi
DMP	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
ERP	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
MBP	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
SCI	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
WBIS	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
cad	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
cam	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
csi	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
dyt	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
ini	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
pcm	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
pdm	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
spi	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Case Firm A	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Case Firm B	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Case Firm C	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

7.7.5 Discussion

The limit matrix demonstrates the local proportional weights for all the factors in the super matrix. With the objective to determine the value of ANP, outcomes of the normalized relative weights of the alternatives obtained from ANP. All three case companies have been considered to assess the capability to adopt and implement mass customization strategy. As per the final out put report from ANP model shown in Table 7.11, Case Firm A and Case Firm B being capable in adopting mass customization strategy compared to Case Firm C. It has been observed that case firm A has adopted mass customization practices formally and extensively and case firm B has also adopted these practices to a considerable extent. However case firm C has implemented only a few mass customization practices. Table 7.11 also shows the local relative weights of the three case firms established on the outcomes from ANP. In this case analysis, case firm A is highly capable to adopt mass customization as the firm considerably implemented relevant practices. It has the largest relative weights (= 0.445, from ANP in Table 7.11) compared to firm B and Firm C.

Table 7.11: Final out put report from ANP model

Alternatives	Total	Normal	Ideal	Ranking
Case Firm A	0.1670	0.4455	1.0000	1
Case Firm B	0.1355	0.3615	0.8115	2
Case Firm C	0.0723	0.1929	0.4331	3

Chapter 8
Conclusion

Chapter 8

Conclusion

8.1 Introduction

The concluding chapter submits the summary of the research with major stress on how this thesis has added to the body of research on mass customization adoption in the context to developing country like India. Emphasis is also placed on the theoretical and practical implications of the study. Furthermore, the limitation of the study and also few suggestions for future research are outlined.

8.2 Summary of the research

Chapter 1 furnishes a general idea of the study and submits the four research questions. To address these research questions, Chapter 2 keys out gaps in existing knowledge via an analysis of currently available literature on mass customization. The next Chapter identifies significantly important enablers for mass customization by means of interpretive structural modeling(ISM). In order to find answers of research question this chapter also builds the theoretical framework of the research and also establishes the research hypotheses among the MC enablers, firms capabilities and competitive advantage based on the finding from the literature and ISM method. Chapter 4 summarizes the research design followed to carry out current research. It was observed that combining survey methods and case study is most suitable way to deal with the issues of mass customization strategy implementation in Indian industries. A brief explanation is offered to make acquainted with suggested methodology to address the research objectives.

Next section of preliminary data analysis examines various responses for enablers of mass customization and organizational capabilities.

A step by step method for structural equation modeling (SEM) was employed using AMOS software version 22.0 in subsequent chapter. The validity of construct and measurement model fit was evaluated at the beginning via confirmatory factor analysis to confirm that the measurement model contented the initial phase of SEM. To assess the importance of theoretical associations by associated hypotheses, addressing the research objectives, the structural framework was then formulated and applied to carrying out the final step of SEM.

Three case studies are conducted to obtain information about the practical implementations of mass customization and to get deeper insights of the findings of research. The manufacturing units of analysis are from modular kitchen, apparel and jewelry industries. Assessment of manufacturing units regarding mass customization implementation is presented with the help of analytical network process (ANP).

8.3 Theoretical contribution

The research caters a vital evaluation of the existing literature on mass customization, organizational capabilities and competitive advantage in mass customization adoption perspective. The critical review of literature directing to a comprehensive outline of appropriate fields of study from which the research gaps were keyed out and a holistic abstract framework of organizational capability-based competitive advantage of the organization on mass customization adoption was formulated. This model represents one of the first endeavors to combine the resource based view (firm's assets like MC enablers) and dynamic capability based perspective (operational and knowledge management capabilities), and their impacts on organizational competitiveness.

A noteworthy difference from earlier studies on mass customization capablenesses (e.g. Tu et al. 2004) is combining and refining the idea of mass customization enablers into modularity and digital manufacturing perspectives. Implementation of firm's existing resources like modularity and digital manufacturing have a direct positive effect on organizational capabilities while indirectly through big data driven supply chain integration.

In addition, the framework emphasizes the significance of operational capabilities as dynamic capabilities to achieve an organization's competitive advantage in mass customization adoption perspective, a viewpoint which was ignored in the previous studies. Therefore, the interrelationships between firm's operational capabilities and competitive advantage were investigated as well to underline their worthy contribution to the strategically important research outcome instead of economic outcomes.

There is a deficiency of empirical support in the text on knowledge management capability and competitive advantage on mass customization adoption, particularly in the Indian context. This research fills this research space by carrying on a questionnaire survey of a cross-section of companies in India to examine the conceptual relations in the suggested framework.

The observed conclusions affirmed the outcomes of ISM hierarchical model as well as hypothetical framework formulated in this study and confirmed that modularity based practices and digital manufacturing practices are strongly related to big data driven supply chain integration. As both are dominating enablers of mass customization; MBP is equally important compared to DMP. These mass customization enablers, however, do not directly affect firm's competitive advantage. Their affects are entirely mediated via firms existing capabilities and, consequently depend upon their effectiveness in backing organizational competitive advantage.

The dynamic capabilities such as firms operational and knowledge management capabilities play a decisive role in achieving competitiveness of the firm, which plans the fundamental component of the research framework. The empirical results too verify that the dynamic capability view based approach of these capabilities is effective in a developing country like India.

One more considerable suggestion of the research links to procedural matters. A mechanism for evaluating enabling factors, capabilities and competitive advantage comprising of six first-order latent factors was developed from the previous text and modified in the context of mass customization for the current research. As nearly all theoretical models of operational and knowledge management capabilities have been formulated and tested in western countries. This research builds a contribution to the literature by examining and altering the measurement model in India. This tool can be employed in other research projects hereafter and can also be adapted in other circumstances such as other countries.

At last, the use of the step wise methodology in structural equation modeling to check the measurement and structural models is of significant importance. Majority of prior studies inquiring the relationship among different capabilities and competitive advantage employed a number of analytical techniques like regression and factor analysis which permitted the assessment of just a solo relationship between the dependent and independent factors at once. The structural equation modeling is capable to examine the relationship involving two or more variables, in a greater extent, is especially helpful. Foremost, multivariate regression techniques allows the investigator to evaluate measurement attributes and examine the fundamental theoretical relationships with single technique. It is also capable to disclose overlooked conceptions in these associations and rectify for measurement error in the estimation process. More particularly, SEM can probe a series of dependence relationships concurrently in which a hypothesized dependent variable becomes an independent variable in a subsequent dependence relationship (e.g. MBP→ SCI; SCI → KMC; and KMC → COA in this study). Altogether these attributes of the structural equation modeling method were employed for evaluating the research framework suggested in the study and, thus, bettering the precision of its results in comparing with results from previous research.

8.4 Managerial implications

Attaining a competitive advantage is invariably one of the strategic goals of each and every organization. To stay sustainable and competitive in the dynamic situations nowadays, companies are essentially obtaining solid dynamic capabilities by carrying out a diverse mass customization practices. Hence, the most significant worry of management must be how to build up and efficiently utilize such exercises to mend the business firm's organizational capabilities. This report seeks to furnish a kind of real life proposals for directing corporate business executive, to be victorious in employing MC projects to accomplish premeditated industrial targets.

First of all, the research proposes that practicing personals should comprehend and acquire a functional approach of carrying out all mass customization enabling factors which is composed of the two perspectives of modularity and digital manufacturing based practices. These two enabling factors should not be considered in isolation but rather should be connected to MC enabling factor i.e. supply chain integration and the firm's capabilities to exploit and sustain a competitive advantage through mass customization adoption.

Secondly, organization should, on one hand of view, align and coordinate information technology and big data driven practices in to the two views of supply chain integration (i.e. external and internal integration) to facilitate dynamic nature of operational and knowledge management capabilities. On the other hand, they need to keep in mind that the practices related to SCI are more important to operational capabilities and also exert authority on other capabilities such as KMC.

Although the organization's critical tactical targets are economic output and competitive advantage, management should realize that firm's resources (tangible and/or intangible) such as mass customization enablers, intrinsically do not improve these outcomes without anything intervening, particularly with the existence of organizational capabilities. Though, enabling factors of MC can, through fully mediated support of organizational capabilities, provide a way to attain a competitive advantage, management should initiate with the practicing mass customization enabling factors from all viewpoints, which successively will offer the policy essential for enhancing the effectuality and competence of existing capabilities, the fundamental driver in meliorating organizational competitiveness.

8.5 Limitations of the study

The limitations of the present research are as follows:

Firstly, the research may suffer from possible reaction prejudice connected with the single respondent and the exclusive modus operandi of data gathering applied. Furthermore, the multifaceted theoretical framework projected in this research has made a single technique survey hard to implement. Hence, future studies may employ the ordered methods of surveying to acquire deeper insight into study matters of concern.

Secondly, in this research collected data from top management dealing with a mixture of job routines, presuming that their judgments' concerning MC enablers, firms' capabilities and competitive advantage are objective. Yet, an over-enthusiastic responses and/or under-describing of few processes may take place as a consequence of the responder's work gratification or job features.

Thirdly, equally in the instance in several similar studies, difficulties with sampling process take place and it is hard to attain an entirely random sample. The sampling population employed in such research, the data base issued by the confederation of Indian industries (CII), despite the fact that trusted as the finest commercial catalog accessible for the Indian market, even possesses few flaws. First, the data related to the firm's was not up to date at the time of the survey and consequently, on one hand, may comprise of out-of-date data such as names of the executives, email addresses, and yet few firms were no more in existent, but then, might also overlook data related to recently launched enterprises. These events may contain a few non-response biases.

It is hard and in certain cases even it is not possible for management to carry out the entire project at once because of unavailability of financial and/or human resources of businesses, especially in a developing country like India.

Lastly, in a wider horizon, it is put forward that a country's social, economic and political circumstance influences commercial behavior and potently affects a firm's capacity to accomplish competitive advantage and economical performance. Within the extent of this research, emphasize is chiefly directed to studying the inner manufacturing situations of the organizations, i.e. their existing resources and capabilities instead of other external condition like cultural, economic and political. This is considered a limitation of the research that may be addressed in future research.

8.6 Future research

The aforesaid limitations of the research extend a number of chances for upcoming study to widen the existing body of knowledge in the area of mass customization. Some of the future research directions are put forward as below:

First, future study could inquire each of the organizational capabilities incorporated in the framework by aggregating both quantitative and qualitative research methods to get a deeper insight into every variable and render better-off and more exact data in a particular setting.

This research unfolds chances for future studies because of the complication and inadequate resources of businesses in existing dynamic landscape. It would be suitable if the framework was more explored to determine if there is an optimum level of enabling practices so that management can utilize available resources and their combination to formulate a proactive way to design long lasting strategies to attain competitive advantage via implementation of mass customization.

Next, as remarked previously that one hypothesis was disapproved in the present conceptual framework; the finding necessitates further examination in like or diverse circumstances to reassert the empirical result and the theory of a dynamic capability-based approach, particularly in less developed countries. Firm's additional capabilities such as organizational learning capability may examine to find importance of learning on firm’s competitive advantage on mass customization adoption.

Future studies could compare organizational capabilities of brand-driven mass customizers, (have only partial flow of revenue through MC) and companies like shoes of Prey and Euro-shoe (product-driven mass customizer have complete flow of revenue generation is happening through MC). It would also be interesting to identify the underlying cross-sector differences in importance of different MC enablers.

References

Akkermans, H. A., Bogerd, P., Yücesan, E., & Van Wassenhove, L. N. (2003). The impact of ERP on supply chain management: Exploratory findings from a European Delphi study. *European Journal of Operational Research*, *146*(2), 284-301.

Akter, Shahriar, Wamba, Samuel Fosso, Gunasekaran, Angappa, Dubey, Rameshwar, & Childe, Stephen J. (2016). How to improve firm performance using big data analytics capability and business strategy alignment? *International Journal of Production Economics, 182*, 113-131.

Alfalla-Luque, R., Medina-Lopez, C., & Dey, P. K. (2013). Supply chain integration framework using literature review. *Production Planning & Control*, *24*(8-9), 800-817.

Anderson, D. M., & Pine, I. I. BJ (1997) Agile Product Development for Mass Customization. *Irwin, Chicago*.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological bulletin*, *103*(3), 411.

Antonio, K. L., Yam, R. C., & Tang, E. (2007). The impacts of product modularity on competitive capabilities and performance: An empirical study. *International Journal of Production Economics*, *105*(1), 1-20.

Arbuckle, J. L. (2007). Amos 18 user's guide. *Crawfordville, FL: Amos Development Corporation*.

Asif, Z. (2005). Integrating the supply chain with RFID: A technical and business analysis. *Communications of the Association for Information Systems*, *15*(1), 24.

Attri, R., Dev, N., & Sharma, V. (2013). Interpretive structural modelling (ISM) approach: an overview. *Research Journal of Management Sciences*, *2*(2), 3-8.

Bacon, D. R., Sauer, P. L., & Young, M. (1995).Composite reliability in structural equations modeling. *Educational and Psychological Measurement*, *55*(3), 394-406.

Bagozzi, R. P., & Yi, Y. (1988).On the evaluation of structural equation models. *Journal of the academy of marketing science*, *16*(1), 74-94.

Bagozzi, R. P., Yi, Y., & Phillips, L. W. (1991).Assessing construct validity in organizational research. *Administrative science quarterly*, 36(3), 421-458.

Baihaqi, I., & Sohal, A. S. (2013). The impact of information sharing in supply chains on organisational performance: an empirical study. *Production Planning & Control*, *24*(8- 9), 743-758.

Baozhuang, N., Shouping, G., Zhiyong, Z., & Xinghua, L. (2008). An optimal inventory model based on postponement strategy: a bilevel programming approach. *International Journal of Mass Customisation*, *2*(3-4), 341-357.

Bardakci, A., & Whitelock, J. (2003). Mass-customisation in marketing: the consumer perspective. *Journal of consumer marketing*, *20*(5), 463-479.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of management*, *17*(1), 99-120.

Barney, J. B., & Clark, D. N. (2007). *Resource-based theory: Creating and sustaining competitive advantage*. Oxford University Press.

Barutcu, S. (2007). Customized products: the integrating relationship marketing, agile manufacturing and supply chain management for mass customization. *Ege Academic Review*, *7*(2), 573-593.

Bharadwaj, A. S. (2000). A resource-based perspective on information technology capability and firm performance: an empirical investigation. *MIS quarterly*, 169-196.

Blecker, T., & Abdelkafi, N. (2006). Mass Customization: State-of-the-Art and Challenges. *Mass Customization: Challenges and Solutions*, 1-25.

Blecker, T., Abdelkafi, N., Friedrich, G., Kaluza, B., & Kreutler, G. (2005).Information and Management Systems for Product Customization. *Integrated Series in Information Systems.*

Bollinger, A. S., & Smith, R. D. (2001).Managing organizational knowledge as a strategic asset. *Journal of knowledge management*, *5*(1), 8-18.

Bourke, R., Arts, J., & Roest, M. V. (1999). Achieving success with mass customization: the vital contributions of engineering. *Computer-Aided Engineering*, *10*, 42-52.

Boyer, K. K., & Lewis, M. W. (2002). Competitive priorities: investigating the need for trade-offs in operations strategy. *Production and operations management*, *11*(1), 9- 20.

Broekhuizen, T. L. J., & Alsem, K. J. (2002). Success factors for mass customization: a conceptual model. *Journal of Market-Focused Management*, *5*(4), 309-330.

Brown, S., & Bessant, J. (2003).The manufacturing strategy-capabilities links in mass customisation and agile manufacturing–an exploratory study. *International Journal of Operations & Production Management*, *23*(7), 707-730.

Brun, A., & Zorzini, M. (2009).Evaluation of product customization strategies through modularization and postponement. *International Journal of Production Economics*, *120*(1), 205-220.

Brusey, J., & McFarlane, D. C. (2009).Effective RFID-based object tracking for manufacturing. *International Journal of Computer Integrated Manufacturing*, *22*(7), 638- 647.

Byrd, T. A., & Turner, D. E. (2001).An exploratory examination of the relationship between flexible IT infrastructure and competitive advantage. *Information & Management*, *39*(1), 41-52.

Byrne, B. M. (2013). *Structural Equation Modeling With AMOS: Basic Concepts, Applications, and Programming*. Routledge.

Cavana, R. Y., Delahaye, B. L., & Sekaran, U. (2001). *Applied business research: Qualitative and quantitative methods*.John Wiley & Sons Australia.

Chae, B. K., Yang, C., Olson, D., & Sheu, C. (2014). The impact of advanced analytics and data accuracy on operational performance: A contingent resource based theory (RBT) perspective. *Decision Support Systems*, *59*, 119-126.

Chen, J. S., & Li, E. Y. (2010).The effect of information technology adoption and design customisation on the success of new product development. *International Journal of Electronic Business*, *8*(6), 550-578.

Cheng, L. C. V. (2011). Assessing performance of utilizing organizational modularity to manage supply chains: Evidence in the US manufacturing sector. *International Journal of Production Economics*, *131*(2), 736-746.

Chu, C. H., Cheng, C. Y., & Wu, C. W. (2006). Applications of the Web-based collaborative visualization in distributed product development. *Computers in Industry*, *57*(3), 272- 282.

Chuang, S. H. (2004). A resource-based perspective on knowledge management capability and competitive advantage: an empirical investigation. *Expert systems with applications*, *27*(3), 459-465.

Coakes, S. J. (2005). *SPSS version 12 for Windows Analysis without Anguish*." Wiley India ltd.

Coronado, A. E., Lyons, A. C., Kehoe, D. F., & Coleman, J. (2004). Enabling mass customization: extending build-to-order concepts to supply chains. *Production Planning & Control*, *15*(4), 398-411.

Da Cunha, C., Agard, B., & Kusiak, A. (2007). Design for cost: module-based mass customization. *IEEE Transactions on Automation Science and Engineering*, *4*(3), 350- 359.

Da Silveira, G., Borenstein, D., & Fogliatto, F. S. (2001). Mass customization: Literature review and research directions. *International journal of production economics*, *72*(1), 1- 13.

Dangayach, G. S., & Deshmukh, S. G. (2001). Manufacturing strategy: literature review and some issues. *International Journal of Operations & Production Management*, *21*(7), 884-932.

Davenport, T. H., & Prusak, L. (1998). *Working knowledge: How organizations manage what they know*. Harvard Business Press.

Davidson, C., & Voss, P. (2002). Getting practical about knowledge management'. *Nz Business*, *16*(3), 10-1.

Davis, D 2004, Business Research for Decision Making, 6th edn, Belmont, CA.

Davis, S. M. (1989). From “future perfect”: Mass customizing. *Planning review*, *17*(2), 16- 21.

Debowski, S. (2006), Knowledge Management, John Wiley & Sons, Milton, QLD

Devaraj, S., Hollingworth, D. G., & Schroeder, R. G. (2004).Generic manufacturing strategies and plant performance. *Journal of Operations Management*, *22*(3), 313- 333.

Devaraj, S., Krajewski, L., & Wei, J. C. (2007). Impact of eBusiness technologies on operational performance: the role of production information integration in the supply chain. *Journal of Operations Management*, *25*(6), 1199-1216.

Diabat, A., & Govindan, K. (2011).An analysis of the drivers affecting the implementation of green supply chain management. *Resources, Conservation and Recycling*, *55*(6), 659-667.

Diamantopoulos, A., & Winklhofer, H. M. (2001). Index construction with formative indicators: An alternative to scale development. *Journal of marketing research*, *38*(2), 269-277.

Dietrich, A. J., Kirn, S., & Timm, I. J. (2006).Implications of mass customisation on business information systems. *International Journal of Mass Customisation*, *1*(2-3), 218- 236.

Droge, C., Vickery, S. K., & Jacobs, M. A. (2012). Does supply chain integration mediate the relationships between product/process strategy and service performance? An empirical study. *International Journal of Production Economics*, *137*(2), 250-262.

Dubey, R., & Singh, T. (2015).Understanding complex relationship among JIT, lean behaviour, TQM and their antecedents using interpretive structural modelling and fuzzy MICMAC analysis. *The TQM Journal*, *27*(1), 42-62.

Duperrin, J. C., & Godet, M. (1973).Methode de hierarchisation des elements d'un systeme. *Rapport economique du CEA*, *1*(2), 49-51.

Duray, R., Ward, P. T., Milligan, G. W., & Berry, W. L. (2000). Approaches to mass customization: configurations and empirical validation. *Journal of Operations Management*, *18*(6), 605-625.

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: what are they?. *Strategic management journal*, 1105-1121.

El Ghazali, Y., Lefebvre, É.,& Lefebvre, L. A. (2012). The potential of RFID as an enabler of knowledge management and collaboration for the procurement cycle in the construction industry. *Journal of technology management & innovation*, *7*(4), 81-102.

Faisal, M. N., Banwet, D. K., & Shankar, R. (2007). Supply chain risk management in SMEs: analyzing the barriers. *International Journal of Management and Enterprise Development*, *4*(5), 588-607.

Feitzinger, E., & Lee, H. L. (1997). Mass customization at Hewlett-Packard: the power of postponement. *Harvard business review*, *75*, 116-123.

Felipe, Carmen M., Roldán, José L., & Leal-Rodríguez, Antonio L. (2016). An explanatory and predictive model for organizational agility. *Journal of Business Research, 69*(10), 4624- 4631

Flynn, B. B., Huo, B., & Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of operations management*, *28*(1), 58-71.

Fogliatto, F. S., Da Silveira, G. J., & Borenstein, D. (2012). The mass customization decade: An updated review of the literature. *International Journal of Production Economics*, *138*(1), 14-25.

Fornell, C., & Larcker, D. F. (1981).Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, 39-50.

Forza, C., Salvador, F., & Trentin, A. (2008). Form postponement effects on operational performance: a typological theory. *International Journal of Operations & Production Management*, *28*(11), 1067-1094.

Franke, N., Schreier, M., & Kaiser, U. (2010).The "I designed it myself" effect in mass customization. *Management science*, *56*(1), 125-140.

Gerbing, D. W., & Anderson, J. C. (1988).An updated paradigm for scale development incorporating unidimensionality and its assessment. *Journal of marketing research*, 186-192.

Ghiassi, M., & Spera, C. (2003).Defining the Internet-based supply chain system for mass customized markets. *Computers & Industrial Engineering*, *45*(1), 17-41.

Gilmore, J. H., & Pine, B. J. (1997). The four faces of mass customization. *Harvard business review*, *75*, 91-101.

Gold, A. H., & Arvind Malhotra, A. H. S. (2001). Knowledge management: An organizational capabilities perspective. *Journal of management information systems*, *18*(1), 185- 214.

Govindan, K., Palaniappan, M., Zhu, Q., & Kannan, D. (2012). Analysis of third party reverse logistics provider using interpretive structural modeling. *International Journal of Production Economics*, *140*(1), 204-211.

Graman, G. A. (2010). A partial-postponement decision cost model. *European Journal of Operational Research*, *201*(1), 34-44.

Grant, R. M. (1991). The resource-based theory of competitive advantage: implications for strategy formulation. *California management review*, *33*(3), 114-135.

Green, P. E., Tull, D. S., & Albaum, G. (1988).Research for marketing decisions.

Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. C. (2006).Multivariate data analysis 6th edition prentice hall. *New Jersey*.

Hart, C. W. (1995). Mass customization: conceptual underpinnings, opportunities and limits. *International Journal of Service Industry Management*, *6*(2), 36-45.

Hauschild, S., Licht, T., & Stein, W. (2001).Creating a knowledge culture. *The McKinsey Quarterly*, 74-81

Havens, T. C., Bezdek, J. C., Leckie, C., Hall, L. O., & Palaniswami, M. (2012). Fuzzy c- means algorithms for very large data. *IEEE Transactions on Fuzzy Systems*, *20*(6), 1130- 1146.

Helander, M. G., & Jiao, J. (2002).Research on E-product development (ePD) for mass customization. *Technovation*, *22*(11), 717-724.

Helfat, C. E., &Winter, S. G. (2011). Untangling dynamic and operational capabilities: Strategy for the (N) ever-changing world. *Strategic management journal*, *32*(11), 1243-1250.

Helms, M. M., Ahmadi, M., Jih, W. J. K., & Ettkin, L. P. (2008). Technologies in support of mass customization strategy: Exploring the linkages between e-commerce and knowledge management. *Computers in Industry*, *59*(4), 351-363.

Howard, M., & Squire, B. (2007). Modularization and the impact on supply relationships. *International Journal of Operations & Production Management*, *27*(11), 1192-1212.

Huang, G. Q., Zhang, Y. F., & Jiang, P. Y. (2007). RFID-based wireless manufacturing for walking-worker assembly islands with fixed-position layouts. *Robotics and Computer-Integrated Manufacturing*, *23*(4), 469-477.

Huang, X., Kristal, M. M., & Schroeder, R. G. (2010). The impact of organizational structure on mass customization capability: a contingency view. *Production and Operations Management*, *19*(5), 515-530.

Huffman,C.,& Kahn, B. E. (1998). Variety for sale: Mass customization or mass confusion? *Journal of retailing*, *74*(4), 491-513.

Jackson, S. E., DeNisi, A., & Hitt, M. A. (Eds.). (2003). Managing knowledge for sustained competitive advantage: Designing strategies for effective human resource management (Vol. 21). John Wiley & Sons.

Jácome, R., Lisboa, J., & Yasin, M. (2002). Time-based differentiation–an old strategic hat or an effective strategic choice: an empirical investigation. *European Business Review*, *14*(3), 184-193.

Jain, V., Wadhwa, S., & Deshmukh, S. G. (2009).Revisiting information systems to support a dynamic supply chain: issues and perspectives. *Production Planning and Control*, *20*(1), 17-29.

James, P. (2005). Knowledge asset management: the strategic management and knowledge management nexus. *Theses*, 25.

Jiao, J., Ma, Q., & Tseng, M. M. (2003). Towards high value-added products and services: mass customization and beyond. *Technovation*, *23*(10), 809-821.

Jiao, J., Zhang, L., & Pokharel, S. (2005). Coordinating product and process variety for mass customized order fulfilment. *Production Planning & Control*, *16*(6), 608-620.

Jitpaiboon, T., Dangols, R., & Walters, J. (2009).The study of cooperative relationships and mass customization. *Management Research News*, *32*(9), 804-815.

Jöreskog, K. G., & Sörbom, D. (1996). *LISREL 8: User's reference guide*. Scientific Software International. Lawrence, Erlbaum, Hillsdale, NJ.

Jørgensen, S., Nielsen, K., & Jørgensen, K. A. (2011).Reconfigurable manufacturing systems as an application of mass customisation. *International Journal of Industrial Engineering and Management*.

Kaplan, A. M., & Haenlein, M. (2006). Toward a parsimonious definition of traditional and electronic mass customization. *Journal of product innovation management*, *23*(2), 168-182.

Kauffman, R. J., Srivastava, J., & Vayghan, J. (2012). Business and data analytics: New innovations for the management of e-commerce. *Electronic Commerce Research and Applications*, *2*(11), 85-88.

Kay, M. J. (1993). Making mass customization happen: Lessons for implementation. *Planning Review*, *21*(4), 14-18.

Kenny, D. A., & McCoach, D. B. (2003). Effect of the number of variables on measures of fit in structural equation modeling. *Structural equation modeling*, *10*(3), 333-351.

Kincade, D. H., Regan, C., & Gibson, F. Y. (2007). Concurrent engineering for product development in mass customization for the apparel industry. *International Journal of Operations & Production Management*, *27*(6), 627-649.

Kisperska-Moron, D., & Swierczek, A. (2011). The selected determinants of manufacturing postponement within supply chain context: An international study. *International Journal of Production Economics*, *133*(1), 192-200.

Kline, R. B. (2005). Principles and practice of structural equation modeling. (2nd edn.). Guilford publications. Newyork

Koren, Y. (2010). *The global manufacturing revolution: product-process-business integration and reconfigurable systems* (Vol. 80). John Wiley & Sons.

Kotha, S. 1996. “From Mass Production to Mass Customization: The Case of the National Industrial Bicycle Company of Japan.” *European Management Journal 14* (5): 442– 450.

Kotler, P. (1989). From mass marketing to mass customization. *Planning review*, *17*(5), 10- 47.

Koufteros, X. A., Cheng, T. E., & Lai, K. H. (2007). “Black-box” and “gray-box” supplier integration in product development: Antecedents, consequences and the moderating role of firm size. *Journal of Operations Management*, *25*(4), 847-870.

Krishnan, V., & Bhattacharya, S. (2002). Technology selection and commitment in new product development: The role of uncertainty and design flexibility. *Management Science*, *48*(3), 313-327.

Kumar BR, R., Sharma, M. K., & Agarwal, A. (2015). An experimental investigation of lean management in aviation: Avoiding unforced errors for better supply chain. *Journal of Manufacturing Technology Management*, *26*(2), 231-260.

Kumar, A. (2004). Mass customization: metrics and modularity. *International Journal of Flexible Manufacturing Systems*, *16*(4), 287-311.

Lall, S. (2001). Competitiveness indices and developing countries: an economic evaluation of the global competitiveness report. *World development*, *29*(9), 1501-1525.

Lampel, J., & Mintzberg, H. (1996).Customizing customization. *Sloan management review*, *38*(1), 21.

Lau, A. K., Tang, E., & Yam, R. (2010). Effects of supplier and customer integration on product innovation and performance: Empirical evidence in Hong Kong manufacturers. *Journal of Product Innovation Management*, *27*(5), 761-777.

Lau, R. S. (1995). Mass customization: the next industrial revolution. *Industrial Management; Norcross*, *37*(5), 18.

Leech, N. L., Barrett, K. C., & Morgan, G. A. (2005). *SPSS for intermediate statistics: Use and interpretation*. Psychology Press.

Lewis-Beck, M., Bryman, A. E., & Liao, T. F. (2003). *The Sage encyclopedia of social science research methods*. Sage Publications.

Li, S., Ragu-Nathan, B., Ragu-Nathan, T. S., & Rao, S. S. (2006). The impact of supply chain management practices on competitive advantage and organizational performance. *Omega*, *34*(2), 107-124.

Liao, K., Ma, Z., Jiung-Yee Lee, J., & Ke, K. (2011).Achieving mass customization through trust-driven information sharing: a supplier's perspective. *Management Research Review*, *34*(5), 541-552.

Lin, Zhou, Shi & Ma. (2009) '3C framework for modular supply networks in the Chinese automotive industry', International Journal of Logistics Management, The Volume: 20 Issue: 3 2009

Liu, G. J., Shah, R., & Schroeder, R. G. (2006). Linking work design to mass customization: a socio technical systems perspective. *Decision Sciences*, *37*(4), 519-545.

Ma, H. (2000).Competitive advantage and firm performance. *Competitiveness Review: An International Business Journal*, *10*(2), 15-32.

Malhotra, N. K. (2008). *Marketing research: An applied orientation, 5/e*. Pearson Education India.

Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C., & Byers, A. H. (2011). Big data: The next frontier for innovation, competition, and productivity.

Mata, F. J., Fuerst, W. L., & Barney, J. B. (1995). Information technology and sustained competitive advantage: A resource-based analysis. *MIS quarterly*, 487-505.

Mathiyazhagan, K., Govindan, K., Noorul Haq, A., & Geng, Y. (2013).An ISM approach for the barrier analysis in implementing green supply chain management. *Journal of Cleaner Production*, *47*, 283-297.

Meade, L. M., & Sarkis, J. (1999).Analyzing organizational project alternatives for agile manufacturing processes: an analytical network approach. *International Journal of Production Research*, *37*(2), 241-261.

Merle, A., Chandon, J. L., Roux, E., & Alizon, F. (2010).Perceived value of the mass-customized product and mass customization experience for individual consumers. *Production and Operations Management*, *19*(5), 503-514.

Mishra, D., Gunasekaran, A., Papadopoulos, T., & Childe, S. J. (2016). Big Data and supply chain management: a review and bibliometric analysis. *Annals of Operations Research*, 1-24.

Mishra, S., Datta, S., & Mahapatra, S. S. (2013).Grey-based and fuzzy TOPSIS decision-making approach for agility evaluation of mass customization systems. *Benchmarking: an international journal*, *20*(4), 440-462.

Moser, K. (2007). *Mass customization strategies: development of a competence-based framework for identifying different mass customization strategies*. NC: Lulu Enterprises, Inc

Moser, K., & Piller, F. T. (2006). Integration challenges of mass customisation businesses: the case of Steppenwolf. *International Journal of Mass Customisation*, *1*(4), 507- 522.

Narasimhan, R., Swink, M., & Kim, S. W. (2006).Disentangling leanness and agility: an empirical investigation. *Journal of operations management*, *24*(5), 440-457.

Naylor, J. B., Naim, M. M., & Berry, D. (1999). Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of production economics, 62*(1), 107-118.

Nepal, B., Monplaisir, L., & Singh, N. (2005).Integrated fuzzy logic-based model for product modularization during concept development phase. *International Journal of Production Economics*, *96*(2), 157-174.

Neuman, L. W. (2002). Social research methods: Qualitative and quantitative approaches. 5th edn, Sage, Allyn and Bacon, Boston.

Nguyen, T. N. Q. (2010). Knowledge management capability and competitive advantage: an empirical study of Vietnamese enterprises. PhD thesis, Southern Cross University, Lismore, NSW.

Ninan, J. A., & Siddique, Z. (2006).Internet-based framework to support integration of customer in the design of customizable products. *Concurrent Engineering*, *14*(3), 245- 256.

Nunnally, J. C., & Bernstein, I. H. (1994).Psychometric theory, 3rd edn. New York: McGraw-Hill.

Olavarrieta, S., & Ellinger, A. E. (1997).Resource-based theory and strategic logistics research. *International Journal of Physical Distribution & Logistics Management*, *27*(9/10), 559-587.

Pan, B., & Holland, R. (2006).A mass customised supply chain for the fashion system at the design-production interface. *Journal of Fashion Marketing and Management: An International Journal*, *10*(3), 345-359.

Panizzolo, R., Garengo, P., Sharma, M. K., & Gore, A. (2012). Lean manufacturing in developing countries: evidence from Indian SMEs. *Production Planning & Control*, *23*(10-11), 769-788.

Piller, F. T. (2004). Mass customization: reflections on the state of the concept. *International journal of flexible manufacturing systems*, *16*(4), 313-334.

Piller, F., & Kumar, A. (2006). For each, their own: The strategic imperative of mass customization. *Industrial Engineer*, *38*(9), 40-46.

Pine, B. J. (1993). *Mass customization: the new frontier in business competition*. Harvard Business Press.

Pine, B. J., Victor, B., & Boynton, A. C. (1993).Making mass customization work. *Harvard business review*, *71*(5), 108-11.

Polit, D., & Hungler, B. (1994). Essentials of nursing research: Methods, appraisal, asid utilization., 6th edn, Lippincott Williams & Wilkins, Philadelphia.

Porter, M. E. (2011). *Competitive advantage of nations: creating and sustaining superior performance*. Simon and Schuster.

Porter, M. E. (1985). Creating and sustaining superior performance. Competitive advantage, 167. Free Press, New York.

Potter, A., Breite, R., Naim, M., & Vanharanta, H. (2004).The potential for achieving mass customization in primary production supply chains via a unified taxonomy. *Production Planning & Control*, *15*(4), 472-481.

Prajogo, D., & Olhager, J. (2012). Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. *International Journal of Production Economics*, *135*(1), 514-522.

Priem, R. L., & Butler, J. E. (2001). Is the resource-based “view” a useful perspective for strategic management research?. *Academy of management review*, *26*(1), 22-40.

Purohit, J. K., Mittal, M. L., Mittal, S., & Sharma, M. K. (2016). Interpretive structural modeling-based framework for mass customisation enablers: an Indian footwear case. *Production Planning & Control*, *27*(9), 774-786.

Qiao, G., Lu, R. F., & McLean, C. (2006).Flexible manufacturing systems for mass customisation manufacturing. *International Journal of Mass Customisation*, *1*(2-3), 374- 393.

Ramamurti, R. (2000). Risks and rewards in the globalization of telecommunications in emerging economies. *Journal of World Business*, *35*(2), 149-170.

Raykov, T., & Widaman, K. F. (1995).Issues in applied structural equation modeling research. *Structural Equation Modeling: A Multidisciplinary Journal*, *2*(4), 289-318.

Ro, Y. K., Liker, J. K., & Fixson, S. K. (2007). Modularity as a strategy for supply chain coordination: The case of US auto. *IEEE Transactions on Engineering Management*, *54*(1), 172-189.

Romero, D., Osorio, J., Bentacur, M. C., Estrada, G., & Molina, A. (2011). Next generation computer-aided tools: Supporting integrated Sustainable Mass-Customized product developments. In *Concurrent Enterprising (ICE), 17th International Conference on* (pp. 1-15). IEEE.

Rosenzweig, E. D., & Roth, A. V. (2004). Towards a theory of competitive progression: evidence from high-tech manufacturing. *Production and Operations Management*, *13*(4), 354-368.

Rosenzweig, E. D., Roth, A. V., & Dean, J. W. (2003). The influence of an integration strategy on competitive capabilities and business performance: an exploratory study of consumer products manufacturers. *Journal of operations management*, *21*(4), 437- 456.

Roth, A. V., & Miller, J. G. (1990).Manufacturing strategy, manufacturing strength, managerial success, and economic outcomes. In *Manufacturing strategy* (pp. 97-108). Springer Netherlands.

Rudberg, M., & Wikner, J. (2004).Mass customization in terms of the customer order decoupling point. *Production Planning & Control*, *15*(4), 445-458.

Ruohonen, M., Riihimaa, J., & Makipaa, M. (2006). Knowledge based mass customisation strategies: cases from Finnish metal and electronics industries. *International Journal of Mass Customisation*, *1*(2-3), 340-359.

Saaty, T. L. (1996). The analytic network process: Decision making with dependence and feedback. Pittsburgh: RWS Publications.

Sage, A. (1977). Interpretive structural modeling: methodology for large-scale systems, 91– 164.

Salvador, F., Forza, C., & Rungtusanatham, M. (2002). Modularity, product variety, production volume, and component sourcing: theorizing beyond generic prescriptions. *Journal of Operations Management*, *20*(5), 549-575.

Salvador, F., Rungtusanatham, M., & Forza, C. (2004).Supply-chain configurations for mass customization. *Production Planning & Control*, *15*(4), 381-397.

Salvador, F., Rungtusanatham, M., Akpinar, A., & Forza, C. (2008). Strategic capabilities for mass customization: theoretical synthesis and empirical evidence. In *Academy of Management Proceedings* (Vol. 2008, No. 1, pp. 1-6).Academy of Management.

Sanchez, R. (1995). Strategic flexibility in product competition. *Strategic management journal*, *16*(S1), 135-159.

Sanchez, R., & Mahoney, J. T. (1996). Modularity, flexibility, and knowledge management in product and organization design. *Strategic management journal*, *17*(S2), 63-76.

Sanders, N. R. (2014). *Big data driven supply chain management: A framework for implementing analytics and turning information into intelligence*. Pearson Education.

Sarkis, J. (1999). A methodological framework for evaluating environmentally conscious manufacturing programs. *Computers & Industrial Engineering*, *36*(4), 793-810.

Sarkis, J. (2003), “A Strategic Decision Framework for Green Supply Chain Management.” Journal of Cleaner Production, 11(4), 397-409.

Schilling, M. A. (2000).Toward a general modular systems theory and its application to interfirm product modularity. *Academy of management review*, *25*(2), 312-334.

Schumacker, R. E., & Lomax, R. G. (2004). *A beginner's guide to structural equation modeling*.Psychology Press.

Sekaran, U. (2006). *Research methods for business: A skill building approach*. John Wiley & Sons.

Sharma, H. D., & Gupta, A. D. (1995). The objectives of waste management in India: a futures inquiry. *Technological Forecasting and Social Change*, *48*(3), 285- 309.

Skinner, W. (1985). *Manufacturing, the Formidable Competitive Weapon: The Formidable Competitive Weapon*. John Wiley & Sons Inc.

Skipworth, H., & Harrison, A. (2004). Implications of form postponement to manufacturing: a case study. *International Journal of Production Research*, *42*(10), 2063-2081.

Son, J., Sadachar, A., Manchiraju, S., Fiore, A. M., & Niehm, L. S. (2012).Consumer adoption of online collaborative customer co-design. *Journal of Research in Interactive Marketing*, *6*(3), 180-197.

Squire, B., Brown, S., Readman, J., & Bessant, J. (2006).The impact of mass customisation on manufacturing trade-offs. *Production and Operations Management*, *15*(1), 10-21.

Su, J. C., Chang, Y. L., & Ferguson, M. (2005).Evaluation of postponement structures to accommodate mass customization. *Journal of Operations Management*, *23*(3), 305- 318.

Talib, F., Rahman, Z., & Qureshi, M. N. (2011).Analysis of interaction among the barriers to total quality management implementation using interpretive structural modeling approach. *Benchmarking: An International Journal*, *18*(4), 563-587.

Tan, K. C., Kannan, V. R., & Narasimhan, R. (2007). The impact of operations capability on firm performance. *International Journal of Production Research*, *45*(21), 5135- 5156.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic management journal*, 509-533.

Trappey, A. J., & Hsiao, D. W. (2008). Applying collaborative design and modularized assembly for automotive ODM supply chain integration. *Computers in Industry*, *59*(2), 277-287.

Trentin, A., & Forza, C. (2010). Design for form postponement: do not overlook organization design. *International Journal of Operations & Production Management*, *30*(4), 338-364.

Trentin, A., Perin, E., & Forza, C. (2014).Increasing the consumer-perceived benefits of a mass-customization experience through sales-configurator capabilities. *Computers in Industry*, *65*(4), 693-705.

Tseng, M. M., & Hu, S. J. (2014).Mass customization.In *CIRP Encyclopedia of Production Engineering* (pp. 836-843).Springer Berlin Heidelberg.

Tu, Q., Vonderembse, M. A., & Ragu-Nathan, T. S. (2001). The impact of time-based manufacturing practices on mass customization and value to customer. *Journal of Operations management*, *19*(2), 201-217..

Tuck, C. J., Hague, R. J., Ruffo, M., Ransley, M., & Adams, P. (2008). Rapid manufacturing facilitated customization. *International Journal of Computer Integrated Manufacturing*, *21*(3), 245-258.

Turowski, K. (2002). Agent-based e-commerce in case of mass customization. *International Journal of Production Economics*, *75*(1), 69-81.

Ullman, J. B., & Bentler, P. M. (2003). *Structural equation modeling*.John Wiley & Sons, Inc.

Ulrich, K. (1994). Fundamentals of product modularity.In *Management of Design* (pp. 219-231).Springer Netherlands.

Van Hoek, R. I. (2001). The rediscovery of postponement a literature review and directions for research. *Journal of operations management*, *19*(2), 161-184.

Vinodh, S., Sundararaj, G., Devadasan, S. R., Kuttalingam, D., & Rajanayagam, D. (2010). Amalgamation of mass customisation and agile manufacturing concepts: the theory and implementation study in an electronics switches manufacturing company. *International Journal of Production Research*, *48*(7), 2141-2164.

Walters, D., Halliday, M., & Glaser, S. (2002). Creating value in the "New economy". *Management Decision*, *40*(8), 775-781.

Wamba, S. F. (2012). RFID-enabled healthcare applications, issues and benefits: An archival analysis (1997–2011). *Journal of medical systems*, *36*(6), 3393-3398.

Wang, H., & Lin, Z. (2007). Defects tracking matrix for mass customization production based on house of quality. *International Journal of Flexible Manufacturing Systems*, *19*(4), 666-684.

Warfield, J. N. (1974). Developing interconnection matrices in structural modeling. *IEEE Transactions on Systems, Man, and Cybernetics*, (1), 81-87.

Warkentin, M., Bapna, R., & Sugumaran, V. (2000).The role of mass customization in enhancing supply chain relationships in B2C e-commerce markets. *J. Electron. Commerce Res.*, *1*(2), 45-52.

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic management journal*, *5*(2), 171-180.

Xie, Kang, Wu, Yao, Xiao, Jinghua, & Hu, Qing. (2016). Value co-creation between firms and customers: The role of big data-based cooperative assets. *Information & Management*, *53*(8), 1034-1048.

Yao, A. C., & Carlson, J. G. (2003).Agility and mixed-model furniture production. *International Journal of Production Economics*, *81*, 95-102.

Yassine, A., Kim, K. C., Roemer, T., & Holweg, M. (2004).Investigating the role of IT in customized product design. *Production Planning & Control*, *15*(4), 422-434.

Zhang, X., & Huang, G. Q. (2010).Game-theoretic approach to simultaneous configuration of platform products and supply chains with one manufacturing firm and multiple cooperative suppliers. *International Journal of Production Economics*, *124*(1), 121- 136.

Zhao, X., Huo, B., Selen, W., & Yeung, J. H. Y. (2011).The impact of internal integration and relationship commitment on external integration. *Journal of Operations Management*, *29*(1), 17-32.

Zikmund, W.G.. (2000). *Exploring Marketing Research*, 7 th (eds), Dryden Press, Fort Worth.

Zipkin, P. (2001). The limits of mass customization. *MIT Sloan Management Review*, *42*(3), 81.

Appendix-I

List of publication out of thesis work

International Refereed Journal:

- Purohit, J. K., Mittal, M. L., Mittal, S., & Sharma, M. K. (2016). Interpretive structural modeling-based framework for mass customisation enablers: an Indian footwear case. *Production Planning & Control*, *27*(9), 774-786.

- Purohit, J. K., Mittal, M. L., Sharma, M. K., & Mittal, S. (2016). Appraisement of Mass Customization Capability Level Using Multi-grade Fuzzy Approach. In *CAD/CAM, Robotics and Factories of the Future* (pp. 821-830). Springer India.

- Jayant K. Purohit, M.L.Mittal. A strategic framework for determining mass customization adoption**:** An empirical investigation**(**communicated**)**

- Benchmarking select Indian organizations by analyzing mass customization enablers Using ANP Approach **(**communicated**)**

- Jayant K. Purohit, M.L.Mittal. An empirical investigation on big data enabled supply chain integration and knowledge management capability for mass customization.(communicated)

- Jayant K. Purohit, M.L.Mittal. Big data enabled supply chain integration for mass customization **(**communicated**)**

International Reviewed Conference Proceedings:

- J.K.Purohit, M.L.Mittal. Mass Customization, Postponement and Modularization Strategies: A Theoretical Consideration.International Conference on Industrial Engineering Nov. 2013 at SVNIT Surat.

- J.K.Purohit, M.L.Mittal. A Strategic Framework for Determining Implementation of Mass Customization Practices.3rd International Conference on Supply Chain management (BPSCM-2014) Nov.2014 at IIM Udaipur.

- J.K.Purohit, M.L.Mittal. Impact of Information Technology and Integrated Supply Chain on Online Mass Customization Capability. XVIII Annual

International Conference of the Society of Operations Management.Dec.2014 at IIT Roorkee.

- Jayant K. Purohit, M.L.Mittal, Milind Kumar Sharma, Sameer Mittal. Ranking the Enablers of mass customization strategy adoption in Indian manufacturing firm by Using Triangular Fuzzy AHP Method. XIX Annual International Conference of the Society of Operations Management.Dec.2015 at IIM Kolakata.

- Jayant K. Purohit, M.L.Mittal, Milind Kumar Sharma, Sameer Mittal. Appraisement of Mass Customization Capability Level Using Multi-Grade Fuzzy Approach. 28th International Conference on CAD/CAM, Robotics and Factories of the Future .Jan.2016 at CEM Kolaghat.

- Jayant K. Purohit, M.L.Mittal, Milind Kumar Sharma, Sameer Mittal. Big data driven supply chain integration for mass customization. International Conference on E-Business and Supply Chain Competitiveness Jointly organised by IIT Kharagpur & POMS India.Feb.2016 at IIT Kharagpur

Appendix-II

Biographical Profile of Researcher

Jayant Kishor Purohit

Born in Jodhpur, India in 1977

Contact Details (Email):jkpurohit17@gmail.com; purohitjay@gmail.com

Educational Qualifications

2017 Currently a candidate (registered in 2012) for the degree of Doctor of Philosophy at Malaviya National Institute of Technology Jaipur, India

2006 M.Tech. from Malaviya National Institute of Technology Jaipur, India

2003 B.Tech. from University of Rajasthan ,Jaipur ,India

Experience

Eight years teaching experience at graduate and postgraduate level in Engineering and Management Institutes.

Four years industrial experience; Worked as SAP-PP functional consultant.

Award and Fellowship

Passed All India GATE examination with 95.14 %; All India Rank 119.