‘An investigation into Manufacturing Planning and Control Systems within Irish Engineering Sector’

George Onofrei BBS, MMII (Grad), MIOM

Master of Business Studies (Research)

Letterkenny Institute of Technology

Supervisors: Paul Tracey

Prof. Rodney McAdam

“Submitted to the Higher Education and Training Awards Council”

February, 2007

DISCLAIMER

This thesis is intended for study and research purposes only and is not intended to be submitted for business or private credit. Neither should it serve as a basis for any investment decision. This study contains a significant number of references to third party information (articles, statements of opinions). This type of information is clearly marked as such where possible and is included for research purposes only. The author of this study disclaims any responsibility for the accessibility and utility of any such information. The information presented in this thesis is as far as possible accurate at the day of submission. However, the author reserves the right at any time to amend any of the information therein.

ABSTRACT

Manufacturing planning and control (MPC) systems, among a number of sub-systems in an organisation, are the pivotal infrastructures that support the organisation's strategy in order to create competitive advantage in the market place. It provides information to efficiently manage the flow of materials, effectively utilize people and equipment, coordinate internal activities with those of suppliers and communicate with customers about market requirements.

Several studies emphasized the need for alignment between the manufacturing planning and control methods and the manufacturing environment, in order to improve companies' performance. Matching the MPC systems dimensions with the manufacturing environment is problematic.

Throughout the literature there is a lack of empirical studies that match specific manufacturing environment and planning methods. This thesis provides a practical knowledge investigating the MPC system used within the Irish engineering sector and examines the effect on performance, of linking those systems to the business environment. The underlying hypothesis is that good performance is the result of matching the MPC system with the manufacturing environment and good use of the MPC system employed. A conceptual framework, based on the literature review has been developed. Further it examines how the use of those systems influences the companies' performance. The thesis concludes that the performance of Irish companies improves when they can match the MPC system with the manufacturing environment and they use it efficiently.

ACKNOWLEDGEMENTS

I would like to take this opportunity to sincerely thank my supervisors: Paul Tracey, Business Studies, Letterkenny Institute of Technology and Professor Rodney McAdam, School of Business, Retail and Financial Services, University of Ulster for their advice and guidance throughout this research. I also want to thank Enterprise Ireland and especially Fergus Ledwith for his help and expertise. Gratitude is also due to all the companies for taking the time to complete the questionnaire and contribute to this research.

Thanks also to the staff of Letterkenny Institute of Technology, in particular the library staff for their support. I would also like to thank Mike Kennerley, Cranfield University for his advice and support. Last, but not least, I thank to my family, particularly Mum and Dad, for continuous support and encouragement to pursue my studies.

TABLE OF CONTENTS

Chapter 1: Introduction 1

1.1 Overview of the research area 2

1.2 Aims and objectives of research 5

Chapter 2: Literature Review 11

2.1 Introduction 12

2.2 Manufacturing environment 12

2.2.1 Dimensions of manufacturing environment 13
2.2.2 Manufacturing environment classifications 18

2.3 The role of Manufacturing planning and control (MPC) systems 29

2.3.1 Definition of an MPC system 29

2.3.2 Manufacturing planning and control dimensions 30
2.3.2.1 Aggregate Planning 32
2.3.2.2 Demand forecasting 33
2.3.2.3 Resource Requirements Planning 34

2.3.3 Master Production Schedule (MPS) 38
2.3.3.1 Bill of materials (BOM) 41
2.3.3.2 MPS techniques 43

2.3.4 Production Activity Control (PAC) 50
2.3.4.1 Basic PAC concepts and techniques 51

2.3.5 Identify MPC Classifications 56

2.4 Linkages and relationships between manufacturing environment and the MPC systems 65

2.4.1 Characteristics of Push systems – MRP type 66
2.4.2 Characteristics of Pull Systems – JIT type 69

2.5 Summary 74

Chapter 3: Research methodology 78

3.1 Introduction 79

3.2 Research Philosophies 81
3.2.1 Positivism 82
3.2.2 Phenomenology: Realism, Critical theory and Constructivism 83

3.3 Research Approaches 84
3.3.1 Deductive Approach 85
3.3.2 Inductive Approach 86

3.4 Research Strategies 86
3.4.1 Observation 88
3.4.2 Survey 88
3.4.3 Experiment 89
3.4.4 Case study 89

3.5 Time Horizons 90
3.5.1 Cross-sectional studies 90
3.5.2 Longitudinal studies 90

3.6 Data Collection Methods 91
3.6.1 Questionnaires 91
3.6.2 Interviews 92

3.7 Research Objectives 93

3.8 Research Process Chosen 95
3.8.1 Research Philosophy 95
3.8.2 Research Approach 96
3.8.3 Research Strategy 97
3.8.4 Time Horizon 98
3.8.5 Data Collection Method 99
3.8.5.1 Design of the questionnaire 101
3.8.5.2 Development of categories 104
3.8.5.3 The Environment type score 107
3.8.5.4 The MPC type score 108
3.8.5.5 The Use score 108
3.8.5.6 The Performance score 109
3.8.6 Credibility of the Research methodology implemented 110
3.8.6.1 Threats to validity 111
3.8.6.2 Threats to reliability 112
3.8.6.3 Threats to generalisability 113

3.9 Summary 114

Chapter 4: Findings and Analysis ____ **115**

4.1 Introduction ____ **116**

4.2 Data Preparation Process ____ **117**

4.3 Empirical Findings ____ **118**

4.3.1 Environment Types ____ 121
4.3.2 Manufacturing Planning and Control System types ____ 123
4.3.3 The degree of match between manufacturing environment and MPC system ____ 126
4.3.4 The degree of use of the MPC system ____ 128
4.3.5 The performance of the MPC system ____ 129

4.4 MPC system types and Performance ____ **139**

4.5 Company size and Performance ____ **143**

4.6 Constructing validity ____ **145**

4.7 Summary ____ **148**

Chapter 5: Conclusions and Recommendations ____ **149**

5.1 Introduction ____ **150**

5.2 Consequences of not linking the MPC system to the manufacturing environment ____ **151**

5.3 Implications for theory and practice ____ **155**

5.4 Research Limitations ____ **156**

5.5 Suggestions for further research ____ **158**

Bibliography 160

Appendices 177

Appendix A 177

Appendix B 183

Appendix C 189

Appendix D 199

Appendix E 200

LIST OF ABBREVIATIONS

ATO	Assemble to Order
BOM	Bill of Material
CBS	Constraint Based Scheduling
CPM	Critical Path Method
CPOF	Capacity Planning using Overall Factors
CRP	Capacity Requirements Planning
DTO	Design to Order
EI	Enterprise Ireland
ETO	Engineer to Order
FCS	Finite Capacity Scheduling
HV	High Variety
JIT	Just in Time
LV	Low Variety
MPC	Manufacturing Planning and Control
MPS	Master Production Schedule
MRP	Material Resource Planning
MTO	Make to Order
MTS	Manufacturing to Stock
OPT	Optimised Technology
PAC	Production Activity Control
PERT	Project Evaluation and Review
PFS	Process Flow Schedule
ROP	Reorder Point

S&OP	Sales and Operations Planning
TOC	Theory of Constraints
WCM	World Class Manufacturing
WIP	Work In Progress

LIST OF FIGURES

Figure 1.1: The structure of literature review ______ 6

Figure 1.2: Manufacturing planning and control (MPC) dimensions and associated methods ______ 9

Figure 2.1: Porter's job-to-continuous classification ______ 18

Figure 2.2: Porter's stock and manufacturing volume classification ______ 21

Figure 2.3: Porter's complexity and uncertainty classification ______ 22

Figure 2.4: Hierarchical planning process ______ 31

Figure 2.5: MPS in the MPC systems ______ 39

Figure 2.6: MPS role within an MPC system ______ 44

Figure 2.7: MPS: Planning, scheduling and sequencing in MPC system ______ 45

Figure 2.9: TOC scheduling ______ 46

Figure 2.10: MPS and PAC ______ 50

Figure 2.11: Gantt chart ______ 52

Figure 2.12: Flow of two Kanbans ______ 54

Figure 2.13: Schematic diagram showing all possible outcomes of mixing match, use and performance ______ 77

Figure 3.1: The research process "onion" ______ 80

Figure 3.2: A representative range of methodologies and their related paradigms ______ 87

Figure 3.3: Matrix of data collection strategies ______ 87

Figure 3.4: Types of questionnaires ______ 92

Figure 3.5: Research methodology chosen ______ 114

Figure 4.1: Respondent's profile based on Company size ______ 119

Figure 4.2: Respondent's profile based on Turnover value 114

Figure 4.3: Histogram showing the pattern variation of number of products delivered last year 120

Figure 4.4: Histogram showing the pattern variation of the environmental scores 121

Figure 4.5: Histogram showing the pattern variation of the MPC system scores 123

Figure 4.6: Histogram showing the pattern variation of the match scores 127

Figure 4.7: Histogram showing the pattern variation of the absolute match scores 127

Figure 4.8: Histogram showing the pattern variation of the use scores 129

Figure 4.9: Schematic diagram showing all possible outcomes of mixing match, use, performance and the empirical results 137

Figure 4.10: MPC systems identified 139

Figure 5.1: Performance in relation to the degree of match and the degree of use of the MPC systems 153

LIST OF TABLES

Table 1: Dimensions and associated variables of manufacturing environment___ 7

Table 2: Summary of literature studies related to environmental variables______ 17

Table 3: Porter's job-to-continuous classification summary________________ 19

Table 4: Porter's stock and manufacturing classification summary___________ 21

Table 5: Porter's complexity and uncertainty classification summary_________ 23

Table 6: Jonsson and Mattson's classification summary____________________ 24

Table 7: Berry and Hill's classification summary__________________________ 25

Table 8: Summary of manufacturing environment classifications___________ 26

Table 9: Manufacturing environment classification and their associated variables_27

Table 10: Advantages of forward and backward scheduling_________________ 48

Table 11: Summary of MPC dimensions and associated techniques___________ 55

Table 12: Berry and Hill's system classification summary_________________ 56

Table 13: Summary of the overall performance ranking___________________ 57

Table 14: MPC system and demand___________________________________ 58

Table 15: Bonney et al's system classification summary___________________ 59

Table 16: Porter et al's system classification summary____________________ 60

Table 17: Jonsson and Mattson's conceptual matching of planning environments and methods____ 61

Table 18: Masuchun et al's system classification summary_________________ 61

Table 19: Summary of MPC system classifications_______________________ 62

Table 20: MPC classification and their associated dimensions______________ 63

Table 21: Summary on literature studies on benefits of MRP type systems 66

Table 22: Summary on literature studies on benefits of JIT type systems 70

Table 23: Framework of the conceptual match between MPC systems and manufacturing environment 76

Table 24: Four categories of paradigms and their elements 81

Table 25: Cross-tabulation of the environment type and variety 122

Table 26: Cross-tabulation of the manufacturing environment and the MPC system type 124

Table 27: Cross-tabulation of the degree of match and the degree of use 131

Table 28: Cross-tabulation of the degree of match and the performance 132

Table 29: Cross-tabulation of the degree of use and the performance 133

Table 30: Possible relationships between the variables studied 134

Table 31: Cross-tabulation of the degree of match, the degree of use and the performance 136

Table 32: Use and performance of the MRP system within the manufacturing environments 140

Table 33: Use and performance of the JIT system within the manufacturing environments 142

Table 34: Cross-tabulation of the company size and performance 144

Table 35: Summary of the interviews 146

CHAPTER 1
INTRODUCTION

1.1 Overview of the Research Area

1.2 Aims and Objectives of research

1.1 Overview of the Research Area

Dan Flinter, Chief Executive of Enterprise Ireland, in Made in Ireland (2001) study states that: "the rate of development in global manufacturing competitiveness is high. As a first step in achieving this level of global competitiveness our companies need to move to adapt world-class standards of human resources development, production, innovation, sales and marketing, product development and logistics". According to the above-mentioned study very few Irish companies scored sufficiently well on manufacturing practices and performance. Ireland has "a large tail of companies" that is scoring particularly low in areas such as production planning horizon, equipment layout, engineering application tools performance measurement, kanban, maintenance, process capability, employee involvement and housekeeping.

The globalisation of markets, growing inter-penetration of economies, rapid technological change, volatility of demand, wider variety of products available, faster delivery, quicker product development and low cost manufacturing indicate a new type of economical environment (Newman and Sridharan, 1995; Davies and Kochhar, 2000; Ramasesh et al, 2001; Humphreys et al, 2001; Sanchez and Perez, 2005). Recent market trends indicate that manufacturing firms are being required to excel in a variety of dimensions. Low cost manufacturing, quicker product development, faster delivery, wider variety of products, wider range of efficient production volumes, and steadily increasing quality standards have all become important. Demand for capabilities that would have been impossible to meet under the more dichotomous strategies of the not too distant past have become the norm for competition in today's manufacturing environment (Chase et al, 2001).

To compete in the economy, manufacturing enterprises are now facing challenges to become more responsive and agile (Koh and Simpson, 2005). Several studies describe many ways to be responsive and agile: using flexible manufacturing systems (Ang, 1995), exploring the competitive basis through integration of reconfigurable resources (Yusuf et al, 1999), fractal organisation in workstations and cellular layout (Mortreuil et al, 1999) or discrete parts manufacturing systems (Van Assen et al, 2000).

Beach et al (2000) is referring to the ability of manufacturing companies to adapt at strategic level to their changing environment as the strategic flexibility of a company. They analyse the flexibility of a manufacturing system in terms of product change, product mix, volume and delivery. Similar, Newman and Sridharan (1995) describe the environmental conditions faced by the manufacturing function through product volume and variety, competitive priorities and process technologies and infrastructure available within the firm.

Vollmann et al (2005) argues that traditional manufacturing planning and control (MPC) frameworks face the challenge to react quickly and dexterously to changing markets and customer needs, to produce high quality products, to reduce lead-times and to provide a superior service.

Jonsson and Mattsson (2003), relating to the changing environment, analyse the implications of fit between planning environments and manufacturing planning and control methods. The description of different planning environments is based on a framework using variables related to the product, the demand and the manufacturing process. The research was limited in some areas; master production schedule and production activity control were poorly differentiated. The lack of explorative case studies, show that the researchers did not identify the major reasons behind their findings.

Koh et al (2005), Olhager and Rudberg (2002), Davies and Kochhar (2000) and Newman and Sridharan (1995) emphasized the importance of understanding the characteristics of the planning environment and using the appropriate manufacturing system. These studies describe different planning environments using frameworks with different variables, but they do not identify specific measures to allow differentiation of unique planning environments. Also they do not match unique planning environments and specific MPC systems.

Masuchun et al (2004), Beach et al (2000), Plenert et al (1999) and Safizadeh and Ritzman (1997) explore the MPC methods and their performance, but they do not identify different manufacturing environments where these systems have been used.

Howard et al (2002) describes a rule-base approach that provides detailed recommendations on the suitability of system activities to individual companies based on company characteristics and management concerns. The rule is applicable only to batch manufacturing and the research does not explain in detail the suitability of specific planning and control methods in various manufacturing environments.

1.2 Aims and Objectives of Research

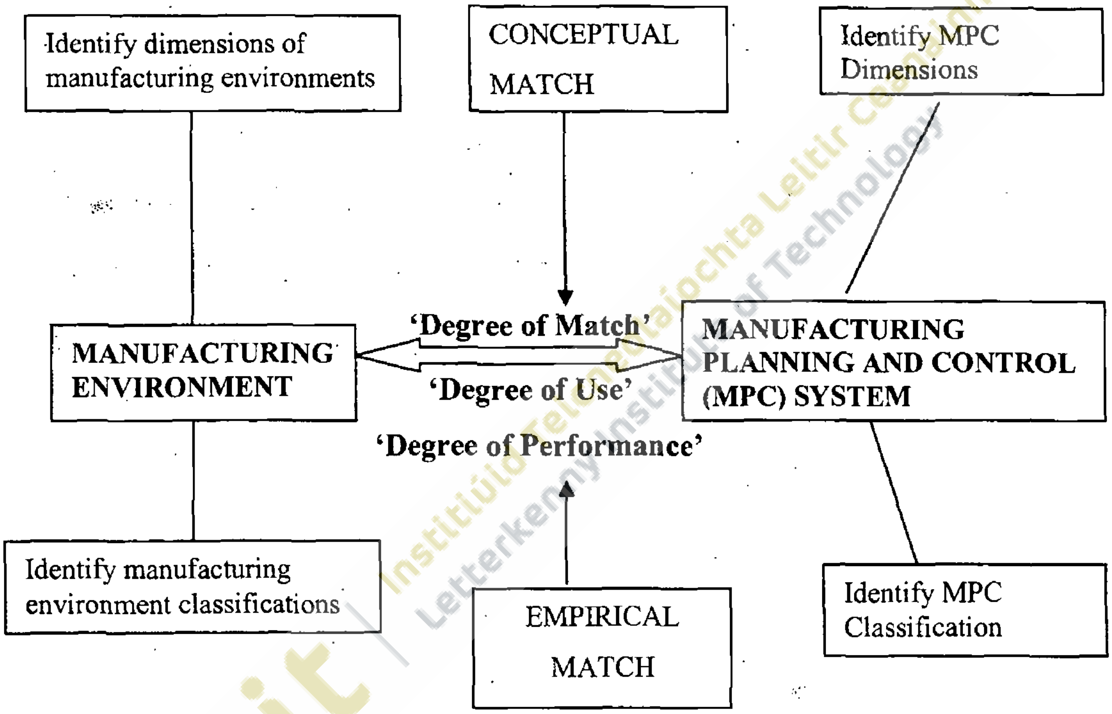
Throughout the literature there is a lack of empirical studies that match specific manufacturing environments and planning methods. This research seeks to fill some of the gaps in the literature by providing practical knowledge on how to differentiate various manufacturing environments and various MPC systems; also by providing conceptual and empirical matches between MPC systems and manufacturing environments.

The researcher proposes that good performance is the result of matching the appropriate planning and control methods for the actual environment and good use of the methods applied.

Howard et al (2002), Berry and Hill (1992) described few case studies of companies with clear misalignments between manufacturing planning and control (MPC) system and market requirements that resulted in substantial difficulties such as lengthy manufacturing cycles, shortages or excesses inventory and poor customer service.

The main objective of this research is to explore the degree of match between the manufacturing environment and planning and control system, as well as the degree of use and performance of MPC systems in these environments. Therefore, the researcher will begin the research by exploring various manufacturing planning environments, in terms of dimensions and classifications. Then various MPC systems will be explored, in terms of their dimensions and classifications. The structure of the literature review is shown in Figure 1.1.

Figure 1.1 The structure of literature review



Newman and Sridharan (1995) characterised the manufacturing environment in terms of product volume/variety, competitive priorities and process technology, and infrastructure available within a firm.

Similar, Jonsson and Mattsson (2003) describe the planning environment using a number of variables related to the demand, the product and the manufacturing process.

See Table 1 for details of environmental variables. Similar, Holweg (2005) defines the dimensions of a manufacturing environment, in terms of responsiveness, as follows: product dimension, process dimension and volume (demand) dimension.

Table 1 Dimensions and associated variables of manufacturing environment

ENVIRONMENTAL VARIABLES		
Demand related	**Product related**	**Manufacturing process related**
P/D ratio	BOM complexity (depth)	Manufacturing mix
Volume/frequency	BOM complexity (width)	Shop floor layout
Set-up times	Product variety	Batch size
Type of procurement ordering	Degree of value added at customer order entry	Through-put time
Demand characteristics	Proportion of customer specific items	Number of operations
Demand type		Sequencing dependency
Time distributed demand		
Source of demand	Product data accuracy	
Inventory accuracy	Level of process planning	

Source: Adapted from Jonnsson and Mattsson (2003)

‘An investigation into Manufacturing Planning and Control Systems within Irish Engineering Sector’

George Onofrei BBS, MMII (Grad), MIOM

Master of Business Studies (Research)

Letterkenny Institute of Technology

Supervisors: Paul Tracey

Prof. Rodney McAdam

“Submitted to the Higher Education and Training Awards Council”

February, 2007

DISCLAIMER

This thesis is intended for study and research purposes only and is not intended to be submitted for business or private credit. Neither should it serve as a basis for any investment decision. This study contains a significant number of references to third party information (articles, statements of opinions). This type of information is clearly marked as such where possible and is included for research purposes only. The author of this study disclaims any responsibility for the accessibility and utility of any such information. The information presented in this thesis is as far as possible accurate at the day of submission. However, the author reserves the right at any time to amend any of the information therein.

ABSTRACT

Manufacturing planning and control (MPC) systems, among a number of sub-systems in an organisation, are the pivotal infrastructures that support the organisation's strategy in order to create competitive advantage in the market place. It provides information to efficiently manage the flow of materials, effectively utilize people and equipment, coordinate internal activities with those of suppliers and communicate with customers about market requirements.

Several studies emphasized the need for alignment between the manufacturing planning and control methods and the manufacturing environment, in order to improve companies' performance. Matching the MPC systems dimensions with the manufacturing environment is problematic.

Throughout the literature there is a lack of empirical studies that match specific manufacturing environment and planning methods. This thesis provides a practical knowledge investigating the MPC system used within the Irish engineering sector and examines the effect on performance, of linking those systems to the business environment. The underlying hypothesis is that good performance is the result of matching the MPC system with the manufacturing environment and good use of the MPC system employed. A conceptual framework, based on the literature review has been developed. Further it examines how the use of those systems influences the companies' performance. The thesis concludes that the performance of Irish companies improves when they can match the MPC system with the manufacturing environment and they use it efficiently.

ACKNOWLEDGEMENTS

I would like to take this opportunity to sincerely thank my supervisors: Paul Tracey, Business Studies, Letterkenny Institute of Technology and Professor Rodney McAdam, School of Business, Retail and Financial Services, University of Ulster for their advice and guidance throughout this research. I also want to thank Enterprise Ireland and especially Fergus Ledwith for his help and expertise. Gratitude is also due to all the companies for taking the time to complete the questionnaire and contribute to this research.

Thanks also to the staff of Letterkenny Institute of Technology, in particular the library staff for their support. I would also like to thank Mike Kennerley, Cranfield University for his advice and support. Last, but not least, I thank to my family, particularly Mum and Dad, for continuous support and encouragement to pursue my studies.

TABLE OF CONTENTS

Chapter 1: Introduction 1

1.1 Overview of the research area 2

1.2 Aims and objectives of research 5

Chapter 2: Literature Review 11

2.1 Introduction 12

2.2 Manufacturing environment 12

2.2.1 Dimensions of manufacturing environment 13
2.2.2 Manufacturing environment classifications 18

2.3 The role of Manufacturing planning and control (MPC) systems 29

2.3.1 Definition of an MPC system 29

2.3.2 Manufacturing planning and control dimensions 30
2.3.2.1 Aggregate Planning 32
2.3.2.2 Demand forecasting 33
2.3.2.3 Resource Requirements Planning 34

2.3.3 Master Production Schedule (MPS) 38
2.3.3.1 Bill of materials (BOM) 41
2.3.3.2 MPS techniques 43

2.3.4 Production Activity Control (PAC) 50
2.3.4.1 Basic PAC concepts and techniques 51

2.3.5 Identify MPC Classifications 56

2.4 Linkages and relationships between manufacturing environment and the MPC systems 65

2.4.1 Characteristics of Push systems – MRP type 66
2.4.2 Characteristics of Pull Systems – JIT type 69

2.5 Summary 74

Chapter 3: Research methodology ______ 78

3.1 Introduction ______ 79

3.2 Research Philosophies ______ 81
3.2.1 Positivism ______ 82
3.2.2 Phenomenology: Realism, Critical theory and Constructivism ______ 83

3.3 Research Approaches ______ 84
3.3.1 Deductive Approach ______ 85
3.3.2 Inductive Approach ______ 86

3.4 Research Strategies ______ 86
3.4.1 Observation ______ 88
3.4.2 Survey ______ 88
3.4.3 Experiment ______ 89
3.4.4 Case study ______ 89

3.5 Time Horizons ______ 90
3.5.1 Cross-sectional studies ______ 90
3.5.2 Longitudinal studies ______ 90

3.6 Data Collection Methods ______ 91
3.6.1 Questionnaires ______ 91
3.6.2 Interviews ______ 92

3.7 Research Objectives ______ 93

3.8 Research Process Chosen ______ 95
3.8.1 Research Philosophy ______ 95
3.8.2 Research Approach ______ 96
3.8.3 Research Strategy ______ 97
3.8.4 Time Horizon ______ 98
3.8.5 Data Collection Method ______ 99
3.8.5.1 Design of the questionnaire ______ 101
3.8.5.2 Development of categories ______ 104
3.8.5.3 The Environment type score ______ 107
3.8.5.4 The MPC type score ______ 108
3.8.5.5 The Use score ______ 108
3.8.5.6 The Performance score ______ 109
3.8.6 Credibility of the Research methodology implemented ______ 110
3.8.6.1 Threats to validity ______ 111
3.8.6.2 Threats to reliability ______ 112
3.8.6.3 Threats to generalisability ______ 113

3.9 Summary ______ 114

Chapter 4: Findings and Analysis ______ 115

4.1 Introduction ______ 116

4.2 Data Preparation Process ______ 117

4.3 Empirical Findings ______ 118

4.3.1 Environment Types ______ 121
4.3.2 Manufacturing Planning and Control System types ______ 123
4.3.3 The degree of match between manufacturing environment and MPC system ______ 126
4.3.4 The degree of use of the MPC system ______ 128
4.3.5 The performance of the MPC system ______ 129

4.4 MPC system types and Performance ______ 139

4.5 Company size and Performance ______ 143

4.6 Constructing validity ______ 145

4.7 Summary ______ 148

Chapter 5: Conclusions and Recommendations ______ 149

5.1 Introduction ______ 150

5.2 Consequences of not linking the MPC system to the manufacturing environment ______ 151

5.3 Implications for theory and practice ______ 155

5.4 Research Limitations ______ 156

5.5 Suggestions for further research ______ 158

Bibliography ______ **160**

Appendices ______ **177**

Appendix A ______ 177

Appendix B ______ 183

Appendix C ______ 189

Appendix D ______ 199

Appendix E ______ 200

LIST OF ABBREVIATIONS

ATO	Assemble to Order
BOM	Bill of Material
CBS	Constraint Based Scheduling
CPM	Critical Path Method
CPOF	Capacity Planning using Overall Factors
CRP	Capacity Requirements Planning
DTO	Design to Order
EI	Enterprise Ireland
ETO	Engineer to Order
FCS	Finite Capacity Scheduling
HV	High Variety
JIT	Just in Time
LV	Low Variety
MPC	Manufacturing Planning and Control
MPS	Master Production Schedule
MRP	Material Resource Planning
MTO	Make to Order
MTS	Manufacturing to Stock
OPT	Optimised Technology
PAC	Production Activity Control
PERT	Project Evaluation and Review
PFS	Process Flow Schedule
ROP	Reorder Point

S&OP	Sales and Operations Planning
TOC	Theory of Constraints
WCM	World Class Manufacturing
WIP	Work In Progress

LIST OF FIGURES

Figure 1.1: The structure of literature review 6

Figure 1.2: Manufacturing planning and control (MPC) dimensions and associated methods 9

Figure 2.1: Porter's job-to-continuous classification 18

Figure 2.2: Porter's stock and manufacturing volume classification 21

Figure 2.3: Porter's complexity and uncertainty classification 22

Figure 2.4: Hierarchical planning process 31

Figure 2.5: MPS in the MPC systems 39

Figure 2.6: MPS role within an MPC system 44

Figure 2.7: MPS: Planning, scheduling and sequencing in MPC system 45

Figure 2.9: TOC scheduling 46

Figure 2.10: MPS and PAC 50

Figure 2.11: Gantt chart 52

Figure 2.12: Flow of two Kanbans 54

Figure 2.13: Schematic diagram showing all possible outcomes of mixing match, use and performance 77

Figure 3.1: The research process "onion" 80

Figure 3.2: A representative range of methodologies and their related paradigms 87

Figure 3.3: Matrix of data collection strategies 87

Figure 3.4: Types of questionnaires 92

Figure 3.5: Research methodology chosen 114

Figure 4.1: Respondent's profile based on Company size 119

Figure 4.2: Respondent's profile based on Turnover value ____ 114

Figure 4.3: Histogram showing the pattern variation of number of products delivered last year ____ 120

Figure 4.4: Histogram showing the pattern variation of the environmental scores ____ 121

Figure 4.5: Histogram showing the pattern variation of the MPC system scores ____ 123

Figure 4.6: Histogram showing the pattern variation of the match scores ____ 127

Figure 4.7: Histogram showing the pattern variation of the absolute match scores ____ 127

Figure 4.8: Histogram showing the pattern variation of the use scores ____ 129

Figure 4.9: Schematic diagram showing all possible outcomes of mixing match, use, performance and the empirical results ____ 137

Figure 4.10: MPC systems identified ____ 139

Figure 5.1: Performance in relation to the degree of match and the degree of use of the MPC systems ____ 153

LIST OF TABLES

Table 1: Dimensions and associated variables of manufacturing environment___ 7

Table 2: Summary of literature studies related to environmental variables______17

Table 3: Porter's job-to-continuous classification summary________________ 19

Table 4: Porter's stock and manufacturing classification summary__________ 21

Table 5: Porter's complexity and uncertainty classification summary_______ 23

Table 6: Jonsson and Mattson's classification summary__________________ 24

Table 7: Berry and Hill's classification summary_________________________ 25

Table 8: Summary of manufacturing environment classifications___________ 26

Table 9: Manufacturing environment classification and their associated variables_27

Table 10: Advantages of forward and backward scheduling_________________ 48

Table 11: Summary of MPC dimensions and associated techniques___________55

Table 12: Berry and Hill's system classification summary__________________ 56

Table 13: Summary of the overall performance ranking____________________ 57

Table 14: MPC system and demand____________________________________ 58

Table 15: Bonney et al's system classification summary___________________ 59

Table 16: Porter et al's system classification summary_____________________ 60

Table 17: Jonsson and Mattsson's conceptual matching of planning environments and methods____ 61

Table 18: Masuchun et al's system classification summary_________________ 61

Table 19: Summary of MPC system classifications________________________ 62

Table 20: MPC classification and their associated dimensions______________ 63

Table 21: Summary on literature studies on benefits of MRP type systems 66

Table 22: Summary on literature studies on benefits of JIT type systems 70

Table 23: Framework of the conceptual match between MPC systems and manufacturing environment 76

Table 24: Four categories of paradigms and their elements 81

Table 25: Cross-tabulation of the environment type and variety 122

Table 26: Cross-tabulation of the manufacturing environment and the MPC system type 124

Table 27: Cross-tabulation of the degree of match and the degree of use 131

Table 28: Cross-tabulation of the degree of match and the performance 132

Table 29: Cross-tabulation of the degree of use and the performance 133

Table 30: Possible relationships between the variables studied 134

Table 31: Cross-tabulation of the degree of match, the degree of use and the performance 136

Table 32: Use and performance of the MRP system within the manufacturing environments 140

Table 33: Use and performance of the JIT system within the manufacturing environments 142

Table 34: Cross-tabulation of the company size and performance 144

Table 35: Summary of the interviews 146

CHAPTER 1
INTRODUCTION

1.1 Overview of the Research Area

1.2 Aims and Objectives of research

1.1 Overview of the Research Area

Dan Flinter, Chief Executive of Enterprise Ireland, in Made in Ireland (2001) study states that: "the rate of development in global manufacturing competitiveness is high. As a first step in achieving this level of global competitiveness our companies need to move to adapt world-class standards of human resources development, production, innovation, sales and marketing, product development and logistics". According to the above-mentioned study very few Irish companies scored sufficiently well on manufacturing practices and performance. Ireland has "a large tail of companies" that is scoring particularly low in areas such as production planning horizon, equipment layout, engineering application tools performance measurement, kanban, maintenance, process capability, employee involvement and housekeeping.

The globalisation of markets, growing inter-penetration of economies, rapid technological change, volatility of demand, wider variety of products available, faster delivery, quicker product development and low cost manufacturing indicate a new type of economical environment (Newman and Sridharan, 1995; Davies and Kochhar, 2000; Ramasesh et al, 2001; Humphreys et al, 2001; Sanchez and Perez, 2005). Recent market trends indicate that manufacturing firms are being required to excel in a variety of dimensions. Low cost manufacturing, quicker product development, faster delivery, wider variety of products, wider range of efficient production volumes, and steadily increasing quality standards have all become important. Demand for capabilities that would have been impossible to meet under the more dichotomous strategies of the not too distant past have become the norm for competition in today's manufacturing environment (Chase et al, 2001).

To compete in the economy, manufacturing enterprises are now facing challenges to become more responsive and agile (Koh and Simpson, 2005). Several studies describe many ways to be responsive and agile: using flexible manufacturing systems (Ang, 1995), exploring the competitive basis through integration of reconfigurable resources (Yusuf et al, 1999), fractal organisation in workstations and cellular layout (Mortreuil et al, 1999) or discrete parts manufacturing systems (Van Assen et al, 2000).

Beach et al (2000) is referring to the ability of manufacturing companies to adapt at strategic level to their changing environment as the strategic flexibility of a company. They analyse the flexibility of a manufacturing system in terms of product change, product mix, volume and delivery. Similar, Newman and Sridharan (1995) describe the environmental conditions faced by the manufacturing function through product volume and variety, competitive priorities and process technologies and infrastructure available within the firm.

Vollmann et al (2005) argues that traditional manufacturing planning and control (MPC) frameworks face the challenge to react quickly and dexterously to changing markets and customer needs, to produce high quality products, to reduce lead-times and to provide a superior service.

Jonsson and Mattsson (2003), relating to the changing environment, analyse the implications of fit between planning environments and manufacturing planning and control methods. The description of different planning environments is based on a framework using variables related to the product, the demand and the manufacturing process. The research was limited in some areas; master production schedule and production activity control were poorly differentiated. The lack of explorative case studies, show that the researchers did not identify the major reasons behind their findings.

Koh et al (2005), Olhager and Rudberg (2002), Davies and Kochhar (2000) and Newman and Sridharan (1995) emphasized the importance of understanding the characteristics of the planning environment and using the appropriate manufacturing system. These studies describe different planning environments using frameworks with different variables, but they do not identify specific measures to allow differentiation of unique planning environments. Also they do not match unique planning environments and specific MPC systems.

Masuchun et al (2004), Beach et al (2000), Plenert et al (1999) and Safizadeh and Ritzman (1997) explore the MPC methods and their performance, but they do not identify different manufacturing environments where these systems have been used.

Howard et al (2002) describes a rule-base approach that provides detailed recommendations on the suitability of system activities to individual companies based on company characteristics and management concerns. The rule is applicable only to batch manufacturing and the research does not explain in detail the suitability of specific planning and control methods in various manufacturing environments.

1.2 Aims and Objectives of Research

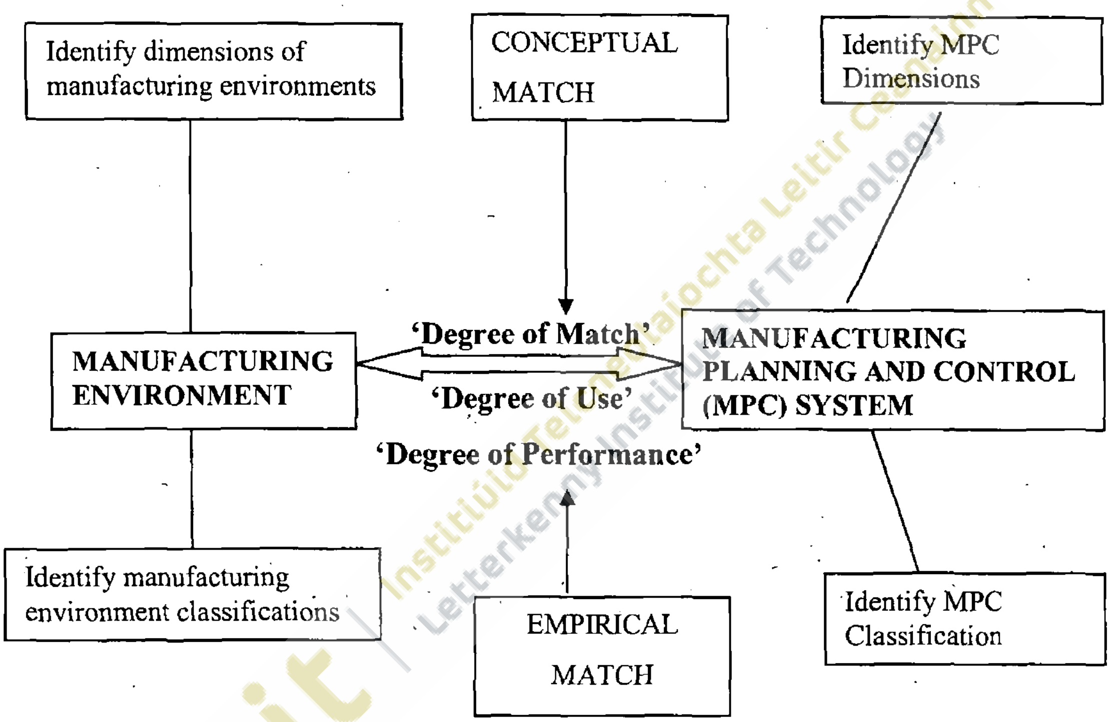
Throughout the literature there is a lack of empirical studies that match specific manufacturing environments and planning methods. This research seeks to fill some of the gaps in the literature by providing practical knowledge on how to differentiate various manufacturing environments and various MPC systems; also by providing conceptual and empirical matches between MPC systems and manufacturing environments.

The researcher proposes that good performance is the result of matching the appropriate planning and control methods for the actual environment and good use of the methods applied.

Howard et al (2002), Berry and Hill (1992) described few case studies of companies with clear misalignments between manufacturing planning and control (MPC) system and market requirements that resulted in substantial difficulties such as lengthy manufacturing cycles, shortages or excesses inventory and poor customer service.

The main objective of this research is to explore the degree of match between the manufacturing environment and planning and control system, as well as the degree of use and performance of MPC systems in these environments. Therefore, the researcher will begin the research by exploring various manufacturing planning environments, in terms of dimensions and classifications. Then various MPC systems will be explored, in terms of their dimensions and classifications. The structure of the literature review is shown in Figure 1.1.

Figure 1.1 The structure of literature review



Newman and Sridharan (1995) characterised the manufacturing environment in terms of product volume/variety, competitive priorities and process technology, and infrastructure available within a firm.

Similar, Jonsson and Mattsson (2003) describe the planning environment using a number of variables related to the demand, the product and the manufacturing process.

See Table 1 for details of environmental variables. Similar, Holweg (2005) defines the dimensions of a manufacturing environment, in terms of responsiveness, as follows: product dimension, process dimension and volume (demand) dimension.

Table 1 Dimensions and associated variables of manufacturing environment

ENVIRONMENTAL VARIABLES		
Demand related	**Product related**	**Manufacturing process related**
P/D ratio	BOM complexity (depth)	Manufacturing mix
Volume/frequency	BOM complexity (width)	Shop floor layout
Set-up times	Product variety	Batch size
Type of procurement ordering	Degree of value added at customer order entry	Through-put time
Demand characteristics	Proportion of customer specific items	Number of operations
Demand type		Sequencing dependency
Time distributed demand		
Source of demand	Product data accuracy	
Inventory accuracy	Level of process planning	

Source: Adapted from Jonnsson and Mattsson (2003)

Several studies identified manufacturing environments and the literature shows that there are many different classifications systems. Porter et al (1999) classified manufacturing environments into mass, batch, jobbing and complex. Jonsson and Mattsson (2003) used a different classification purely from a manufacturing planning and control perspective, while Porter's et al (1999) types are more general operations management types. They classify into complex, configure to order, batch and repetitive mass.

Newman and Sridharan (1995) state that the four most common manufacturing planning and control approaches used in practice and discussed in the literature are the following: materials resource planning-based push systems (MRP), just in time (JIT) - based pull systems, constraint theory-based systems which identify and schedule according to bottleneck resources (OPT) and traditional reorder point-based systems (ROP).

Jonsson and Mattsson (2003) in their study define the planning methods using various planning horizons and levels of detail. They focus on detailed material planning, shop floor control and capacity planning levels. At each level there are a number of planning methods with several variants. See figure 1.2 for details of manufacturing planning and control dimensions and associated methods.

Figure 1.2 Manufacturing planning and control (MPC) dimensions and associated methods

MPC Dimensions		
AGGREGATE PLANNING	**MASTER PRODUCTION SCHEDULE**	**PRODUCTION ACTIVITY CONTROL**
- Forecasting - Aggregate plans - Resource requirements planning	- Overall factors - Capacity bills - Resource profiles - Capacity requirements planning - Theory of constraints - Forward and backward scheduling	- Gantt charts - Priority sequencing rules - Kanban.

Porter et el (1999) describe the common approaches to production planning and control as follows:

- Just-in-time (JIT) – as a philosophy and a production planning and control approach;
- Project evaluation and review (PERT) and critical path (CPM);
- Constraint based scheduling (CBS);
- Process flow scheduling (PFS);
- Manufacturing resource planning (MRP) and derivations;
- Finite capacity scheduling.

Masuchun et al (2004) describe the push systems as systems that embody the MRP concept; and the pull systems as systems that embody the kanban concept. Similar approach is undertaken by Bonney et al (1999), where they describe MRP as a push system and a kanban operated JIT system as a typical pull system.

For the purpose of this research the researcher will investigate the following two main approaches: Push Type System (MRP) and Pull Type System (JIT). Then he will conduct conceptual matches between MPC systems and manufacturing environments identified. To gain a deeper understanding of the appropriateness of various planning methods in a manufacturing environment, the researcher will conduct explorative research through a series of interviews with personnel responsible for planning and control within the Irish engineering sector and specialists consultants from Enterprise Ireland responsible for World Class Manufacturing and Competitiveness Benchmarking Programmes. This objective will enhance the design and the structure of questionnaires.

The next objective will be to identify planning and control systems for the Irish engineering sector and to determine the degree of match with the manufacturing environment. Finally the degree of match, the degree of use and the level of performance with the various MPC systems will be empirically analysed through survey data.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

2.2 Manufacturing Environment

2.3 The role of Manufacturing Planning and Control systems

2.4 Linkages between manufacturing environment and manufacturing planning and control systems

2.5 Summary

2.1 Introduction

The research described in this thesis, addresses some of the problems associated with manufacturing planning and control (MPC) systems; in particular the degree of match between the MPC system and the manufacturing environment. For the purpose of this research the available literature is considered on issues such as:

- Manufacturing industry: manufacturing environment, manufacturing planning and control dimensions and types of systems;
- Manufacturing research: conceptual and empirical studies related to match, use and performance of MPC systems;
- Performance measurement in manufacturing companies;
- Irish publications on manufacturing issues, competitiveness and research in engineering sector.

2.2 Manufacturing Environment

This sub-chapter will explore the manufacturing environment, in terms of its dimensions and it will identify different manufacturing environments characterised by a series of environmental variables. This will enable the research to further explore various manufacturing planning and control systems.

2.2.1 Dimensions of manufacturing environment

The rapidly changing competitive environments, in which most companies operate are forcing them to change their strategies in order to remain competitive. Global competition, rapid technological change, and escalating product variety put new demands on companies. These demands, often call for changes in manufacturing strategy, manufacturing processes, and manufacturing planning and control (MPC) systems (Vollmann et al., 2005).

Olhager and Rudberg (2002), Howard et al (2002), Berry and Hill (1992) concluded that the link between market requirements and process choice heavily influence the role of MPC system, as well as the performance of the manufacturing system. Poor manufacturing planning and control are characterised by: poor customer service; excessive inventories; inappropriate equipment or worker utilisation; high rates of part obsolescence; a large level of expediting and fire-fighting (Vollmann et al., 1992); the inability to quickly translate product concepts into manufacturing reality; and the inability to meet customer demand for customised products (Caridi and Cigolini, 2002).

Newman and Sridharan (1995) describe the environmental conditions faced by the manufacturing function as: product volume and variety, competitive priorities and process technologies and infrastructure available within the organization. The volatility of demand, the level of product design changes, and the rate of new product introduction define the product volume and variety mix. In terms of competitive priorities, firms are faced with the need for holding the line on costs while meeting demand for more frequent and smaller lot deliveries of an increasing variety of products. The process technology available within the firm determines its flexibility and ability to support the competitive priorities.

Jonsson and Mattsson (2003) characterized the planning environment by a number of variables related to the product, the demand and the manufacturing process respectively.

The product related variables that they considered critical from a planning and control perspective are the following:

- *Bill of Material complexity* – the number of levels and the typical number of items on each level;
- *Product variety* – optional product variants;
- *Degree of value added at order entry* – the extent to which the manufacturing of the products is finished prior to receipt of customer order;
- *Proportion of customer specific items* – the extent to which customer specific items are added to the delivered product;
- *Product data accuracy* – the data accuracy in the bill of material and routing file;
- *Level of process planning* – the extent to which detailed process planning is carried out before manufacture products.

The demand related variables characterize demand and material flow from a planning perspective. The following variables are considered critical:

- *P/D Ratio* – the ratio between the accumulated product lead-time and the delivery lead-time to the customer;

- *Volume/Frequency* – the annual manufactured volume and the number of times per year that products are manufactured;

- *Type of procurement ordering* – order by order procurement or blanket order releases from a delivery agreement;

- *Demand characteristics* – independent or dependent demand;

- *Demand type* – demand from forecast, calculated requirements or from customer order allocations;

- *Time distributed demand* – demand being time distributed or just an annual figure;

- *Source of demand* – stock replenishment order or customer order;

- *Inventory accuracy* – accuracy of stock on hand data.

The third group of variables that characterises the manufacturing process are:

- *Manufacturing mix* – homogeneous or mixed products from a manufacturing perspective;

- *Shop floor layout* – functional, cellular or line layout;

- *Batch size* – the typical manufacturing order quantity;

- *Through-put time* – typical manufacturing through-put times;

- *Number of operations* – number of operations in typical routings;

- *Sequencing dependency* – the extent to which set-up times are dependent on manufacturing sequence in work centres.

Howard et al (2002) describes a rule-based approach that provides detailed recommendations on the suitability of system activities to individual companies based on company characteristics (110) and management concerns (40). These characteristics are grouped in several categories as follows:

- *Company characteristics*: market, customers, suppliers, product range, product structure, product management, production approaches, production information, production information and plant.
- *Management concerns:* information, quality, suppliers, lead times, planning, stock, resources and production.

Many other studies in the literature found that the control strategy interacts with environmental variables to impact system performance. Table 2 is a summary of literature studies related to environmental variables that influence planning and control systems, grouped into market, product and manufacturing process related.

Table 2 Summary of literature studies related to environmental variables

	Environmental variables	Authors
Market related	Demand variability	Masuchun et al (2004) , Jonsson and Mattsson (2003), Howard et al (2002), Olhager and Rudberg (2002), Beach et al (2000), Bonney et al (1999), Newman and Sridharan (1995)
	Demand predictability	Newman and Sridharan (1995)
	Demand stability	Porter et al (1999)
	Volume/frequency	Jonsson and Mattsson (2003), Howard et al (2002), Porter et al (1999), Berry and Hill (1992)
	Delivery performance	Howard et al (2002), Berry and Hill (1992)
	Suppliers performance	Howard et al (2002), Berry and Hill (1992)
Product related	Bill of material complexity	Persona et al (2004), Jonsson and Mattsson (2003), Howard et al (2002), Ang et al (1997), Newman and Sridharan (1995), Berry and Hill (1992)
	Product variety	Jonsson and Mattsson (2003), Howard et al (2002), Olhager and Rudberg (2002), Newman and Sridharan (1995)
	Product mix flexibility	Sanchez and Perez (2005), Howard et al (2002), Chan and Burns (2002), Olhager and Rudberg (2002), Ramasesh et al (2001), Persentili and Alptekin (2000), Beach et al (2000), Plenert (1999)
	Product standardisation/design	Sanchez and Perez (2005), Persona et al (2004), Van Assen and Van de Velde (2003), Howard et al (2002), Chan and Burns (2002), Plenert (1999), Porter et al (1999), Ang et al (1997)
	Product data accuracy	Jonsson and Mattsson (2003), Howard et al (2002)
Manufacturing process related	Level of process planning	Jonsson and Mattsson (2003), Olhager and Rudberg (2002)
	Setup time	Jonsson and Mattsson (2003), Olhager and Rudberg (2002), Chan and Burns (2002), Bonney et al (1999), Plenert (1999)
	Production lead time	Masuchun et al (2004), Persona et al (2004), Chan and Burns (2002), Howard et al (2002), Porter et al (1999), Plenert (1999)
	Production batch size	Jonsson and Mattsson (2003),Chan and Burns (2002), Berry and Hill (1992), Bonney et al (1999), Plenert (1999)
	Inventory levels	Jonsson and Mattsson (2003), Howard et al (2002), Chan and Burns (2002), Bonney et al (1999), Plenert (1999)
	Shop layout	Jonsson and Mattsson (2003), Chan and Burns (2002), Howard et al (2002), Plenert (1999), Porter et al (1999), Berry and Hill (1992)
	Scheduling flexibility	Chan and Burns (2002), Plenert (1999), Ramasesh et al (2001)
	Routing flexibility	Ramasesh et al (2001), Porter et al (1999)
	Through-put time	Jonsson and Mattsson (2003), Howard et al (2002), Berry and Hill (1992), Persentili and Alptekin (2000)
	Production process type	Jonsson and Mattsson (2003), Howard et al (2002), Berry and Hill (1992)
	Level of automation	Howard et al (2002)

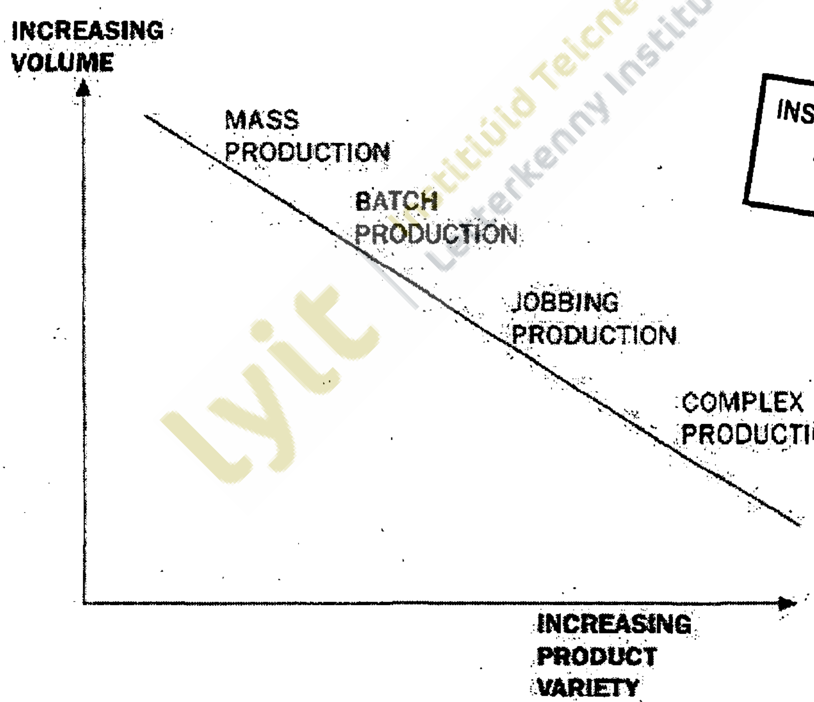
2.2.2 Manufacturing environment classifications

Examination of the literature shows that there are many different classifications systems for a manufacturing environment. Some (for example, Job/Batch/Continuous) are well known and widely applied, others are more novel (Complexity and Uncertainty) (Porter et al, 1999). The most common are described below:

1. Job-to-continuous classification

Porter et al, (1999) depicted along a continuum, the jobbing production to mass production, taking in consideration the scale of production and the degree of product variety (see Figure 2.1).

Figure 2.1 Porter's job-to-continuous classification



Source: Adapted from Porter et al, 1999

The variables used to differentiate these environments are summarised in the table below:

Table 3 Porter's job-to-continuous classification summary

Porter et al (1999) / Variables	Mass Production	Batch Production	Jobbing Production	Complex Production
Volume	Large	Medium	Low/One off	Low/One off
Variety	Low	Medium-size	Wider range	High
Demand	Stable on short term	Difficult to forecast	Difficult to forecast	
Design changes	Minimal			High number of changes
Plant capacity	Calculable, determined by the output of bottle neck processes	Depend on product mix	Depend on product mix	Variable, depend on product completion time
Routeings	Fixed		Dictated by manufacturing needs	
Plant layout	Based on the needs of products	Flexible	Based on manufacturing needs	
Levels of skill	Low, low intensity of labour		High, high intensity of labour	
Batch size		Small lots		
Production facilities	Fixed		Flexible – job-shop	Using also external facilities (outsource)

2. Stock and manufacturing volume classification

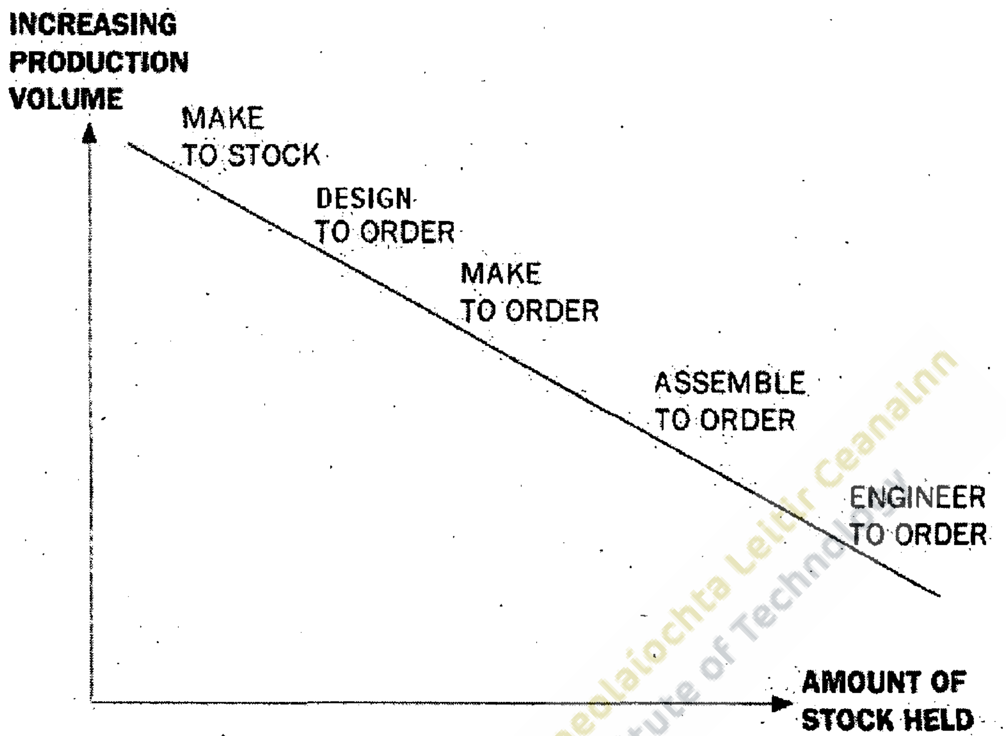
Producing stock to buffer between manufacturing and its customers is a dominant feature of many industries, while success in other sectors relies on responsiveness to customer demand. An ability to rapidly customise products to meet individual customer requirements is becoming an emergent trend as manufacturing capacity evolves to meet demand.

For many companies, future success or survival may depend on their ability to balance stockholding against speed of response to the marketplace. An alternative mechanism for classification is to identify and differentiate between stock driven and order driven manufacturing systems (Porter et al, 1999).

They suggest that there are five classes within which manufacturing systems can be described, as follows:

1. Make to Stock (MTS).
2. Assemble to Order (ATO).
3. Make to Order (MTO).
4. Engineer to Order (ETO).
5. Design to Order (DTO).

Figure 2.2 Porter's stock and manufacturing volume classification



Source: Adapted from Porter et al, 1999

The variables that they are using to differentiate these environments are summarised in the table below:

Table 4 Porter's stock and manufacturing volume classification summary

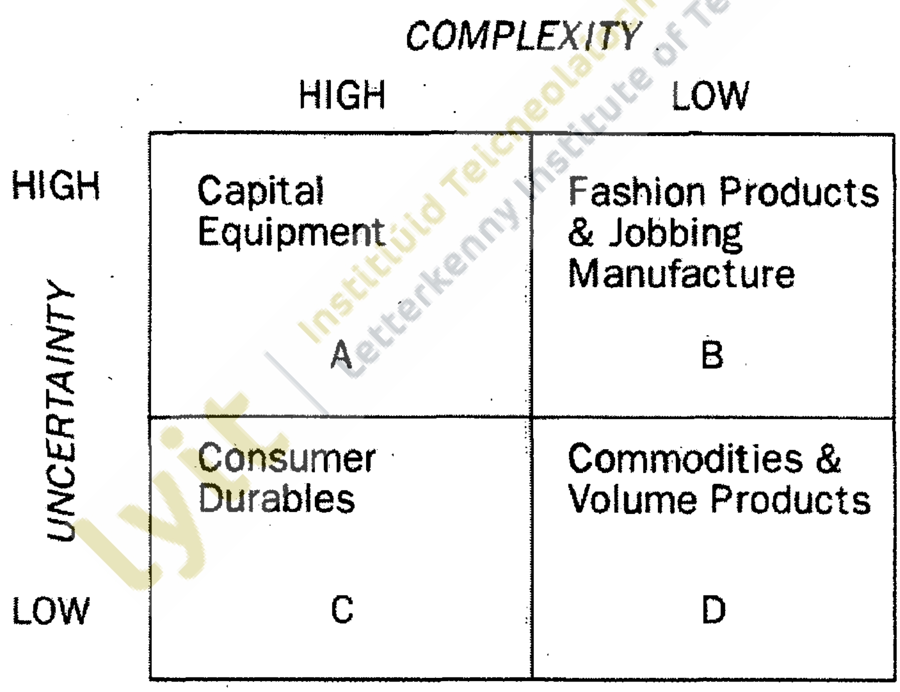
Porter et al (1999) / Variables	Make to Stock (MTS)	Design to Order (DTO)	Make to Order (MTO)	Assemble to Order (ATO)	Engineer to order (ETO)
Demand	Clearly defined		After order receipt		
Volume	Large	Medium		Lower	
Customer satisfaction	Delivery performance				
Stock	Buffer stock			Low stock	Low stock
Inventory cost	High			Low	Low
Product design	Customer input is limited	Specifically built for customer	Standard products		Standard

3. Complexity and uncertainty classification

A set of 2x2 matrices (the base level matrix is shown in Figure 2:3) classify manufacturing organisations in terms of product and market characteristics and their relationship to the complexities and uncertainties that act within and on the organisation.

In this context, Porter et al (1999) describes complexity to concern the volume and variety of different products, components, processes and sources of supply. Uncertainty concerns the volume and stability of demand, also the degree of product design rigidity.

Figure 2.3 Porter's complexity and uncertainty classification



Source: Porter et al, 1999

The variables used to differentiate these environments are summarised in the table below:

Table 5 Porter's complexity and uncertainty classification summary

Porter et al (1999) / Variables	Capital equipment	Durables	Fashion/Jobbing	Commodity
Complexity	High	Medium	Medium	Low
Product variety	High	Medium	Medium	Low
Volume	Low	Medium	Medium	High
Demand stability	High uncertainty	Low uncertainty	High uncertainty	Low uncertainty
Product design	Highly customised	Few design changes	Few design changes	Minimal design changes

4. Jonsson and Mattsson (2003) classification defines the manufacturing environment as being specific to the company and normally differs from company to company. To be able to compare companies with different planning environments they identified four main groups:

1. Complex customer products (type 1);
2. Configure to order products (type 2);
3. Batch production of standardized products (type 3);
4. Repetitive mass production (type 4).

These four types are similar to Hill's (2000) process choice types, although his types are more general operations management types, while these are defined purely from a manufacturing planning and control perspective. The variables that they are using to differentiate these environments are summarised in the table below:

Table 6 Jonsson and Mattson's classification summary

Jonsson and Mattsson (2003) / Variables	Complex customer Type 1	Configure to order Type 2	Batch production Type 3	Mass production Type 4
Volume	Low	Medium-large	Medium-large	High
Variety	High			Low
Design	Engineer to order	Assemble to order	Manufacturing to stock	Mass continuous production
Batch	Small, equal to customer order			
Bill of material	Complex, wide			Flat, simple
Lead-time	Long	Much lower than type 1		
Production process	One-off			
Layout	Functional	Line/cellular		Line layout
Product type	Customised			Standard

5. Berry and Hill (1992) framework is very similar and analyses the impact of the environment at three levels of the MPC system: master scheduling level, materials planning level and shop floor level. At each level a set of market requirement attributes is used to make generic choices among a set of level-dependent MPC design variables. The table below is based on the summary of the three separate tables in Berry and Hill (1992).

Table 7 Berry and Hill's classification

Strategic variables	MTO	MTS
Market requirements:		
Product: Type	Special →	Standard
Range	Wide →	Narrow
Ability to cope with product mix	High potential →	Limited
Product volume per period	Low →	High
Accommodating demand versatility:		
Total volume	Easy/incremental →	Difficult/stepped
Product mix	High →	Low
Delivery: Schedule changes	More difficult	Less difficult
Speed	Difficult →	Easy
Reliability	Difficult →	Easy

Olhager and Rudberg (2002) undertake the same approach and they differentiate the environments analysing the MPC system levels.

6. Chan and Burns (2004) and Mason-Jones et al (2000) analysed the manufacturing environments in terms of supply chain environments; they discussed three types of supply chain. Their classification is very generic and they don't use any variables or measures to classify these environments:

1. The lean supply chain – characterized by waste elimination in order to develop a value stream; is focused on efficiency, quality and cost.
2. The agile supply chain – uses its market knowledge and virtual organisational structure to exploit profitable new niches in a volatile marketplace; is focused on responsiveness, flexibility and quality.
3. The leagile supply chain – combines the lean and agile paradigms for effective and efficient manufacturing.

The literature shows that many authors have classified manufacturing environments using different variables. The table below is a summary of these studies.

Table 8 Summary of manufacturing environments classifications

Authors	Manufacturing environments identified
Berry and Hill (1992)	MTO (push type) , MTS (pull based)
Newman and Sridharan (1995)	MRP, ROP, Kanban and OPT
Porter et al (1999)	Mass, Batch, Jobbing and Complex
Porter et al (1999)	MTS, DTO, MTO, ATO, ETO
Porter et al (1999)	Capital equipment, Durables, Jobbing, Commodity
Olhager and Rudberg (2002)	MTO (push type) , ATO and MTS (pull based)
Jonsson and Mattsson (2003)	Complex (Type1), Configure to order (Type2), Batch (Type3), Mass (Type4)
Chad and Burns (2004)	Lean, Agile and Leagile

Based on the common variables used to distinguish different manufacturing environments, the researcher will group all these classifications to determine strong intra-groups similarities. Similar to Berry and Hill's classification, in order to classify the manufacturing environments the researcher will use the following notations: Type 1 (for high variety environment) and Type 2 (for low variety environment). The common variables used are: volume per product, product variety, demand stability, product design and layout.

Table 9 Manufacturing environment classification

Variables	Type 1 ⟶ Type 2			
Volume per product	Low	Medium	High	Higher
Product variety	High	Medium	Medium to Low	Lower
Demand stability	Low	Medium	Medium to High	Higher
Product design	Highly customised	Few changes	Few changes	Minimal changes
Layout	Functional	Cellular/line	Cellular/functional	Line
Authors				
Berry and Hill (1992)	MTO	ATO	MTS	MTS
Newman and Sridharan (1995)	MRP	OPT	Kanban	ROP
Porter et al (1999)	Capital equipment	Jobbing	Durables	Commodity
Porter et al (1999)	MTO/ETO	ATO/MTO	MTS	MTS/ATO
Porter et al (1999)	Complex	Jobbing	Batch	Mass
Olhager and Rudberg (2002)	MTO	ATO	MTS	
Jonsson and Mattsson (2003)	Complex	Configure to order	Batch	Mass

In conclusion, analysing the literature, the researcher identified a pattern of two different groups of manufacturing environment. There are several studies on manufacturing environment and authors have used different classifications for differentiating them. Studies such as: Masuchun et al (2004), Beach et al (2000), Plenert et al (1999) and Safizadeh and Ritzman (1997) explore the MPC methods and their performance, but they do not identify different manufacturing environments where these systems have been used. They revealed some general patterns, but do not differentiate between manufacturing environments, which is very important in understanding the MPC dimensions and their performance (Berry and Hill, 1992; Porter et al, 1999; Olhager and Rudberg, 2002; Jonsson and Mattsson, 2003). Although several variables are used for differentiation, individual companies/organisations might not necessarily fit into one of these groups, as their operational environment might be a mix of the manufacturing environments described above.

2.3 The role of manufacturing planning and control systems

The second sub-chapter will address the second objective of this research, by exploring the dimensions of an MPC system and it will identify MPC classifications. Then, conducting conceptual matches between planning and control methods and the environment, the researcher will investigate the main two approaches to planning and control: MRP - push systems and JIT - pull systems.

2.3.1 Definition of an MPC System

Amongst a number of sub-systems in an organization, the manufacturing planning and control (MPC) system is recognized as one of the pivotal infrastructures that firmly supports the organization's manufacturing strategy in order to create competitive advantage in the marketplace (Chan and Burns, 2002) .

Chan and Burns (2002), describe the MPC system as diverse and extensive, relating to demand management, production scheduling, capacity planning and management, inventory management and control, materials management, logistics and transportation, shop floor control, performance measurement, management of information flows, and the production decision support system. Its primary goal is to ensure that the organization behaves in a desirable way under a business setting.

An effective MPC system, as part of the supply chain, is not only optimised in terms of the usage of resources but also supports manufacturing strategy for competitiveness. As a result, the research in the MPC discipline continues to be of strategic importance since it will improve organizational effectiveness and enhances the manufacturing excellence of an organization (Kennerley et al., 1996).

The manufacturing planning and control (MPC) system is a major component of the infrastructure that supports the manufacturing process selected for a specific environment (Vollmann et al, 1997). It provides information to efficiently manage the flow of materials, effectively utilize people and equipment, coordinate internal activities with those of suppliers and communicate with customers about market requirements.

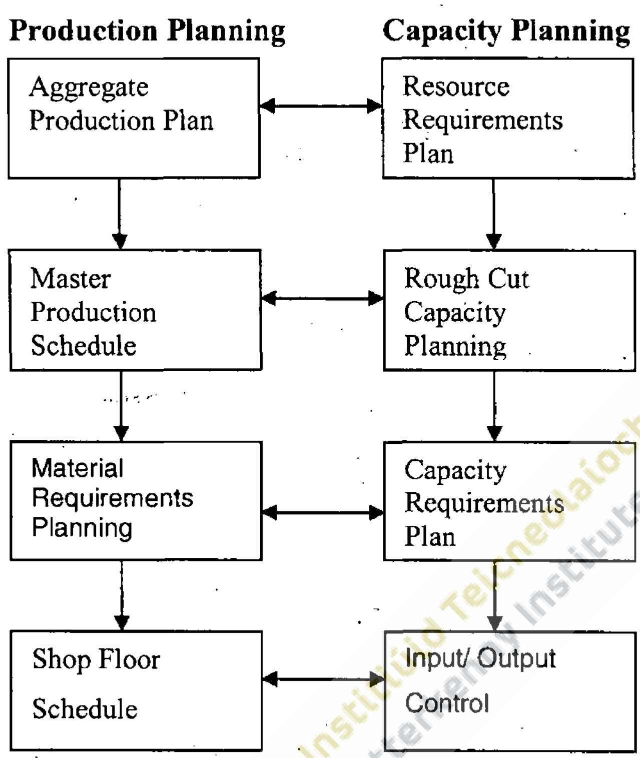
An important aspect is the managers' need to use the information to make the right decisions. The MPC system does not manage operations, managers perform those activities. The system provides the support for them to do so wisely (Masuchun et al, 2004).

2.3.2 Manufacturing planning and control dimensions

MPC systems are a key element of manufacturing infrastructure and comprise functions at three different levels within a business (Berry and Hill, 1992). Olhager and Rudberg (2002) undertook the same framework in their study and added a fourth upper level sales and operations planning (S&OP). They distinguished S&OP level from the master production schedule (MPS): S&OP fundamentally is concerned with volume planning, while MPS is concerned with product mix planning within this volume.

Taylor and Russell (2000) describe the MPC structure as a hierarchical planning process within an organisation. They analyse different levels of production and capacity planning (see figure 2.4).

Figure 2.4 Hierarchical planning process



Source: Adapted from Russell and Taylor, 2000

Howard et al (1998) identify the individual modules of a MPC system: demand management, production scheduling, capacity planning and management, inventory management and control, materials management, logistics and transportation and shop floor control. Examining the literature in terms of similar frameworks for MPC architecture, the researcher has chosen for this research study the following dimensions that an MPC system embraces: aggregate planning, master production schedule and production activity control (PAC).

Each dimension will be defined in the following sub-chapters as follows:

- Aggregate planning – in terms of demand management and resource requirements planning
- MPS – in terms of bill of material, capacity planning and scheduling.
- PAC – techniques.

2.3.2.1 Aggregate planning

Through this function all potential demands on manufacturing capacity are collected and coordinated. A well-developed aggregate planning module within the manufacturing planning and control (MPC) system brings significant benefits. Proper planning of all externally and internally generated demands, means capacity can be better planned and controlled. Physical distribution activities can be improved, so the productive system can be used efficiently and the product delivered on time. Demand management, as part of the aggregate planning encompasses forecasting, order entry, order-delivery-date promising, customer order service, physical distribution and other customer contact related activities. Through demand management, a company maintains the channel of communication between MPC systems and its customers. Specific demands initiate actions throughout MPC, which ultimately results in product delivery and consumption of material and capacities.

2.3.2.2 Demand forecasting

Chase et al (2001) defines the purpose of demand management, as to coordinate and control all sources of demand so the productive system can be used efficiently and the product /service delivered on time.

Silva et al (2000) define the aggregate plan as decisions on the quantity to produce, the size of the workforce and the inventory level. Browne (1996) describes the role of inventory at the aggregate level as a buffer between different operations that allows mismatches between supply and demand rates. Therefore it is important to take in consideration the stock levels in the preparation of the aggregate plan.

Ho and Ireland (1998) suggests that, demand forecasting has a major input into the capacity planning and control decision, which is usually an important operations responsibility. Without an estimate of future demand it is not possible to plan effectively for future events, only to react to them; therefore it is important for operations managers to understand the basis and rationale for these demand forecasts.

Duxey (2005) states that demand for many products conforms to a repetitive annual cycle, due perhaps to the climate, Christmas shopping or the start of the new school year. Seasonal variations cause special difficulties in scheduling production and ensuring that the right resource will always be available.

Demand variability is the most common condition that drives plants to require high levels of volume flexibility and it is important to predict as accurately as possible these fluctuations (Adegoke, 2003).

Regardless of the techniques employed in forecasting demand, there are eight basic principles, suggested by Smith et al (1996): accuracy of forecasts; the time horizons of forecasting; technological change; barriers to entry; dissemination of information; elasticity of demand; consumer/industrial products and aggregate versus disaggregate.

Caridi and Cicolini (2002) state that any model, which describes some aspect of the behaviour of any system or phenomenon, can be used to predict its future behaviour.

Ho and Ireland (1998) identify the need for research in evaluating the performance of various forecasting techniques. They state that there does not seem to be a forecasting method that performs satisfactorily in all production environments; therefore it is very important to take in consideration the environment where these techniques are applied.

2.3.2.3 Resource requirements planning

Buxey (2005) discuss three fundamental alternatives to aggregate planning:

- *Level plan* – the processing capacity is set at a uniform level throughout the planning period, regardless of the fluctuations in forecast demand. This means that the same number of staff operate the same processes and should therefore be capable of producing the same aggregate output in each period. This type of plan can achieve the objectives of stable employment patterns, high process utilisation and usually high productivity with low unit costs; but as well it can create high inventory, which has to be financed and stored. In a rapidly changing and unpredictable environment, level capacity plans can be very expensive and it has a negative impact on the overall business;

- *Chase plan* – this method attempts to match closely the varying levels of forecast demand. It is much more difficult to achieve than level capacity plan, as different number of staff, different working hours and even different amount of equipment may be necessary in each period. The operations managers will face the difficult task of ensuring constant quality standards and that the customer service levels are maintained. This type of plan is usually adopted by operations, which cannot store their output, such as customer-processing operations or manufacturers of perishable products.

- *Mix plan* – this method attempts to mix the approaches above.

Similar classification was suggested by Berry and Hill (1992) and Olhager and Rudberg (2002). Fung et al (2003) taking into account demand fluctuations and capacity variations, suggests a "multiproduct" planning approach that can effectively enhance the capability of an aggregate plan to give feasible family disaggregating plans. Even this approach could not guarantee a global optimal solution, due to the impact of environment, especially through demand related variables.

Resource requirements' planning is defined as the task of setting the effective capacity of the operation so that it can respond to the demands placed upon it. These issues are directly related to the changes in demand and the alternative capacity strategies for dealing with them (Silva et al, 2000).

Resource requirements planning include long and medium term horizons. The decisions taken by operations managers in devising their capacity plans will affect several different aspects of performance: cost, revenues, working capital, quality of goods, speed of response to customer demand, dependability of supply, flexibility.

Porter et al (1996) defines capacity planning as *"the amount of resource inputs available relative to output requirements over a particular period of time"*. They look at the means of capacity planning to individuals at different levels within the operations management hierarchy. The plant manager is concerned with capacity of the plant in order to meet the anticipated demand for products. The supervisor is concerned with capacity of the equipment and staffs mix in his/her department.

Knod and Schonberger (2001) refer to capacity as the provider's capability of performing the transformations necessary to ensure that goods and services satisfy customers' demands. Capacity planning refers to a broad range of activities – all focused on creating and maintaining customer-serving resources and adjusting the levels of those resources as required.

Van Assen et al (2000) suggested a sequence of capacity planning decisions that need to be taken by operations mangers. Before taking any decisions they need quantitative data on both capacity and demand. So the first step is to measure the aggregate demand and capacity levels for planning period. The second step is to identify the alternative capacity plans which would be adopted in response to demand fluctuations and finally to choose the most appropriate capacity plan.

There are several forecasting techniques, as the literature suggests, but the accuracy of the forecast is very important characteristic (Buxey, 2005; Silva et al, 2000; Smith et al, 1996).

Smith et al (1996) suggests that application of forecasting techniques can be improved by using more than one technique. Also, as the forecaster gains experience, the projections tend to be more accurate, but there is always a risk of bias and error. DuBois and Oliff (1991) conducted a postal survey and found that companies had difficulties in obtaining accurate sales forecasts or sufficiently reliable cost information in order to prepare an aggregate plan; also managers lack the necessary mathematical expertise.

Berry and Hill (1992) suggested two approaches to material planning: time phased and rate-based. The use of these methods is dictated by the market and the manufacturing characteristics of a company (Porter et al, 1999). Buxey (2005) states that there is no general rules for choosing the right strategy, but the critical factor is the magnitude of sales in relation to the plant's maximum volume flexibility.

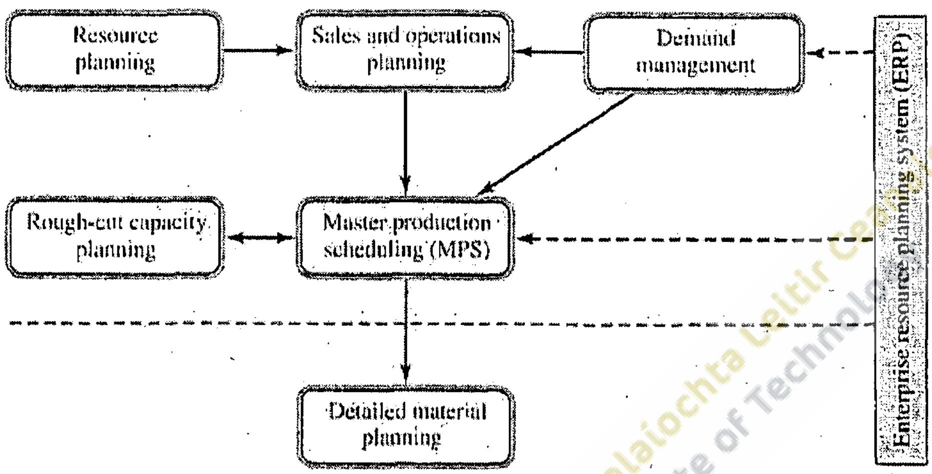
Masuchun et al (2004), Smith et al (1996) and Browne (1996) agreed that inventory levels and errors in demand forecast have significant impact on plant performance effecting the relationship between control strategy and plant performance.

In conclusion, regarding aggregate planning, operations managers have to take decisions that will affect several performance objectives: costs, revenues, quality, speed, dependability and flexibility. Despite the approach used, the objective of aggregate planning is to minimise the annual relevant costs while meeting the forecast demand for the planning horizon (Silva et al, 2000).

2.3.3 Master Production Schedule (MPS)

In this sub-chapter is described the master production schedule (MPS), a central module in the manufacturing planning and control system. The aggregate planning is an important input to the master production schedule. An effective MPS provides the basis for making good use of manufacturing resources, making customer delivery promises, resolving trade-offs between sales and manufacturing and attaining the firm's strategic objectives as reflected in the sales and operations plan. Vollmann et al (2005) describes the role of MPS in MPC system as disaggregating the sales and operations plan, creating a statement of the output from the factory and providing the information for coordinating sales and manufacturing. (See figure 2.5)

Figure 2.5 MPS in the MPC System



Source: Adapted from Vollmann et al, 2005

Berry and Hill (1992), Porter et al (1999) and Olhager and Rudberg (2002) described the manufacturing environment, relating to master production schedule, as the production approach used. They identified three types of MPS approaches: make-to-stock, make-to-order and assemble-to-order.

The *make-to-stock* company produces in batches, carrying finished goods inventories for most of its end items. The MPS is the production statement of how much of and when each end item is to be produced. All identical items are grouped into *consolidated item numbers* and run together in batches to achieve economical runs for component parts and exploit the learning curve in the final assembly areas.

The *make-to-order* company carries no finished-goods inventory and builds each customer order as needed. This form of production is often used when there's a large number of possible production configurations and a small probability of anticipating a customer's exact needs. The customer expects to wait for a large portion of the entire design and manufacturing lead-time. The MPS unit is typically defined as the particular end item or set of items compromising a customer order. Due to the fact that design takes place as the part is built; to define the end product is difficult. Production often starts before a complete product definition and bill of materials have been determined.

The *assemble-to-order* firm is typified by an almost limitless number of possible end item configurations, all made from combinations of basic components and subassemblies. Customer delivery time requirements are often shorter than total manufacturing lead times, so production must be started in anticipation of customer orders. Flexibility is a key point in assemble-to-order firms and tries to maintain it by starting basic components/subassemblies into production, but not starting final assembly until a customer order is received. The MPS unit stated in planning bills of material and it has as its components a set of common parts and options. The option usages are based on percentage estimates, and their planning in the MPS includes buffering or hedging techniques to maximise response flexibility to actual customer orders.

2.3.3.1 Bill of materials (BOM)

Du et al (2005) define the bill of materials as an integral part of an MPS module, an engineering document that specifies the ingredients or subordinate components required physically to make each part number or assembly. An important factor in determining the BOM of a product is the number of levels of subcomponents. A BOM is used for an end product to state raw materials and/or intermediate products required for making the product. To describe how a product is made, a routeing is used to specify the sequence of operations to be performed at corresponding work centres. (Bragg et al, 2005)

An effective control of a production job at the shop-floor level cannot be fulfilled without the integration of planning and control functions. This necessitates that the material contents of BOM's are linked to the relevant assembly operations to reflect the material flow through the production process. (Chung-Hsing, 1995)

Du et al (2005) highlights the challenge of high variety in managing many individual BOM's and they suggest that the generic BOM (GBOM) allows for the specification of product variants by means of describing an item and a set of descriptions at any level in a multilevel BOM, rather than being limited only to top-level item. Yeh (1997) pointed out that manufacturing resource planning (MRP II) has achieved only limited success in its implementation, mainly due to the fundamental weakness of its planning logic and the lack of integration between material requirements planning and capacity planning module. Therefore it is imperative to streamline the impact of product variety on existing manufacturing capabilities and in turn, the implications of production information in managing product variety.

Studies such as Little et al (2000) emphasize the proper handling of customer and production data based on BOM information to achieve an alignment of products and processes. They outline important elements for integrated planning and scheduling in an engineering-to-order system, including product configuration, master production scheduling, design planning, project requirements planning, shop floor scheduling and assembly scheduling. Huang et al (2003) suggests that product structures and cost data, along with proper production information models, impose a significant impact on production planning throughout manufacturing supply chain.

BOM inaccuracies and inaccurate reporting of lost, scrapped or substituted parts all contribute to inaccuracies in on-hand inventory information. Stock outages still occur despite the manual effort and cost to prevent them from happening. It results in production stoppages and lost production, which in turn results in lost sales, customer dissatisfaction and complaints (Petroni and Rizzi, 2001).

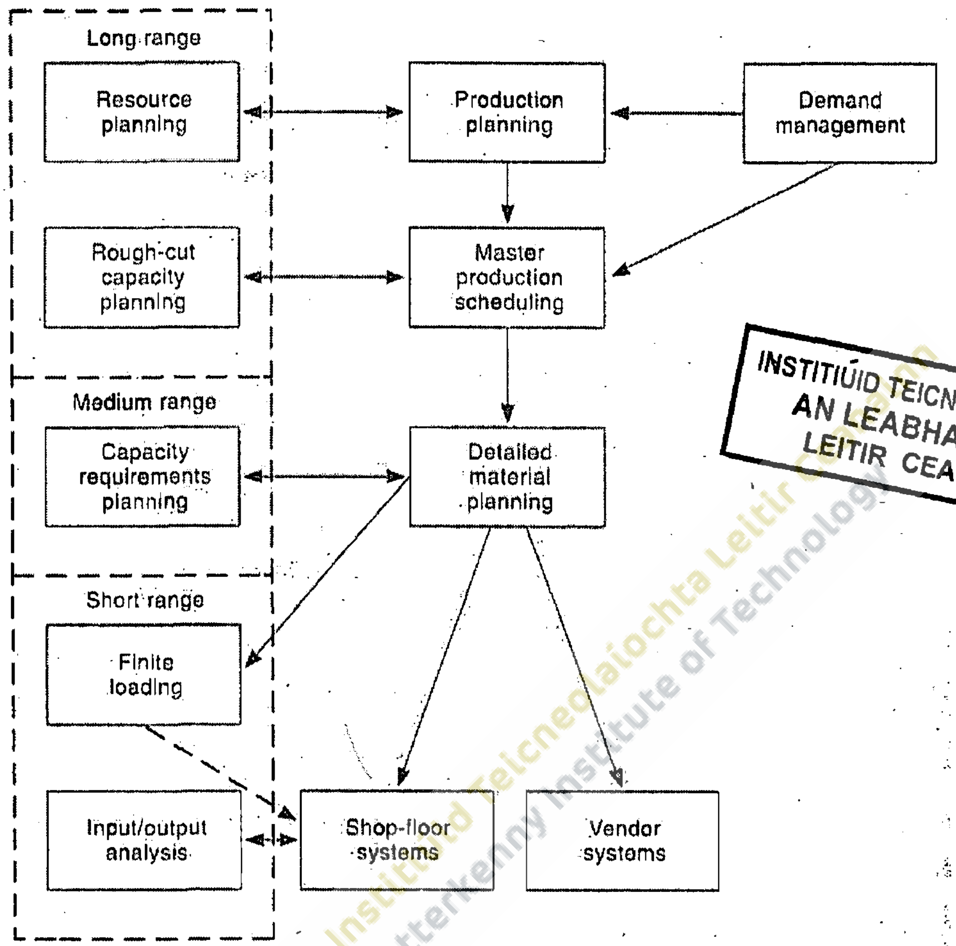
Chung-Hsing (1995) describes a production data model as a logical representation of two key production data structures – bill of material (BOM) and routeing. Its function is to provide a logical way to support the information needs of a production planning and control system for performing functions such as material requirements planning, capacity requirements planning, operations scheduling and shop floor control. It is very important to take in consideration the role of BOM in the inventory control.

2.3.3.2 MPS techniques

A Master Production Schedule or MPS is the plan that a company has developed for production, inventory, staffing, etc. It sets the quantity of each end item to be completed in each week of a short-range planning horizon. A Master Production Schedule is the master of all schedules. It is a plan for future production of end items.

Vollmann et al (1997) defines the scope of MPS *"starting from an overall plan of resources, proceeding to a rough-cut evaluation of a particular master production schedule's capacity implications, moving to a detailed evaluation of capacity requirements based on detailed material plans, then continuing to finite loading procedures, and ending with input/output techniques to help monitor the plans"*. (see figure 2.6)

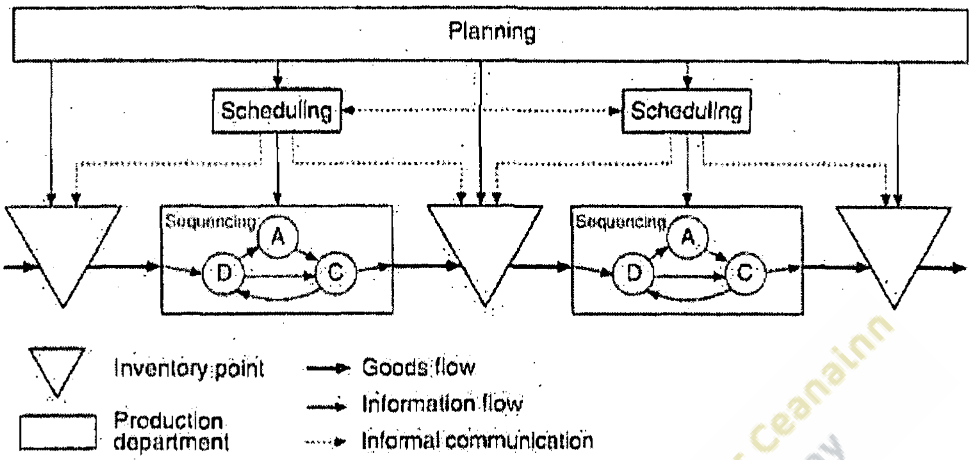
Figure 2.6 MPS role within an MPC



Source: Adapted from Vollmann et al, 1997

Stoop and Wiers (1996) present a similar view by depicting the theoretical relation between planning, scheduling and sequencing (see figure 2.7). According to theory, planning controls the inventory points in the goods flow and gives material requirements to scheduling. The scheduling function then releases jobs to the shop floor. Dependent on the level of scheduling, sequencing decisions are made on the shop floor.

Figure 2.7 MPS: Planning, scheduling and sequencing in MPC system



Source: Stoop and Wiers (1997)

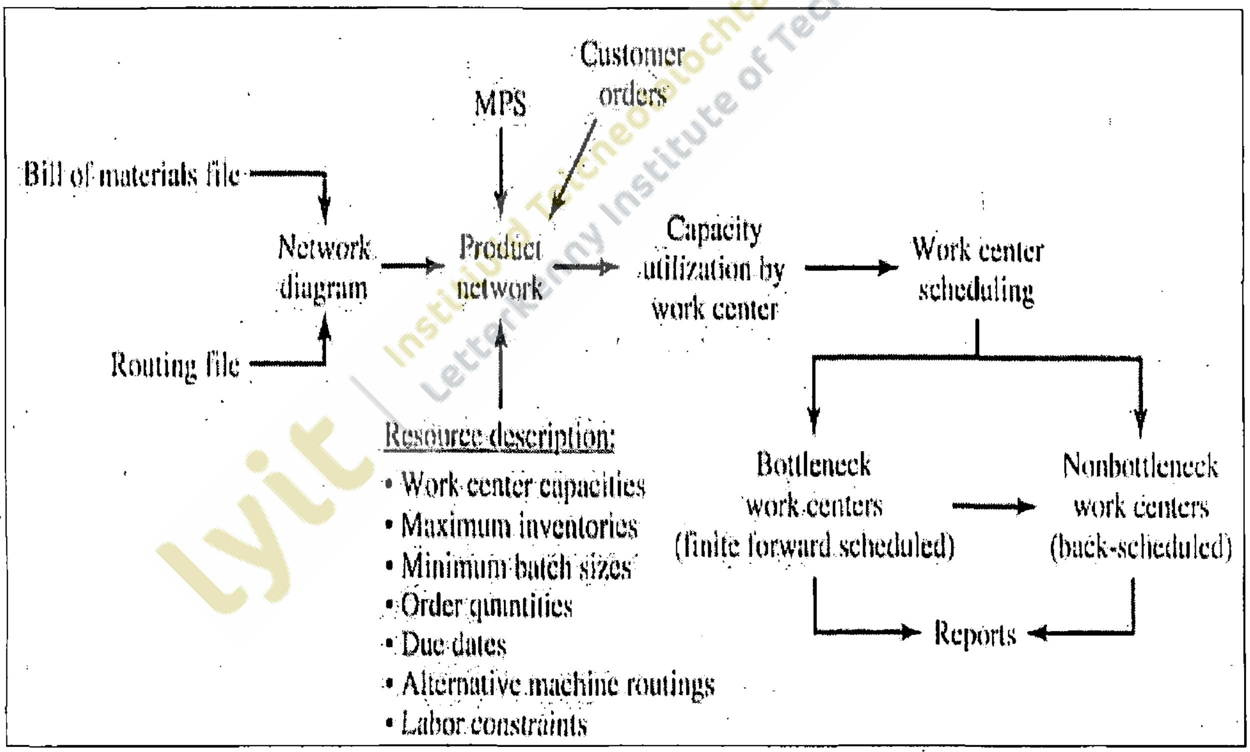
Guide et al (1997) describes the major techniques used for rough cut capacity planning:

1. *Capacity planning using overall factors (CPOF)*
2. *Capacity bills*
3. *Resource profiles*
4. *Capacity requirements planning (CRP)*
5. *Theory of constraints (TOC)*

Vollmann et al (2005) defines the scheduling approach used in TOC systems drum-buffer-rope. The bottleneck centres (constraints) are the drums and are used to control the workflow in a plant. Any resource whose capacity is more than the demand is called a *non-drum*. The rope refers to pull scheduling at the bottleneck work centres. The purpose of the rope is to tie the production at each resource to the drum. A buffer exists at all of the bottleneck work centres.

These buffers are used to protect the throughput of the bottleneck work centres from the inevitable minor fluctuations through the use of time buffers (work in progress - WIP inventory) at a relatively few critical points in the plant. The basic concept is to move material as quickly as possible through non-bottleneck centres until it reaches the bottleneck. The work at the bottleneck resources is scheduled for maximum efficiency. Thereafter, work moves at maximum speed to the finished goods. (See figure 2.9 TOC scheduling)

Figure 2.9 TOC scheduling



Source: Vollmann et al, 2005

Ching et al (2004) suggests that when faced with uncertainties a variety of buffering or dampening techniques can be used to tackle the unwanted effects, such as safety stock, safety lead-time, overtime or outsourcing. Buffering it refers to any extra quantity of materials waiting for processing – an example of buffering technique is safety stock. Dampening refers to planning methods, such as rescheduling and safety lead-times. Lead-time is the elapsed time required to perform a task or job (Knod and Schonberger, 2001). They define the elements of production lead-time for a given part as follows, in descending order of significance: queue time; run-time or service-time: value-adding time during which the item is being produced or the service is being delivered; set-up time; wait times (for instructions, transportation, tools, etc.); inspection time; move-time and other.

Stoop and Wiers (1996) define scheduling as an important part of the MPS and it lies at the very heart of the performance of manufacturing organisations. The need for efficient scheduling has greatly increased in recent decades owing to market demands for product quality, flexibility and order flow times.

Knod and Schonberger (2001) and Vollmann et al (2005), state that queue-time frequently accounts for 80% or more of the total lead-time and it's the most capable element of being managed. Reducing the queuing-time means shorter lead-time and reduced WIP inventory. This reduction requires better scheduling. Dumond (2005) states that finite scheduling should be considered more then a scheduling tool, due the fact it allows firms to generate schedules to meet customer needs and for management of resources to meet these due dates in a dynamic environment. The benefits provided by finite scheduling are significant and those firms using finite scheduling have gained advantages through shorter lead-times, greater efficiency and utilisation, higher quality, improved on-time delivery, better customer relations, lower costs and higher profitability (LaForge and Craighead, 2000). Another approach is suggested by Slack et al (2001) infinite scheduling, where the system does not limit accepting work, but instead tries to cope with it.

Slack et al (2001) describes the scheduling function as "*a detailed timetable showing at what time or date jobs should start and when they should end; a familiar statement of volume and timing*". Dumond (2005) presents two basic finite scheduling approaches:

- Forward scheduling – involves starting work as soon as it arrives; it is normally used for jobs with relative short due date; in addition a forward schedule can be used to quote a realistic delivery date for a particular order;
- Backward scheduling – involves starting jobs at the last possible moment to prevent from being late; it is normally applied to those jobs with long due date.

The choice of backward or forward scheduling depends on circumstances. There are several advantages for using these approaches. (See table 10)

Table 10 Advantages of forward and backward scheduling

Advantages of forward scheduling	Advantages of backward scheduling
High labour utilisation – workers always start work to keep busy	Lower material costs – materials are not used until they have to be, therefore delaying added value until the last moment
Flexible – the time slack in the systems allows unexpected work to be loaded	Less exposed to risk in case of schedule change by the customer
	Tends to focus the operation on customer due dates

Adapted from Slack et al, 2001

Stoop and Wiers (1996) state that the planned or expected performance of production units often deviates from the actual performance, due to several disturbances, such as: capacity disturbances (examples machine breakdowns, illness of operators, unavailability of tools); order disturbances (examples unavailability of machines, extra orders cause by scrap, rework, rush orders) and measurement data (differences between pre-calculated and actual processing time, capacity efficiencies).

Sanderson (1989) suggest that the human factor has an important role in the performance of scheduling techniques; due to the fact that humans may overrule the scheduling technique because they think that they can outperform the techniques by increased mental effort.

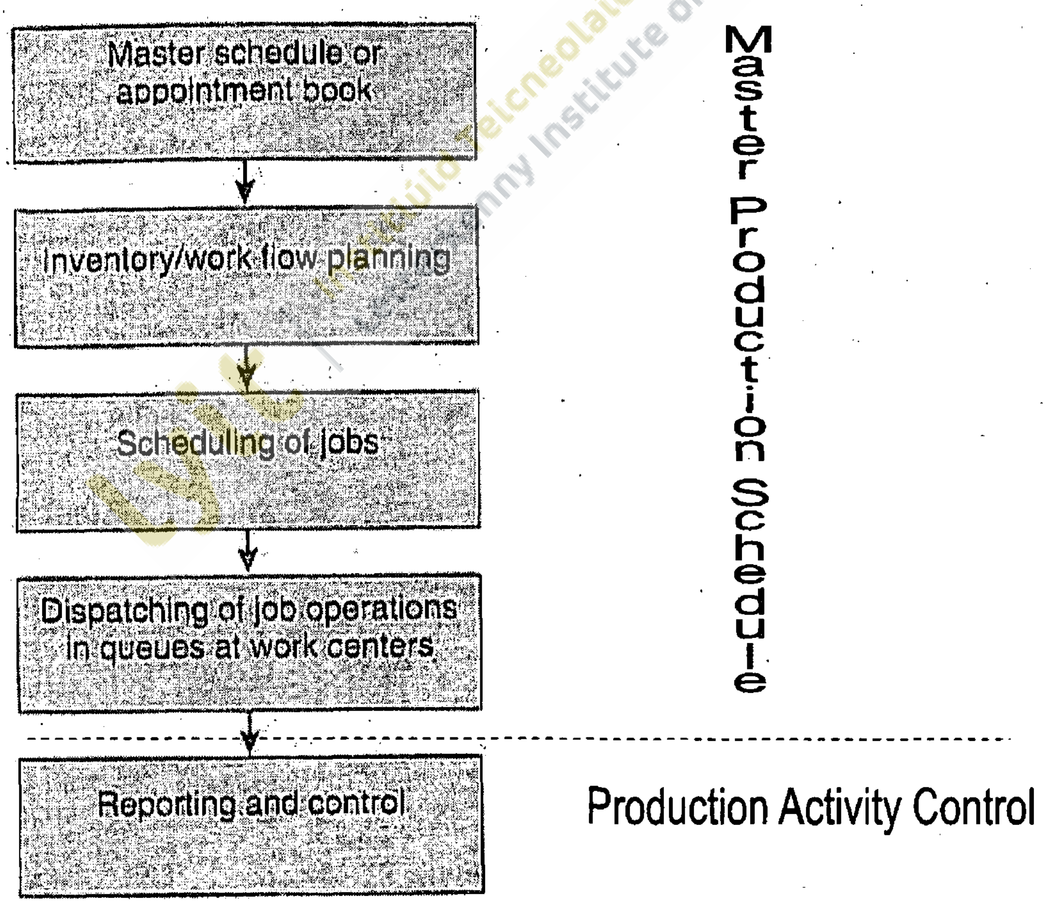
Stoop and Wiers (1996) state, that assessing schedule performance is a very complex problem and the feedback from shop floor is not evaluated in an aggregate way. The scheduler is only interested in detailed feedback about exceptions and does not evaluate aggregate measures such as service level.

Wermus (2001) describes several factors that change scheduling priorities: pressure from customers, change in delivery due date, engineering design change, change in demand, machine breakdown, manufacturing problem, material shortage, labour shortage, insufficient machine capacity. As well, analysing the production process he presents some factors that influence the scheduling process: size of the order, processing time, setup cost, setup time, lead time and material handling capacity.

2.3.4 Production Activity Control

This sub-chapter concerns the execution of detailed material plans. It describes the planning and release of individual orders to both factory and outside vendors. Production activity control (PAC) also concerns detailed scheduling and control of individual jobs at work centres on the shop floor, as well as vendor scheduling. An effective PAC module can ensure meeting company's customer service goals. It can reduce work-in-progress inventories and lead times. A key element of an effective PAC is feedback on shop and suppliers' performance against plans. The primary PAC objective is managing the operation flow to meet MPS plans. (See figure 2.10)

Figure 2.10 MPS and PAC



Source: Adapted from Knod and Schonberger, 2001

2.3.4.1 Basic PAC concepts and techniques

Production activity control or shop-floor control is defined by Vollmann et al (2005) as: "*a system for utilising data from the shop-floor as well as data processing files to maintain and communicate status information on shop orders and work centres*".

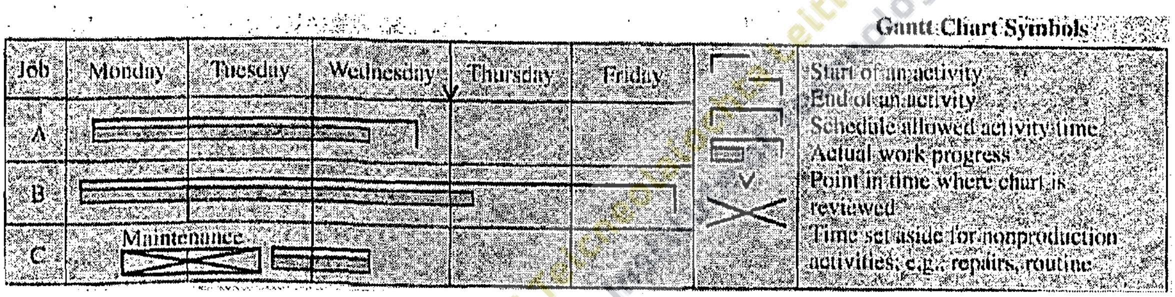
Chase et al (2001) describes the basic tools of shop-control techniques:

1. The *daily dispatch list* – which tells the supervisor which jobs are to be run, their priority and how long each will take
2. Various *status and exception reports* including:
    a. The anticipated delay report, made out by the shop-planner once or twice a week and reviewed by the chief shop planner to see if there are any serious delays that could effect the master schedule
    b. Scrap reports
    c. Rework reports
    d. Performance summary reports giving the number and percentage of orders completed on schedule, lateness of unfilled orders, volume of input;
    e. Shortage list
3. An *input/output control report* - that is used by the supervisor to monitor the workload capacity relationship for each workstation.

Relating to the PAC techniques, literature suggests: Gantt charts and priority sequencing rules.

1. Gantt charts – provides a graphical understanding of the shop-floor control systems. Chase et al (2001) describe Gantt charts as a type of bar chart that plots tasks against time. They are used for project planning as well as to coordinate a number of scheduled activities. (See figure 2.11)

Figure 2.11 Gantt chart



Source: Chase et al, 2001

The advantage of Gantt charts is that they provide a simple visual representation both of what should be happening and of what actually is happening in the operation (Slack et al, 2001). As well, they can be used to test out alternative schedules and it facilitates the development of alternative schedules by communicating them effectively.

2. Priority sequencing rules – determine which job to run next at a work centre. These can be very simple, requiring only that jobs be sequenced according to one piece of data, such as processing time, due date or order of arrival.

Accordingly to Chase et al (2001) the following standard measures of schedule performance are used to evaluate priority rules: meeting due dates of customers or downstream operations; minimising the flow-time (the time a job spend in the process); minimising WIP inventory and minimising idle time of machines or workers.

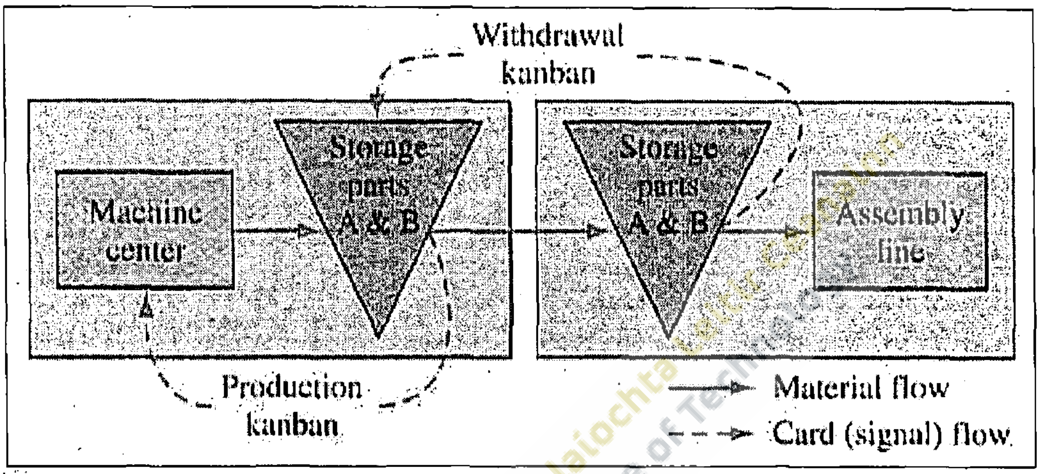
Knod and Schonberger (2001) suggest several factors that should be considered in setting priorities for jobs: customer importance, order urgency, order profitability, impact on capacity utilisation and shop performance.

3. *Kanban technique* - a kanban control system uses a signalling device to control the JIT flows. Kanban means "sign" or "instruction card" in Japanese. The cards or containers make up the kanban pull system. The authority to produce or supply additional parts comes from downstream operations. (See figure 2.12)

Marckham et al (2000) describes two kinds of kanbans: a production ordering kanban – that specifies the kind and quantity of product which the proceeding process must produce and a withdrawal kanban – that specifies the kind and quantity of product which the subsequent process should withdraw from the preceding process. In this way the amount of inventory needed throughout the factory is minimised.

Haslett and Osborne (2000) state that kanban system was designed to introduce stability and predictability into the inventory held between the manufacturing and assembly operations. In practice, managers intervene constantly in an endeavour to prevent stock outs and the consequential expensive line stops in the assembly process.

Figure 2.12 Flow of two Kanbans



Source: Chase et al, 2001

Many authors such as Bhuiyan and Baghel (2005), Brunet and New (2003), Styhre (2001), Savolainen (1998) describe these production activity control techniques as part of kaizen the Japanese approach of continuous improvement. These techniques evolve uniquely within each organisation, following changes to the organisation's business environment. Detailed implementations vary considerably between organisations, but all rely on continuous improvement to achieve targets as an integral element in the operations management system.

In conclusion we can observe that the literature describes several dimensions of an MPC system and each dimension has different techniques available. Identification of these techniques will allow for further research. It is important to associate them with the planning and control systems in order to assess their match, use and performance within a manufacturing environment. See table 11 for summary of literature of MPC dimensions and its associated techniques.

Table 11 Summary of MPC dimensions and its associated techniques

MPC Dimensions	**Associated techniques**	**Authors**
Aggregate planning	- Aggregate plans	Berry and Hill (1992), Olhager and Rudberg (2002), Buxey (2005).
	- "Multiproduct" planning approach	Fung et al (2003)
Master production schedule	- Capacity planning using overall factors, capacity bills, resource profiles, capacity requirements planning	Vollmann et al (2005), Jonssons and Mattsson (2003),Russell and Taylor (2000) Guide et al (1997)
	- Material planning approach: time phased/ rate based	Berry and Hill (1992)
	- Theory of constraints	Vollmann et al (2005)
	- Infinite/finite scheduling	Dumond (2005), Slack et al (2001), Jonsson and Mattsson (2003)
Production activity control	- Input/output control : Priority rules, dispatch lists	Bhuiyan and Bahel (2005), Vollmann et al (2005), Jonsson and Mattsson (2003), Chase et al (2001)
	- Kanban	Bhuiyan and Bahel (2005), Vollmann et al (2005), Brunet and New (2003), Jonsson and Mattsson (2003), Styhre (2001), Marckham et al (2000), Savolainen (1998)

2.3.5 Identify MPC classifications

Many studies have sought to classify manufacturing planning and control approaches. Some classifications are not very well defined; therefore it is difficult to clearly differentiate the rules of operation and other dimensions that describe the systems modelled.

1. Berry and Hill classification

Berry and Hill (1992) analyse manufacturing strategies using specific company examples. They identify two MPC systems: push and pull system that supports the overall business objectives, linking them to the market-process infrastructure.

Table 12 Berry and Hill system's classification summary

Berry and Hill (1992) / Dimensions	Push system	Pull System
Master Production Schedule	- Make-to-order/assemble-to-order - Customer orders/anticipated orders/forecast orders – used for rough cut capacity planning due to long lead time impact on delivery - Customer order promising	- Make-to-stock/manufacture to forecast - Level production - Manufacture to replenish inventories
Material Planning	- Time-phased material planning - Material is particular to customer orders; - High obsolescence risk - Extra-material needed for scrapped items	- Rate-based material planning - Low raw material, component and WIP inventory
Shop-floor control	- Priority scheduling of shop orders - System supported by despatching and production controller personnel - Capacity requirements planning by work centre - Order tracking and status information	- Kanban containers - JIT flow of material

Source: Adapted from Berry and Hill (1992)

2. Newman and Shridharan's classification

When demand is both stable and predictable, there is very little need for a sophisticated system for production planning and control, but when faced with a highly unstable or unpredictable demand, choosing the right kind of MPC system becomes crucial for achieving both effectiveness and efficiency (Newman and Shridhara, 1995). They present four types of MPC systems commonly found in use: MRP, ROP, Kanban and OPT. However they do not describe these systems in term of their dimensions or rules of operation. They superimpose an infrastructure support system (MPC system) that might represent the 'best' for the conditions that define the firm's environment. Therefore it is difficult to classify these systems analysing their dimensions. The criteria that the authors use to differentiate these systems are the system's performance. See table 13 for a summary of the overall performance ratings for each MPC system.

Table 13 Summary of the overall performance ranking

Newman and Shridharan (1995) / Quintile	MRP %	ROP %	Kanban %	OPT %
1	12.00	6.67	2.00	1.33
2	13.33	4.00	1.33	0
3	10.67	5.94	1.33	1.33
4	12.67	4.24	1.33	1.33
5	13.33	3.33	2.97	1.33

Source: Newman and Shridharan, 1995

They conclude that demand predictability and variability has a great input in choosing the right system and their suggestions are summarised in table 15.

Table 14 MPC systems and demand

Demand Predictability	**Demand variability**	
	LOW	**HIGH**
LOW	Kanban	OPT
HIGH	All	MRP

Source: Newman and Shridharan, 1995

3. Miltenburg's classification

Similar approach is undertaken by Miltenburg (1997); he compares JIT and embedded TOC into MRP, without clearly defining the MPC dimensions. He analyse system's performance in terms of output, inventory, cycle time and shortages. MRP with embedded TOC technique gives highest output, lowest shortage, high inventory and long cycle time. JIT gives high output, low inventory, short cycle time and possible high level of shortages. He specifies that balanced schedules and multi skilled operators are typically used in JIT systems and drum-buffer-rope scheduling and transfer batches in MRP.

4. Bonney et al's classification

Bonney et al (1999) classifies MPC systems into push and pull systems, where MRP is described as a push system and a kanban operated JIT is described as a typical pull system. Their definitions of push and pull systems are based on information flow used for control. See table below for details.

Table 15 Bonney et al's system classification summary

Bonney et al (1999) / Dimensions	Push system	Pull System
Aggregate planning	- Level plan - Focus on planning	- Focus on preplanning
MPS	- Based on forecasting - Finite scheduling	- Based on customer orders
PAC	- Priority rules	- kanban

Source: Adapted from Bonney et al (1999)

5. Porter et al's classification

Porter et al (1999) describes the common approaches to production planning as follows: Just-in-Time (JIT); Project evaluation and review (PERT) and critical path (CPM); Constraint based scheduling (CBS); Process flow scheduling (PFS); Manufacturing resource planning (MRP) and derivations and Finite capacity scheduling (FCS). See table 16 for details on their classification.

Table 16 Porter et al's system classification summary

Porter et al (1999) / Dimensions	JIT	PERT/ CPM	CBS	MRP/ FCS/ PFS
Aggregate planning	- Rate based			-Time phased
MPS	- Simple for of schedule		-Finite scheduling	- Back scheduling; - Routeings; - Finite scheduling
PAC	- Kanban			- workflow monitoring

Source: Porter et al (1999)

6. Jonsson and Mattsson's classification

Jonsson and Mattsson (2003) because of the scarcity of literature and reference support for classifying MPC systems, used in their study a conceptual matching of planning environments and planning methods, based on a conceptual analysis of the MPC system's characteristics. Their conclusions are mainly based on logical assumption and represent different types of planning environment using the following notations: type 1, type2, type3 and type 4. Table 17 is a summary of their assessment.

Table 17 Jonsson and Mattsson's conceptual matching of planning environments and methods

Planning method	Planning environment			
	Type 1	Type 2	Type 3	Type 4
Detailed material				
planning		+	++	+
Reorder point		+	++	+
Run-out time planning	+	++	++	+
Material requirements	-	+	+	++
plan	++	+		-
Kanban				
Order-based planning				
Capacity planning				
Overall factors	-		-	++
Capacity bills		+	+	+
Resource profiles	++	+	+	+
Capacity requirements	+	+	++	+
planning				
Scheduling				
Infinite scheduling				++
Finite scheduling	+		+	
Input/output control		++	+	++
Sequencing				
Sequencing by foremen	+			-
Priority rules		+		+
Dispatch lists	++	++	++	+

Note: ++ Strong match; + Poor match; - Mismatch

Source: Adapted from Jonsson and Mattsson (2003)

7. Masuchun et al's classification

Masuchun et al (2004) describe push and pull strategies as embodying the concepts of MRP and JIT/kanban. See table 18 for details.

Table 18 Masuchun et al's system classification summary

Masuchun et al (2004) / Dimensions	Push system MRP concept	Pull System JIT/kanban concept
Aggregate planning	- Demand forecasts	-based on orders
MPS	- Backward scheduling	- low inventory levels
PAC		-Kanban

Source: Adapted from Masuchun et al (2004)

The literature shows that many authors have classified manufacturing planning and control (MPC) systems, using different approaches. The table below is a summary of these studies.

Table 19 Summary of MPC system classifications

Authors	**MPC systems identified**
Berry and Hill (1992)	Push system, Pull System
Newman and Sridharan (1995)	MRP, ROP, Kanban and OPT
Miltenburg (1997)	Just-in-time (JIT), MRP with embedded Theory of constrains (TOC)
Bonney et al (1999)	Push System, Pull System
Porter el al (1999)	Just-in-time (JIT), Project evaluation and review (PERT) and critical path (CPM), Constraint based scheduling (CBS), Process flow scheduling (PFS), Manufacturing resource planning (MRP) and derivations, Finite capacity scheduling (FCS).
Jonsson and Mattsson (2003)	Type 1, Type 2, Type 3, Type 4
Masuchun et al (2004)	Push System, Pull System

We can observe that several authors have classified MPC systems, using different tags to name these systems. Based on the analysis of the literature there is a pattern emerging and the researcher has identified push – MRP type system and pull – JIT type system. For the purpose of this research and to make this study manageable, the researcher will investigate these two main approaches to planning and control and their dimensions with associated methods. Using the common dimensions and methods, he will group all these classifications to determine similarities in the systems modelled. The researcher will use the notations Type A for push system – MRP type and Type B for pull system – JIT type, to classify the manufacturing planning and control systems. The common dimensions used are: aggregate planning, master production schedule and production activity control, along with their associated dimensions.

Table 20 MPC classification and their associated dimensions

Dimensions	Type A Push system – MRP type	Type B Pull system – JIT type
Aggregate planning		
- aggregate plans	Level plan	Chase plan
- material planning approach	Time-phased	Rate based
Master production schedule		
- MPS approach	MTO/ATO	MTS
- Scheduling approach	Finite	Infinite
- Inventory levels	Higher	Lower
Production activity control		
- Control approach	Priority, dispatch rules	Kanban
Authors		
Berry and Hill (1992)	Push system	Pull system
Newman and Sridharan (1995)	MRP	Kanban
Miltenburg (1997)	MRP (TOC)	JIT
Bonney et al (1999)	Push system	Pull System
Porter el al (1999)	MRP/CBS/FCS/PFS	JIT
Jonsson and Mattsson (2003)	Type 1	Type 4
Masuchun et al (2004)	Push system-MRP	Pull system-JIT/Kanban

In conclusion, the researcher has identified two main approaches to planning and control: push system – MRP type and pull system – JIT type. Although several authors used different titles to describe these MPC systems, they have similar dimensions and it is difficult to clearly define them in detail. Some studies suggest that most manufacturing control systems are hybrid: a mixture of both push and pull. However, this observation is not very meaningful if the terms push and pull have been left deliberately vague (Safizadeh and Ritzman, (1997)). Although several authors identified push and pull systems, they didn't define them in detail regarding their rules of operation and other dimensions that describe the system modelled (Bonney et al (1999), Miltenburg (1997), Spencer (1995), Newman and Sridharan (1995)). Others identified push system as a MRP type and pull system as a JIT type, without clearly defining the differences between them (Masuchun et al (2004), Porter et al (1999)). Further in this study the researcher will conduct conceptual matching between the MPC systems identified and manufacturing environments. This will be followed by an empirical match that will differentiate system's performance in manufacturing environments.

2.4 Linkages between manufacturing environment and manufacturing planning and control systems

Today most products are global composites of materials and services from manufacturers throughout the world. Business has to consider customers, suppliers, and competitors in global terms in order to succeed. A company that is considered to be world class recognizes that its ability to compete in the marketplace depends on developing a business strategy that is properly aligned with its mission of serving the customers. Company competitiveness refers to its relative position in comparison to other firms in the local or global marketplace (Chase et al, 2001).

It is argued that what separates winning organizations from their counterparts is the process to address the internal organization and external demands established by the competitive business world. Organization theorists have often emphasized the importance of aligning organization system and strategy with the external environment (Berry and Hill, 1992).

This chapter investigates the two main approaches to manufacturing planning and control push and pull system and their linkages with the environment. It is important to analyse their characteristics in order to explain their fit and use. This will provide the fit through a conceptual matching, followed by the empirical analysis of their use, in terms of performance within the next chapters.

2.4.1 Characteristics of Push systems – MRP type

Several studies in the literature suggested that a well-implemented MRP system has broad benefits for the entire organisation. (See table 21)

Table 21 Summary of literature studies on benefits of MRP type systems

Authors	Benefits
Wong and Kleiner (2001)	- increased productivity; - improved customer service; - reduced purchased costs - reduced traffic costs; - reduced obsolescence; - reduced overtime; - improved quality of life.
Knod and Schonberger (2001)	- improves on-time completion; - cuts inventories; - improves productivity; - facilitates closing the loop with total business planning.
Brown (1996)	- reduced stock levels and highturnover - increased customer service; - more reliable and faster quoted delivery times; - better relationship with suppliers.

Van Assen et al (2000) describes one of the main problems of the MRP system is the lead-time syndrome – MRP use leads to longer and longer lead-times, as a result of ignoring the interactions between WIP, capacity, variability and lead-time.

There are perceived problems with MRP (Brown, 1996). "*On the main factors is that it should present a learning opportunity for firms over a period of time when the system is bought in as a means of solving inventory problems quickly*".

Kumar and Meade (2002) describe two factors that create problems within the MRP systems: the requirement for *immediate delivery* of a product following a customer order and *the increased complexity* of the products being requested.

Immediate delivery – in today's "*instant gratification world*" it is no longer acceptable that a customer waits for the delivery of a product as it happens in the past. For large orders it may be acceptable to wait several weeks if some level of customisation is requested. This development has added the requirement to carry finished goods at the point-of-sale of the right model in the right quantities.

Increased complexity in products – product customisation driven by customer desires, has led to an ever-increasing need for additional component or material inventories to produce the various models. BOM became more and more complicated and more MRP calculations are needed. The various files are required by MRP to calculate material needs and must contain current information and be accurate. Increased computing power to perform the calculations and deal with the expanding volumes of data has kept the pace but the manual entry and maintenance of the records has become a growing issue.

These two factors have led to the inability to accurately forecast future sales at a finished goods level and the inability to ensure adequate inventory levels of material and components to support the changing production demands.

Caridi and Cigolini (2002) state MRP methods rarely are kept accurate, that due to the process employed, back-flushing material out of the inventory based on quantities of final assemblies produced, using BOM data for component quantities and adding scrap/reject information to account for components lost due to failures.

Brown (1996) identifies potential long-term problems with MRP:

- Planning and implementing MRP can take years – although software packages are available, in reality companies must have an individual, tailored approach if the system is to be successful;
- Data entry and maintenance take up much time – even if the reports are exception reports; detailing changes from the last MRP run, this still will take up much time;
- Data integrity is essential – this often is the cause of failure due to inability to provide accurate forecasts of supplies and sales and engineering data, which is incorrect.

Koh et al (2000) presents some limitations of MRP presumptions in terms of fixed lead time, infinite resource, fixed routing, constant scrap rate and 100 percent adherence of schedule receipt and schedule release. They suggest that the performance of MRP system is often poor due to implementation of wrong functionality or systems are considered failures if expectations are not met.

The difficulty with producing a reasonably accurate forecast has increased exponentially (Ip et al, 2000). Globalisation of the market place, technology and the rate in which it advances, continued shortening of the design process for new products and the increased desire of the customer for new and different as well as more material goods, have all been part of the MRP problems.

The more stable, slower moving economic environments, with a predictable forecast are very rare; therefore MRP systems face the problem of not adapting with the environment where they operate (Aghazadeh, 2004).

2.4.2 Characteristics of Pull systems – JIT type

Aghazadeh (2004) presents the JIT as a management philosophy of problem solving, which relies on two main principles: the elimination of waste and the complete utilisation of capabilities of people. Several studies in the literature suggested that successful implementation of a JIT system can bring benefits for the entire organisation. (See table 22)

Table 22 Summary of literature studies on benefits of JIT type systems

Authors	**Benefits of a JIT system**
Vollmann et al (2005)	- throughout time reductions; - less material movements; - reduced changeover time; - greater responsiveness; - inventory reductions; - better team workers; - quality cost reductions and quality improvement.
Aghazadeh (2004)	- eliminates waste; - minimises holding space and reduces costs; - offer quicker response time to customers; - smaller lot sizes can be utilised; - decreased lead, set-up and production time.
Stockton and Lindley (1995)	- reduce lead-times; - reduce the variety of components that need to be processed; - allows greater standardisation of processing procedures; - enable integration or linking of machines; - allows responsibility (ownership) for a family of components to rest with one group of operators;

Knod and Schonberger (2001) describe some problems that a JIT system can encounter:

- Inflexibility – a surge in customers or orders arrival will cause a large queue in production, unless the company has spare resources. As the JIT concept does not imply safety stock, this can raise disturbances. Insufficient physical capacity, lack of cross-trained labour or back-up labour supply can as well disrupt the smooth flow of work.

- Geographical distances – if manufacturing providers and users are separated, the supplier can keep producing and push the product forward. Poor contact with customers can become an important issue.

- Period quotas – when managers feel pressure to attain period production or sales quotas, the result can be an end-of-period push to get the goods out the door.

- Capacity/budget justification – the desire to show high levels of resource utilisation as a way of justifying existing budget levels or capacity allocations can determine managers to push unneeded work onto the process.

Aghazadeh (2004) highlights several limitations of the JIT approach:

- Cultural differences – play an important role when interacting with different firms in order to receive goods on time. Many organisations find that it is difficult to adopt new methods because of present cultures. People are set in their own way and they do not like changes;

- Inventories on hand – the traditional way of having plenty of inventories on hand to cover ordering or product mistakes, is not possible with JIT which creates a source of negative pressure on the participating individuals;

- Loss of autonomy – puts more stress on workers due to the fact they have a set amount of time to do certain things;

- Limit of trust – must be broken between workers and their managers because you cannot have any lack of commitment; trust must be achieved to have complete satisfaction of work;

- The employee's skills – must be maximised and must be flexible to work with different types of equipment.

- Production limit – you can only reach high production if every individual works equally as hard.

Roongrat and Bohez (2004) states that, the disadvantages of JIT include that the items produced cannot have any defects because there are not enough inventories to use as replacement. As well, in order to function effectively a JIT system requires knowledge workers, multi skilled that are not easy to recruit and the company will have to pay more.

Ketokivi and Schroeder (2004) found that JIT is not related to competitive conformance quality performance; it means that a company should not expect to enhance competitive conformance quality by installing a JIT system, since its competitors are likely to also implement JIT to improve their conformance quality.

2.5 Summary

Jonsson and Mattsson (2003) stated that the suitability of various manufacturing planning and control approaches depends on the environment dimensions and it is very important to link performance drivers in MPC to system choice. Howard et al (2002), Berry and Hill (1992) highlighted that misalignment between MPC system and market requirements can result in poor performance (i.e. lengthy manufacturing cycles, shortages or excesses inventory, problems with on-time delivery and poor customer service).

Analysis of published literature relevant to fit between manufacturing planning and control systems and manufacturing environment has revealed some gaps and needs for further research:

- There are some studies that compare the effects of using various manufacturing planning and control systems or develop frameworks in order to differentiate manufacturing environments. However, there is a lack of conceptual and empirical studies that match MPC systems and the manufacturing environment.

- Although the researcher attempted to differentiate several manufacturing environments using different variables, it became more difficult to classify and identify a pattern of MPC systems, due to fuzziness of authors system's definitions and also their vague description of the associated MPC dimensions. Another problem was the titles that several authors used for describing these MPC systems. It was possible to identify a general agreement between their titles and descriptions, but it was very hard to distinguish the MPC systems, due to lack of detailed description of their rules of operation and associated methods.

- Dan Flinter's comments from "Made in Ireland" report, authored by Fynes et al (2001) regarding poor manufacturing practices and performance of Irish companies reinforces the need for research into this area. The literature studied has shown that there aren't many published studies on performance of manufacturing practices in Irish companies and the underlying causes of poor performance. Therefore, this research through its empirical match between the MPC systems and manufacturing environment within Irish engineering sector will fill some of the literature gaps and reflect some causes of poor performance.

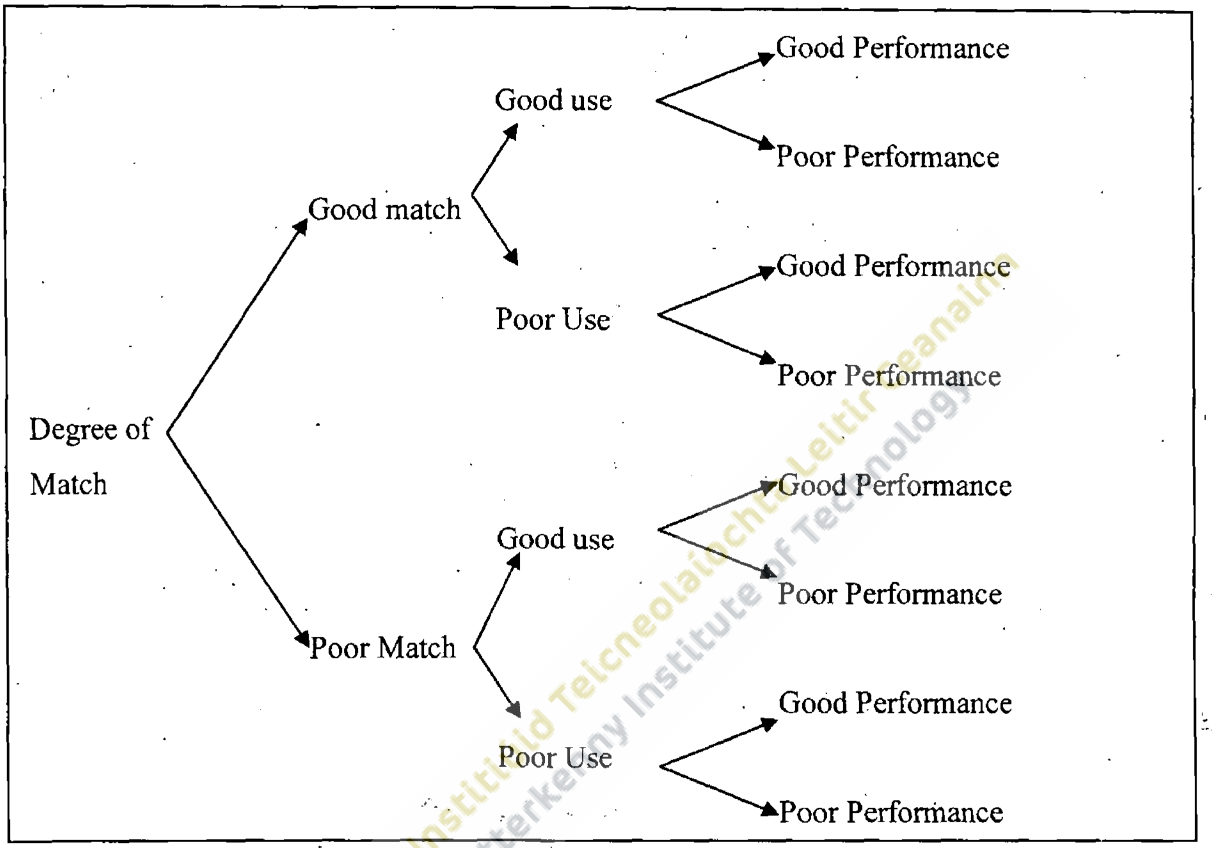
Based on analysis of the characteristics of various manufacturing environments and the investigation of the two main MPC systems and their dimensions, a conceptual match has been developed. Because of the scarcity of literature and reference support for this conceptual match, it is mainly based on logical assumption. The conclusion of this assessment is summarised in the table 23.

Table 23 Framework of the conceptual match between MPC systems and manufacturing environment

Environment Variables	Type 1 – High variety	Type 2 – Low variety
Volume per product	Low	Higher
Product variety	High	Lower
Demand stability	Low	Higher
Product design	Highly customised	Minimal changes
Layout	Functional	Line/Functional
MPC Dimensions	**Type A** **Push system – MRP type**	**Type B** **Pull system – JIT type**
Aggregate planning		
- aggregate plans	Level plan	Chase plan
- material planning approach	Time-phased	Rate based
Master production schedule		
- MPS approach	MTO/ATO	MTS
- Scheduling approach	Finite	Infinite
Production activity control		
- Control approach	Priority, dispatch rules	Kanban

From the conceptual analysis, three variables were identified: the degree of match, the degree of use and performance.

Figure 2.13 Schematic diagram showing all possible outcomes of mixing match, use and performance



In order to address these possible outcomes there is need for further research. The researcher proposed that:

> **Good performance is the result of matching the MPC system with the manufacturing environment and good use of the MPC system employed.**

The following chapters will test this hypothesis and the results will be analysed and discussed.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

3.2 Research Philosophies

3.3 Research Approaches

3.4 Research Strategies

3.5 Time Horizons

3.6 Data Collection Methods

3.7 Research Objectives

3.8 Research Process Chosen

3.9 Summary

3.1 Introduction

Chapter 1 introduced manufacturing planning and control (MPC) systems as a broad field of study for this research, in terms of its conceptual and empirical match with the manufacturing environment. A need was outlined for research on the underlying causes of poor performance of the Irish manufacturing companies and the manufacturing practices employed.

Chapter 2 investigated the published literature relating to the research problem: the fit and use of manufacturing planning and control systems within a manufacturing environment. It explored various manufacturing environments through their environmental variables and the role of manufacturing planning and control system, in terms of its dimensions. Conclusions from the literature review are used to develop the hypothesis and design the research framework.

This chapter presents the research framework that forms the basis of this research which aims to identify, evaluate and determine the effectiveness and usage patterns of the MPC systems within the actual manufacturing environment for the Irish engineering sector. Research methodology can be defined as: "A process of steps used to collect and analyse information in order to increase our understanding of a topic or issue" (Creswell, J., 2005).

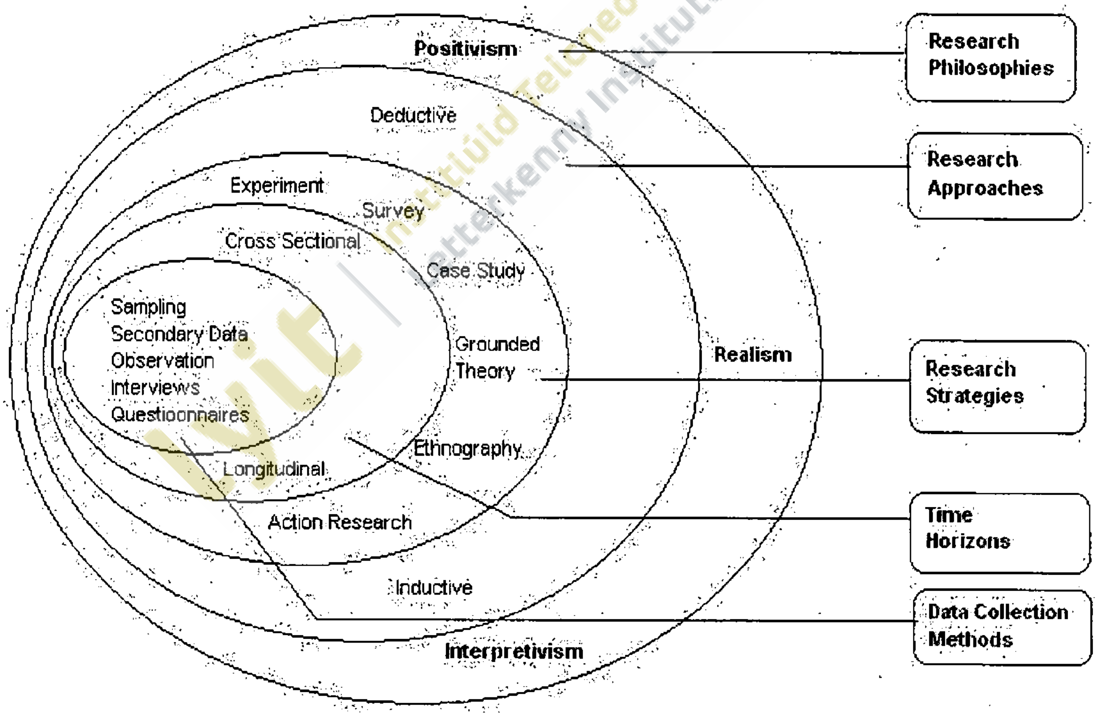
Kumar (1996) identifies the following characteristics of research methodology:

- It is undertaken within a framework of a set of philosophies;
- It uses procedures, methods and techniques that have been tested for their validity and reliability;

It is designed to be unbiased.

The researcher has chosen the research process "onion" (Sauders et al (2003)) as framework for describing the research methodology.

Figure 3.1 The research process "onion"



Source: Adapted from Saunders et al (2003)

3.2 Research Philosophies

The first step in any research is to identify the most appropriate research paradigm to follow in terms of designing and gathering the research. The research philosophy reflects the way that the researcher thinks about the development of knowledge (Vignali and Zundel, 2003). Paradigms are "a set of linked assumptions about the world which is shared by a community of scientists investigating the world" (Deshpande, 1983).

The various paradigmatic positions are now discussed in terms of an antithesis between two schools of philosophy, which are generally referred to and defined as positivism and phenomenology. Healy and Perry's (2000) categorisation is summarised in Table 24.

Table 24 Four categories of paradigms and their elements

	Paradigm			
Element	**Positivism**	**Phenomenology**		
		Critical Theory	**Constructivism**	**Realism**
Ontology	Reality is real and apprehensible	"Virtual" reality shaped by social, economic, ethnic, political, cultural and gender values crystallised over time	Multiple local and specific "constructed" realities	Reality is "real" but only imperfectly and probabilistically apprehensible
Epistemology	*Objectivism*: findings	*Subjectivism*: value mediated findings	*Subjectivism*: created findings	*Modified objectivism*: findings probably true
Common Methodologies	*Experiments/ surveys*: verification of hypothesis, chiefly quantitative methods	*Dialogic/dialectical*: researcher is a "transformative intellectual" who changes the social world within which participants live	*Hermeneutical/ dialectical*: researcher is a "passionate participant" within the world being investigated	*Case studies/ convergent interviewing*: triangulation, interpretation of research issues by qualitative and by some quantitative methods such as structural equation.

Source: Adapted from Healy and Perry (2000)

Creswell (2005), Goulding (2005), Riege (2003), Healy and Perry (2000) and Saunders et al (2003) describe different paradigms to research methodology: positivism and phenomenology where they include: realism, critical theory and constructivism. Gummesson (2000) notes that these paradigms "have many facets and names"; there is oversimplification and confusion between these paradigms.

3.2.1 Positivism

Positivism predominates in science and assumes that science quantitatively measure independent facts about a single apprehensible reality (Tsoukas, 1989). Deshpande (1983) describes this paradigm as being characterised by a deductive method of inquiry seeking for theory confirmation in value-free, statistical generalisations. Easterby-Smith et al (2003) state that the core element of positivism is that the world exists externally rather than being inferred subjectively through sensation, reflection or intuition.

Positivism research has a number of distinguishing characteristics (Gill and Johnson, 2002):

- It is deductive;
- It seeks to explain relationships between variables;
- It generally uses quantitative data;
- It uses controls to test a hypothesis;
- It is highly structured methodology to allow repetition;
- It is economical in terms of time and sampling large number, usually surveys.

3.2.2 Phenomenology: Realism, Critical theory and Constructivism

Mangan et al (2004) classifies the paradigms into positivism and phenomenological; Phenomenological approach described incorporates realism, critical theory and constructivism. From several studies, these paradigms have the following characteristics:

- It use qualitative data and smaller samples;
- Data is rich and subjective;
- It is inductive, is concerned with generating theories;
- Data collection tends to be time consuming and difficult to analyse;
- It often generalises from one setting to another.

In contrast with positivism's relevance to quantitative research, these paradigms are relevant to much qualitative research. Realism believes that there is a real world to discover, does not rely as much on deductive research inquires, but sees more appropriate research methods in those that have an inductive nature for discovering and building theory rather than testing theory through analytical generalisations (Saunders et al, 2003). Qualitative methods such as case studies commonly follow realistic modes of inquiry. The main objectives are to discover new relationships of realities and build up an understanding of the meaning of experiences rather than verify predetermined hypotheses (Goulding, 2005).

Critical theory, according to Healy and Perry (2000), concentrates on social realities incorporating historically situated structures. Assumptions are essentially subjective and hence knowledge is grounded in social and historical routines and is not value-free. Researchers and their investigated subjects are linked interactively, with the belief system of the researcher influencing the enquiry, which requires dialogue between the researcher and subject (Riege, 2003).

Constructivism holds that truth is a particular belief system held in a particular context (Tsoukas, 1989). Similar to critical theory, inquires about the ideologies and values that lie behind a finding so that reality actually consists of multiple realities that people have in their minds. Healy and Perry (2000) state that the phenomenological approach may be suitable for some social science and consumer behaviour research, because excludes concerns about the economic and technological dimensions of business.

3.3 Research Approaches

Saunders et al (2003) states that the two main research approaches are: the deductive approach, in which you develop theory and hypotheses and design a research strategy to test it, or the inductive approach, in which you would collect data and develop theory as a result of your data analysis.

3.3.1 The Deductive Approach

Healy and Perry (2000) state that deductive approach to research is linked to positivism and it involves the development of a theory or hypothesis that is subject to a test.

Gill and Johnson (2002) define the deductive approach as "a method that entails the development of a conceptual and theoretical structure prior to its testing through empirical investigation".

Robson (2002) describes five sequential stages of deduction:

1. Deducing a hypothesis from the theory;
2. Expressing the hypothesis in operational terms, which propose a relationship between two specific variables;
3. Testing this operational hypothesis (this involve an experiment or some other form of empirical enquiry)
4. Examining the specific outcome of the inquiry (it will either tend to confirm the theory or indicate that it needs modification);
5. If necessary, modifying the theory in the light of the findings.

3.3.2 The Inductive Approach

The inductive approach, according to Mangan et al (2004), is linked more to the phenomenological philosophy and it is concerned with developing a hypothesis from collected data.

Hussey and Hussey (1997) define the inductive approach as "a study in which theory is developed from the observation of empirical reality; general inferences are induced from particular instances, which is the reverse of the deductive method".

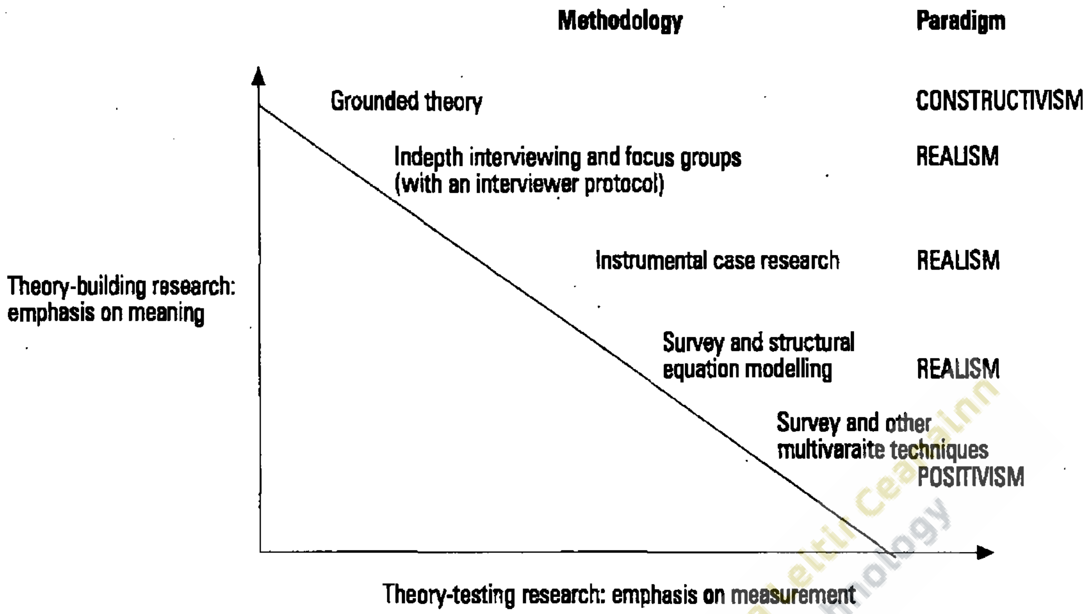
Robson (2002) describes the main steps of induction:

1. To collect and compress extensive raw data into a brief, summary format;
2. To establish clear links between the research objectives and the summary findings;
3. To develop a model or theory.

3.4 Research Strategies

In their studies, Saunders et al (2003), Gill and Johnson (2002), Hussey and Hussey (1997) and Malhotra (1996) outline the main research strategies as follows: observation, survey, experiment, case study. Healy and Perry (2000) present in their study a representative range of methodologies and their related paradigms (see figure 3.4).

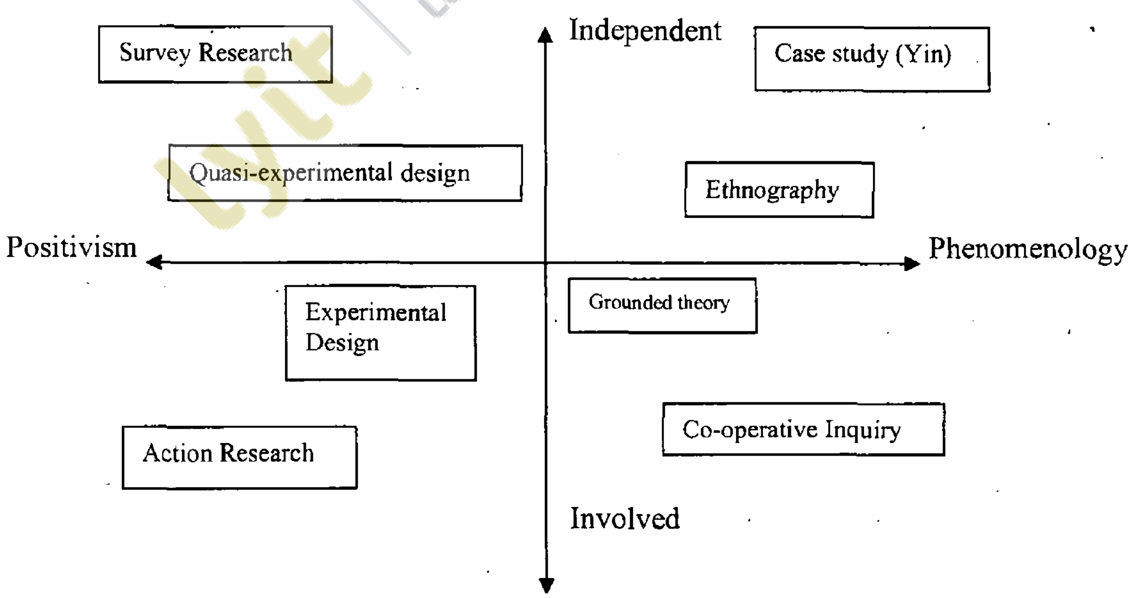
Figure 3.2 A representative range of methodologies and their related paradigms



Source: Healy and Perry (2000)

Easterby-Smith et al (2003) discussed the key philosophical underlying research strategies and looked at the implications these have for the design of management research (see figure 3.3 Matrix of Research Strategies).

Figure 3.3 Matrix of Data Collection Strategies



Source: Adapted from Easterby-Smith et al (2003)

3.4.1 Observation

This research strategy is associated often with phenomenological paradigms (Healy and Perry, 2000) and tends to be used in descriptive research (Malhotra, 1996). Observation can be participant or structured. According to Saunders et al (2003), participant observation is "qualitative and derives from the work of social anthropology. Its emphasis is on discovering the meaning that people attach to their behaviour". Structured observation is described as quantitative method and more concerned with the frequency of actions.

3.4.2 Survey

Surveys allow for a large amount of data to be collected from a wide population in a timely and economical way. Robson (2002) states that surveys are usually associated to the deductive approach. Accordingly to Filippini (1997) "the term survey is usually used to mean a collection of data, information and opinions of a large group of units, referred to as a population. Surveys use structured and pre-defined questions and data collection on the sample or entire population and can be carried out in a variety of ways: mail questionnaire, face-to-face structured interview and questionnaire and/or telephone interview. Studies are usually cross-sectional, in part because these require fewer resources than the longitudinal type".

Creswell (2005) defines surveys as "procedures in a research in which investigators administer a survey to a sample or entire population of people in order to describe attitudes, opinions, behaviours or characteristics of the population". Malhotra (1996) classifies survey methods by mode of administration into: telephone surveys, personal surveys and mail surveys.

3.4.3 Experiment

This research strategy is commonly used to infer causal relationships (Malhotra, 1996). It is linked to the positivism philosophy and involves definition of a theoretical hypothesis, selection of samples from know populations, allocation of samples to different experimental conditions, introduction of planned change on one or more of the variables, measurement and control of other variables (Saunders et al, 2003).

3.4.4 Case study

Robson (2002) defines case study as "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using sources of evidence". Creswell (2005) states that case studies allow researchers to gain deep understanding of the phenomenon being researched. A case study can use different collection instruments, such as questionnaires, interviews and secondary data.

3.5 Time Horizons

The research from a time perspective can be snapshot taken at a particular time or a representation of events over a period of time. Saunders et al (2003) describes these approaches as: cross-sectional and longitudinal.

3.5.1 Cross-sectional studies

Cross-sectional studies study a particular phenomenon at a particular time and are seeking to describe factors that influence it or to compare them in different organisations by employing mainly quantitative techniques. However, they may also use qualitative methods (Saunders et al, 2003). Accordingly to Easterby-Smith et al (2003) and Robson (2002) cross-sectional studies often employ the survey strategy.

3.5.2 Longitudinal studies

Longitudinal studies study a particular phenomenon over a period of time and the main strength is the capacity to analyse the change and development of that phenomenon.

3.6 Data Collection Methods

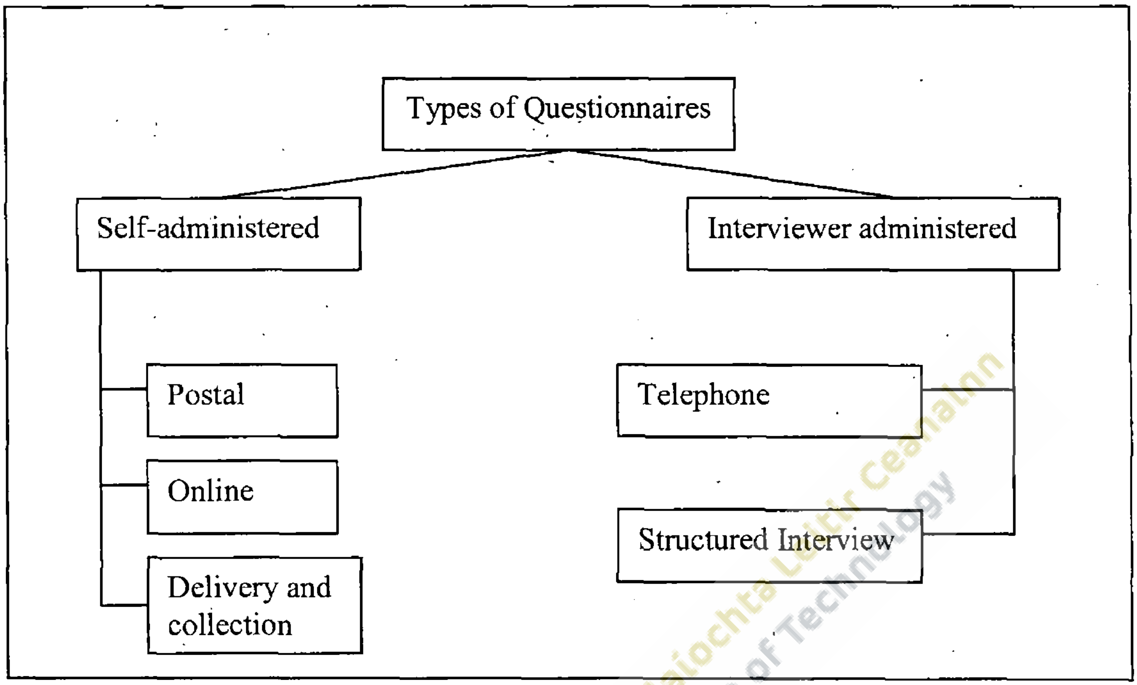
There are different instruments of data collection and each of them has distinct characteristics that need to be considered when making decisions regarding their use. Several studies, such as Creswell (2005), Gill and Johnson (2002), Robson (2002), Saunders et al (2003), Hussey and Hussey (1997) and Malhotra (1996) suggested that researchers typically collect data using two basic instruments: questionnaires and interviews.

3.6.1 Questionnaires

Saunders et al (2003) refers to a questionnaire as a general term to include all techniques of data collection in which each person is asked to respond to the same set of questions in a predetermined order.

A questionnaire is a form used in a survey design that participants in a study complete and return to the researcher; data collected tends to be quantitative (Gill and Johnson, 2002). There are various types of questionnaires (see figure below).

Figure 3.1 Types of questionnaires



Source: Adapted from Saunders et al (2003)

3.6.2 Interviews

Interviews are used generally for obtaining qualitative data (Healy and Perry, 2000) and can take different forms. Malhotra (1996) describe several types of interviews:

- Focus group interviews – conducted by a trained moderator in a non-structured and natural manner with a small group of respondents. They are used to generate research hypotheses that can be submitted to further research and tested using more quantitative approaches. Usually tend to be recorded for further analysis.

- In-depth interviews – an unstructured, direct, personal interview in which a single respondent is probed by a highly skilled interviewer to uncover underlying motivations, beliefs, attitudes and feelings on a topic or area. This technique also can be used to explore conceptual issues at an early stage in the development of a questionnaire.

- Structured interviews – is questionnaire based interview based on a predetermined and standardised set of questions. It enables the researcher to examine the level of understanding a respondent has about a particular topic - usually in slightly more depth than with a postal questionnaire. Provide a reliable source of quantitative data and the researcher is able to contact large numbers of people quickly, easily and efficiently

- Semi-structured interviews - are conducted with a fairly open framework which allow for focused, conversational, two-way communication. They can be used both to give and receive information. Unlike the questionnaire framework, where detailed questions are formulating ahead of time, semi structured interviewing starts with more general questions or topics. Generally are used to obtain specific quantitative and qualitative information from a sample of the population.

3.7 Research Objectives

This primary research sought to determine what types of MPC systems are used within Irish engineering sector and to analyse the fit between these systems and the manufacturing environment. Also the researcher wanted to determine the use and perceived performance of these MPC systems, so he can establish if there is a relationship between fit, use and perceived performance.

Overall Objective

To examine the types of MPC systems used by the Irish engineering sector, their match within the manufacturing environment and the relationship between match, use and perceived performance.

Sub Objectives

Environment type

1. To establish the dimensions of the environment that each company operates within
2. To determine in what type of environment each company operates based on identified dimensions

MPC type

3. To establish the main dimensions of the MPC system used by each company
4. To determine what type of MPC system each company uses based on identified dimensions

The degree of match

5. To determine the degree of match between the MPC system used and the manufacturing environment within which the respondents operate.

The degree of use of the MPC system

6. To examine what is the degree of use of the MPC system employed

The performance of MPC system

7. To determine what is the performance of the MPC system used
8. To establish a relationship between the degree of use and performance of the MPC system.
9. To examine if appears to be a relationship between the degree of match and the performance of the MPC system.

3.8 Research Process Chosen

This sub-chapter describes the research process chosen by the researcher and the main factors that influenced these decisions.

3.8.1 Research Philosophy

In order to decide which research philosophy is appropriate, the researcher analysed the necessary three elements of the research: ontology, epistemology and methodology. Essentially, ontology is the "reality" investigated; epistemology is the relationship between that reality and the researcher, and methodology is the technique used by the researcher to investigate that reality.

From researcher's point of view the "reality" is objective, not socially constructed or understood by examining perceptions of the human actors; the model representing the conceptual match between MPC systems and manufacturing environment, created at the end of second chapter is defined through several variables that can be quantified. In this study the researcher's remains distanced from the material researched. The researcher was independent from the study and not socially or emotionally involved with the subject being studied, which according to Easterby-Smith et al (2003) represents the basic belief of positivism paradigm. All these factors mentioned above, determined the researcher to choose as research philosophy - positivism.

3.8.2 Research Approach

In order to move from the theory to data that could be tested to ascertain the validity of the hypothesis, the researcher chose the deductive approach. From the literature review, the researcher has constructed a conceptual model that led to the development of the hypothesis in chapter two.

The major proposition, which underpins this research, is as follows:

Good performance is the result of matching the MPC system with the manufacturing environment and good use of the MPC system employed.

The proposition leads to the following research questions that are answered in this thesis:

- What planning and control methods are the Irish engineering companies' using?
- What is the degree of match between the systems used the manufacturing environment?

- What are the performance and the degree of use of these systems?
- What is the relationship between degree of match, the degree of use and performance of these systems?

These questions are dealt with using the research methodology outlined in this chapter. The details of the research carried out are described in the following sections and the experiences and findings of the research are described in the rest of the thesis.

3.8.3 Research Strategy

To test the hypothesis within the population targeted, the strategy chosen for this research was survey. Previous studies on manufacturing planning and control practices used survey as their research strategy. Jonsson and Mattsson (2003) in their study on implications of fit between planning environments and manufacturing planning and control methods, have mailed a survey to 380 manufacturing companies in Sweden. Almost all respondents were in the mechanical engineering industry.

Safizadeh and Ritzman (1997) investigated the link between the performance drivers in production planning and inventory control to process choice. They undertook a mailed survey of 800 companies in the United States across several industries such as: food, chemicals, industrial and computer equipment, transportation equipment.

Another study that analysed the link between manufacturing planning and control and the manufacturing environment, carried out by Newman and Shridharan (1995), surveyed 1500 manufacturing firms from the Midwest region of the USA.

As we can observe from previous studies, authors used large samples and data was mainly quantitative, collected with the use of mailed questionnaires. Mangan et al (2004), Healy and Perry (2000), Saunders et al (2003), Hussey and Hussey (1997) suggested that surveys and experiments are the appropriate strategies, when the researcher uses a deductive approach to test a hypothesis and wants to generalize the findings across the industry sector studied.

According to Easterby-Smith et al (2003) survey research is the most appropriate strategy to be taken for a positivism paradigm.

3.8.4 Time Horizon

Due to the fact this research is for academic purposes and is time constrained, the researcher considered a cross-sectional study over a short period of time. Robson (2002) suggests that cross-sectional studies are often employed when the survey strategy is used.

3.8.5 Data Collection Method

"The worldview held by an individual researcher or institute is clearly an important factor which affects the choice of research methods" (Esterby-Smith et al, 2003). Also, they suggested that when the population studied is less than 500, "it is customary to send questionnaires to all members. This 100% percent sample is known as a census". The targeted population was 414 companies, which represent the total population of Irish Engineering firms, so a census was undertaken, in order to achieve maximum participation and representativeness. The data collection method used was mailed questionnaires.

Several studies such as Creswell (2005), Saunders et al (2003), Perry (1998), Filippini (1997) suggested that census study is aiming to reduce coverage error, to generalise the findings and sampling techniques are not required. The researcher targeted the questionnaire to the person with overall responsibility for manufacturing: production managers. The list of Irish engineering companies was developed with the help of Enterprise Ireland (EI). All the main regional offices of EI were contacted by e-mail regarding the engineering company listings. The regional offices replied with their listings of engineering companies and all have been compiled into one database that formed the research population.

The researcher considered this list as being the most appropriate and accurate, due to the fact that majority of the engineering companies in Ireland are registered with Enterprise

Ireland and their reports are used by national organisations such as Forfas or National Competitiveness Council. Also EI clients must employ over ten people except for exceptional circumstances. Companies employing less then ten people are clients of the County Enterprise Boards.

Mailed questionnaire was considered, because it has many advantages: absence of interviewer bias, economical, convenient to reach a geographically dispersed population and involves only duplication and mailing expenses; these survey types typically have low response rates (Malhotra, 1996; Domegan and Fleming, 2003). Newman and Shridharan (1995) stated "any empirical survey questionnaire based may be plague by the confounding of the multiple variables as well as a lack of sufficient responses to cover the diverse range of environments". However, the researcher structured the questionnaire in four main parts: environment, MPC system, the use and the performance of the MPC systems employed by the recipients studied. This framework helped make clear difference between variables used at each level of the manufacturing planning and control system studied.

To improve the response rates the researcher's postal package included a personalised covering letter on letterhead paper (see Appendix D), a questionnaire (see Appendix A) and a stamped self addressed return envelope. Also the postal package was stamped with "Strictly Confidential" stamp. Personalisation of the letter and stamping of the postal package was intended to assist in accessing the production/operations manager in each company as suggested by Domegan and Fleming (2003).

3.8.5.1 Design of the questionnaire

The design of the questionnaire was mainly determined by the qualitative research and the researcher experience within the field studied. The qualitative component included a review of academic and professional literature, as well as interviews with specialist consultants from Enterprise Ireland, responsible for World Class Manufacturing and Competitiveness Benchmarking Programmes. The types of questions used in the questionnaire, were mainly closed-ended, due to the fact there was enough information on the variables of interest and therefore it was possible to pre-specify the categories of response.

To eliminate potential problems in interpreting the questions, the researcher has pilot tested the questionnaire, as recommended in marketing research (Blankson and Stokes, 2002). It was sent to 10 companies and they were asked to mark any problems on the survey, such as poorly worded questions, responses that do not make sense or if it takes an excessive amount of time to complete the instrument. These companies were selected through judgemental sampling technique. Their locations were within the researcher's geographical location. After receiving their feedback, the researcher refined a few questions. Also the questionnaire format was redesigned to cover three double sided A4 pages as opposed to six single sided pages This helped determine that the recipients of the population were capable of completing the survey and that they could understand the questions.

Regarding the match between the systems used and the manufacturing environment, there are little or no studies on measurement techniques. Jonsson and Mattsson (2003) analysed this issue by using indicator for the degree of match such as: two pluses "++" for good match, one plus "+" for a poor match and a minus "-" for a mismatch.

Other authors such as Olhager and Rudberg (2002), Howard et al (2002), Berry and Hill (1992) didn't attempt to empirically analyse the "fit" between MPC methods and environment, but by using several variables, they proposed frameworks that conceptualise this issue.

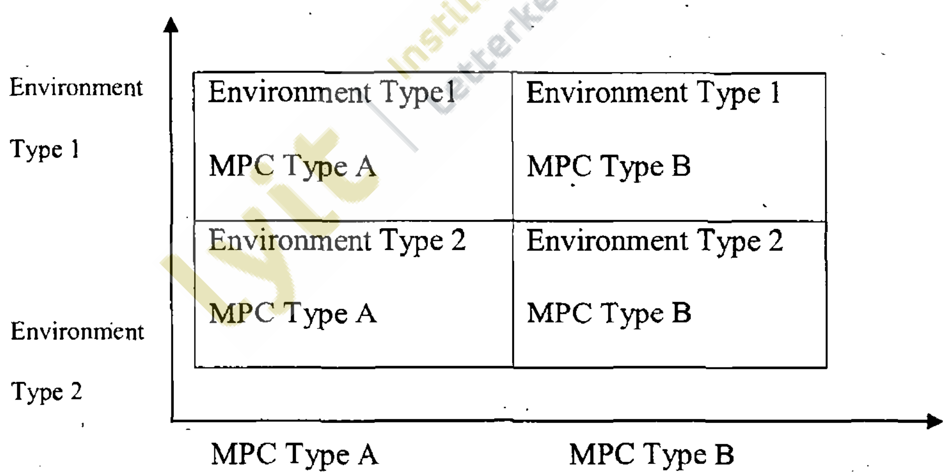
Therefore, in order to test the hypothesis and answer the research questions, the researcher developed a classification system based on the four parts structure of the questionnaire. Within each section a classification system was devised. Due to the fact that most of the variables used, were nominal, ordinal or scale variables, a score from 1 to 5 was attached to each answer in order to create different categories. The researcher constructed four scores: the environment type score, the MPC type score, the performance score and the use score. The conceptual framework, defined at the end of chapter two, was used for developing categories (see table 23).

3.8.5.2 Development of categories

Within each section several categories were created in order to place each answer from each question using the scoring system. For the environment type and MPC type sections the following categories were created:

Section	Categories	
Environment	Type 1 (High variety)	Type 2 (Low variety)
MPC Type	Type A (MRP type)	Type B (JIT type)

The scores will allow the researcher to differentiate between types of environment and also types of MPC and place each company within one of the categories created:



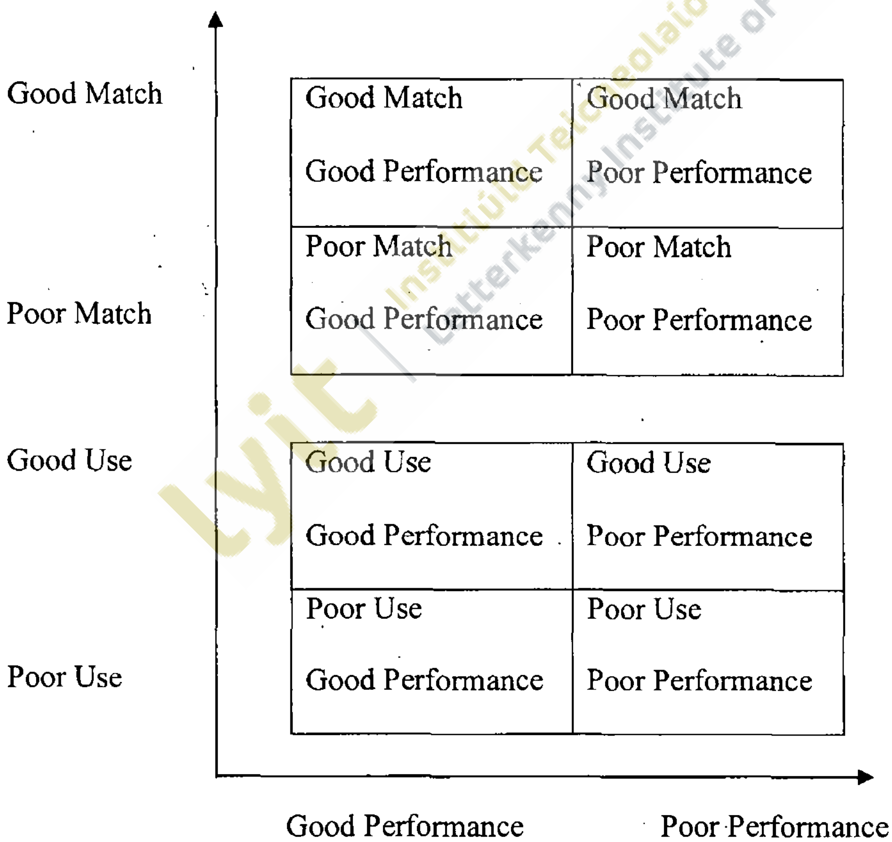
In order to assess the match between the MPC system and the manufacturing environment, the researcher used the above framework as a basis for developing the scoring system. Considering that this framework defines good practices, identified throughout the literature by several authors, the match between environment "type 1" and the MPC system "type A" or the match between environment "type 2" and the MPC system "type B" along with all associated variables and dimensions were representing good matches. Any other combinations would result in poorer matches or mismatches.By using the same scoring approach for both sections, the difference between the environment and MPC system score will show the degree of match; therefore two categories were created: good match and poor patch or mismatch. A low score represent a good match and a high score represent a poorer match or mismatch:

	Maximum Score: 23		Minimum Score: 6
Environment	"Type 1 HV"	→	"Type 2 LV"
MPC System	"MRP Type"	→	"JIT type"

For example if a company scores 6 at the environment score that indicates the Type 2 low variety; and at the MPC system score it has 6 that indicates the JIT type. The difference between them will be zero, which indicates that there is a strong match between them environment and the MPC system. The range of values will be between (-17) and (+17), with middle value zero that will denote a high degree of match. So, a company will have a higher degree of match if the match score will be as close as possible to value zero. A negative value would indicate that the company is operating in a low variety environment and it has a MPC system that tends to have the characteristics of a MRP; or a positive value would indicate that the company is operating in a high variety environment and it has a MPC system that tends to have the characteristics of a JIT system. For the performance and use section, the researcher developed two categories for each:

Section	Categories	
Use	Poor Use	Good Use
Performance	Poor Performance	Good Performance

The scores then will allow the researcher to place each company within a certain category. Also the researcher will analyse possible linkages between the degree of match and the performance, and between the use and the performance by using Chi-square statistics.



3.8.5.3 The environment type score

The environment type score was devised in order to place each company into a certain type of environment. The researcher attached a number from 1 to 5 to each answer of the following questions: 3, 5, 6, 7 and 8. By adding these scores, the results would show different environment scores for individual companies. A low score would imply that the company environment tends to be "type 2" and high score would imply that the company environment tends to be "type 1".

For example, question 3 "How could you describe the business environment where your company operates in terms of:

Score	1	2	3	4	5
	Very Low	Low	Medium	High	Very High
Product variety	☐	☐	☐	☐	☐
Demand stability	☐	☐	☐	☐	☐
	Very High	High	Medium	Low	Very Low
Score	1	2	3	4	5

For question 7, the answer "Other (Please specify)" was marked with "0" score. The companies indicating this answer were eliminated from the study, in order to comply with the conceptual match. This approach was applied also in the calculation of the MPC type score. See Appendix B for details on the allocation of the scores to the entire questionnaire.

3.8.5.4 The MPC type score

For the MPC system section, the researcher used the same approach. For example question 11: "With reference to your planning horizon and demand pattern, which of the following categories come closest to characterising your dominant approach to capacity planning?

		Score
Level capacity plan	☐	4
Chase capacity plan	☐	1
Other (Please specify) ________		0

The questions that defined the MPC system were: question 9, 11, 13, 14, 19, and 23. By adding these scores, the results will show different MPC systems scores for individual companies. A low score would imply that the MPC system tends to be "type B" – pull system – JIT and a high score would imply that the MPC system tends to be "type A" – push system – MRP.

3.8.5.5 The Use score

The use score will be derived by looking at the methods used and also at the frequency of use. The researcher presumes that more methods employed and at a higher frequency of use it enables a company to achieve good performance. Similar approach was undertaken by several studies such as Jonsson and Mattsson (2003), Newman and Shridharan (1995) and Berry and Hill (1992). In calculation of this score the following questions were considered: 16, 17, 21, 22, 25, 26, 27, 29, 30 and 31. These questions covered also the methods and frequency of use for the MPC system employed. A company in order to achieve good performance should have a high use score. See Appendix C - a complete construction of the scores for two companies.

3.8.5.6 The Performance score

The performance score will be calculated by adding the scores from 1 to 5 for questions 28, 32 and 33. This score will differentiate two categories: good performance and poor performance or no performance. For example question 33: "How would your customer rate the satisfaction level with delivery performance:

Very Poor	☐	1
Poor	☐	2
Average	☐	3
Good	☐	4
Very good	☐	5

When calculating the performance scores, if the respondents answered "No" to question 25 and 29, the researcher used only the score from question 32. It was considered that if a company does not compare MPC practices with other companies (question 25), it can't rate their performance in relation to their significant competitors (question 28) and also if they do not measure level of customer satisfaction (question 29), then respondent couldn't rate the satisfaction level with delivery performance (question 33). All the answers for the above-motioned questions were cumulated and a performance score was designed. Therefore a low score will elicit a bad or poor performer and a high score a good performer. These scores will be correlated with the degree of match score in order to test the first part of hypothesis proposed; looking at the relationship between the use score and companies' performance score will test the effect of use of these MPC's.

3.8.6 Credibility of the research methodology implemented

Accordingly to Easterby-Smith et al (2003) there is an underlying major issue amongst researchers that the research will not stand up to outside scrutiny. In order to prevent this potential problem Creswell (2005) suggests that the following issues should be addressed: validity, reliability and generalisability. Validity is the extent to which the research findings accurately represent what is really happening in the situation; reliability is concerned with the findings of the research and if it can be repeated and generalisability is concerned with the application of research results to cases or situations beyond those examined in the study.

3.8.6.1 Threats to validity

To construct validity the researcher used a predetermined questionnaire that was sent to the entire population studied. The questions were merely closed-ended, used to determine and measure several variables related to manufacturing environment and MPC systems predefined in chapter two. Also the questionnaire analysed the perceived performance of the companies using several variables such as percentage of customer delivery commitments, customer satisfaction levels and overall perceived performance of the MPC system used by the subjects studied. The researcher was aware that beside the variables studied, there are a number of phenomena that are not analysed, such as people motivation, satisfaction, management involvement, organisational culture and training. Appropriate for these variables would have been depth interviews with the subjects studied and also analysis of employee's profiles. Due to the time constraint and in order to make this study manageable, the researcher limited his study to the variables presented in the end of chapter two. However, the variables used in this study, were also found in Enterprise Ireland's report Made in Ireland (2001) and Competitiveness Benchmarking programme developed by ESF, London Business School and Enterprise Ireland. The researcher pilot tested the questionnaire by sending it to 10 typical respondents to ensure that the subjects studied understand and can answer the questions.

In order to construct validity the researcher undertook also interviews, after the questionnaires were analysed. Wass and Wells (1994) suggested that interviews, semi-structured or in-depth may be used as a means to validate findings from the use of questionnaire. Due to time constraints, the researcher decided to interview a company with the good match and one with poor match. The companies were chosen based on their geographical location, as close as possible to the researcher. Creswell (2005) recommends that when using semi-structured interviews the researcher should have a list of themes and questions to be covered. Accordingly to Saunders et al (2003), to control bias and to produce reliable data for analysis, the interviews should be tape-recorded, with the permission of the interviewee. The selected companies for the interviews were asked for permission to record and both agreed. Researcher used a theme sheet (see Appendix E) and the questions were focusing on the following issues: match between the MPC system and the environment, the use and its performance. In designing the interview theme sheet the researcher used the questionnaire as guideline and also table 23. Due to the fact that only two companies were interviewed, the researcher didn't use the findings to draw conclusions; their role was to verify if the data received from the population selected was accurate and reflected the reality.

3.8.6.2 Threats to reliability

The researcher was independent from the recipients studied and when designing the data collection instrument he ensured the anonymity of respondents to questionnaire in order to avoid subject or participant bias. Through the fact that the variables used in the data collection instrument, have been found in other studies and by sending the same questionnaire to all recipients of the population studied, the researcher assured that the study is reliable, it can be replicated at any period in time and it will have similar results given that the manufacturing environments are defined by the same variables used in this study.

3.8.6.3 Threats to generalisability

In order to increase participation and representativeness, the researcher has undertaken a census of all Irish engineering companies, which were clients of Enterprise Ireland. Gummesson (2000) argues that by using statistics to analyse the data received, the researcher will be able to generalise his results across the sector studied. However there are some concerns with whether the patterns, concepts and theories, which have been generated in a particular environment, can be applied in other environments.

3.9 Summary

This sub-chapter represents a summary of the research methodology. The Figure 3.2 it depicts the research methodology (see figure 3.1) used by the researcher. The next chapter will present the analysis and findings of this research.

Figure 3.2 Research Methodology chosen

Research:	**Philosophy**	→	**Positivism**
	Approach	→	**Deductive**
	Strategy	→	**Survey**
	Time Horizon	→	**Cross-sectional**
	Data Collection Method	→	**Questionnaires**

CHAPTER 4

FINDINGS AND ANALYSIS

4.1 Introduction

4.2 Data preparation Process

4.3 Empirical Findings

4.4 MPC system types and Performance

4.5 Company size and Performance

4.6 Summary

4.1 Introduction

This chapter analyses the overall findings of the research and it examines the implications of the research with respect to the following research questions:

1. What type of systems the Irish engineering companies are using for manufacturing planning and control and in what type of manufacturing environment they operate?

2. What is the degree of match between these systems and the manufacturing environment?

3. What are the degree of use and the level of performance of these systems within the Irish engineering sector?

4. What is the relationship between the degree of match, the degree of use and performance of the MPC systems?

The researcher used survey - mailed questionnaire as data collection method. The survey was sent out to all 414 Irish engineering companies, clients of Enterprise Ireland between the 24th - 31st of May 2006. A response rate of 74 companies or 17.87% was achieved. To increase the response rate, follow up e-mails and calls were conducted between 1st -15th of June 2006 with every operations/production manager who did not return their questionnaire. When contacted by telephone, 12 companies replied that they could not complete the questionnaire due to company policy of not taking part in any survey or study of that nature. Four returned questionnaires were incomplete and other three were returned to sender due to either change of address or gone out of business. Before the cut off date of 30th of June 2006 and after eliminating out all the non-respondents, the final response rate was 111 or 26.81%. Comparing the response rate with other studies Newman and Sridharan (1995) – 12.3%, Safizadeh and Ritzman (1997) – 36% or Jonsson and Mattsson (2003) – 22%, the current research had a good response rate.

4.2 Data Preparation Process

Saunders et al (2003) identifies the data preparation process as having several steps: preparation of preliminary plan of data analysis, checking the questionnaires for completeness, coding and transcribing the responses, checking for errors in the data entered, exploring and summarising of data. Firstly, the researcher checked the questionnaires for completeness. Then, the responses were checked for ambiguity, consistency and completeness, as suggested by Domegan and Fleming (2003). All questions and answers were coded in order to facilitate speedy data input and to create the scoring system (see Appendix B for details on coded data). The data was then entered in the Statistical Package for Social Sciences (SPSS) package. Malhotra (1996) highlights the need for care when inputting the data into SPSS. All respondents were coded in order to facilitate any changes and ensure accuracy of data entered.

Berenson et al (2004) suggests that SPPS or MINITAB is suitable for analysis of large amounts of data. This package is frequently used to analyse data in marketing research and is widely recognised as a valid computer data analysis tool. Descriptive statistics were then calculated in order to present and summaries the data. It allowed identification of distribution frequencies and graphical representations. Statistical tests were then carried out to determine the significance of associations within the data. Due to the fact most of data collected was nominal and ordinal in nature, a series of non-parametric tests were employed such as Spearman rank correlation coefficient, chi-square tests or cross tabulations.

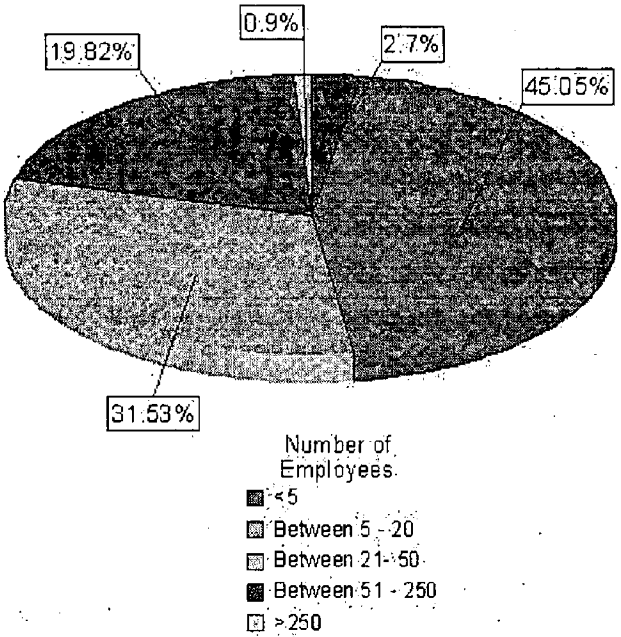
4.3 Empirical findings

This section discusses and explains some of the empirical findings. It identifies different types of manufacturing environments and MPC systems employed by the Irish engineering companies. It also indicates that the choice of MPC system should depend on the manufacturing environment and that the performance of a system should be higher if the system fits the environment. In addition, this section analyses the empirical fit between the MPC system and the manufacturing environment.

Respondents Profile

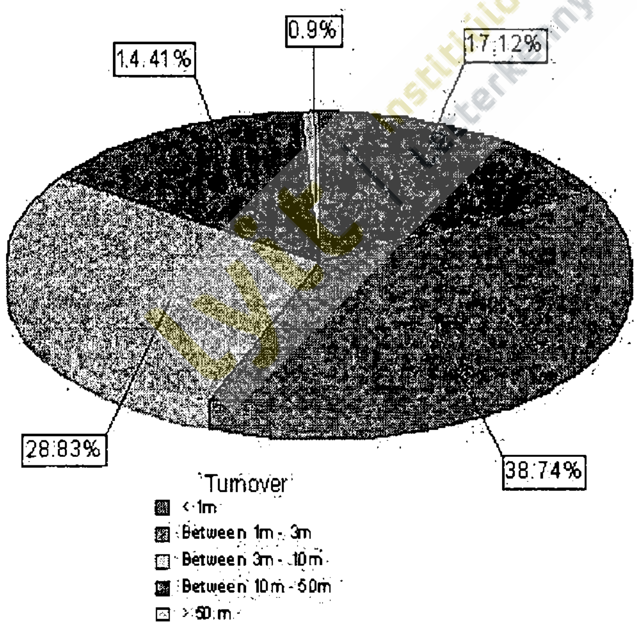
Of the 414 companies surveyed, 111 responded. Almost half of the respondents had a turnover higher than 3 million euros and more than half employed over 20 people. In order to obtain an overview of the respondents the researcher grouped them as per figures 4.1 and 4.2.

Figure 4.1 Respondent's profile based on Company size



Number of Employees	Frequency	%	Cumul %
<5	3	2.70	2.70
Between 5 - 20	50	45.05	47.75
Between 21- 50	35	31.53	79.28
Between 51 - 250	22	19.82	99.10
>250	1	0.90	100.00
Total	111	100.00	

Figure 4.2 Respondent's profile based on Turnover value

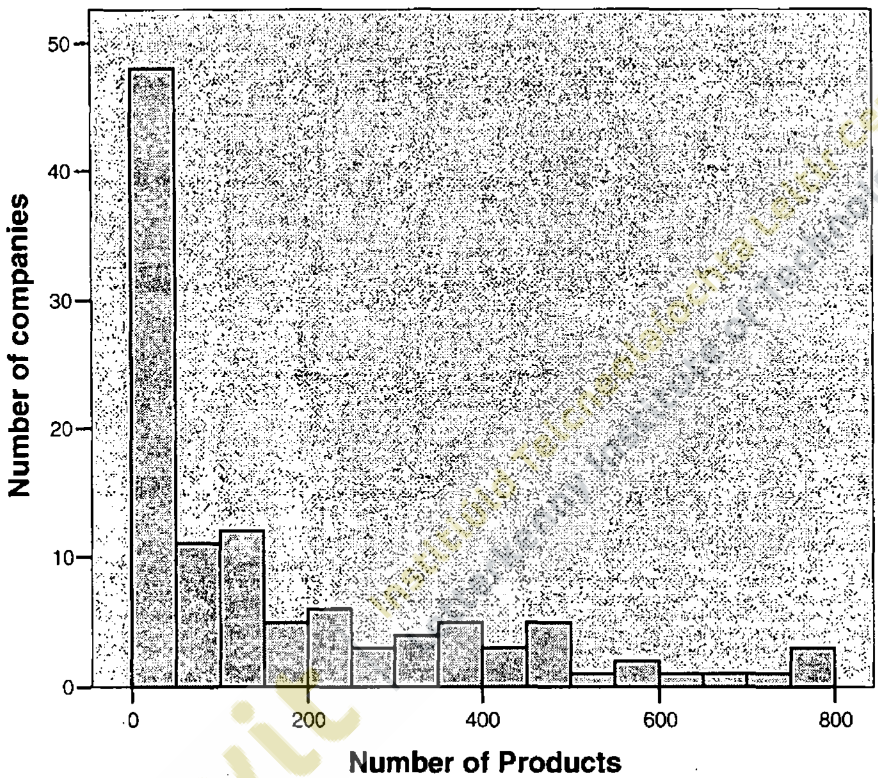


Turnover	Frequency	%	Cumul %
< 1m	19	17.12	17.12
Between 1m - 3m	43	38.74	55.86
Between 3m - 10m	32	28.83	84.68
Between 10m-50m	16	14.41	99.10
> 50 m	1	0.90	100.00
Total	111	100.00	

Business Environment

Respondents were asked to describe the variety of the business environment within which the company operates through the number of products they delivered last year.

Figure 4.3 Number of products delivered in 2005



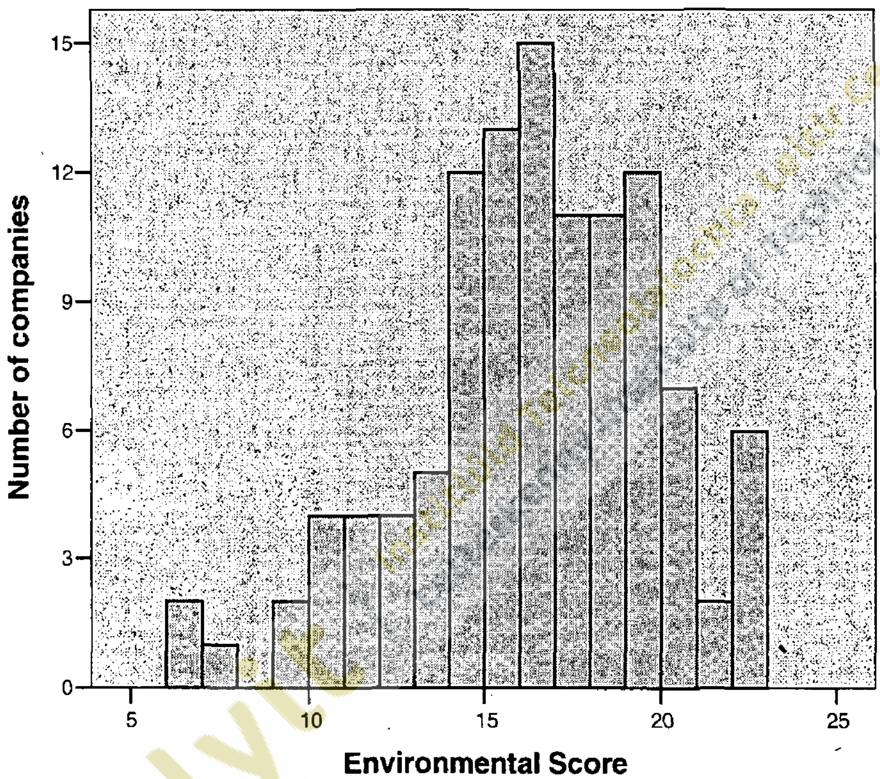
Looking at the pattern of the data, the researcher observed that 50% of the companies have delivered less than 70 products in the last year. Therefore the answers were grouped into two categories: Low variety (up to 70 products delivered) and High variety (over 70 products delivered). These categories were then cross-tabulated with the environment type categories obtained from the environment score, in order to test the validity of the devised scoring system.

Statistics		
Range		797
Minimum		3
Maximum		800
Percentiles	25	15.00
	50	70.00
	75	250.00

4.3.1 Environment Types

The researcher in order to place each company within a certain type of manufacturing environment devised a scoring system. The environment score was devised from the answers of questions 3,5,6,7 and 8 (for details on scoring system see Appendix B).

Figure 4.4 Histogram showing pattern of variation of the environmental scores



The researcher observed that 50% of the respondents had an environmental score lower than 16. Therefore the answers were grouped into two categories: "Type 1" - environment (characterized by a score higher than 16) and "Type 2" - environment (characterized by a score lower than 16).

Statistics		
Range		17
Minimum		6
Maximum		23
Percentiles	25	14.00
	50	16.00
	75	18.00

In order to detect if there were statistically significant associations between the environment type constructed by the scoring system and the variety type, the researcher used cross-tabulations and the chi square test.

Table 25: Cross-tabulation of the environment type and variety

Variety	Environment type		
	Type 1	Type 2	Total
Low variety (number of products <70)	12 24.5%	44 71%	56 50.5%
High variety (number of products >70)	37 75.5%	18 29%	55 49.5%
Total	49	62	111
	100%	100%	100%

H0: There is no association between variety and the environment type

H1: There is an association between variety and the environment type

Critical $X^2_{0.01}$=6.636 with 1 degree of freedom

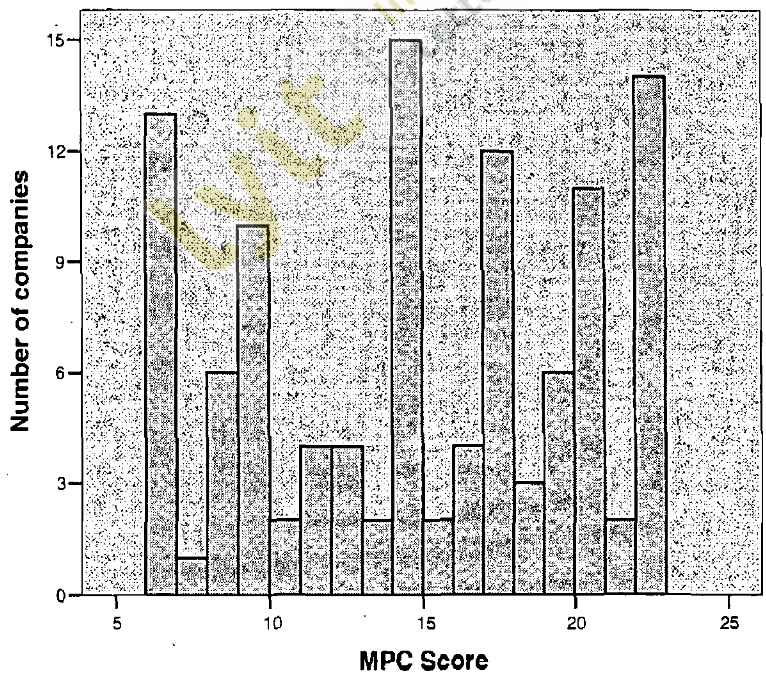
Sample $X^2_{0.01}$=23.65 with 1 degree of freedom

A significance value (p value) of 0.010 was generated along with a chi square value of 23.65 at one degree of freedom, which considerable more than the 1% level of significance minimum value (6.635). The researcher observed the continuity correction factor, which is a modification of the chi-square for 2 x 2 tables. However most statisticians agree that the modification is unnecessary and can be ignored (Norusis, 2005). This indicated that the environment type and variety were not independent and that there was a strong association between the environment type and variety. The researcher used the environment type categories to classify the manufacturing environment where the respondents operate: 44.1% of respondents (49) described their environment as Type 1 – High variety environment and 55.9% of respondents (62) described their environment as Type 2 – Low variety environment.

4.3.2 Manufacturing Planning and Control System Types

In order to identify what type of MPC system the Irish engineering companies use, the researcher asked the respondents to describe their systems through several dimensions: capacity planning, material planning, master production schedule, scheduling approach and control techniques. To differentiate between systems categories the researcher devised a scoring system. The MPC system score was constructed from the answers of the questions 9,11,13,14,19 and 23 (for details on scoring system see Appendix B).

Figure 4.5 Histogram showing pattern of variation of the MPC system scores



The researcher observed that 50% of respondents scored lower than 14; he split the data in two categories: Type A-MRP (with a score higher than 14) and Type B-JIT (with a score up to 14); then cross-tabulation of MPC type with the manufacturing environment type was performed, in order to test if there is an association between them.

Statistics		
Range		17
Minimum		6
Maximum		23
Percentiles	25	9.00
	50	14.00
	75	19.00

Table 26: Cross-tabulation of the manufacturing environment and the MPC system type

Manufacturing environment type	MPC Type		
	Type A MRP	Type B JIT	Total
Environment Type 1 High variety	34 62.97%	15 26.32%	49 44.15%
Environment Type 2 Low variety	20 37.03%	42 73.68%	62 55.85%
Total	54 100%	57 100%	111 100%

H0: There is no association between the MPC system and the manufacturing environment type

H2: There is an association between the MPC system and the manufacturing environment type

Critical $X^2_{0.01}$=6.636 with 1 degree of freedom

Sample $X^2_{0.01}$=15.104 with 1 degree of freedom

A significance value (p value) of 0.010 was generated along with a chi square value of 15.104 at one degree of freedom, which is more than the 1% level of significance minimum value (6.635). This indicated that the two variables were not independent and that was an association between the MPC system and the manufacturing environment.

Safizadeh and Ritzman (1997) noted that there was a strong association between process choice and the environment - described through customization and volume. They calculated Spearman correlation coefficient between process choice and customization 0.45 ($p<0.01$) and between process choice and volume 0.50 ($p<0.01$). The researcher calculated the Spearman correlation coefficient between the MPC system choice and the manufacturing environment; the result was 0.468 ($p<0.01$). This indicated that there is a strong association between the MPC system and the manufacturing environment. These findings lend credibility to researcher's data and provided a good foundation for testing the main hypothesis of the research. The conceptual framework developed at the end of the literature review was confirmed by the empirical research, in that there is a match between certain types of systems and manufacturing environments.

Although 48.64% of respondents described their system as being a MRP system - Type A, only 34 out of 54, matched the MPC system with the manufacturing environment Type 1 - High variety; and from 51.36% that described their system as a JIT system - Type B, only 42 out of 57 matched the system with the manufacturing environment Type 2 - Low variety.

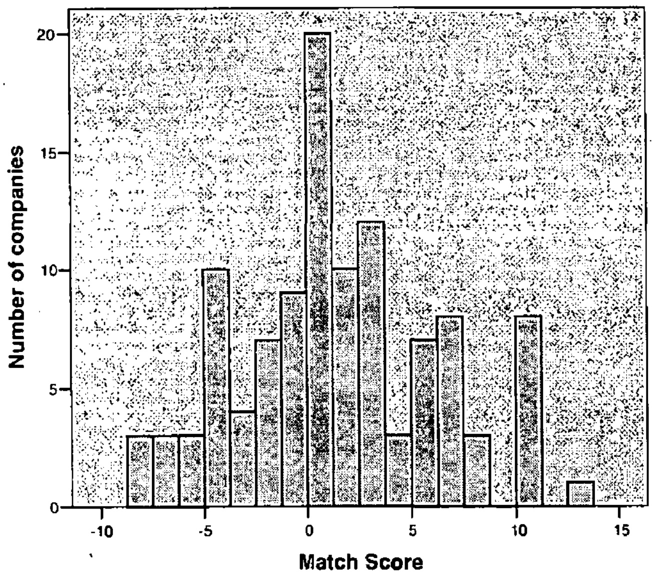
The next step of the research was to measure the degree of match, the degree of use and performance, in order to verify if there are any relationships between them.

4.3.3 The degree of match between manufacturing environment and MPC system

Throughout the literature review, the researcher identified Jonsson and Mattsson (2003) approach of measuring the degree match. They used an indicator for the degree of match: two pluses "++" for good match, one plus "+" for a poor match and a minus "-" for a mismatch. Other studies that studied the linkages between the MPC system and the manufacturing environment, Olhager and Rudberg (2002), Howard et al (2002), Berry and Hill (1992) didn't attempt to measure the degree of match between them, but by using several variables, they proposed frameworks that conceptualised this issue. Due to lack of measurement techniques for measurement the degree of match, the researcher developed his own system in order to able to place each company within a category. By using the same approach for both scores: the environment and MPC, where a low score would represent a low variety environment Type 2 and an JIT system or a high score would represent a high variety environment Type 1 and an MRP system, the difference between the environment and MPC system score would show the degree of match.

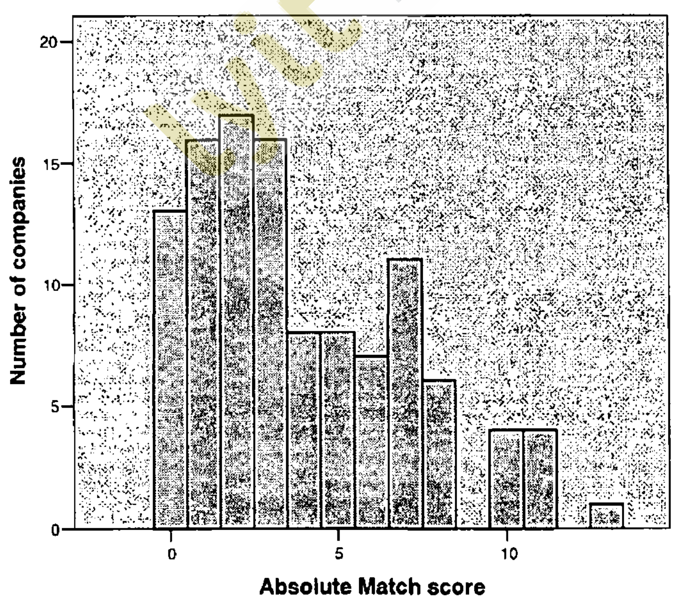
	Maximum Score: 23		Minimum Score: 6
Environment	"Type 1 HV"	→	"Type 2 LV"
MPC System	"MRP Type A"	→	"JIT type B"

Figure 4.6 Histogram showing pattern of variation of the match scores



The range of match score was 21, with a minimum of −8 and maximum of 13. Irrespectively to whether it would be a negative match (for example MRP system operating in a low variety environment); or a positive match (for example a JIT system - operating in a high variety), the absolute value would show the degree of match.

Figure 4.7 Histogram showing pattern of variation of the absolute match scores



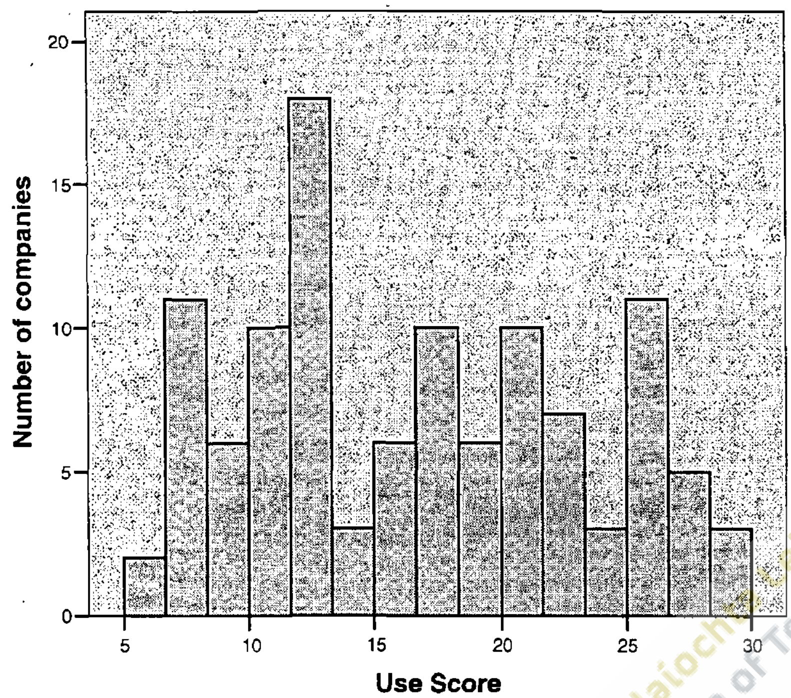
The researcher observed that 50% of the respondents had a score over 3; therefore he split the data in two categories: good match (with a score lower than 3) and poor match or mismatch (with a score higher than 3). It resulted that from all the respondents 62 (55.9%) companies had a good match and 49 (44.1%) companies had a poor match. These categories would be then cross tabulated with the performance categories in order to indicate if there is any association between them.

Statistics		
Range		13
Minimum		0
Maximum		13
Percentiles	25	1.00
	50	3.00
	75	6.00

4.3.4 The degree of use of the MPC system

The researcher then analysed the degree of use of these systems within the manufacturing environment. The degree of use was constructed through the use score. The score was derived by looking at the methods employed and the frequency of use. In calculation of this score the following questions were considered: 16, 17, 21, 22, 25, 26, 27, 29, 30 and 31; therefore a high use score would mean that the company uses a high number of techniques very often.

Figure 4.8 Histogram showing pattern of variation of use scores



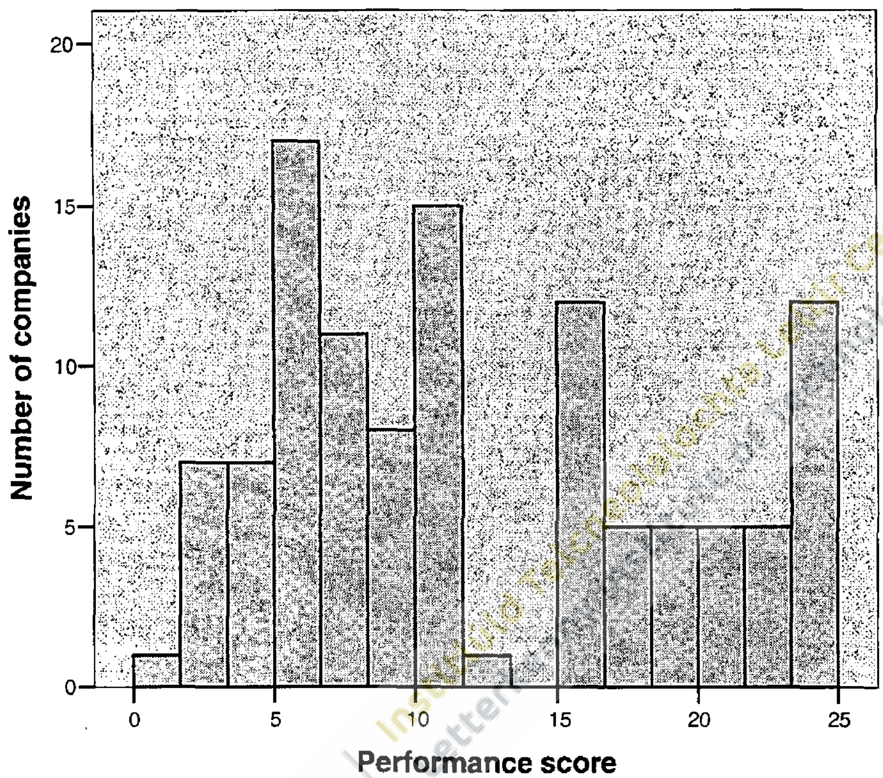
Statistics		
Range		25
Minimum		5
Maximum		30
Percentiles	25	11.00
	50	16.00
	75	22.00

The researcher noticed that 50% of the respondents achieved a use score lower than 16; he decided to split the data in two categories: good use (with a use score higher than 16) and poor use (with a use score lower than 16). It resulted that 56 companies (50.5%) had poor use and 55 had good use (49.5%). The researcher then correlated these results with the performance to verify if there is an association between them.

4.3.5 The Performance of the MPC system

Once the degree of use categories and degree of match categories were identified, the researcher investigated the relationship with the performance. In order to elicit the performance of the MPC system, a performance score was devised and answers were placed within categories.

Figure 4.9 Histogram showing pattern of variation of performance scores



Analysing the pattern of variation of the performance scores, the researcher observed that 50% of the respondents scored lower than 10; he decided to split the data in two categories: good performance (with a score higher than 10) and poor performance (with a score lower than 10). It resulted that 45 companies (40.5%) had good performance and 66 (59.5%) had poor performance.

Statistics		
Range		24
Minimum		1
Maximum		25
Percentiles	25	6.00
	50	10.00
	75	18.00

In order to verify if there is a relationship between the degree of match, between the manufacturing environment and the MPC system employed, the degree of use and the performance of that MPC system, the researcher calculated the chi square values (X^2) to establish if there is an association between them and the Spearman correlation coefficients (R) to measure the strength of the association.

1) Relationship between: Degree of Match – Degree of Use

In order to verify the relationship between the degree of match and the degree of use, the researcher cross tabulated the two variables.

Table 27: Cross-tabulation of the degree of match and the degree of use

Degree of Match	Degree of Use		
	Poor Use	Good Use	Total
Good Match	12 10.8%	50 45%	62 55.85%
Poor match	44 39.6%	5 4.5%	49 44.15%
Total	56 50.5%	55 49.5%	111 100%

H0: There is no association between the degree of match and the degree of use

H3: There is association between the degree of match and the degree of use

Critical $X^2_{0.01}$=6.636 with 1 degree of freedom

Sample $X^2_{0.000}$=51.545 with 1 degree of freedom

A significance value (p value) of 0.000 was generated along with a chi square value of 51.545 at one degree of freedom, which is more than the 1% level of significance minimum value (6.636). This indicated that the variables were not independent and that there was an association between the degree of match and the degree of use. To test the strength of the association the researcher analyzed the Spearman correlation coefficient between the two variables. The result obtained was 0.709 ($p<0.01$) and indicated that there was a strong association between the degree of match and the degree of use, which led to the conclusion that companies that match their MPC system with the manufacturing environment, tend to use it properly. This can be due to the fact that by matching the MPC system with the environment they need to analyze each dimension of the system and therefore the implementation and the use of it is more appropriate.

2) Relationship between: Degree of Match – Performance

To verify if there is a relationship between the degree of match and the performance the researcher cross tabulated the two variables.

Table 28: Cross-tabulation of the degree of match and performance

Degree of Match	Performance		
	Poor Performance	Good Performance	Total
Good Match	27 24.3%	35 31.5%	62 55.9%
Poor match	39 35.1%	10 9%	49 44.1%
Total	66 59.5%	45 40.5%	111 100%

H0: There is no association between the degree of match and the performance

H4: There is association between the degree of match and the performance

Critical $X^2_{0.01}$=6.636 with 1 degree of freedom

Sample $X^2_{0.000}$=13.293 with 1 degree of freedom

A significance value (p value) of 0.000 was generated along with a chi square value of 13.293 at one degree of freedom, which is more than the 1% level of significance minimum value (6.636). This indicated that the variables were not independent and that there was an association between the degree of match and the performance. To test the strength of the association the researcher analyzed the Spearman correlation coefficient between the two variables. The result obtained was 0.308 ($p<0.01$) and indicated there was a weak association between the degree of match and the performance. These findings led to the conclusion that by matching the MPC system with the environment it will not necessarily result in good performance and one of the possible causes might be that the system is not being used it properly.

3) Relationship between: Degree of Use – Performance

To verify if there is a relationship between the degree of use and the performance the researcher cross tabulated the two variables.

Table 29: Cross-tabulation of the degree of use and performance

Degree of Use	Performance		
	Poor Performance	Good Performance	Total
Good Use	17 15.3%	38 34.2%	55 49.5%
Poor Use	49 44.1%	7 6.3%	56 50.5%
Total	66 59.5%	45 40.5%	111 100%

H0: There is no association between the degree of use and the performance

H5: There is association between the degree of use and the performance

Critical $X^2_{0.01}$=6.636 with 1 degree of freedom

Sample $X^2_{0.000}$=34.554 with 1 degree of freedom

A significance value (p value) of 0.000 was generated along with a chi square value of 34.554 at one degree of freedom, which is more than the 1% level of significance minimum value (6.636). This indicated that the variables were not independent and that there was an association between the degree of use and the performance. To test the strength of the association the researcher analyzed the Spearman correlation coefficient between the two variables. The result obtained was 0.711 ($p<0.01$) and indicated there was a strong association between the degree of use and the performance. These findings led to the conclusion that companies that use their MPC system properly tend to achieve a good level of performance.

Table 30: Possible relationships between the variables studied

Relationship	**Degree of Match**	**Degree of Use**	**Performance**
Degree of Match		$X^2_{0.000}$= 51.545 R= 0.709	$X^2_{0.000}$= 13.293 R=0.308
Degree of Use			$X^2_{0.000}$=34.554 R=0.711
Performance			

By analyzing table 27, the researcher's hypothesis:

Good performance is the result of matching the MPC system with the manufacturing environment and good use of the MPC system employed.

is accepted due to the fact between any two of the variables used there is an association and an important observation is the strength of the association.

In order to further analyze and reinforce these findings, the researcher split the data in two: companies with good match and companies with poor match. Within each of the two categories, the association between the degree of use and the performance was analyzed. In order to obtain the categories the degree of match, the degree of use and the performance variables were cross tabulated (see table 31).

Table 31: Cross-tabulation of the degree of match, the degree of use and the performance

Match	Use		Performance: Poor	Performance: Good	Total
Good Match	Poor Use	Count	**10**	**2**	12
		% within Performance	37.03%	5.71%	19.35%
		% of Total	16.12%	3.22%	19.35%
	Good Use	Count	**17**	**33**	50
		% within Performance	62.96%	94.28%	80.65%
		% of Total	27.41%	53.22%	80.65%
	Total	Count	27	35	62
		% within Performance	100%	100%	100%
		% of Total	43.54%	56.45%	100%
Poor Match	Poor Use	Count	**39**	**5**	44
		% within Performance	100%	50%	89.80%
		% of Total	79.60%	10.20%	89.80%
	Good Use	Count	**0**	**5**	5
		% within Performance	0%	50%	10.20%
		% of Total	0%	10.20%	10.20%
	Total	Count	39	10	49
		% within Performance	100%	100%	100%
		% of Total	79.60%	20.40%	100%

This table can be translated also within the conceptual framework (see figure 2.13) defined at the end of chapter 2.

Figure 4.9 Schematic diagram showing all possible outcomes of mixing match, use and performance and the empirical results

Degree of Match	Degree of Use	Performance	No of Companies
Degree of Match → Good match 62(55.9%)	Good use 50(45%)	Good Performance	**33(29.7%)**
		Poor Performance	**17(15.3%)**
	Poor Use 12(10.8%)	Good Performance	**2(1.8%)**
		Poor Performance	**10(9%)**
Degree of Match → Poor Match 49(44.1%)	Good use 5(4.5%)	Good Performance	**5(4.5%)**
		Poor Performance	**0 (0%)**
	Poor Use 44(39.6%)	Good Performance	**5(4.5%)**
		Poor Performance	**39(35.1%)**
Total **111 (100%)**	**111 (100%)**		**111 (100%)**

Good match Category

55.9% of total respondents had a good match. Within this category the researcher analysed the association between degree of use and the performance.

H0: There is no association between the degree of use and the performance

H6: There is an association between the degree of use and the performance

Critical $X^2_{0.025}$= 5.024 with 1 degree of freedom

Sample $X^2_{0.020}$=9.581 with 1 degree of freedom

Poor match Category

44.1% of total respondents had a poor match between the MPC system employed and the manufacturing environment. Within this category the researcher analysed the association between degree of use and the performance.

H0: There is no association between the degree of use and the performance

H7: There is an association between the degree of use and the performance

Critical $X^2_{0.01}$=6.636 with 1 degree of freedom

Sample $X^2_{0.00}$=16.602 with 1 degree of freedom

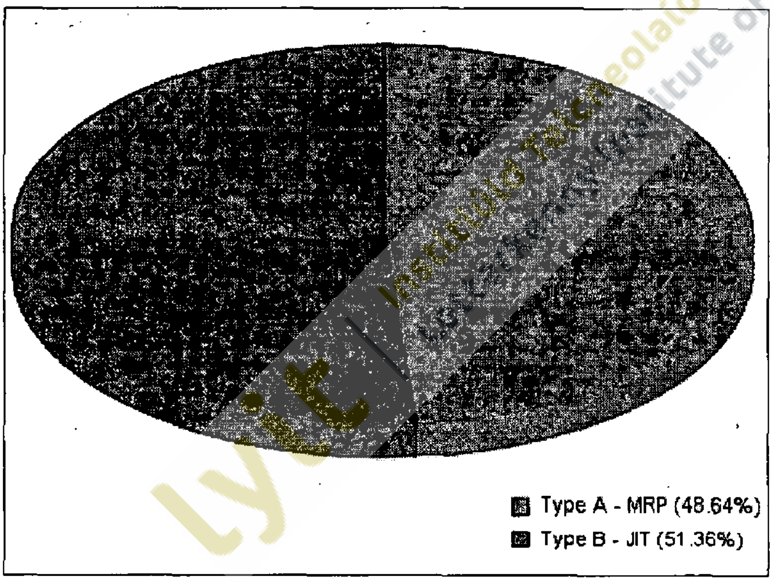
In both cases, good match and poor match, significance levels of 0.02 and 0.00 with chi square values of 9.581 and 21.716 at one degree of freedom was generated which were more than 2.5% level of significance minimum value (5.024), respectively 1% level of significance minimum value (6.636). These findings indicated that the variables were not independent and there was an association between the degree of use and performance, when it was a good match and also poor match, therefore the researcher's hypothesis was accepted.

4.4 MPC system types and Performance

In order to analyse the manufacturing planning and control system types employed by the respondents, the researcher cross tabulated the MPC system types and their use and performance in relation to the manufacturing environment where they operate.

Out of 111 respondents, 54 (48.64%) described their MPC system as Type A – MRP and 57 (51.36%) described their MPC system as Type B – JIT (see figure 4.10).

Figure 4.10 Manufacturing Planning and Control Systems identified



1) Type A – MRP Systems

The use and the performance of the MRP systems are distributed among manufacturing environments, as illustrated in table 32.

Table 32 Use and performance of the MRP systems within the manufacturing environments

Degree of use	Environment Type 1 – High Variety		
	Poor Performance	Good performance	Total
Poor Use	8 23.5%	0 0%	8 23.5%
Good use	7 20.6%	19 55.9%	26 76.5%
Total	15 44.1%	19 55.9%	34 100.00%
Degree of use	**Environment Type 2 – Low variety**		
	Poor Performance	**Good performance**	**Total**
Poor Use	13 65%	4 20%	17 85%
Good use	1 5%	2 10%	3 15%
Total	14 70%	6 30%	20 100.00%

The empirical analysis revealed that 54 companies that described their system as Type A – MRP, in only 34 cases it was matched with the manufacturing environment where they operated. Within this category the researcher tested the association between the use of the MRP system and the performance.

H0: There is no association between the degree of use of MRP systems and the performance

H8: There is an association between the degree of use of MRP systems and the performance

Critical $X^2_{0.01}$= 6.635 with 1 degree of freedom

Sample $X^2_{0.000}$=13.251 with 1 degree of freedom

Fisher's Exact test value=0.000

A significance value (p value) of 0.000 was generated along with a chi square value of 13.251 at one degree of freedom, which is more that 1% level of significance minimum value (6.635). When analysing the use and the performance of MRP systems in low variety manufacturing environments, the researcher observed that the systems didn't perform as good as in the high variety environments. 14 respondents out of 20 had poor performance, although in 2 situations, even if the system didn't match the environment, when used properly the companies achieved good performance. This can be the result of adapting their systems to the manufacturing environment and using mixed approaches. Therefore the researcher concluded that MRP systems, used properly, tend to perform better when are employed within high variety environments.

2) Type B – JIT Systems

The use and the performance of the JIT systems are distributed among manufacturing environments, as illustrated in table 33.

Table 33 Use and performance of the JIT systems within the manufacturing environments

Degree of use	Environment Type 1 – High Variety		
	Poor Performance	Good performance	Total
Poor Use	10 73.3%	1 6.7%	11 80%
Good use	1 6.7%	3 13.3%	4 20%
Total	11 80%	4 20%	15 100.00%
Degree of use	Environment Type 2 – Low variety		
	Poor Performance	Good performance	Total
Poor Use	17 40.5%	2 4.8%	19 45.2%
Good use	8 19%	15 35.7%	23 54.8%
Total	25 59.5%	17 40.5%	42 100.00%

The empirical analysis revealed that 57 companies that described their system as Type B – JIT, in only 42 cases it was matched with the manufacturing environment where they operated. Within this category the researcher tested the association between the use of the JIT system and the performance.

H0: There is no association between the degree of use of JIT systems and the performance

H9: There is an association between the degree of use of JIT systems and the performance

Critical $X^2_{0.01}$= 6.635 with 1 degree of freedom

Sample $X^2_{0.000}$=12.917 with 1 degree of freedom

Fisher's Exact test value=0.000

A significance value (p value) of 0.000 was generated along with a chi square value of 12.917 at one degree of freedom, which is more that 1% level of significance minimum value (6.635). When analysing the use and the performance of JIT systems in high variety manufacturing environments, the researcher observed that the systems didn't perform as good as in the low variety environments. 11 respondents out of 15 had poor performance, although in 3 situations, even if the system didn't match the environment, when used properly the companies achieved good performance. Therefore the researcher concluded that JIT systems, used properly, tend to perform better when are employed within low variety environments.

4.5 Companies size and Performance

Accordingly to Denton and Hodgson (1997) the most basic categorisation of manufacturing companies is by size. The researcher presented the profile of the respondents at the beginning of sub-chapter 4.3. Glancey (1998) analysed the relationship between company size and the performance, indicating that the size can represent the growth, profitability and age of a company. In other terms, company size can be used a proxy for its experience, knowledge, performance. Accordingly to Berenson et al (2004), five recipients within a category is a reasonable number for performing a chi square test, therefore the researcher re-grouped the respondents in three categories:

- less than 20 employees – 53 companies;
- between 21 – 50 employees – 35 companies
- higher than 50 employees – 23 companies.

These categories were then cross tabulated with the performance, in order to verify if there is an association between company size and the performance.

Table 34: Cross-tabulation of the company size and performance

Company size	Performance		
	Poor Performance	Good Performance	Total
Less then 20	35 31.5%	18 16.2%	53 47.7%
Between 21 – 50	24 21.6%	11 9.9%	35 31.5%
Higher than 50	7 6.3%	16 14.4%	23 20.7%
Total	66 59.5%	45 40.5%	111 100%

H0: There is no association between the company size and the performance

H10: There is association between the company size and the performance

Critical $X^2_{0.005}$=10.597 with 2 degree of freedom

Sample $X^2_{0.006}$=11.095 with 2 degree of freedom

A significance value (p value) of 0.006 was generated along with a chi square value of 11.095 at two degree of freedom, which is more than the 0.5% level of significance minimum value (10.597). This indicated that the variables were not independent and that there was an association between the company size and the performance. Therefore companies that have a higher number of employees tend to have a better performance, which can be achieved through accumulation of years of knowledge and experience.

4.6 Constructing validity

In order to construct validity, the researcher undertook interviews with two companies: one from the good match category and one from poor match. The company with good match was a large size company (between 51 and 250 employees) and the poor match company was a small size firm (between 20 and 50 employees). Both companies were asked the same set of questions that were prepared onto the theme sheet (see Appendix E).

The objective of these interviews was to verify that the questionnaires completed by those respondents were accurate and they were reflecting their company situation. Both companies were chosen on a judgmental basis and geographical position, as close as possible to the researcher. For the purpose of this analysis companies were denoted as company A and company B. The interviews last an hour each and they were tape-recorded (see table 34 for a summary of the two interviews). The researcher asked them to describe the environment and the MPC system used and then cross-checked their answers with the questionnaires. Both companies answered similarly to the questionnaire completed. They presented evidence of the system employed: Company A employed an MRP system and they showed reports regarding their finite scheduling approach and also dispatch lists for their goods. They had weekly meeting regarding production planning and the run-time was an important factor for measuring their operational performance. Reports were generated at the end of the week in order to verify the Overall Equipment Effectiveness (OEE) and also forecasting reports were issued for planning the production for the following week. There was a monthly and a weekly plan. The weekly plan was closely monitored and corrective action was taken if needed. Also they had a quality control department that was mainly focusing on customer complaints and quality of their products.

Table 35 Summary of the interviews

	Company A	Company B
Did the person interviewed complete the questionnaire?	Yes	Yes
Did they understand the questions from the questionnaire that they completed?	Yes	Yes
MATCH		
Did their description of the environment correspond to the one given in the questionnaire	Yes High variety	Yes High variety
Did their description of the MPC system used correspond to the one given in the questionnaire?	Yes MRP type	Yes JIT type
Did their MPC match the business environment within which they operate, accordingly to the scores obtained? What was the degree of match?	Yes Good Match	No Poor Match
USE		
Did they present evidence of the system used? Examples	Yes – very detailed Production meetings agendas, OEE reports, Planning/forecasting figures, MRP scheduling reports, dispatch lists	Yes – very little Dispatch lists and production planning agendas
Did they present evidence of how often they use the system?	Daily monitoring of the production, daily reports for quality, weekly schedules, monthly reports on quality, OEE, deliveries, customer complaints	Weekly production meetings and monthly sales reports
What was their degree of use accordingly to the use score system?	Good use	Poor use
PERFORMANCE		
How did they measure the performance?	Run-time, OEE, quality reports, absenteeism, breakdown time, delivery on-time	Turnover value
Did they have an operating procedure for improvement?	Yes	Yes
Did they benchmark their performance?	Yes	yes
Did they measure the level of customer satisfaction? How often?	Yes Every week	Yes Every six months
How did they classify their performance?	Good	Average
What was the performance accordingly to the performance score system?	Good performance	Poor Performance
Did they performance measures correspond to their answers from the questionnaires?	Yes	Yes
Did the answers from the questionnaire reflected the situation presented in the interviews?	Yes	Yes

Company B employed a JIT system and they didn't have a formal production planning. Their system was operating week by week, and there was no evidence of medium or long term planning. Their orders were accepted as they arrived and then pulled through the production stages. The company had weekly meetings regarding production planning, but the process was described as "being an informal meeting", "on the factory floor". The main performance indicator for the company was the turnover value. The operations manager interviewed didn't show any evidence regarding their productivity levels or their effectiveness. He mentioned that the company has a monitoring system in place and each product before it is sent to the customer, is checked by quality control person.

The researcher asked as well what their performance measures were: Company A emphasised on OEE, run-time, quality (they measure how many defect parts per million they had), customer complaints and delivery on-time. Company B used the turnover value as a measure for their performance.

Analysing the interviews and the questionnaires completed by those two companies, the researcher was satisfied with the results. The questionnaires reflected the situation of each company and also their system and environment within which they operated. The researcher felt that scores, constructed to place each company within a certain category (for example degree of use, performance) reflected the characteristics of each company.

4.7 Summary

The research questions proposed at the begging of this chapter were answered. The researcher identified the main types of manufacturing environments where the Irish engineering companies operate, as well as the type of MPC system they employ. Then the researcher measured the degree of match between the MPC systems identified and the manufacturing environment within which they operated. The main hypothesis of the research:

"Good performance is the result of matching the MPC system with the manufacturing environment and good use of the MPC system employed".

was tested and it was accepted; the conceptual match framework developed at the end of literature review chapter was reinforced by the empirical study. Relationships between degree of match, degree of use and performance were analysed. The researcher concluded that a company, in order to achieve good performance, needs to match the MPC system with the manufacturing environment within which operates and use that system properly.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

5.2 Consequences of not linking the MPC system to the manufacturing environment

5.3 Implications for theory and practice

5.4 Research limitations

5.5 Suggestions for further research

5.1 Introduction

Over the last decades, the literature regarding manufacturing planning and control systems has emphasized the need for alignment between the MPC system employed and the manufacturing environment within which companies operate. Several studies compared the effects of using various MPC systems and developed frameworks in order to differentiate manufacturing environments. However, there is a lack of conceptual and empirical research that matches MPC systems and the manufacturing environment.

This study investigated the degree of match between manufacturing environments and the MPC systems. More important, it explored the effect of matching and using these systems on company's performance. The value of this study lies in the substantial information and invaluable insights into manufacturing planning and control systems, their match, use and performance in Irish engineering companies.

This chapter consolidates the remarks made in previous chapters and draws overall conclusions of the research described in this thesis. The research findings, in terms of both academic contribution and implications for practice in the manufacturing industry, are discussed in addition to the limitations of the work and suggestions for future research.

5.2 Consequences of not linking the MPC system to the manufacturing environment

The research reported in this thesis set out to test the proposition that:

"Good performance is the result of matching the MPC system with the manufacturing environment and good use of the MPC system employed".

A review of the relevant literature suggested a conceptual framework that linked the MPC system with the manufacturing environment. Then the researcher has described different types of MPC systems used by the Irish engineering companies and also the manufacturing environment within which they operate. He analysed the degree of match between them and then verified if there are any relationships between the degree of match, the degree of use and the performance. The empirical findings agree with the conceptual/ theoretical expectations, regarding the relationship between the MPC type choice and the manufacturing environment. More, importantly the results showed that the performance of a company improves when they can match the MPC system with the manufacturing environment and they use it efficiently.

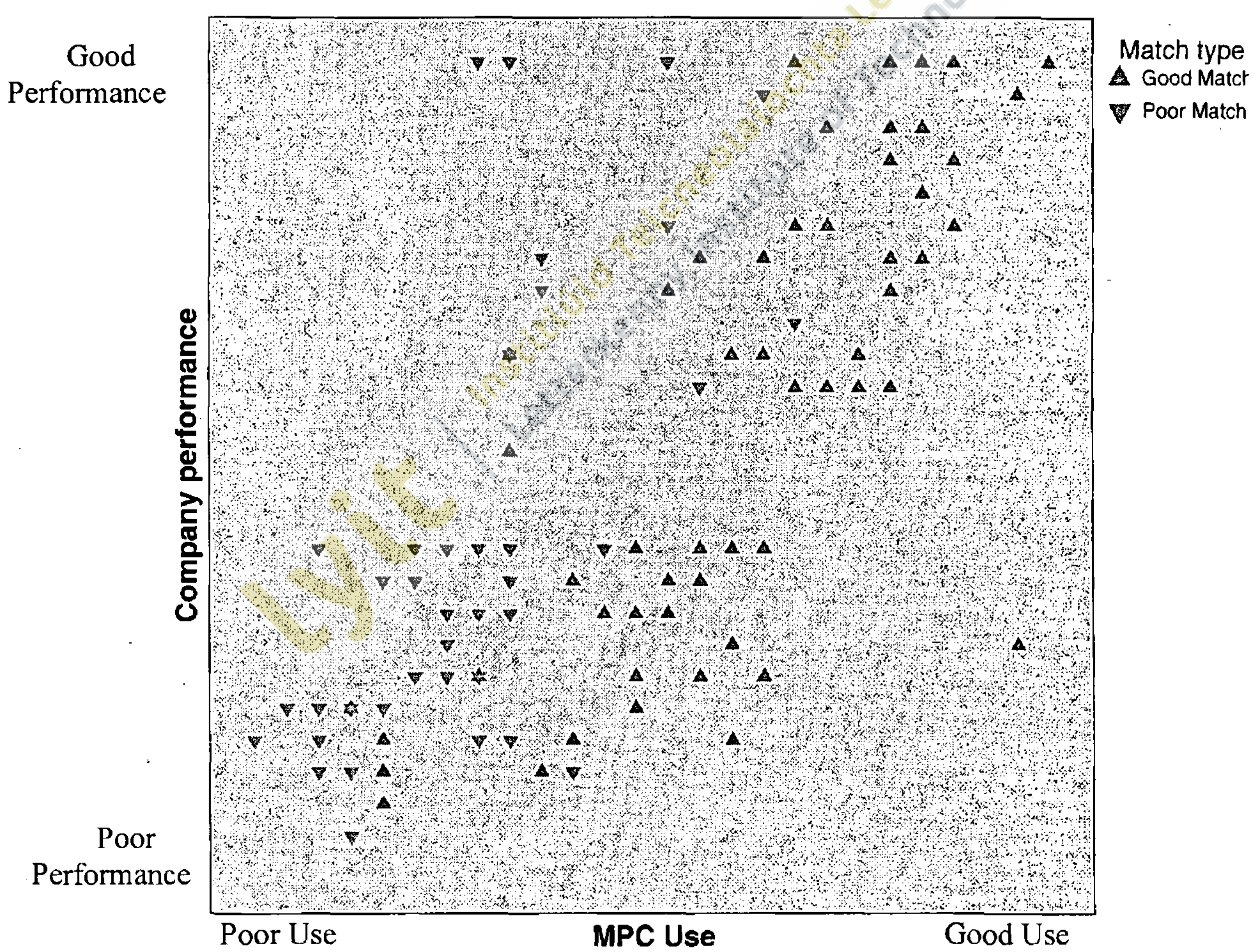
Therefore, if there is a match or alignment between MPC system choice and the manufacturing environment, then the task of the MPC is simpler than should there be a mismatch. In the latter case, the MPC systems would need to work around this mismatch and still deliver good plans and schedules in order to support the corporate objectives of customer satisfaction, delivery on time and manufacturing efficiency. Ward et al (1988) report that the MPC system is perceived by the managers as having the capability to help them address problems in a variety of areas and also to overcome a mismatch between marketing/sales and manufacturing strategies.

Berry and Hill (1992) describe a situation where there are substantial mismatches between the MPC and the manufacturing environment. A company changed their marketing strategy and decided to enlarge their range of options produced in low volume to specific customer orders. To support this shift in marketing strategy, the company would have had to invest in a new MPC system in order to adapt it to the new environment. The firm decided to retain its previous MPC system, which was designed to support standardised products. Major difficulties were encountered, which resulted in lengthy manufacturing cycles, simultaneous shortages, excesses inventory and poor customer service.

Jonsson and Mattsson (2003) describe a few cases with clear misalignments between MPC systems and the manufacturing environments, affecting the performance of the company. More importantly, they address the issue that choosing a planning method that fits the environment and that is applicable to the planning situation does not necessarily result in a satisfactory utilisation of the method, it only improves the chances of the user satisfaction with the method.

This research suggested that there are differences between environment types and MPC types. Companies need to link their systems to the environment, in order to be able to respond to the costumer's requests. Although choosing the right system, does not guarantee good customer satisfaction. The empirical study indicated an association between the degree of match and performance of a MPC system; when the methods were used in a proper manner, the company achieved good performance (see figure 5.1).

Figure 5.1 Performance in relation to the degree of match and degree of use of the MPC systems



When the researcher examined each type of MPC system used within Irish engineering sector, found that both MRP type and JIT type perform well, when matched with the environment and used properly. So, no system was found to be superior or perform better, but it suggested some patterns: MRP type systems perform better than a JIT type system, when used properly in a high-variety manufacturing environment and JIT systems were more effective when used properly in a low-variety manufacturing environment.

The empirical study revealed that the number of products that a company fabricates influenced the type of MPC system chosen. It showed that companies with high number of products and low volumes tend to employ MRP type systems and companies with low number of products and high volumes tend to use JIT type systems. Again the use factor was found to be paramount to the success of the system. If the system was used effectively the company's performance was improved.

The researcher also investigated the relationship between company size and the performance. Company size can be seen as a substitute for good long-term performance, accumulation of knowledge and experience. The study revealed that there was an association between them. The researcher's opinion was that large companies with over fifty employees tend to have a better performance, when compared with small or medium size ones. This might be due to the fact that over years of practice, the companies aligned the MPC system employed to the manufacturing environment and also had the experience and knowledge to use it properly.

5.3 Implications for theory and practice

The main contribution of this research to knowledge is the development and validation of a conceptual framework that link dimensions of a MPC system with manufacturing environments. The inputs to this framework are effectively a checklist that can be used to assess manufacturing companies, their environments and MPC systems. The dimensions are objective measures of a company that can be used to compare companies and could be used in further projects to make decisions on suitable systems. Also insights from this study could serve as guidelines to the operations managers for selecting an appropriate MPC system. Being aware that Japanese companies were using JIT type systems in high variety environments and subject to the assumptions and limitations of this study, the researcher suggests that generally MRP type systems should be used if the company operates within high variety manufacturing environments, and JIT type systems should be adopted when operating in low variety environment.

This research reviewed previous studies on MPC systems and suggested a conceptual framework that differentiated between main two approaches to manufacturing planning and control: MRP and JIT type. Also, along with these systems, were described the manufacturing environments in which they achieve a good performance. This framework can be used by other researchers as a basis for empirical studies.

For the Irish literature related to manufacturing practices, this research revealed that matching the manufacturing practices to the business environment would enhance the chances of the companies to achieve better performance. Also, companies that did not use the systems properly, for example: did not closely monitor their activities, did not measure the customer satisfaction level, did not benchmark their practices against their competitors encountered difficulties in meeting customer needs and they had a poor performance. Also, the companies with over fifty employees tend to perform better than small or medium companies.

Therefore Irish engineering companies need to focus their resources towards matching the MPC system with the environment within which they operate. Paramount is the usage of that system, in terms of productivity measurement, reporting and adjusting their techniques if necessary. Due to the fact that business environment is rapidly changing, companies need to continuously review the system employed and its use. It is easier to prevent a mismatch, than to dissatisfy the customers due to the impact that has on business.

5.4 Research limitations

It is important to consider the claims of this research in the context of its limitations. The use of postal survey as main data collection method, has limited the number of questions and also the information accuracy, due to the fact that other persons than operation/production managers within companies could have completed the questionnaires. The length of the survey may have had a negative impact on the overall response rate. It is possible that it could have been improved upon had the survey been more condensed.

The high number of nominal and ordinal variables did not facilitate advanced statistical manipulations. Devising the scoring system the researcher facilitated the use of non-parametric test to analyse the data. Without using a weighting system when scores were attached to questions, the researcher was not able to identify the differences between MPC dimensions when comparing companies. The match score was an artificially devised system that could identify the degree of match for an MPC system, but could not describe it in terms of matched or unmatched dimensions within an environment.

The present study did not identify the major reasons behind its finding. Therefore, explorative case studies are important in order to gain a deeper understanding of the appropriateness of various planning and control methods in any given environment and perhaps to develop new planning and control approaches for mixed environments. Also some in-depth interviews after the administration of the questionnaire would have resulted in finer refinements of the conceptual framework and identification of other causes of poor performance. The measure of performance used in the present study could also be developed and linked directly to companies' operational performances. Therefore studies that focus on the application of the MPC systems and link their dimensions to the operational level of performance would be interesting. Such studies would further fill some gaps in the literature and provide empirical knowledge of manufacturing planning and control dimensions.

Overall, this research was an important stage in the author's personal development. The literature review, the design of a data collection instrument, the activity of ensuring the achievement of a significance response rate and the process of analysing and interpreting the large amount of information collated were difficult and challenging tasks. Completion has resulted in the gaining of a vast amount of information and knowledge of not only manufacturing practices matters, but also of the research process itself.

5.5 Suggestions for further research

The research reported in this thesis provides opportunities for further work in a number of areas. The conceptual framework can be further developed using more variables in order to facilitate a finer distinction between MPC systems used. Focusing on the use of these systems and linking their dimensions to the performance, would allow determining the impact that each dimension has on company's performance. As well, it would be interesting to see what are the financial implications of aligning the MPC system with the manufacturing environment.

Explorative case studies would be interesting to use in order to gain deeper understanding of MPC system dimensions and also what other internal and external factors determine the use of those dimensions.

Because it is possible to apply MRP and JIT dimensions to different parts of a supply network, it would be valuable to investigate mixed or hybrid systems.

The research described in this thesis can be used as a starting point for work exploring different manufacturing information systems, their specifications and applicability within different manufacturing environments. Also the studies on the effect of information technology on the MPC system design would fill some gaps in the literature and provide wider perspective on future developments of manufacturing planning and control systems.

BIBLIOGRAPHY

Adegoke, O., 2003, "Drivers of volume flexibility requirements in manufacturing plants", International Journal of Operations & Production Management, Volume 23, Number12, pp. 1497-1513

Aghazadeh, S.M., 2004, "Does manufacturing need to make JIT delivery work?", Journal of Management Research News, Volume 27, Number 1, pp. 27-42

Ang, C.L., 1995, "On the performance of hybrid multi-cell flexible manufacturing systems", International Journal of Production Research, Volume 33, Number 10, pp. 2779-2799

Beach, R., Muhlemann, A.P., Price, H.R.D., 2000, "Manufacturing operations and strategic flexibility: survey and cases", International Journal of Operations& Production Management, Volume 20, Number 1, pp. 7-30

Berenson,M., Levine,D.M.., Krehbiel, T.C., 2004, "Basic Business Statistics: Concepts and Applications", Pearson Prentice Hall

Berry, W.L., Hill, T., 1992, "Linking systems to strategy", International Journal of Operations and Production Management, Volume 12, pp. 3-15

Blankson, C., Stokes, D., "Marketing practices in the UK small business sector", Marketing Intelligence Planning, Volume 20, Number 1, pp. 49-61

Bhuiyan, N., Baghel, A., 2005, "An overview of continuous improvement: from the past to the present", Management Decision, Volume 43, Number 5, pp.761-771

Bonney, M.C., Zongmao, Z., Head, M.A., Tien, C.C., Barson, R.J., 1999, "Are push and pull systems really so different?", International Journal of Production Economics, Number 59, pp. 53-64

Bragg, D.J, Duplaga, E.A., Penlesky, R.J., 2005, "Impact of product structure on order review/evaluation procedures", Industrial Management&Data Systems, Volume 105, Number 3, pp.307-324

Brown, S., 1996 "Strategic manufacturing for competitive advantage", Prentice Hall, pp. 9-30

Brunet, A.P., New, S., 2003, "Kaizen in Japan: an empirical study", International Journal of Operations&Production Management, Volume 23, Number 12, pp.1426-1446

Buxey, G., 2005, "Aggregate planning for seasonal demand: reconciling theory with practice", International Journal of Operations& Production Management, Volume 25, Number 11, pp. 1083-1100

Caridi, M., Cigolini, R., 2002, "Improving materials management effectiveness – A step towards agile enterprise", International Journal of Physical Distribution and Logistics Management, Volume 32, Number 7, pp. 556-576

Chan J.W.K, Burns N.D., 2002, "Benchmarking manufacturing planning and control (MPC) systems", International Journal of Operations Management, Volume 9, Number 3, pp. 256-277

Chang, C., Hastings, N.A.J., White, C., 1994, "A very fast production scheduler", International Journal of Operations and Production Management, Volume 14, Number 8, pp. 88-101

Chase, R.B., Aquilano, N.J., Jacobs, F.R., 2001, "Operations Management for Competitive Advantage", Ninth edition, McGraw-Hill Irwin

Chung-Hsing, Y., 1995, "Production data modelling: an integrated approach", International Journal of Operations and Production Management, Volume 15, Number 8, pp.55-62

Creswell, J.W., 2005, "Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research", 2nd Edition, Merrill Prentice Hall

Davies, A.J., Kochhar, A.K., 2000, "A framework for the selection of the best practices", International Journal of Operations&Production Management, Volume 20, Number 10, pp. 1203-1217

Denton, P.D., Hodgson, A., 1997, "Implementing strategy led BPR in a small manufacturing company", 5th International Conference on Factory 2000, IEE Conference Publication number 435, April 2-4, pp. 1-8

Deshpande, R., 1983, "Paradigms lost: on theory and method in research in marketing", Journal of Marketing, Volume 47, pp. 101-110

Domegan, C., Fleming, D., "Marketing Research in Ireland. Theory and Practice", 2nd Edition, Dublin, Gill and Macmillan

Du J., Jiao, Y., Jiao, J., 2005, "Integrated BOM and routing generator for variety synchronisation in assembly-to-order production", Journal of Manufacturing Technology Management, Volume 16, Number 2, pp.233-243

Dubois, F.L., Oliff, M.D., 1991, "Aggregate production planning in practice", Production and Inventory Management Journal, Volume 32, Number 3, pp. 26-30

Dumond, E.J., 2005, "Understanding and using the capabilities of finite scheduling", Industrial Management&Data Systems, Volume 105, Number 4, pp. 506-526

Easterby-Smith, M, Thorpe, R., Lowe, A., 2003, "Management Research: An Introduction", 2nd Edition, Sage

Filippini, R., 1997, "Operations management research: some reflections on evolution, models and empirical studies in OM", International Journal of Operations&Production Management, Volume 17, Number 7, pp. 655-670

Fung, R.Y.K., Tang, J., Wang, D., 2003, "Multiproduct aggregate production planning with fuzzy demands and fuzzy capacities", IEEE Transactions on systems, man and cybernetics – Part A:Systems and humans, Volume 33, Number 3

Gill, J, Johnson, P., (2002), "Research Methods for Managers", 3rd Edition, Paul Chapman

Glancey, K., 1998, "Determinants of growth and profitability in small entrepreneurial firms", International Journal of Entrepreneurial behaviour & Research, Volume 4, Number 1,pp. 18-27

Goulding, C., 2005, "Grounded theory, ethnography and phenomenology: A comparative study analysis of three qualitative strategies for marketing research", European Journal of Marketing, Volume 39, Number ¾, pp. 294-308

Guide, V.D.R, Srivastava, R., Spencer, M.S., 1997, "An evaluation of capacity planning techniques in a remanufacturing environment", International Journal of Production Research, Volume 35, Number 1, pp.67-82

Gummesson, E, 2000, "Qualitative methods in Management Research", 2nd Edition, Sage Publications, London

Haslett, T., Osborne, C., 2000, "Local rules: their application in a kanban system", International Journal of Operations&Prodcution Management, Volume 20, Number 9, pp.1078-1092

Healy M., Perry, C., 2000, "Comprehensive criteria to judge validity and reliability of qualitative research within the realism paradigm", Qualitative Market Research: An International Journal, Volume 3, Number 3, pp. 118-126

Hill, T., 2000, "Manufacturing strategy: Text and Cases", Hampshire, 2nd Edition

Howard, A., Kochhar, A., Dilworth, J., 2002, "A rule-base for the specification of manufacturing planning and control systems activities", International Journal of Operations&Production Management, Volume 22, Number 1, pp. 7-29

Howard, A., Kochhar, A., Dilworth, J., 1998, "An objective approach for generating the functional specification of manufacturing planning and control systems", International Journal of Operations&Production Management, Volume 18, Number 8, pp. 710-726

Huang, G.Q., Lau, J.S.K., Mak, K.L., 2003, "The impacts of sharing production information on supply chain dynamics: a review of the literature", International Journal of Production Research, Volume 41, Number 7, pp.1483-1517

Humphreys, P., McCurry, L., McAleer, E., 2001, "Achieving MRPII Class A status in an SME", Benchmarking: An International Journal, Volume 8, Number 1, pp. 48-61

Hussey,J., Hussey, R., 1997, "Business Research: A practical guide for undergraduates and postgraduates students", MacMillan Press, Basingstoke

Ip, W.H., Kwong, C.K., Fung, R., 2000, "Design of maintenance system in MRPII", Journal of Quality in Maintenance Engineering, Volume 6, Number 3

Jonsson, P., Mattsson, S.A., 2003, "The implications of fit between planning environments and manufacturing planning and control methods", International Journal of Operations&Production Management, Volume 23, Number 8, pp. 872-900

Kennerley, M.P., Davis, A.J, Kochhar, A.K, 1996, "Manufacturing strategy, performance and best practices - the contribution of manufacturing planning and control systems", Third International Conference of European Operations Management Association on Manufacturing Strategy in a Global Context, London, pp. 363-368

Ketokivi, M., Schroeder, R., 2004, "Manufacturing practices, strategic fit and performance", International Journal of Operations&Production Management, Volume 24, Number 2, pp.171-191

Koh L.S.C., Simpson M., 2005, "Change and uncertainty in SME manufacturing environments using ERP", Journal of Manufacturing Technology Management, Volume 16, Number 6, pp. 629-653

Koh, L.S.C., Gunasekaran, A.,Saad, S.M., 2005, "A business model for uncertainty management", Benchmarking: An International Journal, Volume 12, Number 4, pp. 383-400

Creswell, J.W., 2005, "Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research", Pearson Merrill Prentice Hall

Knod, E., M., Schonberger, R., J., 2001, "Operations Management – meeting customers' demands", McGraw-Hill Irwin

Kumar, R., 1996, "Research methodology: A step by step guide for beginners", 2nd Edition, Longman

Kumar, S., Meade, D., 2002, "Has MRP run its course? A review of contemporary developments in planning systems", Industrial Management and Data Systems, Volume 102, Number 8, pp. 453-462

LaForge, R.L., Craighead, C.W., 2000, "Computer based scheduling in manufacturing firms: some indicators of successful practice", Production and Inventory Management Journal, First Quarter, pp.29-34

Little, D., Rollins, R., Peck, M., Porter, J.K., 2000, "Integrated planning and scheduling in the engineer-to-order sector", International Journal of Computer Integrated Manufacturing, Volume 13, Number 6, pp.545-554

Malhotra, N.K., 1996, "Marketing Research: An Applied Orientation", 2nd Edition, Prentice Hall

Mangan J., Lalwani, C., Gardner, B., 2004, "Combining quantitative and qualitative methodologies in logistics research", International Journal of Physical Distribution& Logistics Management, Volume 34, Number 7, pp. 565-578

Markham, I.S., Mathieu, R.G., Wray, B.A., 2000, "Kanban setting through artificial intelligence: a comparative study of artificial neural networks and decision trees", Integrated Manufacturing Systems, Volume 11, Number 4, pp.239-246

Masuchun, W., Davis, S., Patterson, J.W., 2004, "Comparison of push and pull control strategies for supply network management in a make-to-stock environment", International Journal of Production Research, Volume 42, Number 20, pp. 4401-4419

Motreuil, B., Venkatadri, U., Rardin, R.L., 1999, "Fractal layout organisation for job shop environments", International Journal of Production Research, , Volume 37, Number 3, pp. 501-521

Miltenburg, J. (1997), "Comparing JIT, MRP and TOC, and embedding TOC into MRP", International Journal of Production Research, Vol. 35 No.4, pp.1147-69

Newman W.R., Shridharan V., 1995, "Linking manufacturing planning and control to the manufacturing environment", Integrated Manufacturing Systems, Volume 6, Number 4, pp.36-42

Norusis, M., 2005, "SPSS 13.0 Guide to Data Analysis", Prentice Hall

Olhager, J., Rudberg, M., 2002, "Linking process choice and manufacturing planning and control systems", International Journal of Production Research, Volume 40, Number 10, pp. 2335-2352

Petroni, A., Rizzi, A., 2001, "Antecedents of MRP adoption in small and medium sized firms", Benchmarking: An International Journal, Volume 8, Number 3, pp. 17-22

Perry, C., 1998, "Processes of a case study methodology for post-graduate research in marketing", European Journal of Marketing, Volume 32, Number 9/10, pp. 785-802

Persona, A., Regattieri A., Romano, P., 2004, "An integrated reference model for production planning and control in SMEs", Journal of Manufacturing Technology Management, Volume 15, Number 7, pp. 626-640

Persentili, E., Alptekin, S.E., 2000, "Product flexibility in selecting manufacturing planning and control strategy", International Journal of Production Research, Volume 38, pp. 2011-2021

Plenert, G., 1999, "Focusing material requirements planning (MRP) towards performance", European Journal of Operational Research, Volume 119, pp. 91-99

Porter K., Little D., Peck M., Rollins R., 1999, "Manufacturing classifications: relationships with production control systems", Integrated Manufacturing Systems, Volume 10, Number 4, pp. 189-199

Porter K., Jarvis, P., Little, D., Laakmann, J., Hannen, C., Schotten, M., 1996, "Production planning and control system developments in Germany", International Journal of Operations and Production Management, Volume 16, Number 1, pp. 27-39

Ramasesh R., Kulkarni S., Jayakumar M., 2001, "Agility in manufacturing systems: an exploratory modelling framework and simulation", Integrated Manufacturing Systems, Volume 12, Issue 7, pp. 534-548

Riege, A.M., 2003, "Validity and reliability tests in case study research: a literature review with hands-on applications for each research phase", Qualitative Market Research: An International Journal, Volume 6, Number 2, pp. 75-86

Robson, C., 2002, "Real World Research", 2nd Edition, Blackwell

Roongrat, S., Bohez, E.L.J., 2004, "Integration of JIT flexible manufacturing, assembly and disassembly system using Petri net approach", Journal of Manufacturing Technology Management, Volume 15, Number 7, pp.700-714

Russell, R.S., Taylor, B.W., 2000, "Operations Management", Prentice Hall, 3rd Edition

Safizadeh, M.H., Ritzman, L.P., 1997, "Linking performance drivers in production planning and inventory control to process choice", Journal of Operations Management, Volume 15, pp. 389-403

Sanchez M.A., Perez M.P., 2005, "Supply chain flexibility and firm performance", International Journal of Operations& Production Management, Volume 25, Number 7, pp. 681-700

Sanderson, P.M., 1989, "The human planning and scheduling role in advanced manufacturing systems: an emerging human factors domain", Human Factors, Volume 31, Number 6, pp.635-666

Saunders, M, Lewis, P., Thornhill, A., (2003), "Research methods for business students", Prentice Hall, 3rd Edition

Savolainen, T., 1998, "Cycles of continuous improvement, realizing competitive advantages through quality", International Journal of Operations&Production Management, Volume 19, Number 11, pp.1203-1222

Silva, J.P., Lisboa, J., Huang, P., 2000, "A labour constrained model for aggregate production planning", International Journal of Production Research, Volume 38, Number 9, pp. 2143-2152

Slack, N., Stuart C., Robert, J., "Operations Management", Third Edition, 2001

Smith, C., H., Herbig, P., Milewicz, J., Golden, J.E., 1996, "Differences in forecasting behaviour between large and small firms", Journal of Marketing Practice: Applied Marketing Science, Volume 2, Number 1, pp. 35-51

Stockton, D.J., Lindley, R.J., 1995, "Implementing Kanbans within high variety/low volume manufacturing environments", International Journal of Operations and Production Management, Volume 15, Number 7, pp. 47-59

Stoop, P.P.M., Wiers, V.C.S., 1996, "The complexity of scheduling in practice", International Journal of Operations and Production Management, Volume 16, Number 10, pp. 37-53

Styhre, A., 2001, "Kaizen, ethics and care of the operations: management after empowerment", Journal of Management Studies, Volume 38, Number 6, pp.795-810

Tsoukas, H., 1989, "The validity of idiographic research explanations", Academy of Management Review, Volume 14, Number 4, pp. 551-561

Tiwari, M.K., Mondal, S., 2002, "Application of an autonomous agent network to support the architecture of a holonic manufacturing system", International Journal of Advanced Manufacturing Technology, Volume 20, Number 12, pp. 931-942

Van Assen, M., F., Hans, E., W., Van de Velde, S., L., 2000, "An agile planning and control framework for customer-order driven discrete parts manufacturing environments", International Journal of Agile Management Systems, Volume 2, Number 1, pp. 16-23

Van Assen, M.,Van de Velde, S., 2003, "The impact of complexity, rate of change and information availability on the production planning and control structure: Evidence from medium size Dutch discrete manufacturing firms", ERIM Report Series Reference No. ERS-2003-083-LIS

Vignali, C., Zundel, M., 2003, " The marketing management process and heuristic devices: an action research investigation", Journal of Marketing Intelligence and Planning, Volume 21, Number 4, pp. 205-219

Vollmann T.E., Berry W.L., Whybark D.C., 2005, "Manufacturing Planning and Control Systems", 5th Edition, McGraw-Hill Irwin

Waller, B., 2004, "Market responsive manufacturing for the automotive supply chain", Journal of manufacturing Technology Management, Volume 15, Number 1, pp. 10-19

Waas,V., Wells,P., 1994, "Research methods in action: an introduction", Principles and Practice in Business and Management Research, Aldershot Darmouth, pp. 1-34

Wermus, M., 2001, "A survey on shop floor control techniques in Polish make-to-order companies", International Journal of Operations&Production Management, Volume 21, Number 11, pp. 1452-1459

Wong, C.M., Kleiner, B.H., 2001, "Fundamentals of material requirements planning", Management Research News, Volume 24, Number 3, pp. 9-12

Yeh, C. H., 1997, "Schedule based production", International Journal of Production Economics, Volume 51, Number 3, pp. 235-242

Yusuf, Y.Y., Sarhadi, M., Gunasekaran, A., 1999, "Agile manufacturing: the drivers, concepts and attributes", International Journal of Production Economics, Volume 62, pp. 33-43

Publications:

Enterprise Ireland, ESF and London Business School, "Competitive Benchmarking" – this reference relates to a benchmarking questionnaire that Enterprise Ireland has been using for years.

Forfas and National Competitiveness Council, "Annual Competitiveness Report 2005", 2005

Dr. Fynes, B., Keegan, R., McSherry, R., Roche, E., Dr. Sean de Burca, 2001, "Made in Ireland – Benchmarking Ireland's SMEs – An Irish European study", Enterprise Ireland and UCD

Appendix A
QUESTIONNAIRE

1. How many full-time people (or equivalent) are employed in your business?

Less than	5	☐
Between	5 - 20	☐
Between	21 - 50	☐
Between	51 - 250	☐
Over 250		☐

2. During the last business year, what was the approximate firm's turnover?

Less than	€ 1m	☐
Between	€1m – €3m	☐
Between	€3m – €10m	☐
Between	€10m – €50m	☐
Over	€50m	☐

3. How could you describe the business environment where your company operates in terms of:

	Very Low	Low	Medium	High	Very High
Product variety	☐	☐	☐	☐	☐
Demand stability	☐	☐	☐	☐	☐

Product variety – represent the number of different products in your product range (not including material or minor model differences) from last year.
Demand stability – represent how often your customer volume orders fluctuate over your planning horizon.

4. Please specify the approx. number of different types of end products delivered last year ____________

5. How would you describe your order's pattern over planning horizon:

Mainly one-off orders	☐
Few orders	☐
Several orders	☐
High number of orders	☐

6. How would you describe your customers' order:

Small	☐
Medium	☐
Large	☐

7. How would you describe your shop floor layout:

Functional layout (Process layout)	☐
Cellular layout (Flow layout)	☐
Continuous line layout	☐
Other (Please specify)	____________

8. From a design point of view, the products that you offer are:

Low customised – products tend to be standard, usually delivered to more than one customer; the supplier takes responsibility for design ☐

Medium customised - some in-service monitoring and customer feedback; ☐

Highly customised - customer seen as a part of the development team. Designers in direct contact with customers;. ☐

9. Which type of manufacturing planning and control (MPC) system does your company apply? Please tick more if you use a mix of systems.

MRP type (Material requirements planning) ☐

JIT(kanban) type (Just-in-time) ☐

Others (Please specify) _______________

10. How would you describe from a planning horizon perspective your capacity plan:

Short term planning (Up to a month) ☐
Medium term planning (1 to 6 months) ☐
Long term planning (6 months – years) ☐
Other (please specify) ____________

11. With reference to your planning horizon and demand pattern, which of the following categories come closest to characterising your dominant approach to capacity planning?

Level capacity plan ☐

Chase capacity plan ☐

Other (Please specify) _________

Level capacity plan: A constant level of activity is maintained and capacity doesn't change much.
Chase capacity plan: Capacity is adjusted to reflect the fluctuations in demand.

12. What percentage of the planned capacity is based on actual customer orders for future delivery? Please write an estimate % within the range selected.

1-20%___ 21-40%___ 41-60%___

61 -80%___ 81-100%___

13. Which is the closest description to your material planning approach:

Rate based - Calculated in terms of output of a product per unit of time ☐

Time phased - The absolute number of products to be made by a given schedule delivery date ☐

Other (Please specify) ______________________

14. How would you describe your main approach to Master Production Scheduling:

Make to order (complex production) ☐

Assemble to order (jobbing production) ☐

Make to stock (batch/mass production) ☐

Or Other (Please describe) __________________

Make to order – Production often starts before a complete product definition and bill of material have been determined. Design takes part as the product is built. The customer expects to wait for a large portion of the entire design and manufacturing lead-time.

Assemble to order – the company has to start production in anticipation of customer orders. Forecasting accuracy is very important to avoid over-stocking. Customer delivery time requirements are often shorter than manufacturing lead time.

Make to stock – the company produces in batches, carrying low finished goods inventories. All *identical* assemblies or sub-assemblies are grouped and produced together in batches.

15. Regarding the batch sizes, they best can be described as:

Equivalent to customer order quantities/call-offs ☐

Small, equivalent to one week of demand ☐

Medium, equivalent to a few weeks of demand ☐

Large, equivalent to a month's demand or more ☐

16. What factors do you take into account when scheduling work? Tick more than one, if applicable.

Machine/people effectiveness ☐
Downtime ☐
Plant maintenance ☐
Rework ☐
Others (Please specify) ____________

17. Do you know the constraint of your plant and the bottlenecks in your operations?

Yes ☐
No ☐

18. Which of the following would best describe your dominant bill of material?

1-2 levels ☐
3-5 levels ☐
More that 5 levels ☐

19. When scheduling your work, what type of approach do you undertake:

Finite scheduling approach ☐
Infinite scheduling approach ☐
Other (Please describe) ________________

Finite scheduling – is an approach which only allocates work to a work centre up to a set limit. This limit is the estimate of capacity for the work centre (based on the times available for loading)

Infinite scheduling – is an approach to loading work which does not limit accepting work, but instead tries to cope with it.

20. Which of the following would best describe your through-put times in manufacturing:

Short through-put times, a week or less ☐
Medium through-put times, a few weeks ☐
Long through-put times, several weeks ☐

21. Is schedule adherence monitored throughout the business?

Very little consideration ☐
Little consideration ☐
Some consideration ☐
Significant consideration ☐
High consideration ☐

22. How often do you monitor your schedule adherence?

Once every hour ☐
At the end of the shift ☐
Once a week ☐
Other (Please specify) ________

23. Which of the following techniques do you use to control your production flow:

Kanban ☐
Dispatch rules ☐
Others (Please specify) ______________

24. Using the answer above (Question 23), please briefly describe your production flow controlling technique.

____
____
____
____

25. Do you compare your manufacturing planning and control practices with other companies?
Yes ☐
No ☐

26. If "Yes" to Question 25, how often do you undertake this comparison study?
Once a month ☐
Every three months ☐
Every six months ☐
Other (Please specify) ________

27. If "Yes" to Question 25, what basis do you use for comparison (tick more if applicable):
Cost ☐
Quality ☐
Reliability ☐
Speed ☐
Others (Please specify) __________

28. If "Yes" to Question 25, how would you rate the performance of the following functions in relation to your significant competitors?

	Very poor	Poor	Equal	Good	Very good
Capacity planning	☐	☐	☐	☐	☐
Master production schedule	☐	☐	☐	☐	☐
Production activity control	☐	☐	☐	☐	☐

29. Do you measure your level of customer satisfaction?

Yes ☐
No ☐

30. If "Yes" to Question 29, how often do you measure your level of customer satisfaction?

Once a month ☐
Every three months ☐
Every six months ☐
Other (Please specify) ________

31. If "Yes" to Question 29, what basis do you use for measurement of customer satisfaction? (Tick more than one, if applicable).

Number of complaints ☐
Number of deliveries on-time ☐
Number of defective end products ☐
Other (Please specify) ____________

32. In terms of meeting customer delivery commitments, how you rate your company; please write an estimate % within the range selected.

1-20%____ 21-40%____ 41-60%___

61 -80%_____ 81-100%_____

33. If "Yes" to Question 29, how would your customer rate the satisfaction level with delivery performance:

Very Poor ☐
Poor ☐
Average ☐
Good ☐
Very good ☐

34. Would you be interested in receiving a summary study report on Irish Manufacturing Planning and Control Practices?

Yes ☐

No ☐

If yes, then please provide your contact details:

Name: ______________________

Phone number: ______________________

Email address: ______________________

Appendix B - Scoring System

Part 1. The environment type score

Q3. How could you describe the business environment where your company operates in terms of:

Score	1	2	3	4	5
	Very Low	Low	Medium	High	Very High
Product variety	☐	☐	☐	☐	☐
Demand stability	☐	☐	☐	☐	☐
	Very High	High	Medium	Low	Very Low
Score	1	2	3	4	5

Q5. How would you describe your order's pattern over planning horizon:

Mainly one-off orders	☐	1
Few orders	☐	2
Several orders	☐	3
High number of orders	☐	4

Q6. How would you describe your customers' order:

Small	☐	3
Medium	☐	2
Large	☐	1

Q7. How would you describe your shop floor layout:

Functional layout (Process layout)	☐	3
Cellular layout (Flow layout)	☐	2
Continuous line layout	☐	1
Other (Please specify)_________________		0

Q8. From a design point of view, the products that you offer are:

Low customised	☐	1
Medium customised	☐	2
Highly customised	☐	3

Part 2. The MPC type score

Q9. Which type of manufacturing planning and control (MPC) system does your company apply? Please tick more if you use a mix of systems.

MRP type (Material requirements planning)	☐	4
JIT(kanban) type (Just-in-time)	☐	1
Others (Please specify) ________________		0

Q.11 With reference to your planning horizon and demand pattern, which of the following categories come closest to characterising your dominant approach to capacity planning?

Level capacity plan	☐	4
Chase capacity plan	☐	1
Other (Please specify) __________		0

Q13. Which is the closest description to your material planning approach:

Rate based	☐	1
Time phased	☐	4
Other (Please specify)___		0

Q14. How would you describe your main approach to Master Production Scheduling:

Make to order (complex production)	☐	3
Assemble to order (jobbing production)	☐	2
Make to stock (batch/mass production)	☐	1
Or Other (Please describe) ___________________		0

Q19. When scheduling your work, what type of approach do you undertake:

Finite scheduling approach	☐	4
Infinite scheduling approach	☐	1
Other (Please describe) ________________		0

Q23. Which of the following techniques do you use to control your production flow:

Kanban	☐	1
Dispatch rules	☐	4
Others (Please specify) _		0

Part 3. The use score

Q16. What factors do you take into account when scheduling work? Tick more than one, if applicable.

Machine/people effectiveness	☐	1
Downtime	☐	1
Plant maintenance	☐	1
Rework	☐	1
Others (Please specify) ________		1 if other specified.

Q17. Do you know the constraint of your plant and the bottlenecks in your operations?

Yes	☐	1
No	☐	0

Q21. Is schedule adherence monitored throughout the business?

Very little consideration	☐	1
Little consideration	☐	2
Some consideration	☐	3
Significant consideration	☐	4
High consideration	☐	5

Q22. How often do you monitor your schedule adherence?

Once every hour	☐	4
At the end of the shift	☐	3
Once a week	☐	2
Other (Please specify) __		1

Q25. Do you compare your manufacturing planning and control practices with other companies?

Yes	☐	1
No	☐	0

Q26. If "Yes" to Question 25, how often do you undertake this comparison study?

Once a month	☐	4
Every three months	☐	3
Every six months	☐	2
Other (Please specify)_____		1

Q27. If "Yes" to Question 25, what basis do you use for comparison (tick more if applicable):

Cost	☐	1
Quality	☐	1
Reliability	☐	1
Speed	☐	1
Others (Please specify) _____		1 if other criteria specified.

Q29. Do you measure your level of customer satisfaction?

Yes	☐	1
No	☐	0

Q30. If "Yes" to Question 29, how often do you measure your level of customer satisfaction?

Once a month	☐	4
Every three months	☐	3
Every six months	☐	2
Other (Please specify)___		1

Q31. If "Yes" to Question 29, what basis do you use for measurement of customer satisfaction? (Tick more than one, if applicable).

Number of complaints	☐	1
Number of deliveries on-time	☐	1
Number of defective end products	☐	1
Other (Please specify) __________		1 if other criteria mentioned.

Part 4. The performance score

Q28. If "Yes" to Question 25, how would you rate the performance of the following functions in relation to your significant competitors?

	1 Very poor	2 Poor	3 Equal	4 Good	5 Very good
Capacity planning	☐	☐	☐	☐	☐
Master production schedule	☐	☐	☐	☐	☐
Production activity control	☐	☐	☐	☐	☐

Q32. In terms of meeting customer delivery commitments, how you rate your company; please write an estimate % within the range selected.

1-20%____	1
21-40%___	2
41-60%___	3
61 -80%__	4
81-100%__	5

Q33. If "Yes" to Question 29, how would your customer rate the satisfaction level with delivery performance:

Very Poor	☐	1
Poor	☐	2
Average	☐	3
Good	☐	4
Very good	☐	5

Other Questions

Q1. How many full-time people (or equivalent) are employed in your business?

Less than	5	☐	1
Between	5 - 20	☐	2
Between	21 - 50	☐	3
Between	51 - 250	☐	4
Over 250		☐	5

Q2. During the last business year, what was the approximate firm's turnover?

Less than	€ 1m	☐	1
Between	€1m – €3m	☐	2
Between	€3m – €10m	☐	3
Between	€10m – €50m	☐	4
Over	€50m	☐	5

Q4. Please specify the approx. number of different types of end products delivered last year ______________

The answers for this question were grouped into 3 categories (by using the calculation of the quartiles).

Q10. How would you describe from a planning horizon perspective your capacity plan:

Short term planning (Up to a month)	☐	1
Medium term planning (1 to 6 months)	☐	2
Long term planning (6 months – years)	☐	3
Other (please specify)	______	0

Q12. What percentage of the planned capacity is based on actual customer orders for future delivery? Please write an estimate % within the range selected.

1-20%____ 1 21-40%____ 2 41-60%____ 3

61 -80%____ 4 81-100%____ 5

Q18. Which of the following would best describe your dominant bill of material?

1-2 levels	☐	1
3-5 levels	☐	3
More that 5 levels	☐	5

Q20. Which of the following would best describe your through-put times in manufacturing:

Short through-put times, a week or less	☐	1
Medium through-put times, a few weeks	☐	2
Long through-put times, several weeks	☐	3

Q24. Using the answer above (Question 23), please briefly describe your production flow controlling technique.

____

____

Q34. Would you be interested in receiving a summary study report on Irish Manufacturing Planning and Control Practices?

Yes	☐	1
No	☐	2

If yes, then please provide your contact details:

Name: ____________________

Phone number: ____________________

Appendix C

The construction of the scores for a Company A.

Part 1. The Environment type score

Q3. How could you describe the business environment where your company operates in terms of:

	1 Very Low	2 Low	3 Medium	4 High	5 Very High
Product variety	☐	☐	☐	☒	☐

	5 Very High	4 High	3 Medium	2 Low	1 Very Low
Demand stability	☐	☒	☐	☐	☐

Q5. How would you describe your order's pattern over planning horizon:

Mainly one-off orders	☐	1
Few orders	☐	2
Several orders	☒	3
High number of orders	☐	4

Q6. How would you describe your customers' order:

Small	☒	3
Medium	☐	2
Large	☐	1

Q7. How would you describe your shop floor layout:

Functional layout (Process layout)	☒	3
Cellular layout (Flow layout)	☐	2
Continuous line layout	☐	1
Other (Please specify)______________		0

Q8. From a design point of view, the products that you offer are:

Low customised	☐	1
Medium customised	☒	2
Highly customised	☐	3

The Environment Type Score is: 4+4+3+3+3+2 = 19

Part 2. The MPC type score

Q9. Which type of manufacturing planning and control (MPC) system does your company apply? Please tick more if you use a mix of systems.

MRP type (Material requirements planning)	☒	4
JIT (kanban) type (Just-in-time)	☐	1
Others (Please specify) ________________		0

Q.11 With reference to your planning horizon and demand pattern, which of the following categories come closest to characterising your dominant approach to capacity planning?

Level capacity plan	☒	4
Chase capacity plan	☐	1
Other (Please specify) __________		0

Q13. Which is the closest description to your material planning approach:

Rate based	☐	1
Time phased	☒	4
Other (Please specify)___		0

Q14. How would you describe your main approach to Master Production Scheduling:

Make to order (complex production)	☐	3
Assemble to order (jobbing production)	☒	2
Make to stock (batch/mass production)	☐	1
Or Other (Please describe) ___________________		0

Q19. When scheduling your work, what type of approach do you undertake:

Finite scheduling approach	☐	4
Infinite scheduling approach	☒	1
Other (Please describe) ________________		0

Q23. Which of the following techniques do you use to control your production flow:

Kanban	☐	1
Dispatch rules	☒	4
Others (Please specify) _		0

The MPC Type score is: 4+4+4+2+1+4 = 18

Part 3. The use score

Q16. What factors do you take into account when scheduling work? Tick more than one, if applicable.

Machine/people effectiveness	☒	1
Downtime	☒	1
Plant maintenance	☒	1
Rework	☐	1
Others (Please specify)	________	1 if other specified.

Q17. Do you know the constraint of your plant and the bottlenecks in your operations?

Yes	☒	1
No	☐	0

Q21. Is schedule adherence monitored throughout the business?

Very little consideration	☐	1
Little consideration	☐	2
Some consideration	☒	3
Significant consideration	☐	4
High consideration	☐	5

Q22. How often do you monitor your schedule adherence?

Once every hour	☐	4
At the end of the shift	☐	3
Once a week	☒	2
Other (Please specify)	__	1

Q25. Do you compare your manufacturing planning and control practices with other companies?

Yes	☐	1
No	☒	0

Q26. If "Yes" to Question 25, how often do you undertake this comparison study?

Once a month	☐	4
Every three months	☐	3
Every six months	☐	2
Other (Please specify)	_____	1

Q27. If "Yes" to Question 25, what basis do you use for comparison (tick more if applicable):

Cost	☐	1
Quality	☐	1
Reliability	☐	1
Speed	☐	1
Others (Please specify) ______		1 if other criteria specified.

Q29. Do you measure your level of customer satisfaction?

Yes	☒	1
No	☐	0

Q30. If "Yes" to Question 29, how often do you measure your level of customer satisfaction?

Once a month	☐	4
Every three months	☒	3
Every six months	☐	2
Other (Please specify)___		1

Q31. If "Yes" to Question 29, what basis do you use for measurement of customer satisfaction? (Tick more than one, if applicable).

Number of complaints	☒	1
Number of deliveries on-time	☒	1
Number of defective end products	☐	1
Other (Please specify) ______________		1 if other criteria mentioned.

The Use score is: (1+1+1)+1+3+2+0+0+0+1+3+(1+1) = 15

Part 4. The performance score

Q28. If "Yes" to Question 25, how would you rate the performance of the following functions in relation to your significant competitors?

	1 Very poor	2 Poor	3 Equal	4 Good	5 Very good
Capacity planning	☐	☐	☐	☐	☐
Master production schedule	☐	☐	☐	☐	☐
Production activity control	☐	☐	☐	☐	☐

Q32. In terms of meeting customer delivery commitments, how you rate your company; please write an estimate % within the range selected.

1-20%____	1
21-40%___	2
41-60%___	3
61 -80%_☒	4
81-100%__	5

Q33. If "Yes" to Question 29, how would your customer rate the satisfaction level with delivery performance:

Very Poor	☐	1
Poor	☐	2
Average	☐	3
Good	☒	4
Very good	☐	5

The Performance score is: (0+0+0)+4+4 = 8

Summary of the scores:

The Environment type Score:	19
The MPC Type Score:	18
The Use score:	15
The Performance Score:	8

The degree of match = ¦the Environment type score – The MPCype score¦ = ¦19-18¦= 1

The construction of the scores for a Company B.

Part 1. The Environment type score

Q3. How could you describe the business environment where your company operates in terms of:

	1 Very Low	2 Low	3 Medium	4 High	5 Very High
Product variety	☒	☐	☐	☐	☐

Demand stability	☐	☐	☐	☒	☐
	Very High 5	High 4	Medium 3	Low 2	Very Low 1

Q5. How would you describe your order's pattern over planning horizon:

Mainly one-off orders	☒	1
Few orders	☐	2
Several orders	☐	3
High number of orders	☐	4

Q6. How would you describe your customers' order:

Small	☐	3
Medium	☐	2
Large	☒	1

Q7. How would you describe your shop floor layout:

Functional layout (Process layout)	☐	3
Cellular layout (Flow layout)	☒	2
Continuous line layout	☐	1
Other (Please specify)________________		0

Q8. From a design point of view, the products that you offer are:

Low customised	☒	1
Medium customised	☐	2
Highly customised	☐	3

The Environment Type Score is: 1+2+1+1+2+1 = 8

Part 2. The MPC type score

Q9. Which type of manufacturing planning and control (MPC) system does your company apply? Please tick more if you use a mix of systems.

MRP type (Material requirements planning)	☐	4
JIT (kanban) type (Just-in-time)	☒	1
Others (Please specify) ________________		0

Q.11 With reference to your planning horizon and demand pattern, which of the following categories come closest to characterising your dominant approach to capacity planning?

Level capacity plan	☒	4
Chase capacity plan	☐	1
Other (Please specify) __________		0

Q13. Which is the closest description to your material planning approach:

Rate based	☒	1
Time phased	☐	4
Other (Please specify)___		0

Q14. How would you describe your main approach to Master Production Scheduling:

Make to order (complex production)	☐	3
Assemble to order (jobbing production)	☐	2
Make to stock (batch/mass production)	☒	1
Or Other (Please describe) ___________________		0

Q19. When scheduling your work, what type of approach do you undertake:

Finite scheduling approach	☐	4
Infinite scheduling approach	☒	1
Other (Please describe) ________________		0

Q23. Which of the following techniques do you use to control your production flow:

Kanban	☒	1
Dispatch rules	☐	4
Others (Please specify) _		0

The MPC Type score is: 1+4+1+1+1+1 = 9

Part 3. The use score

Q16. What factors do you take into account when scheduling work? Tick more than one, if applicable.

Machine/people effectiveness	☒	1
Downtime	☐	1
Plant maintenance	☒	1
Rework	☐	1
Others (Please specify)	________	1 if other specified.

Q17. Do you know the constraint of your plant and the bottlenecks in your operations?

Yes	☐	1
No	☒	0

Q21. Is schedule adherence monitored throughout the business?

Very little consideration	☐	1
Little consideration	☐	2
Some consideration	☐	3
Significant consideration	☒	4
High consideration	☐	5

Q22. How often do you monitor your schedule adherence?

Once every hour	☐	4
At the end of the shift	☐	3
Once a week	☒	2
Other (Please specify) __		1

Q25. Do you compare your manufacturing planning and control practices with other companies?

Yes	☒	1
No	☐	0

Q26. If "Yes" to Question 25, how often do you undertake this comparison study?

Once a month	☐	4
Every three months	☒	3
Every six months	☐	2
Other (Please specify)_____		1

Q27. If "Yes" to Question 25, what basis do you use for comparison (tick more if applicable):

Cost	☒	1
Quality	☒	1
Reliability	☒	1
Speed	☐	1
Others (Please specify) _____		1 if other criteria specified.

Q29. Do you measure your level of customer satisfaction?

Yes	☒	1
No	☐	0

Q30. If "Yes" to Question 29, how often do you measure your level of customer satisfaction?

Once a month	☐	4
Every three months	☒	3
Every six months	☐	2
Other (Please specify)____		1

Q31. If "Yes" to Question 29, what basis do you use for measurement of customer satisfaction? (Tick more than one, if applicable).

Number of complaints	☒	1
Number of deliveries on-time	☒	1
Number of defective end products	☐	1
Other (Please specify) ___________		1 if other criteria mentioned.

The Use score is: (1+1)+0+4+2+1+3+(1+1+1)+1+3+(1+1) = 21

Part 4. The performance score

Q28. If "Yes" to Question 25, how would you rate the performance of the following functions in relation to your significant competitors?

	1 Very poor	2 Poor	3 Equal	4 Good	5 Very good
Capacity planning	☐	☐	☐	☐	☒
Master production schedule	☐	☐	☐	☐	☒
Production activity control	☐	☐	☐	☒	☐

Q32. In terms of meeting customer delivery commitments, how you rate your company; please write an estimate % within the range selected.

1-20%____ 1
21-40%___ 2
41-60%___ 3
61 -80%__ 4
81-100%_☒ 5

Q33. If "Yes" to Question 29, how would your customer rate the satisfaction level with delivery performance:

Very Poor ☐ 1
Poor ☐ 2
Average ☐ 3
Good ☐ 4
Very good ☒ 5

The Performance score is: (5+5+4)+5+5 = 24

Summary of the scores:

The Environment type Score: 8
The MPC Type Score: 9
The Use score: 21
The Performance Score: 24

The degree of match = ¦the Environment type score – The MPCype score¦ = ¦8-9¦= 1

(this represents the absolute value).

APPENDIX D

Irish Manufacturing Planning and Control Practices Survey

Dear Sir / Madam,

My name is George Onofrei and I am currently enrolled in a Master's by Research Programme in Business Studies, at Letterkenny Institute of Technology.

I would like to ask for your help in completing the questionnaire attached, which is an assessment tool on Irish manufacturing planning and control practices, part of my final Master's dissertation. All the information that you provide is strictly confidential and only the research supervisors Paul Tracey, Lecturer at LYIT and Rodney McAdam, Professor in Innovation Management at University of Ulster, will have access to it. Your company name will not be mentioned in the research study or summary report and all the data will be analyzed for research purposes only.

- ***Who is conducting the study?*** **Letterkenny Institute of Technology**.
- ***Do I have to participate?*** No, of course not. But **I hope you will**. Your answers will help make my research study valid.
- ***How long will this take?*** It only takes about **10 minutes** to complete.
- ***Is it confidential?*** Your answers will be **strictly confidential**.
- ***OK, what do I do?*** Fill in the questionnaire as quickly and honestly as you can. **Send it back to us in the enclosed self addressed envelope**
- ***Any special requirements?*** Please **tick only one answer**, unless asked for more.
- ***Any benefits?*** You can avail of a **summary study report of Irish Manufacturing Planning and Control Practices.**

I truly appreciate your co-operation and help. Thank you

George Onofrei

APPENDIX E: Interview theme sheet

1. Briefly describe the environment within your company operates, in terms of: variety, demand stability, number of orders, volume and customisation.

2. Which of the dimensions presented below do you employ?

MPC Dimensions		
Aggregate planning - aggregate plans - material planning approach	 Level plan Time-phased	 Chase plan Rate based
Master production schedule - MPS approach - Scheduling approach	 MTO/ATO Finite	 MTS Infinite
Production activity control - Control approach	 Priority, dispatch rules	 Kanban

3. How did you choose each dimension? What factors influenced decision at each level?

4. Can you briefly describe each of the method employed?

5. Can you show me some evidence of these dimensions? (Meetings, agendas, benchmarking studies, performance measures, performance reports, customer satisfaction reports)?

6. How well do you think these methods meet your customer needs? What changes/developments are planned?

7. How is the performance of the MPC assessed within these dimensions?

8. Is each dimension presented above formally recognised as the proper way or carried out as an informal ad-hoc process?

9. What is the most important information consulted while undertaking these activities; how frequently are they consulted and what action is taken?

10. How do you measure your operational performance? How often and what action is taken?

11. What are the top five measures of performance within your company?

12. What factors influences your operational performance?

13. What do you think accounts for good performance?

14. Are there any other major activities within these functional areas which are important and have not been mentioned?