COPING WITH MEDIUM VOLUME - LOW VARIETY MANUFACTURING ENVIRONMENT IN AUTOMOBILE INDUSTRY OF PAKISTAN

DOCTOR OF PHILOSOPHY (PhD) THESIS

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy (PhD) in Mechanical Engineering (specialization in Industrial and Manufacturing Engineering)

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ABSTRACT

Manufacturing companies all around the world are facing unstable environment due to global competition, improvement in manufacturing processing technologies, innovative product development and marvelous customer service. The survival of these companies depends on rapid solutions to obtain effective management, marketing, finance and decision making process. This demands to take right decisions making at the right time. The problem is therefore multi- dimensional i.e. timely related decision making process, agility and utilization of information (resources) to coordinate between various activities like design, manufacturing, marketing, financing, distribution to achieve specific corporate objectives. Manufacturing is the second largest sector of the economy contributing more than 17% of GDP and engaging 11% of employed labor force in Pakistan. Basic manufacturing sector can be classified into process industry and discrete parts manufacturing industry. The growth in discrete parts sector has picked up during the last couple of years and plays a vital role in economic development of country. Unfortunately, not much attention had been paid in discrete parts sector (especially on automobile as this is one of the fastest growing sector) which is considered as a back bone of economy. Due to this reason, discrete parts automobile manufacturing industry in Pakistan is affected with more turbulent, dynamic and jolting business environment. In order to compete in the world market, local manufacturing industry needs to acquire world class performance irrespective of whether they are domestic manufacturers or exporters. To some extent industry has realized this fact and risen to the challenges, but the battle for survival and industrial growth has just begun. Obviously, the success of industry lies in meeting the challenge and effectively cope with existing situation by proposing concrete solutions to move itself from protected domestic market to a world class manufacturing status quickly and efficiently in a systematic and coherent manner. Apparently, one logical solution would be to invite major changes in the national level policies that rationalize tax/ tariff structures on the one hand while increasing the size of the middle class on the other so that a larger demand of products can be created. This approach, however, does not allow a major role for the manufacturers. We have therefore adopted an alternative course of action, which suggests concrete actions (in the form of

manufacturing strategies/framework) on the part of local manufacturers as there is a lot of pressure on Pakistani manufacturers to increase their product quality and reliability particularly due to increasing competition and likely changes in the world trade structure. It is therefore, imperative for the industry to improve its productivity and competitiveness which aid local manufacturers as no significant studies are available for utilization by the manufacturers in Pakistan.

The plan of action in this regard is to develop an understanding of existing scenario of manufacturing industries and assess the direction in which it is heading. A questionnaire was designed in consultation with the practicing managers, discussions with Engineering Development Board (EDB) Pakistan sector development group. The questionnaire containing questions like manufacturing firm's objectives; familiarization/practicing of methods/systems, assessing existing infrastructure and problems encountered. From the responses of questionnaire, the manufacturers rated agility, supply chain and faster product development as the most important strategic objectives, but are still operating business in conventional ways. The quality practices are also at infancy stage as companies are not focusing on continuous improvement philosophies both in products and processes. However, manufacturers are quite aware of the tools/techniques/ methods being practiced in industry. In order to assess level of tools/ techniques practices, we have calculated breadth versus depth approach. The breadth assesses the manufacturer's know-how about tools/techniques/methods and depth spot out what manufacturers are actually practicing. Based on breadth and depth percentages, it was found that breadth (know-how of systems) is moderate, but depth (practicing within shop floor) is very low. This illustrate that manufacturers are aware of strategic objectives, but their practices are far away from their stated goals. Having right objectives may not lead to superior performance, but operating without them would guarantee to lead to competitive disadvantage. The findings of the survey exercise also identified three types of manufacturers by comparing their stated objectives with international standards. The manufactures identified in our benchmarking exercise are termed; 'Protector', 'Offensive' and 'Innovative' corresponding to low cost, high quality with customer focused and value added ones to outperform competition. Most of the companies claimed that they are practicing tools/techniques (as asked in the questionnaire), but it was evident from questionnaire responses that they have achieved a necessary not a significant condition.

An alternate method for analyzing of existing manufacturing environment is plotting industrial data on standard PPMx. It showed that there exists 'medium volume- low variety manufacturing environment in automobile industry' which is uneconomic as major investments are made haphazardly without knowing Product – Process match of their existing infrastructure as advocated by Hayes and Wheelwright (1979a,b). In order to cope with this environment a framework is developed for operationalizing of tools/techniques systematically for each type of manufacturers (Protector, Offensive and Innovative) on PPMx so that manufacturers can be benefited from these tools/techniques. The framework consists of four phases, i.e. competitiveness/objective identification phase, strategy formulation phase, model development and evaluation phase, validation phase. A company may opt for being the lowest cost producer, highest quality/customer focused and product differentiators with improved customer satisfaction level. Each of these competitive advantages forces the organization to adopt a particular manufacturing strategy, which may in turn demand a particular type of manufacturing system, organizational set-up, material handling methods, information processing and manufacturing control systems (characteristics). It starts typically by comparing existing industrial sector analysis (capacity, technology/manufacturing capabilities) and current market environment. The comparison results in identifying competitive drivers and hence setting the objectives accordingly. Based on the objective settings and competitive drivers, manufacturing option strategy is formulated comprising of three types of manufacturers (protector, offensive and innovative) identified as a part of research in our benchmarking/survey exercise. Having selected an objective e.g. either low cost, high quality/flexibility and innovation, strategies are formulated with objective, operationalization and continuum (characteristics). The strategies are termed 'protector' corresponding to low cost, 'offensive' corresponding to quick response to customers and 'innovative' corresponding to product differentiation respectively.

A simulation model is developed using real world data from case companies at tactical level. Experimentation is performed by changing the base values important to see its impact on performance measures. Slopes of the functions are then computed using standard spreadsheet software. The values are prioritized based on decreasing order of sensitivity. Important performance measures related to the three strategies are discussed with the company's management. The model results are finally prioritized which aid manufacturers to focus on most sensitive parameters for business settings at tactical level. It has been found from simulation experimentation that P_{MAX} is the most sensitive parameters for protector, Y_{IMP} and Y_{MIN} for offensive and M_{FLEX} for the innovative manufacturers. Thus minimization of wastes and other non productive times compel manufacturers to think about lean production system; which is termed '*lean and clean*'. The results at offensive stage (local level) confirm that use of flexible processes not only improves agility but also yield related parameters which are rated the most sensitive in prioritization. This is termed as '*perfect first time quality*' i.e. focus is on improving process flexibility to accommodate product variety and improve process yield. The prioritized results in innovative stage advocate of using more flexible processes and improve value of product using value analysis approaches like 'importance versus cost'. This is termed *'value adding by continuous innovation'* i.e. to enhance product importance at same or reduced cost. The combined prioritization (at global level) also showed that yield related parameters are the most sensitive hence reinforcing our belief '*make it right-first time every time*' to become world class manufacturers.

Whole business process activities have also been modeled and analyzed using AHP at strategic level. The necessary information needed in this regard is filled up in 'n x n' matrix in which the judgments are recorded and calculated. It has been found using Analytical Hierarchical Process (AHP) that at strategic level production planning & control, quality assurance and product development are most important activities which affect business settings for each type of manufacturers. It is therefore imperative for manufacturers to keep special emphasis on production planning and control issues at protector, quality assurance at offensive and product development techniques at innovative stage respectively.

It is strongly recommended for Pakistani automobile industry to streamline manufacturing process by reducing/minimizing waste time from systems (P_{MAX}, H_{RATE}), use time compression with more flexible technologies (PV_{FLEX}, M_{FLEX}), incorporate optimized processes in their businesses (V_{FLEX}), use rapid product development solutions, using standard machines/equipments to reduce defects before rework (Y_{MIN}, Y_{IMP} and M_{RATE}), use SMED and flexible fixtures (MH_{TIME}, SU_{TIME}) etc to meet requirements of world market to become competitive. Pakistani discrete parts automobile manufacturing industry should focus on issues of competitiveness both at tactical and strategic level in the near future other wise their future would be in jeopardy.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	Title page	i
	Title page with signatures	ii
	Acknowledgement	iii
	Abstract	v
	Table of Contents	x
	List of Figures	xiv
	List of Tables	xix
	List of Abbreviations/Nomenclature	xx
1	**INTRODUCTION**	
	1.1 Introduction	1
	1.2 Background of Automobile Industry	2
	1.3 Research Theme/Focus	4
	1.4 Research Objectives	7
	1.5 Thesis Organization	7
2	**LITERATURE REVIEW & OVERVIEW OF AUTOMOBILE INDUSTRY**	
	A. LITERATURE REVIEW	
	2.1 Introduction	10
	2.2 Literature Review	10
	2.2.1 Manufacturing Strategy/Product Process Matrix (PPMx)/ World Class Manufacturing	10
	2.2.2 Dimensions of Competitiveness	18
	2.2.2.1 Time Based Competition	19
	2.2.2.2 Flexibility in Manufacturing	19
	2.2.2.2.1 Agile Manufacturing	20
	2.2.2.3 Innovation as a Competitive Strategy	22
	2.3 Conclusions	23
	B. OVERVIEW OF AUTOMOBILE INDUSTRY	
	2.4 Industry Overview	25
	2.4.1 Production Environment	26
	2.4.2 Domestic Markets	27
	2.4.3 Export Markets	27
	2.5 Conclusions	27

TABLE OF CONTENTS CONT'D

3 RESEARCH METHODOLOGY: QUESTIONNAIRE DESIGN AND ANALYSIS

A. QUESTIONNAIRE DESIGN

3.1 Introduction 29
3.2 Research Methodology 29
3.2.1 Objective of Manufacturers 31
3.2.2 Manufacturing Management Practices 32
3.2.3 Major Obstacles 32
3.2.4 Infrastructure 33
3.2.4.1 Inventory 33
3.2.4.2 Quality Practices 34
3.2.4.3 Layout Type 34
3.2.4.4 Setup/Changeover Time 35
3.2.4.5 Research & Development 36
3.2.4.6 Training of Employees 36
3.2.4.7 Number of Employees 37
3.2.4.8 Product Process Choice 37

B. RESEARCH QUESTIONNAIRE ANALYSIS

3.3 Analysis of Findings of Survey 39
3.3.1 Objectives of Manufacturers Vs. International Standards/ Classifications 39
3.3.2 Level of Manufacturing Practices in Industry 41
3.3.3 Analysis Based on Product Process Matrix 44
3.3.4 Manufacturing Strategic Framework 46
3.4 Conclusions 46

4 THEORETICAL CONSIDERATION- MANUFACTURING STRATEGY FRAMEWORK

4.1 Introduction 50
4.2 Theoretical Framework 50
4.2.1 Competitive Identification Phase 52
4.2.2 Strategy Formulation Phase 52
4.2.2.1 Objective 52
4.2.2.2 Strategies 53
4.2.2.2.1 Protector Strategies 54
4.2.2.2.2 Offensive Strategies 54
4.2.2.2.3 Innovative Strategies 63
4.2.2.3 Operationalization of Strategies 63

TABLE OF CONTENTS CONT'D

	4.2.2.3.1 Movements on Product Process Matrix	64
	4.2.2.4 Continuum	66
	4.2.3 Model Development & Evaluation Phase	70
	4.2.3.1 Simulation Model Development	70
	4.2.3.2 Experimentation	70
	4.2.3.4 Validation of the Model	71
	4.2.4 Validation of Results	71
	4.3 Conclusions	71
5	**MODEL DEVELOPMENT AND EVALUATION**	
	5.1 Introduction	74
	5.2 Problem Formulation	74
	5.2.1 Process Flow Description	74
	5.2.2 Data Required	78
	5.2.2.1 Arrival & Service Time Data	78
	5.2.2.2 Costing Data	80
	5.2.2.3 Importance vs. Cost Ratings	81
	5.3 Review of Solution Methodologies	83
	5.3.1 Analytical Methods	83
	5.3.2 Optimization Techniques	84
	5.3.3 Expert Systems	85
	5.3.4 Queuing Theory	86
	5.3.5 Simulation Modeling	86
	5.4 Methodology Adopted	88
	5.5 Choice of Simulation in Development of Strategy	90
	5.6 Specific Objectives of Simulation Models	96
	5.7 Manufacturing Simulation Model	97
	5.7.1 Terminologies Used	97
	5.7.2 Model Structure	98
	5.7.3 Key Accumulators in Entity Flow	100
	5.7.4 Assumptions of the Model	101
	5.7.5 Validation of the Model	101
	5.7.6 Conclusions	102
6	**MODEL BEHAVIOR ANALYSIS (TACTICAL LEVEL)**	
	6.1 Introduction	104
	6.2 Design of Simulation Experiments	104
	6.3 Sensitivity Analysis	107
	6.3.1 Simulation Experimentation	108
	6.4 Summary of Simulation Experiments	156

TABLE OF CONTENTS CONT'D

	6.4.1 Protector Manufacturers Results	162
	6.4.2 Offensive Manufacturers Results	165
	6.4.2.1 Technology Driven Results	167
	6.4.3 Innovative Manufacturers Results	170
	6.4.4 Global Strategies Results	173
	6.5 Conclusions	175
7	**STRATEGIC LEVEL DECISION MAKING**	
	7.1 Introduction	178
	7.2 Strategic Management- An Overview	178
	7.3 Analytical Hierarchal Process (AHP)	180
	7.3.1 AHP Preference Weights & Steps	180
	7.3.2 Methodology	181
	7.3.2.1 Prioritization for Protector Manufacturers	182
	7.3.2.2 Prioritization for Offensive Manufacturers	187
	7.3.2.3 Prioritization for Innovative Manufacturers	188
	7.5 Conclusions	193
8	**RECOMMENDATIONS & FUTURE WORK**	
	8.1 Introduction	196
	8.2 Summary of Research	196
	8.3 Significant Findings and Contributions	198
	8.3.1 General Findings	198
	8.3.2 Company Specific Findings	200
	8.4 Recommendations	200
	8.5 Recommendations for Further Study/Future work	207
	8.6 Concluding Remarks	208
9	**REFERENCES**	209
	APPENDIX A: Research Questionnaire	
	APPENDIX B: Numerical Valued Functions	
	APPENDIX C: List of Publications	

LIST OF FIGURES

FIGURE TITLE	Page No.
Figure1.1 Percentage share of auto sector in manufacturing	3
Figure 1.2 Product Process Matrixes (PPMx)	6
Figure 1.3 Thesis flow chart	9
Figure 2.1 Product Process Matrix (PPMx)	12
Figure 2.2 Expansion in feasible region	13
Figure 2.3 Logical cycle connecting three distinct paradigms	15
Figure 2.4 Dimensions for competitiveness	18
Figure 2.5 Manufacturing System Level and hierarchy of....	20
Figure 3.1 Objectives of Manufacturers	31
Figure 3.2 Manufacturing Management Practices	32
Figure 3.3 Major obstacle faced by manufacturers	33
Figure 3.4 Raw material inventory held	33
Figure 3.5 Finished goods inventory held	34
Figure 3.6 Average percent defect rate before rework	34
Figure 3.7 Layout types in use	35
Figure 3.8 Setup/changeover time	35
Figure 3.9 R&D activities	36
Figure 3.10 Training expenditure	36
Figure 3.11 Number of employees	37
Figure 3.12 Product Process percentages	37
Figure 3.13 Industrial cluster	38
Figure 3.14 Percentage of overall usage of systems	42
Figure 3.15 Route of three strategies	45
Figure 4.1 Manufacturing Strategy framework	51
Figure 4.2 Cone type Strategy trade-off diagram	53
Figure 4.3 Technology Driven Framework	55
Figure 4.4 Flow chart of TD methodology	60
Figure 4.5 Movement on PPMx	65
Figure 4.6 Manufacturing Strategy trade-off paths	66
Figure 5.1 Process Flow diagram- case company production	76
Figure 5.2 General Layout	77
Figure 5.3 Case company historical data	79
Figure 5.4 Importance versus cost relationship	82
Figure 5.5 Ways to study a system	84
Figure 5.6 Developments of Modules	91
Display 1: Simulation Model	92
Display 2: Data and Modeling process	93
Display 3: Output model	94
Display 4: Output Graphical Interface	95
Figure 5.7 Schematic Diagram - Simulation model logic	100
Figure 6.1 Effect of max. Processing time (bal. line) on total cost	108
Figure 6.2 Effect of max. Processing time (bal. line) on avg. waiting time	108

Figure 6.3 Effect of max. Processing time (bal. line) on non value added cost 109
Figure 6.4 Effect of max. Processing time (bal. line) on cost per part 109
Figure 6.5 Effect of max. Processing time (bal. line) on work in process 109
Figure 6.6 Effect of max. Processing time (bal. line) on flow time 110
Figure 6.7 Effect of max. Processing time (bal. line) on rejection cost 110
Figure 6.8 Effect of max. Processing time (bal. line) on 0.5BV utilization 110
Figure 6.9 Effect of max. Processing time (bal. line) on 0.25BV utilization 111
Figure 6.10 Effect of max. Processing time on total cost 111
Figure 6.11 Effect of max. Processing time avg. waiting time 111
Figure 6.12 Effect of max. Processing time on non-value added cost 112
Figure 6.13 Effect of max. Processing time on cost per part 112
Figure 6.14 Effect of max. Processing time on work in process 112
Figure 6.15 Effect of max. Processing time on flow time 113
Figure 6.16 Effect of max. Processing time on utilization 113
Figure 6.17 Effect of max. Processing time on rejection cost 113
Figure 6.18 Effect of wage rate on cost per part 114
Figure 6.19 Effect of wage rate on total cost 114
Figure 6.20 Effect of wage rate on rejection cost 115
Figure 6.21 Effect of wage rate on value added cost 115
Figure 6.22 Effect of wage rate on cost per part 115
Figure 6.23 Effect of wage rate on total cost 116
Figure 6.24 Effect of wage rate on value added cost 116
Figure 6.25 Effect of wage rate on rejection cost 116
Figure 6.26 Effect of changing machine rate on total cost 117
Figure 6.27 Effect of changing machine rate on reworking cost 117
Figure 6.28 Effect of changing machine rate on value added cost 118
Figure 6.29 Effect of changing machine rate on cost per part 118
Figure 6.30 Effect of changing machine rate on rejection cost 118
Figure 6.31 Effect of machine rate on total cost 119
Figure 6.32 Effect of machine rate on reworking cost 119
Figure 6.33 Effect of machine rate on rejection cost 119
Figure 6.34 Effect of machine rate on value added cost 120
Figure 6.35 Effect of machine rate on cost per part 120
Figure 6.36 Effect of Material handling time on cost per part 121
Figure 6.37 Effect of Material handling time on flow time 121
Figure 6.38 Effect of Material handling time on non-value added cost 121
Figure 6.39 Effect of Material handling time on flow time 122
Figure 6.40 Effect of Material handling time on non value added cost 122
Figure 6.41 Effect of Material handling time on utilization 122
Figure 6.42 Effect of min quantity to be reworked on cost per part 123
Figure 6.43 Effect of min quantity to be reworked on total cost 123
Figure 6.44 Effect of min quantity to be reworked on rejection cost 123
Figure 6.45 Effect of min quantity to be reworked on non-value added cost 124
Figure 6.46 Effect of changing quality level on cumulative yield 124
Figure 6.47 Effect of min quantity to be reworked on reworking cost 124
Figure 6.48 Effect of min quantity to be reworked on WIP 125

Figure 6.49 Effect of min quantity to be reworked on non-value added cost 125
Figure 6.50 Effect of min quantity to be reworked on cost per part 125
Figure 6.51 Effect of min quantity to be reworked on total cost 126
Figure 6.52 Effect of min quantity to be reworked on rejection cost 126
Figure 6.53 Effect of min quantity to be reworked on cumulative yield 126
Figure 6.54 Effect of min quantity to be reworked on YBRW 127
Figure 6.55 Effect of min quantity to be reworked on reworking cost 127
Figure 6.56 Effect of min quantity to be reworked on WIP 127
Figure 6.57 Effect of min quantity to be reworked on utilization 128
Figure 6.58 Effect of yield improvement on cost per part 128
Figure 6.59 Effect of yield improvement on rejection cost 129
Figure 6.60 Effect of yield improvement on total cost 129
Figure 6.61 Effect of yield improvement on non-value added cost 129
Figure 6.62 Effect of yield improvement on cost per part 130
Figure 6.63 Effect of yield improvement on total cost 130
Figure 6.64 Effect of yield improvement on YBRW 130
Figure 6.65 Effect of yield improvement on rejection cost 131
Figure 6.66 Effect of yield improvement on reworking cost 131
Figure 6.67 Effect of yield improvement on value added cost 131
Figure 6.68 Effect of yield improvement on WIP 132
Figure 6.69 Effect of yield improvement on non-value added cost 132
Figure 6.70 Effect of yield improvement on cumulative yield 132
Figure 6.71 Effect of setup time on cost per part 133
Figure 6.72 Effect of changing setup time on flow time 133
Figure 6.73 Effect of changing setup time on WIP 133
Figure 6.74 Effect of changing setup time on non-value added cost 134
Figure 6.75 Effect of changing setup time on flow time 134
Figure 6.76 Effect of changing setup time on cost per part 134
Figure 6.77 Effect of changing setup time on total cost 135
Figure 6.78 Effect of changing setup time on WIP 135
Figure 6.79 Effect of changing setup time on YBRW 135
Figure 6.80 Effect of changing setup time on value added cost 136
Figure 6.81 Effect of changing setup time on non-value added cost 136
Figure 6.82 Effect of changing setup time on flow time 136
Figure 6.83 Effect of changing reworking times on cost per part 137
Figure 6.84 Effect of changing reworking times on total cost 137
Figure 6.85 Effect of changing reworking times on reworking cost 137
Figure 6.86 Effect of changing reworking times on non value added cost 138
Figure 6.87 Effect of reworking times on cost per part 138
Figure 6.88 Effect of reworking times on WIP 138
Figure 6.89 Effect of reworking times on reworking cost 139
Figure 6.90 Effect of reworking times on non-value added cost 139
Figure 6.91 Effect of reworking times on flow time 139
Figure 6.92 Effect of reworking times on cumulative yield 140
Figure 6.93 Effect of changing fast reworking time on rejection cost 140
Figure 6.94 Effect of fast reworking time on cost per part 141

Figure 6.95 Effect of fast reworking time on waiting time 141
Figure 6.96 Effect of fast reworking time on WIP 141
Figure 6.97 Effect of fast reworking time on rejection cost 142
Figure 6.98 Effect of fast reworking time on non-value added cost 142
Figure 6.99 Effect of fast reworking time on flow time 142
Figure 6.100 Effect of volume flexibility on cost per part 143
Figure 6.101 Effect of volume flexibility on total cost 143
Figure 6.102 Effect of volume flexibility on WIP 143
Figure 6.103 Effect of volume flexibility on rejection cost 144
Figure 6.104 Effect of volume flexibility on waiting time 144
Figure 6.105 Effect of volume flexibility on flow time 144
Figure 6.106 Effect of volume flexibility on non-value added cost 145
Figure 6.107 Effect of volume flexibility on cost per part 145
Figure 6.108 Effect of volume flexibility on total cost 145
Figure 6.109 Effect of volume flexibility on waiting time 146
Figure 6.110 Effect of volume flexibility on WIP 146
Figure 6.111 Effect of volume flexibility on rejection cost 146
Figure 6.112 Effect of volume flexibility on non-value added cost 147
Figure 6.113 Effect of volume flexibility on flow time 147
Figure 6.114 Effect of product variety flexibility on cost per part 147
Figure 6.115 Effect of product variety flexibility on total cost 148
Figure 6.116 Effect of product variety flexibility on waiting time 148
Figure 6.117 Effect of product variety flexibility on flow time 148
Figure 6.118 Effect of product variety flexibility on cost per part 149
Figure 6.119 Effect of product variety flexibility on av. waiting time 149
Figure 6.120 Effect of product variety flexibility on WIP 149
Figure 6.121 Effect of product variety flexibility on rejection cost 150
Figure 6.122 Effect of product variety flexibility on YBRW 150
Figure 6.123 Effect of product variety flexibility on reworking cost 150
Figure 6.124 Effect of product variety flexibility on non-value added cost 151
Figure 6.125 Effect of product variety flexibility on flow time 151
Figure 6.126 Effect of machine flexibility on rejection cost 152
Figure 6.127 Effect of machine flexibility on reworking cost 152
Figure 6.128 Effect of machine flexibility on YBRW 152
Figure 6.129 Effect of machine flexibility on cost per part 153
Figure 6.130 Effect of machine flexibility on total cost 153
Figure 6.131 Effect of machine flexibility on waiting time 153
Figure 6.132 Effect of machine flexibility on YBRW 154
Figure 6.133 Effect of machine flexibility on rejection cost 154
Figure 6.134 Effect of machine flexibility on reworking cost 154
Figure 6.135 Effect of machine flexibility on non-value added cost 155
Figure 6.136 Effect of machine flexibility on cumulative yield 155
Figure 6.137 Effect of machine flexibility on flow time 155
Figure 6.138 Parameters on PPMx matrix 173
Figure 7.1 Protector Manufacturers results w.r.t goal 185
Figure 7.2 Protector Manufacturers priorities in decreasing order of importance 185

Figure 7.3 Offensive Manufacturers results w.r.t goal 187
Figure 7.4 Offensive Manufacturers priorities in decreasing order of importance 188
Figure 7.5 Innovative Manufacturers results w.r.t goal 189
Figure 7.6 Innovative Manufacturers priorities in decreasing order of importance 191
Figure 7.7 VA applied in innovative stage 192
Figure 7.8 Hierarchical levels 194

LIST OF TABLES

TABLES TITLE	Page No.
Table1.1. Share of Auto sector in manufacturing	3
Table 1.2 Production Volumes versus Variety	6
Table 2.1 Total Production of Vehicles	26
Table 3.1 Main sections of questionnaire	30
Table 3.2 Region wise responses (%)	31
Table 3.3 Relationship of three strategies with practice	43
Table 4.1 Machine and Labor costs	61
Table 4.2 Range of Sensitivity Analysis	62
Table 4.3 Characteristics of Strategies	69
Table 5.1 Arrival data over time	78
Table 5.2 Service time (sample)	80
Table 5.3 Costing data	81
Table 5.4 Cost versus Importance over whole Business Process	82
Table 5.5 Input parameters and output variables	97
Table 6.1 Summary of Results	156
Table 6.2 Protector partial sensitivity results	163
Table 6.3 Protector completed sensitivity results	164
Table 6.4 Offensive partial sensitivity results	165
Table 6.5 Offensive completed sensitivity results	166
Table 6.6 Results & Conclusions	168
Table 6.7 Completed Sensitivity Results	169
Table 6.8 Innovative partial sensitivity results	170
Table 6.9 Innovative completed sensitivity results	171
Table 6.10 Prioritization at each manufacturers	172
Table 6.11 Global strategies results	174
Table 7.1 Scale of preference between two elements	180
Table 7.2 Protector Manufacturer's matrix	184
Table 7.3 Offensive Manufacturer's matrix	186
Table 7.4 Innovative Manufacturer's matrix	190
Table 7.5 Summary of strategic level results	193

LIST OF ABBREVIATIONS/NOMENCLATURE

ABBREVIATIONS		MEANINGS
PPMx	:	Product Process Matrix
WCM	:	World Class Manufacturing
RSM	:	Response Surface Methodology
JIT	:	Just In Time
MTS	:	Make To Stock
MTO	:	Make To Order
VA	:	Value Added/Value Analysis
NVA	:	Non- Value Added
CI	:	Continuous Improvement/Consistency Index
CR	:	Consistency Ratio
AMT	:	Advanced Manufacturing Technology
AM	:	Agile Manufacturing
ABC	:	Activity Based Costing
OEM	:	Original Equipment Manufacturers
ISO	:	International Standard Organization
EDB	:	Engineering Development Board
SMEDA	:	Small and Medium Enterprises Development Authority
NPO	:	National Productivity Organization
LCV	:	Light Commercial Vehicles
SME	:	Small and Medium Enterprises
WTO	:	World Trade Organization
PAAPAM	:	Pakistan Association of Automotive Parts & Accessories Manufacturers
TQM	:	Total Quality Management (ISO-9000, Charts, analysis etc)
AMS	:	Advanced Manufacturing System
BEA	:	Break Even Analysis
GT	:	Group Technology
OPT	:	Optimized Production Technology
SMED	:	Single Minute Exchange of Dies
R&D	:	Research and Development
CAD/CAM	:	Computer Aided Design/Computer Aided Manufacturing
PCA	:	Process Capability Analysis
TDS	:	Technology Driven Strategy
NC	:	Numerical Control
CNC	:	Computer Numerical Control
RSM	:	Response Surface Methodology
NPD	:	New Product Development
BOTM	:	Balanced Operation Time Module
WTMM	:	Waste Time Minimization Module
WIP	:	Work In Process
AHP	:	Analytical Hierarchal Process
MKT	:	Marketing
PPC	:	Production Planning & Control
FIN	:	Finance

SFC	:	Shop Floor Control
QA	:	Quality Assurance
CP	:	Capacity Planning
PD	:	Product Development
SCM	:	Supply Chain Management
IM	:	Inventory Management
PKG	:	Packaging
HRM	:	Human Resource Management
MMT	:	Maintenance Management
S&D	:	Sales and Dispatch
EC	:	Expert Choice™

NOMENCLATURE

H_{RATE}	:	Hourly Labor /wage rate
M_{RATE}	:	Hourly Machining / processing rate
P_{MAX}	:	Maximum processing / machining time
MH_{TIME}	:	Maximum material handling times (workstations)
Y_{MIN}	:	Minimum or starting yield
Y_{IMP}	:	Improvement in yield
SU_{TIME}	:	Maximum setup time
RW_{TIME}	:	Reworking time
FR_{TIME}	:	Fast reworking time
M_{FLEX}	:	Machine replacement flexibility
PV_{FLEX}	:	Parts mix (variety) flexibility
V_{FLEX}	:	Volume flexibility
UT_{SYS}	:	System Utilization
C_{PART}	:	Cost per part / unit
TM_{COST}	:	Total manufacturing cost
WIP	:	Work In Process
WT_{AVG}	:	Average waiting time
YBRW	:	Yield before reworking
C_{REJ}	:	Rejection cost
C_{REWORK}	:	Reworking cost
C_{VAD}	:	Value added cost
C_{NVAD}	:	Non-value added cost
Y_{CUM}	:	Cumulative yield
FT	:	Flow Times
P	:	Total number of parts produced
N	:	Number of entities passed through system
Σ WQ	:	Sum of queues observed so far
WQ^*	:	Maximum time in queue
Σ TS	:	Sum of total time in the system
TS^*	:	Maximum total time in system observed so far
Q (t)	:	Queue length
B (t)	:	System utilization

CHAPTER 1
INTRODUCTION

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Manufacturing companies all around the world are facing unstable and dynamic environment due to global competition, improvement in manufacturing processing technologies, innovative product development and marvelous customer service. The survival of these companies depend on rapid and innovative products, time compression technologies and better ways to obtain effective management, marketing, finance and decision making process. This demands to take right decisions making at right time. The problem is therefore multi-dimensional i.e. timely related decision process, agility and utilization of information (resources) to coordinate between activities like design, manufacturing, marketing, financing, distribution to achieve specific corporate objectives.

The manufacturing industries in the developing countries are also affected with more turbulent, dynamic and jolting business environment. Though many internal and external factors like increase in population growth rate, political instability and foreign debts have prevented many developing countries from achieving sufficient socio-economic improvements, yet countries like Pakistan made economic growth its prime agenda. Many initiatives had already been taken for restructuring economy by increasing privatization and enhancing competition, but industry is still far from global manufacturing practices and standards. This is because; Pakistani companies have paid very little attention to their shop-floors (SWOT analysis, EDB 06). This results in poor product quality, no awareness of competition and non-integration of various businesses such as marketing, sales, production, finance, dispatch etc. On the other hand, world class manufacturers operating in global markets tend to have world class performance. These world class companies are characterized by three main strategies; customer focus, innovation and quality/agility (the ability to respond efficiently, quickly and effectively). Other supporting competencies are employee's empowerment, supply chain management, product development, technology and sustainable environmental responsibility (Kinni, 1996). To become competitive in the marketplace, there is a need to make an understanding of existing industrial environment and then proposing workable solutions (in the form of strategies) which would aid manufacturers in their long run to become competitive. In order to understand the current scenario, the subsequent section briefly describes background of automotive industry, research theme/focus (normative description at this stage), and objectives of research followed by thesis organization.

1.2 BACKGROUND OF AUTO INDUSTRY

A regular car industry was started in 1983, when Suzuki commenced production eyeing the small and LCV (Light Commercial Vehicle) car segment of 800-1000cc range. Then there was a long gap until the early 90's when Indus motor company was established to manufacture Toyota vehicles in Pakistan. Honda and Ghandara Nissan entered in the market with civic and sunny models respectively. Some years later, Dewan motors established joint-venture with Korean company to run a plant to manufacture Hyundai and Kia vehicles in Pakistan. Since then the market has changed all together. The automobile sector has posted a phenomenal growth during 2003-04 and 2004-05 (SMEDA, 2006) in the wake of sharp increase in the demand of automobiles. It was noted that due to increasing size of middle class both OEMs and vendors made heavy investments during the last three years, which helped them to enhance their production capacities besides achieving progressively higher indigenization levels.

The local discrete parts manufacturers are facing competition both from imports and multinationals in the domestic markets. The new competition faced by manufacturers is rapid delivery, differentiated products that delight customers in short span of time and at reduced cost. There are more than 300 (of varying size) units in the auto parts manufacturing industry, some of them are registered vendors to assemblers/OEMs. They are bound to supply only to OEMs as per their agreements, but due to low demands by the assemblers, these manufacturers are forced to sell their products in the replacement market in one or the other way. Though the growth in this sector has picked during last couple of years yet the industry is faced with various challenges of competitiveness which are due to productivity on account of outdated infrastructure, low technology levels, non-serious attitude towards human resource development, absence of R&D and innovation, ancient drawing/designing and styling capability, absence of standards, certifications and accreditation etc. The job multiplier in auto industry is quite high; the ratio of employment in the OEM to vendors is nearly 1: 10 in Pakistan which has created 192,000 direct jobs. Likewise the ratio of direct employment in this sector to jobs created outside the vending and OEM sector would safely be 1: 12. Auto industry in Pakistan because of its gross sales turnover of Rs 214 billion during 2005-06 contributed to GDP by 2.8% and its contribution to indirect taxes i.e. Rs 63 billion was over 9% of country's indirect taxes.

Auto industry share in the total manufacturing sector remains at 16% by the close of 2005-06 which was only 6.7% during 2001-02 as given in table1.1 and presented in figure 1.1. Recognized auto part suppliers are placed mainly around Lahore (Punjab) and Karachi

(Sindh). Most of the vendors are new business entities (entered in the market haphazardly after analyzing extensive growth in auto sector) that have limited financial capacity, low manufacturing base, know how/skills, poor technology levels, and lack the vision (strategies which help them to become competitive in the marketplace) to transform the existing levels despite huge potential in the sector (EDB, 2006).

Table1.1. Share of Auto sector in manufacturing

Years	*Share of sectors in GDP (%)*			*GDP growth rate (%)*
	Manufacturing	Auto	Auto in manufacturing	
2000-01	15.9	--	--	1.8
2001-02	16.1	1.09	6.77	3.1
2002-03	16.4	1.25	7.62	5.1
2003-04	17.6	2.7	15.34	6.4
2004-05	18.3	2.8	15.30	8.4
2005-06	18.2	2.8	15.93	6.6

Source: (EDB, 2006)

Despite rapid growth, Pakistan auto industry contribution in global terms is still very low i.e. 0.3% of world production of 66.5 million passenger and commercial vehicles. World installed capacity for passenger and commercial vehicles is 85 million units. Similarly export of auto products was only US$ 35 million which is negligible in the world trade. The annual world trade of auto products is over US $ 800 billion (components constitute about 40% of World Trade).

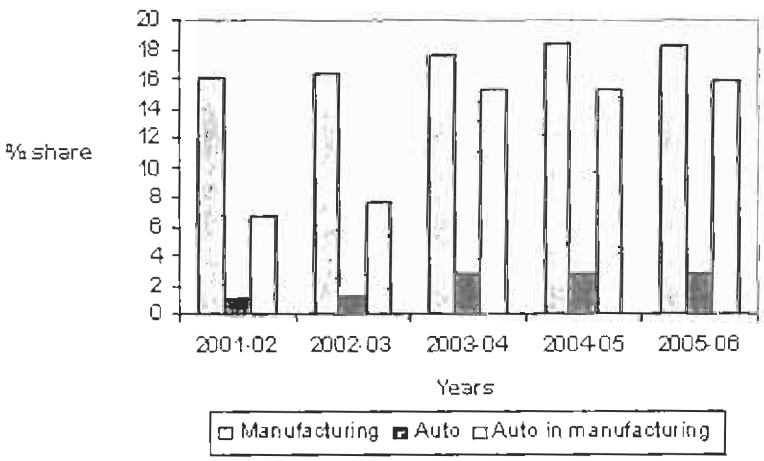


Figure1.1 Percentage share of auto sector in manufacturing

1.3 RESEARCH THEME/FOCUS

In order to compete in the world class market, local manufacturing industry needs to acquire world class performance irrespective of whether they are domestic manufacturers or exporters. To some extent industry has realized this fact and risen to the challenges, but the battle for survival and industrial growth has just begun. Obviously, the success of industry lies in meeting the challenge and effectively cope with existing situation by proposing concrete solutions to move itself from protected domestic market to a world class manufacturing status quickly and efficiently. Apparently, one logical solution would be to invite changes in the national level policies that rationalize tax/ tariff structures on the one hand while increasing the size of the middle class on the other so that a larger demand of products can be created. This approach, however, does not allow a major role for the manufacturers. We have therefore adopted an alternative course of action, which suggests concrete actions (in the form of manufacturing strategies) on the part of local manufacturers as there is a lot of pressure on Pakistani manufacturers to increase their product quality and reliability particularly due to increasing competition and likely changes in the world trade structure. It is therefore, imperative for the industry to improve its productivity and competitiveness which aid manufacturers as no such studies are available for utilization by the manufacturers in Pakistan. Therefore, there is a need to address this issue which would help local manufacturers to become competitive in the marketplace.

To become competitive and coping with existing manufacturing environment, there is a need to develop an understanding of existing scenario of manufacturing industries and assess the direction in which it is heading. In this regard, a questionnaire was designed in consultation with the practicing managers, discussions with Engineering Development Board (EDB). The questionnaire containing questions like manufacturing firm's objectives: familiarization/practicing of methods/systems, assessing existing infrastructure *By taking a case of automobile part vendors (this being a growing sector), we suggest a framework consisting of strategies using standard approaches/techniques. The framework is developed which can cope with strategic objective of low cost, high quality/customer focused and innovative in a systematic and orderly manner.* The framework consists of four phases, (a brief description is presented of research work carried out has been presented here and elaborated in chapter 4):

1. Competitiveness/objective identification phase
2. Strategy formulation phase
3. Model development and evaluation phase

4. Validation phase

A company may opt for being the lowest cost producer, highest quality/customer focused and product differentiators with improved customer satisfaction level. Each of these competitive advantages forces the organization to adopt a particular manufacturing strategy, which may in turn demand a particular type of manufacturing system, organizational set-up, material handling methods, information processing and manufacturing control systems (characteristics). It starts typically by comparing existing industrial sector analysis (capacity, technology/manufacturing capabilities) and current market environment. The comparison results in identifying competitive drivers and hence setting the objectives accordingly. Based on the objective settings and competitive drivers, manufacturing option strategy is formulated comprising of three types of manufacturers (protector, offensive and innovative) identified as a part of research in our benchmarking/survey exercise. Having selected an objective e.g. either low cost, high quality/flexibility and innovation, strategies are formulated with objective, operationalization and continuum (characteristics). The strategies are termed 'protector' corresponding to low cost, 'offensive' corresponding to quick response to customers and 'innovative' corresponding to product differentiation respectively.

A simulation model is developed using real world data from case companies. Experimentation is performed by changing the base values to see its impact on performance measures. Slopes of the functions are then computed using standard spreadsheet software. The values are prioritized based on decreasing order of sensitivity. Important performance measures related to the three strategies are discussed with the company's management. The model results are finally prioritized which help manufacturers to become competitive in the marketplace.

An alternative way of analyzing the existing manufacturing environment is plotting data of production volume (total production) versus product variety (number of models per year) on standard Product Process Matrix (the discussion of PPMx is presented in literature review section 2.2.1). This assist to identify present status of manufacturing industries which are providing manufactured parts to OEMs (as exports are negligible, and rest of parts sold in the replacement market) and guide manufacturers to shift existing manufacturing environment volume zone to a more viable place on PPMx. The application of Product Process Matrix (PPMx) for analyzing current practices of industries using production volume versus product variety (Product vs. Process in operation management terms) data has been strongly supported by many researchers for the last three decades like Hayes and Wheelwright, 1984; Skinner 1985; Akhtar et al 1993; Miller and Roth 1994; Spencer and

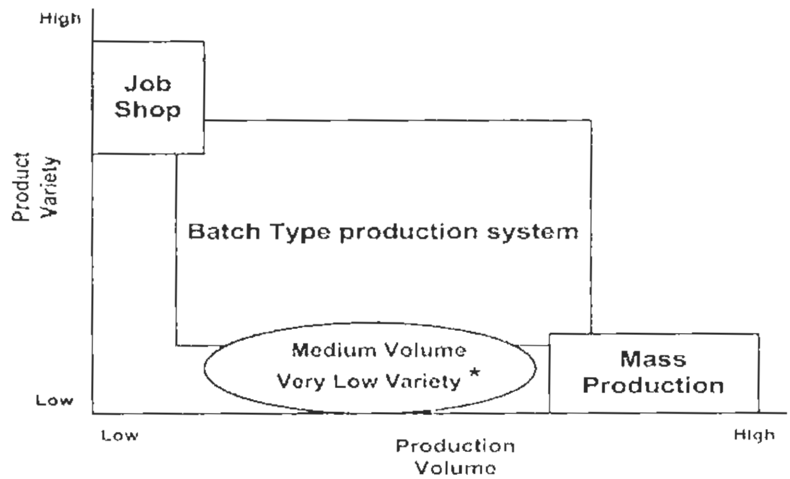
Cox. 1995; Safizadeh et al 1996; Hill 1993, 2000; Ariss S, 2002; Ahmad and Schroeder. 2002; Frank E Rowbotham 2004; Taps et al 2005; and Johansson P et al 2006. The PPMx assist us in analyzing current scenario where auto industry is located. Manufacturing strategies are developed using standard manufacturing management tools/techniques in an orderly and systematic manner in order to reach at most viable place on PPMx. The product volume versus product variety data is given in table 1.2 and is shown on PPMx matrix in figure 1.2 marked (*).

Table 1.2 Production Volumes versus Variety

	In Year 2005-2006	
Type	**Production Volume**	**Product Styles (Variety)**
Cars	160,642	30
Trucks	4518	8
Buses	825	5
LCVs	32,053	13
Tractors	48,887	10

(Source: Statistical Bureau of Pakistan, 2006)

It is evident from the figure 1.2, that there exists medium volume- very low variety manufacturing environment. This is obviously uneconomic as major investments in the sector are made haphazardly without knowing their shop floor position to become world class manufacturer (i.e. mass producer/high quality producers etc).



(* marked sign showing Medium Volume- Low Variety environment. Pakistani Auto Industry data, EDB, 2006)

Figure 1.2 Product Process Matrix (PPMx)

In order to face challenges and cope with existing environment, there is a need to understand competitiveness and world class manufacturing. This research is focused to develop a framework (consisting of strategies) which assists discrete parts manufacturers to become competitive in local (providing parts to OEMs/replacement market) and world marketplace (improving export). Therefore, the research work aims at developing a framework for *"Coping with medium volume- low variety manufacturing environment in automobile industry of Pakistan"*.

1.4 RESEARCH OBJECTIVES

The objectives of this research are:

1. To explore the **stated objectives of manufacturers**, level of manufacturing management practice, assess industry infrastructure and location/position of industry on standard Product Process Matrix (PPMx) as advocated by (Hayes and Wheelwright 1984).
2. Clustering of manufacturers based on stated objectives versus international standards and identifying manufacturer's type.
3. **Assessing manufacturing management practices** of existing environment and **identify level of such practices** in industry.
4. **Developing a generic framework** consisting of manufacturing strategies to cope with low cost, more agile with high quality and innovative type manufacturers to compete in the local as well as in world marketplace.
5. **Devising a path on PPMx**, for operationalization of strategies by employing traditional/conventional approaches and characterizes each archetype.
6. Development of **analytical tools** using manufacturing simulation for operationalization/**testing of** strategies and identifying/prioritize key performance indicators at **tactical and strategic** level in discrete parts industry.

1.5 THESIS ORGANIZATION

The thesis is organized as follows: Literature related to manufacturing strategies, competitiveness, Product Process Matrix (PPMx), flexibility/agility and innovation is reviewed in chapter 2. Chapter 3 is about research methodology and questionnaire analysis. In chapter 3 results of survey/benchmarking exercise, analysis and findings is presented which identified three types of manufacturers, assess level of manufacturing management practices/infrastructure and location of industry on PPMx matrix. A framework is proposed consisting of manufacturing strategies for each type of manufacturers i.e. 'Protector', 'Offensive' and 'Innovative' described and is described in chapter 4. Chapter 5 is about model development/evaluation in which data collection is described/analyzed, specific modeling tool is selected and justification for exploiting simulation is elaborated. The behavior of simulation model and experimentation performed is analyzed in chapter 6 in which sensitivity analysis is carried out to observe impact of changing input variables on output performance measures. The results are prioritized based on decreasing level of sensitivity. Chapter 7 is about evaluation of important business activities at strategic level. Both generic and company specific findings are presented in chapter 8 and final recommendations based on conclusions are then drawn. The organization of thesis is presented in the form of flow chart as shown in figure 1.3.

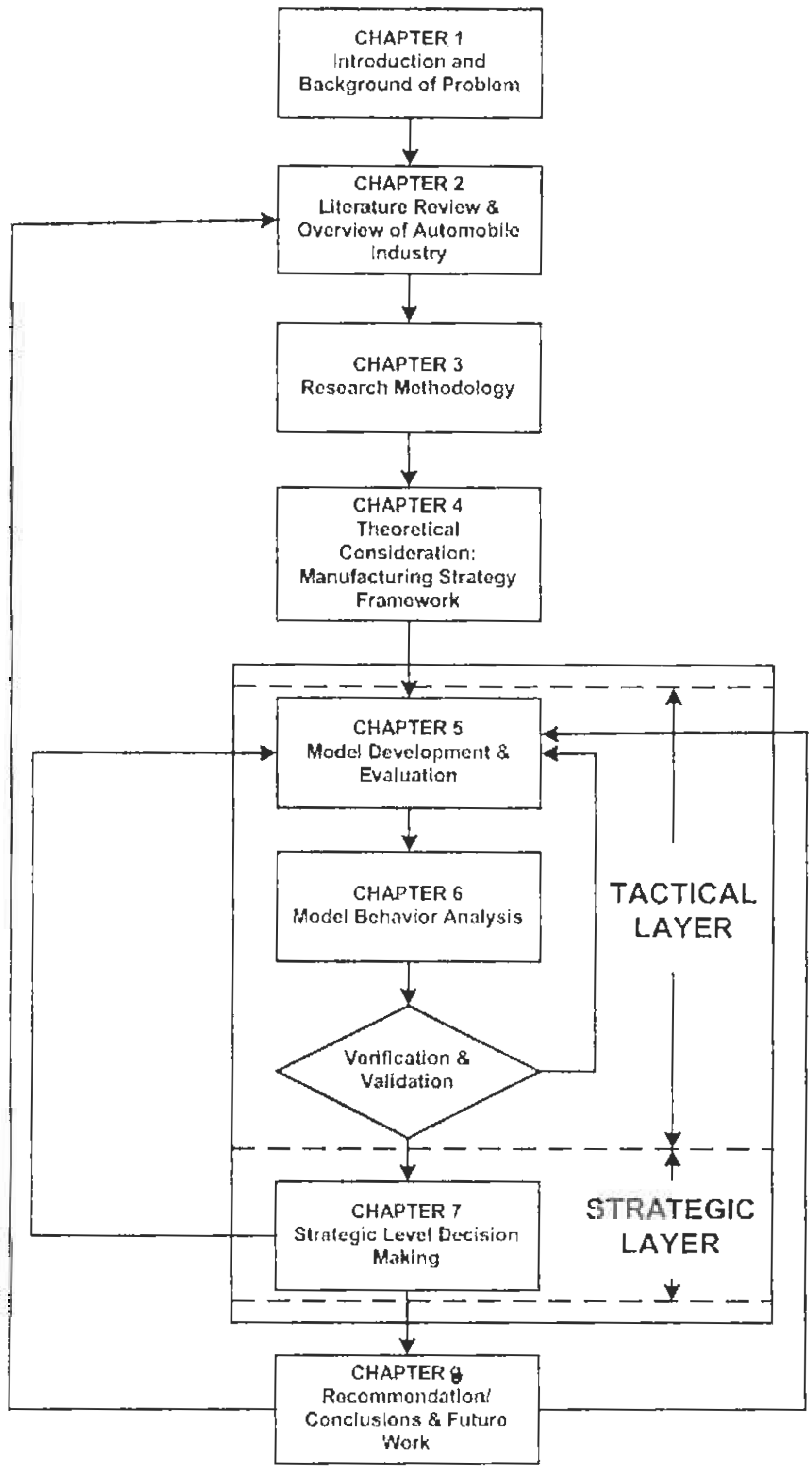


Figure 1.3 THESIS FLOW CHART

CHAPTER 2
LITERATURE REVIEW AND OVERVIEW OF AUTOMOBILE INDUSTRY

CHAPTER 2
A. LITERATURE REVIEW

2.1 INTRODUCTION

This has been recognized world over that manufacturing can be a formidable competitive weapon if equipped and managed properly. Manufacturing industries recently has prompted renewed interest due to globalization, flexible processing technologies, marvelous customer services and a lot of innovation potential in products/processes. The development of coherent manufacturing strategy is inevitable for sustainable growth to face new manufacturing challenges and to cope with dynamic environment. In new manufacturing environment, time is considered as one of the primary motives for operating business these days. This does not mean that other motives like cost, quality and service can be ignored. In fact, they are considered as a pre-requisite to sustain competition. Other than time, cost, quality and services; there is an increasing trend to explore and implement issues like flexibility, agility, lean principles, innovation; activity based costing, value analysis etc to achieve competitive edge over competitors. This chapter is about literature review in which core competitive issues are reviewed. The identification of gaps in the literature help to identify shortcomings in existing literature and then address issues like low cost, quality improvement and rapid product development in a more coherent and systematic manner. The subsequent section review the literature related to PPMx, WCM, manufacturing strategies, time based competition, flexibility and innovation. The present status of Pakistani automotive industry practices is presented in section B.

2.2 LITERATURE REVIEW

2.2.1 MANUFACTURING STRATEGY/PRODUCT PROCESS MATRIX (PPMx)/WORLD CLASS MANUFACTURING (WCM)

Researchers like (Hayes and Wheelwright 1984, Skinner 1985, Hill 1993, Miller and Roth 1994) have depicted manufacturing function as the missing link in corporate strategic processes and emphasized that manufacturing can be a formidable competitive weapon, if equipped and managed properly. Hayes and Wheelwright (1979a, 1984) classify production process types into four generic typologies of process technologies by how manufacturing plants organize and deploy their production resources, i.e. equipment, people and procedures used to produce the firm's product (1) job shops where machinery and equipment tends to be relatively general purposes because jobs arrive in different forms and require different tasks;

(2) batch shop in which batches of a given product proceed irregularly through a series of work stations; (3) connected line in which relatively mechanized and connected production processes produce few product models with similar product features; and finally (4) continuous flow in which the production process is highly specialized, inflexible and capital intensive where a high product volume passes through standardized production processes. The model outlines the increasing role that the manufacturing function can play in formulating business strategy. At one extreme, a manufacturing firm may decide to compete in a market characterized by uncertain demand for many low-volume product variants. At the other extreme, a firm may decide to compete in a market characterized by high-volume demand for a standardized product. Thus, to achieve low production costs it is necessary to reduce product variety and process flexibility and to adopt a dedicated manufacturing process. (Hayes and Wheelwright 1984) assert that the diagonal as shown in figure 2.1 offers the best match of product volume/ mix and process characteristics. Hayes and Wheelwright (1984) warn that because of the variety of options available to the firm and the impact of each variable on a number of competitive dimensions, selecting the right process requires careful analysis. The process choice is linked to the customer's demand for specific valuable product features, because a given manufacturing process type supports some product features for example low price and high volume at the expense of other competitive priorities.

This content of fit between Product and Process choice has been strongly argued in literature (Hill 1993, 2000). The configuration depends on how managers believe to win orders in the market defined through the volume flexibility and the degree of product customization, the two most important criteria for the configuration of manufacturing activities. Hayes and wheelwright (1984) study is based on (Woodward and Skinner 1969) and proposed a direct relationship between product and process structure, which is known as Product Process Matrix (PPMx). According to this PPMx, being on the diagonal of this matrix or very close to it, properly matches product and process structure. Therefore, when a firm's product structure or product mix changes, its process structure should also changed by moving along the diagonal of the matrix to balance the benefits of flexibility and efficiency. In Hayes and Wheelwright (1979a) article, authors discussed the static aspects of selecting a position on the matrix, and the subsequent article in 1979b, included dynamic aspects of PPMx too, i.e. how a firm's position on the matrix may change over time and the implications of such moves effect the firms.

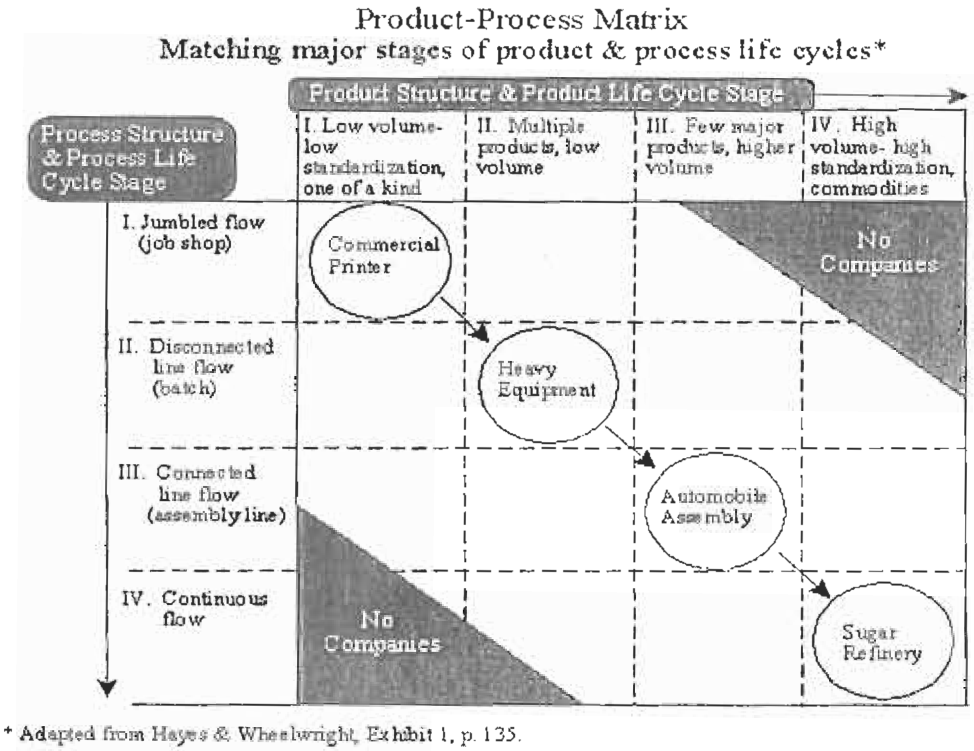


Figure 2.1 Product Process Matrix (PPMx)

Regarding validated of PPMx, Safizaded (1996) tested the Product-Process Matrix cohesion in their study of 110 US manufacturing firms using 13 variables and find strong support for an association between product plans and manufacturing process choice. Nearly 75% of the respondents lie on the diagonal. Their findings support the deductive argumentation in literature that firms with different process choices emphasize different competitive priorities. The PPMx is one of the most widely recognized concepts in the manufacturing strategy arena too, and has been frequently commented upon e.g. (Spencer and Cox. 1995), (Safizadeh at al. 1996) etc.

(Ahmad et al, 2002) explained that the relationship between product and process structure is significant, but not strong. Furthermore, less than half of the plants operate near the diagonal of the matrix. The only deviations from the matrix are plants using innovative initiatives to overcome the lack of product and process structure match. The authors proposed a third dimension be added to the product process matrix that measures how aggressively plants are implementing these innovative initiatives in off-diagonal behavior.

Safizadeh (1996) strongly supported the matrix, whereas (McDermott et al 1997) raises serious questions about the validity of PPMx framework. The later author explains that due to complex manufacturing environment in the world today, there is demise in utility of product process matrix. (Ahmad. S and Schroeder 2002) believe that inability of these studies to reach a definite conclusion is the fact that manufacturing firms have several strategic options to foster between consumer preferences and manufacturing decision making. One firm emphasizes the need of processing technology like flexible process, whereas another may emphasize managerial practice and de-emphasize other e.g. Just-In-Time (JIT) and yet another may emphasize both or combination of new approaches. The authors also investigated the impact of innovative management and technological approaches on the PPMX framework and allow other frameworks to emerge. This comes out that study of Product-Process Matrix represents a rich area for future research.

(Ariss S 2002) discussed and empirically tested the impact of flexible processing capability on the product-process matrix and provided further evidence of the compatibility of multiple competitive performances rather than tradeoffs. In today's customization and dynamic environment, industries such as electronics, pharmaceuticals, and automobiles seem to compete largely on the basis of product innovation. In fact, underlying the competition of product innovation are the firm's flexible process capability and its ability to customize the production to changing environment. The authors argued that (Hayes and Wheelwright 1984) provided a specific tool, product-process matrix, to coordinate marketing (products) and manufacturing (processes) and to prevent non-focused manufacturing capability building. He argued that the environment has dramatically changed and a firm can achieve competitive performance simultaneously. The research illustrated how the high flexible process enlarges the feasible zones and reduces the constrained zones in the product-process matrix as shown in figure 2.2.

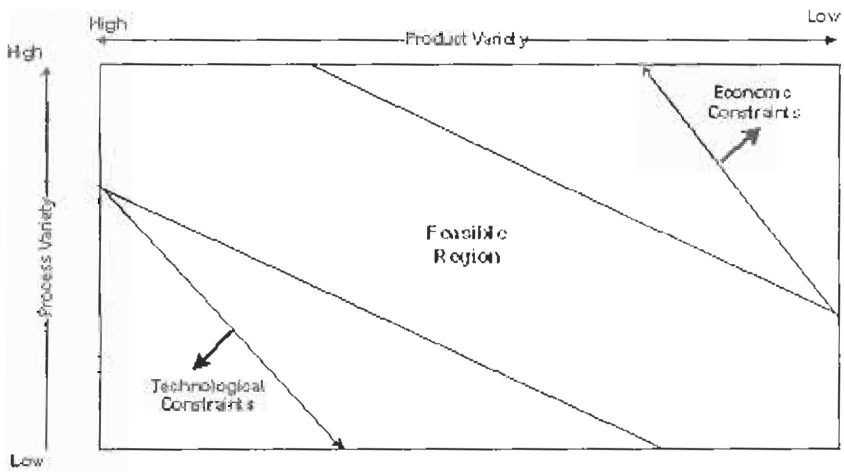


Figure 2.2 Expansion in feasible region due to constraints as proposed by (Ariss 2002)

(Taps et al 2005), strongly supported the use of Product Process Matrix (PPMx) in Danish firms. Based on the empirical analysis, authors concluded that firms even in developing geographical regions follow an on-diagonal position on the Product Process Matrix (PPMx), which indicates that the theory of matching process choice to volume and product content is universal. Furthermore, the choice of process type is not influenced by local factor advantages such as low wages. The important independent variable that influences the process choice is volume, which is measured on an interval scale ranging from low to high order size.

(Johansson P et al 2006) derived a framework for the process choice in joint manufacturing and after-sales service operations by exploring a linkage between manufacturing goods and service operations on Product-process Matrix. Their study aimed to integrate approaches for manufacturing and service operations decisions on process choice. The authors have explored a linkage between goods manufacturing and service operations on Product Process Matrix.

(Voss C, 2005) presented three distinct paradigm of manufacturing strategy. These are (1) "Competing through manufacturing": Cost, quality, dependability and flexibility are considered first important factors in this paradigm. The second factor is capabilities which involved choosing appropriate manufacturing technology to achieve particular desired capabilities. The third factor is shared vision i.e. through clear articulation of cooperate missions and strategies a company will be shared by its managers and other employees.

(2) "Strategic choices in manufacturing" is the second paradigm based on the need for internal and external consistency between choices in manufacturing strategy. Selection of right process for manufacturing as advocated by (Hayes and Wheelwright and Hill 1984, 2000), and focus of the firm specialization is important aspects in strategies choices in manufacturing.

(3) "Best Practice" is the third paradigm in the study. Best practice came from many sources like MRP from USA, OPT from Israel, FMS from UK, GT from Russia etc are some of the examples of best practices. World Class Manufacturing (WCM) in term of practice and performance is also part of this paradigm. The authors defined WCM sharing best practice in total quality, concurrent engineering, lean production, manufacturing systems, logistics and organization and practice. The authors argued that the content of manufacturing strategy has developed into several distinct paradigms as described above. None by itself is sufficient for effective development of manufacturing strategy to gain long term benefits. Together they

contain all that is required for an effective strategy and there exists a logical cycle connecting the three as shown in figure 2.3.

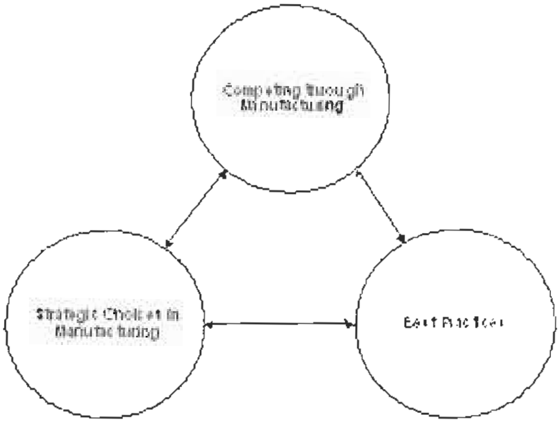


Figure 2.3 Logical cycle connecting three distinct paradigms (Voss 2005)

The work of (Flynn B. B, Schroeder 1999) determined the practical issues related to Hayes and Wheelwright's (1984) world class manufacturing. First, the authors explained that Hayes and Wheelwright's thought of world class manufacturing practices were developed in the early 1980s are robust to the changes that have taken place. Second, the proposed world class manufacturing practice developed by Hayes and Wheelwright significantly related to cost, quality-performance, product flexibility and volume flexibility is still valid. The use of practices in new manufacturing systems has increased the competitive performance significantly. Third is the trade-off between dimensions of competitive performance in terms of cost, quality and flexibility. The authors concluded that the work of (Hayes and Wheelwright 1984) provides a solid foundation for achieving competitive edge in manufacturing.

(Linda C Hendry 1998) described that most of the advice on becoming a WCM company in the literature is aimed at Make to Stock (MTS) mass producers or Mass Customized (MC) sector and does not apply in full to the Make to Order (MTO) sector. This paper proposed some guidelines which are designed for MTO Company that makes a strategic decision to retain a high variety of products, prefers to retain the job shop layout. The proposals suggest ways in which the current guidelines in the literature can be adapted and provide a more appropriate set of criteria for assessing the performance of companies in this sector.

(Partanen. J & Haapasalo 2004) reviewed elements of mass customization for fast productions systems. Scale, cost, quality and time in a row is the targets and also paradigms where business is managed. Mass customization is the one of these modern means to achieve these goals. It is customizing product to individual customers and producing those with principles of mass production. The key issue is customer focus. Fast production means delivering products to customer faster than the lead time of the whole manufacturing process in order to satisfy customers. This can be achieved by utilizing standardized methods and modularized product structure. Companies are continuously forced to improve their performance in order to create VA customers and to remove NVA activities. As companies seek to provide product faster, cheaper and better than the competitors, they have realized that they cannot do it alone. They need to collaborate with upstream and downstream partners in the supply chain. A competitive supply chain must be synchronized from upstream to downstream against real customer demand in order to deliver the right product, to the right place, on the right time. This is achieved with mass customization for customizing products for the customers with principles of mass production. In there model, they identified that 80-90% companies can be benefited with mass customization. To conclude, mass customization in electronic industry is an effective way to improve operations but requires many developments of product structures to enable extensive adaptation of the concept of fast production in order to fulfill and implement mass customization in electronic industry.

(H. J Bullinger 2006) discussed ways to sustain in the markets; many enterprises with mass production are challenged to link two strategic options: simultaneous improvement in differentiation and cost structures. Attempts to find a solution in the context of conventional business models showed the following characteristics:

1. A strong increase in information and communication,
2. An increase in the product type and number of variants,
3. A reduction in manufacturing lot size and
4. Frequently changing production processes and extensive storekeeping at several stock levels.

Enterprises which introduce the mass production for the individual customer try to combine the advantages of mass production with those of individual manufacture. Intelligent competitive strategies approach aim to overcome the traditional duality of cost leadership or differentiation strategy and to make both efficiency and effectiveness possible.

(Tang Chen et al 2005) presented the operational framework which is termed as manufacturing paradigm tree of instant customerisation. It can categorize the operational doctrine, the relationships between different operational tactics and the objectives, and the relationships among different operational tactics. Instant customerisation can be understood more effectively and holistically. The need for such framework arises due to customer demanding their orders for customized products or services be fulfilled under zero customer lead time and at the price near the price of mass production. The author described the operational tactics, operational tenets and an operational framework of instant customerisation.

(Kao C and Hung 2005) identified four stages development path from management viewpoint perspective i.e. production, marketing, finance and human resource. Based on the four functions, management patterns are identified via a cluster analysis. From the relationship between the organizational performance and the four management functions, the management development path of manufacturing firms can be traced. The research is based on case studies and authors argued that development path of Taiwanese companies comprises of four stages. The first stage begins at low production management-low marketing management, and is characterized by low performance. This stage develops into the stage of high management- low marketing stage, which is of higher performance. The next is high production management-high marketing management with a further increase in performance. Finally, it reaches the stage of very high production management- high marketing management. This stage is characterized by the highest performance. Being aware of the development path and the current management status, a firm is able to determine what to do in order to achieve better performance.

(Akhtar K& Tabucanon 1993) proposed a framework for generating and evaluating strategies systematically in a top-up and bottom-down manner, thereby eliminating some of the drawbacks in the current frameworks. It is proposed that strategies be divided in terms of typology, referred to as the 'defensive', 'aggressive' and 'innovative' strategies. By properly clustering, it should be possible to define the typical characteristics of each archetype.

(Alan Harrison 1998) discussed manufacturing strategy concepts in world class manufacturing. The conclusions drawn is that lean systems must be viewed in terms of performance over time rather than performing under WCM and major processes change appear to facilitate operator commitment to continuous improvement (CI).

(Frank E Rowbotham 2004) formulated a questionnaire to classify manufacturing companies under Hayes and Wheelwright four-stage model and assessed the reliability of the instrument. In an application of the questionnaire to three small manufacturing companies, the paper finds that half of the questions asked are statistically reliable according to the interclass correlation method. An in-depth cross-case study of the three organizations reveals patterns of management which further supported the statistically reliable questions. The overall conclusion is that further research on questionnaire as instruments for exploring the four stage concept is necessary before reliable method is available.

(Ajay Das et al 2003) investigated the issue of the fit between process environment and Advanced Manufacturing Technology (AMT) and its impact on manufacturing and business performance. Different process environments tend to align AMT investments in distant profiles, which are associated with superior performance. Deviations from these ideal profiles have shown a negative impact on manufacturing performance. The findings also suggest that firms are not fully exploring the potential afforded by AMT investments to compete in off-diagonal positions in Hayes-Wheelwright framework.

(Shaladdin Muda et al 2002) demonstrated the applicability of a new world class manufacturing (WCM) model developed for the MTO sector. The model aims to fill a gap in the WCM literature that concentrates on the characteristics of the larger traditional MTS sector. The MTO principle is the current version of the model after all the modifications have been incorporated. Its intended purpose is to aid MTO companies to determine their strengths and potentials areas for improvements so that they can continue to be competitive in the future.

2.2.2 DIMENSIONS OF COMPETITIVENESS

Time based competition, flexibility; innovation and quick response to customer services have revolutionized the manufacturing industry as shown in figure 2.4. To face challenges of world; time, agility and innovation are considered core areas to focus as advocated by researchers already discussed in above section. The subsequent section review time based competition, flexibility (agility) and innovation issues which are pre-requisite to survive in the marketplace. The competitive dimensions are shown in figure 2.4.

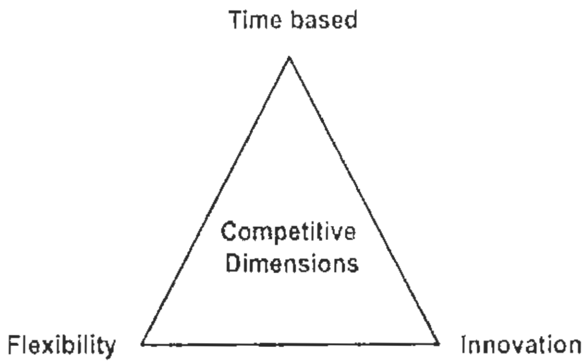


Figure 2.4 Dimensions for competitiveness (Jahanzaib & Akhtar 2007)

2.2.2.1 TIME BASED COMPETITION

The underlying success lies in continuous striving for customer focus, quality and agility (Debra. E et al 2004). In the new manufacturing environment, time is the primary competitive motive of business. This does not means that other motives like cost, quality and service can be ignored. In fact, they are pre-requisite to sustain competitiveness (Peters S Davis 2002). But the winning factor is provided by time and enhancement to the basic products (Stalk & Hout 1990). Optimal utilization of resources can be achieved by balancing of production line and distribution of work contents equally among work stations to reduce cost per part. Therefore, balancing of production line is considered as essential pre-requisite in industry for streamlining operations in order to reduce production cost per unit (Hadi 2006).

2.2.2.2 FLEXIBILITY IN MANUFACTURING

Flexibility is the capacity to deploy or redeploy production resources efficiently as required by changes in the environment. Flexibility is thus one of the basic characteristics of any production process. While it primarily corresponds to time, it is also linked to two other cross-functional objectives: quality and cost. There are several types of flexibility which correspond to the various types of changes likely to occur either in a firm's internal resources or in its environment as shown in figure 2.5. The main sources of variability are demand and technology. Demand varies depending on the nature of the products, thus requiring product flexibility. Quantities in demand may fluctuate, thus requiring volume flexibility. Firms may also have to cope with other sources of variability, each requiring a particular type of flexibility: seasonally produced raw materials, uncontrollable lead times from suppliers, breakdown, absenteeism, excessive personnel turnover, etc. (Beckman 1990). Furthermore, they must adapt to greater variations or mutations such as raw material availability or technological changes. In short, a flexible organization has the ability to adapt not only to fluctuations in demand but also too many other changes in its environment. In landmark report "Made in America", the MIT Commission has gone further using total flexibility to designate the ability 'to deliver high-quality products tailored to each customer at mass production prices' (Dertouzos 1989).

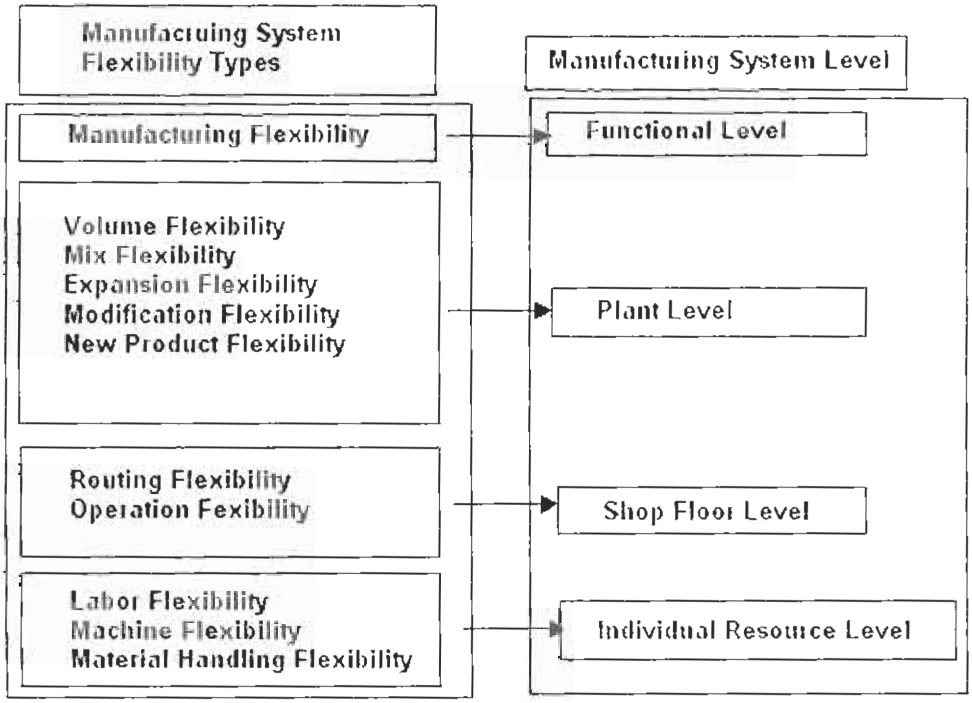


Figure 2.5 Manufacturing System Level and hierarchy of manufacturing flexibility (Koste & Malhotra, 1998)

Manufacturing flexibility is the ability to change or react with little penalty in time, effort, cost or performance (Upton 1994). Two major types of flexibilities are reactive and proactive. The reactive nature of flexibility addresses both the internal and external environment uncertainty faced by organization. The proactive nature comes from the market uncertainties and customers that expect some flexibility from particular industry (Slack 1983). Contemporary manufacturing organizations are facing challenges from two directions. In one direction, newer manufacturing philosophies and technologies emerge to make the existing ones obsolete. In the other direction, today's customers are becoming more and more aggressive in demanding new products and services within a short period of time (Maskell, 2001, Tersine and Wacker, 2000; Gunasekaran, 1999; Lau et al., 2002; Helo, 2004; Ho et al., 2005).

2.2.2.2.1 AGILE MANUFACTURING

In order to meet the challenges that invade from these two directions, today's manufacturing organizations are required to act quickly in accordance with the surrounding competitive situations. On realizing this trend, during the past few years, the manufacturing arena had been orienting towards the relatively new type of paradigm, under the umbrella name, "agile manufacturing" (AM) (Power et al., 2001; Jin-Hai et al., 2003; Crocitto and Youssef, 2003). A considerable number of academicians and manufacturers view AM as a new approach (Rigby et al., 2000, Hormozi, 2001). As a matter of fact, agility in manufacturing arena had been occurring as the spontaneous responsiveness to high degree of competition (Parkinson, 1999).

As evidence to this statement, the performance of today's mobile phone manufacturing companies can be cited. It is a common observation that these companies have been introducing several models to market very quickly. During the recent years, many automobile manufacturing companies have also been evolving new models relatively at quicker speed (Maskell, 2001). In fact, this agility trend has been dominating various types of manufacturing organizations with different levels of its adoption. Thereafter a handful of researchers have contributed very valuable AM principles. The major contribution of researchers is the spelling out of its meaning and definition. Jin-Hai et al. (2003) and Dowlatshahi and Cao (2005) have enumerated the definitions of AM given by various authors. The most noticeable is the development of the following Equation (Sarkis, 2001):

Agile manufacturing = (Flexible manufacturing system + Lean manufacturing)

Although various definitions of AM are available in literature, these definitions do not contrast with each other. The commonality among most of them is the enunciation that AM is the capability of the manufacturing enterprise to quickly respond to the market requirements. Thus, AM calls for radical changes in the system, culture and management styles being currently followed in traditional manufacturing environment. Meanwhile, the adoption of AM has been established as the need of the hour to face the high competitive market (Vokurka and Fliedner, 1998; Meredith and Francis, 2000). On the other hand, the gradual and spontaneous adoptions of AM principle have consumed long time to enable organizations to attain agility. This situation persists because majority of the manufacturers are devoid of the knowledge on AM criteria. The problem of how organizations can successfully deal with unpredictable, dynamic and constantly changing environment has been a prevailing topic both in industry and academia for the last few years. Many different solutions have been proposed: networking, reengineering, modular organization, virtual corporation, FMS and JIT etc. Among proposals how to deal with an uncertain and unpredictable environment, notion like 'agile enterprises' is the most common. Agility is defined as a rapid and proactive adaptation of enterprise elements to unexpected and unpredicted changes (Kidd, 1994). Agile Manufacturing (AM) is the ability of surviving and prospering in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-defined products and services (Gunasekaran, 1999). Despite the differences, all definition of 'agility' emphasis the speed and flexibility is the primary attributes of an agile organization.

Taxonomy developed for US small manufacturing industries in which emphasis placed on competition priorities i.e. cost, delivery, flexibility and quality is proposed by (Kathursia, 2000). The work of (Zhao, 2002) is also significant in which relative importance and competitiveness strength of different Chinese manufacturing companies have been investigated empirically. The authors have found that innovation, after sales service, quality and flexibility are the most important competitive priorities among Chinese enterprises. (Bohdana S, 2007) identified global characteristics of agility which can be applied to all aspects of enterprises: flexibility, responsiveness, speed, culture of change, integration and low complexity, high quality and customized products and mobilization of core competition. Therefore, in the new era of production, strategic priorities rather than cost contained focus have proved to be important for competition namely: quality, dependability, flexibility, customer service, after sales service, supply chain management etc. Some supported use of IT related technologies which are critical for thriving competition as it can facilitate the attainment of these strategic targets (Petros T, 2006; K. Sexena 2000).

2.2.2.3 INNOVATION AS A COMPETITIVE STRATEGY

The third important dimension for competitiveness is innovation. Innovation is a process of creating something new in the organization and hence organizations that encourage diversity and calculated risk taking ability are more innovative (Rajiv N, 2006). Innovation is essential in order to generate long term stability, growth, shareholder returns, and sustainable performance and remain at the leading edge (Cook P, 1998: Davis et al, 1997). One way to achieve growth and sustain performance is to foster and encourage creativity and innovative practice internally within the organization. A commitment from senior management to facilitate this kind of innovative working is also required (Ahmad and Abdalla, 1999). (Stanley et al 1995) argued that it is no longer to do things better, it's about 'doing new and better things'. Innovation is also viewed as the single most important factor in developing and sustaining competitive advantage (Tidd et al, 2001). Several empirical studies were carried out to explore the application of innovation within small to medium sized enterprises (SME). The work of (Paul et al 2005) showed that for innovation implementation in SMEs require ongoing effort, commitment and understanding beyond that of continuous improvement. An approach termed as value analysis tear-down approach which is a comparative process and analyzes all aspects of cost, material etc of products with those of competitors. Six types of tear down described are dynamic, cost, material, matrix, process and static (Kaufman & Sato, 2004). Other than VA, ABC/M system can serve as a useful information system to support effective decision making processes (M Gupta et al 2003). An operation hexagon is proposed to discuss the managerial implications of an ABC/M system for various operations management decisions related to product planning and design, quality management and control, inventory management, capacity management and work force management. By viewing an ABC/M system as an enabler to improve the operations decision making, we demonstrate that these systems enable an operations manager to enhance the quality of decision making process.

2.3 CONCLUSIONS

This chapter reviewed literature related to PPMx, world class manufacturing, dimensions of competitiveness etc. It is evident from literature review section that PPMx is linked to the customer choice for specific products and the matrix is widely recognized concepts in manufacturing strategy arena. The following conclusions are drawn after comprehensive reviewing of literature:

i. The PPMx has been tested empirically and found that a strong association exists between product and process matrix as advocated by academician and practitioners.

ii. Some authors suggested that the diagonal should be expanded in order to accommodate innovative and technological issues, which is commented by McDermott (1997) and Ariss (2002).

iii. The most important dimension (process choice) supported by researchers is 'volume' which can range between low to high volumes depending upon manufacturing environment.

iv. Companies who are 'make to order' manufacturers prefer to retain job shop environment but the environment is changed. Now companies should focus on mass customization which offers high variety of products at mass production price.

v. Intelligent competitive strategies have been developed to overcome traditional duality of cost leadership or differentiation strategy and to make both efficiency and effectiveness possible.

vi. The use of advanced manufacturing technology (AMT) is associated with superior performance. It is strongly commented that deviations from using AMT have shown a negative impact on manufacturing performance.

vii. Time based competition is considered as most important dimension to achieve competitive edge over competitors. Streamlining of production line shrink the lead time, which help reducing cost per unit.

viii. Agility and flexibility are evolved as manufacturing strategies to deliver products tailored to each customer at mass production price.

ix. The agile manufacturing accommodates flexible and lean manufacturing principles. Different stand alone solutions are available like FMS, JIT, Networking, re-engineering etc. Among proposals agile enterprises terms are commonly referenced.

x. Innovation is the process of something new in the organization. To encourage creativity and innovative practice, senior management commitment is required. Innovation is viewed as single most important factor in developing and sustaining competitive advantage.

xi. Tools like Value Analysis (VA), Activity Based Costing (ABC), VA tear down approaches are used to increase value and decreasing cost.

It is evident from above discussion that PPMx is widely acceptable matrix which is used by researchers to cope with existing dynamic manufacturing environment. Although intelligent manufacturing strategies have been devised which can model cost and product differentiations i.e. internal and external focused, but not deal with agility issues. The competitive dimensions identified in literature are cost/time based competition (Balancing operations), agility (flexibility/quality improving /lean) and innovation (product/process/Value Analysis/Non Value Added Cost). Manufacturing strategy, Product Process Matrix (PPMx) and World Class Manufacturing (WCM) are also reviewed for coping with low cost with high quality, customer focused and innovative products in an orderly and coherent manner. *There is a need to link these dimensions in the form of workable strategy to become world class manufacturers. There exists a significant gap in the existing literature to address competitive dimensions systematically i.e. (low cost, improve quality/ agility and innovative differentiated products) within a single framework in the form of manufacturing objectives, strategy formulation, evaluation and validation. This also calls for an investigation of manufacturing strategies that enable manufacturing companies to achieve competitiveness as a company may opt for being the lowest cost producer, highest quality/customer focused and innovators with differentiated products and improve customer satisfaction level. To fill the gap, a new framework has been developed to meet challenges of marketplace.*

B. OVERVIEW OF AUTOMOBILE INDUSTRY

2.4 INDUSTRY OVERVIEW

The automotive industry is an important segment of the economy in any country as it links industries and services. Production of parts for the transport vehicles incorporates possible industrial activities which give strategic advantage for local manufacturers to develop their capabilities for achieving competitive edge over competitors. Recent years have seen several new foreign joint venture companies set up manufacturing and assembling plants in Pakistan. Much of the production carried out by these manufacturers is providing finished parts to OEMs mainly operated by international assemblers; however a purely indigenous industry has developed as well.

Pakistan automobile industry started in 1950 when National Motors Limited, a public limited company and pioneer in the industry, came into existence. The industry was highly regulated until early 1990's. After de-regulation, major Japanese manufacturers entered in the market thereby creating some form of competition in auto parts manufacturing sector. In recent years there has been a huge build-up of the automobile industry in Pakistan, with companies like Honda, Toyota, Nissan, Hyundai, Kia, Ford etc. Of all car manufacturers, Japanese automotive companies have by far the strongest hold in the Pakistani market.

Foreign automotive manufacturers have laid down the foundation of automotive assembling plant and developed strong networks of parts suppliers, dealership and service centers. However, until very recently, Pakistani government sought to protect local parts manufacturers to supply indigenously made parts to assemblers. Automotive industry was liberated after 1990 to encourage local parts manufacturers to improve efficiency, technology as well as product quality. This market liberalization has helped to attract foreign automobile assemblers. Since, Pakistan is offering domestically manufactured and assembled car, beside that there is no need for economic measures restricting the operations of foreign automotive manufacturers.

Presently, industry is going through process of upgrading product quality and innovation. As quality, innovation and customer focused is now primary concern for competition as a large number of international automobile manufacturers are operating in Pakistan. For attaining quality at component level (discrete parts manufacturers), ISO 9000 and 14000 certification is currently becoming a necessary standard for the main producers. Automotive parts industry has still been regulated by the government and many steps has been taken for restructuring the sector by promoting and providing manufacturers with updated know how of critical parts manufacturing, human resource management, manufacturing hubs etc, but still industry is far from global standards (EDB, SMEDA, NPO 2006).

Apart from governmental policies, automotive sector is facing with various challenges and barriers like fragmented locations of manufacturers (not more than 300 units of varying size scattered all over Pakistan), lack of training schools for producing human resources, lack of knowledge about latest tools/ methods/ systems, low level of technology, innovation and absence of R&D. Auto industry is volume driven (EDB, 2006) and certain critical mass is a pre-requisite for economic production. The production volumes showing an increasing trends, but unable to meet customer requirements (exports are negligible). The total number of cars, trucks, buses, LCVs and tractors produced are given in table 2.1 and is far from global mass production.

Table 2.1 Total Production of Vehicles

Type	Year wise number of units				
	2001-02	2002-03	2003-04	2004-05	2005-06
Cars	40,088	62,073	98,481	126,403	160,642
Trucks	1,134	1,929	2,022	3,204	4,518
Buses	1,086	1,296	1,380	1,762	825
LCV	9,055	12,548	14,896	25,177	32,053
Tractors	23,801	26,240	35,770	43,200	48,887
Total	75,164	104,086	152,549	199,746	246,925

(Source EDB 2006)

2.4.1 PRODUCTION ENVIRONMENT

There are more than 300 units of varying size in the auto parts industry; some of them are registered vendors to assemblers/OEMs. Along with the organized sector, a good number of small and large units are operating in un-organized sector. 90% of automotive parts industry constitutes of small to medium enterprises (SMEs), out of which about 95% are self-financed. These units produce a wide range of parts for the replacement market as quality of locally manufactured parts are not adequate to fulfill world quality criteria and standards. Therefore, these manufacturers are bound to sell parts in the replacement markets. Although some of them are successful in making critical parts which are available in the replacement market at competitive prices. Pakistan is the only country in the world which has formulated industry specific deletion program (EDB, 2006) to specify local content requirements for cars, buses, trucks, tractors and motorcycles. The basic purpose of the deletion program is to develop and project the local auto parts industry. This is a healthy sign but most manufacturers lack vision and strategy.

2.4.2 DOMESTIC MARKETS

The domestic demand for automotive parts is increasing, however due to high tariff protection and local contents rules; industry is facing competition from international players like China, Brazil and India. The situation is improving as depicted in production volume table 2.1. But to reduce the effect of the crisis, automotive parts manufacturers turned their focus to overseas markets as operating cost in Pakistan are relatively cheaper than in other countries. In recent years, there has been massive investment in the automotive industry from companies such as Toyota, Suzuki, Nissan, Honda, Kia, Hyundai etc. This kind of investment enhances the possibility of Pakistan becoming the automotive hub for this region.

2.4.3 EXPORT MARKETS

The export of motor vehicle parts and accessories has become an increasingly important part of Pakistani economy. In 2001, the total value of exports in this sector was 262 million (Pak Rs.1US$ = 60.5 Rs), which in 2002 climbed to 383 and 648 million during 2004-05 showing 69% increase. The major exporting partners are USA, Germany, Nigeria, Kenya, Saudi Arabia, Sri Lanka, UAE, Bangladesh and Iran. Despite rapid growth, *Pakistan auto industry contribution in global terms is still low i.e. 0.3 % of the world production of 66.5 million passenger and commercial vehicles. Thus the export of motor vehicle parts and accessories will continue to form an important part of Pakistani economy.*

2.5 CONCLUSIONS

Pakistan automotive industry is operating in low volume range of production as compared with other car manufacturers in the region (EDB, 2006). The industry benefits from high tariff protection and local contents rules which might disappear soon due to WTO regulation. In the view of the huge recent increase in the local car market and the projected performance, consideration for such production should present opportunities for the local markets as well as for exports. With car factories and auto parts manufacturers in Pakistan having the capacity to produce 1 million units a year, the country is positioned to make significant gains in its exports too.

The automobile industry is operating in low to medium volume range and choices for customers (variety) are also low as compared with the world to become competitive in cost, quality and product development as competition is getting tougher day by day. The existing world class manufacturing practices and manufacturing strategies might help to cope with this situation. (Jahanzaib & Akhtar 2005) has proposed three manufacturing strategies which work within a framework (will be explained in chapter 4). So, there is a need to address these issues in the form of following questions:

i. Automobile industry is volume driven, and certain volumes are required to justify production. Therefore, production volumes should be paid due consideration in order to use right type of manufacturing system for production.

ii. Exports are negligible and Pakistani share is only 0.3% of world installed capacity of 66.5 million passenger cars and commercial vehicles, which is negligible.

iii. Various challenges faced by manufacturers are low level technology, lack of understanding of tools/ manufacturing systems and absence of R&D, which can be controlled using advanced manufacturing technologies, training of man power on state of the art techniques/tools.

iv. Clustering of manufacturing sector in industrial zone, which not only improve business but also provide trained man power in the same zone to cope with challenges of innovation and dynamic environment.

v. The operating cost of running auto business in Pakistan is relatively lower in the region. To attract customer, emphasis should be made to improve R&D capabilities and produce in masses to reduce per unit cost.

vi. The commitment of senior management for incorporating innovation in business is essential. Value Analysis (VA) and other value adding techniques should be taught to shop floor personnel. This may attract the foreign customers and improve business in the world marketplace.

In this chapter, literature related to manufacturing strategy, dimensions of competitiveness, mass customization have been reviewed. Pakistani automobile industry scenario is also presented in order to get know how of current auto industry practices and compare with world market. A lot of potential exists in this sector; therefore concrete workable solutions would aid manufacturers to cope with present environment. In literature review section, it is identified that there exists a significant gap in literature to address dimensions of competitiveness together within a single framework using PPMx. Therefore, using PPMx as a platform necessitates identifying location of auto industry and then suggesting a route which aid local manufacturers to sell their products in the local as well as in international markets at competitive prices.

CHAPTER 3
RESEARCH METHODOLOGY: QUESTIONNAIRE DESIGN AND ANALYSIS

CHAPTER 3

RESEARCH METHODOLOGY: QUESTIONNAIRE DESIGN & ANALYSIS

A. RESEARCH QUESTIONNAIRE DESIGN

3.1 INTRODUCTION

This chapter is about research questionnaire design and analysis. A comprehensive survey was designed in order to assess level of manufacturing management practices, objectives of the manufacturers, and basic infrastructure i.e. quality practices, volume versus variety information and questions related to human resources, cost, innovation etc. The questionnaire is attached in the appendix. Based on the responses received from manufacturers, questionnaire is analyzed and three types of manufacturers identified using depth and width classifications. The width is knowledge of manufacturers about techniques and depth assessed by level of implementation of techniques. The manufacturers have rated objectives well, but actual practice is far from stated objectives and international standards. So the analysis of questionnaire identified three types of manufacturers termed as Protector, offensive and innovative. 'Protector' is the type of manufacturers whose emphasis is to become mass producer to reduce cost. 'Offensive' manufacturer's main focus is achieving high quality and offer number of models to satisfy customer requirements with high quality. 'Innovative' manufacturers are those who survive or differentiate in the marketplace with uniqueness and innovative design with rapid product development. The archetypes work in a framework which consists of four phases which are explained in chapter 4 as 'manufacturing strategy framework'.

3.2 RESEARCH METHODOLOGY

A comprehensive survey was designed for identification of manufacturer's objectives, manufacturing management practices, problems faced and basic infrastructure analysis. The questionnaire was designed in consultation with the practicing managers and discussions with Engineering Development Board (EDB) sector development cell as given in table 3.1. A number of questionnaires were also reviewed before designing questions. The work of (G. S. Dangayach, 2001 and K. Sexana 2000) is significant. It is important to note that no significant studies of Pakistani industry context are available for utilization by manufacturers. There is a need to address this core issue and use more scientific base in selecting appropriate decision making both at tactical and strategic level. A survey of automobile discrete parts industry was conducted. The target companies were selected from industrial directory published yearly by PAAPAM (Pakistan Association of Automotive Parts & Accessories Manufacturers, 2006). Personal visits to some companies were also made to get first hand information and questionnaire validated by sample questions from shop floor managers. The questionnaire contained three sections i.e. section one contained questions pertaining to manufacturing objectives, section two about manufacturing management practices and last section contained questions about problems of industries encountered and basic infrastructure (quality level, defect rate before rework, inventory held, setup time, R&D activities, training of workers and major barriers faced by manufacturers) are given in table 3.1.

Table 3.1 Main sections of questionnaire

Section No.	Type	Questions relating to
Section I	Manufacturing Objectives	• Waste reduction • Capacity utilization • Supply chain management • Quick response to customers • Agile Manufacturers • Innovative Product Development
Section II	Manufacturing Management Practices	• Just In Time • Optimized Production Technology • Group Technology • Value Analysis • Activity Based Costing • Break Even Analysis • Total Quality Management • Process Capability Analysis • Advanced Manufacturing System
Section III	Major obstacles and Infrastructure	• Major obstacles • Inventory related • Quality Practices • Layout Type • Setup time • R&D activities • Training activities • Number of Employees • Volume- Variety

Based on the feedback of practicing managers and discussions with EDB sector development professionals, final version of questionnaire was sent to the companies. Out of 180 questionnaires mailed to CEO/MDs/Managers, 66 responses were received out of which 60 were found useful. This gives a response rate of 33.4% which is considered adequate for this type of survey in fragmented discrete parts manufacturing industry. Frohlich M (2002) suggested ways to improve response rate, which is also considered in designing of questionnaire. The distribution of the responding companies in terms of region is shown in Table 3.2. (Delphi technique was also studied/ sent postal & email questionnaire)

Table 3.2 Region wise responses (%)

Region	Percentage Responses (%)
Sindh (Karachi/Hyderabad)	41
Punjab (Lahore/Faisalabad/North)	48
NWFP (Gadoon /Hattar)	11

3.2.1 MANUFACTURERS OBJECTIVES

The respondents were asked to rate the strategic objectives of manufacturing listed in the questionnaire using 5-point scale, with a score of 1 indicating 'not important', 2 'least important', 3 'moderately important', 4 'important' and a score of 5 indicating 'very important'. Supply chain management, quick response to customers (customer focused) and agile systems were identified as the most important objectives by the respondents, whereas innovative product development, waste reductions and capacity utilization were considered relatively less important. This is satisfactory as manufacturers are aware of their strategic objectives and rated objectives quite well. This is shown in figure 3.1.

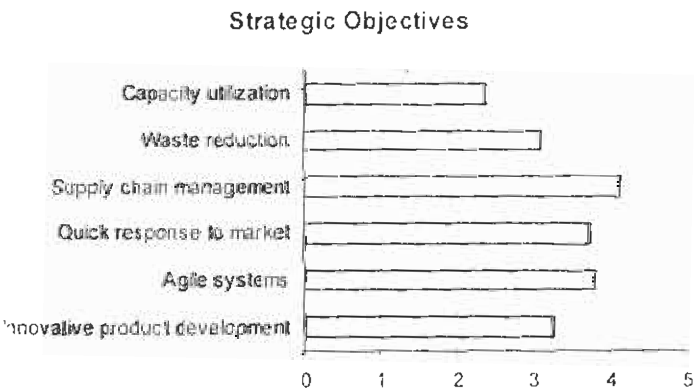


Fig 3.1 Objectives of Manufacturers

Despite this, some of the respondents rated capacity utilization (resources) as the most important strategic objective. This is perhaps in the mindset of some manufacturers to utilize capacities to gain competitive edge in the long run. Utilization of capacities is viewed as a function of current demand of a product and not being considered as a corporate strategic objective.

3.2.2 MANUFACTURING MANAGEMENT PRACTICES

The manufacturers were asked to rate the manufacturing methods/systems on a 5-point scale in terms of usability as 1 'not familiar with', 2 'Not considering', 3 'considering', 4 'practicing for last 1 year' and 5 'practicing more than 1 year'. This is shown in figure 3.2.

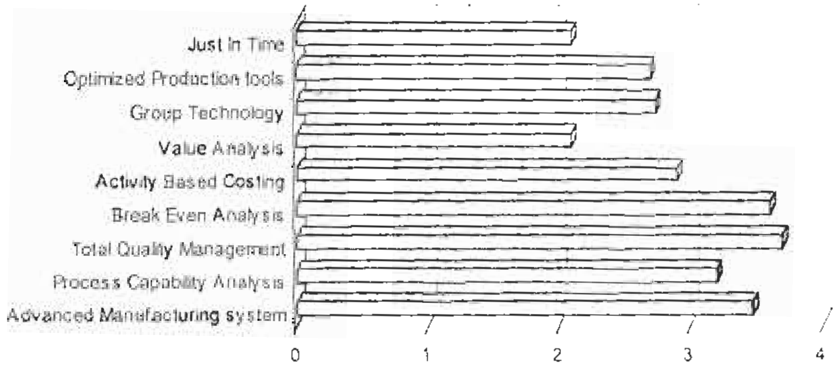


Fig 3.2 Manufacturing Management Practices

The systems which are popular among manufacturers are Total Quality Management (TQM i.e. ISO 9000, charts etc), use of Advanced Manufacturing System (AMS) like stand alone CNC's and Break Even Analysis (BEA) in make/buy decision making. The other important manufacturing systems/methods like Group Technology (GT), Optimized Production Technologies (OPT) like balancing of production line, Activity Based Costing (ABC) and Value Analysis (VA) are relatively less practiced in the local industry. More attention was paid for the investment in islands of automation systems like CNC's. There is a lot of pressure on Pakistani manufacturers to increase their product quality and reliability particularly due to increasing competition and likely changes in the world trade structure. It is therefore, imperative for the industry to improve its productivity and competitiveness. One way of achieving this competitiveness is through automation. These help manufacturers to gain process flexibility and give long term competitive edge to companies.

3.2.3 MAJOR OBSTACLES

The respondents were asked to rate the major obstacles in achieving production targets. For them timely supply of materials from vendors and workers/ employees attitude are the main obstacles, followed by power cuts and break downs problems as shown in figure 3.3.

Major Barriers

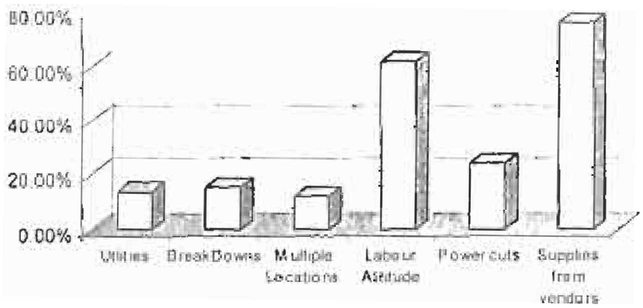


Figure 3.3 Major obstacle faced by manufacturers

As power cuts are merely external factors which can be controlled through national power generation facilities. The major obstacle which is felt by manufacturers in supply chain management system is varying demand (expressed as deviation in sales forecast), which is added up by longer manufacturing cycle times, which makes it necessary to forecast for longer time horizons. This is due to lack of standards and forecast data. (Since emphasis is to shift industry to a viable place on PPMx, hence we are not focusing on supply chain issues).

3.2.4 INFRASTRUCTURE

3.2.4.1 INVENTORY

Regarding raw material and finished goods inventory, respondent were aware of material requirement planning methods, but depend on shortage list inventory mechanism.

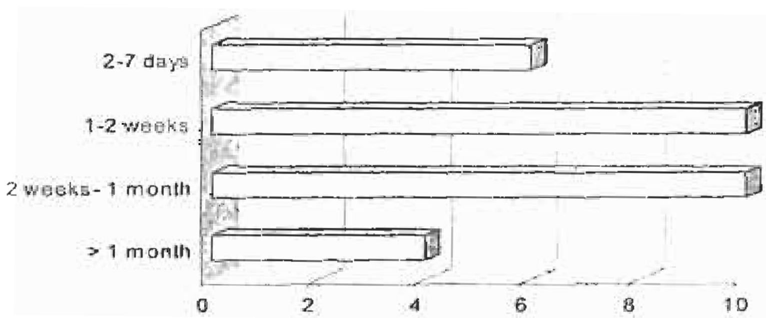


Figure 3.4 Raw material inventory held

The raw material and finished goods inventory figures stated that industry is operating in high inventory mode, which is far from adoption of just-in-time concepts. About 60-65% of the manufacturers maintain raw material and finished inventory for 1-2 weeks to 1 month. Interestingly, there are few companies which are trying to minimize raw material and finished goods inventory. The ultimate goal would be achieved when vendors becomes reliable (zero defect stage) which will cut out a lot of waste from the system. The raw material and finished goods inventory are shown in figures 3.4 and 3.5 respectively.

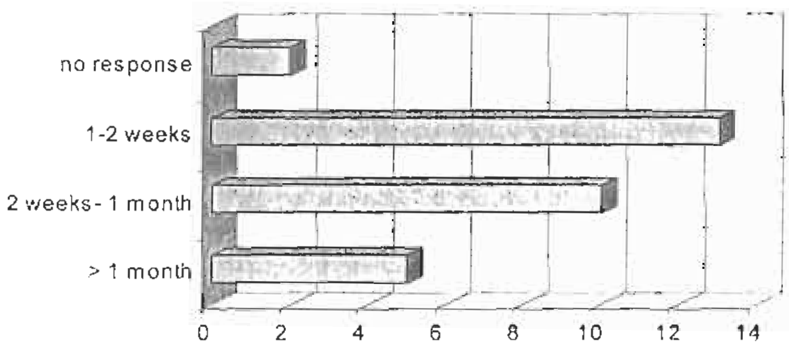


Figure 3.5 Finished goods inventory held

3.2.4.2 QUALITY PRACTICES

Though industry is claiming of practicing TQM philosophies, still the quality level is far from defects per million. The quality levels are only beginning to show on the shop floor. About 34% companies have defect rates before rework of up to 1%, 40% companies have defect rates between 1-3% and there are 6 percent companies which reported above five percent. These defect rates percentages are far from the global standards of defects per million as shown in figure 3.6.

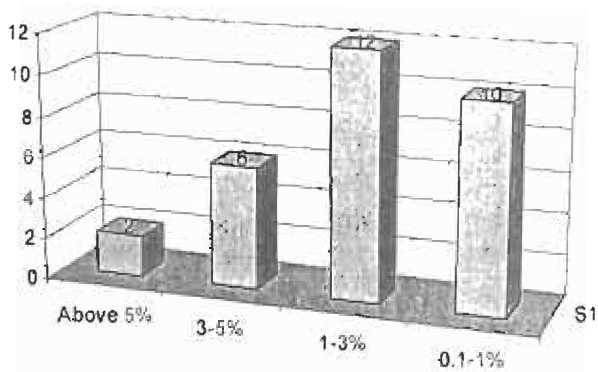


Figure 3.6 Average percent defect rate before rework

3.2.4.3 LAYOUT TYPE

Regarding the layout type in practice, none of the company has implemented cellular layout which is generally considered as one of the foundations to achieve competitiveness at shop floor level. The other types frequently in use are product, process, fixed position and quantity flow lines etc. Product layout are used when the scale of production favors dedicated production facilities, process layouts in case of batch and fixed position usually for heavy industries. Quantity type flow lines are like product layouts but variety can change over period of model type and style as shown in figure 3.7.

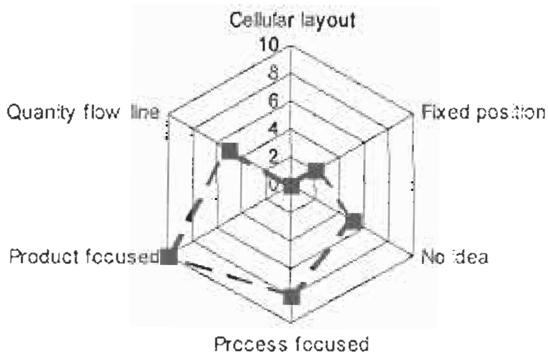


Figure 3.7 Layout types in use

3.2.4.4 SETUP/CHANGEOVER TIME

Setup/changeover time plays a vital role by processing multiple materials/product/model types on the same equipment/machines. Larger setup/changeover times in multiple products forces longer cycle and slow response to the market. This led to the development of Single Minute Exchange of Dies (SMED) in Japan in 1950s which refers to setup time in single minutes i.e. less than 10 min. Two companies have reached this stage and seven of them are very close to it. Both make up a sample of about fourteen percent as shown in figure 3.8.

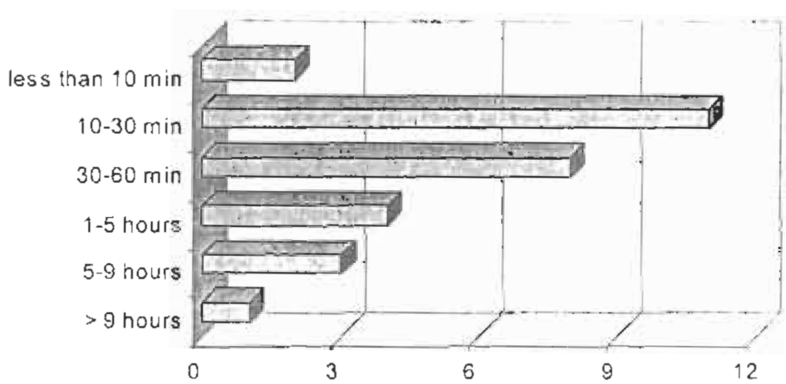


Figure 3.8 setup/changeover time

3.2.4.5 RESEARCH & DEVELOPMENT

The respondents were asked to rate the research and development activities being carried out as shown in figure 3.9. Fifty eight percent stated that R&D activities are carried out to some extent. These activities are not regarded as important as few (3.44%) have indigenous R&D capabilities of product designing and integrating it with manufacturing. This indicated an unsatisfactory practice and is away from CAD/CAM integration.

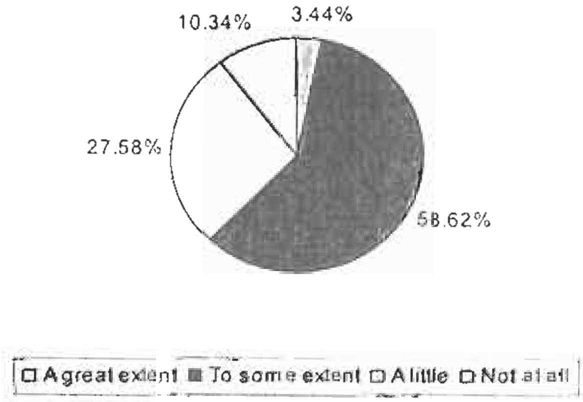


Figure 3.9 R&D activities

3.2.4.6 TRAINING OF EMPLOYEES

Training of employees and learning is an essential part in firm's success. Training schools and institutes financed by industry is very common practice in developed countries. The respondents were asked to rate the training expenditures carried out. Only 4% have considered it for the last five years, 17% are at the stage of considering it to be important and rest 69% far away and ten percent are not sure of it as shown in figure 3.10.

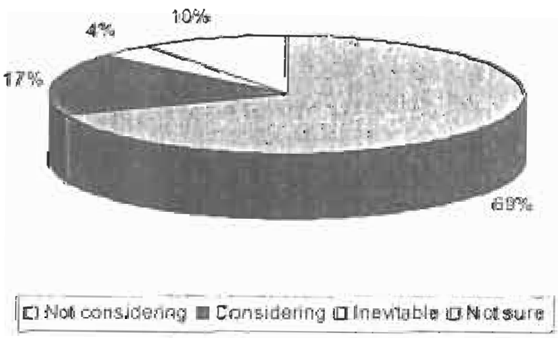


Figure 3.10 Training expenditure

3.2.4.7 NUMBER OF EMPLOYEES

The next question asked was number of employees working in the industry. These figures are shown in percentage in figure 3.11 (research focuses both large and medium industry).

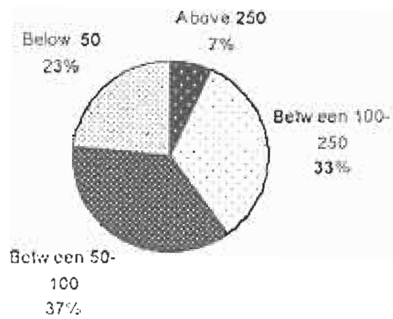


Figure 3.11 Number of employees

3.2.4.8 PRODUCT PROCESS CHOICE

The questions asked from respondents about Product Process choice i.e. number of products produced per annum. The respondents stated that although they feel that some of manufacturers are operating in mass production zone, but in reality are far away from mass production ranges and philosophies of million parts per annum. Twenty six percent stated that their annual rate is below fifty thousand units, forty percent lie between medium volume ranges, thirty percent are producing above one hundred thousand parts and three percent are not sure about it as shown in figure 3.12.

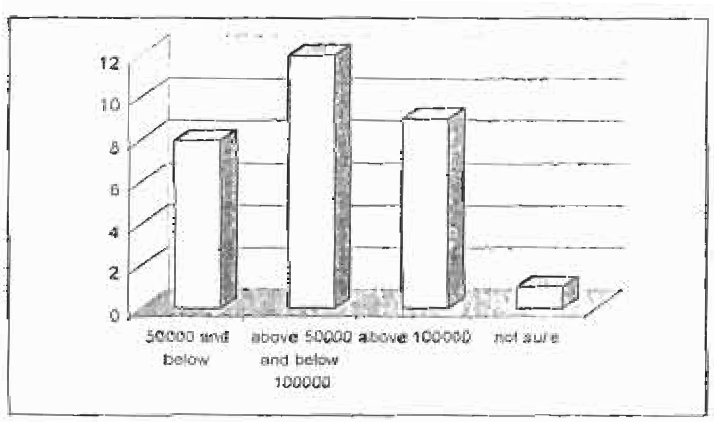


Figure 3.12 Product Process percentages

Another way of analyzing production system performance is total number of parts produced versus product variety as advocated by (Hayes and Wheelwright, 1984; Skinner 1985; Akhtar et al 1993; Miller and Roth 1994; Spencer and Cox. 1995; Safizadeh et al 1996;

Hill 1993, 2000; Ariss S, 2002; Ahmad and Schroeder, 2002; Frank E Rowbotham 2004; Taps et al 2005; and Johansson P et al 2006). The data of the production volumes and product verities have been plotted on standard Product Process Matrix (PPMx) and it represent '*low to medium volume with low variety manufacturing*' scenario as shown in figure 3.13.

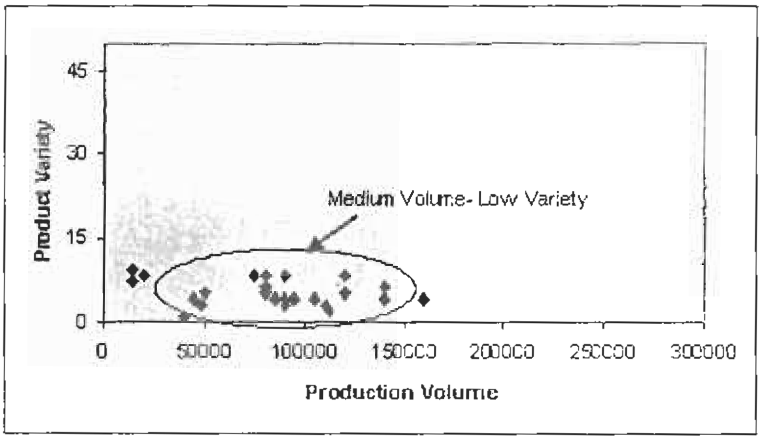


Figure 3.13 Industrial cluster

B. RESEARCH QUESTIONNAIRE ANALYSIS

3.3 ANALYSIS OF THE FINDINGS OF SURVEY

The survey of the industry has been presented in the previous section. The figures showed existing scenario of automobile manufacturing industry in terms of objectives, manufacturing management practices and infrastructure. The survey raises some important research questions/issues that have been addressed briefly as:

3.3.1 Objectives of industry versus international trends to classify type of manufacturers.

3.3.2 Level of manufacturing management practices i.e. (knowledge of system/techniques and actual practice).

3.3.3 Location of industry on Product Process Matrix (PPMx).

3.3.4 Coping with the existing manufacturing environment in the form of strategies i.e. '*Manufacturing strategy framework*'.

3.3.1 OBJECTIVE OF INDUSTRY VS. INTERNATIONAL STANDARDS/CLASSIFICATION:

In order to compare the objectives of the participant companies with those of the international trends; we propose an approach which is:

i) Companies which rated capacity utilization greater than or equal to 3 against agile manufacturing below 3 are 'protector manufacturers'. As traditional mass producers emphasize more on internal objectives like efficiency i.e. to protect the under utilized resources. The best example of efficiency based system is capacity utilization. In capacity utilization, efforts are made to effectively utilize the resources, as main concern for such players is cost per unit. On the other hand, 'agility' is the ability of surviving and prospering in a competitive environment for continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-defined products and services (Gunasekaran, 1999). The agility is meeting needs of customers i.e. external focused. Some of the key characteristics of 'protector manufacturers' are:

1. Low cost is the dominant competitive priority so degree of cost control is very high.
2. Production methods are manual/rigid automation and setup times usually large.
3. Capacity utilization is very high and flexibility is relatively low.
4. Multi skill requirements are low, so training is "generally" focused.

'Protector Manufacturers' would correspond to mass production in Hayes and Wheelwright (classification of 1984) and reactive enterprises (G. S. Dangayach, 2001). They represent 16.7% of the companies who responded.

ii) Companies which rated capacity utilization below 3, agile systems above 3 and faster product development being equal to three are 'offensive manufacturers'. These manufacturers emphasize agility and de-emphasize capacity utilization, but give significant rating to innovation. Speed, coping with uncertain demand, meeting the customer requirement (quality) and flexibility are the primary attributes for them. These are referred to as 'offensive manufacturers'. They have full potential to capture the market with high quality and customer focused. Some characteristics of offensive manufacturers are:

1. Top preferred activities are customer focused, total quality improvements and flexibility.
2. Degree of cost control is low/medium.
3. Production methods are flexible, so setup times are usually small.
4. Multi skill requirement is medium/high, so trainings are diversified.

This is similar to stage II of Hayes and Wheelwright (1984) model and neutral enterprises (G. S. Dangayach, 2001). A major chunk of companies lie in this cluster and represents 70% of the respondents. The companies that are in this cluster have achieved a necessary, but not sufficient condition.

iii) Companies which rated agile systems above 3 and at the same time, faster product development above 3 are 'innovative players'. These companies have well established product development centers and can play well in the world marketplace. Implementation of innovation in SMEs requires ongoing effort, commitment and understanding beyond that of continuous improvement (Paul et al 2005). Innovation is also viewed as the single most important factor in developing and sustaining competitive advantage (Tidd, 2001). Some characteristics of innovative manufacturer are:

1. More investment in innovation and R&D activities is required.
2. Design change flexibility, product mix changes are given more importance as compared with agile and protectorate manufacturer.
3. Outperforming competition in terms of product performance and quality of service.
4. Training and educational level of operators is very high, so training requirement is much diversified.

This group corresponds to Hayes and Wheelwright's stage III model and active/proactive enterprises (G. S. Dangayach, 2001). This is the smallest group in our study representing

13.4% of the companies who responded. This group is still far from achieving significantly to out perform competition in the marketplace.

From this objective analysis, three types of manufacturers identified, are 'protector' corresponding to low cost, 'offensive' corresponding to customer focused with high quality and 'innovative' corresponding to outperforming competition with product differentiation.

3.3.2 LEVEL OF MANUFACTURING PRACTICES IN INDUSTRY:

In order to assess the perception of manufacturing practices, we propose an analysis based on the familiarity (know how) and usage (practicing) of the manufacturing methods/systems. The questions asked in this section were linked with the objectives analysis section as described above. The respondent were asked to rate the systems used on a 5-point scale in terms of usability (practicing).

In Optimized Production Technology (OPT), objective is achieving improved efficiency and processes, streamlining of operations, minimizing waste time etc which reduces per unit cost. The major beneficiaries for such systems are 'protector manufacturers' as major concern for them is efficiency i.e. 'capacity utilization' to reduce cost per unit. The use of Total Quality Management (TQM) is rated top by respondents and its applicability exists for 'protector, offensive and innovative' manufacturers respectively. The other systems/methods are Break Even Analysis (BEA), Advanced Manufacturing System (AMS), Process Capability Analysis (PCA), Activity Based Costing (ABC), Group Technology (GT), Value Analysis (VA), and Just in Time (JIT). The relevance with strategic objectives is presented in table3.3. Value analysis and Just-In-Time production systems were identified as the least practiced manufacturing methods/systems in the industry.

The results of the survey are briefly presented as under:

OPT: 16.7% stated that they have been practicing it for last one year, 46.7% are in state of considering it and 26.7% have not yet considered it while 10% are unaware of it.

PCA: 30% stated that they have considered it over last one year, 60% are in state of consideration and 10% have not considered it.

BEA: 53.4% have been considering it over last one year, 3.4% for last 2 years, while 43.4% are in consideration phase.

GT: 13.4% are practicing it over last one year, 46.7% are still in consideration stage and non consideration percentage is 40%.

AMS: Fifty percent of respondents are using AMS like CNC's or other automatic/semi-automatic machines for last one year, 13.3% for last two years respectively. Consideration and non consideration make up 6.7 and 30 percentages sample respectively.

ABC: 16.7% have implemented activity based costing in their shop floor over last one year, 56.7% are in consideration phase, while 26.70% have not yet considered it as useful.

VA: Surprisingly, 26.7% are only in consideration stage, 56.7% have not considered it and 16.7% are unaware of it.

JIT: Only 10% are in consideration phase, while 90% are not considering it.

TQM: 13.4% & 56.7% have been practicing it for the last one and two years respectively. 23.4% are in considering stage and still 6.7% have not yet considered it as important system for industry.

In general, overall ratings for manufacturing management systems in percent are; 2.96% are unaware, 32.6% not considering, 35.3% considered it, 25.7% and 3.4% practicing for last 1 and 2 years respectively as shown in figure 3.14. In order to analyze level of manufacturing management practices, we introduce breadth and depth concept. The breadth dimension is assessed by the number of respondents who are considering and practicing the methods/systems, whereas, depth only assesses what respondents are actually practicing. The 'breadth' is the level of understanding of the manufacturing methods/system under consideration and 'depth' is what companies actually practicing for last years.

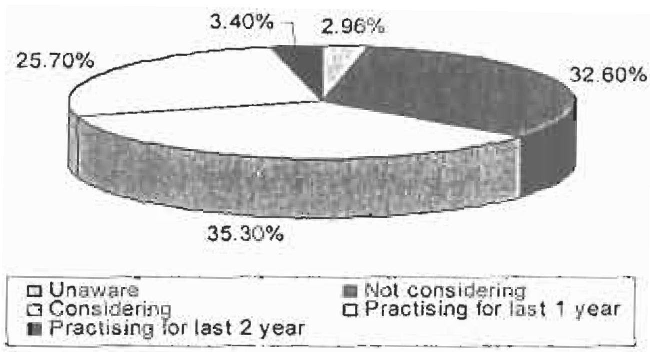


Figure 3.14 Percentage of overall usage of systems

Activity (Practice)	*Mean*	*Standard error*	***Relevance with strategic objective***	***Description/ Meaning***
TQM	3.7	0.1412	Protector/offensive /Innovative	- Continuous improvement - Quality enhancement
BEA	3.6	0.1028	Protector/offensive	- Feasible technology Decisions - Make/Buy - decision making
AMS	3.47	0.1961	Offensive	- Flexibility - Product mix
PCA	3.2	0.1114	Protector/offensive	- Process capability - M/c replacement decision making
ABC	2.9	0.1208	Innovative	- Costing at activity level - Value added costing
GT	2.74	0.1262	Protector/offensive	- Cells formation - Flexible manufacturing - Balancing of production lines
OPT	2.7	0.1600	Protector	- work contents among stations
VA	2.1	0.1208	Innovative	- Cost~ Importance
JIT	2.1	0.0557	Offensive/Innovative	- Improving supply chain - Vendor relationship

On five-point Likert scale (interval scale 1-5: 1, not familiar with; 5, practicing for last 1 year)
Mean and standard errors were derived from descriptive statistics

Table 3.3 Relationship of three strategies with practice

Therefore, breadth and depth are calculated by the familiarity and usage percentages as under:

Breadth: respondents who are familiar with methods = 35.3% + 25.7% +3.4% = 64.4%, and Depth: respondent who are actually practicing the tools within their shop floor = 25.7% +3.4% = 29.1%, therefore, ***Breadth = 64.4%; Depth = 29.1%.*** *This showed that breadth (information about systems/methods) is moderate (manufacturers are aware of tools/techniques/methods), but depth is low (level of actually practicing). This comes out that companies are not practicing what they know which hampers them to become competitive in the marketplace. Therefore, we concluded that companies in strategic objectives have responded well, but actual practice is far from their stated strategic objectives. So, having right objectives may not lead to superior performance, but operating without them guaranteed to lead to competitive disadvantage.* ***This calls for proposing a framework in the world of possibilities making use of known techniques/tools in a systematic and orderly manner to effectively cope with the existing manufacturing environment effectively.***

3.3.3 ANALYSIS BASED ON PRODUCT PROCESS MATRIX (PPMx)

Three types of manufacturers have been identified in the previous section are protector, offensive and innovative. In order to assess industry current scenario by suggesting normative path, there is a need to effectively use standard platform. One such platform is Product Process Matrix (PPMx) which has been extensively used for analyzing industries based on volume vs. product variety. It is evident in the previous section that ***'medium volume- low variety'*** manufacturing environment has been identified, therefore, it is imperative for industry to operate near economical production diagonal as suggested by (Hayes & wheelwright, 1984; Akhtar et al 1993, Hill 2000). The major role is to shift industry to a more viable place in PPMx without much capital involved at first stage using known techniques. The object is to obtain increase in productivity by being more efficient and overcoming losses. The tools for protector manufacturers can be any traditional approaches like line balancing technique, stream lining of operations, minimizing non produtive times etc which will help reduce operational losses and hence allow production to increase thus reducing per unit cost. This is now operating just same as in mass production system.

In next stage, flexible processing systems are needed to increase variety to accommodate number of models and improve product quality. Use of advanced manufacturing systems is feasible as it can accommodate any design changes made. The changeover between production runs takes time called the setup time or changeover time. It is the time to change tooling and to set up and reprogram the machinery. This is lost production time, which is a disadvantage of conventional/traditional manufacturing systems. The major role of offensive strategy is to shift from traditional manufacturing system to different level of automation (as per requirement) which are more agile, improve product quality and enhance responsiveness to capture the world market. In the competitive environment the significance of value addition cannot be over-emphasized. In innovative strategy, those processes (manufacturing or business) are eliminated which do not contribute higher value to the product i.e. more costly and less important. The value deliberately implies looking at cost – importance relationships of the manufacturing processes involved. This allows even higher volumes and variety due to the additional purchase power of the customer in the developed world. The normative route (complete discussion of strategy formulation will be discussed in chapter 4) for three strategies which is given in the main framework and shown in figure 3.15.

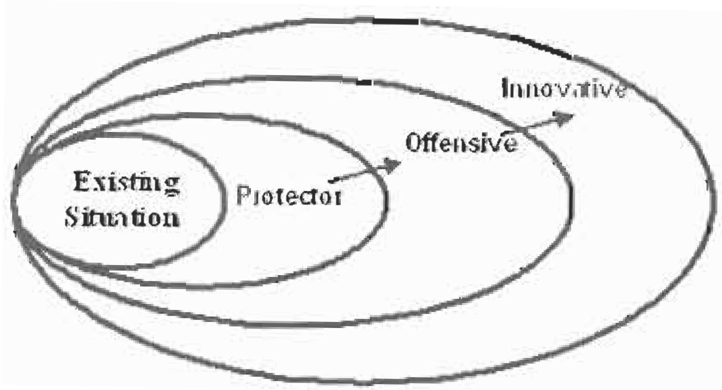


Figure 3.15 Route of three strategies (Jahanzaib & Khalid, 2005)

3.3.4 MANUFACTURING STRATEGY FRAMEWORK

The framework presented in chapter 4 can deal with strategic objective of low cost, high quality/customer focused and innovative in an orderly manner. The framework starts by comparing existing industrial sector analysis (capacity, technology/manufacturing capabilities) and current market environment. The comparison results in identifying competitive drivers and hence setting the objectives accordingly. Based on the objective settings and competitive drivers, manufacturing option strategy is formulated with three types of manufacturers identified in our survey/benchmarking exercise. Having selected an objective e.g. either low cost, high quality/flexibility and innovation, strategies are formulated with objective, operationalization and continuum. The triple strategies are 'protector' corresponding to low cost, 'offensive' corresponding to quick response to customers and 'innovative' corresponding to product differentiation respectively.

Simulation as a tool is used and model is developed using data obtained from case companies. Experimentation is performed by changing the base values to see its impact on performance measures. Slopes of the functions are then computed using standard spreadsheet software (MS Excel®). The values are prioritized based on decreasing order of sensitivity. Performance measures important for case companies related to three strategies are discussed with the company's management. The model results are finally prioritized to be used to achieve competitive edge. The framework will be explained in chapter 4.

3.4 CONCLUSIONS

This chapter surveyed the automobile industry of Pakistan as there are no significant studies available for utilization by manufacturers. A questionnaire was designed in consultation of practicing managers, EDB executives and vice-chairman and surveyed similar type of questionnaire (Sexana 2000, G. S. Dangayach, 2001). It is interesting to note that no such significant work for assessing industry available in international literature. The following conclusions are drawn from the survey/benchmarking exercise of industry:

i. The response rate was 33.4%, which is adequate for this type of survey in fragmented industry of auto parts manufacturers.

ii. The manufacturers rated agility, supply chain and faster product development as the most important strategic objectives, but are still operating and running business in conventional ways.

iii. The manufactures are quite aware of the techniques/ methods used for improvements in industry. In order to identify level of tools/ techniques practices, we have calculated breadth and depth approach. The breadth assess the manufacturers know how about system/methods and depth spot out what manufacturers are actually practicing. Based on breadth and depth percentages, it is found that breadth (know how of systems) is moderate, but depth (practicing within shop floor) is very low. This illustrate that manufacturers are aware of strategic objectives, but their practices are far away from their stated goals. Having right objectives may not lead to superior performance, but operating without them would guarantee to lead to competitive disadvantage.

iv. The companies are facing obstacles of supply chain management, which is due to unreliable vendor supply system which would hamper manufacturers to become externally focused (customer satisfaction) because of longer supply time of material. This can be overcome if vendor would become reliable by eliminating weaknesses in the system (zero defect/JIT etc). An in-depth study should be carried out for utilization by manufacturers which would cut out waste time from the system (from supply chain perspective).

v. The quality practices are at infancy stage as companies are not focusing on continuous improvement philosophies both in products and processes. The defect rate before rework would be achieved by proper training of human resources and using advanced manufacturing systems for quality improvement. One way of improving quality is through automation. It is essential for manufacturers to improve product quality and reliability as market scenario is changing rapidly which is offering pressure on manufacturer to become competitive.

vi. None of the manufacturers are practicing cellular layout which is generally considered as one of the pre-requisite to become world class manufacturers. The manufacturers are using product type layout which help them to become mass producers, but turn into external focused manufacturers (for exports), require systematizing their shop floor to meet the customer expectations (accommodating variety). This would be possible by reorganize shop floor layout.

vii. The longer setup times forces longer lead times, which slow down manufacturer's performance. Changeover/ setup time play an important role in business settings which can be overcome by shifting their processes from traditional to automation. This not only reduces lead time and setup time but also improves quality and accommodates product flexibility.

viii. Companies are far away from R&D activities as many few companies have separate R&D centers. This would be achieved if companies focus to establish training schools and design centers for training man power on multiple skills. Off-line simulation and virtual software training should be part of such school curriculum.

ix. An analysis is performed to identify the position of industry on PPMx matrix. The production volumes and variety information has been collected from manufacturers in questionnaire. It showed that companies are clustered in medium volume low variety location on PPMx. Therefore, it is found that automobile discrete parts industry lie in medium volume-low variety place. This is not economical as companies have made investments either to become mass producer (high volume- very low variety) or batch type manufacture (medium volume-medium variety) but lie in medium volume- low variety cluster.

x. The findings of the survey exercise identify three types of manufacturers by comparing their stated objectives with internal trends. The manufactures are termed; 'Protector', 'Offensive' and 'Innovative' corresponding to low cost, high quality with customer focused and value added ones to outperform competition. In this classification, 70% companies claimed that they are practicing tools/techniques of offensive manufacturers. It is found that they have achieved a very necessary not a significant condition.

xi. There exists a relationship between three strategies when companies shift from existing situation to a more viable place on PPMx. It is found that a relationship exists among manufacturers in normative way.

This chapter described research methodology and analyzed a questionnaire based on a comprehensive survey in order to access level of manufacturing management practices, objectives of the manufacturers, and basic infrastructure i.e. quality practices, volume versus variety information and questions related to human resources etc. The results of the survey/benchmarking exercise identified three types of manufacturers i.e. 'protector', 'offensive' and innovative corresponding to low cost, customer focused with high quality and innovative with rapid product development capabilities. Analysis based on PPMx is also presented which spot out 'medium volume- low variety manufacturing environment in automobile industry. This lead us to develop a framework for operationalizing of strategies as identified in our survey/benchmarking exercise. The framework which consists of four phases is presented in chapter 4 for assisting manufacturers to cope with manufacturing environment.

CHAPTER 4
THEORETICAL CONSIDERATION-MANUFACTURING STRATEGY FRAMEWORK

CHAPTER 4

THEORETICAL CONSIDERATION-MANUFACTURING STRATEGY FRAMEWORK

4.1 INTRODUCTION

There exists a significant gap in the existing literature to address low cost, high quality/ agility and innovative differentiated products manufacturers as analyzed in survey/benchmarking exercise. Three types of manufacturers have been identified to cope with low cost, high quality and innovative issues in chapter 3. A company may opt for being the lowest cost producer (protector manufacturers), highest quality/customer focused (offensive manufacturers) and product differentiators (innovative manufacturers) with improved customer satisfaction level. Each of these competitive advantages forces the organization to adopt a particular manufacturing strategy, which may in turn demand a particular type of manufacturing system, organizational set-up, material handling methods, information processing and manufacturing control systems. To overcome the limitations above, we propose a framework for manufacturing strategy analysis appropriate for the environment portrayed in the objective and manufacturing industry practices and is shown in figure 4.1.

4.2 THEORETICAL FRAMEWORK

It starts typically by comparing existing industrial sector analysis (capacity, technology/manufacturing capabilities) and current market environment. The comparison results in identifying competitive drivers and hence setting the objectives accordingly. Based on the objective settings and competitive drivers, manufacturing option strategy is formulated with three types of manufacturers identified in our benchmarking exercise. Having selected an objective e.g. either low cost, high quality/flexibility and innovation, strategies are formulated with objective, operationalization and continuum. The triple strategies are 'protector' corresponding to low cost, 'offensive' corresponding to quick response to customers and 'innovative' corresponding to product differentiation respectively. Simulation as tool is used to develop models for analyzing real systems in question. Experimentation is performed slopes of the functions are then computed values prioritized by carrying out sensitivity analysis.

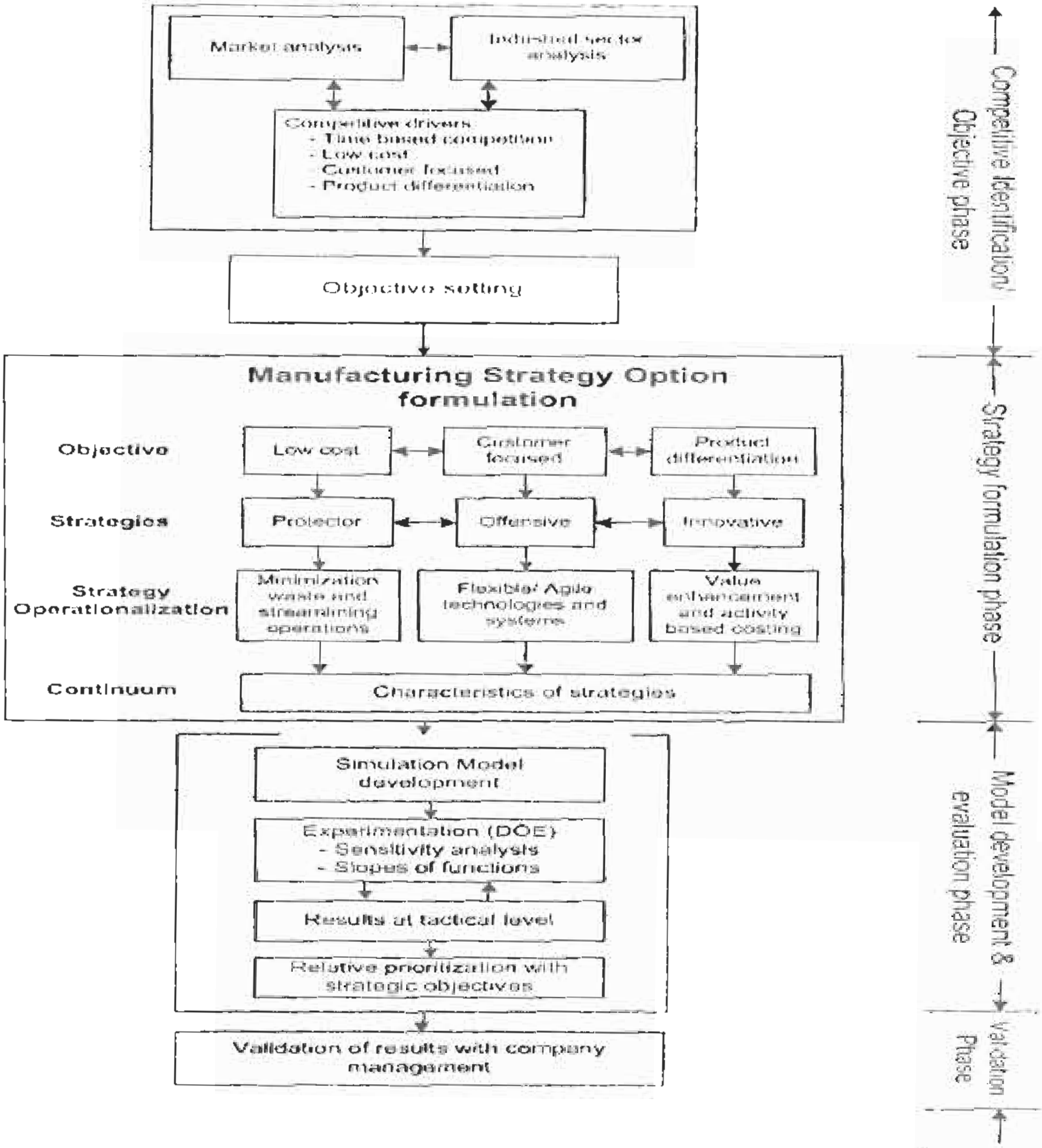


Figure 4.1 Manufacturing Strategy framework (Jahanzaib & Akhtar 2007)

The model results are finally prioritized to be used to achieve competitive edge and discussed with case companies' management. The theoretical framework for identification of market scenarios, formulation of strategies for types of manufacturers, model development/evaluation and validation is described in subsequent section below. The framework consists of following four phases and is shown in figure 4.1:

4.2.1 Competitiveness identification phase

4.2.2 Strategy formulation phase

4.2.3 Model development and evaluation phase

4.2.4 Validation phase

The main phases of the framework are described below:

4.2.1 COMPETITIVENESS IDENTIFICATION PHASE

In this phase market is analyzed, industrial environment is assessed to identify competitive drivers. In existing resources analysis; capacity, technology and human resource capabilities are assessed. Market situation, future trends and competition is analyzed in industrial environment analysis. This helps to understand the dynamic behavior so that objective setting can be accomplished taking into consideration the requirements of the market i.e. time based competition, low cost and high quality attributes.

4.2.2 STRATEGY FORMULATION PHASE

4.2.2.1 OBJECTIVE:

The benchmarking exercise helped to identify objectives of the industries, usability of the systems (depending upon the industry environment) and to assess infrastructure. This helps to choose a particular competitive advantage emerging as a result of the right combination of manufacturing strategies. These competitive advantages force the organization to adopt a particular manufacturing strategy which demands particular type of manufacturing system. This is explained with the help of cone type strategy trade-off diagram as shown in figure 4.2.

Three types of manufacturers have been identified i.e. protector, offensive and innovative as shown in figure 4.2, which forces to plan for a trade-off to cope with existing manufacturing environment. Strategy names already identified from benchmarking exercise are 'protector' for capacity utilization objective is to reduce cost; 'offensive' with high quality/flexibility and product differentiation for 'innovative' respectively. As stated in the literature the work of (Hayes and Wheelwright 1979a, 1984), (K Akhtar et al 1993), (Hill 1993, 2000), (G. S. Dangayach 2001), (Safizadeh

1996), (McDermott et al 1997), (Ahmad 2002), (Ariss S 2002), (Voss C, 2005), (Taps et al 2005), (Skinner 1985) and (Johansson P et al 2006) are significant in this regard.

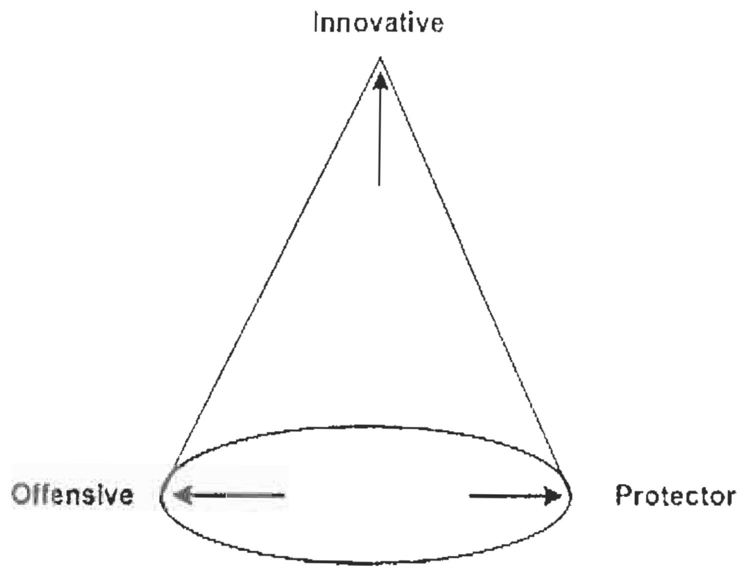


Figure 4.2 Cone type Strategy trade-off diagram (Jahanzaib & Akhtar 2007)

4.2.2.2 STRATEGIES

Referring to the figure 4.2, we introduce the strategies, which are identified during benchmarking survey. The definitions for strategies are:

'Protector Strategies' are the set of decisions as a result of which organizations achieves low cost producer status. Using traditional approaches like line balancing, world load control; line is balanced which help to reduce cost by minimizing waste time/operations hence reducing cost. The word 'protector' is used as a defensive approach for manufacturers to produce at lowest cost using traditional approaches so as to become low cost producers. 'Offensive strategies' are derived from the set of decisions which results in the production with high quality, flexibility and customer focused. Technology Driven Strategy (TDS) framework as an offensive strategy is also implemented for analyzing the means of improving productivity by improved manufacturing systems and increased automation. The focus is to find out the impact of costs when manufacturing organizations replace manual work with automation. Automation does not allow poorly designed products and inefficient processes to exist (Russell and Taylor, 1998). 'Innovative strategies' are derived from the set of decisions which results in the organization undergoing value adding changes with high customer service so as to become market differentiators with an emphasis on outperforming the competition. Over the last decade or so, there appear to be a clear grouping of work in terms of three types of strategies: Hayes and Wheelwright (1979a, 1984), Hill (1993, 2000), Safizadeh (1996), Ahmad (2002), Ariss S (2002), Voss C (2005), Stig B et al (2005) and Johansson P et al (2006).

4.2.2.2.1 PROTECTOR STRATEGIES

Protector strategies correspond to a least cost producer as major emphasis is capacity utilization and focused towards internal issues. By utilizing capacities and minimizing waste times, streamlining of operations reduces cost per unit. We find following strategy names given to them: Defenders (Louis, 2004; B.C Ghosh 2001), Defensive (Akhtar et al 1993), Care taker (Miller & Roth 1994), Idlers (Frohlich 2001), Reactors (Bryan 1999), Starters (Kathursia 2000), Low emphazer (Frohlich 2002), Quick fix (Jugulum 1998), Quick relief mode (W. Acar 1989).

4.2.2.2.2 OFFENSIVE STRATEGIES

Offensive strategies correspond to a flexible, customer focused and high quality producer. The major role of such manufacturers is to produce high quality of parts with external focused i.e. customer related. This would be achieved using combination of advanced manufacturing systems/technologies and improvements in human skills and management practices. We find following strategy names given to them: Technology driven (B. C Ghosh 2001), Aggressive (Akhtar 1993), Analyzers (Louis 2004) Prospectors (Bryan 1999; Morgan 1998), Dynamism (Zahra 1996), Designers and servers (Frohlich 2001), Do all (Kathursia 2000), Quality customizer (Frohlich 2002), Catch up (Jugulum 1998), Performance driven (2003). An analysis is carried out to see impact of selecting level of automation/technology in Pakistani discrete parts manufacturing industry (Jahanzaib & Akhtar 2007). It is quite helpful for manufacturers when they shift their business towards automation. An offensive strategy (for technology system analysis termed as *Technology Driven*) is proposed for analyzing the means of improving productivity by improved manufacturing systems and increased automation. The focus is to find out the impact on costs when manufacturing organizations replace manual work with automation. Automation does not allow poorly designed products and inefficient processes to exist (Russell and Taylor, 1998). There is a lot of pressure on Pakistani manufacturers to increase their product quality and reliability particularly due to increasing competition and likely changes in the world trade structure. It is therefore, imperative for the industry to improve its productivity and competitiveness. One way of achieving this competitiveness is through automation. However, no such studies are available for utilization by the manufacturers in Pakistan. So there is a need to address this area which would help local manufacturers to use more scientific base rather than educated guessing in selecting appropriate level of technology for manufacturing system.

Technology driven consists of three modules 1) Data module, 2) Expression module and 3) Output module as shown in figure 4.3. The three modules are briefly discussed as under;

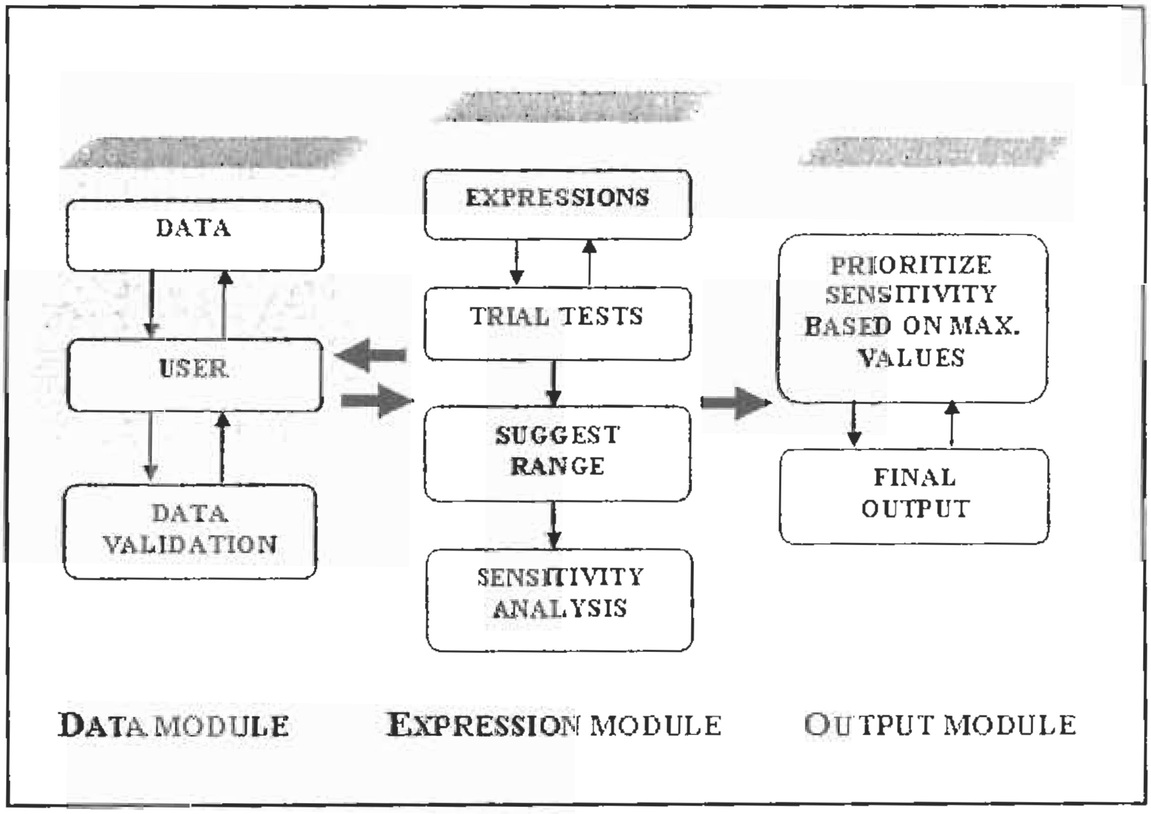


Figure 4.3 Technology Driven Framework (Jahanzaib & Akhtar 2007)

DATA MODULE:

Industrial data from the same product class manufacturing companies are analyzed and validated for the purpose of use. Various costs contribute towards the selling price of a finished product including, manufacturing costs, design R&D costs and overheads (typically marketing, sales, customer service and administration costs). The percentage of total cost attributed to manufacturing is about 40%, design R&D costs are about 15% and profit about 20%. These figures vary in different organizations depending on the product and associated market. However, manufacturing costs are usually the single largest cost element in the selling price and can be broken down further into four main elements with typical percentages: parts and material about 50%, energy, plant and equipment depreciation almost 15%, direct labor nearly 10% and indirect labor about 25% (Mair 1993). It is essential that manufacturing costs be identified and properly classified to allow their appropriate allocation to a particular job (Meigs et al. 1999). The costs involved in producing a product can be classified as variable costs, fixed costs and sometimes semi-variable costs (Usry et al. 1988). Overhead costs typically include rent and rates, heating, lighting costs, office staff salaries, general laborers, store-men, insurance, equipment costs, depreciation on equipment and servicing costs, i.e. maintenance, etc. The majority of these costs are fixed because they are incurred irrespective of production rates. In order to determine the total overhead for each department, cost centers are identified within the company. This allows costs to be gathered together according to their incidence (Lucey 1996). The unit cost is the average cost of manufacturing a finished product. This is generally found by taking the total cost of production and dividing it by the number of units produced. It is also of utmost importance that the selected materials (both for the job as well as for the cutting tool) have appropriate properties that allow them to perform satisfactorily during service (Edwards & Endean 1990). In terms of cost, the higher the level of performance required, the greater the expense incurred. Therefore, the materials selection decision will generally be a compromise between performance and cost (Dieter 2000). The cost data is taken from different companies used for analyzing level of technology.

This is the main module in which data is entered in routines that are coded in a spreadsheet. These routines work like mathematical simulations offering what if scenarios by changing input design parameters (process parameters) one at a time to observe the impact of these changes on output (per unit cost). For this, trial tests are carried out and validated in expression module. The appropriate range is suggested after comprehensive analysis. Sensitivity analysis is carried out by changing the process design parameters like labor, machine cost, etc, as specified in the range. The next step is to obtain the slope of the function from sensitivity results. The mathematical expressions used in simulation process are briefly explained as follows:

The cost of production on an engine lathe is given by White (1989):

$$Cost/order = (direct\,labor\,cost + machine\,cost/unit + cutting\,tool\,cost/unit) * x \quad (1)$$

where x = units per order

Turret lathe differs from the engine lathe in that the tailstock of the engine lathe is replaced by a hexagon turret, which permits the mounting of multiple tools. The cross slide is made long enough to permit the mounting of another tool post of square turret at the rear of the slide. The turret may be indexed automatically so that each tool can be presented to the work piece in rapid succession (Boothroyd 1977). The subsequent section describes the equations which have been used in the analysis of technology driven in offensive strategy for selecting appropriate level of technology. For a turret lathe

$$Cost/order = setup\,cost/order * n + (direct\,labor\,cost + machine\,cost/unit + cutting\,tool\,cost/unit) * x \quad (2)$$

where n = no of setup per order

Transfer machines are used exclusively for mass production, the class of machine tool referred to as automatic is used in both mass and large-batch production. For automatic machines, it is assumed that one operator can service 'Na' automatic machines, that the operator's rate (including overheads) is W_o' and that the rate for one machine (including overheads) is M_t'. The cost of production C_{pr} per component will then be given by:

$$Cpr = Cb/Nb + (Wo' + Mt')t1 + (Wo'/Na + Mt')tm + [(Wo' + Mt')tct + Ct]tm/t \quad (3)$$

where, C_b = cost of setting up the machine (including manufacture of cams etc), N_b = batch size, t_{ct} = tool-changing time, C_t= cost of providing one new cutting edge, t_m = machining time, t = tool life and t1= loading and unloading time.

With automatics, programming is expensive and can be justified only for long production runs. However, with machines incorporating feedback control, programs can be provided in the form of punched tapes or punched cards, which are relatively inexpensive to produce compared with disc and drum cams. These machines are known as numerically controlled (NC) machines and can be used economically in small- batch production. For NC machines, the cost of the preparation for machining a batch of components C_b will mostly consist of programming costs. There is a direct relationship between these costs and the machining time 'tm' as follows:

$$Cb = Kp * tm \qquad (4)$$

where K_p is the cost of programming and tape-preparation per unit machining time.
The production cost per component is therefore given by:

$$Cpr = Kp * tm / Nb + M\,(t1 + tm) + tm / t\,(M * tct + Ct) \qquad (5)$$

where N_b = batch size, M = total machine and operator rate, C_t = cost of a tool, t = tool life, t1 = loading and unloading and tool-advance and tool-withdrawal time, and t_{ct} - tool-changing time.

In transfer machines the component is automatically transferred from one machining operation to the next either by a circular indexing table (the rotary-transfer system) or along a conveyor (the in-line-transfer system). It is assumed that on a transfer machine having 'Ns' stations the same cutting-tool material is used at each station. Therefore, for any stations s, the tool life relation is

$$Vs / Vrs = (trs / ts) * n \qquad (6)$$

where V_s = cutting speed, t_s = tool life, and V_{rs} = cutting speed for a tool life of trs. The machining time tm for each operation is given by

$$tm = Ks / Vs \qquad (7)$$

where K_s is the distance moved by the tool corner relative to the work piece during the machining time t_m, and related to

$$(Vrs * tm / Ks)^{1/n} \qquad (8)$$

The total time to produce Nb components is given by:

$$Nb\,(tt + tm)\,Nb \sum (tm\,tc * tc / ts) \qquad (9)$$

where t_l = time taken to index the machine and advance and withdraw the tools, t_c*t_s = tool changing time at any stations, and Σ = sum of the terms for all the stations on the machine. Thus, the average production time per component is

$$Tpr = tl + tm + \sum (tm\,tc * tc / ts) \qquad (10)$$

If the rate (costs per unit time) for each station (including the section of the transfer machine associated with that station) is M_s, the total rate for the transfer machine will be ΣM_s, and production cost per component C_{pr} will be given by:

$$Cpr = \sum (Ms * tpr) + \sum tm * Cts / ts \qquad (11)$$

where C_{ts} is the cost of providing a new tool at stations. Substitution of Eqs. (8) and (10) in Eq. (11) and rearrangement gives:

$$Cpr = \sum Ms(ts + tm) + tn^{1-1/n}\left[\sum Ms \sum \left[(Ks / Vrs)^{1/n} tcts / trs\right] + \sum \left[(Ks / Vrs)^{1/n} Cts / trs\right]\right] \qquad (12)$$

Equation (12) can now be differentiated with respect to 'tm' to find the machining time 't_{mc}' giving minimum production costs. Thus,

$$tmc = \left[(1/n - 1)\left[\sum [Ks / Vrs]^{1/n} tcts / trs\right] + \sum [Ks / Vrs]^{1/n} (Cts / trs) / \sum Ms\right]^{n} \qquad (13)$$

Output module

Based on the slopes of functions, process parameters are prioritized in order of highest level of sensitivity. The recommendations are based on mathematical simulation by carrying out sensitivity to get different responses at each level. Output responses are given in a narrative style so that users can comprehend it, and take right decisions at the right time, just like the case of knowledge based systems, which require intensive knowledge from experts and display results in common sense format.

TD METHODOLOGY

The mathematical routines relating various manufacturing process parameters with per unit cost have been presented and are taken from standard texts. Figure 4.4 shows the mathematical simulation flow chart. In data module, real life data from different manufacturers have been collected from industry. The data is used in expression module as described above in TDS framework. The relationships expressed in the formulas have been implemented in spreadsheet to set up corresponding mathematical models. This model behaves like mathematical simulation, as controllable input design factors can be changed one at a time to see the response at the output.

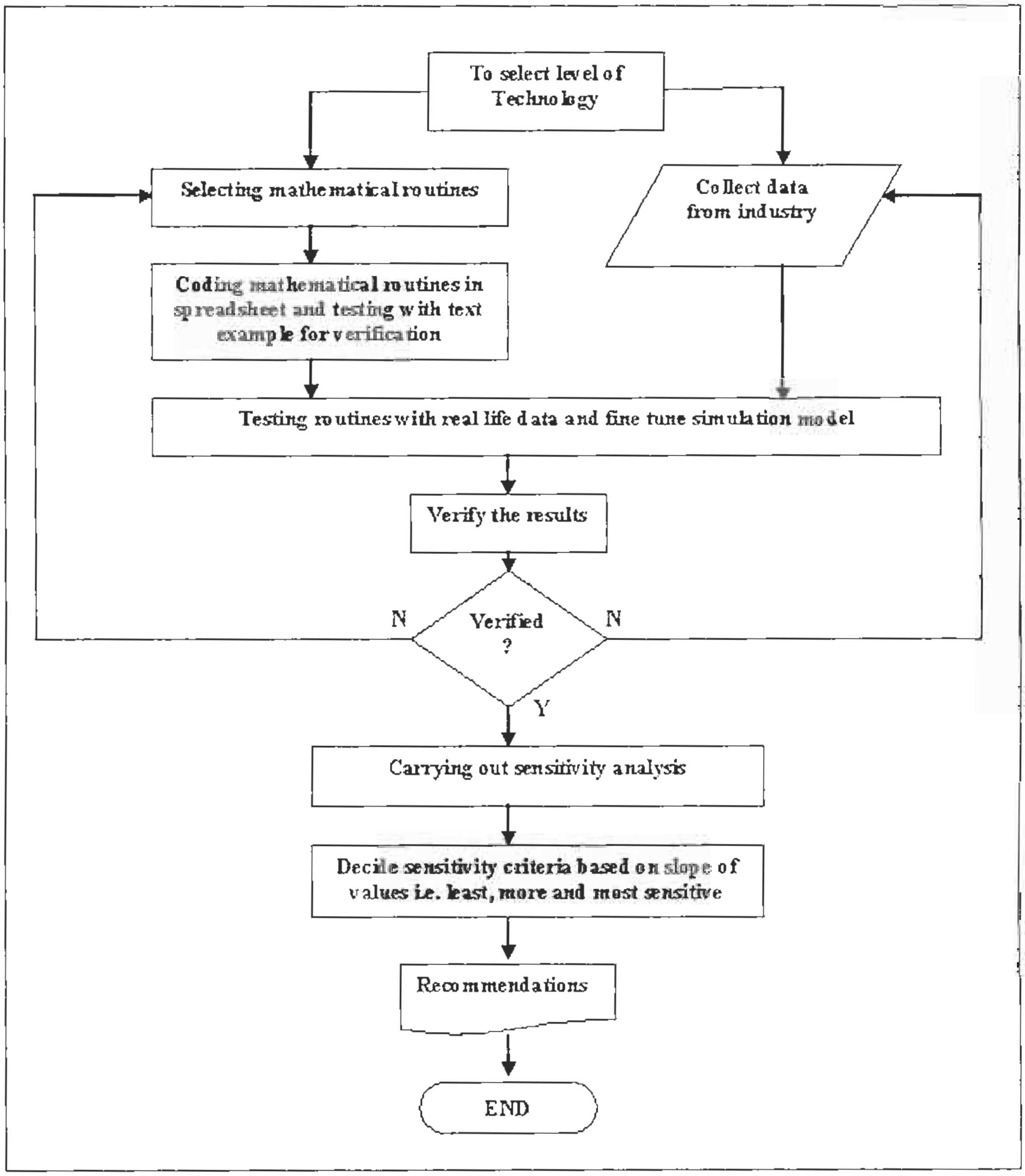


Figure 4.4 Flow chart of TD methodology

We are trying achieving the optimum results from the slopes just like in Response Surface Methodology (RSM) (Law et al, 2000). The next step in the expression module is trial testing which was done to ensure the correct setting up of these models.

Examples from the literature mentioned in the preceding sections were used. A comparison of the results obtained using spreadsheet models and the standard examples showed that the models have been correctly set up and perform as desired. Having validated the models through these examples, data pertaining to labor, machine rates, and other related parameters, were obtained from discrete part manufacturing industries in Pakistan. These comprised of manufacturers producing products like automobile parts as mentioned earlier. Average values of this set of data were used as base values for carrying out a detailed simulation analysis. The next step was to change one parameter at a time to see the impact on costs per unit for the five different levels of automation. Varying the parameters in small increments and observing the impact on per unit costs gave a greater insight into the economics of each automation level. A comparison of the slopes of these functions allowed us to identify the most sensitive, less sensitive and least sensitive process parameters. The base values were obtained from the Pakistani industries and given in Table 4.1. Sensitivity analysis was carried out taking 500 iterations for each case. This was done by changing the base values according to the plan as given in Table 4.2 (a) (b) and (c) respectively.

Table 4.1 Machine and Labor costs

(a) Machine Costs (Rs)			*(b) Labor Costs (Rs)*	
Levels	**Cost**	**Useful Life**	**Levels**	**Cost per Hour**
Engine Lathe	1,000,000	5	Engine Lathe	30
Turret Lathe	2,500,000	5	Turret Lathe	35
Automatic	4,000,000	10	Automatic	40
NC	9,500,000	10	NC	55
Transfer	45,000,000	15	Transfer	60

(1 US $ = Rs. 60.5)

Regarding validation process, a) the models have been tested with real life industrial data at data validation and expression module trial test stage. b) Sensitivity has been carried out after excluding the initial transient period. c) Data from a number of discrete part manufacturers was obtained and average figures used in order to reduce organization to organization variability. d) Results from sensitivity are generally consistent with findings mentioned in the literature in section above.

Table 4.2 Range of Sensitivity Analysis

(a) Changing Machine Rate	
Levels	**Base Value changed from**
Engine Lathe	Rs 0.072216 to Rs. 5.062216 (a step change of 0.01)
Turret Lathe	Rs 0.00828 to Rs. 7.49328 (a step change of 0.015)
Automatic	Rs. 0.00638 to Rs. 0.0313 (a step change of 0.00005)
NC	Rs. 0.1709 to Rs. 0.4204 (a step change of 0.0005)
Transfer	Rs. 0.23 to Rs. 2.725 (a step change of 0.005)
(b) Changing Labor Rate	
Levels	**Base Value changed from**
Engine Lathe	Rs 14 to Rs. 54.32 (a step change of 0.025)
Turret Lathe	Rs 12.95 to Rs. 87.8 (a step change of 0.15)
Automatic	Rs. 0.00035 to Rs. 0.0253 (a step change of 0.00005)
NC	Rs. 30 to Rs. 80 (a step change of 0.1)
Transfer	Machine rate (M) inclusive of operator's rate
(c) Changing Tool changing time, Setup, C_b, t_{rs}, n	
Levels	**Tool Changing Time, Base Value changed from**
Automatic	40.24 secs to 80.16 secs (a step change of 0.08)
NC	40.24 secs to 80.16 secs (a step change of 0.08)
	Number of setups (n) for Turret Lathe Base Value changed from
Turret Lathe	Setup after every 100 units to setup after every 1000 units
	C_b (Cost of setup) for Automatic Machines, Base Value changed from
Automatic	Rs 0.01966 to Rs 051866 (a step change of 0.0001)
	(t_{rs}) Tool Life, Base value changed from
Automatic	2000s to 8000s
Transfer	25s to 105s (a step change of 10)
	(C_{ts}) Cost of a tool, Base value changed from
NC	Rs 5.3 to 55.2
Transfer	Rs 100 to 900
	(n) Tool Material Exponent, Base value changed from
Transfer	0.111 to 0.25 (a step change of 0.0001)
	Overhead rates for all five levels, Base value changed from
All five levels	Overhead rate (100%) was changed from 25% to 225%

The results and final recommendations for this section will be presented in chapter 6 and 8 respectively.

4.2.2.2.3 INNOVATIVE STRATEGIES

Innovative strategies correspond to a high market differentiator. The main role for such manufacturers is to add more value at reduced cost. We find the following strategy names given to them: Futurity (Venkatraman 1989), Reactors (Morgan 1998; B C Ghosh 2001; Bryan 1999), Breakthrough (Jugulum 1998), Market differentiator (Frohlich 2001), Marketeers and innovators (Miller 1996), efficient conformers (Kathursia 2000), Innovators (Zahra 1996), Innovative (Akhtar 1993), Innovation (Zhao 2002) and Competing through manufacturing (Voss 2005).

4.2.2.3 OPERATIONALIZATION OF STRATEGIES:

Identification of manufacturers and strategies has been proposed in the above sections. This section describes operationalization of three strategies using bundle of approaches in an orderly manner. Minimization of waste and streamlining of production line are used for operationalization of protector players as major concern for them is capacity utilization to reduce cost per unit. Using techniques like line balancing and load oriented control to streamline the operations, minimize the waste time from the system and distribute work content equally among work stations. This balances the production line and system behaves like mass production as suggested by (Hayes and Wheelwright, 1984).

Flexible and agile systems are used in 'offensive stage'. As advanced manufacturing systems like CNC's do not allow poorly designed products and inefficient processes to exist (Russell and Taylor, 1998) and can accommodate any design changes for delighting customers, there is a lot of pressure on manufacturers to increase their product quality/reliability and product style particularly due to increasing competition and likely changes in the world trade structure. It is therefore, imperative for the industry to improve its productivity and competitiveness. One way of achieving this competitiveness is through flexible and agile systems. Group Technology (GT), AMS and other bundle of approaches can also be used in offensive stage.

Value enhancement and activity based costing are used in 'innovative stage'. Activity based costing uses costing at each activity level. On the other hand, importance versus cost in value analysis helps to identify more costly-less important activities. An in depth study of competitor product and applying value analysis tear down approach is also recommended at this stage. This may help to add value to product and perform well in the market after implementation of both tools.

4.2.2.3.1 MOVEMENTS ON PRODUCT PROCESS MATRIX

As it is stated in chapter 1 about challenges faced by manufacturers like inadequate infrastructure, lack of knowledge about competition etc, it is imperative to use standard tool like Product Process Matrix for explaining typical characteristics of each strategy type. As discussed about Product Process Matrix (PPMx) in literature review, that different type of process structure provide different competitive advantage, e.g. standardized process emphasizes on reliability and cost, where as combination of flexible and some dedicated processes provide flexibility both in volumes and product. PPMx provides a natural way for managers in planning process to effectively organize marketing strategies to achieve corporate goals. It starts with a company using traditional manufacturing resources and enters in the market with low degree of automation. After some times, it stabilizes and need improvements in business. The company is more interested in standardization as product variety demands capital intensive technology and human resources. The goal at this stage is minimizing waste times, streamlining of operations using some traditional industrial engineering approaches like balanced production lines and work load oriented control. These help reduce operational losses and hence allow production to increase and reducing the costs. The effect of these tools will result in higher utilization of the resources and allow higher volumes as shown in figure 4.5.

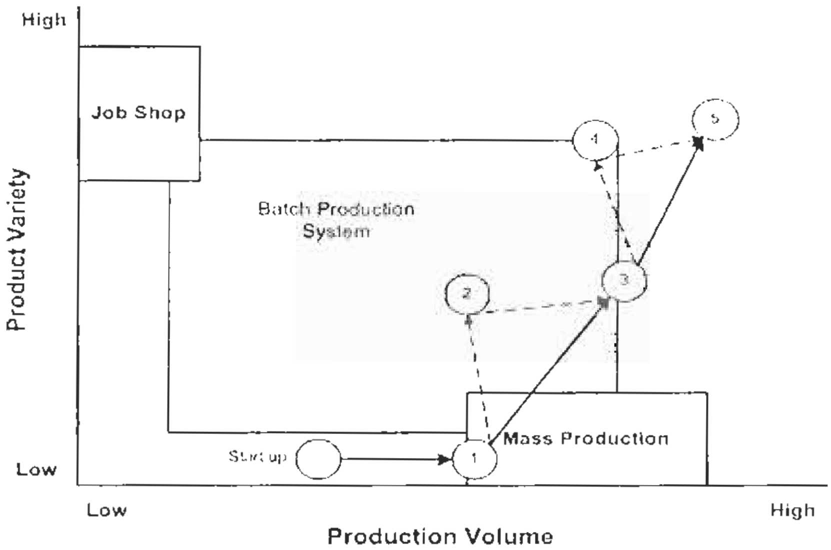


Figure 4.5 Movement on PPMx (Jahanzaib & Akhtar 2005)

The production systems now operate in mass production system mode. At stage 1, which is named as 'Protector Players' in our benchmarking exercise, some key characteristics for interest are capacity utilization, speed of process (after minimization of waste times and streamlining of operations) etc as given in table 4.5. To expand business and enter into the next stage, other than significant investments, company need to understand typical characteristics as increased investment raise the company's break even point offsetting gains from increased sales volumes. In stage 2, company can add less standardized, more flexible processes in an attempt to increase quality and more responsive to customer. It is argued that if a company continues to utilize traditional systems and try to incorporate flexibility, it may lead to inappropriate process and organizational structure and it may face issues like production planning and control with existing process flow. For coping with customized orders, company may opt flexible processes by properly analyzing existing resources and market demand. Typical characteristics help managers for migrating from traditional to higher degree of automation at stage 2. The company in next stage needs research and development activities like value analysis tear down, activity based costing to out perform competition both in product importance and cost. At this stage, company faces complexity in growth and deals with introducing new products much faster to delight customers. Company invests on human resource, research and development activities in order to increase share in the market by adding more value to product at reduced cost. This is shown in stage 3 on PPMx. Typical characteristics of each type of strategy defined above are outlined in table 4.5.

4.2.2.4 CONTINUUM:

If cone type strategy trade-off diagram as shown in figure 4.2 is considered to represent a continuum instead of discrete strategies, then figure 4.2 can be redrawn with some roughly marked points representing known manufacturing strategies corresponding to generic business strategies. For example in figure 4.6, point (1, 3, and 5) denotes highly protector, highly offensive and highly innovative strategies. Since the diagram is illustrating a continuum, we can locate two more points, namely (2 and 4). Point (2) denotes semi protector, semi offensive and less innovative strategies, while point (4) denotes partially protector, semi offensive and fairly innovative strategies.

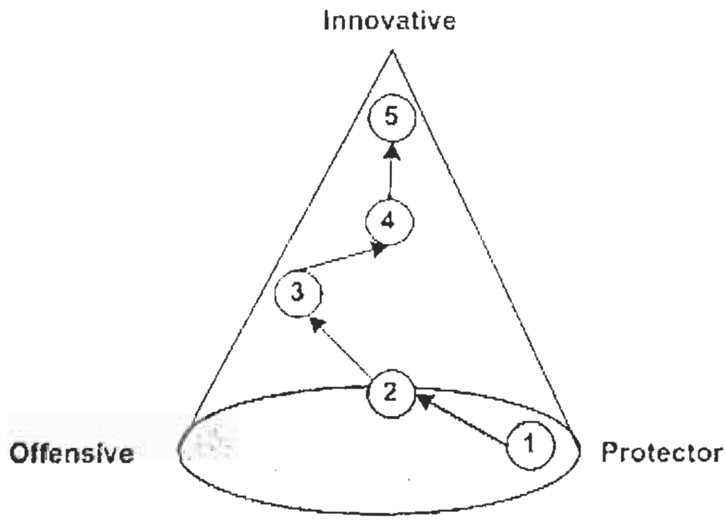


Figure 4.6 Manufacturing Strategy trade-off paths (Jahanzaib & Akhtar 2007)

In the literature, we can find references of point (2) in terms of world class competitor, along with following strategy names given to them: Prospectors (Barbara, 1998), Market driven (Hawawini, 2003; Weerawandena, 2006), Stretch (M. T Sweeney, 1990) and Market oriented group (A De Meyer, 1990). As regards point (4), a closer study of the literature reveals that point (4) actually denotes what has been defined for point (5), because very few companies have ventured to take the risk of applying these strategies. Some of the names given for point (4) are: Incremental innovation (Nirmalya, 2000), and

Technological innovation (Zhu, 2007). In most cases point (4) comes out to be the turning point and after some time, companies again move to point (1) and (3) for cost reduction and agility. From the foregoing, one can conclude that this strategy is fairly robust as it can accommodate a large number of manufacturing types (protector, offensive and innovative) mentioned in the literature. Since these strategies described in the literature have been suggested after rigorous empirical investigations, our proposed model is assumed to be practical, close to reality and helps us to explain the spread over continuum and work as helping aid for manufacturer to understand competitiveness. Typical characteristics of each type of strategy defined above are outlined in Table 4.3.

Characteristics	*Protector*	*Offensive*	*Innovative*
<u>Shop Floor related</u>			
level of automation	Low	Medium/High	Very high
Hierarchical levels	Low	Medium/High	Very high
Training needs	Focused	Flexible	Diversified
Labor force requirements (multi skills)	Low	Medium /High	Very high
Real time information	Low /medium	High	High
Equipment type	General purpose/ Some specialization	High technology	Low and high technology
Level of automation in material Handling	Low	Medium / High	Very high
Speed of Decision making	Low	High	Very high
<u>Hardware related</u>			
Production methods	Manual/ Rigid automation	Flexible automation	Flexible automation/manual
Capacity	High	Medium	Medium
Addition to capacity	Incremental, needs rebalancing	Varies	Incremental over wide range
Utilization	Very high	Medium /High	Medium
Ability to cope with flexibility	Very low	Very high	High
Set-ups	Large	Small	Medium /small
System reliability	Medium	Very high	Very high
Speed of process	Fast	Fast /moderate	Moderate
Process standardization	Very high	Medium	Low
Bottlenecks	Known and stationary	Shifting frequently	Shifting frequently
Process flow	Rigid flow pattern	Flexible flow	Flexible / one or two dominant patterns
Number of new products per Unit time	Low	High	Very high
<u>Control related</u>			
Waste control	High	Very high	High / medium
Material requirements	Very Predictable	Predictable	Difficult to predict

Raw material inventory	Frequent delivery	Moderate	Small
Cost control	Very high	Low /medium	Low
Throughput time control	Low	Very high	High
Production planning & Control	Low /Medium	High	Medium /low
Queuing time control	Low	Very high	Medium/ high
Efforts on scheduling	Low	High	Medium
Workforce related			
Work life (fatigue)	Medium	High	High
Pay (performance based)	Low	High	Very high
Pay (skill based)	Low	High	Very high
Educational needs	Low	Medium/ High	Very high
Computer aided Information	Medium	Very high	High
Maintenance efforts	Medium	Very high	Medium

Table 4.3 Characteristics of Strategies

4.2.3 MODEL DEVELOPMENT AND EVALUATION PHASE

In this phase, simulation as tool is used to develop model. Then experimentation is performed by varying the input parameters and seeing its effect on output variables. The model results are validated with similar type of analysis carried out in spreadsheet and sharing with case company management.

4.2.3.1 SIMULATION MODEL DEVELOPMENT

This is in fact not a single model but a group of models to satisfy various needs. It may have analytical queuing models or detailed simulation models prepared by using software like Arena, ProModel, and Witness etc (Banks 2002). The purpose is to simulate the real world situation as closely as possible, by selecting key performance measures.

In our case we may prepare simulation models to monitor utilization of resources (protector trait), product mix/customer focused/high quality (offensive trait) and value addition/flow time to outperform competitor (innovative trait). The model also incorporates the effect of uncertainty in case of new product development (NPD). For example, in the case of innovative trait, learning curve phenomenon must be included in the model as it affects the capacity of work cell whenever new product is introduced. This in turns affects material planning and procurement processes and makes model more complex, but it would be close to reality.

4.2.3.2 EXPERIMENTATION

Designing of simulation experiments essentially involves selection of performance measures, factors that would have to be varied, and the levels of each of these factors that we want to investigate. The series of experimental scenarios and the ranges of values used for carrying out sensitive analysis are required. The model behavior is analyzed by carrying out sensitivity analysis. Sensitivity analysis is carried out by varying the values of the model's parameter and seeing how these changes affect the system. This is done with the objective of ascertaining sensitive parameters. Two kinds of analysis have been performed. The time dependent effect in terms of the pattern, secondly the change in average (or maximum) numerical values of the parameters in question. The effect was observed with respect to the slope of the functions, e.g. a large slope signifies a 'considerable effect', comparatively less slope signifies a 'moderate effect' while very little slope represents a 'nominal' or very small effect. These scores can also be placed against each model parameter for relationships that have to be studied. The prioritization so obtained is based according to equal priority to all factors.

4.2.3.3 VALIDATION OF THE MODEL

A simulation model provides excellent opportunity for obtaining an analysis of the casual behavior of the underlying process. However, two types of validations are always required. Correctness of the internal structure, as well as nature of the output results, dictate the degree of user confidence in validity of the model. They are a) simplification of assumptions, b) transient behavior c) bias in the random samples and d) accuracy of the data (Law M & Kelton, 2000). The assumptions are simple and did not affect the outcome of the model because they are made using real world system. Simulation runs is carried out including warm-up period for long time (525 hours) so that system gets stable to minimize randomness in results. 't-test' is also carried out so as to obtain the sensitivity of performance measures under study. Mathematical routines for each module are tested separately using spreadsheet program.

4.2.4 VALIDATION OF RESULTS

The prioritized results are validated against previous studies and verifying the results with case company management.

4.3 CONCLUSIONS

This chapter described the manufacturing strategy framework. In this framework, market/industrial existing situation is analyzed, objectives are explored, manufacturing strategy is formulated (strategies, operationalization and its continuum) and model is developed for testing of proposed strategies. The model results are validated against previously published literature and verified with case company management. This is the pivoted part in research work by contributing a framework which can cope with industrial environment portrayed. The conclusions are presented below:

i. A generic framework has been developed to cope with industrial environment in discrete parts manufacturing. The framework is helpful for low cost, customer focused and innovator manufacturers. The way strategies are placed and progress on PPMx is unique.

ii. The industrial scenario is assessed by conducting a survey which was presented in chapter 3. This identified three types of manufacturers which are 'Protector', 'Offensive' and 'Innovative'. The strategies devised in strategy formulation phase are for these types of manufacturers.

iii. 'Protector Strategies' are set of decisions as a result of which organizations achieves low cost producer status. These manufacturers can be benefited by employing minimization of waste time from system. The ultimate benefits to become such type of manufacturer are to reduce per unit cost (produce in masses).

iv. 'Offensive Strategies' are set of decisions which results in production of customer focused with high quality and accommodating product variety. Productivity as well as product variety is improved using automation. This helps improve quality and reliability.

v. 'Innovative Strategies' correspond to produce in masses and variety as well. They are market differentiator and major role is to add more value to product at same or reduced cost and help to enhance exports.

vi. In strategy formulation phase, major role for three types of manufacturers have been elaborated with objectives/focus.

vii. The strategies are operationalized using traditional/conventional/state of the art industrial engineering techniques in a systematic manner. Each type of manufacturers is befitted and a continuum showed characteristics of three types of manufacturers.

viii. The strategies are tested taking data from case companies and model developed in manufacturing simulation Arena®. The model incorporates real life data and experimentation is performed to analyze behavior of system. The way simulation is used for analysis of strategies is distinctive.

A theoretical manufacturing strategic framework for coping with existing environment is proposed which consists of four phase. Existing industrial sector (capacity, technology/manufacturing capabilities) and current market environment is analyzed on objective phase. This resulted in identification of competitive drivers and setting of the objectives accordingly. Manufacturing option strategy is formulated based on the objective settings and competitive drivers, with three types of manufacturers identified in benchmarking exercise. The objectives are low cost, high quality/flexibility and innovative and strategies are formulated with objective, operationalization and continuum. A simulation model is developed which aid manufacturers to take corrective and timely decision making process in day to day business settings. The theoretical framework presented is unique in a sense; it can cope with low cost, high quality and innovation in a coherent and orderly manner. The framework provides manufacturers a sustainable solution to face challenges of marketplace to become competitive. The chapter 5 is about model development/evaluation in which detailed treatment of model development is described.

CHAPTER 5
MODEL DEVELOPMENT AND EVALUATION

CHAPTER 5
MODEL DEVELOPMENT AND EVALUATION

5.1 INTRODUCTION

In previous chapters, research questionnaire design/analysis and theoretical framework is presented. Three types of manufacturers have been identified as 'protector' corresponding to low cost, 'offensive' corresponding to customer focus with high quality and 'innovative' corresponds to product differentiators. A theoretical framework is also presented which consist of four phases as competitive identification/objective, strategy formulation, model development/evaluation and validation phases respectively. This chapter is about building of computer experimental model used for analyzing behavior of real system. The generic process flow and layout is defined with data requirements, bounds in the systems and necessary performance metrics/measures. Different solution methodologies like analytical methods, optimization theory, expert system and simulation are also reviewed. Manufacturing simulation as a tool is selected for modeling of real system under investigation. Operational data like processing times, current quality practices, frequency of up and down time of production line, operator schedules, process plans and model mix etc is modeled in simulation tool Arena®. Different modules are developed which work under proposed strategies and model is validated by t-test and more replications. The discussion with case company existing practices also verify model.

5.2 PROBLEM FORMULATION

The problem is formulated by defining the process flow of system, input/process data required, boundaries of the system and performance measures important for case companies. Based on the information, more appropriate tool for modeling is selected which aid manufacturers to analyze behavior of system.

5.2.1 PROCESS FLOW DESCRIPTION

In the case company studied (processing typical automobile parts) parts arrive from outside of system are send to next processing stage according to their due dates and production plans as dictated in process plan. Parts get delayed by processing time of first manually operated operation. It takes 10 minutes to machine the part at first manual operation and setup by the same operator. The parts then move to next manually operated similar type of machine according to process plan which take 10 more minutes to process the part. Quality control is performed at this stage; in which all kinds of reworking (if required) is done on the part. The part is transported to next operation in which critical bores and diameters are finished. The main feature of this operation is that both bearing bores are finished in single clamping so as to achieve perfect concentricity. High surface finish and accuracy is required in this process. Normally, it takes seven minutes to perform the required task; however, some fast reworking is also witnessed in which same operator rework the part on same stage otherwise part is sent to separate reworking stage and inspection is done at this stage.

The parts are then routed to next operation, which is performed on computerized machine and takes two minutes. The parts are then sent to computerized operation in which major work includes critical operations on each side of part, which take 20 minutes to perform this task. After this operation, parts which pass through the quality check leave the system as 'good parts'. The remaining parts are sent to reworking stage which is a separate stage dedicated for reworking jobs. The parts which fulfill quality test in reworking leave the system as 'salvaged parts', whereas parts which could not be reworked leave the system as 'scrap'. Stage wise inspections are carried out and parts are finally checked for any rework required. After reworking, the parts leave the system as salvaged and remaining are scrap from the system as shown in figure 5.1 and general layout in figure 5.2 respectively.

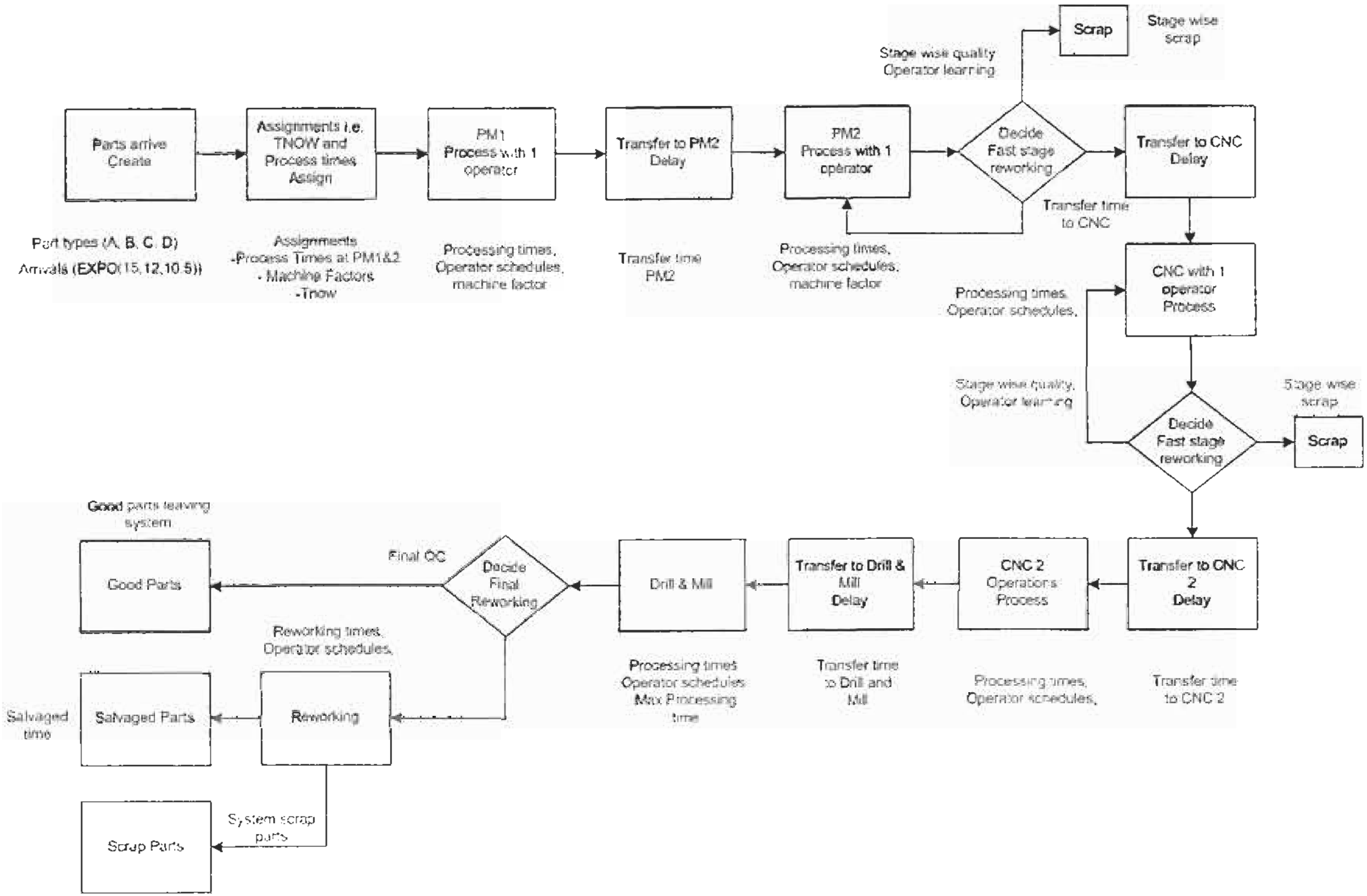


Figure 5.1 Process Flow diagram- case company production

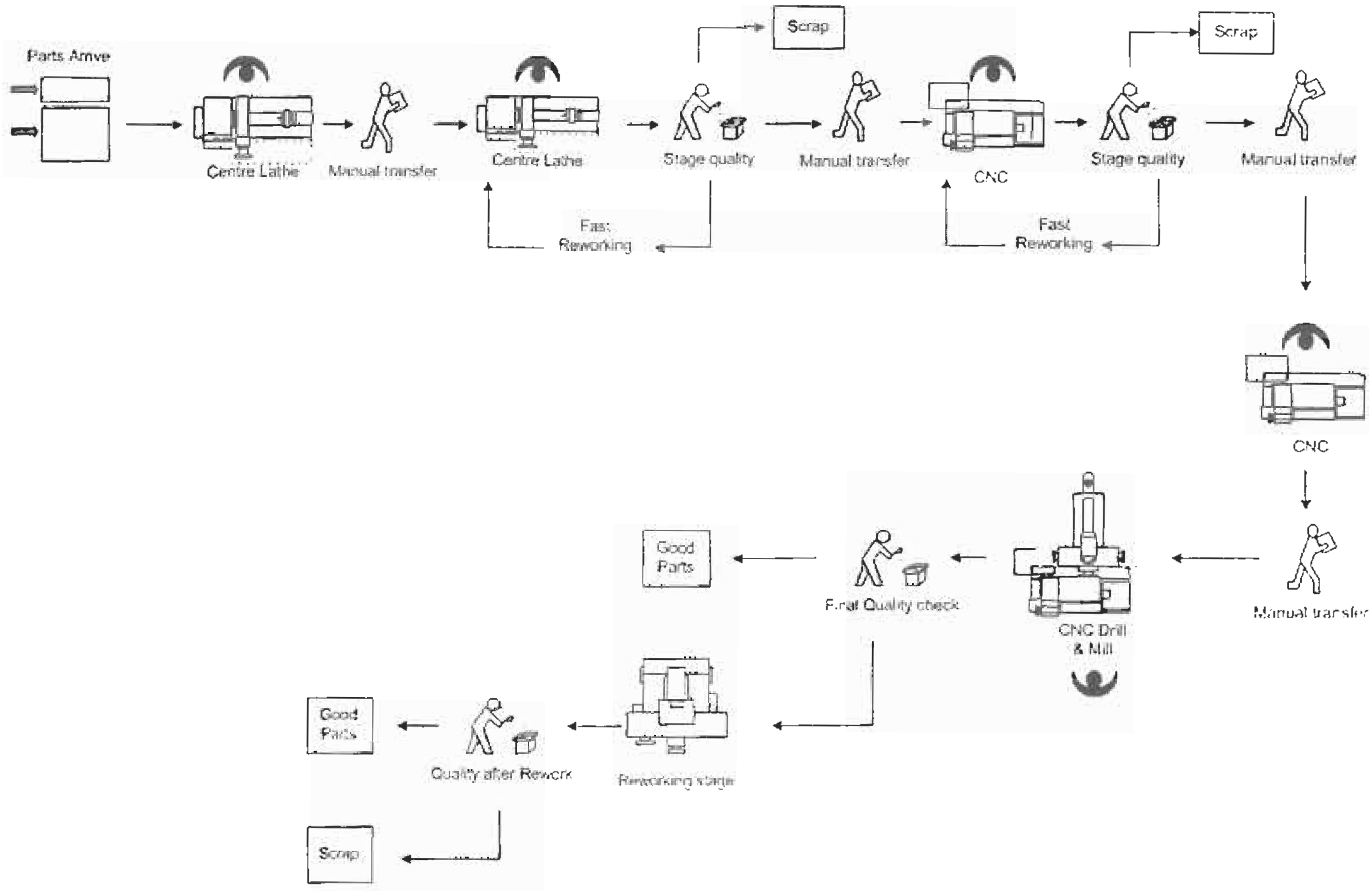


Figure 5.2 General Layout

5.2.2 DATA REQUIRED

The input data required is process plan, sequence of operations, costing data, importance (for value analysis), up and down time of production line, operator schedules etc. Product process plan and sequence of operations is shown in figure 5.1 and 5.2 respectively. There are more than 80 different types of parts which require different sequences and process plans. Model development and analysis has been done on parts/models recommended by the case company based on typical complexities.

5.2.2.1 ARRIVAL AND SERVICE TIMES DATA

The estimates required for the arrival time is given in table 5.1 and presented in figure 5.3.

Table 5.1 Arrival data over time

Year	*Total production*
1999	8000
2000	12000
2001	18000
2002	30000
2003	48000
2004	60000
2005	72000
2006	80000

The data is plotted in standard spreadsheet and trend lines drawn showing R-squared values. This depicts automobile discrete parts manufacturing sector progress over time. One logical argument made is why not to use normal distribution as input arrival distribution. Based on the trend lines, the best trend fit on the data is exponential as the arrival may vary and is not constant over time as shown in figure 5.3. Some other researchers have also used negative exponential (Carrie 1988). (Kelton et al 2006) suggested using Weibull and exponential distribution provide fits of similar quality, both exponential equation and values (EXPO [30, 20, 15, 10, and 5]) etc can be used in the model as input values.

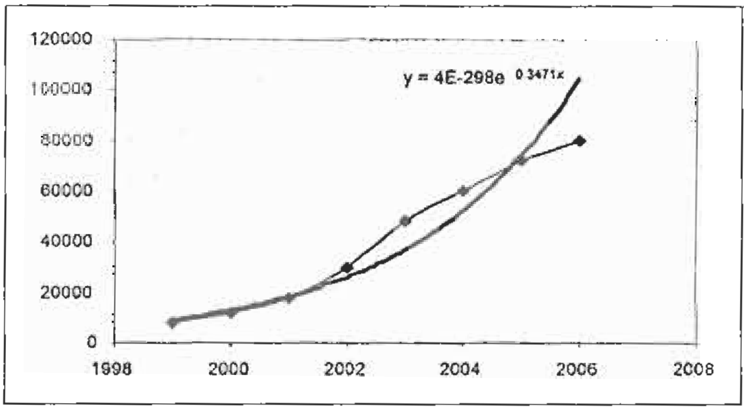


Figure 5.3 Case company historical data (exponential)

The sample of service/processing time data is also given in table 5.2 (there are more than 80 part types with different sequences and processing time, and have been incorporated in the model). Two types of distributions are generally recommended i.e. normal and triangular. (Kelton et al 2006) also suggested using triangular and normal distributions for service /processing time and both provide best fit. Over long run, both provide similar results, but during the run, normal distribution might periodically return fairly large values that do not practically occur in real systems. A normal distribution with a mean that is close to zero may return an artificially large number of zero-valued samples if the distribution's being used for something that can't be negative, such as processing time are a compelling reason to avoid normal distribution. Therefore, triangular distribution is used in our case. It has three estimates i.e. pessimistic, most likely and optimistic respectively. Other types of information collected comprised of up and down time of production lines, operator schedules and product types (number of models). The values collected are converted into probability distribution and then used in the model.

Table 5.2 Service time (sample)

Process type	*Type*	*Processing times (minutes)*	*Likely Probability Distribution*
OPT 1	Processing	10	TRIA (10,11,12)
Transfer to OPT 2	Delay	2	Constant
OPT 2	Processing	10-12	TRIA (10,12,14)
Stage QC	Inspect/Delay	3	Constant
OPT 3	Processing	6	TRIA (6,7,8)
Stage QC	Inspect/Delay	3	Constant
OPT 4	Processing	2	TRIA (2,2.5,3)
OPT 5	Processing	20	TRIA (20,21,22)
OPT 6	Processing	5	TRIA (5,5.5,6)
OPT 7	Processing	5	TRIA (5,5.5,6)
QC	Inspect/Delay	5	Constant
OPT 8	Processing	2	Constant
OPT 9	Processing	2	Constant
OPT 10	Processing	10-15	TRIA (10,13,15)

5.2.2.2 COSTING DATA

Various costs contribute towards the selling price of a finished product. These are manufacturing, design R&D, overheads (typically marketing, sales, customer service and administration) costs. The percentage of total cost attributed to manufacturing is about 40%, Design R&D costs are about 15% and profit about 20 percent. These figures are different in different organizations depending on the product and the associated market. However, manufacturing costs are usually the single largest cost element in the selling price and can be broken down further into four main elements with typical percentages - Parts and material about 50%, energy, plant and equipment depreciation almost 15%, direct labor nearly 10%, indirect labor about 25% (Mair, 1993). It is essential that manufacturing costs must be identified and classified properly to allow them to be allocated appropriately to a particular job (Meigs et al, 1999). The costs involved in producing a product can be classified as variable, fixed and sometimes semi variable costs (Usry el at, 1988). Overhead costs typically include rent and rates, heating/lighting costs, office staff salaries, general laborers, store men, insurance, equipment costs, depreciation on equipment and servicing costs, that is, maintenance etc. The majority of these costs are fixed costs because they are incurred irrespective of production rates. In order to determine the total overhead for each department, cost centers are identified within the company. This allows costs to be gathered together according to their incidence (Lucey, 1996). The unit cost is the average cost of manufacturing a finished product. This is generally found by taking the total cost of production and dividing it by the number of units produced. It is also of utmost importance that the selected materials (both for job as well as for the cutting tool) have appropriate properties that allow them to perform satisfactorily during service (Edwards, et al, 1990).

Both fixed and variable cost data were collected from the case companies. It include material cost, per month rent of building, machine lease cost, consumables cost, tooling/instruments cost, electricity and energy cost. The costing values are approximately same for all model types and slightly different costing values occur in different products. These cost data obtained is given in table 5.3.

Table 5.3 Costing data

S. No	*Type*	*Cost (Rs)*
1	Raw Material	Rs 35/kg
2	Building cost (rent)	Rs 150000/month
3	Machine (lease cost)	Rs1000000/month for all type of machines
4	Consumables	Rs 500000/month (approx. based on usage)
5	Tooling/Instrument	Rs 350000/month
6	Electricity/energy	Rs 250000/month

5.2.2.3 IMPORTANCE VERSUS COST RATINGS

Value Analysis (VA) is used as a tool for obtaining cost versus importance relationship of various departments. Value Analysis is the systematic application of techniques, which is used to identify the function of a product or service, establish a monetary value for the function and provide the necessary function reliably at the lowest cost. Value can be increased either by increasing the importance for the same cost or by decreasing the cost for the same utility.

Let; I = Importance; C = Cost Therefore; Value = I / C. The information collected is on the basis of importance versus cost out of hundred percent (%). Importance at operation 1, 2, ..,n is I_1, I_2,..., I_{13} respectively. Similarly related cost at operation 1, 2, ..., n is C_1, C_2,... C_{13} respectively.

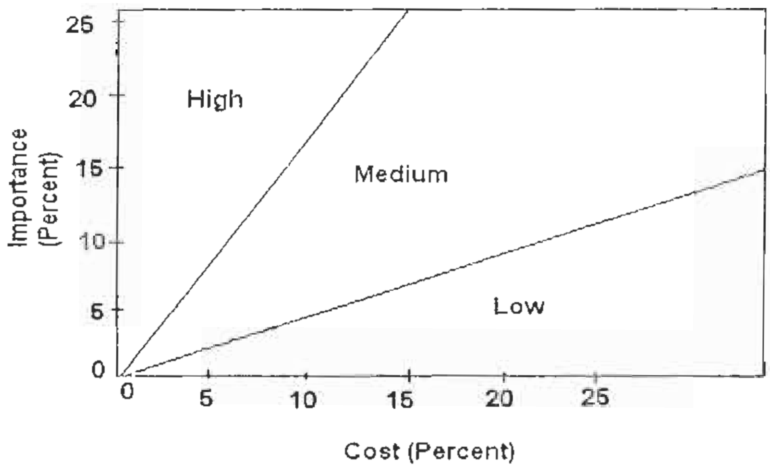


Figure 5.4 Importance versus cost relationship

The weights are given in percentage. There are thirteen departments/activities engaged for the manufacturing of automobile parts. Department's importance and corresponding cost is given in Table 5.4.

Table 5.4 Cost versus Importance over whole Business Process

S. No	*Departments*	*Importance %*	*Cost %*
1	Marketing	8	6.5
2	Production Planning & Control (PPC)	15	9.5
3	Finance	7	6
4	Shop floor control	12	22
5	Quality assurance	15	14
6	Capacity planning	5	4
7	Product development	9	12
8	Supply chain management	5	6
9	Inventory management	4	7
10	Packaging	2	2
11	Human resource management	6	3
12	Maintenance management	8	5
13	Sales and dispatch	4	3

The values given are based on qualitative judgment of personnel working with the company for the last ten years. The object is to analyze whole business process using Value Analysis (VA) and find out which activities are under the diagonal based on qualitative judgment of the personnel. Therefore, presented tool helps to identify more costly-less important activities/operations at macro level. Data in table 5.4 has been used in chapter 6 value analysis case.

Innovation, flexibility and other desirable performance characteristics are inevitable to gain market shares. These characteristics play a vital role for manufacturers shifting from offensive stage into innovative zone as given in our characterization in Table 4.5 (chapter 4). For this purpose, Value Analysis as a tool is used which serves to cope with more costly-less important activities at macro level.

The data required has been described in the above section. Process plans, sequence of operation, costing data and value data (importance versus cost) have been obtained and are used in the model. Next section reviews different solution methodologies used to develop model for analyzing behavior of system.

5.3 REVIEW OF SOLUTION METHODOLOGIES

Approaches like analytical methods, queuing theory, optimization techniques, expert systems and simulation are used for modeling work. This section review these approaches and selecting the best which is suited for modeling and analysis.

5.3.1 ANALYTICAL METHODS:

A system can be modeled by experimenting with the actual or model of the system as shown in figure 5.5. If the relationships that compose the model are simple enough, it may be possible to use mathematical methods (such as algebra, calculus, or probability theory) to obtain exact information on question of interest; this is called an analytic solution. These models demand too many assumptions and it is difficult to model complex real world problems. It employs the deductive reasoning of mathematics to solve the model, as differential calculus is used to determine the minimum cost policy for some inventory models (Banks et al 2002). Many a times, it is necessary to have the feeling of the basic system performance measures. The analytical methods are preferred in such situations. These situations occur in our day-to-day problems. For instance, in line balancing problem many heuristics can be applied for single product model and it is proved to be effective in these cases. However, for the many models launching, the analytical problems can even become more complex in which size if equations become large and consume computation time so modeling such systems are very difficult to solve analytically.

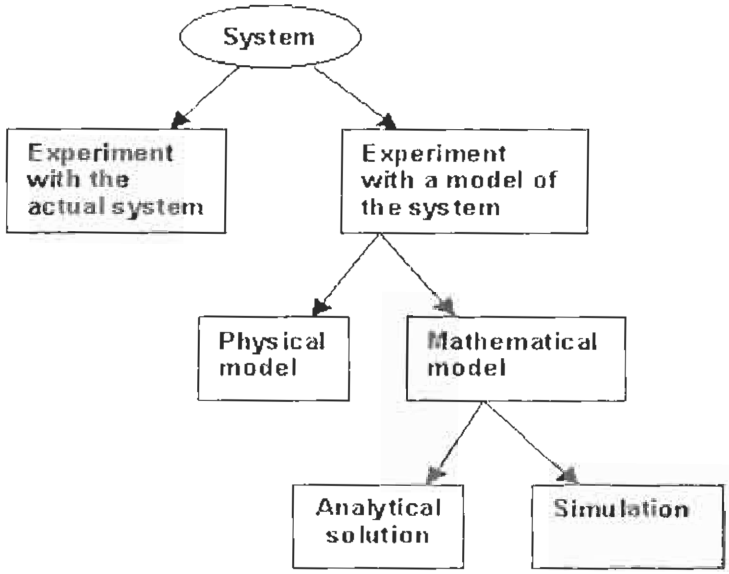


Figure 5.5 ways to study a system (adopted from Law & Kelton 2001)

5.3.2 OPTIMIZATION TECHNIQUES:

Optimization is a key tool used by operations researchers and management scientists, and there are well-developed algorithms for many classes of problems, and the most famous be the linear programming. Much of the work on optimization deals with problems in which all aspects of the system are treated as being known with certainty; most critically, the performance of any design (cost, profit, make-span, etc) can be evaluated exactly.

The most common definition of optimization is to Maximize or Minimize F ($Y(x_1, x_2, \ldots, x_m)$), where Y is a random variable and we cannot optimize the actual value of Y. A more complex optimization problem occurs when we want to select the system design that is most likely to be the best. Such an objective is relevant when one-short, rather than long-run average performance matters. Examples include a space shuttle launch or delivery of a unique order of products. (Bechhofer et al 1995) address this problem under the topic of 'multinomial selection'. The main problem with optimization is that of computer time. It takes a lot of time for running an optimization on a complex model. This is related to number of variables, the type of variables (discrete or continuous), the number of constraints on the solution space, the type of constraints (simple bound linear or nonlinear), and the type of objective function (linear, quadratic, or nonlinear). Using fractional factorial experiments to reduce the number of combinations can decrease the time. As far as, simulation is concerned, optimization is an area that will continue to receive attention (Banks et al 2002).

5.3.3 EXPERT SYSTEM:

An expert system is a computing system capable of representing and reasoning about some knowledge-rich domain with a view to solving problems and giving advice (Jackson 1983). Most expert systems are PC based and are built with commercial shells. The three main components of expert systems are:

1. Knowledge Base (to store knowledge).
2. An inference Engine (which controls reasoning with the knowledge).
3. And an interface.

The following phases are important for developing an expert system:

1. Knowledge acquisition: it is the transfer and transformation of potential problem solving expertise from some knowledge source to a program (Buchanan 1983).
2. Knowledge representation is the encoding of knowledge in data structures for symbolic (non-numeric) data, such as rule sets, generalized graphs and predicate logic.
3. Knowledge application deals with how and when to use the knowledge using meta- knowledge or knowledge about knowledge.

These systems have been used for many purposes in manufacturing. 'Knowledge based manufacturing management' by (Kerr 1991) gives a good cross section of such systems in manufacturing. (Smith P, et al 1994) reviewed the use of expert systems within manufacturing in Britain and entire European companies. Expert systems work best for situations in which extensive experience of personnel is available as these systems require plenty of information. In planning and operations of new system where knowledge of personnel is rare, expert systems are not recommended for such situations.

5.3.4 QUEUING THEORY:

The simple form of queuing theory is the M/M/1 queue. The first 'M' stands that the arrival process is Markovian i.e. inter-arrival times are independent and identical distributed drawn from exponential probability distribution. The second 'M' stands for service time distribution. The '1' indicates that there is just a single server. Most of performance measures can be expressed as simple formulas. For instance, the average waiting time in queue is:

$$\mu^2 s / \mu_A - \mu_S$$

Where μ_A is the expected value of the inter-arrival time distribution and μ_S is the expected value of the service-time distribution. There are some problems with these expression while estimates μ_A and μ_S:

1. The estimates of 'μ_A' and 'μ_S' are not exact, so there will be error in the results as well.
2. The assumptions of the exponential inter-arrival and service time distributions are essential for deriving the formula. This calls into questions of validity of the formula.
3. The formula is suited for long run performance, not for some short runs, which is typical for most of queuing theory.
4. The formula does not provide any information on the natural variability (dynamism) in the system.

Therefore, queuing theory is used as 'first cut approximation' to get idea of basic system understanding and simulation provides concrete brute force way of dealing directly with the model and analyzing systems.

5.3.5 SIMULATION MODELING:

'The technique of imitating the behavior of system by means of an analogous situation, model or apparatus, either to gain information more conveniently or to train personnel', is the definition of simulation from the *Oxford English Dictionary*. To simulate according to *Webster's Collegiate Dictionary*, is 'to feign to obtain the essence of, without the reality'. Simulation refers to a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software (Kelton 1998).

A simulation is the imitation of the operations of a real world process or system over time (Banks 2002). Simulation involves the modeling of a process or system in such a way that the model mimics the response of the actual system to events that take place over time (Schriber 1987). the more practical definition of simulation as (in our case too), '*the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system*' (Pegden 1995). The authors of the above quoted references consider simulation to include both the construction and the experimental use of the model for studying a problem. Thus, we can think of simulation modeling as an experimental and applied methodology that seeks to accomplish the following: describe the behavior of systems, construct theories or hypotheses that account the observed behavior and use the model to predict future behavior, i.e., the effects produced by changes in the system or in its method of operation.

There are also several surveys related to the use of operations-research techniques. Some of them reported from a longitudinal study, spanning 1973 through 1988, that '*simulation was consistently ranked as one of the three most important operations-research techniques*'. The other two were 'math-programming' and statistics (not an OR technique) (Gupta 1997). In this paper, Gupta analyzed 1294 papers from the journal Interfaces (one of the leading journals dealing with applications of operations research) from 1970 through 1992, and found that simulation was second only to 'math programming' among 13 techniques considered. The above research surveyed importance of simulation which means that application of simulation is vast. Many scientific events are organized each year to learn about latest tools/techniques related to simulation. One important event organized each year is Winter Simulation Conference (WSC). Six technical societies and National Institute of Standards and Technology (NIST) sponsor the conference. The technical societies are: American Statistical Association (ASA), Association for Computing Machinery/ Special Interest Group on Simulation (ACM/SIGSIM), Institute of Electrical and Electronics Engineers: Computer Society (IEEE/CS), Institute of Electrical and Electronics Engineers: Systems, Man and Cybernetics Society (IEEE/SMCS), Institute of Industrial Engineers (IIE), Institute of Operations Research and the Management Sciences: College on Simulation

(INFORMS/CS), and The Society for Computer Simulation (SCS).The information about the upcoming WSC conference and proceedings of papers can be obtained from www.wintersim.org. Some of application areas with major subject matters are: manufacturing applications (analysis, design, comparison, evaluation, optimization, investigation and modeling etc), semiconductor manufacturing (comparison, corrupting influence, assessment, capacity planning and logic risk system), construction Engineering, military applications, Logistics, Transportation, and Distributed applications, Business process simulation and human system.

There are however several impediments to even wider acceptance and usefulness of simulation. First, model used to study large systems, tend to be very complex, and writing computer programs to execute them can be an arduous task indeed. This task has been made much easier in recent years by the development of excellent software products that automatically provide many of the features needed to 'program' a simulation model. A second problem with simulation of the complex systems is that a large amount of computer time is sometimes required. However, this difficulty is becoming much less severe as computers become faster and cheaper.

As discussed earlier that simple systems are to be solved using differential calculus, probability theory, algebraic methods or other mathematical techniques. The solution consists of one or more numerical parameters, which are *measures of performance* of the system. However many real systems are very complex that they cannot be solved mathematically and takes large amount of time in decision making process. In these instances, numerical computer based simulation can be used to imitate the behavior of the system. The data is collected from the real world, and simulated generated data would be used to estimate the *measure of performance* of the system (that is probably the case of research work).

5.4 METHODOLOGY ADOPTED

The methodology adopted in this part is '*simulation*' as it can model the way we organized operations (arrivals, service, and quality). As the movements and changes of things in the simulation model occur at the right time in the right order and have effects on each other and the statistical accumulator variables. In this way, simulation provides a completely concrete way of dealing directly with the model.

There are guides to simulation software published every year by IIE (Institute of Industrial Engineers) 'Simulation Software Guide'. Every two years, OR/MS Today publishes a simulation software survey (Swain 1999). There are many features that are relevant when selecting simulation software (Banks 1996). Some of the key features are: Model building features (modeling world view, graphical model building, input flexibility, randomness, built in custom objects, interface with other languages etc), Run time feature (execution speed, model size, status and statistics etc),animation and layout feature (Type of animation, dimension, movement, navigation, views, quality of motion etc), Experimentation and analysis features (Scenario manager, run manager, optimization, costing module, file export etc), Vendor support and product documentation (training, documentation, help system, tutorials, support, track record etc). Simulation Languages, Software and Packages for modeling are:

1. Simulation using C++, GPSS/H and CSIM (general purpose simulation languages).
2. Simulation packages/ software (Arena, Extend, Micro Saint, ProModel, Taylor ED, WITNESS).
3. Statistical and Experimentation Tools (Arena's output and process analyzer for Arena, AutoStat for AutoMod, SimRunner for ProModel and OptQuest for optimization i.e. it can support Arena, CSIM, MicroSaint, QUEST, and Taylor ED).

Arena® from Rockwell software has been selected for the modeling work which has capabilities to move between high to low level. This is performed using alternative and interchangeable templates of graphical simulation modeling and analysis modules. These templates are combined to build a fairly wide variety of simulation modules. These modules are grouped into panels to compose a template. By switching panels from the template attach/detach, one can gain access to a whole different set of simulation modeling constructs and capabilities. In our case, modules from different panels (basic/advanced/block/etc) are integrated to develop one model and modules run to compute performance measures as required.

5.5 CHOICE OF SIMULATION IN DEVELOPMENT OF STRATEGY (MODULAR APPROACH)

Every simulation starts with a problem statement. The objective is to propose strategies for discrete parts manufacturers. Therefore, three manufacturing strategies with objective, operationalization and continuum have already proposed in previous chapters. For strategy operationalization, traditional approaches are used under three strategies of 'protector', 'offensive' and 'innovative' using simulation. It consists of not a single model, but a number of models which work for each type of strategies. These models are verified and validated by sensitive analysis and t-test is also carried out in this regard for validation of model. Experimentation is performed and sensitivity analyses are carried by varying the input controllable design parameters and see its impact on out performance measures (complete set of experimentations is given in chapter 6). The results are prioritized and final decision is recorded. The choice of simulation development strategy is explained with the help of following figure 5.6.

As explained earlier that the development of strategy within the simulation systems consists of different modules i.e. data, balanced operation, flexibility, value added and response modules respectively. Arena ® provides the modeling flexibility and can model any type of system (discrete or continuous). Because of such flexibilities, we have used Arena for our work to compute the performance measures. Last year WSC, the percentage of papers who used Arena was 54% (WSC history 2006).

Data Modules: This module consists of process plan, sequence of operations for different model type, costing data and value derivations. Processing times and arrival times are modeled in input analyzer to get the best fit (although some researchers proposed using of exponential for arrival and triangular for operation process times) (Law 2000).

Balanced Operation Modules: Two types of modules are developed by writing routines in which operation time of the production line is balanced. These modules are Balanced Operation Time Module (BOTM) and Waste Time Minimization Module (WTMM).

Flexibility Modules: Five different modules developed in this regard are machine replacement, quality enhancement, machine flexibility, operator flexibility and rework control.

Value Added Modules: Two modules developed are value adding and activity based costing.

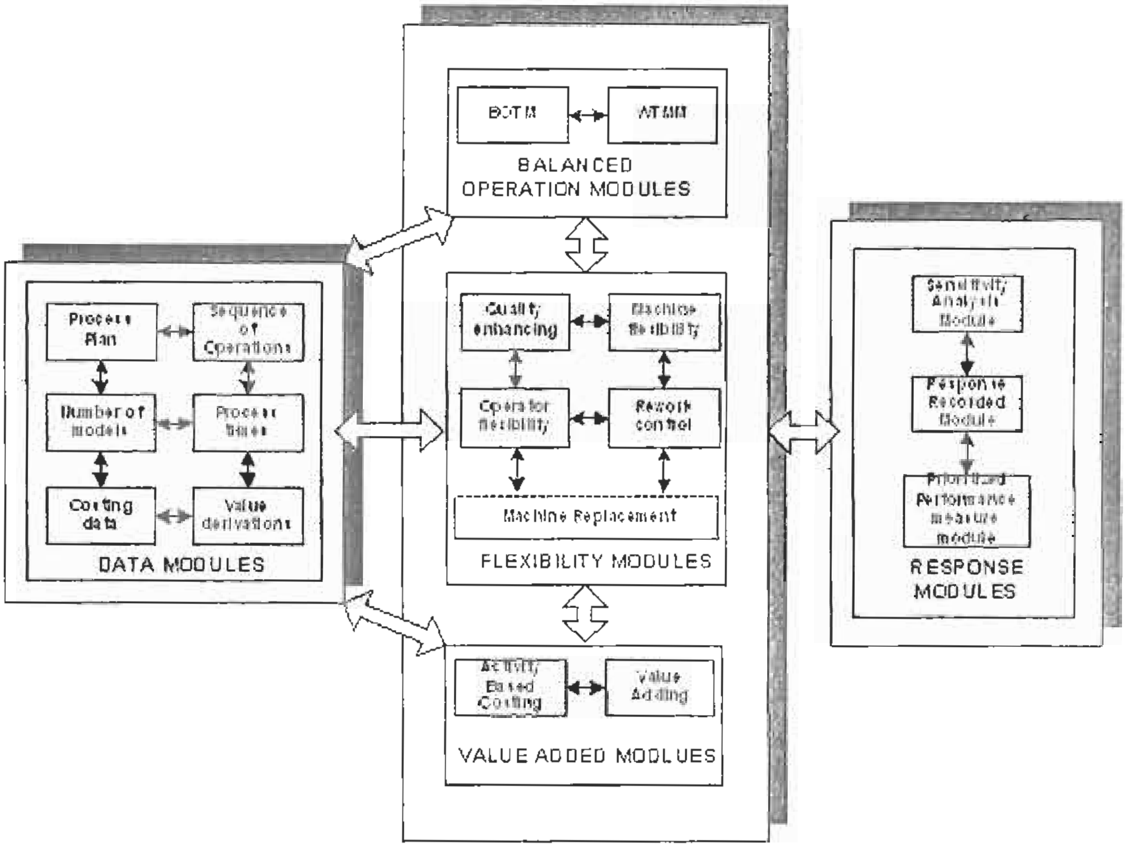
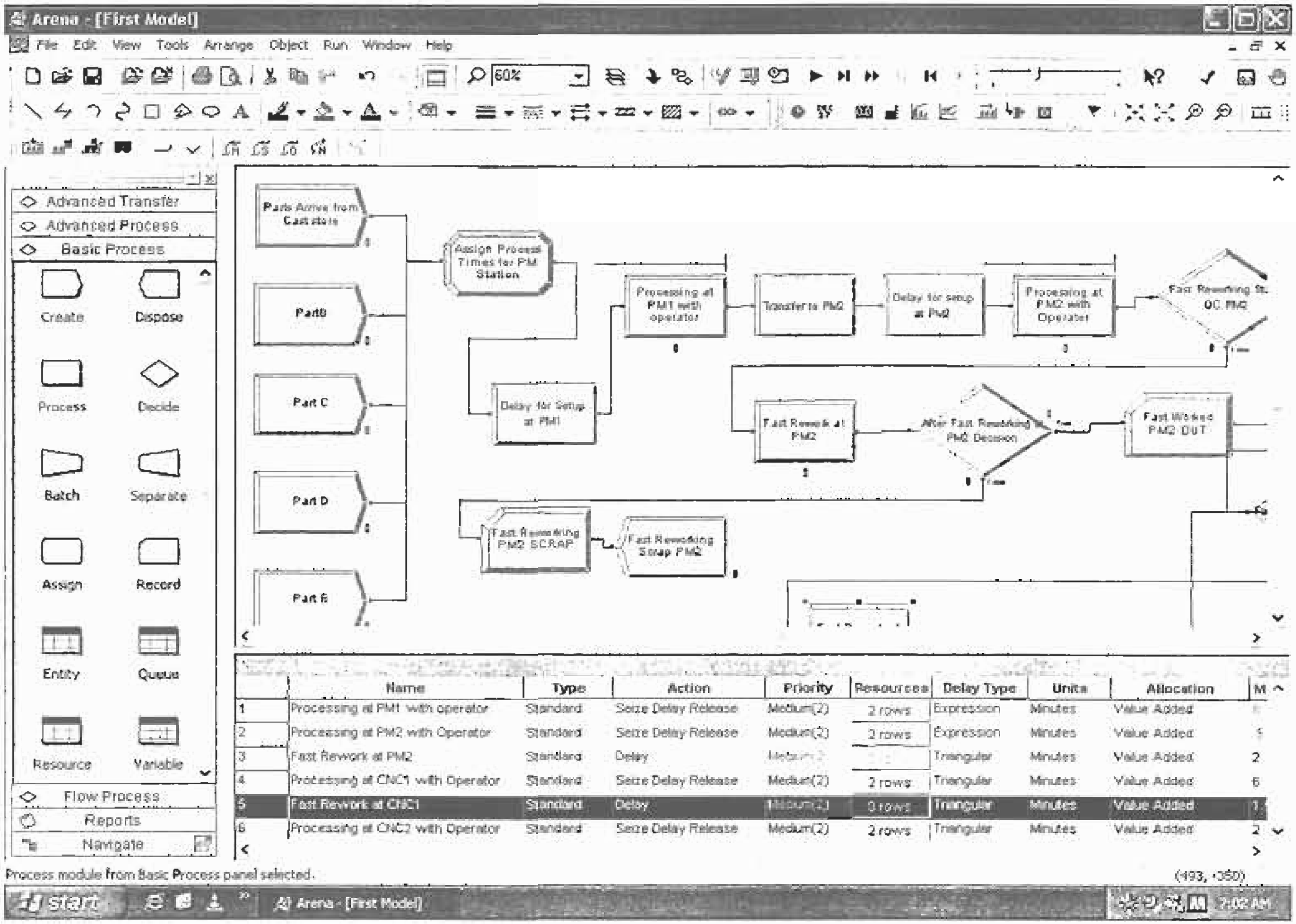


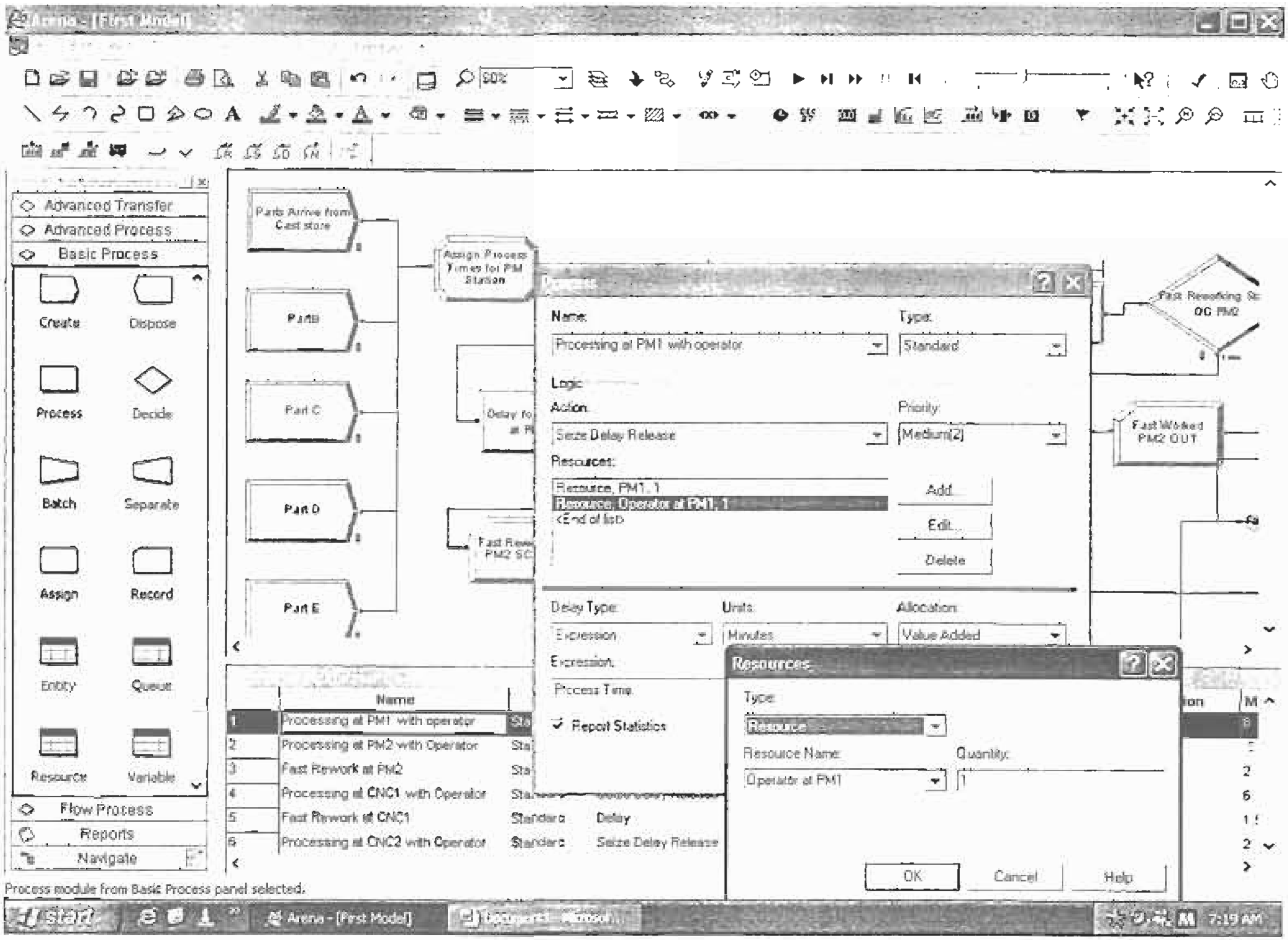
Figure 5.6 Developments of Modules (Jahanzaib & Akhtar, 2007)

Response Modules: It include sensitivity, response recorded and prioritized performance measurement modules (in output analyzer).

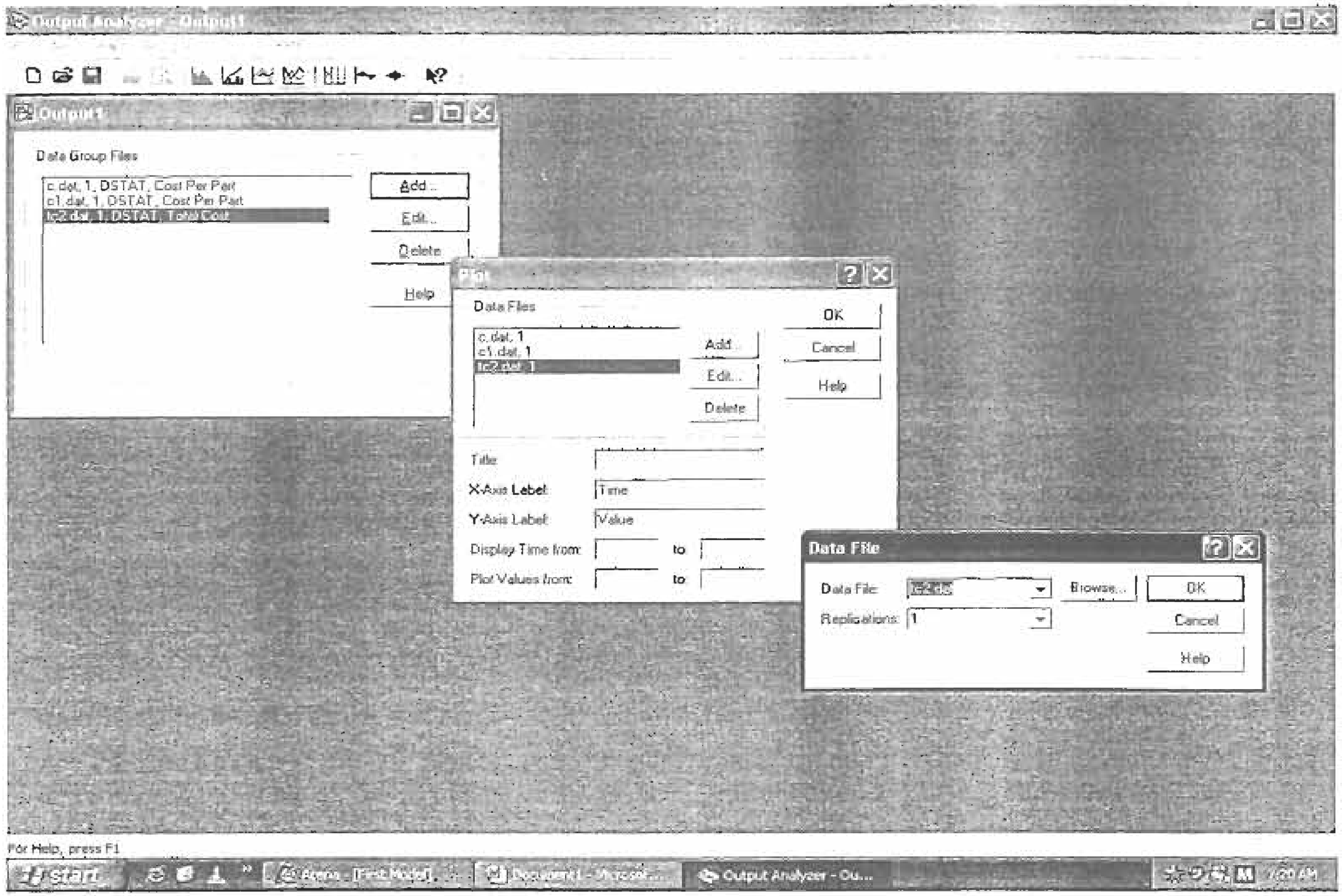
So, simulation as a tool assists in operational as well as tactical level decision making process. Display 1 shows main model, display 2 about data module and logic/modeling, display 3 about output analysis and display 4 about results respectively. These are shown from display 1 to 4.



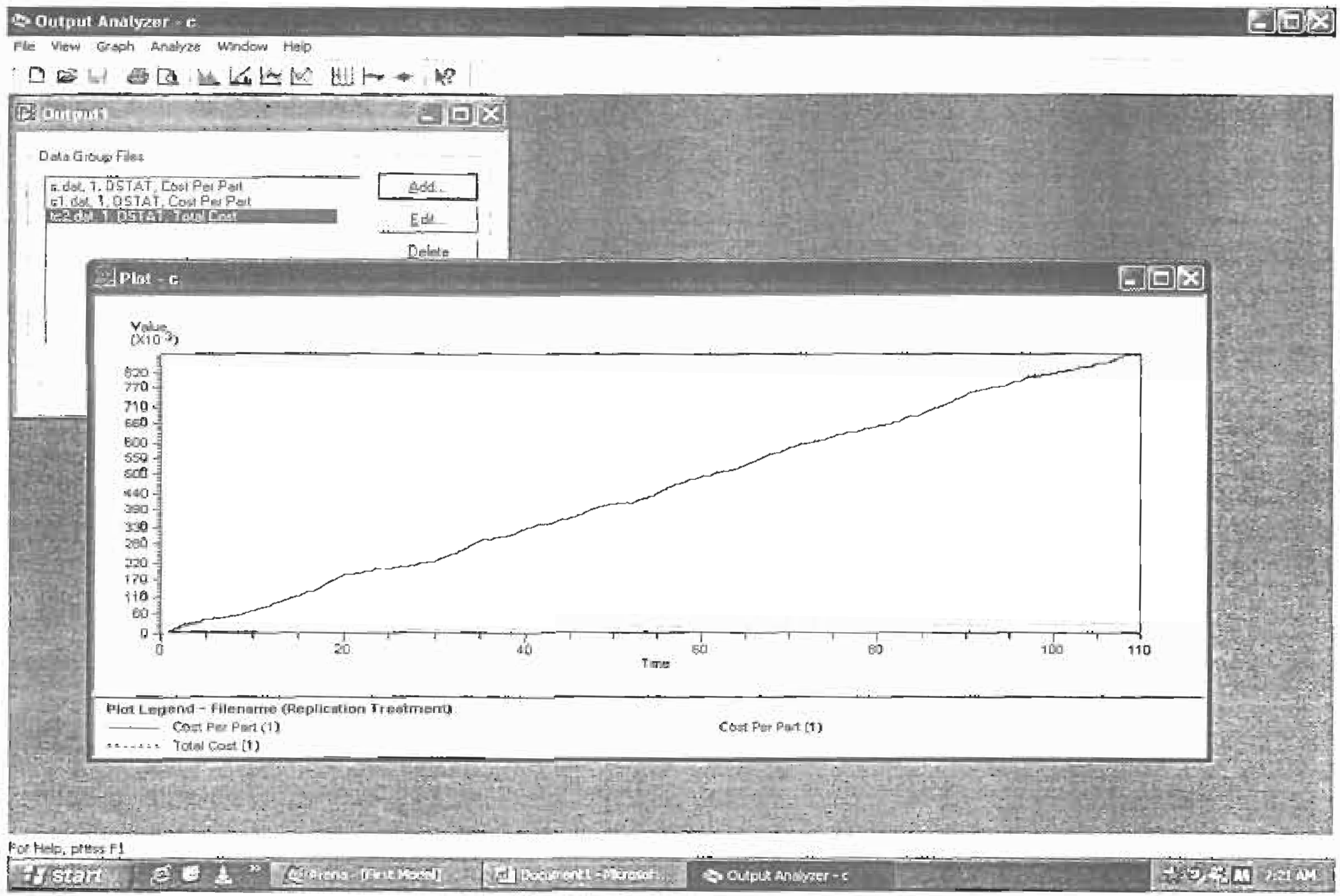
Display 1: Simulation Model



Display 2: Data and Modeling process



Display 3: Output model



Display 4: Output Graphical Interface

5.6 SPECIFIC OBJECTIVES OF SIMULATION MODELS

The simulation experimentation is carried out for evaluating performance of system. The objective of the study is to propose generic solution for three types of strategies proposed (as in chapter 3). Generally, for any system, important performance measures (but are not limited to) are resource utilization, number in queue, time in queue and cycle time. In our case following are the objectives at 'Protector', 'Offensive' and 'Innovative' manufacturers. These measures have been discussed with case companies and are used in our model:

For Protector:

1. *Improving utilization of resources*: This would be achieved by purging waste time from the system so as to obtain balanced production line.
2. *Reduce Work In Process (WIP)*: Balancing of production line and streamlining of operations would reduce WIP.
3. *Cost per Unit*: Keeping WIP and other non value added times at a minimum, significantly reduces the cost per unit.

For Offensive:

In offensive stage, advanced manufacturing systems/or hybrid (manual + automated) systems would be used as automation does not allow poorly designed products and inefficient processes to exist It is therefore, imperative for the industry to improve its productivity and competitiveness. One way of achieving this competitiveness is through automation. An analysis is also performed to see level of automated technologies and its impact in Pakistani context. The objectives at this stage would be:

1. *Reduce average waiting time*: Change-over/setup time would be reduced using advanced manufacturing systems.
2. *Reduce rejection/reworking cost*: Due to inherent characteristics of the advanced systems, high quality and reliability would be achieved.
3. *Improve Flexibility*: Both operator and operational flexibility would be improved.
4. *Improve Yield*: The yield would also be improved.

For Innovative:

1. *Improve value of product*: Using activity based costing identifies high costly processes/operations. Importance versus cost derivations would be used which identified high costly-less important operations.
2. *Cumulative yield*: Cumulative yield would also be increased.

5.7 MANUFACTURING SIMULATION MODEL

In order to explain the model structure and simulation process logic, the important parameters of interest at input and out are defined. These terms have been used to compute different performance measures in study. The terminologies used in model are given in table 5.6.

5.7.1 TERMINOLOGIES USED

The terminologies (input/output factors) used in the model are presented in table 5.5 and are explained in the model structure section.

Table 5.5 Input parameters and output variables

INPUT PARAMETERS	
Parameters	**Meanings/definition**
H_{RATE}	Hourly Labor /wage rate
M_{RATE}	Hourly Machining / processing rate
P_{MAX}	Maximum processing / machining time
MH_{TIME}	Maximum material handling times (workstations)
Y_{MIN}	Minimum or starting yield
Y_{IMP}	Improvement in yield
SU_{TIME}	Maximum setup time
RW_{TIME}	Reworking time
FR_{TIME}	Fast reworking time
M_{FLEX}	Machine replacement flexibility
PV_{FLEX}	Parts mix (variety) flexibility
V_{FLEX}	Volume flexibility

OUTPUT VARIABLES	
UT_{SYS}	System Utilization
C_{PART}	Cost per part / unit
TM_{COST}	Total manufacturing cost
WIP	Work In Process
WT_{AVG}	Average waiting time
YBRW	Yield before reworking
C_{REJ}	Rejection cost
C_{REWORK}	Reworking cost
C_{VAD}	Value added cost
C_{NVAD}	Non-value added cost
Y_{CUM}	Cumulative yield
FT	Flow times

5.7.2 MODEL STRUCTURE

The movements of the parts through various machines are modeled as an entity (parts) flows through the simulation model. The arriving parts enter the system, stay in the queue till the resource is available, and get delayed by the processing time of the respective stage. It is further delayed by the fast reworking time (if required) and is checked for any rework. If the fast reworking is not required on the respective stage, it goes to the next station as dictated by the product model type. After completing all operations on resources, if no rework is required then the parts exit the systems as 'good parts'. On the other hand, if during final inspection it transpires that reworking is required, the part is sent to the rework stage, where it is reworked and all operations are performed at the final reworking stage and recorded as 'salvaged parts'. If it is found that parts cannot be repaired even after it has been reworked, it is rejected and leave the system as 'scrap parts'. Every effort is first made to rework the parts failing to meet the desired quality level. Fast reworking phenomenon does not occur at all stages but differ according to the product model type and respective resource stage. The inter-arrival time is usually constant in simulation studies, but in our case it varies exponentially and incorporated in the model on the basis of discussion with the case company and actual data observed. The stage operation time is triangularly distributed with the minimum, mean and maximum values. The parameters of interest in simulation study are the maximum processing time (P_{MAX}), the stage operation times and part mix (PV_{FLEX}). At some stages, there is fast rework which does not require the part to be routed to the reworking stage but still results in some additional time delays. This kind of rework is carried out by same stage operator who performed the original operations. There are buffer storages where parts are temporarily held and then transferred to the next respective station. Setup times at certain stations is also witnessed which slowed down the pace of production line under investigation. So, the parameters of interest are fast reworking times (FR_{TIME}), setup times (SU_{TIME}) and transfer times / material handling time (MH_{TIME}).

Separate reworking stage is dedicated to rework parts and any remaining subsequent operations as they dictate not only the amount of rework but also the unit costs that are based on cumulative yield figures. The parameters of interest include starting quantity of good parts (Y_{MIN}), the yield improvement (Y_{IMP}) after process gets stabilized. All parts identified for reworking are transferred to the reworking area where they undergo an additional time delay equal to reworking time (RW_{TIME}). All parts are again inspected and good ones leave the system as 'good/salvaged' and remaining is rejected. Rejection and reworking costs are directly computed by multiplying the per unit rejection and per unit reworking costs with the corresponding quantity rejected or reworked. Effect of hourly wage rate and machining rate is also investigated. A balance production line is found to be essential pre-requisite of the system. This is achieved by properly distributing work contents equally to all stations, the parameter of interest is (P_{Max}) in stream-lining of operations so as to achieve minimum queue length, while trying to achieve maximum desirable resource utilization as shown in figure 5.7 (schematic model logic).

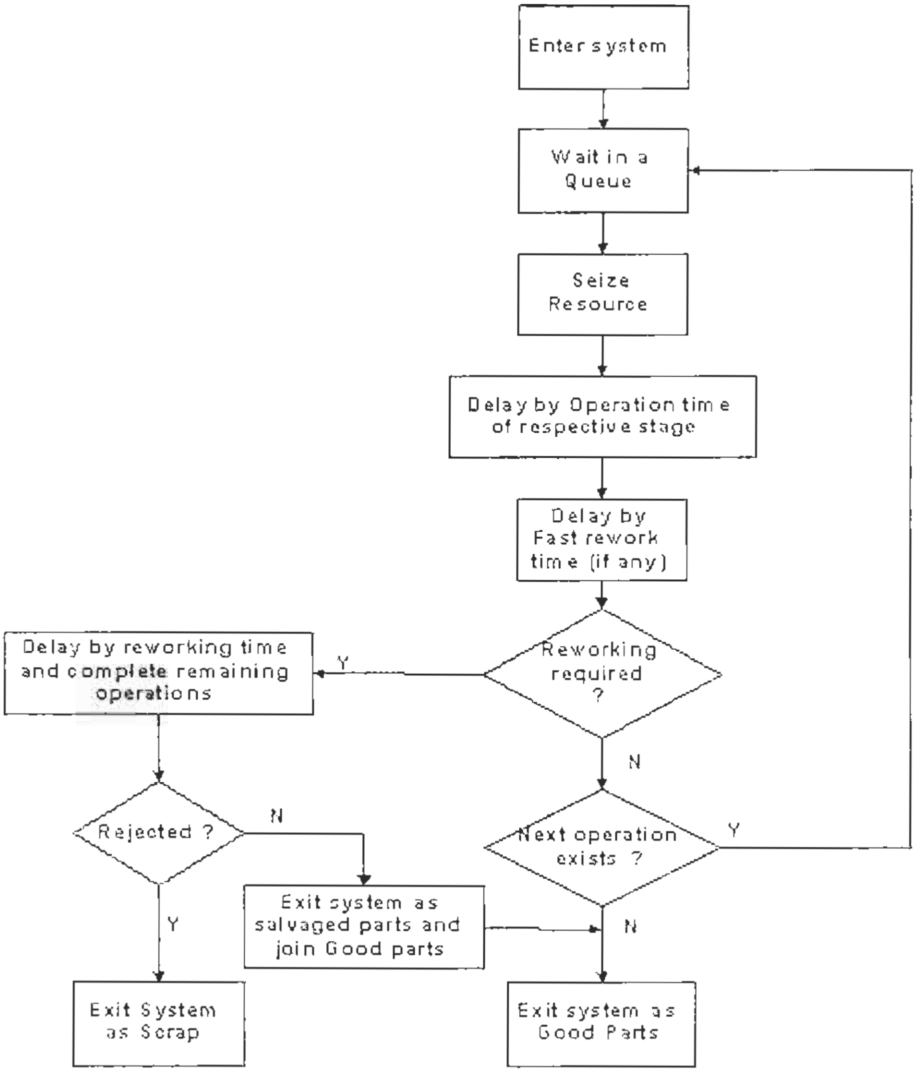


Figure 5.7 Schematic Diagram - Simulation model logic

5.7.3 KEY ACCUMULATORS IN ENTITY FLOW

Every simulation study has arrival, departure and some stopping condition. The generic process of simulation demands key relationships for governing of entity flow which have been used in different modules and are embedded in the software. Typical statistical accumulators for study are (not limited to):

1. Total number of parts produced (P)
2. Number of entities that have passed through the queue so far (N)
3. Sum of queue times that have observed so far (Σ WQ)

4. Maximum time in queue observed so far (WQ^*)
5. The sum of total times in system that have been observed so far (Σ TS)
6. The maximum total time in system observed so far TS^*
7. The queue length Q(t)
8. Highest level Q(t) has attained so far
9. Server busy B(t) i.e. utilization

As explained earlier that for 'protector strategy manufacturers' are cost conscious as they places more emphasis on utilization of capacities in order to reduce cost (cost per unit as well as system cost). The same logic is used in simulation model. Factors like hourly labor rate, machining rate, maximum processing times and failure rates are used in protector strategy stage. Other factors like material handling times, yield minimum / improvement, setup times, reworking times, machine replacement flexibility, labor flexibility, parts not requiring reworking, parts mix flexibility, importance rating and fast reworking times are used in offensive and innovative strategy stages respectively.

5.7.4 ASSUMPTIONS OF THE MODEL

1. Every lot has a fixed number of parts
2. Learning of operator is only affecting the respective stages.
3. Unscheduled breakdowns occur with an exponential distribution which is ignored as we have already included failure times in our model.
4. Parts arrive to the resources from incoming store with an exponential distribution is independent of each other arrival, as we are not studying JIT system.
5. Infinite buffer space is available within cells.

5.7.5 VALIDATION OF THE MODEL

Verification is the process of ensuring that the model behaves in the way it was intended according to the modeling assumptions made. Validation is the process of ensuring that model behaves the same as the real system. A simulation model provides excellent opportunity for obtaining an analysis of the casual behavior of the underlying process. However, two types of validations are always required. Correctness of the internal structure, as well as nature of the output results, dictate the degree of user confidence in validity of the model. They are a) simplification of assumptions, b) both transient and numerical valued behavior c) bias in the random samples and d) accuracy of the data (Law M & Kelton, 2000). The assumptions are simple and do not affect the outcome of the model because they have been made using real world system. Simulation runs is carried out including warm-up period so that system gets stable to minimize randomness in results and is run for many number of replications. 't test' is also carried out so as to obtain the sensitivity of performance measures under study. The prioritization is validated through discussions and sharing of the results with case company management.

5.8 CONCLUSIONS

The following conclusions are made drawn from this chapter:

i. The progress of the company showed an exponential trend $Y = 4E\text{-}298e^{0.3471x}$. This is an important finding as the case company started from low volumes and variety environment and matured over time with an increasing trend as shown in figure 5.3.

ii. The service times (processing times) of servers are triangular distributed with min, max and mean values. This is because the failure rate and variations in processing in different shifts is incorporated in order to get more realistic results.

iii. The solution methodologies are reviewed for modeling work. It is found that analytical methods are not used as it requires lot of assumptions. Optimization theory is either maximized or minimized.

iv. Expert systems overcome the limitations, but it requires a lot of information from expert. Therefore, the expert systems are knowledge intensive.

v. Simulation modeling is used for modeling real world problem in question. The model so developed to imitate real life scenario to obtain results.

vi. Modules are also developed which work for each type of strategy. The modules developed are data, balanced operation, flexibility and response.

vii. The performance measures important are discussed with companies and used in the model. The key performance measures are: utilization, work in process, per unit cost, yield related, cumulative yield etc.

viii. The model is validated using both transient and numerical valued functions, simplification in the assumptions and accuracy of the data by modeling it in input analyzer and then used for modeling work.

This chapter presented a detailed discussion of data requirement to develop simulation model and different modules within the model. The process flow and general layout of the system is presented and model explained with the help of logic diagram. Different solution methodologies like analytical methods, optimization theory, expert system and simulation are also reviewed. Manufacturing simulation methodology as a tool has been adopted for modeling of real system under investigation because of advantages and both time dependent and numerical valued analysis can be obtained. Building model in simulation provide flexibility to take right decisions. Operational data like processing times, current quality practices, frequency of up and down time of production line, operator schedules, process plans and model mix etc is modeled in Arena®. Modules are developed which work for each proposed strategies. Model is verified, validated and t-test carried out in this regard. The replications and comparison of results with case company existing management also validate and verify model and results. The behavior of the model is analyzed in chapter 6.

CHAPTER 6
MODEL BEHAVIOR ANALYSIS
(TACTICAL LEVEL)

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6.1 INTRODUCTION

One of the goals of the simulation is to find out how changes in the input parameters affect the output measures of performance in manufacturing systems. This chapter is about model behavior analysis in which real world model is developed so that it behaves like actual system. The model is analyzed using sensitivity analysis by changing the base values systematically. This helps to identify the most sensitive parameters so as to capture dynamic behavior of model. Two different behaviors have been analyzed i.e. time dependent and numerical values in question. The simulation was run for time of 525 hours so that longer time stabilized the behavior of model can be replicated. By changing the base values, slopes of functions are computed and scores are allotted. The values are then prioritized for three types of manufacturers i.e. protector, offensive and innovative in decreasing order of sensitivity. It has been learnt that balanced line and quality related parameters are the most sensitive. The following sections describe simulation experiments, summary of results and draw conclusions.

6.2 DESIGN OF SIMULATION EXPERIMENTS

Designing of simulation experiments essentially involves selection of performance measures, factors that would have to be varied and the levels of each of these factors that we want to investigate (Law et al 2001). Based on the model structure and logical use of parameters as explained in chapter 5 and discussion with the case companies about importance of responses for each manufacturer, the performance measures selected are:

1. **Protector related**
    a) Utilization of resources (UT_{SYS})
    b) Cost per part (C_{PART})
    c) Total cost of the part (TM_{COST})
    d) Average waiting time (WT_{AVG})
2. **Offensive related**
    a) Work In Process (WIP)
    b) Yield before rework (YBRW)

c) Cumulative rejection costs (C_{REJ})

d) Cumulative reworking costs (C_{REWORK})

3. Innovative related

a) Value added cost (C_{VAD})

b) Non- value added cost (C_{NVAD})

c) Cumulative yield (Y_{CUM})

d) Flow time (FT)

Typical existing values of the parameters of particular interest are now discussed in order to have a clear understanding about their impact. The current labor/wage rate is Rs 30 per hour. We have varied it from 30 to 180 rupee (1 US$ = Rs. 60.5). Maximum processing time is 0.34 hours which is varied up to 25 percent of this value. The arrival rate is also varied up to 25 percent as volume flexibility factors affecting the system are also studied. Maximum yield and rejection rate is also varied up to 25 percent of the base values.

For the purpose of carrying out sensitivity analysis, we first used data module which consists of process plan, sequence of operations for different model type, number of models launched, costing data and value derivations. The data is used in Balanced Operation Time Module (BOTM) and Waste Time Minimization Module (WTMM) in which relevant responses at the output are recorded. Different modules developed for offensive stage are machine replacement, quality enhancement, machine flexibility and rework control. For innovative stage, two modules developed are value addition using value added and non value added costing and importance ratings.

The range of values used in the modules for carrying out sensitivity analysis is given below.

1) Effect of balanced line (maximum processing time) (P_{MAX})

At base value
0.75 times base run value
0.5 times base run value
0.25 times base run value

2) Effect of hourly wage/ labor rate (H_{RATE}) in rupee

At base value
2.0 times base run value
4.0 times base run value
6.0 times base run value

3) Effect of hourly machine rate (M_{RATE}) in rupee

At base value
1.5 times base run value
3.0 times base run value
4.5 times base run value

4) Effect of material handling time (MH_{TIME})

At base run value
0.5 base times run value
0.25 times base run value
0.1 times base run value

5) Effect of minimum or starting value of quantity to be reworked (Y_{MIN})

75 percent
85 percent
95 percent
99 percent

6) Effect of change in quantity to be reworked (Y_{IMP})

1 percent
10 percent
15 percent
19 percent

7) Effect of maximum setup time (SU_{TIME})

At base value
0.6 times base run value
0.3 times base run value

8) Effect of reworking time (RW_{TIME})

Set1, at yield min = base values (0.5 and 0.75)
Set2, at yield min = 0.85 (0.5 times base run values)

9) Effect of fast reworking time (FR_{TIME})

05 times base run value
At zero, with 25% good produced parts
At zero, with 95% good produced parts

10) Effect of machine flexibility at stage 1 and 2 (M_{FLEX})

At base value
0.5 times base value with 85% yield
0.5 times base value with 95% yield

0.5 times base value with 99% yield

11) Effect of volumes (volume flexibility) on changing levels of arrivals (V_{FLEX})

At base value
0.5 times base run value
0.4 times base run value
0.25 times base run value

12) Effect of changing variety flexibility (number of models) (PV_{FLEX})

With (1, 3 and 5 models)

6.3 SENSITIVITY ANALYSIS

Sensitivity analysis is carried out by varying the values of the model's parameter and seeing how these changes affect the behavior of the model. Thus the purpose is to ascertain those parameters that are sensitive and significantly affect the system. Sensitive parameter also helps in our understanding of the system and is useful for deriving strategy implications. On the other hand, less or least sensitive parameter will not affect the behavior of the model and hence does not play much role on policy/strategy setting. Two kinds of analysis have been done. The time dependent effect and change in average (or maximum) numerical values of the parameter in question. The effect is observed with respect to the slope of the function e.g. a large slope signifies 'considerable effect' hence termed 'most sensitive', comparatively fewer slopes signifies 'moderate effect' hence termed 'moderately sensitive', while very little slope represents a 'nominal' or very small effect. For the sake of more realistic results, five sensitive levels are used which are; 'most sensitive', 'sensitive', moderately sensitive', 'less sensitive' and 'least sensitive' respectively. Simulation experiments as explained above are carried out for a simulated time period of 525 hours because the longest time constant used in the model enables the system to stabilize within this time. The following experiments were performed:

6.3.1 SIMULATION EXPERIMENTATION

Experiment 1) Effect of balanced line (max. processing time, P_{MAX})

Figure 6.1 shows the time dependent effect of changing maximum processing time for achieving balanced line. The effect is significant in both cost per part, total cost of part, waiting time, non- value added cost, flow times and work in process as shown from figures 6.2 to 6.6, while effect is moderate and less sensitive on yield before rework, rejection cost and has little effect on cumulative yield respectively. There is not much deviation in time dependent effect of graph on cost per part as shown in figure 6.4 as deviations in the graph would be witnessed at comparatively much larger volumes. Balancing of the line i.e. streamlining of the operations is pre-requisite as it is affecting the performance measures and significantly effecting system.

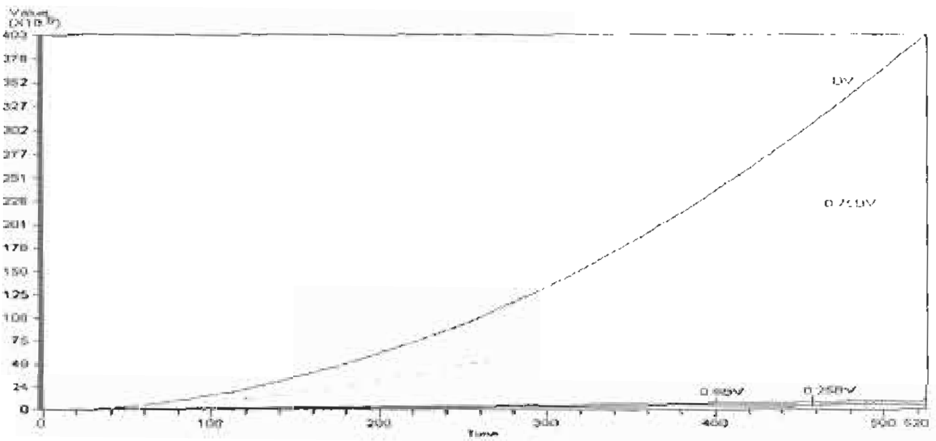

Figure 6.1 Effect of max. Processing time (bal. line) on total cost

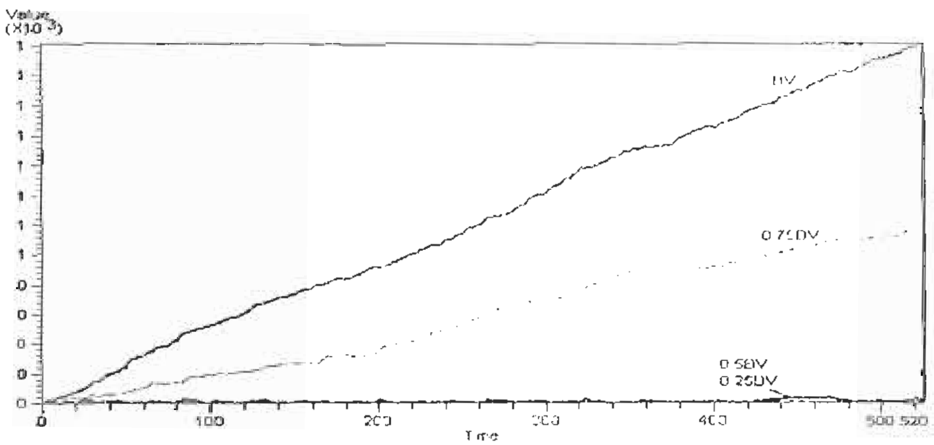

Figure 6.2 Effect of max. Processing time (bal. line) on avg. waiting time

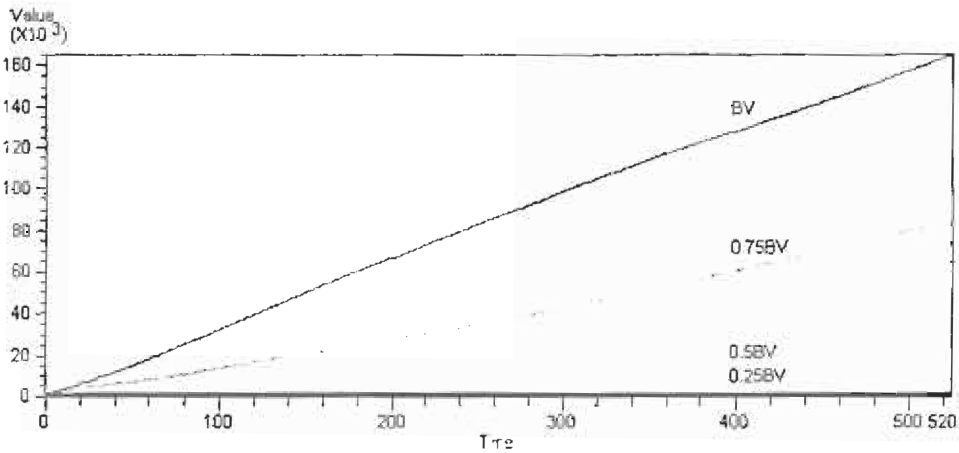

Figure 6.3 Effect of max. Processing time (bal. line) on non value added cost

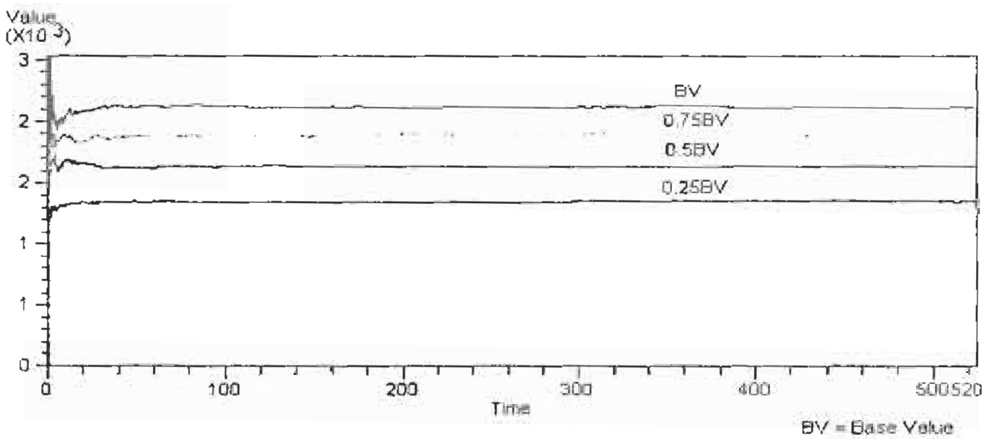

Figure 6.4 Effect of max. Processing time (bal. line) on cost per part

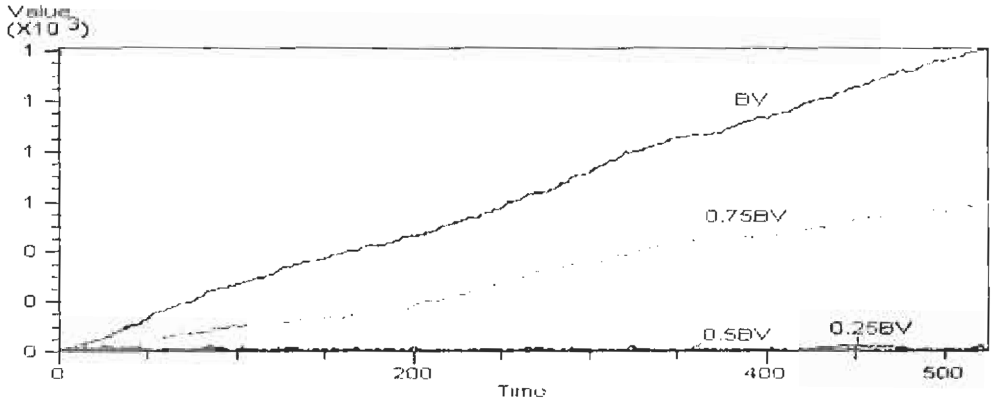

Figure 6.5 Effect of max. Processing time (bal. line) on work in process

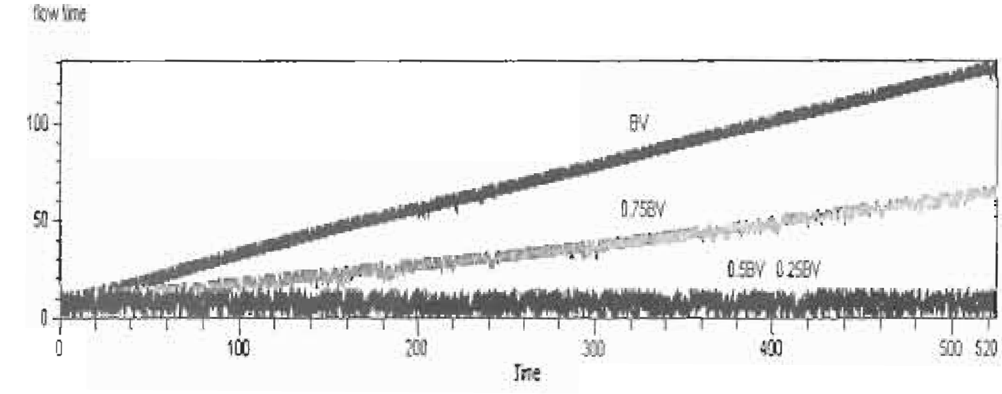

Figure 6.6 Effect of max. Processing time (bal. line) on flow time

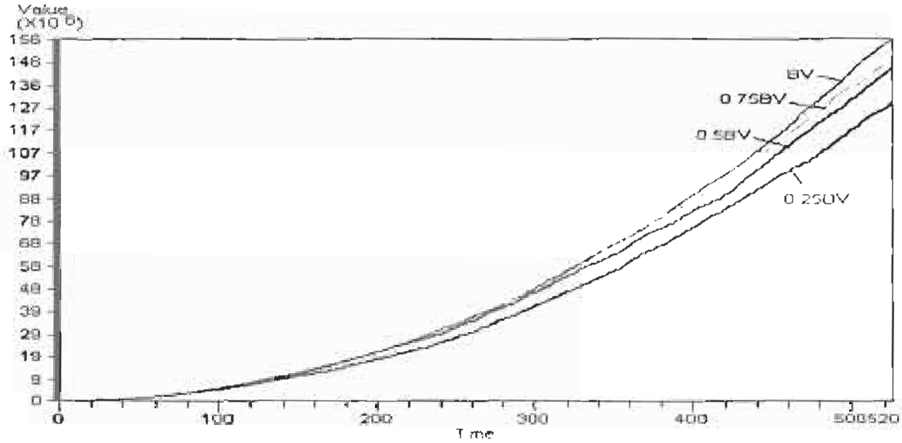

Figure 6.7 Effect of max. Processing time (bal. line) on rejection cost

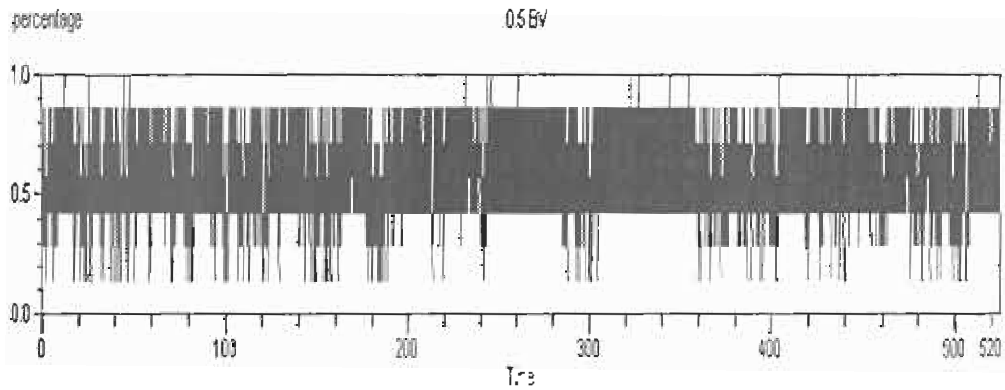

Figure 6.8 Effect of max. Processing time (bal. line) on 0.5BV utilization

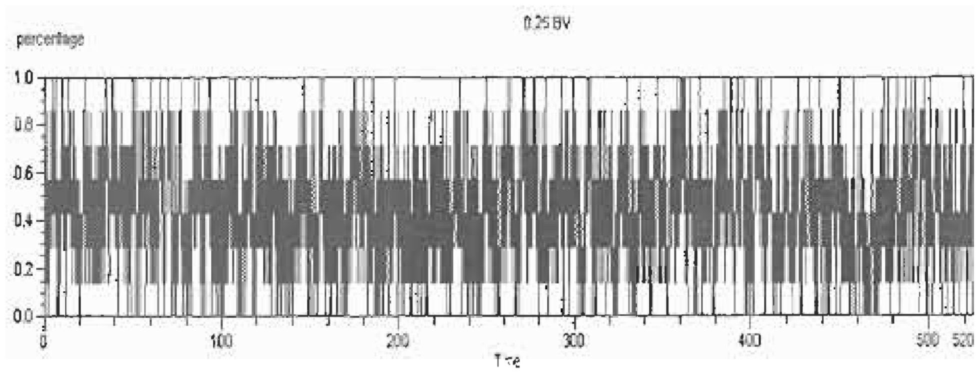

Figure 6.9 Effect of max. Processing time (bal. line) on 0.25BV utilization

In order to have clear understanding of the behavior of simulation model results, numerical values effects (obtained during simulation runs) are also plotted in standard spreadsheet to obtain the slopes of the function. These values are drawn in MS excel and presented from figures 6.10 to 6.17 respectively.

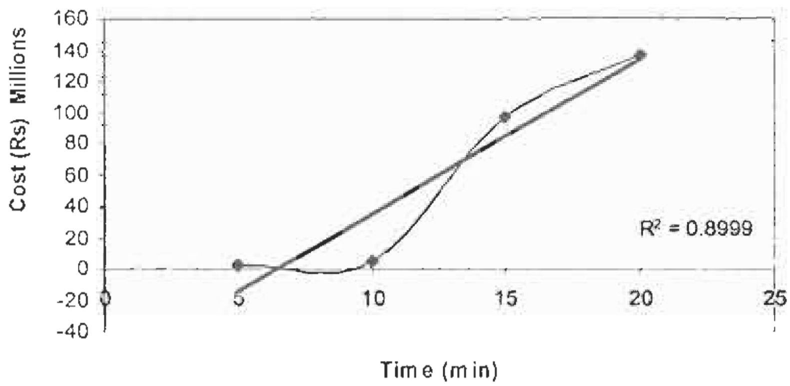

Figure 6.10 Effect of max. Processing time on total cost

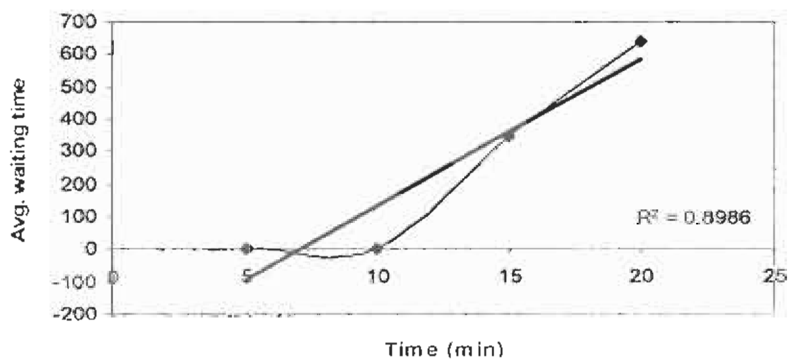

Figure 6.11 Effect of max. Processing time avg. waiting time

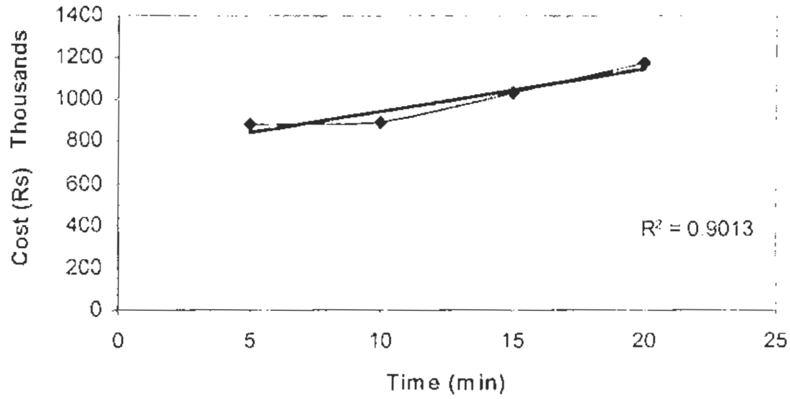

Figure 6.12 Effect of max. Processing time on non-value added cost

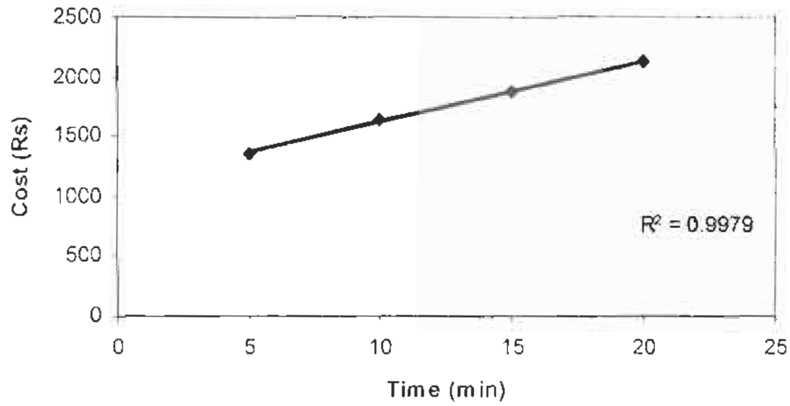

Figure 6.13 Effect of max. Processing time on cost per part

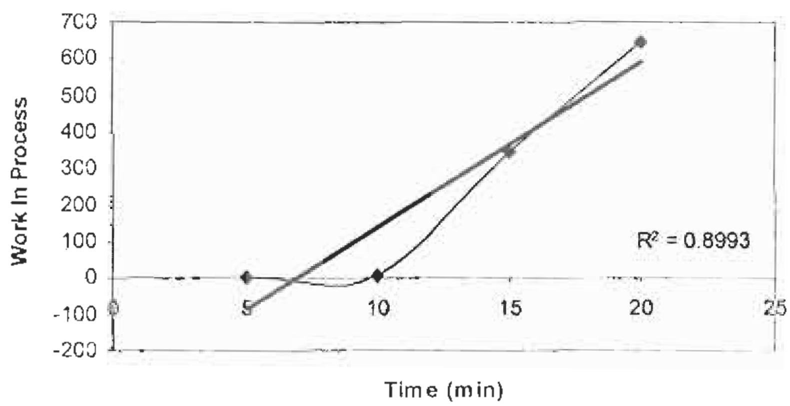

Figure 6.14 Effect of max. Processing time on work in process

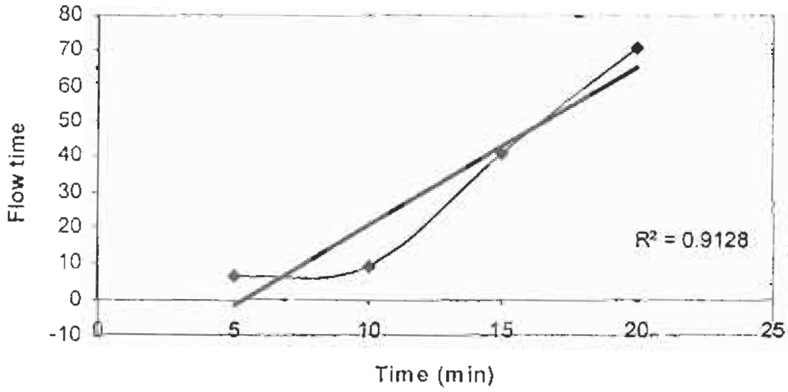

Figure 6.15 Effect of max. Processing time on flow time

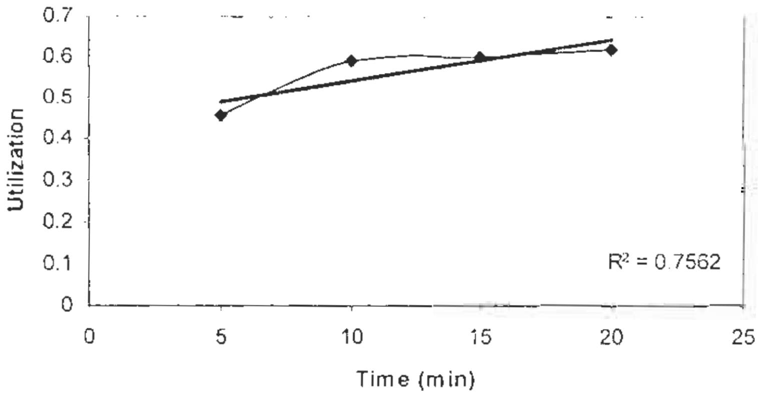

Figure 6.16 Effect of max. Processing time on utilization

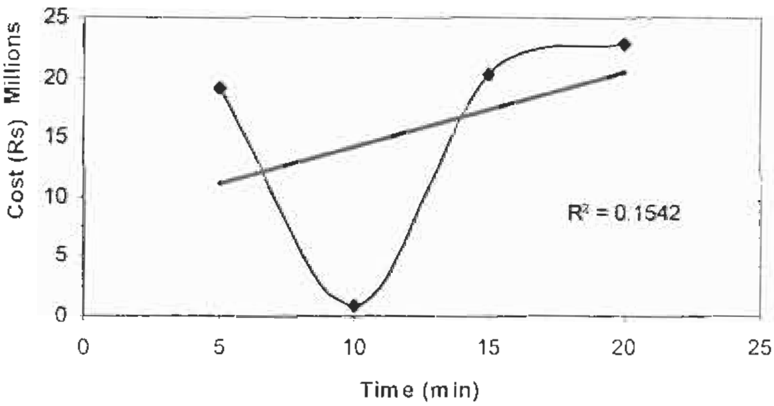

Figure 6.17 Effect of max. Processing time on rejection cost

It is therefore evident from the time dependent behavior and numerical valued responses (graphs) that balancing of production line is prerequisite in traditional as well as advanced systems.

Experiment 2) Effect of hourly wage rate (labor rate, H_{RATE})

The hourly labor rate is also found a sensitive parameter in our study which significantly affects the behavior of system. When companies shift from low to high volume in our PPMx matrix, labor rate affect the system. Because of automation semi-skilled labor would be needed at this stage. To delight customers and add value of product, improved quality and design innovation (variety) fulfill the requirements. In order to accommodate new design innovation, highly skilled labor would be needed which increases labor rate and its effect is shown from figures 6.18 to 6.21. Interestingly, hourly wage rate has no significant effect on work in process, yield before reworking, average waiting time, cumulative yield and flow time respectively.

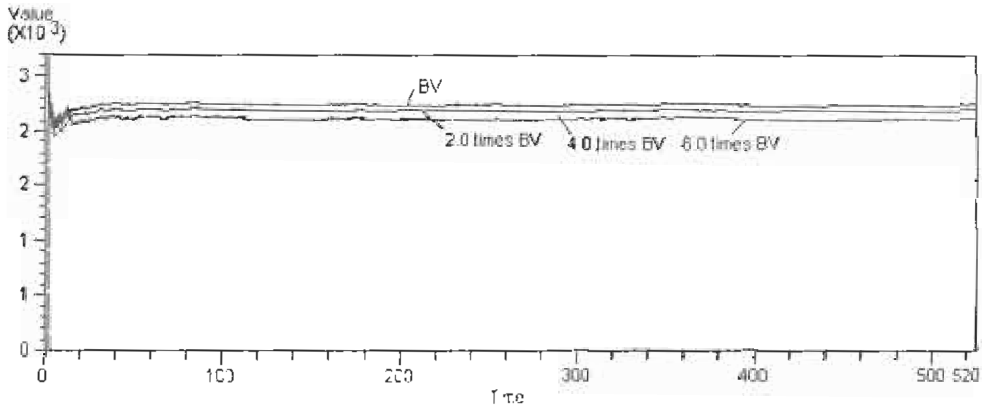

Figure 6.18 Effect of wage rate on cost per part

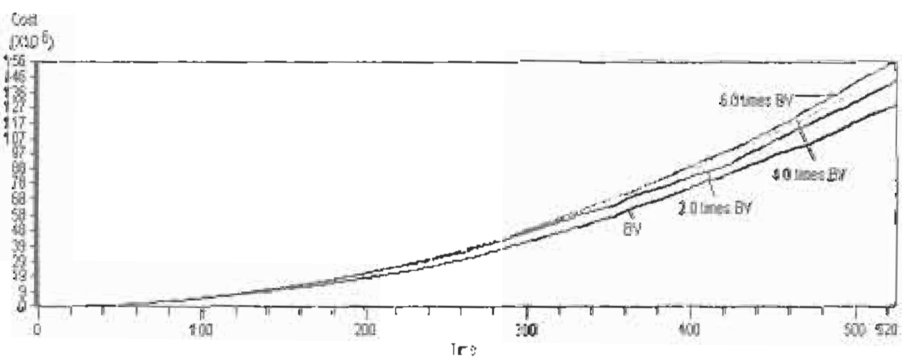

Figure 6.19 Effect of wage rate on total cost

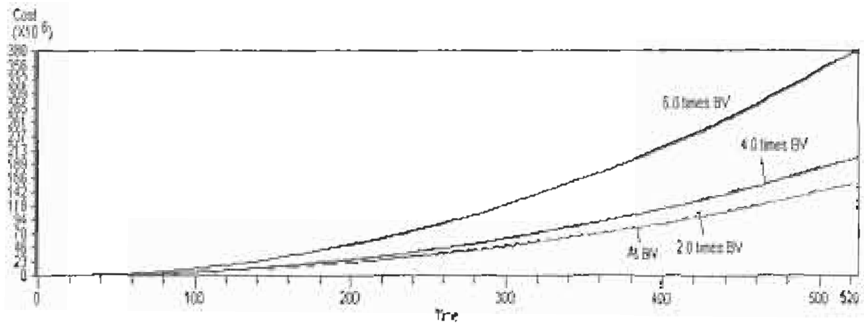

Figure 6.20 Effect of wage rate on rejection cost

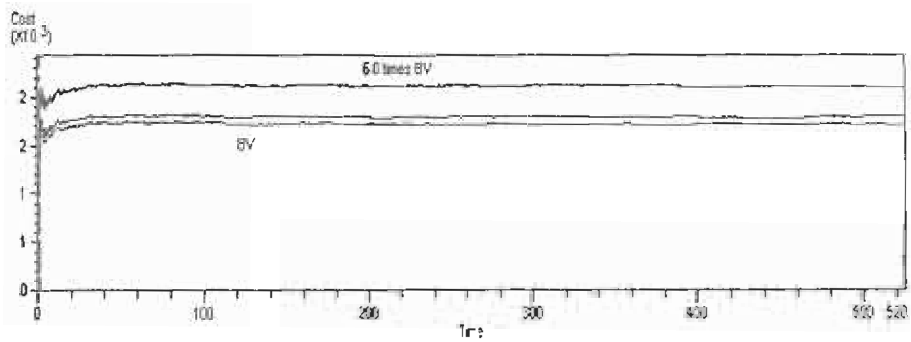

Figure 6.21 Effect of wage rate on value added cost

The numerical valued effects of most sensitive parameters for the wage rate case have been presented from figures from 6.22 to 6.25 respectively which are plotted in standard spreadsheet. The graphs show that wage rate is most sensitive on cost per unit, total cost, value added and rejection cost respectively.

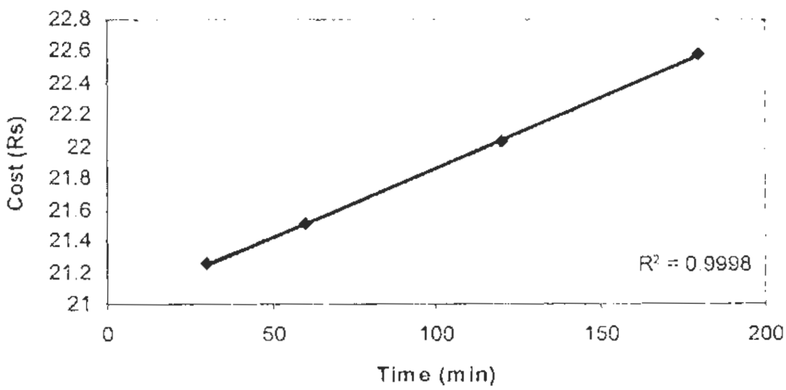

Figure 6.22 Effect of wage rate on cost per part

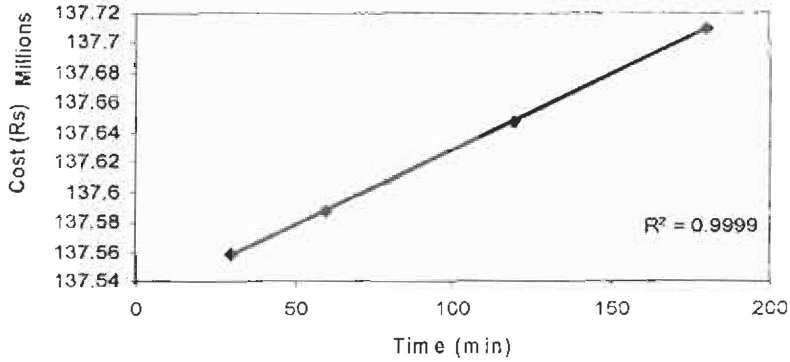

Figure 6.23 Effect of wage rate on total cost

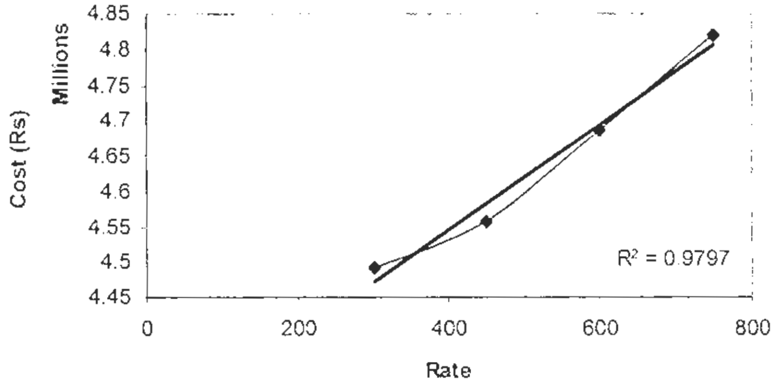

Figure 6.24 Effect of wage rate on value added cost

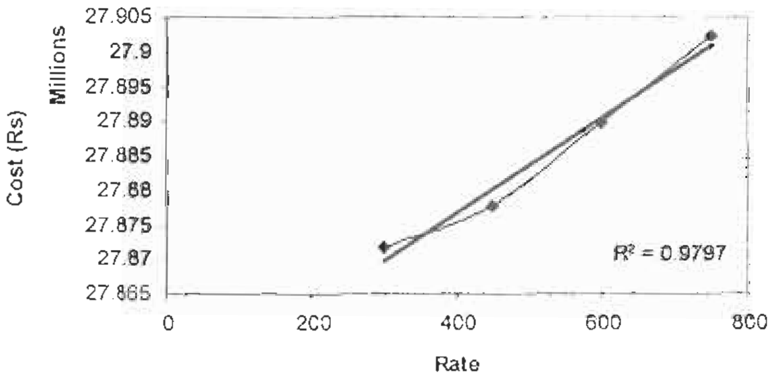

Figure 6.25 Effect of wage rate on rejection cost

Experiment 3) Effect of machine rate (M_{RATE})

When the company shift from manual production to semi or automatic machine (just like automation migration strategy), the machine rate affect the behavior of the system.

The focus is to find out the impact on costs when manufacturing organizations replace manual work with automation. Automation does not allow poorly designed products and inefficient processes to exist (Russell and Taylor, 1998). There is a lot of pressure to increase product quality and reliability. It is imperative for the industry to improve its productivity and competitiveness. The effects of machine rate on different performance measures is plotted and shown from figures 6.26 to 6.35 respectively. The effect is significantly seen on cost related parameters. This is so when companies shift their business from manual to more automation system, cost per part and total cost is increased. Using advanced manufacturing system improve product quality, reliability as demanded by the customer as tough competition forces manufacturers to use automation for production.

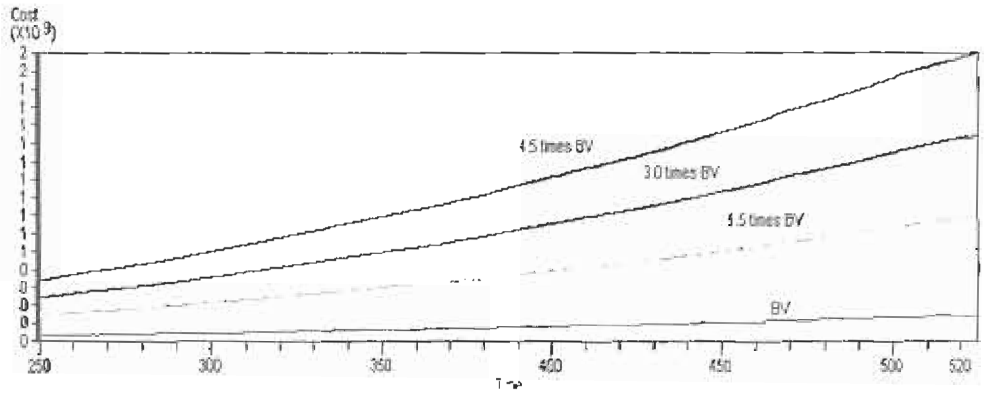

Figure 6.26 Effect of changing machine rate on total cost

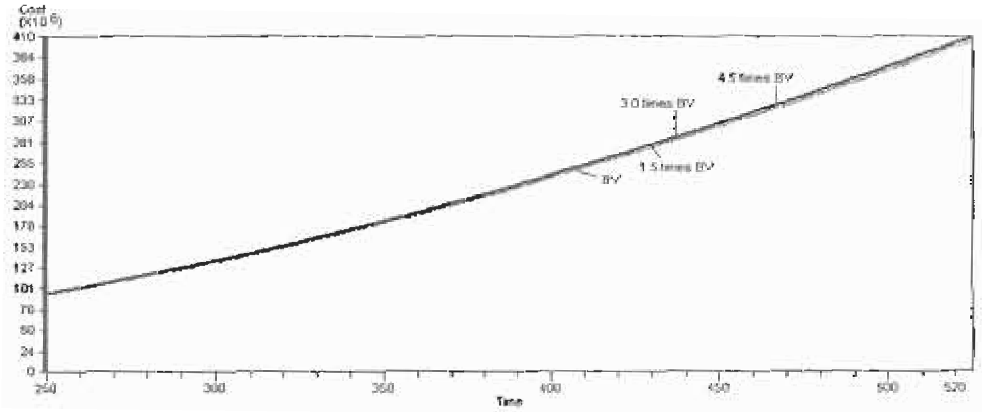

Figure 6.27 Effect of changing machine rate on reworking cost

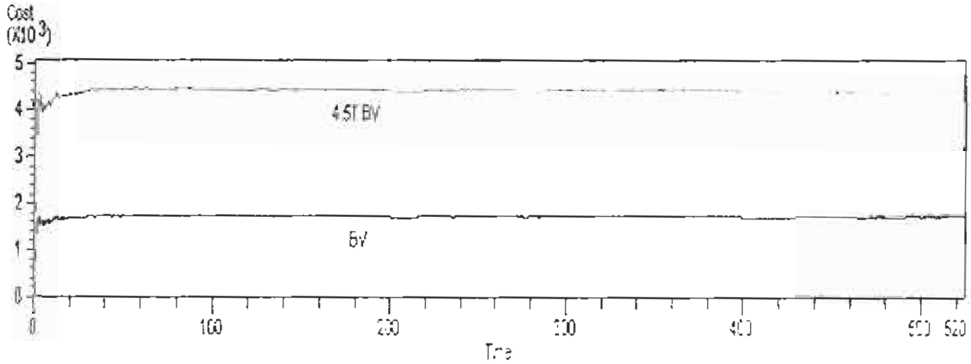

Figure 6.28 Effect of changing machine rate on value added cost

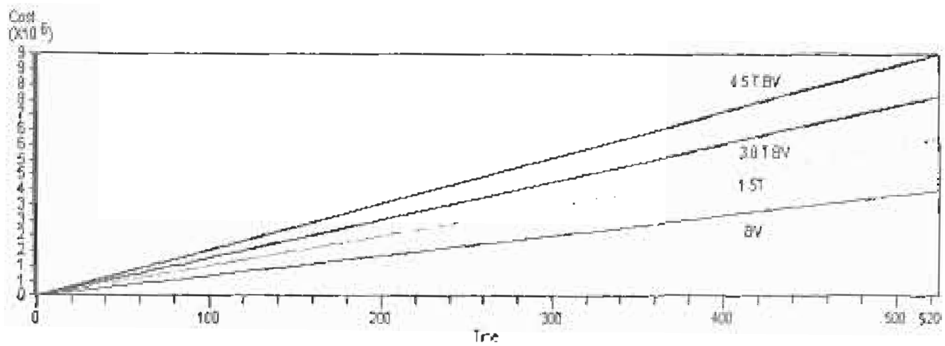

Figure 6.29 Effect of changing machine rate on cost per part

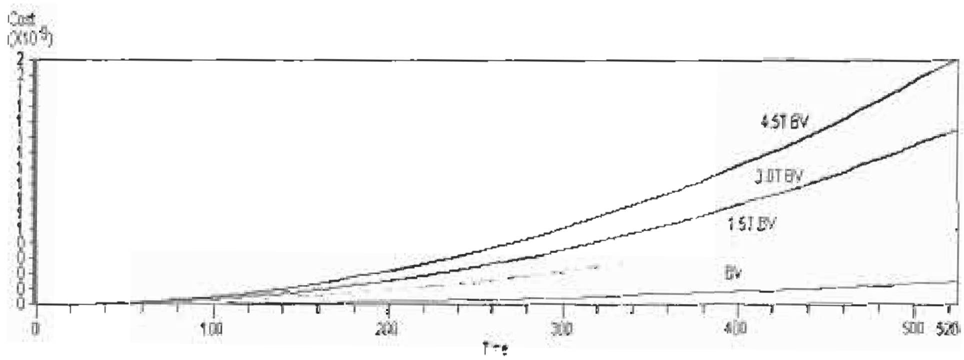

Figure 6.30 Effect of changing machine rate on rejection cost

The numerical valued effects of machine rate on different performance measures are observed and plotted as shown from 6.31 to 6.35 respectively.

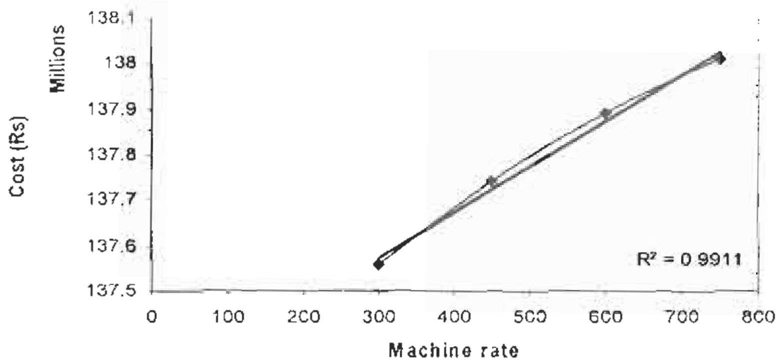

Figure 6.31 Effect of machine rate on total cost

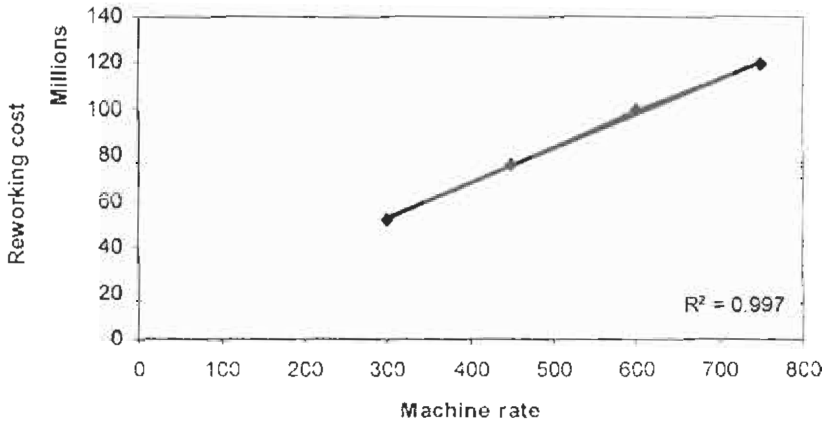

Figure 6.32 Effect of machine rate on reworking cost

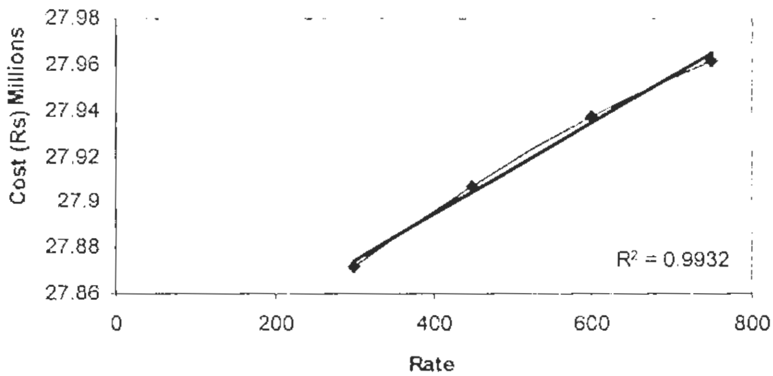

Figure 6.33 Effect of machine rate on rejection cost

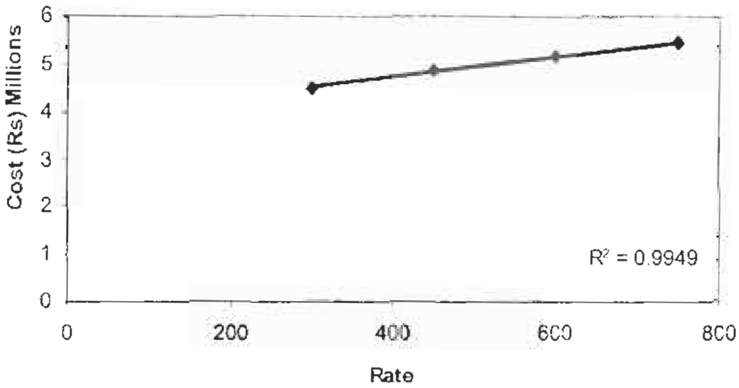

Figure 6.34 Effect of machine rate on value added cost

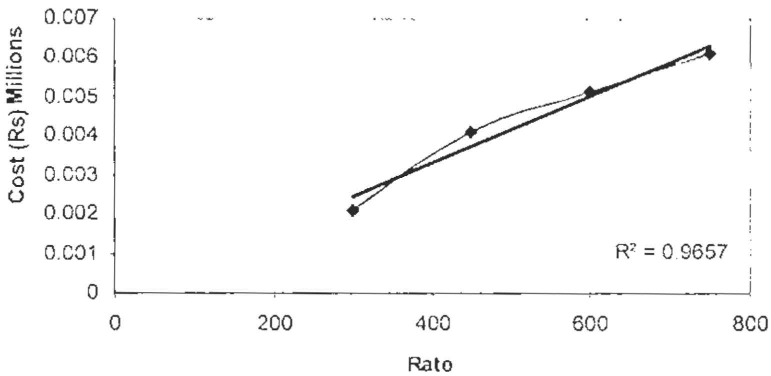

Figure 6.35 Effect of machine rate on cost per part

Experiment 4) Effect of material handling time (MH_{TIME})

Material handling is an important parameter effecting on system utilization, flow times and non-value added cost respectively. Material handling can be manual, semi-automated and fully automated depending on nature of job required. The level of automation varies depending on type of production system. In present scenario, case companies are not paying any attention on material handling, but this is one of the key factors to achieve competitive edge.

As shown in figure 6.36, the effect of material handling time is not sensitive on cost per part. Its effect is quite significant on utilization and flow time whereas it is moderately sensitive on non-value added cost. This means that material handling time reduce lead time and improve customer satisfaction at much higher volumes and varieties.

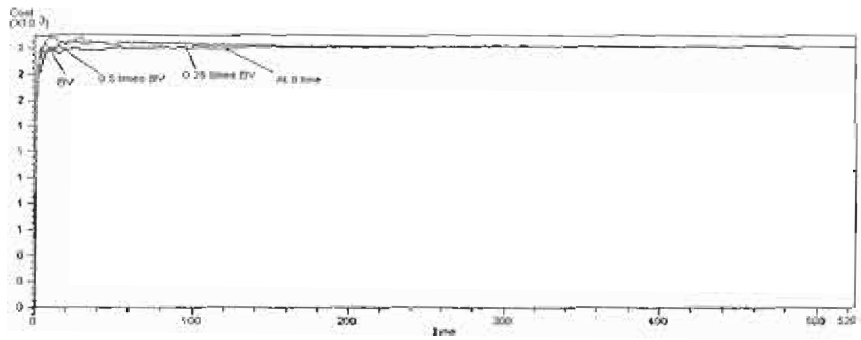

Figure 6.36 Effect of Material handling time on cost per part

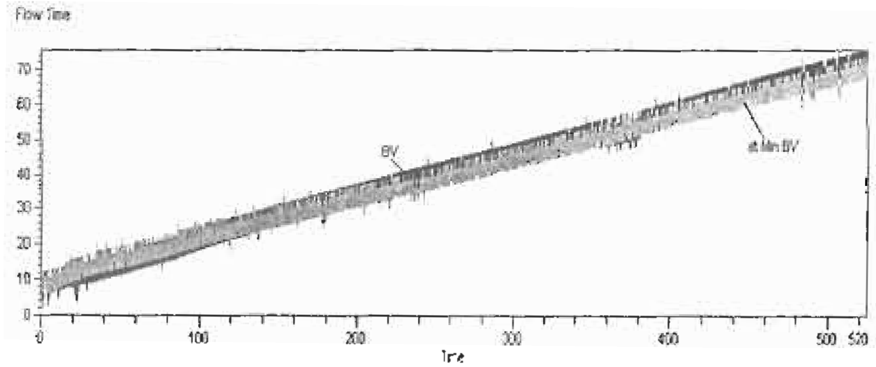

Figure 6.37 Effect of Material handling time on flow time

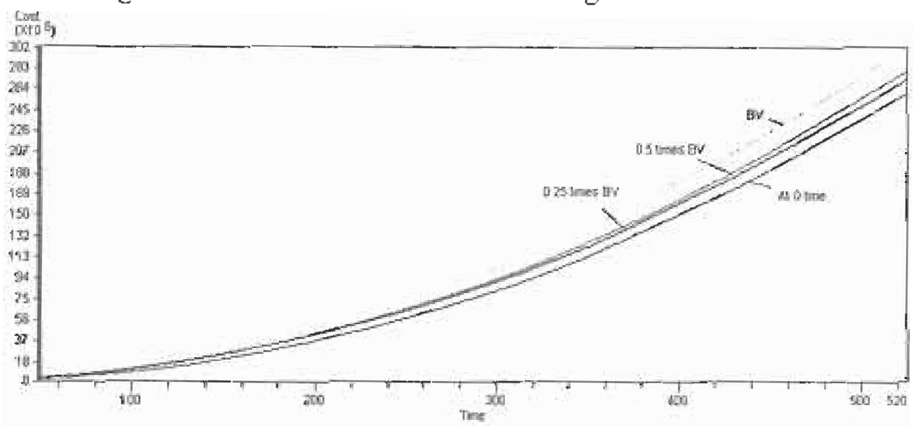

Figure 6.38 Effect of Material handling time on non-value added cost

The numerical valued effects of material handling cost on performance measures like flow times, non-value added cost and utilization of system are observed and plotted as shown from figures 6.39 to 6.41 respectively.

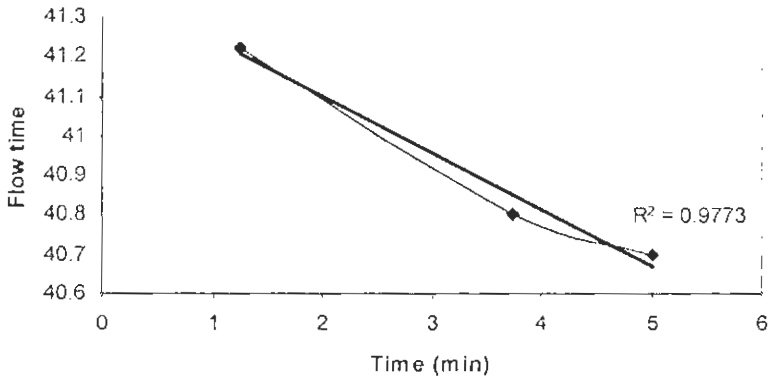

Figure 6.39 Effect of Material handling time on flow time

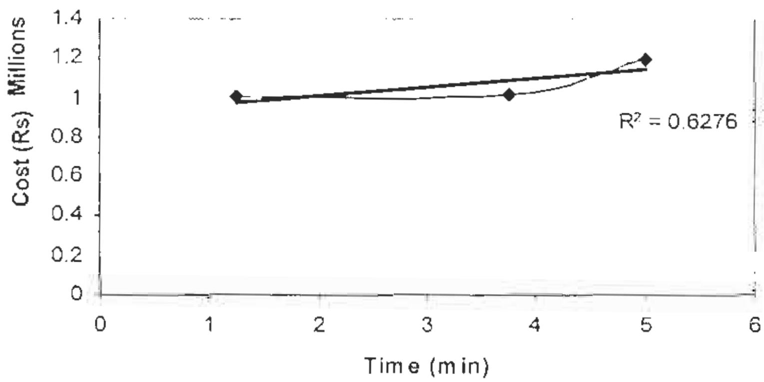

Figure 6.40 Effect of Material handling time on non value added cost

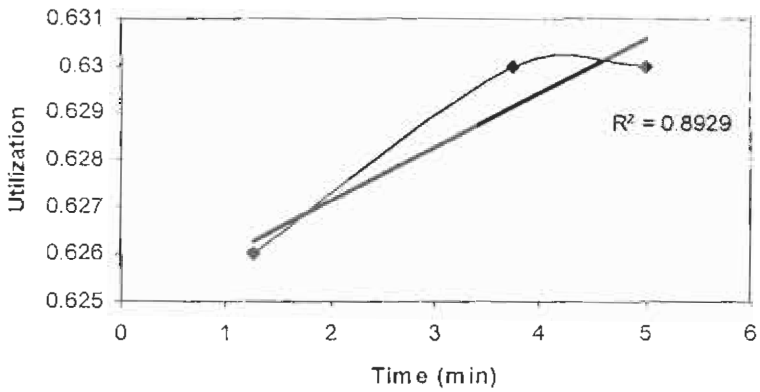

Figure 6.41 Effect of Material handling time on utilization

Experiment 5) Effect of starting or minimum quantity to be reworked (Y_{MIN})

The effect of Y_{MIN} on various costs and yields are shown from figures 6.42 to 6.57. It is found the most sensitive parameter that has considerable effect on all variables/responses.

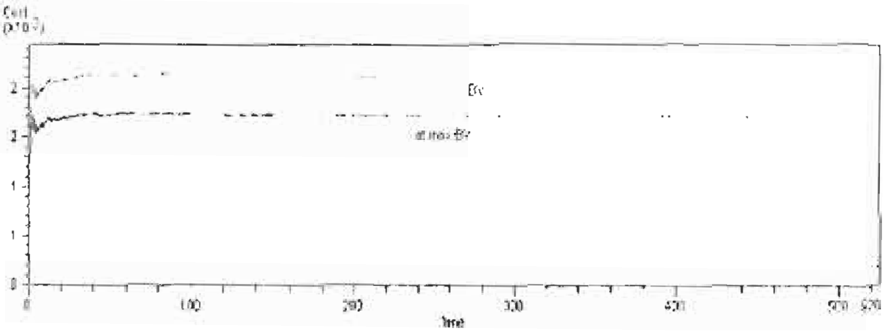

Figure 6.42 Effect of min quantity to be reworked on cost per part

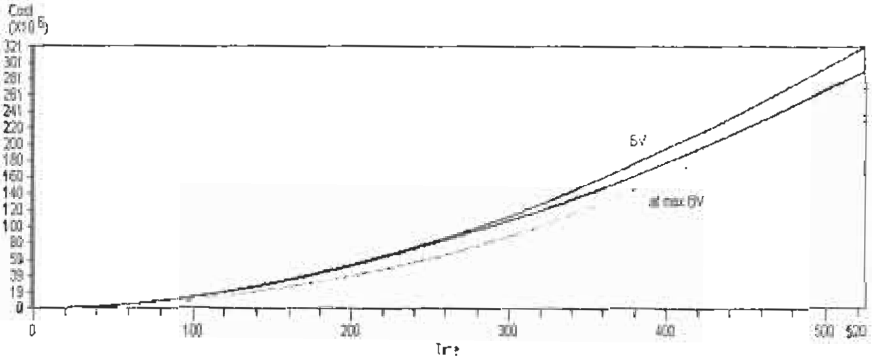

Figure 6.43 Effect of min quantity to be reworked on total cost

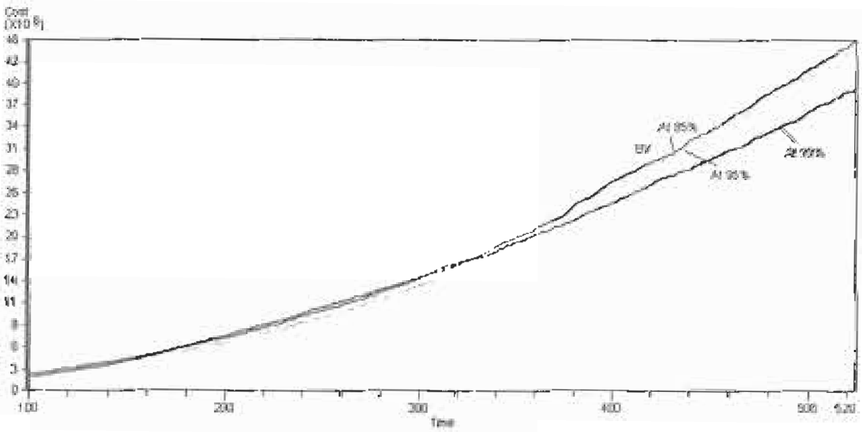

Figure 6.44 Effect of min quantity to be reworked on rejection cost

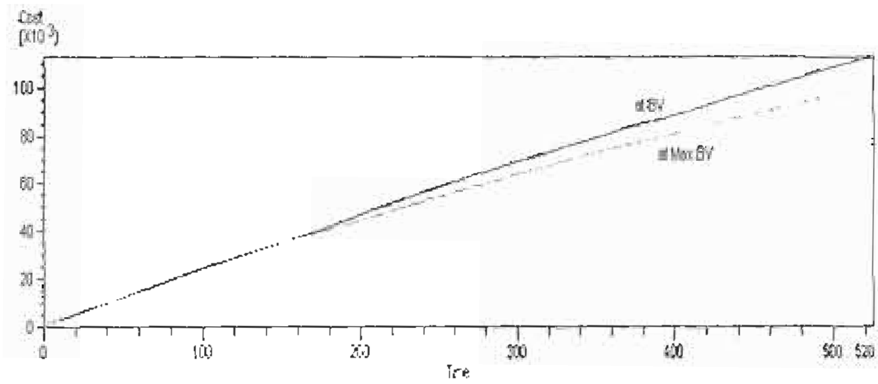

Figure 6.45 Effect of min quantity to be reworked on non-value added cost

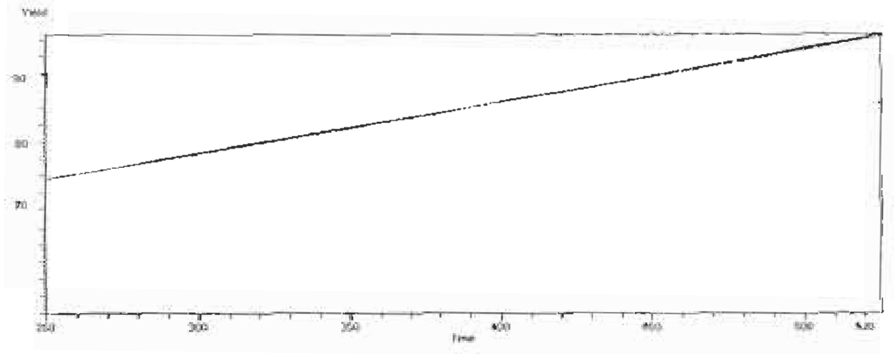

Figure 6.46 Effect of changing quality level on cumulative yield

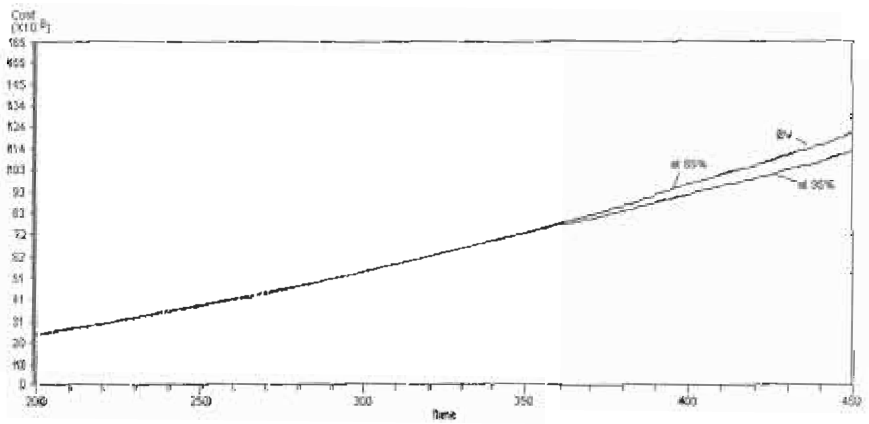

Figure 6.47 Effect of min quantity to be reworked on reworking cost

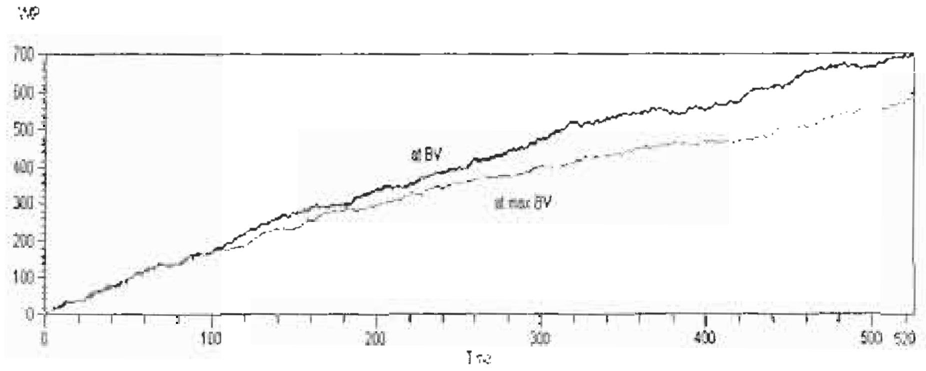

Figure 6.48 Effect of min quantity to be reworked on WIP

The numerical valued effects of 'Y_{MIN}' on performance measures as recorded during simulation experiments are observed and plotted which are shown from 6.49 to 6.57 respectively.

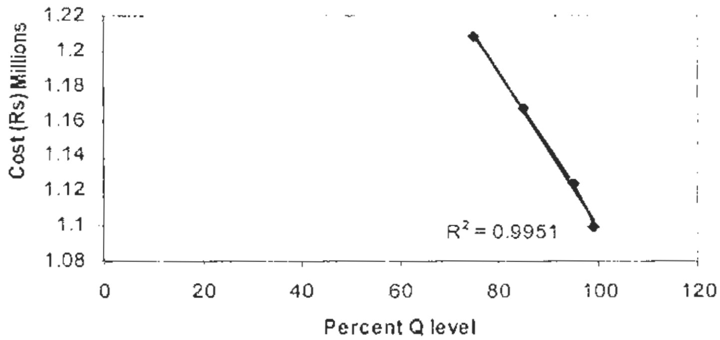

Figure 6.49 Effect of min quantity to be reworked on non-value added cost

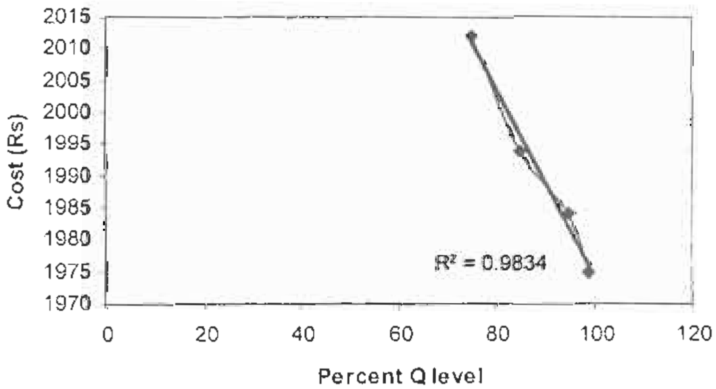

Figure 6.50 Effect of min quantity to be reworked on cost per part

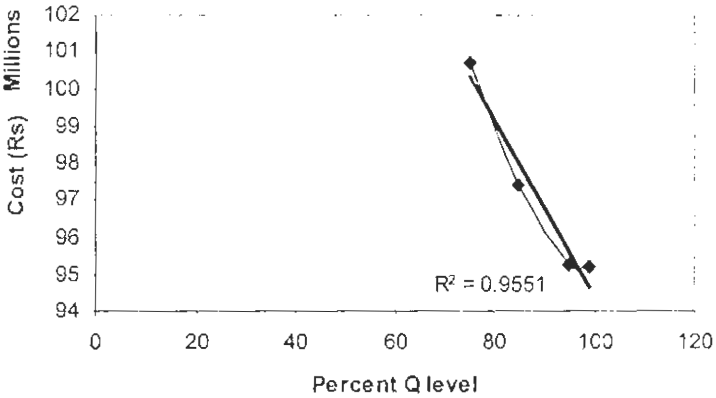

Figure 6.51 Effect of min quantity to be reworked on total cost

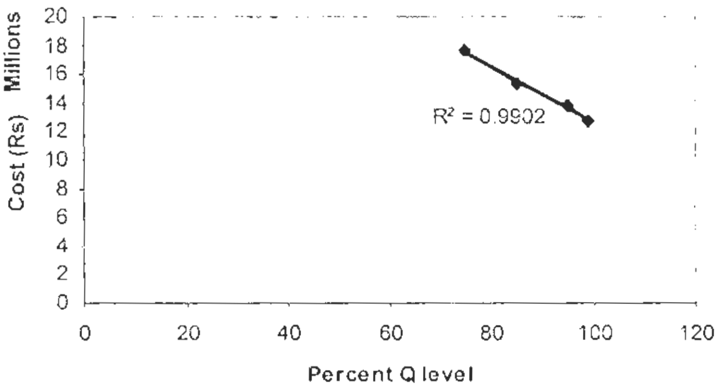

Figure 6.52 Effect of min quantity to be reworked on rejection cost

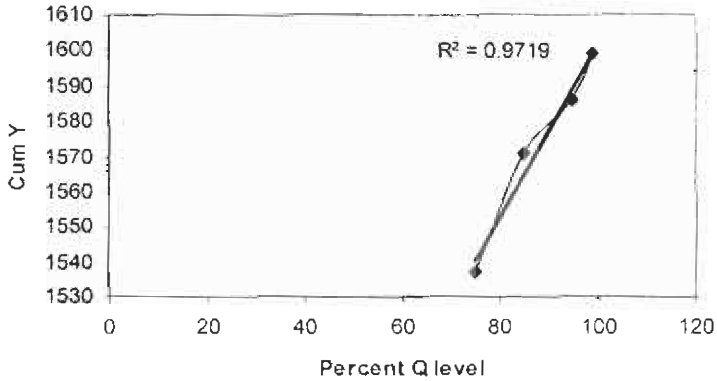

Figure 6.53 Effect of min quantity to be reworked on cumulative yield

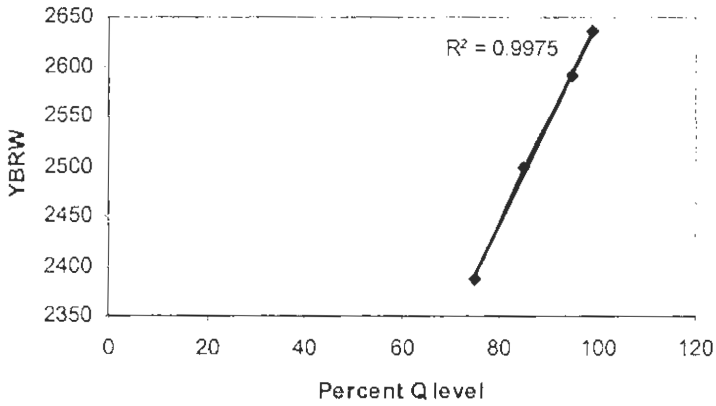

Figure 6.54 Effect of min quantity to be reworked on YBRW

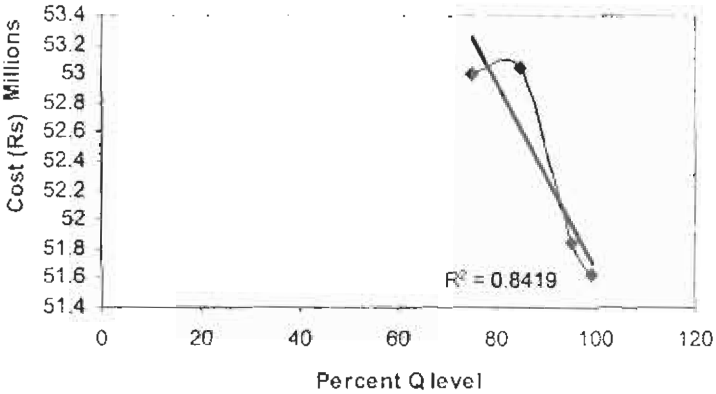

Figure 6.55 Effect of min quantity to be reworked on reworking cost

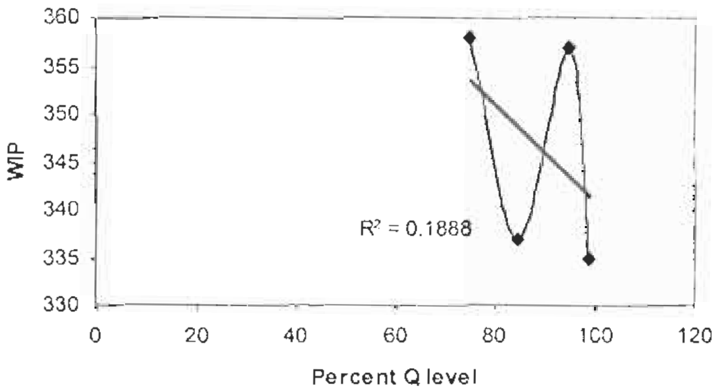

Figure 6.56 Effect of min quantity to be reworked on WIP

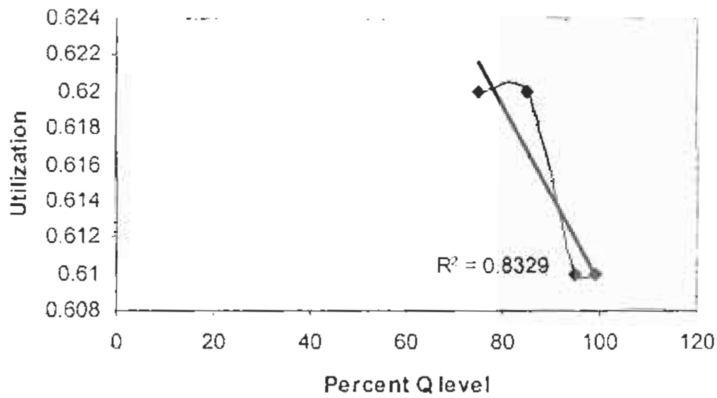

Figure 6.57 Effect of min quantity to be reworked on utilization

Experiment 6) Effect of change in quantity to be reworked (Y_{IMP})

The effect of Y_{IMP} on various costs and yields are shown from figures 6.58 to 6.70. When advanced manufacturing system is introduced, it not only increase quality of parts but also enhances product variety as these systems can accommodate any type of flexibility required in processes. It can be seen that this is also most sensitive parameter that has considerable effects on all of the factors above.

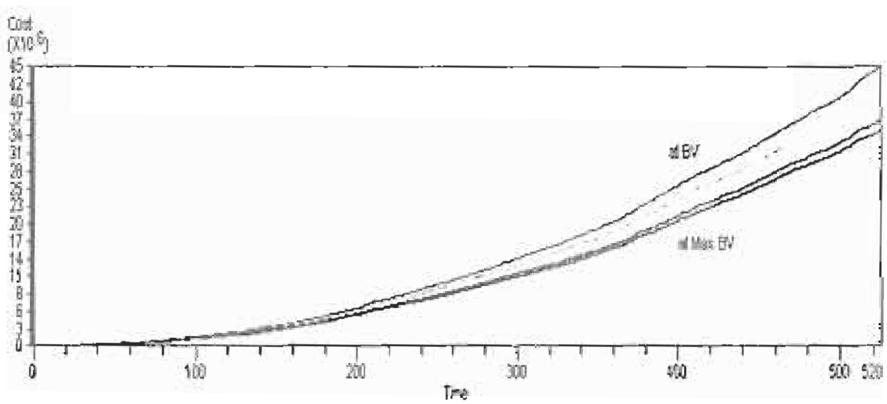

Figure 6.58 Effect of yield improvement on cost per part

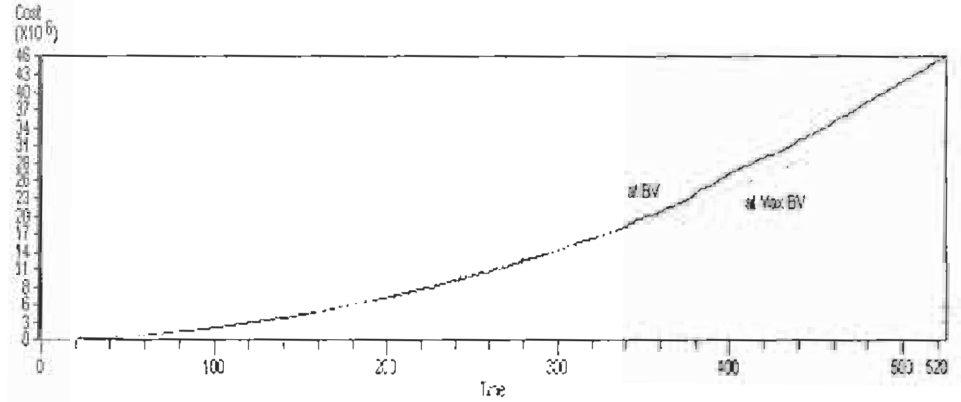

Figure 6.59 Effect of yield improvement on rejection cost

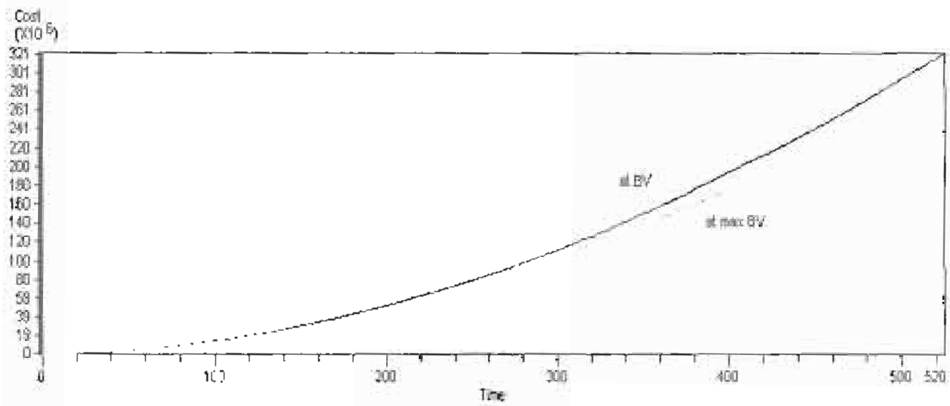

Figure 6.60 Effect of yield improvement on total cost

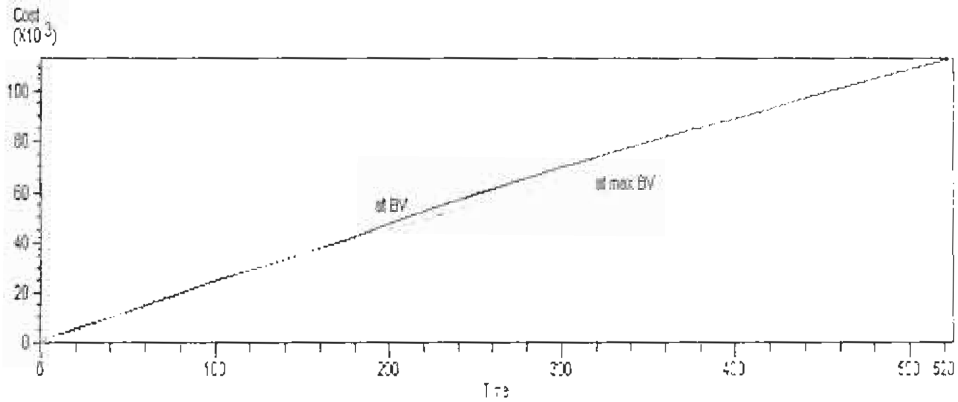

Figure 6.61 Effect of yield improvement on non-value added cost

The numerical valued effects of yield improvement on different performance indicators recorded during simulation experiments are observed and plotted which are shown from figures 6.62 to 6.70 respectively.

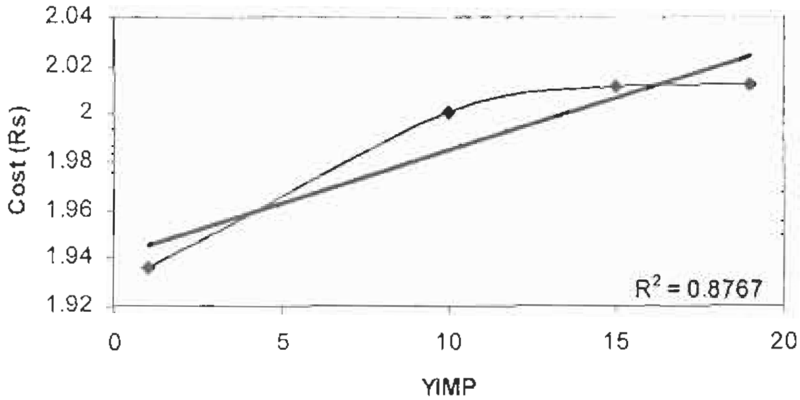

Figure 6.62 Effect of yield improvement on cost per part

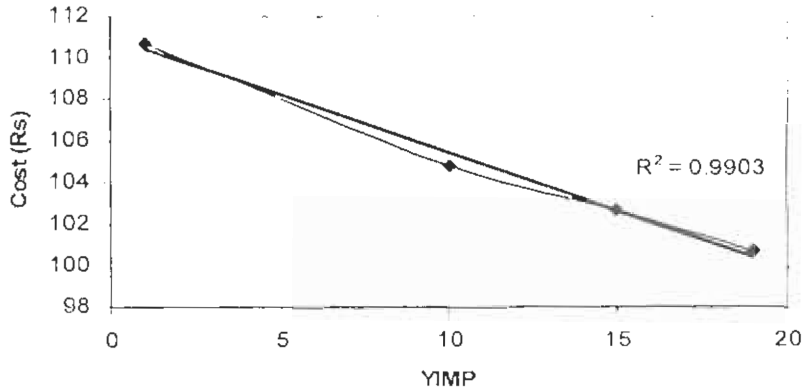

Figure 6.63 Effect of yield improvement on total cost

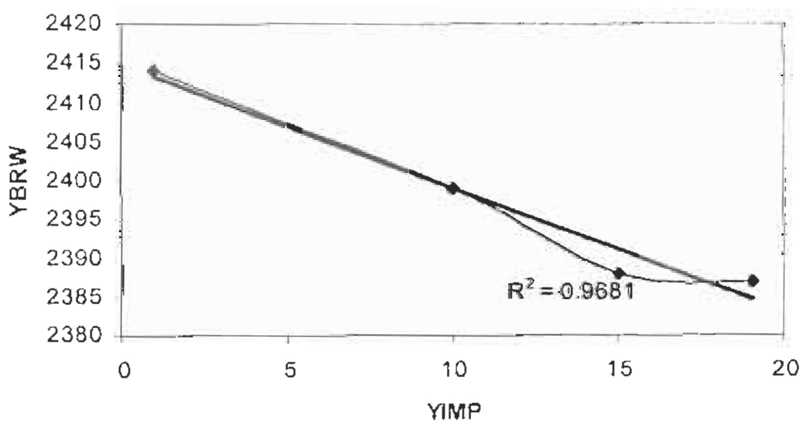

Figure 6.64 Effect of yield improvement on YBRW

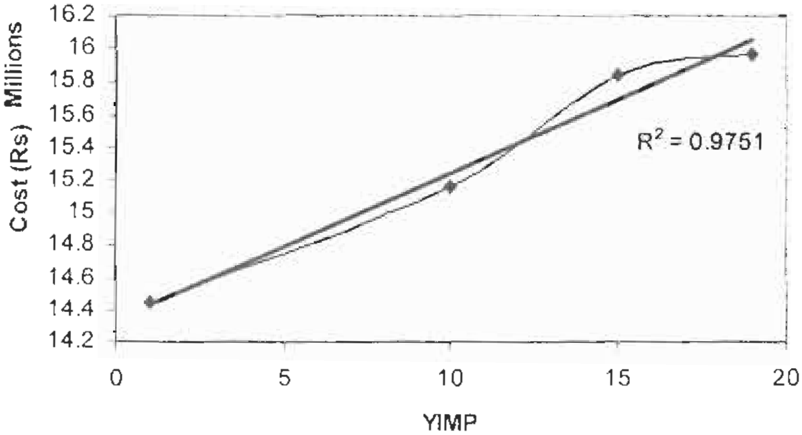

Figure 6.65 Effect of yield improvement on rejection cost

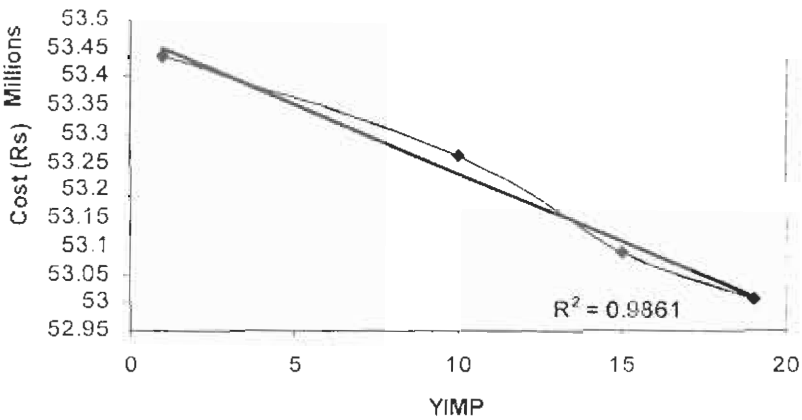

Figure 6.66 Effect of yield improvement on reworking cost

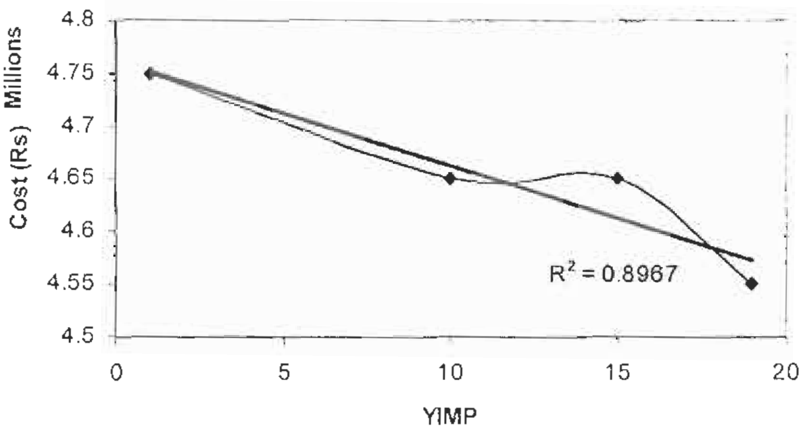

Figure 6.67 Effect of yield improvement on value added cost

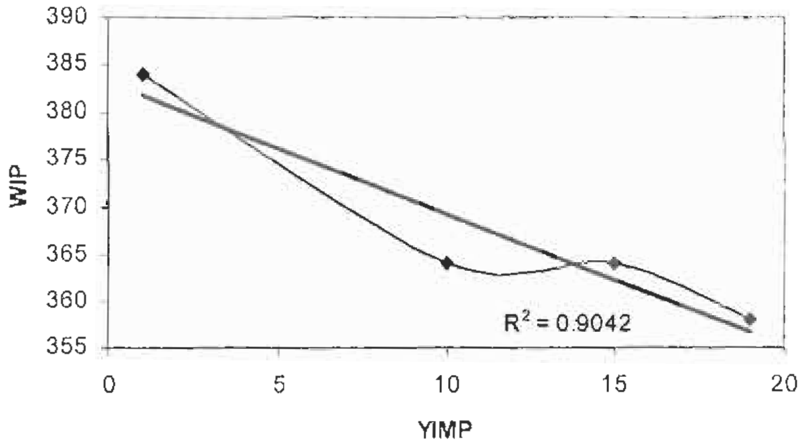

Figure 6.68 Effect of yield improvement on WIP

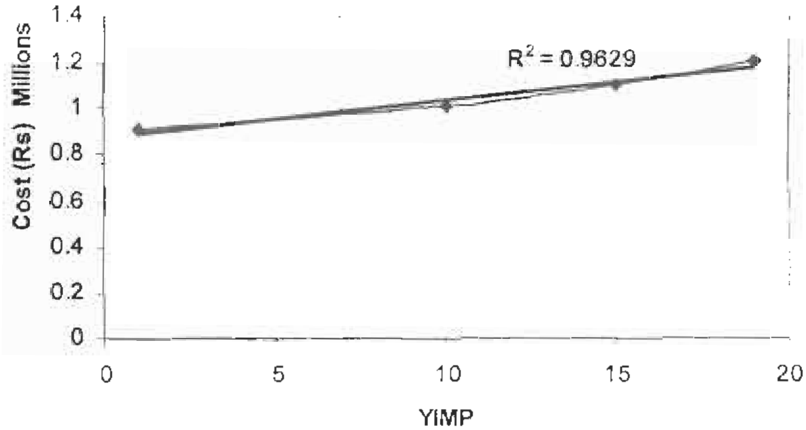

Figure 6.69 Effect of yield improvement on non-value added cost

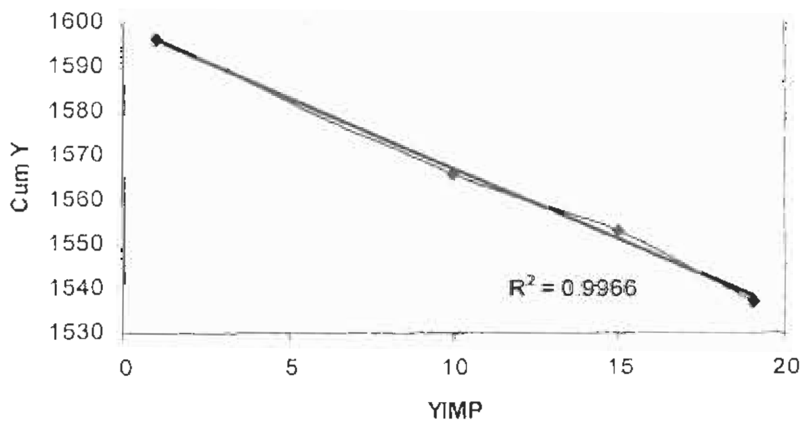

Figure 6.70 Effect of yield improvement on cumulative yield

Experiment 7) Effect of maximum setup time (SU_{TIME})

The effect of setup time on various costs, yields and others factors is shown from figures 6.71 to 6.80. It can be seen that setup time has considerable effect on non-value added cost. Its effect is moderate on cost per part, flow time and work in process. The drawbacks in conventional systems are setup time which forces production to run for long times. Many approaches have been developed such as flexible jigs/fixtures/ SMED, FMS to reduce setup times.

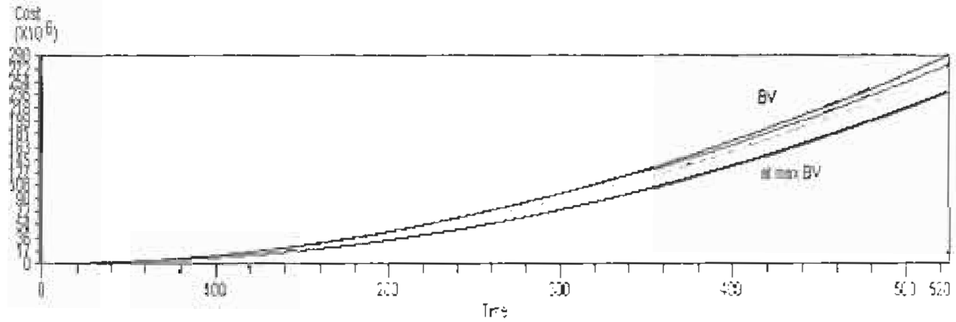

Figure 6.71 Effect of setup time on cost per part

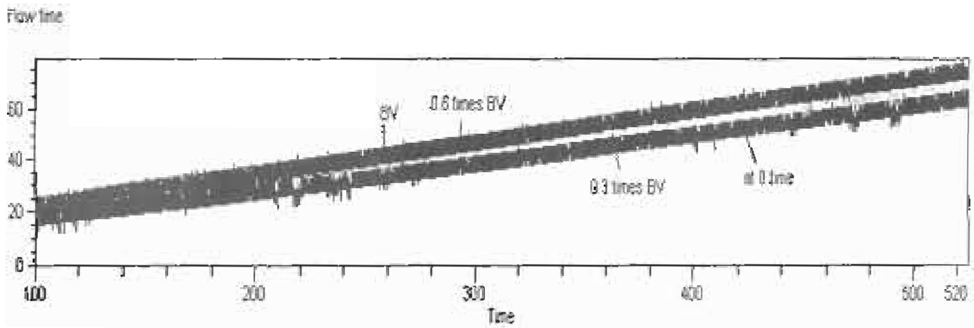

Figure 6.72 Effect of changing setup time on flow time

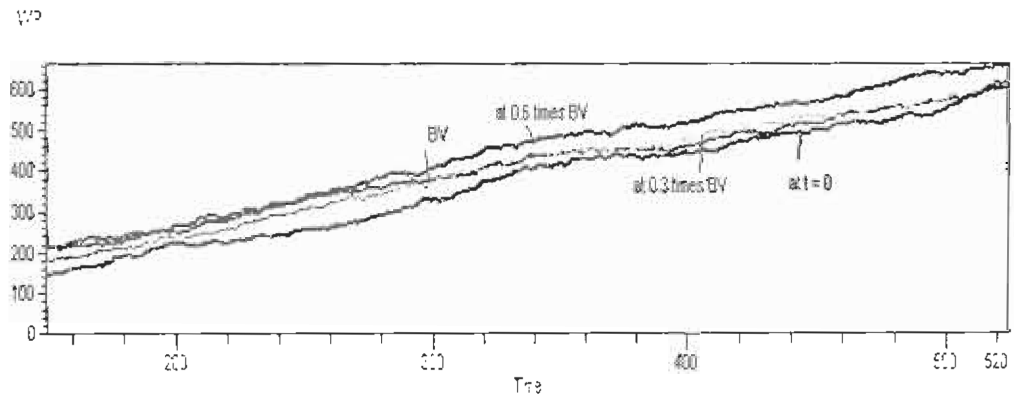

Figure 6.73 Effect of changing setup time on WIP

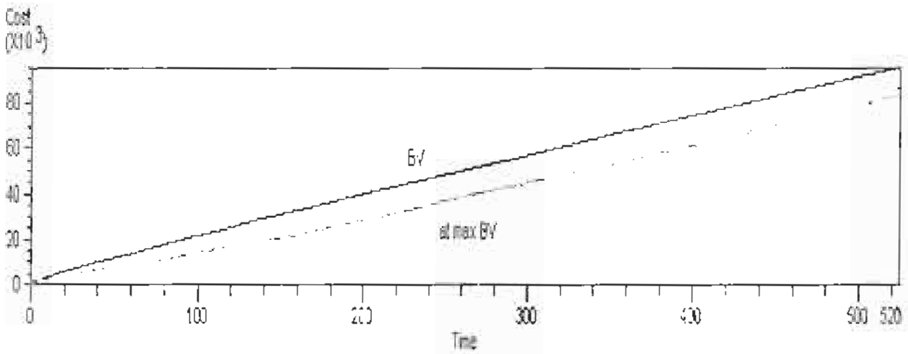

Figure 6.74 Effect of changing setup time on non-value added cost

The numerical valued effects of setup time on different performance indicators recorded during simulation experiments are observed and plotted as shown from 6.75 to 6.82 respectively.

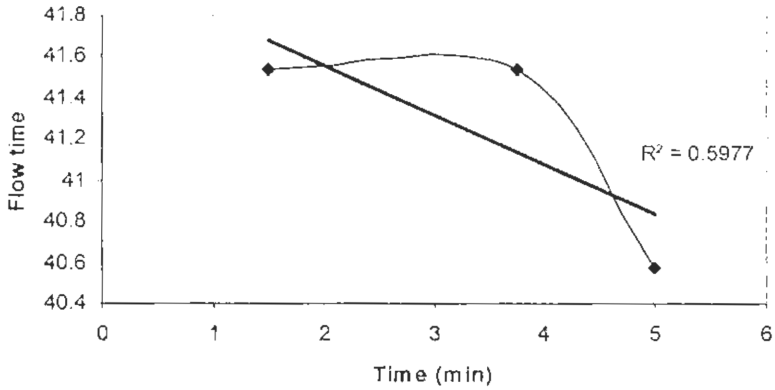

Figure 6.75 Effect of changing setup time on flow time

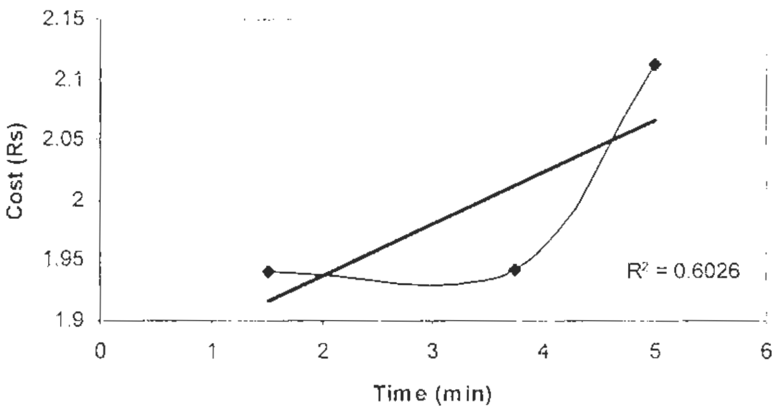

Figure 6.76 Effect of changing setup time on cost per part

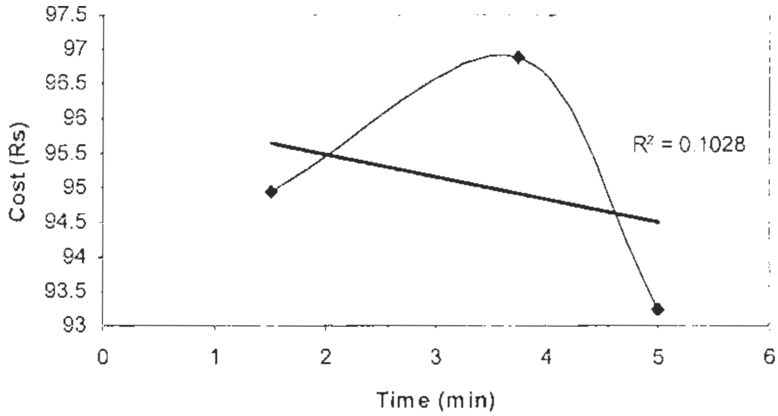

Figure 6.77 Effect of changing setup time on total cost

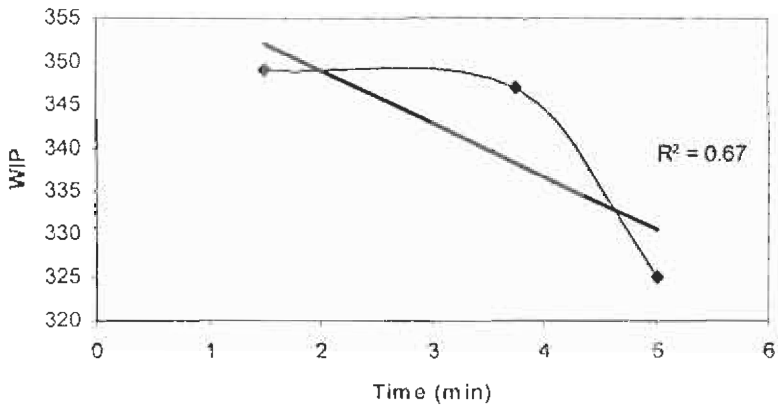

Figure 6.78 Effect of changing setup time on WIP

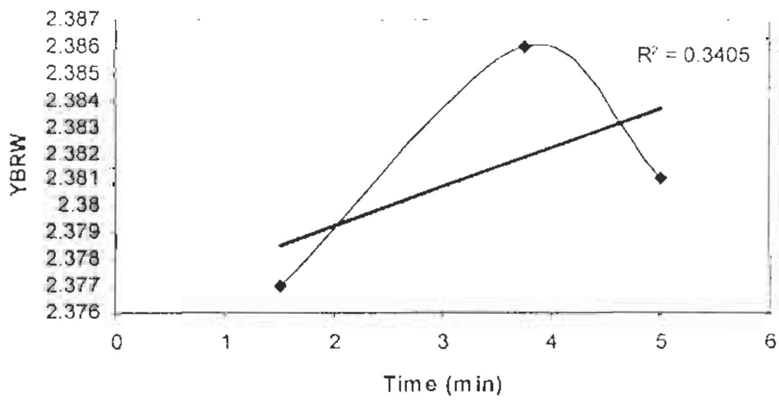

Figure 6.79 Effect of changing setup time on YBRW

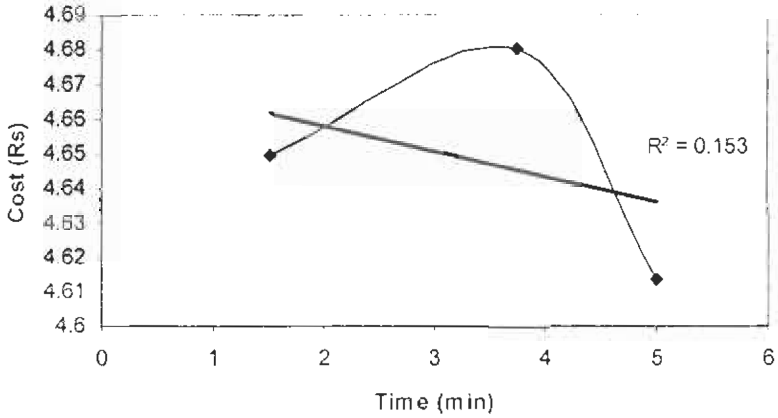

Figure 6.80 Effect of changing setup time on value added cost

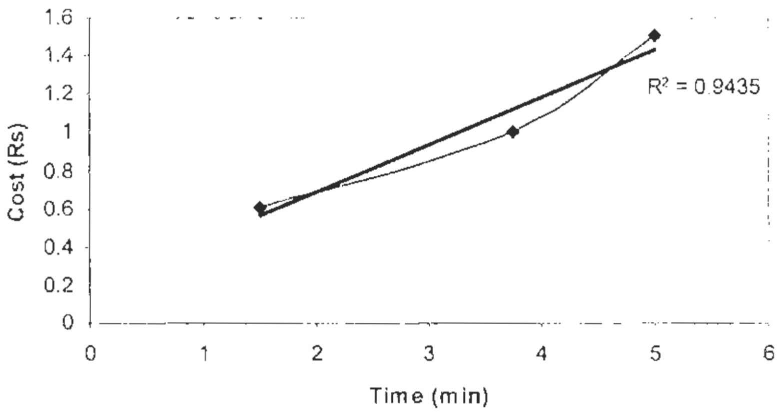

Figure 6.81 Effect of changing setup time on non-value added cost

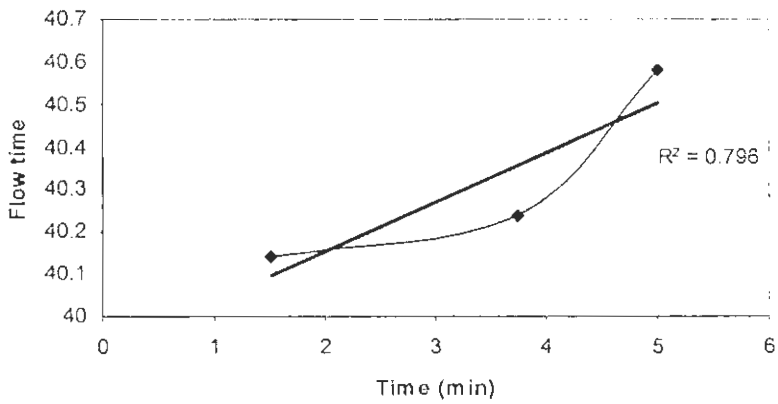

Figure 6.82 Effect of changing setup time on flow time

Experiment 8) Effect of reworking time (RW_{TIME})

When advanced systems are used, it possibly increase quality so non value added operations and reworking time is reduced. The effect of reworking times on various costs, yields and other factors is shown from figures 6.83 to 6.92. It is found that reworking times significantly effect on cost per part and reworking cost while it has little effect on other performance variables.

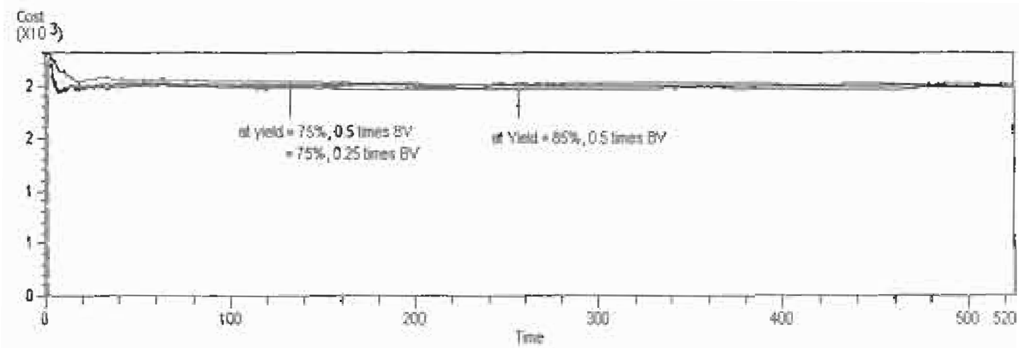

Figure 6.83 Effect of changing reworking times on cost per part

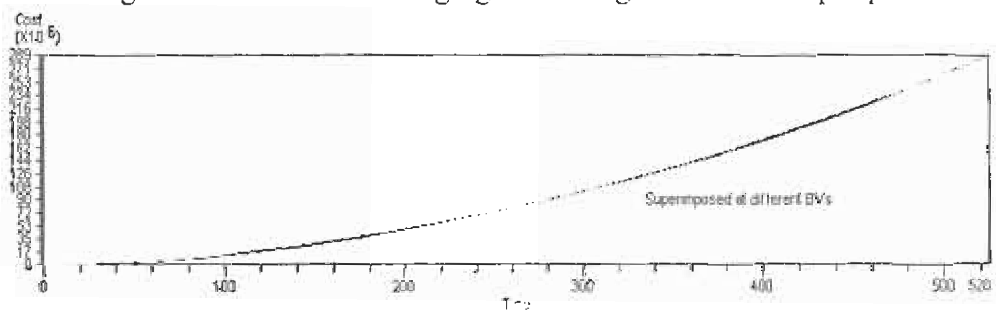

Figure 6.84 Effect of changing reworking times on total cost

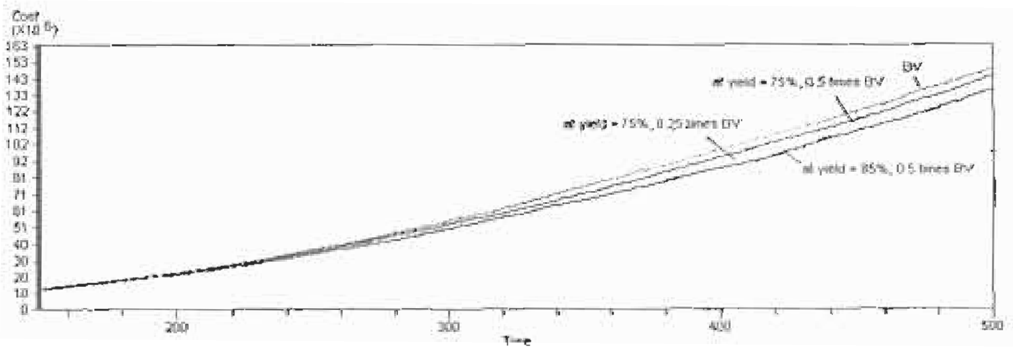

Figure 6.85 Effect of changing reworking times on reworking cost

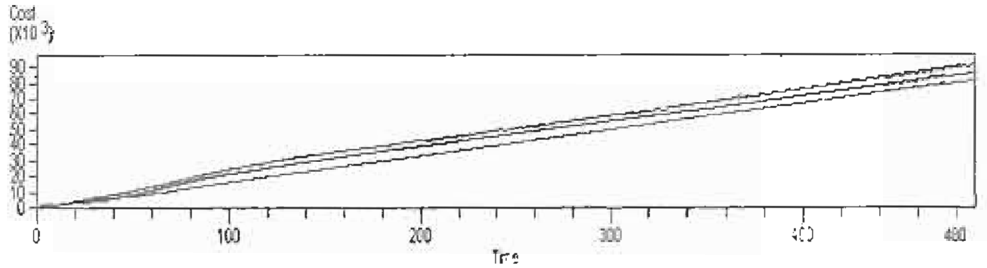

Figure 6.86 Effect of changing reworking times on non value added cost

The numerical valued effects of reworking time on performance measures observed and plotted on standard spreadsheet are shown from 6.86 to 6.92 respectively.

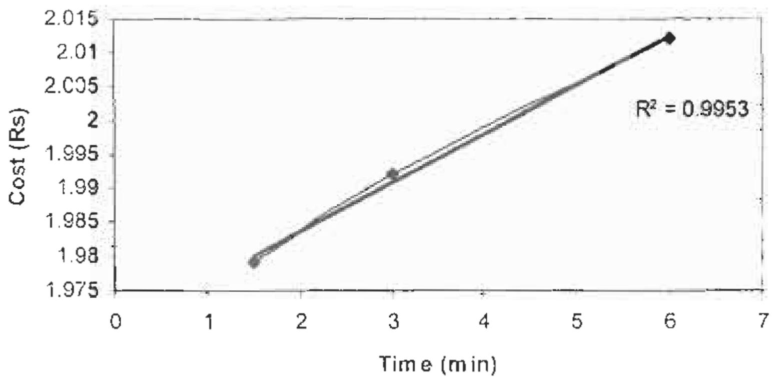

Figure 6.87 Effect of reworking times on cost per part

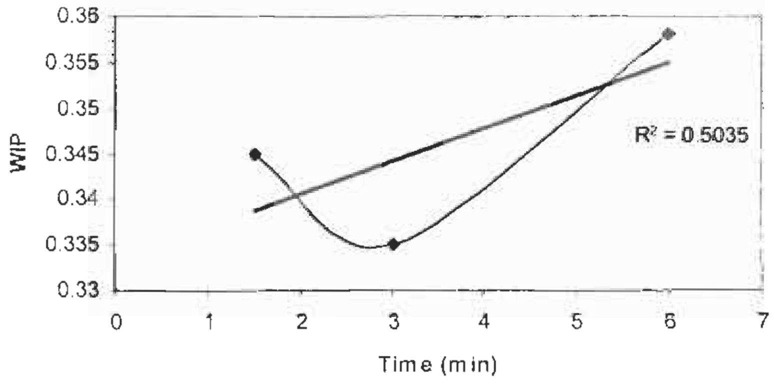

Figure 6.88 Effect of reworking times on WIP

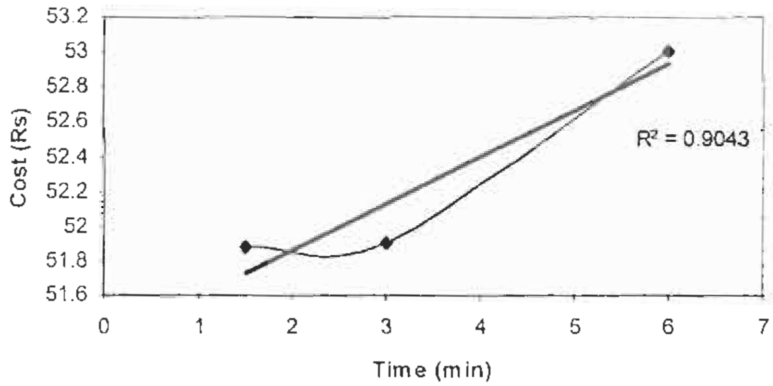

Figure 6.89 Effect of reworking times on reworking cost

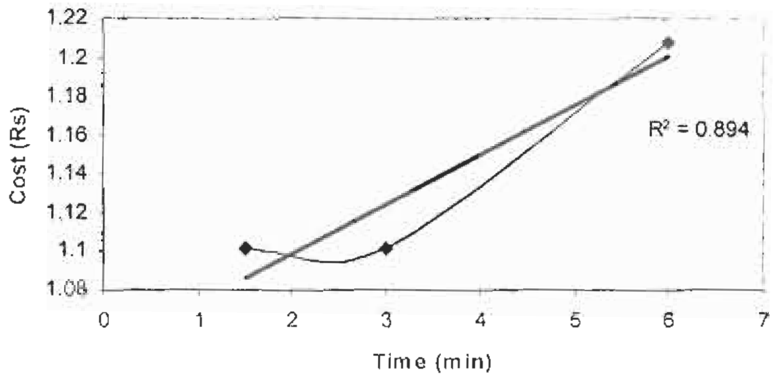

Figure 6.90 Effect of reworking times on non-value added cost

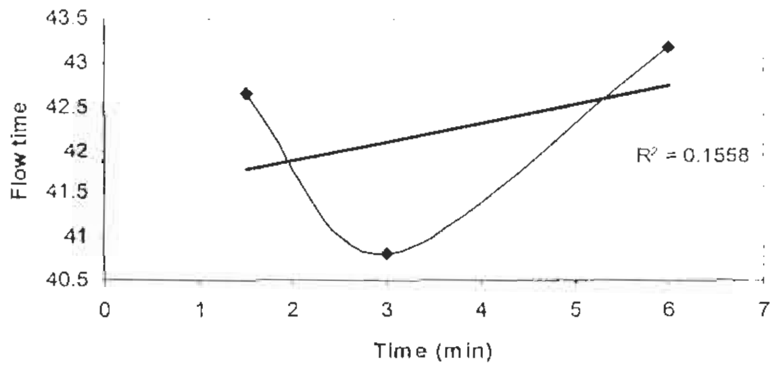

Figure 6.91 Effect of reworking times on flow time

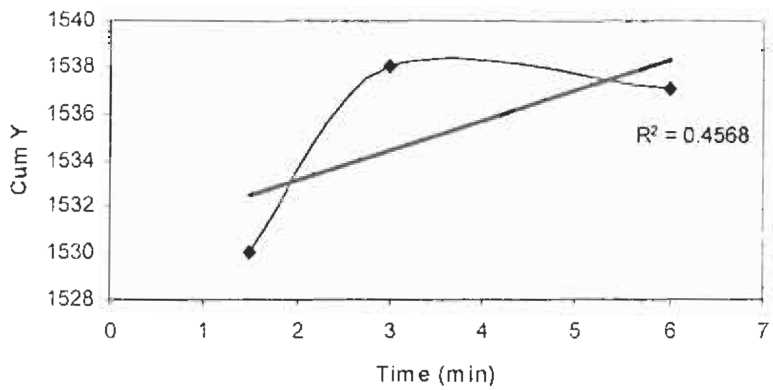

Figure 6.92 Effect of reworking times on cumulative yield

Experiment 9) Effect of fast reworking time (FR_{TIME})

In fast reworking, operator learning i.e. learning and forgetting occurs. When a new product is introduced, skilled labor is assigned to perform the job. As soon as, the model is fully understood by semi skilled and multifunctional workers, job is handed over to them. In such situations learning curve phenomenon affect the system which is shown in figures 6.94, 6.95, 6.96, 6.97, 6.98 and 6.99 respectively. It is found that the effect of fast reworking times on cost per part, waiting times, work in process, rejection cost, non-value added cost and flow times respectively is less sensitive. Only strong effect has been witnessed on non-value added cost.

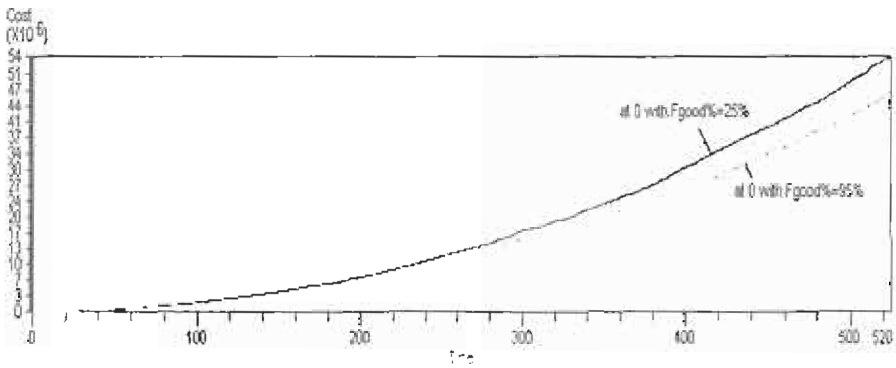

Figure 6.93 Effect of changing fast reworking time on rejection cost

The numerical valued effects of fast reworking time on performance measures observed and plotted which are shown from 6.94 to 6.99 respectively.

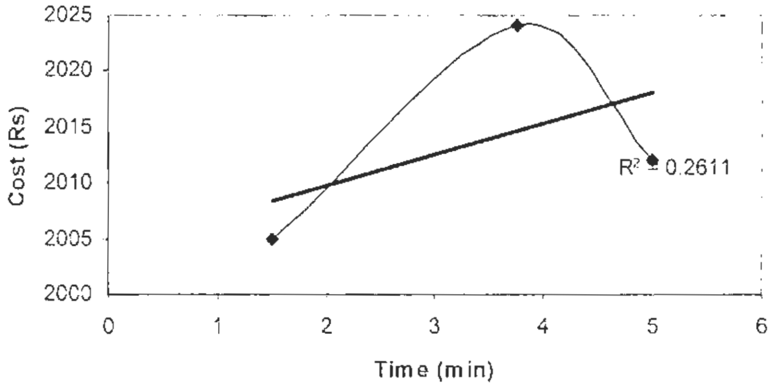

Figure 6.94 Effect of fast reworking time on cost per part

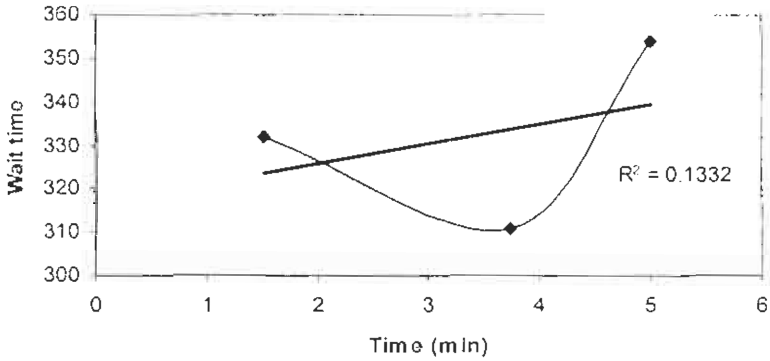

Figure 6.95 Effect of fast reworking time on waiting time

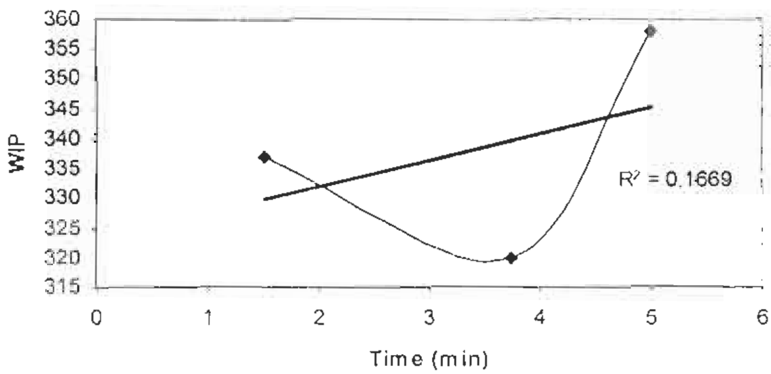

Figure 6.96 Effect of fast reworking time on WIP

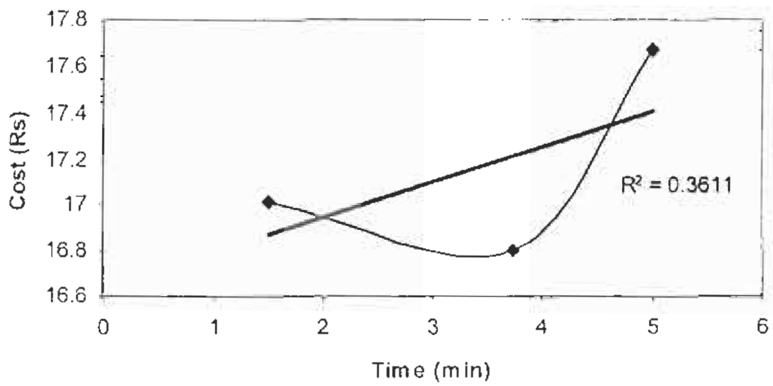

Figure 6.97 Effect of fast reworking time on rejection cost

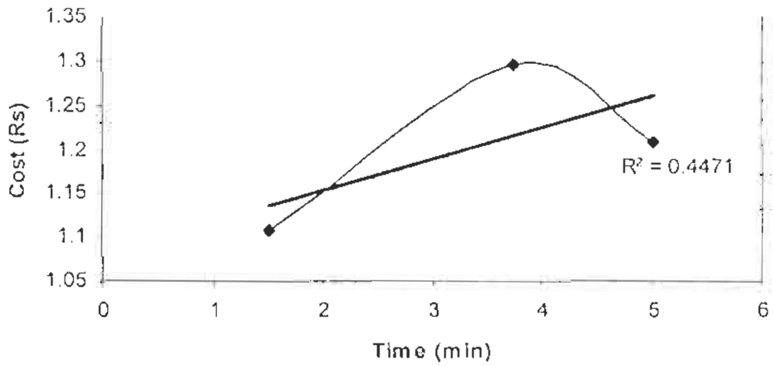

Figure 6.98 Effect of fast reworking time on non-value added cost

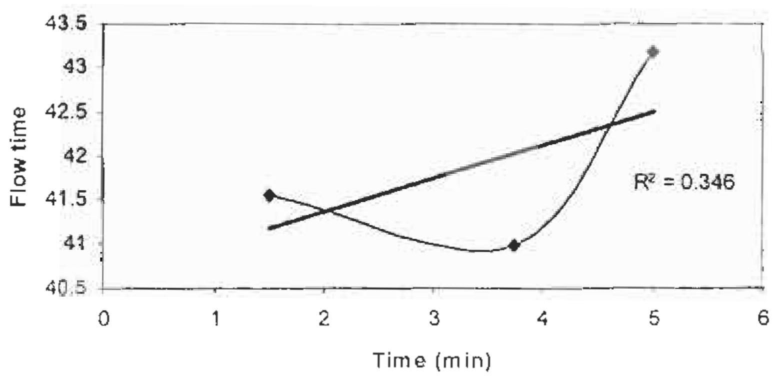

Figure 6.99 Effect of fast reworking time on flow time

Experiment 10) Effect of volume change flexibility at different arrivals (V_{FLEX})

The effect of volume flexibility at different arrivals on various costs, yields and other related factors is shown in figures 6.100 to 6.113. It can be seen that 'V_{FLEX}' is most sensitive on total cost and flow times while moderately sensitive on work in process, waiting time and cost per part respectively. This is so when volume increases, capacity problems occur and it affect performance of the system.

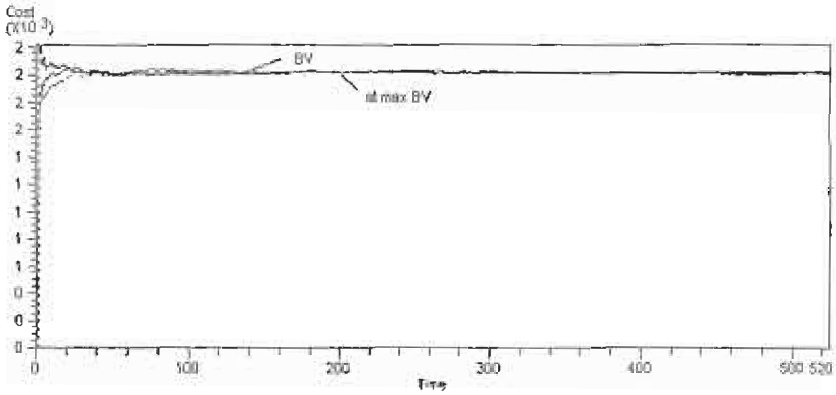

Figure 6.100 Effect of volume flexibility on cost per part

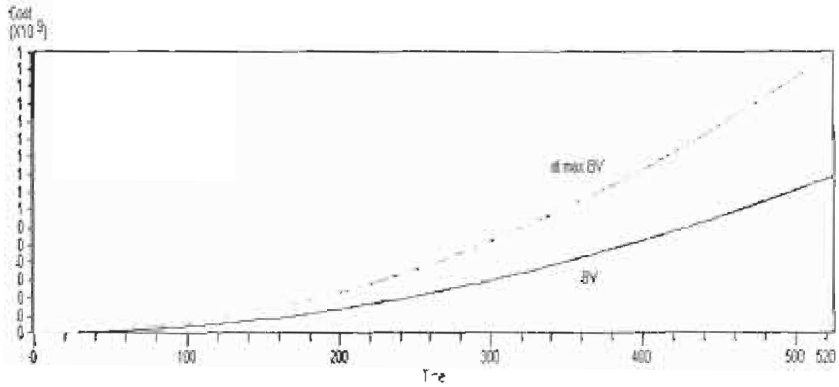

Figure 6.101 Effect of volume flexibility on total cost

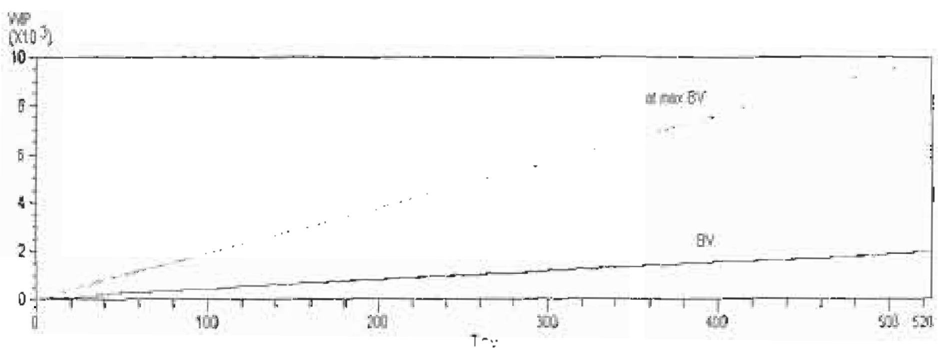

Figure 6.102 Effect of volume flexibility on WIP

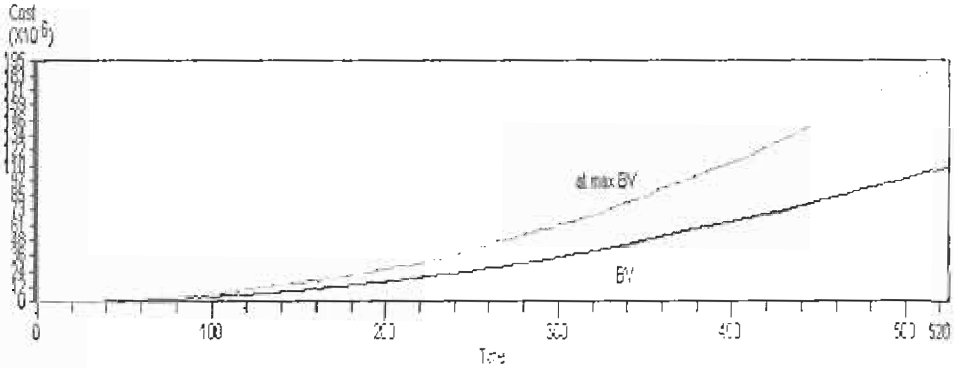

Figure 6.103 Effect of volume flexibility on rejection cost

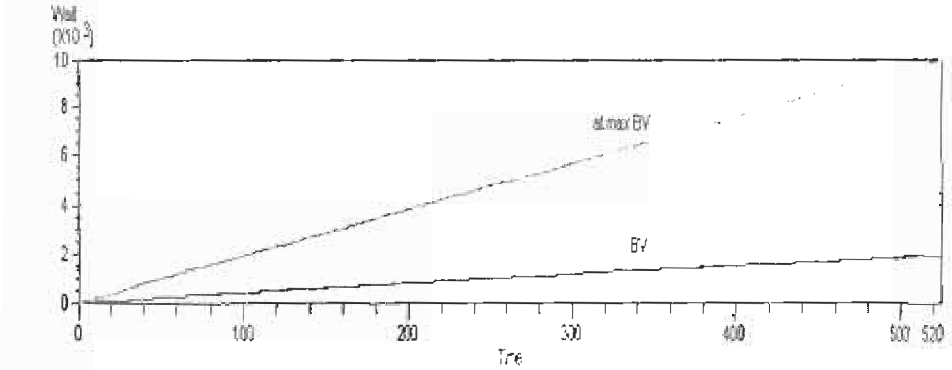

Figure 6.104 Effect of volume flexibility on waiting time

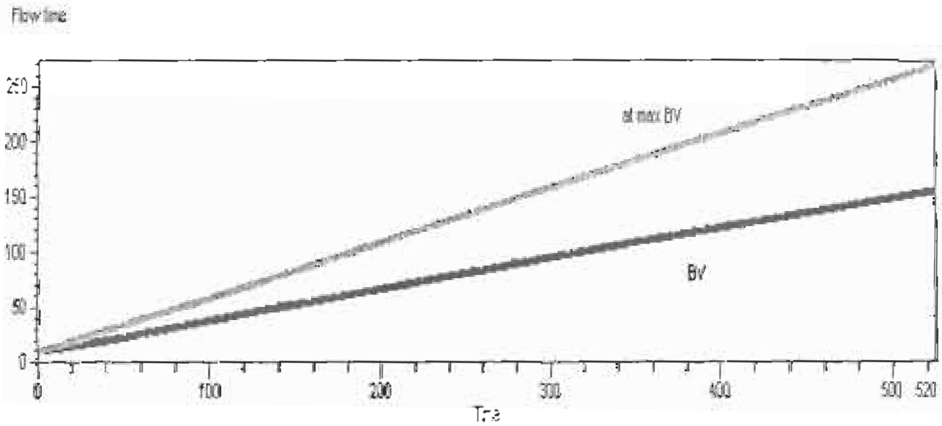

Figure 6.105 Effect of volume flexibility on flow time

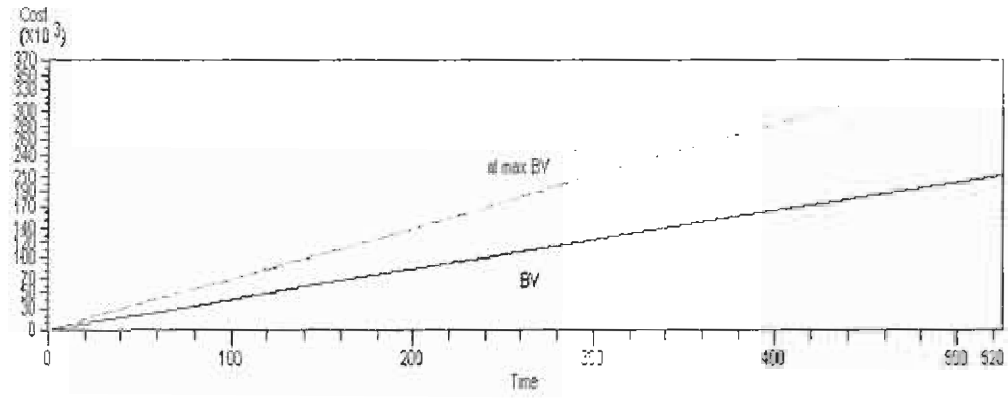

Figure 6.106 Effect of volume flexibility on non-value added cost

The numerical valued effects of volume flexibility on performance measures observed and plotted which are shown from 6.107 to 6.113 respectively.

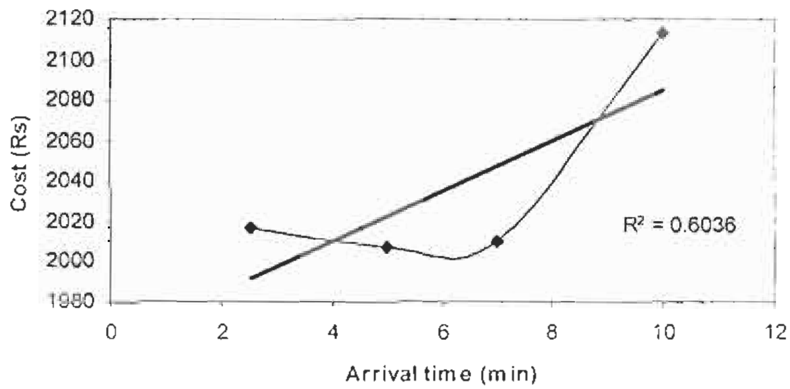

Figure 6.107 Effect of volume flexibility on cost per part

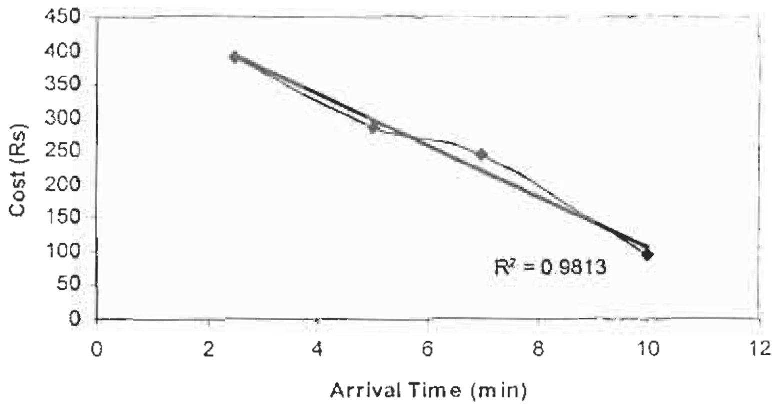

Figure 6.108 Effect of volume flexibility on total cost

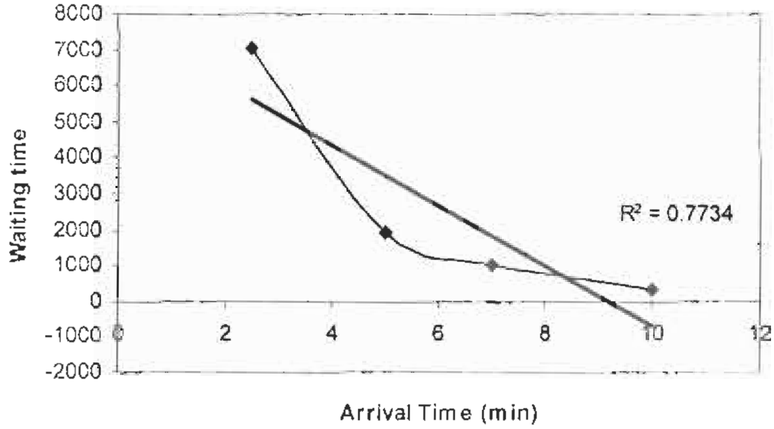

Figure 6.109 Effect of volume flexibility on waiting time

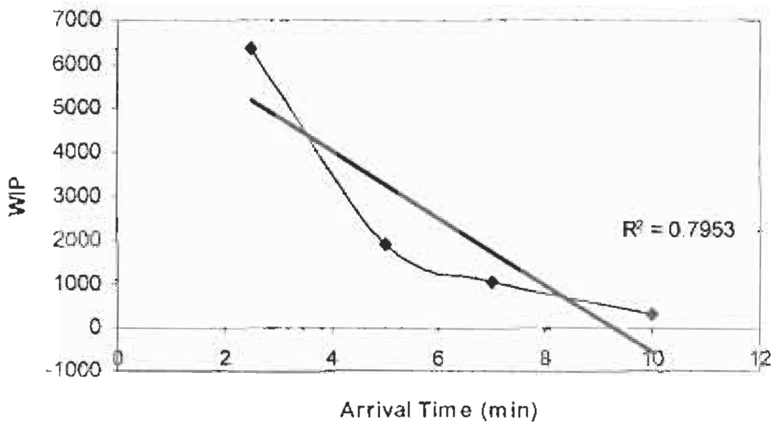

Figure 6.110 Effect of volume flexibility on WIP

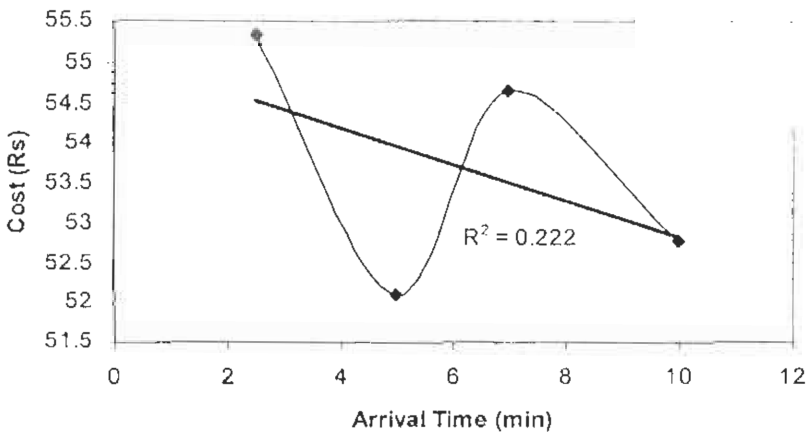

Figure 6.111 Effect of volume flexibility on rejection cost

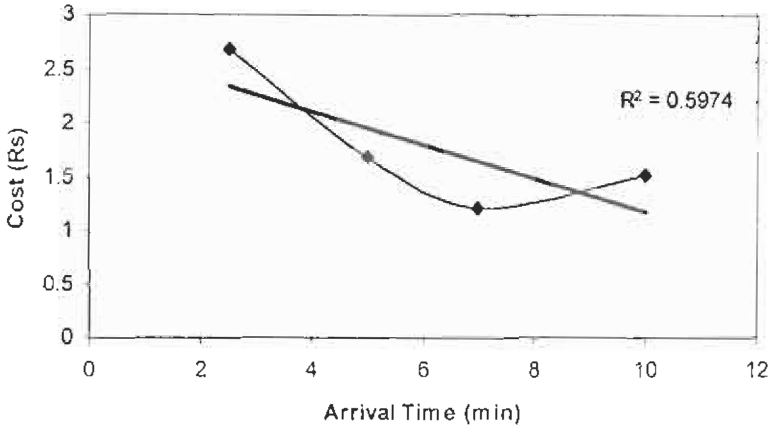

Figure 6.112 Effect of volume flexibility on non-value added cost

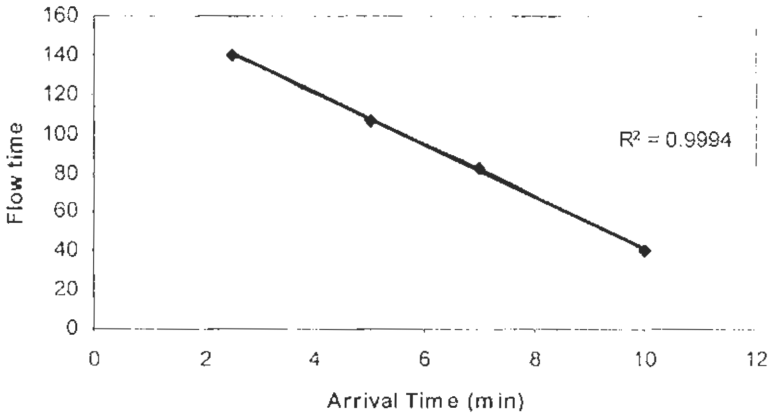

Figure 6.113 Effect of volume flexibility on flow time

Experiment 11) Effect of product variety flexibility (No. of models) (PV_{FLEX})

The effect of product variety flexibility on various costs, yield and other performance factors is shown from figures 6.114 to 6.125. It can be seen that 'PV_{FLEX}' is most sensitive parameter that has considerable effect on all of the above factors.

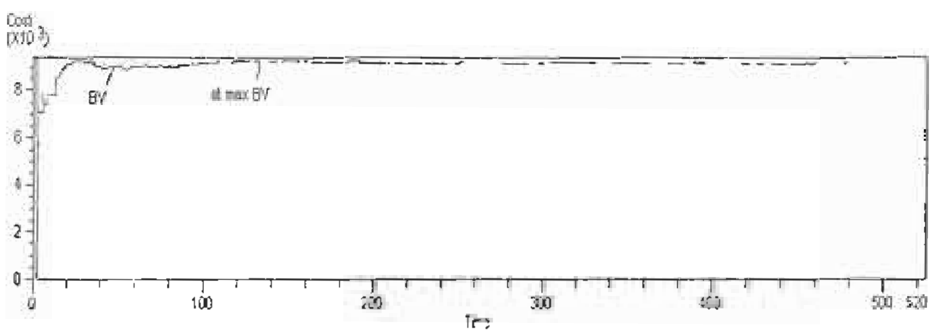

Figure 6.114 Effect of product variety flexibility on cost per part

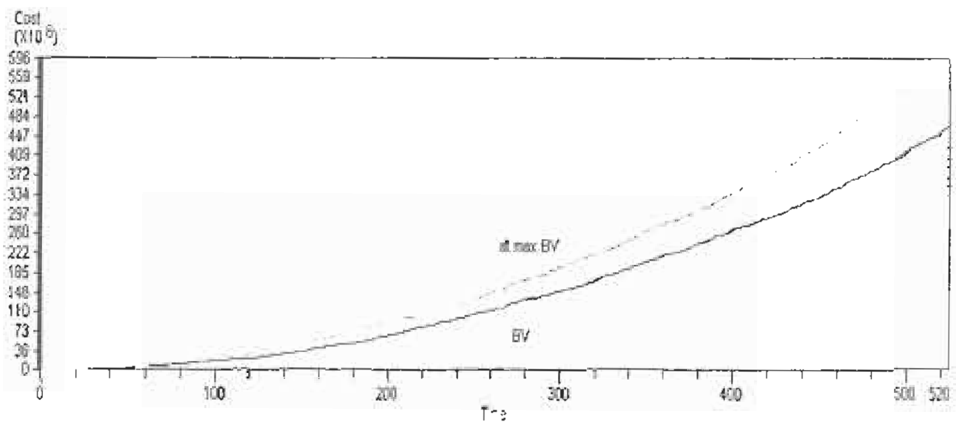

Figure 6.115 Effect of product variety flexibility on total cost

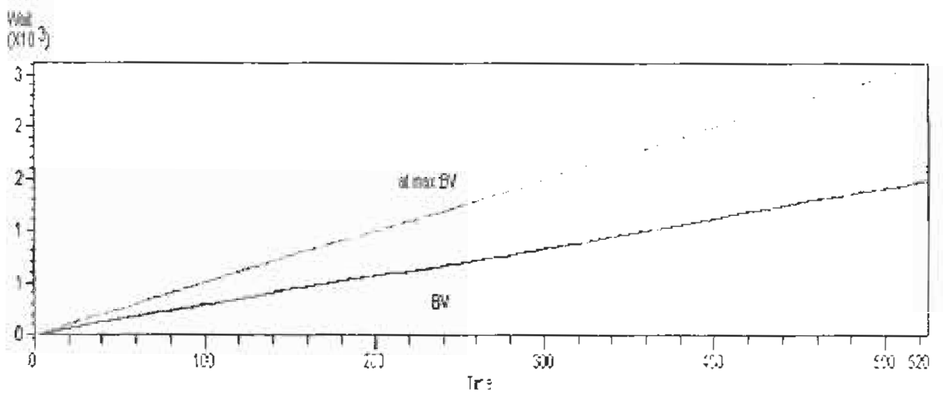

Figure 6.116 Effect of product variety flexibility on waiting time

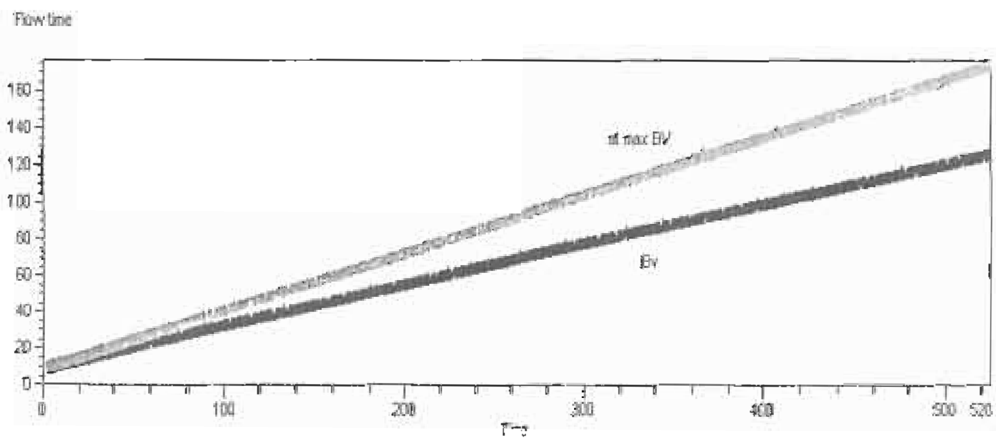

Figure 6.117 Effect of product variety flexibility on flow time

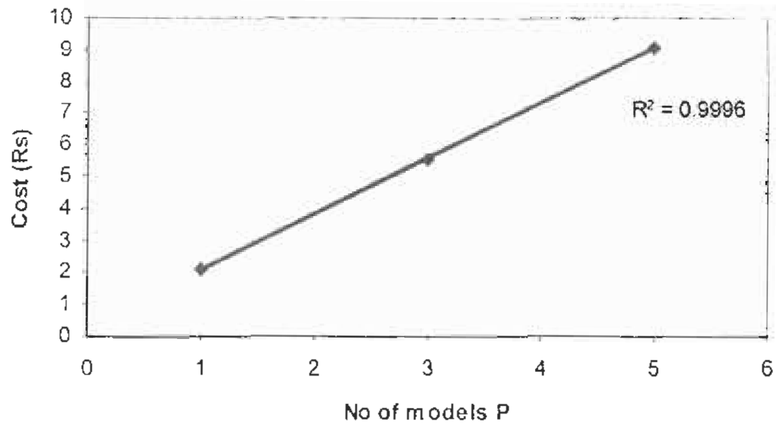

Figure 6.118 Effect of product variety flexibility on cost per part

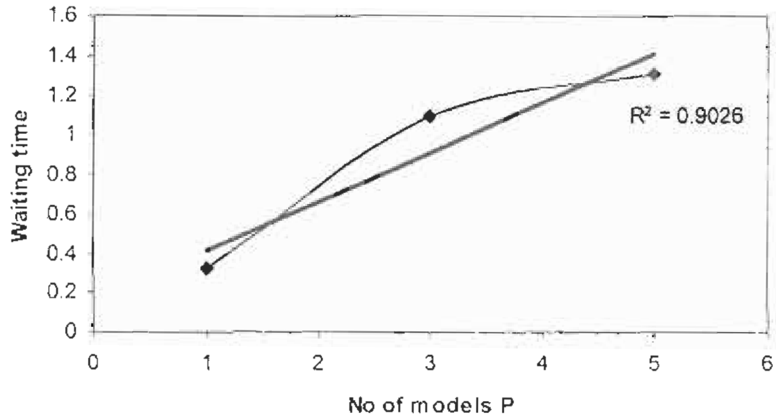

Figure 6.119 Effect of product variety flexibility on av. waiting time

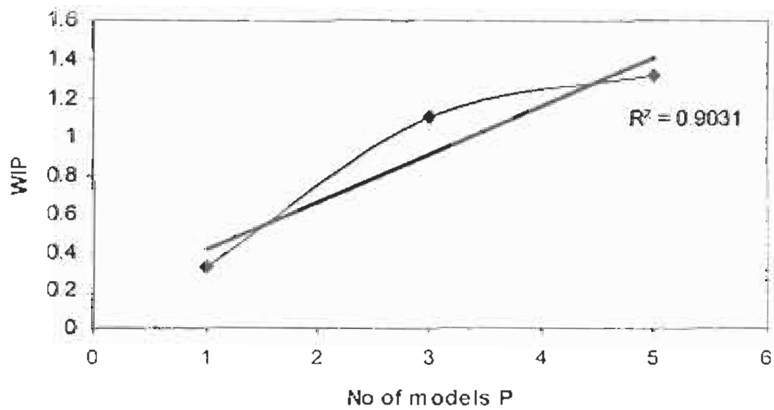

Figure 6.120 Effect of product variety flexibility on WIP

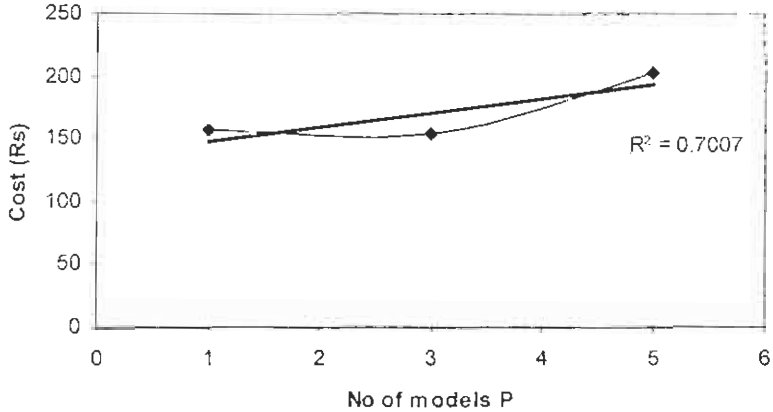

Figure 6.121 Effect of product variety flexibility on rejection cost

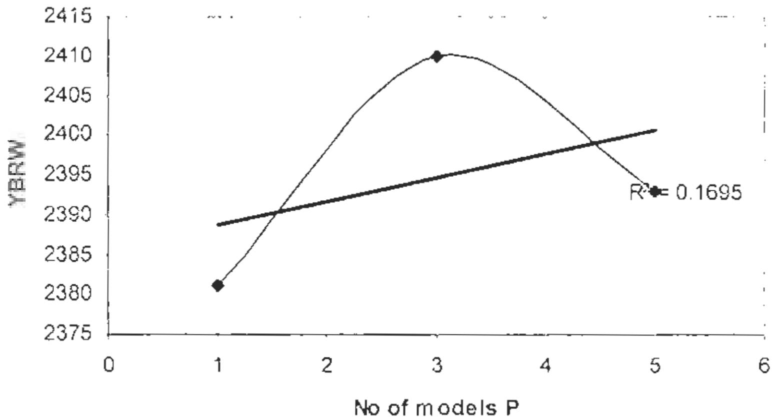

Figure 6.122 Effect of product variety flexibility on YBRW

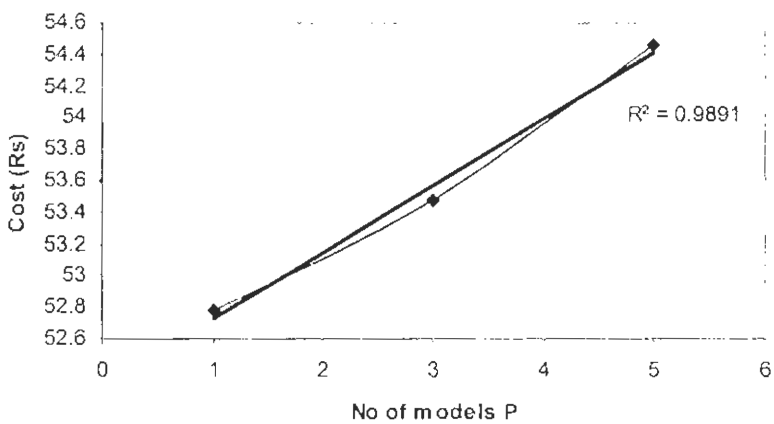

Figure 6.123 Effect of product variety flexibility on reworking cost

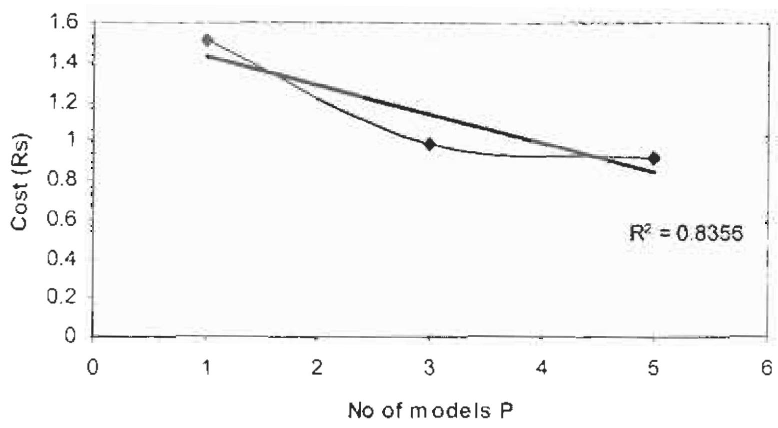

Figure 6.124 Effect of product variety flexibility on non-value added cost

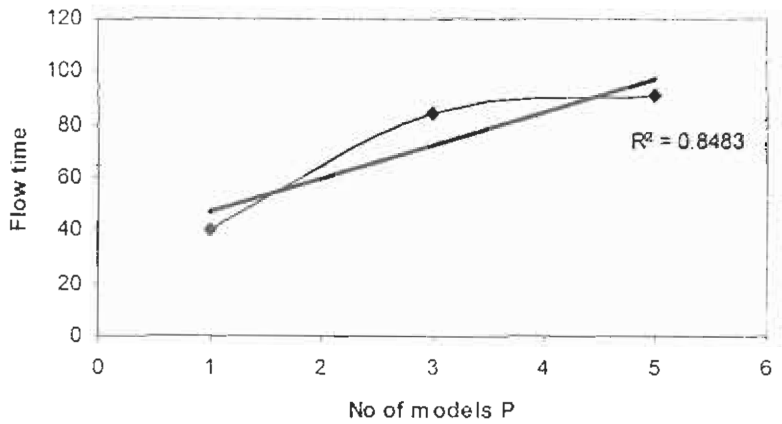

Figure 6.125 Effect of product variety flexibility on flow time

Experiment 12) Effect of Machine flexibility at stage 1&2 with 0.5T BV (M_{FLEX})

This experiment was performed by changing the yield with flexible processing using 0.5T base value. It effect is analyzed at stage 1 and 2, but also effect the system and increase line to run at faster pace. The effect of machine flexibility at stage 1 and 2 on various costs and yields is shown in figures 6.126 to 6.137. It is found that machine flexibility effect is most sensitive on cost per part, yield before rework, rejection cost and non-value added cost respectively.

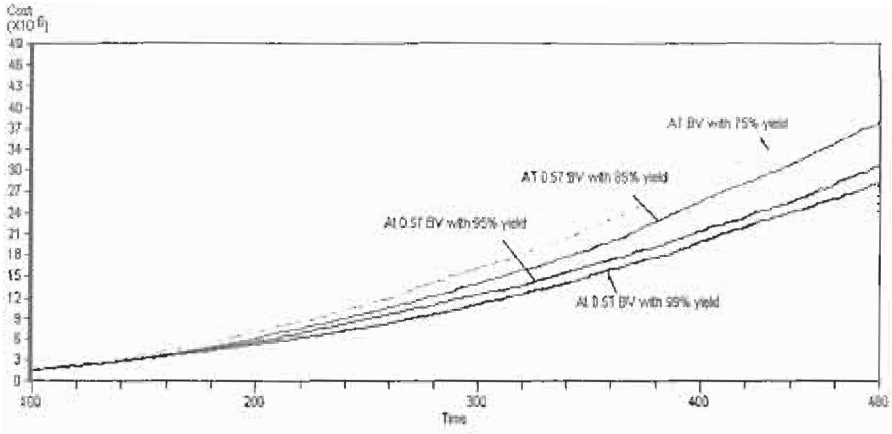

Figure 6.126 Effect of machine flexibility on rejection cost

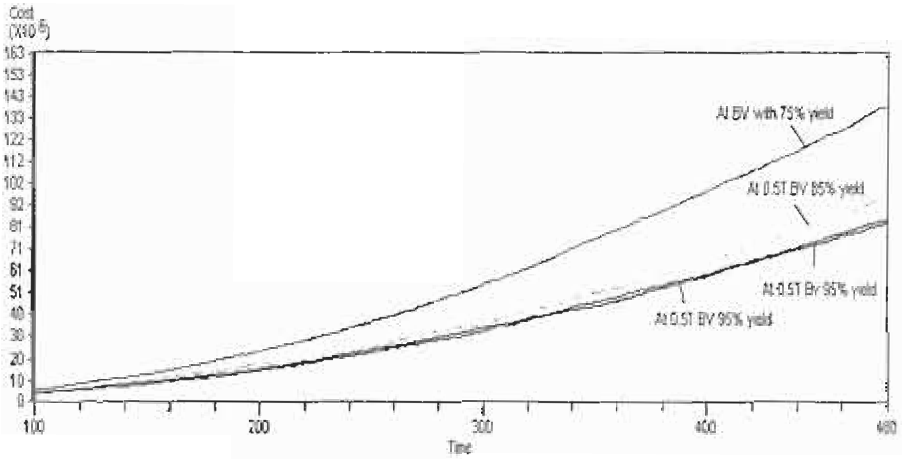

Figure 6.127 Effect of machine flexibility on reworking cost

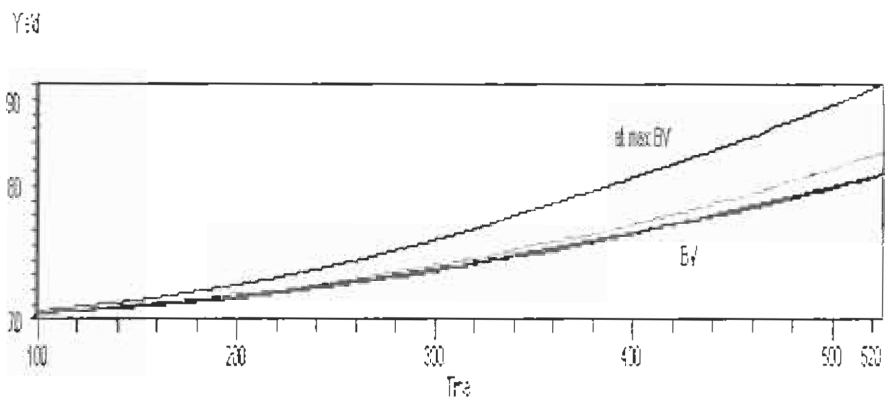

Figure 6.128 Effect of machine flexibility on YBRW

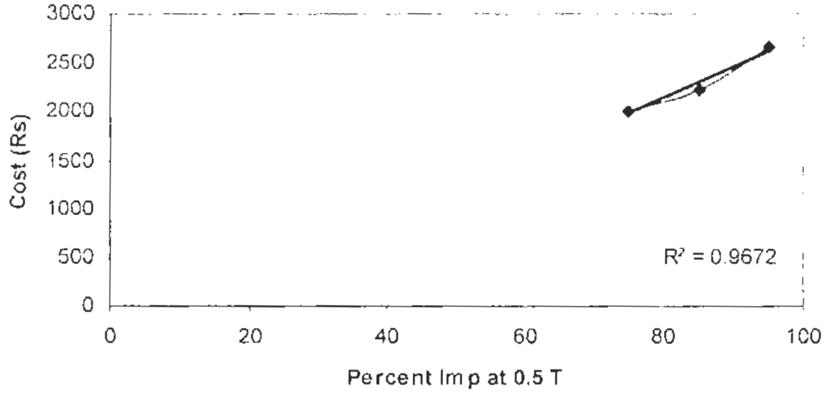

Figure 6.129 Effect of machine flexibility on cost per part

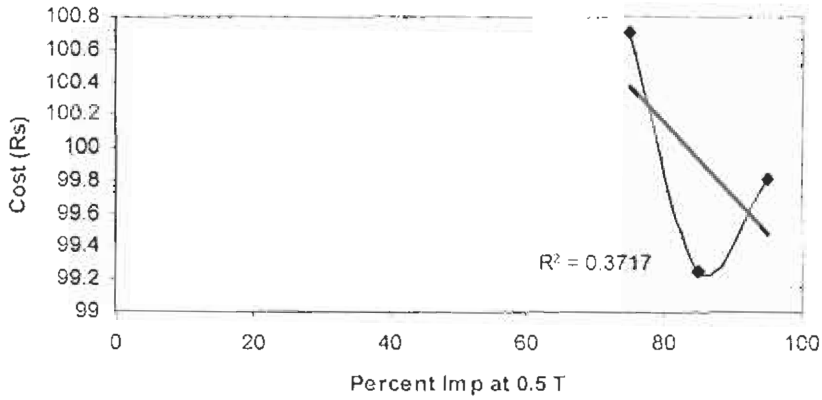

Figure 6.130 Effect of machine flexibility on total cost

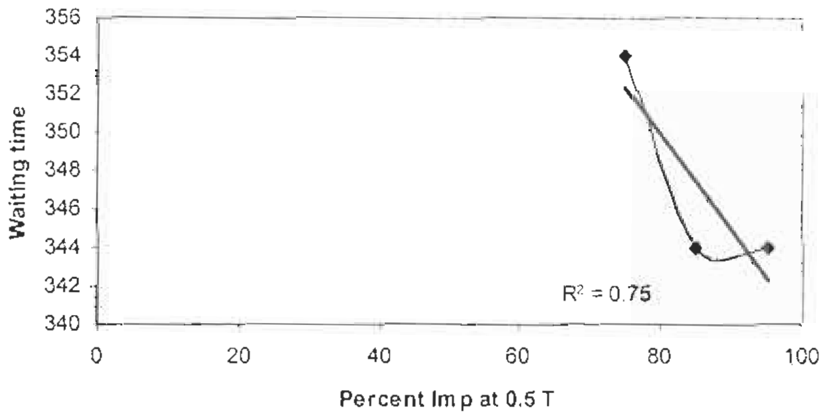

Figure 6.131 Effect of machine flexibility on waiting time

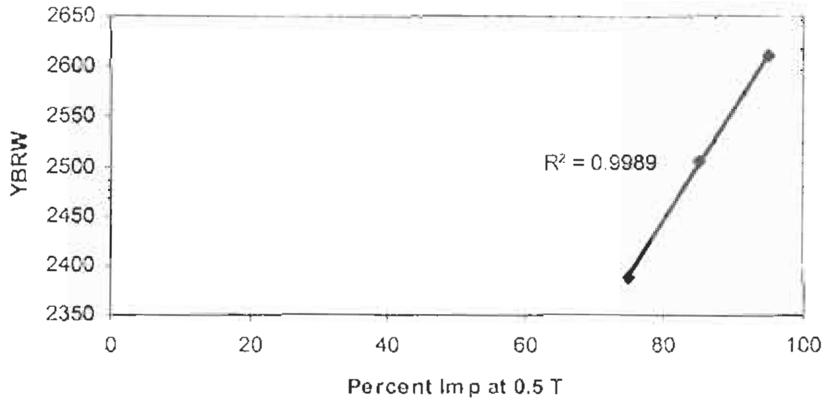

Figure 6.132 Effect of machine flexibility on YBRW

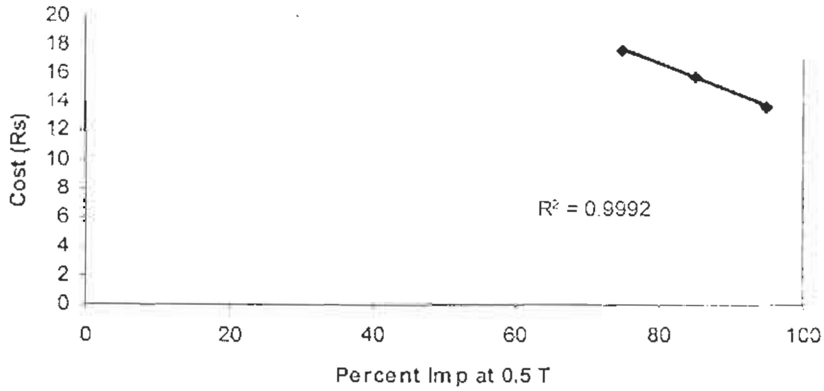

Figure 6.133 Effect of machine flexibility on rejection cost

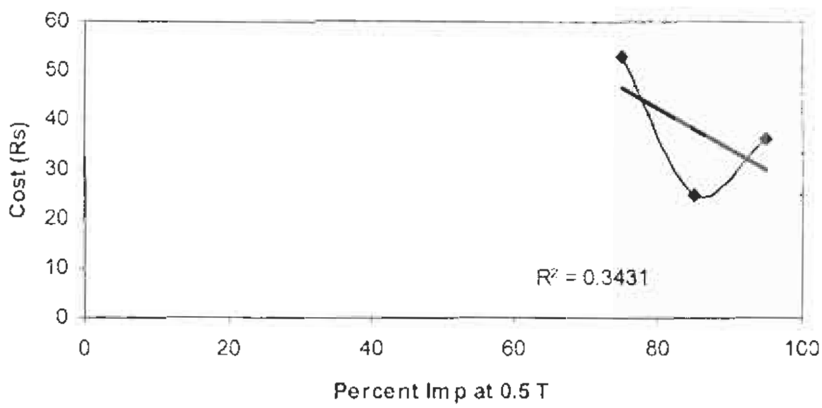

Figure 6.134 Effect of machine flexibility on reworking cost

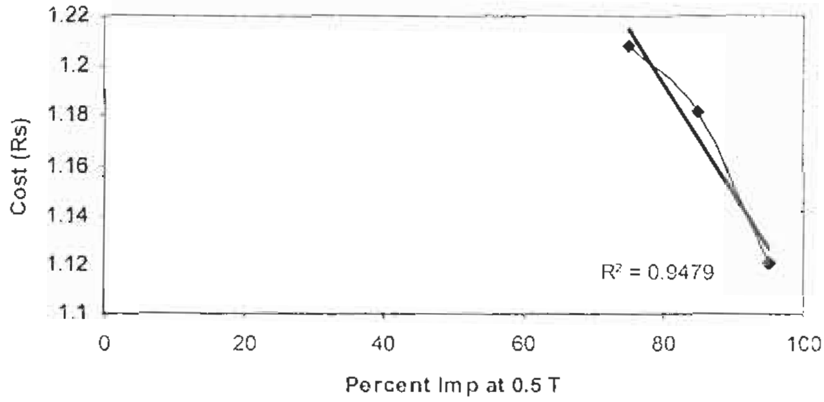

Figure 6.135 Effect of machine flexibility on non-value added cost

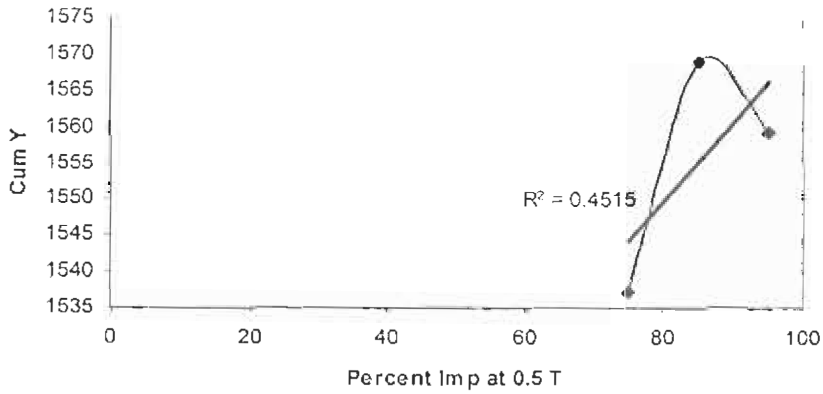

Figure 6.136 Effect of machine flexibility on cumulative yield

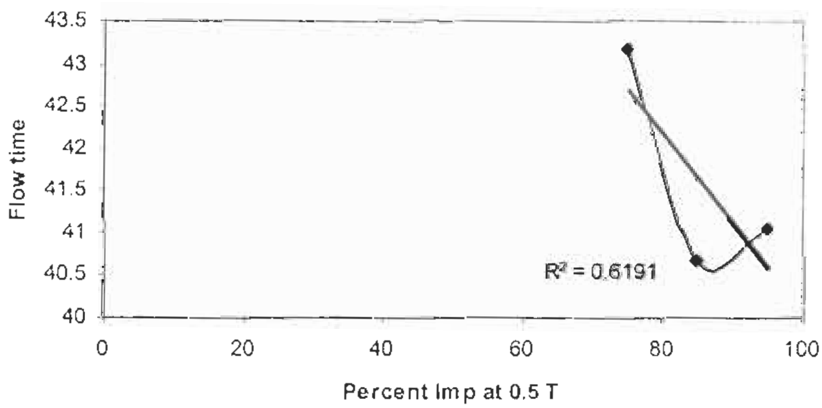

Figure 6.137 Effect of machine flexibility on flow time

6.4 SUMMARY OF SENSITIVITY ANALYSIS

Computer simulation experimentation showed the behavior of real case study which is analyzed in above section. Based on time dependent and numerical valued simulation results, the graphs are plotted and values of slopes are obtained. These scores are placed against each model parameter for relationships that have been studied. The scores are assigned against respective slopes in which the following arbitrary criterion is selected:

Slope (0.8 or more); Score = 5 (Most sensitive), Slope (0.6 to 0.79); Score = 4 (Moderately sensitive), Slope (0.4 to 0.59); Score = 3 (Sensitive), Slope (0.2 to 0.39); Score = 2 (Less sensitive) and Slope (below 0.2 and above 0); Score = 1 (Least sensitive) Slope (0 and below); unstudied factors

The scores are placed against respective slopes. Based on the numerical value functions, the results with scores are tabulated as given in table 6.1.

Table 6.1 Summary of Results

S. NO	SENSITIVITY	SLOPES	SCORE
1.	Effect of balanced line on utilization	0.7562	4
2.	Effect of balanced line on cost per part	0.9979	5
3.	Effect of balanced line on total cost	0.8999	5
4.	Effect of balanced line on average waiting time	0.8986	5
5.	Effect of balanced line on work in process	0.8993	5
6.	Effect of balanced line on yield before rework	0.5205	3
7.	Effect of balanced line on rejection cost	0.1542	1
8.	Effect of balanced line on reworking cost	0.089	0
9.	Effect of balanced line on value added cost	0.7274	4
10.	Effect of balanced line on non-value added cost	0.9013	5
11.	Effect of balanced line on cumulative yield	0.032	0

12.	Effect of balanced line on flow times	0.9128	5
13.	Effect of fast reworking time on cost per part	0.4251	3
14.	Effect of fast reworking time on total cost	0.0946	0
15.	Effect of fast reworking time on WIP	0.1669	1
16.	Effect of fast reworking time on average waiting time	0.1332	1
17.	Effect of fast reworking time on yield before rework	0.0308	0
18.	Effect of fast reworking time on rejection cost	0.3106	2
19.	Effect of fast reworking time on reworking cost	0.0112	0
20.	Effect of fast reworking time on value added cost	0.0724	0
22.	Effect of fast reworking time on non value added cost	0.4471	3
23.	Effect of fast reworking time on cumulative yield	0.0174	0
24.	Effect of fast reworking time on flow time	0.346	2
25.	Effect of machine flexibility on waiting time	0.75	4
26.	Effect of machine flexibility on cost per part	0.9672	5
27.	Effect of machine flexibility on total cost	0.3717	2
28.	Effect of machine flexibility on WIP	0.016	0
29.	Effect of machine flexibility on yield before rework	0.9989	5
30.	Effect of machine flexibility on rejection cost	0.9992	5
31.	Effect of machine flexibility on reworking cost	0.3431	2
32.	Effect of machine flexibility on value added cost	0.7235	4
33.	Effect of machine flexibility on non- value added cost	0.9479	5
34.	**Effect of machine flexibility on cumulative yield**	**0.4515**	3

35.	Effect of machine flexibility on flow time	0.6191	4
36.	Effect of changing machine rate on cost per part	0.9657	5
37.	Effect of changing machine rate on total cost	0.9911	5
38.	Effect of changing machine rate on rejection cost	0.9932	5
39.	Effect of changing machine rate on reworking cost	0.9970	5
40.	Effect of changing machine rate on value added cost	0.9949	5
41.	Effect of changing machine rate on non- value added cost	0.9659	5
42.	Effect of changing material handling time on cost per part	0.0556	0
43.	Effect of changing material handling time on total cost	0.0778	0
44.	Effect of changing material handling time on average wait time	0.0147	0
45.	Effect of changing material handling time on utilization	0.8929	5
46.	Effect of changing material handling time on WIP	0.0163	0
47.	Effect of changing material handling time on yield before rework	0.0030	0
48.	Effect of changing material handling time on rejection cost	0.5443	3
49.	Effect of changing material handling time on reworking cost	0.0085	0
50.	Effect of changing material handling time on value added cost	0.0020	0
51.	Effect of changing material handling time on non- value added cost	0.6276	4
52.	Effect of changing material handling time on cumulative yield	0.0185	0
53.	Effect of changing material handling time on flow time	0.9773	5
54.	Effect of changing starting or minimum yield on utilization	0.8329	5
55.	Effect of changing starting or minimum yield on cost per part	0.9834	5
56.	Effect of changing starting or minimum yield on total cost	0.9551	5

57.	Effect of changing starting or minimum yield on yield before rework	0.9975	5
58.	Effect of changing starting or minimum yield on rejection cost	0.9902	5
59.	Effect of changing starting or minimum yield on reworking cost	0.8419	5
60.	Effect of changing starting or minimum yield on cumulative yield	0.9719	5
61.	Effect of changing starting or minimum yield on flow time	0.037	0
62.	Effect of changing starting or minimum yield on WIP	0.1888	1
63.	Effect of changing starting or minimum yield on waiting time	0.0225	0
64.	Effect of changing starting or minimum yield on value added cost	0.8023	5
65.	Effect of changing starting or minimum yield on non-value added cost	0.9951	5
66.	Effect of yield improvement on cost per part	0.8767	5
67.	Effect of yield improvement on reworking cost	0.9861	5
68.	Effect of yield improvement on rejection cost	0.9997	5
69.	Effect of yield improvement on yield before rework	0.9751	5
70.	Effect of yield improvement on cumulative yield	0.9966	5
71.	Effect of yield improvement on WIP	0.9042	5
72.	Effect of yield improvement on value added cost	0.8329	5
73.	Effect of yield improvement on non- value added cost	0.9629	5
74.	Effect of yield improvement on total cost	0.9903	4
75.	Effect of reworking time on cost per part	0.9953	5
76.	Effect of reworking time on total cost	0.0031	0
77.	Effect of reworking time on WIP	0.5035	3
78.	Effect of reworking time on reworking cost	0.9043	5

79.	Effect of reworking time on non- value added cost	0.894	5
80.	Effect of reworking time on cumulative yield	0.4568	3
81.	Effect of reworking time on flow time	0.1558	1
82.	Effect of reworking time on value added cost	0.0995	0
83.	Effect of setup time on cost per part	0.6026	3
84.	Effect of setup time on total cost	0.1028	1
85.	Effect of setup time on WIP	0.670	3
86.	Effect of setup time on waiting time	0.1608	1
87.	Effect of setup time on cumulative yield	0.0998	0
88.	Effect of setup time on flow time	0.796	4
89.	Effect of setup time on value added cost	0.153	1
90.	Effect of setup time on non-value added cost	0.9435	5
91.	Effect of setup time on yield before rework	0.3406	2
92.	Effect of setup time on rejection cost	0.0693	0
93.	Effect of setup time on reworking cost	0.0109	0
94.	Effect of changing wage rate on cost per part	0.9998	5
95.	Effect of changing wage rate on total cost	0.9999	5
96.	Effect of changing wage rate on rejection cost	0.9797	5
97.	Effect of changing wage rate on reworking cost	0.7937	4
98.	Effect of changing wage rate on value added cost	0.9797	5
98.	Effect of product variety flexibility on utilization	0.075	0
99.	Effect of product variety flexibility on cost per part	0.9996	5

100	Effect of product variety flexibility on total cost	0.0843	0
101	Effect of product variety flexibility on WIP	0.9031	5
102	Effect of product variety flexibility on average waiting time	0.9026	5
103	Effect of product variety flexibility on yield before rework	0.1695	1
104	Effect of product variety flexibility on rejection cost	0.7007	4
105	Effect of product variety flexibility on reworking cost	0.9891	5
106	Effect of product variety flexibility on value added cost	0.895	5
107	Effect of product variety flexibility on non value added cost	0.8356	5
108	Effect of product variety flexibility on cumulative yield	0.025	0
109	Effect of product variety flexibility on flow time	0.8483	5
110	Effect of volume flexibility on utilization	0.6632	4
111	Effect of volume flexibility on cost per part	0.6036	3
112	Effect of volume flexibility on total cost	0.9813	5
113	Effect of volume flexibility on WIP	0.7953	4
114	Effect of volume flexibility on average waiting time	0.7734	4
115	Effect of volume flexibility on yield before rework	0.6559	4
116	Effect of volume flexibility on reworking cost	0.0784	0
117	Effect of volume flexibility on rejection cost	0.222	2
118	Effect of volume flexibility on value added cost	0.7045	4
119	Effect of volume flexibility on non- value added cost	0.5974	4
120	Effect of volume flexibility on cumulative yield	0.024	0
121	Effect of volume flexibility on flow time	0.9994	5

Let us now return to more practical approach of performance measurement (protector, offensive and innovative). We still need to carry out sensitivity at tactical level on the basis of protector, offensive and innovative manufacturers individually. Individual prioritized is beneficial for local manufacturers at each level. From the section 6.2, we can use the clustering of operational entities as below:

1. **Protector related**
   a. Utilization of resources (UT_{SYS})
   b. Cost per part (C_{PART})
   c. Total cost of the part (TM_{COST})
   d. Average waiting time (WT_{AVG})
2. **Offensive related**
   a. Work In Process (WIP)
   b. Yield before rework (YBRW)
   c. Cumulative rejection costs (C_{REJ})
   d. Cumulative reworking costs (C_{REWORK})
3. **Innovative related**
   a. Value added cost (C_{VAD})
   b. Non- value added cost (C_{NVAD})
   c. Cumulative yield (Y_{CUM})
   d. Flow time (FT)

6.4.1 PROTECTOR MANUFACTURERS RESULTS

The summary of parameters which effect the performance variables have been given in table 6.1. The table is now used individually for 'Protector Manufacturers' at tactical level decision making. The objects from table 6.1 for protector manufacturers are separately used as shown in table 6.2. The values/objects are now filled in which column 1 shows the parameters of interest and rows represents the performance variables. We are interested to find the most sensitive parameters in our study. For the purpose of completeness, the remaining relationships may be allotted a sensitivity score of 0, representing 'insensitive' or unstudied factors. It is pertinent to point out that this approach may bring slight inaccuracy in our analysis when speaking in absolute terms:

however it results in relatively less error because even otherwise we have no concrete information about behavior of such relationships.

Table 6.2 Protector partial sensitivity results

	UT_{SYS}	C_{PART}	TM_{COST}	WT_{AVG}
H_{RATE}		5	5	
M_{RATE}		5	5	
P_{MAX}	4	5	5	5
MH_{TIME}	5			
Y_{MIN}	5	5	5	
Y_{IMP}		5	4	
SU_{TIME}		3	1	1
RW_{TIME}		5		
FR_{TIME}		3		1
M_{FLEX}		5	2	4
PV_{FLEX}		5		5
V_{FLEX}	4	3	5	4

The table 6.2 is filled with values/objects obtained during simulation experimentation (numerical values). Now the values are summed and placed in separate column as 'ROW SUM'. The maximum value in the 'ROW SUM' column is most sensitive parameters affecting the system at protector level. The objects as derived from the above table 6.3 with respect to performance objectives as 'protector' has been placed below in the decreasing order of sensitivity.

Table 6.3 Protector completed sensitivity results

	UT_{SYS}	C_{PART}	TM_{COST}	WT_{AVG}	**ROW SUM**
H_{RATE}	0	5	5	0	**10**
M_{RATE}	0	5	5	0	**10**
P_{MAX}	4	5	5	5	**19**
MH_{TIME}	5	0	0	0	**5**
Y_{MIN}	5	5	5	0	**15**
Y_{IMP}	0	5	4	0	**9**
SU_{TIME}	0	3	1	1	**5**
RW_{TIME}	0	5	0	0	**5**
FR_{TIME}	0	3	0	1	**4**
M_{FLEX}	0	5	2	4	**11**
PV_{FLEX}	0	5	0	5	**10**
V_{FLEX}	4	3	5	4	**16**

1. P_{MAX}
2. V_{FLEX}
3. Y_{MIN}
4. M_{FLEX}
5. M_{RATE} , H_{RATE} , PV_{FLEX}
6. Y_{IMP}
7. MH_{TIME} , SU_{TIME}, RW_{TIME}
8. FR_{TIME}

It is interesting to note that processing time is found most sensitive parameters. This means that protector manufacturers should focus on balancing of production line in order to reduce cost per unit and effectively utilizing capacities. By streamlining operations, minimizing of waste times from the production line would results in more production volumes hence reducing cost per unit and beneficial for manufacturers.

6.4.2 OFFENSIVE MANUFACTURERS RESULTS

The table 6.4 for offensive manufacturers at tactical level as derived from the table 6.1 with respect to performance objective as offensive has been placed below in the decreasing order of sensitiveness. The table 6.4 for offensive manufacturers is made by placing objects/values against performance variables.

Table 6.4 Offensive partial sensitivity results

	WIP	YBRW	C_{REJ}	C_{REWORK}
H_{RATE}			5	4
M_{RATE}			5	5
P_{MAX}	5	3	1	
MH_{TIME}			3	
Y_{MIN}	1	5	5	5
Y_{IMP}	5	5	5	5
SU_{TIME}	3	2		
RW_{TIME}	3			5
FR_{TIME}	1		2	
M_{FLEX}		5	5	2
PV_{FLEX}	5	1	4	5
V_{FLEX}	4	4	2	

Again, for the purpose of completeness, the remaining relationships may be allotted a sensitivity score of 0, representing 'insensitive' or unstudied factors for completing table 6.5 as shown below. Add the ROW SUM column parameters values. The maximum parameter value is the most sensitive and affecting the system.

Table 6.5 Offensive completed sensitivity results

	WIP	YBRW	C_{REJ}	C_{REWORK}	**ROW SUM**
H_{RATE}	0	0	5	4	**9**
M_{RATE}	0	0	5	5	**10**
P_{MAX}	5	3	1	0	**9**
MH_{TIME}	0	0	3	0	**3**
Y_{MIN}	1	5	5	5	**16**
Y_{IMP}	5	5	5	5	**20**
SU_{TIME}	3	2	0	0	**5**
RW_{TIME}	3	0	0	5	**8**
FR_{TIME}	1	0	2	0	**3**
M_{FLEX}	0	5	5	2	**12**
PV_{FLEX}	5	1	4	5	**15**
V_{FLEX}	4	4	2	0	**10**

The prioritized values on decreasing order of sensitiveness are given below:

1. Y_{IMP}
2. Y_{MIN}

3. PV_{FLEX}
4. M_{FLEX}
5. M_{RATE}, V_{FLEX}
6. H_{RATE}, P_{MAX}
7. RW_{TIME}
8. SU_{TIME}
9. MH_{TIME}, FR_{TIME}

It is found that improvement in yield is the most sensitive parameter followed by minimum or starting yield. This is proved that use of advanced manufacturing technology is justified which not only improve product quality but also enhances variety as it comes out to be next sensitive parameter in our study. It is evident that advanced system should be used by offensive manufacturers to improve product quality, reliability and flexibility. Fast reworking and material handling times are found less sensitive for such manufacturers.

As discussed in chapter 4 about analysis of machine cost which works within offensive strategy in order to identify appropriate level of technologies. The methodology has been explained, this section present results as described in section 4.2.2.2.2.

6.4.2.1 TECHNOLOGY DRIVEN RESULTS

Running of the simulation models as mentioned in the preceding section allowed comparing the slopes of different parameters so that the most sensitive ones could be differentiated from comparatively less and least sensitive ones. This has been done in terms of the five levels, i.e. most sensitive, moderately sensitive, sensitive, less sensitive, and least sensitive. Higher the value of slope, higher is the sensitivity. The slopes are available in terms of impact on per unit cost obtained as a result of making per rupee change in the process parameter. In order to make the result more useful and comparable for the international reader, percentage increase/ decrease in cost per unit has been represented by doubling the cost of cutting tool, machine rate, labor rate, overheads etc. The results and conclusions are shown in Table 6.6. It can be concluded that some parameters are more important (sensitive) than others. Sensitivity has been ascertained on the basis of impact on per unit cost and is given in Table 6.7.

Table 6.6 Results & Conclusions

Percentage change in Cost per unit	
Engine Lathe	Doubling the machine rate results in 2.3 percent increase in cost Doubling the labor rate results in 16.6 percent increase in cost Doubling the overhead rate results in 0.51 percent increase in cost
Turret Lathe	Doubling the machine rate results in 2.53 percent increase in cost Doubling the labor rate results in 25 percent increase in cost Doubling the overhead rate results in 0.7 percent increase in cost Doubling the number of set ups result in 95 percent increase in cost
Automatic Machines	Doubling the machine rate results in 74 percent increase in cost per unit Doubling the labor rate results in 0.53 percent increase in cost per unit Doubling the overhead results in 18 percent increase in cost per unit Doubling the set up cost results in 71.8 percent increase in cost per unit Doubling the tool changing time increases the cost per unit by 1.5 percent. Doubling the tool life results in 4.75 percent decrease in cost per unit Ten times increase in batch size results in 85 percent decrease in cost per unit. Doubling the batch size results in 40 percent decrease in cost per unit.
Numerically Controlled (NC) Machines	Doubling the machine rate results in an increase of 81.56 percent in the cost per unit Doubling the labor rate results in an increase of 7.69 percent in cost per unit Doubling the overhead rate results in 44.7 percent increase in cost per unit Doubling the tool changing time results in 3.82 percent increase in cost per unit Doubling the cost of tool results in 2.7 percent increase in cost per unit Doubling the batch size results in only 1.55 percent decrease in cost per unit
Transfer Machine	Doubling the machine rate results in an increase of95.2 percent in the cost per unit There seems to be 86.3 percent reduction in cost per unit by using material with half the value of tool material exponent (n). Doubling the cost of tool results in an increase of 20 percent in the cost per unit Doubling the tool life results in a decrease of 21 percent in the cost per unit

Table 6.7 Completed Sensitivity Results

Final Sensitivity					
Levels	**Most Sensitive**	**Moderately Sensitive**	**Sensitive**	**Less Sensitive**	**Least Sensitive**
Engine Lathe					
1. Labor rate	X				
2. Machine rate			X		
3. Overhead rate					X
Turret Lathe					
1. Number of setup (n)	X				
2. Labor rate		X			
3. Machine rate			X		
4. Overhead rate				X	
Automatic Machines					
1. Machine rate	X				
2. Setting up cost		X			
3. Overhead rate			X		
4. Tool life				X	
5. Tool changing time					X
6. Labor rate					X
NC Machines					
1. Machine rate	X				
2. Overhead rate		X			
3. Labor rate			X		
4. Tool changing time				X	
5. Cost of a tool					X
Transfer Machines					
1. Machine rate	X				
2. Tool material exponent (n)		X			
3. Tool life			X		
4. Cost of a tool				X	

Five different levels of technology are analyzed which include Engine lathe, Turret lathe, Automatic machines, numerically controlled machines (NC), and Transfer machines. A comparison of these functions allowed us to identify the most, less and least sensitive process parameters. In general, machine rate turns out to be most important parameter. For Automatic and N.C. machines, machine rates and overheads must be given special consideration. Tool life turns out to be a sensitive parameter for transfer machines. Adequate tool life is, therefore important in this case. Labor rates should be given due attention when using Engine and Turret lathes but seem less important in automatics.

Machine setting is a moderately sensitive parameter in Automatic machines. Thus, sequence of operations should be designed and planned in such a way that machine set up cost is minimized. It is evident from results that certain parameters are important at different levels depending upon the process parameters under investigation. In order to face challenges of the world, Pakistani manufacturers should pay due attention using proper technology at right time to become competitive. This might be achieved using a stepwise analysis of machine cost as a supporting tool for selecting appropriate level of technology in future.

6.4.3 INNOVATIVE MANUFACTURERS RESULTS

The table 6.8 for innovative manufacturers at tactical level as derived from the table 6.1 with respect to performance objective as innovative has been placed below in the decreasing order of sensitiveness.

Table 6.8 Innovative partial sensitivity results

	C_{VAD}	C_{NVAD}	Y_{CUM}	FT
H_{RATE}	5			
M_{RATE}	5	5		
P_{MAX}	4	5		5
MH_{TIME}		4		5
Y_{MIN}	5	5	5	
Y_{IMP}	5	5	5	
SU_{TIME}	1	5		4
RW_{TIME}		5	3	1
FR_{TIME}		3		2
M_{FLEX}	4	5	3	4
PV_{FLEX}	5	5		5
V_{FLEX}	4	4		5

The table 6.8 is made in the same way as of 'protector and offensive' manufacturers. The objects for each parameter are added in ROW SUM. The values are prioritized based on decreasing order of sensitivity. For the purpose of completeness, the remaining relationships may be allotted a sensitivity score of 0, representing 'insensitive' or unstudied factors for completing table 6.9 as shown below.

Table 6.9 Innovative completed sensitivity results

	C_{VAD}	C_{NVAD}	Y_{CUM}	FT	**ROW SUM**
H_{RATE}	5	0	0	0	**5**
M_{RATE}	5	5	0	0	**10**
P_{MAX}	4	5	0	5	**14**
MH_{TIME}	0	4	0	5	**9**
Y_{MIN}	5	5	5	0	**15**
Y_{IMP}	5	5	5	0	**15**
SU_{TIME}	1	5	0	4	**10**
RW_{TIME}	0	5	3	1	**9**
FR_{TIME}	0	3	0	2	**5**
M_{FLEX}	4	5	3	4	**16**
PV_{FLEX}	5	5	0	5	**15**
V_{FLEX}	4	4	0	5	**13**

The prioritized values on decreasing order of sensitiveness are given below:

1. M_{FLEX}
2. Y_{MIN} , Y_{IMP} , PV_{FLEX}
3. P_{MAX}
4. V_{FLEX}

5. M_{RATE} , SU_{TIME}
6. MH_{TIME} , RW_{TIME}
7. H_{RATE} , FR_{TIME}

Machine flexibility is the most sensitive parameter as it affects the business at innovative level. Innovation is defined as 'something unique, giving more importance at same or reduced cost. This help to increase confidence level of customer in the international market. Quality related parameters are the second sensitive in our prioritization.

Now the prioritization obtained from three types of manufacturer are tabulated together. This gives clear understanding and guide us the path to follow on PPMX. The table 6.10 is given below:

Table 6.10 Prioritization at each manufacturer

PROTECTOR	OFFENSIVE	INNOVATIVE
P_{MAX}	Y_{IMP}	M_{FLEX}
V_{FLEX}	Y_{MIN}	Y_{MIN} , Y_{IMP} , PV_{FLEX}
Y_{MIN}	PV_{FLEX}	P_{MAX}
M_{FLEX}	M_{FLEX}	V_{FLEX}
M_{RATE} , H_{RATE} , PV_{FLEX}	M_{RATE}, V_{FLEX}	M_{RATE} , SU_{TIME}
Y_{IMP}	H_{RATE}, P_{MAX}	MH_{TIME} , RW_{TIME}
MH_{TIME} , SU_{TIME}, RW_{TIME}	RW_{TIME}	H_{RATE} , FR_{TIME}
FR_{TIME}	SU_{TIME}	

Now, the most sensitive parameters are positioned together with respective strategies as shown in figure 6.138.

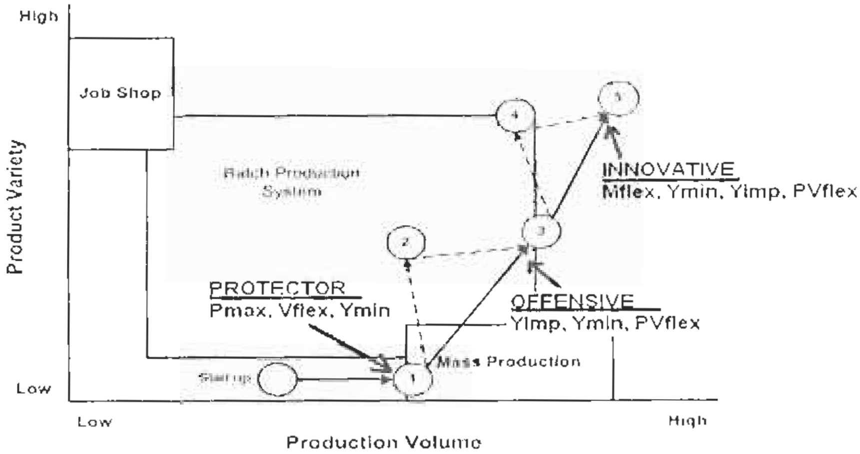

Figure 6.138 Parameters on PPMx matrix

6.4.4 GLOBAL STRATEGIES RESULTS

The table 6.11 below show cumulative results of parameters in decreasing order of sensitiveness. It is found that yield related parameters are the most sensitive followed by improvement in yield, processing times, product variety flexibility and machine flexibility respectively. The companies who are interested to compete in global environment should focus on yield related parameters and processing times. This means to incorporate automation in their production facilities to achieve high quality and compress lead time. Interestingly, material handling and fast reworking times comes out to be the least sensitive parameters in our study.

The prioritized values on decreasing order of sensitiveness are given below:

1. Y_{MIN}
2. Y_{IMP}
3. P_{MAX}
4. PV_{FLEX}
5. M_{FLEX} , V_{FLEX}
6. M_{RATE}
7. H_{RATE}
8. RW_{TIME}
9. SU_{TIME}
10. MH_{TIME}
11. FR_{TIME}

Table 6.11 Global strategies results

	UT_{SYS}	C_{PART}	TM_{COST}	WT_{AVG}	WIP	YBRW	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	FT	ROW SUM
H_{RATE}	0	5	5	0	0	0	5	4	5	0	0	0	24
M_{RATE}	0	5	5	0	0	0	5	5	5	5	0	0	30
P_{MAX}	4	5	5	5	5	3	1	0	4	5	0	5	42
MH_{TIME}	5	0	0	0	0	0	3	0	0	4	0	5	17
Y_{MIN}	5	5	5	0	1	5	5	5	5	5	5	0	46
Y_{IMP}	0	5	4	0	5	5	5	5	5	5	5	0	44
SU_{TIME}	0	3	1	1	3	2	0	0	1	5	0	4	20
RW_{TIME}	0	5	0	0	3	0	0	5	0	5	3	1	22
FR_{TIME}	0	3	0	1	1	0	2	0	0	3	0	2	12
M_{FLEX}	0	5	2	4	00	5	5	2	4	5	3	4	39
PV_{FLEX}	0	5	0	5	5	1	4	5	5	5	0	5	40
V_{FLEX}	4	3	5	4	4	4	2	0	4	4	0	5	39

6.5 CONCLUSIONS

In this chapter the behavior of the model is analyzed using simulation. The experimentation is performed and responses are recorded. The following conclusions are drawn from the experimentation:

i. The effect of balancing of production line (P_{MAX}) is most significant on cost per part, total cost while its effect is less sensitive on yield before rework and reworking cost. This comes out that balancing of production line is pre-requisite to reduce per unit. The protector manufacturers can be benefited by implementing techniques like line balancing, streamlining of operations, load oriented control etc in their shop floor.

ii. The effect of hourly labor is found most significant on cost related parameters whereas it no effect on work in process, yield before rework, average waiting time and flow time. When the companies shift their business at higher value addition phase i.e. mass customization, the impact of hourly labor cost becomes most sensitive. The innovative manufacturers face hourly labor cost issues. Therefore, it is recommended that these manufacturers should invest on R&D and training of workforce on multi-skills in order to reduce hourly labor cost.

iii. The machine rate is also one of the most sensitive in our study which effect cost related parameters. An analysis is also carried out to see impact of changing level of technology when companies will shift from conventional to automation. The automation will improve the reliability of the system, but care should be taken to use advanced manufacturing systems when certain volumes are break even to justify production in automation stage.

iv. The material handling cost an important parameters found in the study which effect utilization, flow times and non-value added cost respectively. Material handling time reduces lead time and improves business by eliminating waste time and offers more flexibility. Both offensive and innovative manufacturers can be benefited by properly analyzing their shop floor and then using appropriate level of material handling system in shop floor.

v. The most sensitive parameters found in the study are yield related which significantly affect the performance of manufacturing system. This can be achieved using quality techniques in a systematic manner depending upon type of organization. The use of automated systems is also justified by analyzing level of technology and then proposing suitable equipment.

vi. The setup time is an important factor which has considerable effect on non-value added cost. The drawbacks of using conventional systems are large setup time which forces production to run for longer time which ultimately increases lead time. Use of flexible jigs/ fixtures/SMED approach and FMS help to improve responsiveness and delight customer by cutting out waste time from system. Both offensive and innovative manufacturers are benefited by analyzing current businesses and implementing such flexible techniques/systems.

vii. Fast reworking and reworking times are important parameters and affecting the systems. This could be minimized by training of operators, off-line experimentation and involving them in R&D activities. Groups are formed which consists of semi, highly skilled and multi tasking operators.

viii. Machine, volume and variety flexibilities are also important factors which affect systems and offers challenges for each type of manufacturers i.e. protector, offensive and innovative respectively. This can be controlled by properly utilizing capacities for protector manufacturers for optimum volumes, using flexible machines for accommodating design changes (varieties) and group technology/FMS etc for minimizing lead time and improve customer satisfaction.

ix. The prioritization is obtained for each type of manufacturers. It comes out that the most sensitive parameters for protector manufacturers are processing time by balancing production line, volume flexibilities by properly utilizing capacities. Yield related parameters (both Y_{IMP} AND Y_{MIN}) are the most sensitive for offensive manufacturers which forces manufacturers to use automation at this stage as poor quality does not exist when automation is used. More flexible processing systems should be used as variety flexibility is the next most sensitive parameter found in prioritization. Machine flexibility, yield related parameters (both types) and variety flexibility are the sensitive for innovative manufacturers. Using flexible systems is therefore justified in order to face challenges of the world marketplace.

x. To compete in the world market and become competitive, companies should focus on yield related parameters as they comes out to be the most sensitive parameters which forces manufacturers to use more flexible, agile and productive systems.

This chapter is about model behavior analysis. Important parameters have been identified have been used and simulation experimentation carried out for 525 hours with ranges of values used in various modules. The effects are analyzed in two ways i.e. time dependent behavior and numerical values in question. Results are plotted in output analyzer of Arena software and Excel respectively. Simulation runs and numerical value graphs have been made and sensitiveness is calculated using slops of functions are. These slopes are placed against respective scores according to the plan as described earlier. The parameters are prioritized with respect to the performance objective i.e. protector, offensive and innovative manufacturing at individual level. This help to identify key performance parameters for three manufacturers. Both local level (for individual manufacturers) and global level prioritization is obtained. At global level yield related parameters are found most sensitive which forces us to focus on quality related and time compression technologies to become competitive in the marketplace.

CHAPTER 7
STRATEGIC LEVEL DECISION MAKING

CHAPTER 7
STRATEGIC LEVEL DECISION MAKING

7.1 INTRODUCTION

The behavior of model is analyzed using manufacturing simulation at tactical level. Main focus at that stage is to prioritize most sensitive parameters at tactical level, so the emphasis is to identify practical design parameters which help manufacturers within shop floor. Performance parameters are prioritized for 'protector' corresponding to low cost, 'offensive' corresponding to high quality, more agile and 'innovative' manufacturers correspond to attracting customers respectively. Both tactical and strategic level decision making process is involved for improving business. It is true that dynamic and rapidly changing business environment offers challenges to manufacturing industries which demands timely related and right strategic decisions in order to compete in the marketplace. Therefore, analytical hierarchal process (AHP) at strategic decision making is used. At strategic level whole business process is involved which includes activities like marketing, production planning and control, finance etc. A brief overview about strategic decision making process is described followed by introduction to AHP and justification for it use. The final strategic hierarchy is presented in last section.

7.2 STRATEGIC MANAGEMENT- AN OVERVIEW

Strategy is defined by Farjoun (2002) as "the planned or actual co-ordination of the firm's major goals and actions, in time and space that continuously co-align the firm with its environment". This definition encapsulates three interrelated points: behavior, co-ordination and adaptation. In practice, the essence of strategy is the improvement of competitiveness. This is probably one of the most challenging tasks facing any firm, given the increasingly volatile business environment. To survive and gain competitive advantage, organizations of all sizes increasingly need to pursue well developed and clear cut strategies (Christopher. Bartlett and Ghoshal, 1990; Powell, 1992). Yet small firms are often stated to be 'naive about planning and the development of strategy' (Deakins and Freel, 1998). The number of ways that small firms tend to respond to change exemplifies this. Firstly, they tend to look inward rather than outwards and ignore change (focused only at tactical decision making). Secondly, some continue to rely on efficiency based measures as their 'strategic plan' for the future (Protector Manufacturers). Thirdly, some firms believe that, as they are part of a localized supply chain, they are immune to any external influences (focusing only on services).

In research world, many approaches have been developed for coping with strategic level decisions. At that level, the focus is to identify key and prioritize factors in whole business process. Therefore, AHP as a tool is selected which aid in prioritizing key activities in whole business settings. Much research work has been carried out over the last few decades of using AHP as multi criteria decision making tool. The most significant in this regard is: AHP for facility layout (Jiaqan 1997), AHP study of TQM (W. G. Lewis, 2005), multi criteria supplier selection using AHP (Cengiz, 2003), prioritization of key performance indicators using AHP (Arash 2006), AHP in FMS decision making (Ozden 2004).

In prioritizing whole business process, main departments are selected. The main departments include marketing (MKT), production planning and control (PPC), finance/accounts (FIN), shop floor control (SFC)/assembly, quality assurance (QA), capacity planning (CP), product development (PD), supply chain management (SCM), inventory management (IM), packaging(PKG), human resource management (HRM), maintenance management (MMT) and sales/dispatch (S&D). AHP has been used in a wide variety of complex decision-making problems, such as the strategic planning of organizational resources (Saaty, 1990), the evaluation of strategic alternatives (Tavana and Banerjee, 1995), and the justification of new manufacturing technology (Albayrakoglu, 1996). In order to minimize the risks involved in goal setting, the prioritization of whole business process should be viewed as a multi-criteria, decision-making problem. Analytical hierarchy process (AHP) can be used for multi-criteria decision making. It is evident from our discussion that AHP is referred to as the most powerful and widely acceptable technique for decision making process which allows decision maker(s) to measure the consistency and stability of their decisions. AHP has been shown to be useful in prioritizing alternative variables. The next section briefly describes procedure of AHP and steps involved in calculating prioritizing.

7.3 ANALYTICAL HIERARCHAL PROCESS (AHP)

The analytical hierarchal process (AHP) is a powerful and flexible decision-making tool that helps people set priorities and make decision when both quantitative and qualitative aspects of a decision need to be considered. This is done by reducing complex decisions to a series of pair wise comparisons, computing Eigen values and then synthesizing results. AHP not only helps in decision makers arrive at the best decision, but also provides a clear rationale for the decision. The decision maker judges the importance of each criterion in pair-wise comparisons. The outcome of AHP is a prioritized ranking or weighting of each decision alternative.

7.3.1 AHP PREFERENCE WEIGHTS AND STEPS

AHP weights with level of importance information are given in table 7.1:

Table 7.1 Scale of preference between two elements

Preference weights/ level of importance	Definitions	Explanation
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately preferred	Experience & judgment slightly favor one activity over another
5	Strongly preferred	Experience & judgment slightly favor one activity over another
7	Very strongly preferred	An activity is strongly favored over another and its dominance demonstrated in practice
9	Extremely preferred	The evidence favoring one activity over another is of the highest degree possible of affirmation
2,4,6,8	Intermediate preferred	Used to represent compromise between the preferences listed above
Reciprocals	Reciprocals for inverse comparison	

Generally AHP consists of following five steps:

1. Decide upon the criteria for selection
2. Rate the relative importance of these criteria using pair-wise comparisons

3. Rate each potential choice relative to each other choice on the basis of each selection criterion – this is achieved by performing pair-wise comparisons of the choices
4. Combine the ratings derived in steps 2 and 3 to obtain an overall relative rating for each potential choice as

$$a_j = \sum_i (w_i k_{ij})$$

Where; aj = overall relative rating for method j; w_i = average normalized weight for criterion I; k_{ij} = average normalized rating for method j w.r.t. criterion i.

5. Synthesis of priorities and the measurement of consistency
   i) Calculate the eigenvector or relative weights and λ_{max} for each matrix
   ii) Compute consistency index (CI) for each matrix of order n by the formula:

   $$CI = (\lambda_{max} - n)/(n-1)$$

   iii) The consistency ratio (CR) is then calculated using the formulae:

   $$CR = CI/RI$$

Where; RI is a known random consistency index obtained from a large number of simulations runs and varies depending upon the matrix size. For example; 0.05 value is for 3x3 matrix, 0.08 for 4x4 and 0.1~0.2 for all other matrices.

7.3.2 METHODOLOGY

As stated above that whole business process activities have been used as key performance indicators affecting the business at strategic level. So these are used as a factor affecting the whole business settings so that important ones are identified and prioritized. The way in which we have used these indicators in AHP for prioritization is unique to find out the relationship and importance of one indicator over the other using pair-wise comparison. It is obvious that one who is involved in the process being asked to judge pair-wise relative importance of one indictor over the other may lead to inconsistence results. Therefore, senior executives (Vice-Chairman Engineering Development Board (EDB), Pakistan) and two business executives have been selected to fill the 'nxn' matrix. They have been involved in operational and strategic decision making process in industry for decades. A questionnaire has been distributed in matrix form asking a simple question 'How much important is one indicator over the other' using a scale of 0-9 as given in table 7.2, 7.3 and 7.4 for protector, offensive and innovative manufacturers respectively. This is because; sometimes-major investment is made without proper identification of key issues. This may lead us to wrong decisions; therefore, relative comparisons of different alternatives of key indicators are very necessary. One logical argument is that the relative importance is different for person who is filling up the 'n x n' matrix. This is overcome as averaged values have been used for final prioritization calculations.

Now, set up the 'n' requirement in the rows and columns of an 'n x n' matrix. Since, there are thirteen activities in whole business process; therefore the requirement matrix consists of thirteen rows and columns. The matrix is filled up above the diagonal (since the values below the diagonal are reciprocals for each corresponding indicator). The main question asked is 'how much important is one indicator over the other using a given scale' as shown in figure 7.1. Then, perform the pair-wise comparison of all the requirements using the scale value as mentioned above. We have used Expert Choice® software for easing and calculating importance ratings and Eigen value calculations (as we are interested in prioritization and related inconsistencies). The judgments are recorded, 'n x n' values calculated and any inconsistencies shown in final results.

7.3.2.1 PRIORITIZATION FOR PROTECTOR MANUFACTURERS

Figure 7.1 and 7.2 show normal and prioritized results in decreasing order of importance for 'Protector Manufacturers'. As explained earlier that three executives are contacted to fill this part. Three strategies and its relationship have been discussed with executives and they are asked to fill the n x n matrix as shown in figure 7.2. Expert choice is used for calculating the prioritization. As production planning and control is the most important activity in prioritization. This is so as executives are feel it utmost important at shop floor level followed by capacity and inventory management. Thus focusing on production planning and control reduce cost per part and increase efficiency of system by minimizing waste times. Thus concentrating on these activities would capture the market so marketing is the least sensitive rated by them at protector level. Therefore, it comes out that production planning and control followed by capacity planning; inventory management and shop floor control are the most sensitive activities in whole business settings for protector players as shown in figure 7.2. So the prioritization for protector players in decreasing order of importance is:

- Production Planning and Control
- Capacity Planning
- Inventory Management
- Shop Floor Control
- Maintenance Management
- Quality Assurance
- Product Development
- Supply Chain Management
- Sales & Dispatch
- Finance
- Packaging
- Human Resource Management
- Marketing

Much attention should be placed on streamlining of operations, minimization of waste times from the processes using standard tools and methods of production planning and control, shop floor control etc.

Table 7.2 Protector Manufacturer's matrix

	MKT	PPC	FIN	SFC	QA	CP	PD	SCM	IM	PKG	HRM	MMT	S&D
MKT		1/4	1	1/5	1/4	1/4	1	1/2	1/4	1/3	1	1/4	1/3
PPC			4	1	1	1	3	3	1	5	4	2	4
FIN				1/5	1/4	1/4	1/3	1/2	1/4	2	2	1/3	1/3
SFC					1	1	3	3	1	4	4	1	3
QA						1/2	2	1	1	3	3	2	4
CP							4	3	1	4	3	1	4
PD								1	1/3	3	2	1/2	1
SCM									1/2	1	2	1/4	1
IM										6	5	1	5
PKG											1/2	1/5	1
HRM												1/5	1
MMT													6
S&D													

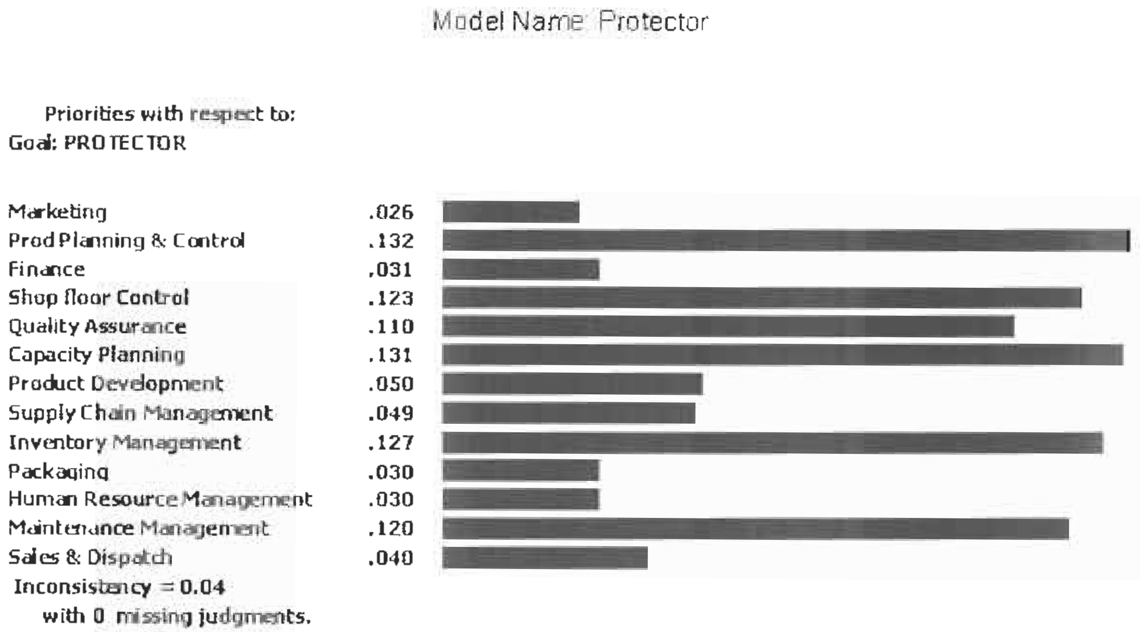

Figure 7.1 Protector Manufacturers results w.r.t goal

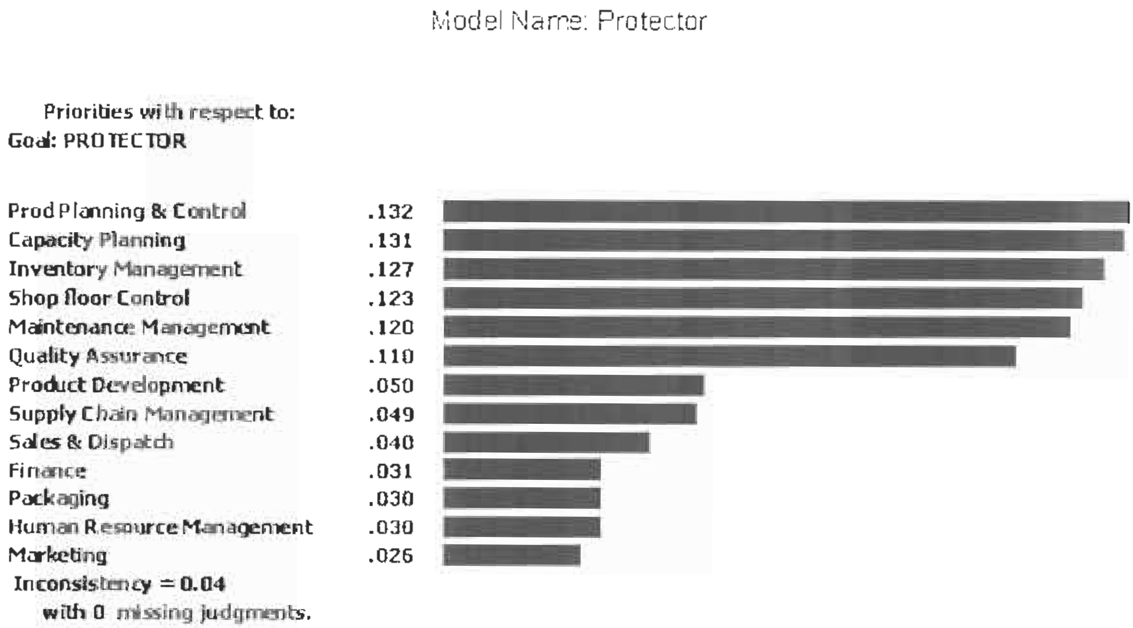

Figure 7.2 Protector Manufacturers priorities in decreasing order of importance

Table 7.3 Offensive Manufacturer's matrix

	MKT	PPC	FIN	SFC	QA	CP	PD	SCM	IM	PKG	HRM	MMT	S&D
MKT		1	1	1/5	1/6	1/3	1	1/2	1/3	1	1/2	1/4	1
PPC			3	1/2	1/3	1	1	1	1	3	2	1	4
FIN				1/4	1/5	1/3	1/3	1	1/3	2	2	1/3	1
SFC					1/2	1	1	2	1	2	2	1/2	3
QA						3	2	3	3	4	5	3	4
CP							1	1	1	2	3	1	3
PD								3	3	5	3	2	4
SCM									1	3	1	1	3
IM										3	2	1/2	3
PKG											1/2	1/4	1
HRM												1/3	1
MMT													3
S&D													

7.3.4.2 PRIORITIZATION FOR OFFENSIVE MANUFACTURERS

Figure 7.3 and 7.4 show normal and prioritized results for offensive manufacturers. As offensive manufacturers aim is to satisfy customized requirements and enhancing variety, so they are termed external focused. Quality assurance, product development is rated as the most important activities in whole business settings for offensive manufacturers. This means that executives are quite aware that this is the most important stage and turning point to become competitive. Therefore, much attention should be paid in quality assurance and product development activities by introducing advanced systems and increasing level of know how to shop floor personnel.

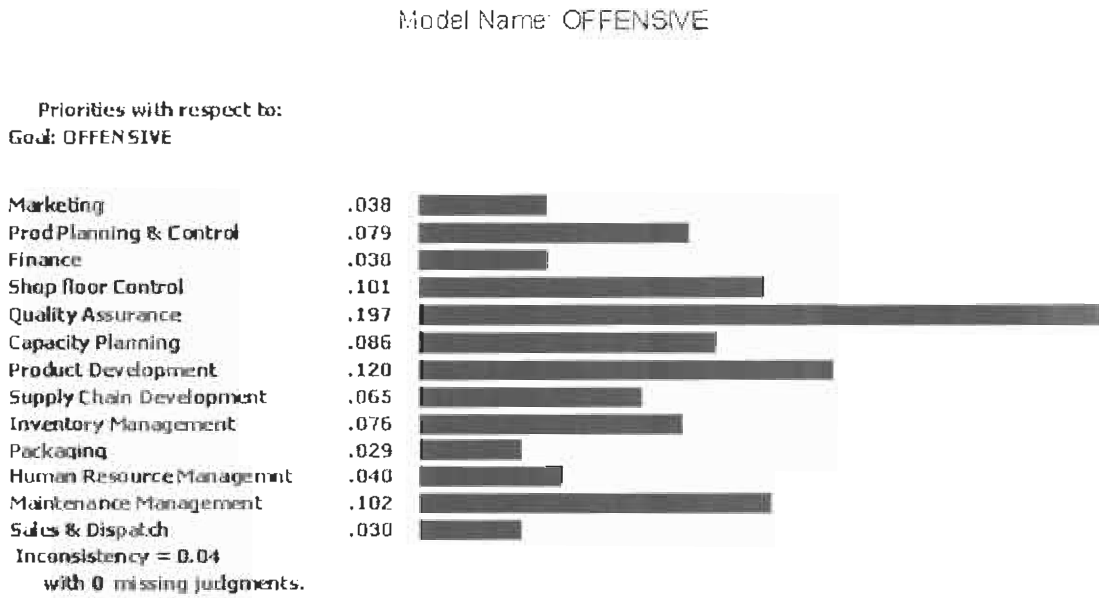

Figure 7.3 Offensive Manufacturers results w.r.t goal

The importance of prioritization in decreasing order of importance is:

- Quality Assurance
- Product Development
- Maintenance Management
- Shop Floor Control
- Capacity Planning
- Production Planning and Control
- Inventory Management

- Supply Chain Management
- Human Resource Management
- Marketing
- Finance
- Sales and Dispatch
- Packaging

It is pertinent to note that at offensive stage, quality assurance and product development are the most sensitive activities and affect the whole business setting.

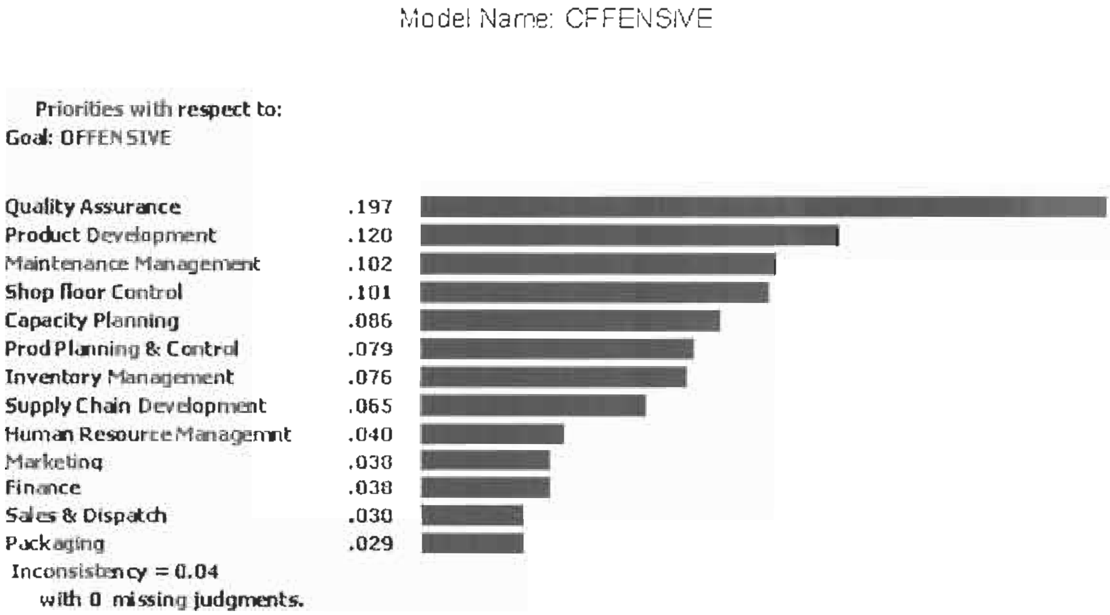

Figure 7.4 Offensive Manufacturers priorities in decreasing order of importance

7.3.4.3 PRIORITIZATION FOR INNOVATIVE MANUFACTURERS

Figure 7.5 and 7.6 show normalized and prioritized results for innovative manufacturers. It is interesting to note that quality assurance, product development and maintenance management are rated to be the most sensitive activities in whole business settings for innovative manufacturers.

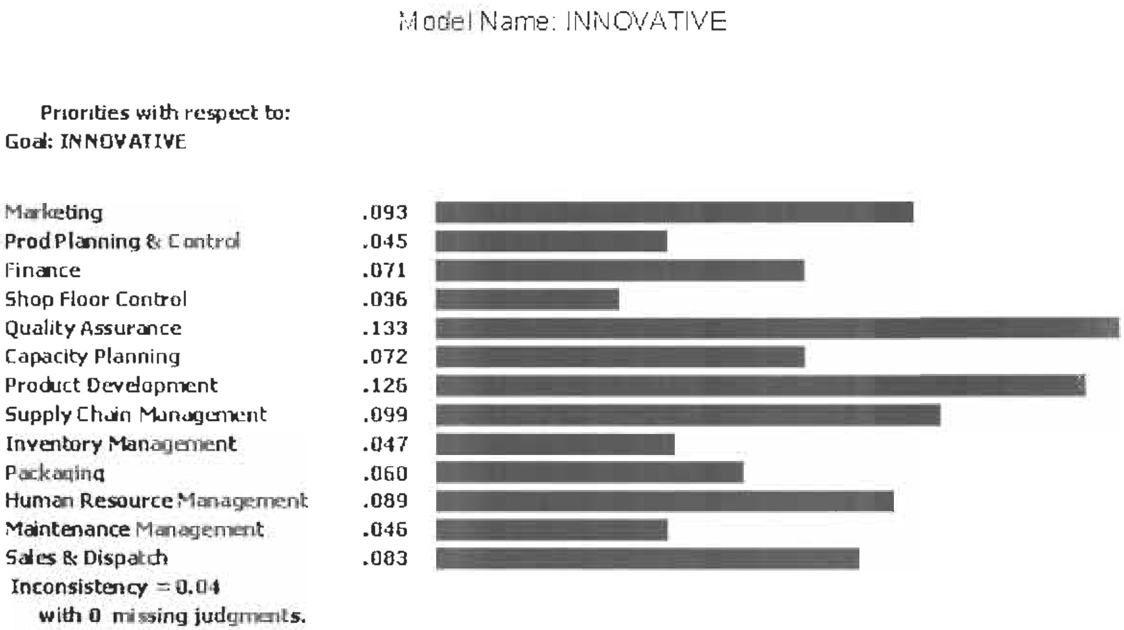

Figure 7.5 Innovative Manufacturers results w.r.t goal

The importance of prioritization in decreasing order of importance is given below:

- Quality Assurance
- Product Development
- Supply Chain Management
- Marketing
- Human Resource Management
- Sales & Dispatch
- Capacity Planning
- Finance
- Packaging
- Inventory Management
- Maintenance Management
- Production Planning and Control
- Shop Floor Control

Table 7.4 Innovative Manufacturer's matrix

	MKT	PPC	FIN	SFC	QA	CP	PD	SCM	IM	PKG	HRM	MMT	S&D
MKT		3	1	2	1	1	1	1	2	2	1	2	1
PPC			1	1	½	1	½	1/3	1	½	½	1	½
FIN				1	1/3	1	½	½	1	2	1	2	2
SFC					1/3	½	¼	½	1	½	¼	1/3	1/3
QA						1	1	2	3	3	2	3	2
CP							1	1	2	1	½	1	½
PD								1	3	3	2	2	3
SCM									1	2	1	3	2
IM										1	½	1	1/3
PKG											1	2	1
HRM												3	1
MMT													1/3
S&D													

It is found that quality assurance, product development and supply chain management are the most important activities in whole business settings. One similarity between offensive and innovative manufacturers is quality assurance and product development come out most important for both type of manufacturers. This is because at medium to high variety, new product development and quality offer challenges to manufacturers for achieving highest degree of reliability and innovation as demanded by domestic and international customers.

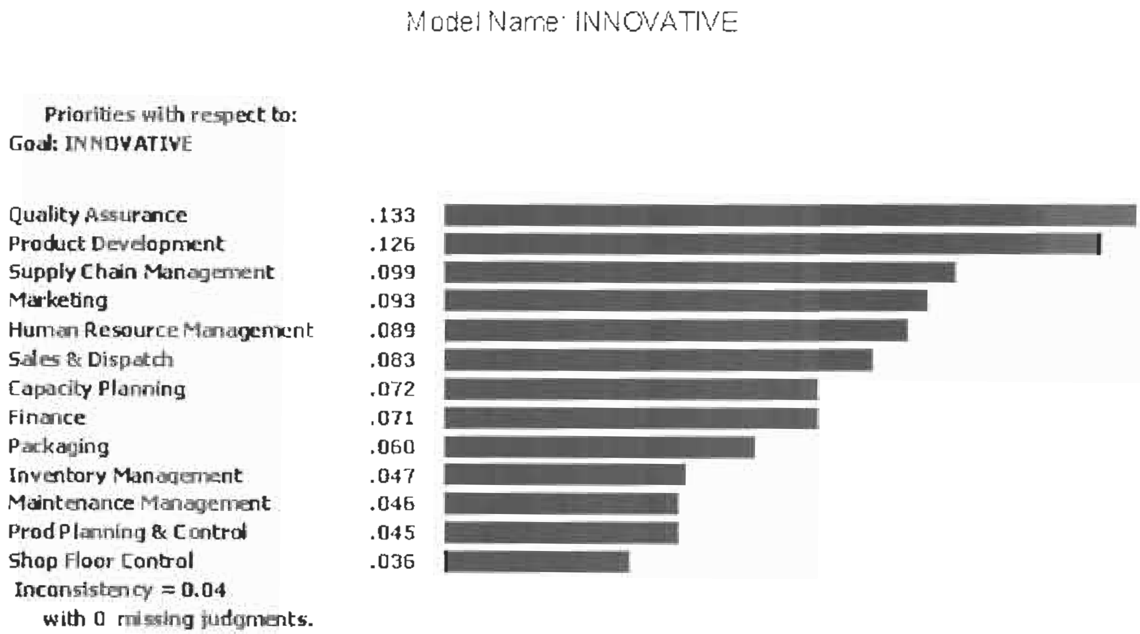

Figure 7.6 Innovative Manufacturers priorities in decreasing order of importance

In order to shift business from the existing environment to a more viable place, the following table is used which is made according to prioritized results for each type of manufacturers i.e. Protector, Offensive and Innovative respectively.

As discussed earlier in chapter 5 that Value Analysis (VA) is the systematic application which is used to identify the function of a product or service, establish a monetary value for the function and provide the necessary function reliably at the lowest cost. Value can be increased either by increasing the importance for the same cost or by decreasing the cost for the same utility.

Let; I = Importance; C = Cost Therefore; Value = I / C. The information collected is on the basis of importance versus cost out of hundred percent (%). Importance at operation

1, 2, ..,n is I_1, I_2,..., I_{13} respectively. Similarly related cost at operation 1, 2, ..., n is C_1, C_2,... C_{13} respectively. There are thirteen departments/activities engaged for the manufacturing of automobile parts. Department's importance and corresponding cost as given in Table 5.4 in chapter 5, VA graph is drawn as shown in figure 7.7 below:

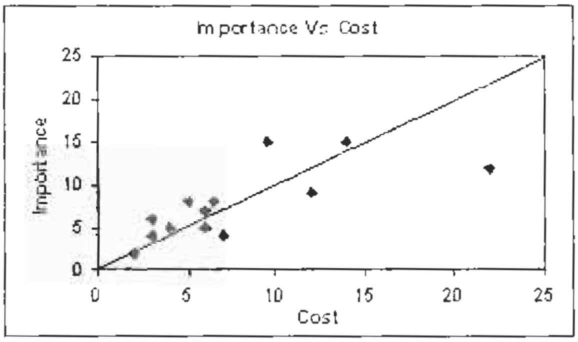

Figure 7.7 VA applied in innovative stage

Four departments which require consideration are shop floor control, product development, supply chain management and inventory management in which cost is more than importance as they lie below the line in figure 7.7. It is required to carry out detailed *VA analysis using tear down approach* for identifying causes. By carrying out detailed analysis within the departments for innovative manufacturers can improve satisfaction level of customers at reduced cost.

Table 7.5 Summary of strategic level results

S. NO	PROTECTOR	OFFENSIVE	INNOVATIVE
1.	Production Planning & Control	Quality Assurance	Quality Assurance
2.	Capacity Planning	Product Development	Product Development
3.	Inventory Management	Maintenance Management	Supply Chain Management
4.	Shop Floor Control	Shop Floor Control	Marketing
5.	Maintenance Management	Capacity Planning	Human Resource Management
6.	Quality Assurance	Production Planning & Control	Sales & Dispatch
7.	Product Development	Inventory Management	Capacity Planning
8.	Supply Chain Management	Supply Chain Management	Finance
9.	Sales & Dispatch	Human Resource Management	Packaging
10.	Finance	Marketing	Inventory Management
11.	Packaging	Finance	Maintenance Management
12.	Human Resource Development	Sales & Dispatch	Production Planning & Control
13.	Marketing	Packaging	Shop Floor Control

7.4 CONCLUSIONS

Based on prioritized results as given in table 7.5, there occur different levels of hierarchies i.e. most, moderately, and least important. The following figure 7.7 show different levels of hierarchies based on the results as tabulated in table 7.5.

- Production Planning and control is most important activity for protector manufacturers, whereas quality assurance is equally important for both offensive and innovative manufacturers respectively. This confirms that even executives are quite aware of their decisions at strategic level.

Figure 7.8 Hierarchical levels

- Capacity planning is the second most important activity for protector whereas product development both for offensive and innovative manufacturers respectively. This comes out that attention be placed on capacity building for protector whereas emphasis should be placed on product development for offensive and innovative manufacturers.
- Much attention should be paid on inventory management, maintenance management and supply chain management by improving standards of forecasting data and using state of the art techniques like JIT, Kaizan, and 5S for material management.
- Value Analysis (VA) as a tool assists innovative manufacturers to increase importance and reduce cost. It has been found that shop floor control, product development, supply chain and inventory management is most costly-less important departments. Value analysis tear down approach should be implemented to find out less important and mostly costly activities. This help to improve product by such innovation.

Whole business process activities have been modeled and analyzed using AHP (Expert Choice software®). The necessary information needed in this regard is filled up in n x n matrix. The judgments are recorded and calculated as shown in figures 7.1 to 7.6. Figure 7.2, 7.4 and 7.6 shows the prioritized most important business settings and are presented in table 7.5. Production planning & control, quality assurance and product development are most important activities which affect business at each type of manufacturers. It is therefore imperative for manufacturers to keep special emphasis on production planning and control issues at protector, quality assurance at offensive and product development techniques at innovative stage respectively. Given the strategic level decision making for automobile industry, manufacturers should focus on most important issues otherwise there future will be in jeopardy.

CHAPTER 8
RECOMMENDATIONS AND FUTURE WORK

CHAPTER 8

RECOMMENDATIONS AND FUTURE WORK

8.1 INTRODUCTION

This chapter concludes, recommend and discuss about new research avenues. In literature review section, we identified that there exists a gap to address low cost, high quality with more agile and innovative issues within a single framework. For this purpose, a questionnaire was developed to identify manufacturers stated objectives, level of manufacturing management practices, infrastructure and location of companies on PPMx matrix. Three types of manufacturers were identified i.e. 'Protector', 'Offensive' and 'Innovative' corresponding to low cost, high quality with more agility and valued added to delight customers. Strategies are proposed and a framework developed in this regard to cope with existing manufacturing environment. The framework consisted of four phases i.e. objective analysis, strategy formulation, model development/evaluation and validation phase. A model is developed using manufacturing simulation as a tool. The tool was selected because we were interested to obtain both time dependent and numerical valued responses which help us to analyze behavior of system and give recommendations to manufacturers. The framework was tested using data from case companies and validated through discussion and sharing of the model results with existing real life systems. The research significant findings, recommendations and future work are presented in the subsequent section:

8.2 SUMMARY OF RESEARCH

Manufacturing companies all around world are facing dynamic, turbulent and fast changing environment due to time compression technologies, remarkable improvement in product design and customer service. The same competitive environment faced by developing countries like Pakistan is even more challenging. Many initiatives have been taken for restructuring economy by increasing privatization and enhancing competition but local manufacturing industry is still far away from global practices and standards. This is because; Pakistani companies have paid very little attention to their shop floors. This results in poor product quality, no awareness of competition and non integration of various businesses such as marketing, sales, production etc. On the other hand, world class manufacturers operating in global markets almost tend to have world class performance.

In order to cope with this environment and to become competitive in the marketplace, a research questionnaire was developed. The questionnaire containing questions related to manufacturer's stated objectives, level of manufacturing management practices, infrastructure and position/location of companies on PPMx matrix as advocated by Hayes and Wheelwright (1984). It is concluded from survey exercise that companies in strategic objectives have responded well, but actual practice is far from their stated strategic objectives. So, having right objectives may not lead to superior performance, but operating without them guaranteed to lead to competitive disadvantage. This call for investigating issues to identify ways to become competitive in the marketplace.

A framework is developed consisting of objective analysis (capacity, technology/manufacturing capabilities and current market environment), strategy formulation (protector, offensive, innovative: with objective, operationalization and continuum), model development/evaluation and validation phases. A simulation model is developed using data from case companies. Experimentation is performed by changing the base values (controllable design parameters) to see its impact on performance measures (output responses). Slopes of the functions (numerical values) are then computed using standard spreadsheet software. The values are prioritized based on decreasing order of sensitivity. Performance measures important for case companies related to three strategies are discussed with the company's management. The model results are finally prioritized which are tried to achieve competitive edge. The theoretical framework developed is generic as it can cope with any type of discrete parts manufacturing/assembling firms. The framework has flexibility to cope with low cost, high quality and innovative manufacturers systematically in an orderly manner. Thus presented framework provides manufacturers a sustainable solution for their survival in marketplace and become competitive.

8.3 SIGNIFICANT FINDINGS AND CONTRIBUTIONS

Manufacturing is the second largest sector of Pakistan's economy. Industries are classified into process and discrete parts manufacturing industries. Not much attention had been paid in discrete parts manufacturing sector, so it is operating in low volume/sub optimal manner (EDB 2006). Among discrete parts industry, automobile is one of the fastest emerging and growth in this sector has picked up over the last few years. Therefore, automobile discrete parts manufacturing industry is selected to identify sub-optimality issues by proposing concrete workable solutions and corrective actions which aid Pakistani manufacturers to become competitive. In order to assess manufacturing industry environment, world class industrial models have already been studied and one important matrix practiced for analyzing industry is PPMx. PPMx has been in use for last three decades or so and considered to be foundation; therefore, industries volume versus variety related information has been collected and plotted on this standard matrix. The cluster showed low to medium volume manufacturing environment. So, research work is needed to cope with this environment and a study has been focused to address this important issue i.e. 'how *to cope with low to medium volume- low variety manufacturing environment in automobile industry of Pakistan'*.

The major work done is identification of the core issues which hampers in manufacturers to become competitive in the marketplace. The findings of the research are both general and company specific which are beneficial for manufacturers in the long run and incorporate them in business to become competitive.

8.3.1 GENERAL FINDINGS

A questionnaire containing of questions about manufacturer's objectives, level of manufacturing management practices, infrastructure and location/position of industry on PPMx. The analysis of the questionnaire identified three types of manufacturers i.e. *'Protector', 'Offensive' and 'Innovative'* which are unique and related names are used exists in research literature as discussed in chapter 4. These names had been identified after thorough review process so that more precise and generic terminologies for representing of manufacturers types are obtained.

A *framework* has been presented which uses; protector, offensive and innovative strategy names. As discussed above those names of strategies are unique which is representing type to manufacturers and close to reality. The framework starts with objective analysis phase so that market situation is analyzed, existing manufacturing environment information is assessed and industrial sector pre-requisites be obtained. This help to develop objective settings. This phase is followed by strategy formulation phase in which the above stated names have been used now as strategies in which emphasis is placed to become low cost, high quality with more agile and customer focused manufacturer respectively. The strategies are than operational using traditional approaches like balancing of production lines, minimization of waste times etc as protector strategy; using more agile and flexible systems for high quality and agility as offensive strategy; and using value analysis for increasing value and decreasing cost of product as innovative strategies for attracting and delighting customers.

A review of solution methodologies has also been presented in chapter 5 in which use of simulation as a tool is justified at tactical level decision making process. The simulation is carried out to analyze system and slopes of function from numerical valued graphs are also obtained. The highest slope represent most sensitive and corresponding values of the slopes have been assigned score from 1 to 5 respectively (5 means most sensitive and 1 least sensitive). The results are tabulated and parameters prioritized for each type of manufacturers individually. The way in which we have used simulation and carried out analysis to find the most sensitive parameter is unique and is close to response surface methodology (RSM).

The next step is to identify key activity over whole business process. The way simulation experimentation is performed and identifying key parameters at tactical and AHP at strategic level is therefore distinctive. AHP has been used for strategic level decision making process. The way in which AHP has been used for prioritization is unique to find out the relationship and importance of one indicator over the other using pair-wise comparison. It is obvious that one who is involved in the process being asked to judge pair-wise relative importance of one indictor over the other may lead to inconsistence results.

It can be argued that separate applications of simulation and AHP exists, but as explained earlier that the way in which both are integrated within a single framework is distinctive and any discrete parts/assembling industry can benefited from the framework. Therefore, use of traditional approaches (bundle of approaches) using simulation at tactical and AHP at strategic level aid manufacturers in long run to take right decision making to become competitive.

8.3.2 COMPANY SPECIFIC FINDINGS

Simulation as a tool has been used for modeling real world problem for many years. The case company's data has been collected and model developed, verified, validated using sensitivity analysis and discussion with executives. The use of balancing production line and minimizing waste times streamlining production lines reducing cost per unit. Thus minimization of wastes and other non productive times compel manufacturers to think about lean production system; which is termed '*lean and clean*'. The use of flexible process improves not only quality of product, but also compresses new product development time. The result of the simulation at offensive stage confirms that use of flexible processes improves quality and is rated most sensitive in prioritization. This is termed as '*perfect first time quality*'. The prioritized results in innovative stage advocate of using more flexible processes and improve value of product using value analysis approaches like importance versus cost. This is termed 'value added continuous innovation'. The combined prioritization also show quality at the top and reinforce our belief '*make it right-first time every time*'.

Thus from above discussion company planning personnel should use simulation as a tool for scheduling as it is utmost important to become world class manufacturer.

8.4 RECOMMENDATIONS

The following recommendations are made for manufacturers which aid them to understand and become competitive in the world marketplace:

i. The study is based on PPMx matrix (sec. 2.2.1) which is generally considered as foundation in the field of manufacturing to become world class. The manufacturers should understand the matrix and follow it for planning in future.

The investments should be made keeping in view of the best match between product-process choices.

ii. It is advisable that companies should use advanced manufacturing technologies which is associated with superior performance and the process-product must be followed (sec. 2.2.1)

iii. Time compression (by minimizing waste time from system) and cost (reducing per unit cost) are the primary motives to become competitive (sec. 2.2.2.1). Automobile industry is volume driven and certain mass is required to justify production and our share in world total production is 0.3% (sec. 2.4.3), therefore, volumes should be paid due attention which can be achieved by minimizing waste and non productive times from the system. (Other than time and cost, agility (lean system + flexibility) are also important motives to become world class manufacturers (sec. 2.2.2.2 and 2.2.2.2.1). The most important dimension which should be focused is innovation, in which senior management commitment is required. Product and process innovation are the two core areas for investments. Presently, manufacturers should teach (conducting seminars/training programs) value analysis tear down approaches to industry personnel which help to improve business by delighting customers at reasonable cost (sec. 2.2.2.3). Incorporating innovation in the products also improve export to delight customers.

iv. Various challenges faced by manufacturers are low technology base; know how, absence of R&D etc (sec. 2.4). The manufacturers assess themselves where they are locating in PPMx and then take corrective actions in a systematic manner to utilize resources using traditional approaches, using flexible tools to become customer focused manufacturers.

v. The manufacturers have rated agility as the second most important objective (sec. 3.2.1), but are operating their business in traditional ways. It is recommended that manufacturers should focus on lean and flexible issues to become agile players. The manufacturers know the importance of manufacturing management techniques (sec. 3.2.2). The breadth and depth have been calculated in this regard, but depth is very low (sec. 3.3.2) which identified that manufacturers are not implementing them in shop floor. It is utmost important that manufacturers should use these management practices (sec. 3.2.2) in a systematic manner. The management practices benefits are different for each type of manufacturers. For example, JIT should be used by 'offensive manufacturer', optimized production technology by the 'protector manufacturers' and activity based costing by the 'innovative manufacturers' etc. The applicability of each technique should be assessed and implemented after comprehensive analysis of existing environment.

vi. The manufacturers are facing problems of unreliable vendor supplying raw material. This is a serious obstacle which hampers manufacturer to become competitive in the world marketplace (sec.3.2.3). The manufacturers should focus on reliable vendors who provide zero defects raw material and improve supply chain.

vii. There are only few companies who have minimized defects before rework (sec.3.2.4.2). Standard equipment and advanced manufacturing systems should be used which not only improve quality, but also enhance flexibility/agility and can accommodate any variety (type/style).

viii. Cellular manufacturing layout is considered as pre-requisite to compete in world market as such type of layout can accommodate part types and styles. Each cell is dedicated for the production of parts and similar parts can be grouped together in the form of cells. It is recommended for the offensive/innovative manufacturers who can be benefited from such implementation.

ix. Longer setup times slow down pace of production line and performance (sec. 3.2.4.4). It is recommended to use flexible jigs/fixtures/flexible systems/ SMED approaches to reduce effects of setup times. This may help to minimize setup time by carrying out comprehensive analysis before implementation.

x. R&D and training of employees is also a week area which hampers manufacturers to become competitive (sec. 3.2.4.5 and 3.2.4.6). It is suggested of establishing training schools financed by industry. Off-line experimentation and virtual tools also help manufacturers to train man power on multi tasking skills.

xi. Balancing of the production line (P_{MAX}) 0.75, 0.5 and 0.25 times base run values (sec. 6.3.1 Expt no 1) decreases cost per unit, total production cost, reduces work in process, waiting time and flow time. It comes out that traditional line balancing techniques like largest candidate rule, Kilbridge and Wester method and Ranked Positional Weight (RPW) method must be implemented which can assign work content equally amongst workers, stream lining process to reduce per unit cost. RPW can provide more practical results and considered as pre-requisite even in manual and automated production/assembling processes (Grover 2001). It is recommended to implement any line balancing technique to reduce cost of unit.

xii. Changing hourly labor rate 2.0, 4.0 and 6.0 times base run value (sec. 6.3.1 Expt no 2) significantly increases cost per part and total cost. Labor rate in product mix environment complicates scheduling because in order to meet the varying flexibility requirements at all times, work force are needed which is mixture of semi-skilled, highly skilled and multifunctional workers. When a new product comes in, the highly skilled group at higher labor rate is assigned to do task which increases cost of part. Gradually, multifunctional and semi-skilled labor takes over the charge of production. When both types of workers fully understand part complications, learning time is reduced. This situation occurs both for 'offensive' and 'innovative' manufacturers. It is found that companies should have pool of workers which include mixture of semi-skilled, multifunctional and skilled labor force to cope with new product development/manufacturing. Therefore, emphasis must be paid on human resource development and formation of groups (semi-skilled, multifunctional and highly skilled labor force) to reduce wage rate effects on cost per unit.

xiii. Changing machine rate 1.5, 3.0 and 4.5 times base run values (sec. 6.3.1 Expt no 3) significantly increases cost per part and total production cost. Machine rate is also found a sensitive parameter. To justify for using NC machines, production lines to be properly balanced, failures and jams minimized. Overcoming these problems will lower the unit price and product manufactured from these systems may get more shares in the market at competitive price. For ultra large production volumes, transfer machines should be used with particular care taken for the machine origin as machine rate - most sensitive parameter. Machine sensitivity analysis is carried out and recommendations are given under TDS heading below.

xiv. Changing material handling time 0.5 and 0.25 times base run value (sec. 6.3.1 Expt no 4) significantly effect flow times, non value added times and utilization. The state of the art manufacturing systems can be justified here after detailed market analysis. The systems like Flexible Manufacturing Systems (FMS), Group Technology (GT), Cellular manufacturing and some disintegrated forms of Computer Integrated (CIM) can be implemented. This may help to reduce the material handling/ transportation time at shop floor level and provide a competitive edge. The use of above stated systems are time compression technologies and offer great advantages for manufacturers.

xv. The most sensitive factors investigated in our study are minimum or starting and change in yield (sec. 6.3.1 Expt no 5&6) which can be controlled using various quality techniques like acceptance sampling, control charting, gauging systems, stage wise quality controls and total quality management philosophies. In mass production systems, gauging technique can be used whereas in batch type customization, total quality management is more appropriate. Use of advanced manufacturing systems not only provide flexibility (variety) but also improve product quality by minimizing role of human. An analysis has been carried out for finding most appropriate level of technology which justifies production as explained in point iii. Attentions to be paid on both 'starting or minimum yield' and 'quantity to be reworked', as maximum benefits are associated with quality related parameters. Thus, both yield related parameters which found the most sensitive parameters, hence reinforcing our belief to 'make it right, first time every time'.

xvi. Setup time reduction (sec. 6.3.1 Expt no 7) has been a detailed topic of research over last few decades or so. An approach i.e. Single Minute Exchange of Dies 'SMED', use of flexible jigs/fixtures, turret/capstan combination etc can be used for reducing setup times. Its effect has been witnessed on flow time and non value added cost/time. In shop floor production, detailed analysis must be carried out to combine operations on the production line to reduce setup time. Therefore, SMED, flexible jigs/fixtures and combined operations help to reduce setup time.

xvii. Reworking and fast reworking times (sec. 6.3.1 Expt no 8&9) can be minimized/eliminated by implementing proper level of automation technology like CNC as recommended in point 5. Training of the operator also play a vital role, so line operators should be properly trained and group be prepared i.e. mixture of trained, multi functional and semi skilled labor. When a complex part arrives, work should be carried out by skilled workers, this is taken over by semi skilled workers, once production got smooth. Learning curves phenomena occurred and manufacturers should incorporate and focus their attention on these issues so as to minimize reworking and fast reworking time.

xviii. Use of flexible systems (variety and volumes) has been analyzed for the respective stage and it is found that such systems not only improve product quality, volumes, but also enhance variety (for customized orders). As in traditional mass production systems, the emphasis is to reduce cost, but at customized stage, due importance is given to variety. In order to attract customers and become world class players both in volume and variety, attention should be paid on volume and variety issues.

The following recommendations are made to identify sensitive level of technology when companies will shift from manual to automated system. These are given below:

i. Doubling the machine, labor, and overhead rate results in 2.3%, 16.6% and 0.51% (sec. 4.2.2.2.2 table 4.2& sec. 6.4.2 table 6.6) increases in cost respectively. It comes out that machine rate is the least sensitive (sec. 6.4.2 table 6.7) so engine lathes should be employed and labor rate is the most sensitive parameter which can be controlled using as cheap labor as possible.

ii. Doubling the machine, labor, overhead rates and number of setups results 2.53%, 25%, 0.7% and 95% (sec. 4.2.2.2.2 table 4.2& sec. 6.4.2 table 6.6) increases in cost respectively. Turret lathe should be used with comparatively large batch size; much smaller number of setups can be obtained (sec. 6.4.2 table 6.7). Cost of the labor to be given due priority since it is moderately sensitive in this case.

iii. Doubling the machine, labor, overhead rates and setup cost results (sec. 4.2.2.2.2 table 4.2& sec. 6.4.2 table 6.6) increase 74%, 0.53%, 18% and 71.8% in cost respectively. We have adopted an alternate course of action making increase in batch size ten times which significantly decreases 85% cost per unit and doubling the batch size results in 40% decrease in cost (sec. 6.4.2 table 6.7). This means to produce in as much large volumes batches as possible. Machine setup cost is also a sensitive parameter investigated during analysis, and can be controlled by employing a single setter engaged for setting up a number of automatic machines.

iv. Machine and overhead rate comes out to be the sensitive indicators (sec. 6.4.2 table 6.7). To justify for using NC machines, production lines to be properly balanced, failures and jams minimized. Overcoming these problems will lower the unit price and product manufactured from these systems may get more shares in the market at competitive price. Tool changing time and cost of tool comes out to be less sensitive. It does not mean that it is unimportant but it means that tool-changing time is less important than machine rate and overheads.

For ultra large production volumes, transfer machines should be used with particular care taken for the machine origin (machine rate - most sensitive) and tool material exponent (n), being moderately sensitive. Tool life should be given due consideration as it is found to be a sensitive parameter (sec. 6.4.2 table 6.7). Cost of tooling turns out to be comparatively less sensitive parameter, probably because of its small magnitude in comparison with capital cost of the machine

The following recommendations based on results as presented in chapter 7, table 7.4 for protector, offensive and innovative manufacturers at strategic level for manufacturers respectively are:

i. Production planning & Control and quality assurance issues are rated as most important at strategic level. It is evident that manufacturers should focus on production planning and quality assurance issues. This would be achieved using conventional approaches like work load control, line balancing algorithms and Kaizan, 5S etc at shop floor.

ii. Use of flexible systems lie CNC, NC and transfer machines not only mitigate capacity constraints issues on one side, but also help in product development with CAD/CAM integrated features. Other than above stated systems, quality related tools like gauging systems for mass production, control charting, acceptance sampling, total quality management, zero defects approaches should be used which can eliminate waste from system.

iii. In order to reduce lead and product development time, flexible processing and time compression technologies like rapid prototyping machines, 3-D scanner, and coordinate measuring machines should be used which provide fastest development time.

iv. Manufacturers should focus on manufacturing management systems for material management and supply chain management issues. This would be achieved by implementing MRP-I and II. To minimize new material and finished goods inventories, the reliability of vendors are important (zero defect stage) which will cut a lot of waste from the system.

v. Office automation tools and implementation of CAD/CAM in ARIS architecture should be understood in order to implement different hierarchies of ARIS within the organization.

vi. Special attention should be paid on human resource development as it is found sensitive for innovative manufacturers. Simulation courses, off-line machine practice for new product development, making models in rapid product machines, learning of CAD software, training on advanced systems, seminars would help them to learn about latest tool/ techniques.

8.5 RECOMMENDATIONS FOR FURTHER STUDY/FUTURE WORK

The following recommendations are proposed for carrying out further study/future work:

i. The framework presented has been tested for industries focusing on manufacturing whereas it is equally applicable in assembling, semi conductor manufacturing and any other discrete parts manufacturing. The framework should be tested in such types of industries too for validation.

ii. Three types of manufacturers, cone type strategy trade-off diagram and characterization have been presented. However, work can be done on development of expanded cone type strategy diagram in which previous benefits of tools used associated with each type of strategy are linked with prior ones.

iii. Simulation as a tool has been used for operationalization of strategies. Model is developed and coded in manufacturing simulation platform. Experimentation is performed by changing the input design parameters to analyze effects on output variables. Different responses at each level are achieved just like the case of Response Surface Methodology (RSM). The major work is to obtain the optimized parametric values; therefore simulation based optimization can be used in such cases. Process Analyzer and OptQuest® are the separate platform which can be used to obtain optimized results at tactical level.

iv. Other types of discrete parts industries with many levels of hierarchies can use the model and framework both in tactical and strategic level decision making process. The industries include fans, pumps, air conditioners, heaters, washing machines etc can be benefited with presented framework and simulation model.

v. Comprehensive SWOT analysis be considered before designing questionnaire, effect of product life cycle and demographic of sector can also be studied.

8.6 CONCLUDING REMARKS

The goal of the study is 'Coping with medium Volume-Low Variety manufacturing environment in automobile industry of Pakistan'. The above mentioned strategies, framework, tools used meet all the stated requirements up to quite satisfactorily extent as results from simulation tests confirmed our framework. The major contribution in our work is to conduct a survey in automobile sector (as no significant work has been found in international literature for utilization by manufacturers), analyze existing scenario to identify type of manufacturers and suggest concrete workable solutions in the form of strategies which can aid manufacturers in their long run to become competitive (local OEM, replacement and export markets) in the marketplace. Pakistani manufacturing industries especially automobile (as one of fastest growing sector) or any other discrete parts industry should focus on issues of competitiveness in the near future by following the framework presented other wise their future would be in jeopardy.

By conducting comprehensive survey, identifying types of manufacturers, proposing strategies for each archetype, modeling tools and generic frameworks (for any type of discrete parts industry), we have actually coped with medium volume- low variety manufacturing environment in automobile industry of Pakistan.

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Appendix

RESEARCH QUESTIONNAIRE

Section A

Q1. What are total **production volumes** (parts / products manufactured)?
______ Parts / Products per year

Q2. What are different **product varieties** (all types) produced / year?
10 15 20 30 40 50 60 70 80 90 100

Q3. How many parts / product types are most frequently run on production line at a time?
1 2 3 4 5 8 10 15 20 30

Q6. How your manufacturing systems **accommodate design changes** of product within same product class?
50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%

Q4. What is the Plant **installed capacity**?
________ Parts per year

Q5. What is the overall **system utilization** based on installed capacity?
50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%

Q7. Which of the following is the **most sensitive** in your system?
Labor rate Setup time (for changeovers) Machine rate

Q8. For **streamlining of operations**, Line Balancing technique is implemented in your company?
Yes No Partially Unaware of this technique

Section B

Q1. Which **Quality system** your company is practicing?
Acceptance sampling 100% inspection Control charts gauging system TQM 6-Sigma

Q2. Is company **ISO9000** certified?
Yes No In progress

Q3. What is the average **defect rate** in your organization?
0% 0.25% 0.5% 1% 1.5% 2% 2.5% 3% 3.5% 4% 5% Above 5%

Q4. What is the average **scrap rate** of your organization?
0% 0.25% 0.5% 1% 1.5% 2% 2.5% 3% 3.5% 4% 5% Above 7%

Q5. Which of them are used for **machine replacement** decision making?
Machine history Management guessing Process Capability Analysis

Q6. What is the **fixed cost** of your system?
Small Medium High Very High

Q7. What is the **variable cost** of your system?
Small Medium High Very High

Q8. What is the **cost of tooling** in your system?
Small Medium High Very High

Q9. What is the **unit cost** of the product?
Small Medium High Very High

Q10. What is the **cost of reworking** of parts in your system?
Small Medium High Very High

Q11. What amount of **mass storage quantities** are authorized by the system? (Percentage by total stock by value)
Small Medium High Very High

Q12. **Break Even Analysis** (BEA) is being practiced in your company as technique for selection of appropriate technology?
Yes No Partially Unaware of BEA

Section C

Q1. **Research and Development** activities are being carried out in your company, at what level?
Very Low Low Moderate Moderate to High High Very High

Q2. Activity Based Costing (**ABC**) is carried out in your company? (Hint: ABC is Calculating cost at each activity / stage)
Yes No

Q3. What amount of **delicate components storage** is authorized by the system? (Percentage by total stock by value)
Small Medium High Very High

Q4. What is your response on **customized products** within same or different product class?
Quick response Moderate response slow response

Q5. What are the **learning opportunities** for workforce in your organization?
Very Low Low Moderate High Very High

Q6. What is the **training expenditure** of manpower as percentage of turnover?
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Q7. How many numbers of **new parts/ products** are manufactured / introduced each year in your organization?
________ Parts each year

Q8. Do you have separate **Value Addition** department for increasing Value and Decreasing Cost of product?
Yes No Unaware of VA technique

Q9. What is the **fatigue in work life** of operator (where operator learns and relearns frequently) OR operators are trained with different part types your company is manufacturing?
Very small Small Medium High Very High

Q10. Is your organization engaged in **exporting parts**, if yes, what is percentage over total parts/ products made?
_______ (percentage)

Q11. What are major **problems/hurdles** faced by you

1) ____________________ 2) ________________________ 3) ________________________

4)_____________ 5) ________________ 6) ________________________

Section D

Q1. Please rate **strategic objectives** using scale from 1-5 (1 = not important, 2 = least important, 3 = moderately important, 4 = Important and 5 = very Important)

- Capacity utilization
- Waste reduction
- Supply Chain management
- Quick response to customers
- Agile manufacturing
- Innovative product development

Q2. At what level following **manufacturing management practices** are followed in industry using a scale (1 = not familiar with, 2 = not considering, 3 = considering, 4 = practicing for the last 1 year and 5 = practicing for more than 1 year):

- Just in time

- Optimized Production tools
- Group Technology
- Value Analysis
- Activity Based Costing
- Break Even Analysis
- Total Quality management
- Process Capability Analysis
- Advanced Manufacturing system

Contact Person Name: ______________________________

Name of Organization/Company: ______________________________

Address: ______________________________

____

Tel Phone No: ______________

Fax .No: ______________

E-Mail: ______________

Web Site: ______________

Total number of employees: ________

NUMERICAL VALUED FUNCTIONS

A. BALANCED LINE: (P_{MAX})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.62	2125	137558122	643	639	1861	22871702	52037526	4491986	1177092	1253	70.76
0.75	0.60	1882	96628762	347	343	2393	20235551	51349599	4459301	1031598	1746	40.87
0.5	0.59	1638	4647742	7.87	3.60	3503	860317	50483230	4312266	886398	2085	8.93
0.25	0.46	1346	2634857	4.0	0.6267	2001	19123868	42606377	3360518	880743	1674	6.62

B. Fast reworking times: (FR_{TIME})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.62	2012	100708919	358	354	2387	17666801	51006729	4649280	1208187	1537	43.17
At 0, 75%	0.62	2024	90140745	320	311	2684	16800336	58086286	4848001	1294772	1634	40.99
At 0, 95%	0.61	1999	95858971	337	332	2596	17014078	51461494	4622482	1106848	1591	40.06

C. Machine processing flexibility: (M_{FLEX})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.62	2012	100708919	358	354	2387	17666801	53006729	4649280	1208187	1537	43.17
85%	0.48	1645	99254903	348	344	2505	15778734	32642529	3604385	1182187	1563	40.67
95%	0.47	1631	99814702	347	344	2610	13697688	36305985	3574971	1120647	1559	44.05
99%	0.47	1627	100518521	359	332	2641	12706061	39580030	3574011	1107806	1832	39.7

D. Machine rate : (M_{RATE})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.60	2125	137558122	643	639	1861	27871702	52037526	4491986	1177092	1253	70.7
1.5	0.60	4125	137740747	643	639	1861	27907103	76291484	4854427	1187239	1253	70.7
3.0	0.60	5125	137889723	643	639	1861	27937475	100132573	5180958	1192876	1253	70.7
4.5	0.60	6125	138008905	643	639	1861	27961772	119205444	5442183	1197385	1253	70.7

E. Material handling time: (MH_{TIME})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.63	2017	93429656	324	320	2374	163223144	51254924	4604981	1188529	1523	40.7
0.5	0.63	2008	103726425	367	362	2395	18551937	53587188	4661707	1014244	1542	40.8
0.25	0.625	2012	92890171	325	321	2392	16325466	52125985	4619402	1002293	1535	41.22
0.1	0.626	2018	94985203	338	334	2375	16843764	52228999	4625268	995928	1523	41.35

F. Minimum or starting quantity to be reworked: (Y_{MIN})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.62	2012	100708919	358	354	2387	17666801	53006729	4649280	1208187	1537	43.17
85	0.62	1994	97385378	337	333	2500	15334972	53038423	4644324	1166940	1571	40.85
95	0.61	1984	95237096	357	352	2590	13842301	51832910	4744471	1124192	1586	42.41
99	0.61	1975	95198225	335	330	2635	12744877	51613281	4742300	1098783	1599	40.42

G. Yield improvement: (Y_{IMP})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.62	2012	100708919	358	354	2387	15966801	53006729	4549280	1208187	1537	43.17
85	0.62	2011	102708919	364	354	2388	15847531	53090659	4649380	1208187	1553	43.17
95	0.62	2000	104808919	364	354	2399	15167593	53261679	4649980	1208187	1566	43.17
99	0.62	1936	110708919	384	354	2414	14441458	53435653	4749280	1208187	1596	43.17

H. Reworking time: (RW_{TIME})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
			SET 1: at yield min = Base value (0.5 and 0.25)									
BV	0.62	2012	100708919	358	354	2387	17666801	53006729	4649280	1208187	1537	43.17
0.5	0.61	1992	94744899	335	330	2390	16670083	51901097	4683130	1101733	1538	40.81
0.25	0.62	1979	102406587	345	321	2376	18269988	51876729	4688694	1101513	1530	42.64
			SET 2: at yield min = 0.85 (0.5)									
0.5	0.61	1984	101026916	360	356	2484	16114011	51886617	4680187	1106350	1558	43.05

I. Setup Time: (SU_{TIME})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.62	2113	93224618	325	321	2381	16482030	52776320	4613287	1509176	1534	40.58
0.6	0.62	1942	96893298	347	343	2386	17828148	54592876	4680151	999125	1529	40.24
0.3	0.62	1942	94951844	349	333	2377	17045505	53273593	4649136	608757	1535	40.14

J. Wage rate: (H_{RATE})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.60	2125	137558122	643	639	1861	27871702	52037526	4491986	1177092	1253	70.7
2.0	0.60	2151	137587917	643	639	1861	27877776	57905744	4557293	1178220	1253	70.7
4.0	0.60	2203	137647508	643	639	1861	27889925	56942179	4687905	1180475	1253	70..7
6.0	0.60	2258	137709199	643	639	1861	27902073	75878615	4818517	1182729	1253	70.7

K. Product Variety Flexibility: (PV_{FLEX})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.62	2113	93224618	325	321	2381	156482030	52776320	4613287	1509176	1534	40.58
3	0.63	5475	138514728	1100	1096	2410	153479514	53467609	3436185	981954	1529	84.40
5	0.63	9074	106724398	1314	1309	2393	201984795	54465808	3135542	912833	1539	91.17

L. Volume Flexibility: (V_{FLEX})

	UT_{SYS}	C_{PART}	TM_{COST}	WIP	WT_{AVG}	YBR_{WKG}	C_{REJ}	C_{REWORK}	C_{VAD}	C_{NVAD}	Y_{CUM}	F_{TIMES}
BV	0.62	2113	93224618	325	321	2381	16482030	52776320	4613287	1509176	1534	40.58
At 7	0.63	2010	243637095	1028	1023	2400	36174462	54655817	4680057	1209553	1551	82.32
At 5	0.63	2007	284537869	1904	1899	2388	58129097	54094880	4679667	1672098	1543	106.5
At 2.5	0.63	2017	389981701	6351	7047	2416	62039540	55331369	4683640	2685029	1561	140.37

LIST OF PUBLICATIONS

1. M. Jahanzaib., Khalid Akhtar, "Manufacturing Competitive Strategic Framework for Discrete Parts in Automotive Industry". Under Review (HEC recognized).

2. M. Jahanzaib., Khalid Akhtar, "Technology Driven Strategy (TDS) Using Machine Automation Cost in Discrete Parts Manufacturing", Published with Kuwait Journal of Science and Engineering (KJSE), Dec. 2007 (HEC recognized).

3. M. Jahanzaib., Dr. Khalid Akhtar, "Macro and Micro Strategies Using Performance Value Analysis for Low Volume- Low Variety Manufacturing Environment", European Journal of Scientific Research Vol 15, No. 1 2006, pp. 64-74 (HEC recognized June 05).

4. M. Jahanzaib., Dr. Khalid Akhtar, "Strategies for Low Production Volumes - Low Variety Manufacturing Environment for Automobile Industry – A Normative Approach". World Transactions on Business & Economics. Issue 4, Vol 2, Oct 2005 ISSN: 1109-9526 pp. 253-258 (HEC recognized June 05).

5. M. Jahanzaib., Dr. Khalid Akhtar, "Characterization of Performance Measures for Low to Medium Volume- Low Variety Manufacturing Environment in the wake of WTO Scenario". Published with 16th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM-2006), June, Limerick University, Ireland. (Refereed conference)

6. M. Jahanzaib., Dr. Khalid Akhtar, "On Testing Manufacturing Strategies for Coping with Low to Medium Production Volumes- Very Low Variety Manufacturing Environment for Automobile Industry of Pakistan". Published in 6th Asia Pacific Industrial Engineering & Management Sciences conference, December 4-7, 2005, Manila, Philippines .ISBN: 962-8286-11-0. (IIE conference)

7. M. Jahanzaib., Dr. Khalid Akhtar, "Coping with Low Production Volumes and Very Low Variety for Pakistani Automobile Industry - A Normative Model". Published with 15th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM- 2005), July 18-20, 2005, University de Deusto, Bilbao, Spain .ISBN:84-7485-991-3. (Refereed conference)

8. Dr. Khalid Akhtar., M. Jahanzaib, "Production Management for the High Tech. Products – A Manufacturing Simulation Based Approach". Published with 14th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM- 2004), July 12-14, 2004, Ryerson's University, Toronto, Canada .ISBN:0-662-37218-2. (Refereed conference)

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Manufacturing Competitive Strategic Framework for Discrete Parts in Automotive Industry

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Abstract

The success of manufacturers in meeting the global challenges depends on low cost, high quality and product differentiation to delight customers. The environment facing by many developing countries has become even more complex. To become competitive, manufacturers need to acquire world class performance. This paper presents manufacturing competitive strategies for discrete parts in automobile industry of Pakistan. The paper presents a survey to identify manufacturer's types and manufacturing management practices. The findings show that companies are practising far from global standards which hamper their becoming competitive. A framework is presented consisting of strategies which are divided in terms of their typology, referred to as 'protector', 'offensive' and 'innovative' corresponding to low cost, high quality and product differentiation attributes. A simulation model is developed with important performance measures obtained from case company which help managers in decision making process. The final prioritization helps to identify most sensitivity parameters in business settings.

Keywords: Customer focused; Competitive strategies; Discrete event Simulation; Innovation.

Introduction

Time based competition, improved processing technologies and faster customer service is offering unstable and dynamic manufacturing environment. The survival of these companies depends on coping with dynamic market demand by effectively managing marketing, finance and decision making process This requires taking right decisions at the right time which require timely related decision process and utilization of information (resources) to coordinate between activities i.e. design, manufacturing, marketing, financing, distribution to achieve specific corporate objectives.

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Technology driven strategy (TDS) using machine automation cost in discrete parts manufacturing

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ABSTRACT

The success of Pakistani manufacturers in meeting the global world challenges will depend on its speed in moving from protected domestic to world class global manufacturing status. To face world challenges, three manufacturing strategies devised in chronological order are: cost cutting, technology driven and value enhancement which uses world class practices tools, and methods and techniques in a systematic and coherent manner with a stepwise refinement approach. The present work deals with technology driven strategy by analyzing five levels of automation, including engine lathe, turret lathe, automatic machines, numerically controlled machines (NC), and transfer machines. A proposed framework is tested using real life data from discrete parts manufacturing industries processing similar types of parts. Standard mathematical routines already developed are coded in spreadsheets and analyzed by carrying out sensitivity analysis on different process parameters. A comparison of these functions allowed identification of the most, less and least sensitive process parameters. Process parameters were then prioritized based on highest order of sensitivity at each level of technology. A simulation model so developed will help manufacturers to make informed decisions in selecting the most appropriate manufacturing systems based on process parameters.

Keywords: discrete parts manufacturing; machine automation cost; mathematical simulation; sensitivity analysis; technology driven strategy

INTRODUCTION AND BACKGROUND

Developing countries are facing tremendous pressures and challenges due to more turbulent, dynamic and complex competition in the marketplace. A combination of both external and internal factors like weak infrastructure, foreign debts, increasing inequalities between individuals and geo-political environment have prevented many countries from achieving significant socio-economic improvement over the last decade. Some developing countries like Pakistan have made economic management their prime agenda and thus are going through the process of restructuring their economy to

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Macro and Micro Strategies Using Performance Value Analysis for Low Volume - Low Variety Manufacturing Environment

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Abstract

Pakistani automobile industries are facing very tough competition of cost, quality and responsiveness with others manufacturing companies of Far East region. It is argued that automobile sector is operating in low volume- very low variety manufacturing environment. Systems like mass customization and world class manufacturing are used now-a-days, but it is practically difficult to implement these systems directly to enhance productivity and quality without adequate information about current processes and systems. To cope with this situation, we have proposed three manufacturing strategies for low production volume - low variety manufacturing environment. These strategies are: good governance (cost cutting strategy), automation (quality improvement strategy) and export (value enhancement strategy). The three strategies are mutually inclusive - a subsequent strategy assumes that the previous strategy has been executed earlier and its benefits/ results still exist when the subsequent strategy is implemented. The perceptible impact of these three strategies lies in attaining the far reaching key performance measures/indicators. For this purpose, a questionnaire has been developed for the characterization of key performance measures which are related to these three strategies. The major performance measures for the questionnaire are (but are not limited to) Productivity (P), Flexibility (F), Innovation (In), Quality (Q), Cost (C), Inventory (I), Customer relations (R), Safety (S), Morale (M), and Competitive advantage (A). The questionnaire has been distributed to some major automobile companies engaged in the business i.e. local parts manufacturers. The results of such characterization would help to identify the present status of automobile industry and how proposed strategies are related with each other. Macro and micro level strategy using performance value analysis as a tool is also presented to obtain prioritization.

1. Introduction

To be competitive in the market, manufacturing systems like mass customization, world class manufacturing etc has emerged and many industries of the world are practicing these systems. It is practically difficult to implement advanced systems directly to improve performance in our

Strategies for Low Production Volumes - Low Variety Manufacturing Environment for Automobile Industry – A Normative Approach

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Abstract: - A normative approach for coping with low production volume – low variety manufacturing environment for the automobile sector of Pakistan has been presented. Basic industries include process and discrete parts manufacturing. Process industries are meant for mass production with very limited variety. These industries have unique product line of processes, routings and planning, where as discrete parts manufacturing industries have many different models in their product line. For economic manufacturing, the optimum combinations of Volume – Variety exists i.e. job shop, batch production system or mass production. In this paper, the authors have looked at the typical production volumes and varieties of the discrete part manufacturing in Pakistan and have argued that there exists very low variety and low production volumes for this particular sector. This is obviously uneconomic because they are operating below the break-even quantities. This calls for investigating ways and strategies to effectively cope with the situation. A triple strategy normative approach has been suggested. The three strategies are not mutually exclusive – a subsequent strategy assumes that the previous strategy has been executed earlier and its benefits/ results still exist when the subsequent strategy is implemented. The three proposed strategies are: A good governance (cost cutting) strategy, an automation (technology driven) strategy and an export (value adding) strategy.

Key-Words: - Manufacturing strategies, Flexibility, Line balancing, Volume- Variety, Value Analysis, Quality

1 Introduction

Pakistan manufacturing sector is passing through a very tough period as WTO regulations will be implemented in 2007. Manufacturing is the second largest sector contributing more than 17% of the GDP and engaging more than 11% of employed labour force in Pakistan. The growth in this sector has picked up during the last couple of years from 1.4% in 1999-2000 to an average of 4.4% during 2003-2004 [1]. Major contributors to this sector include textile, engineering goods, leather and automobiles manufacturers.

Manufacturing Industries can be classified into Process Industries (PI) and Discrete Parts Manufacturing Industries (DPMI). Process industries are mass production industries, which have dedicated production of single items. On the other hand discrete parts manufacturing industries can have many products types/ styles with flexible routings. The automobile industry falls in the category of discrete parts manufacturing industries. Unfortunately, not much attention has been paid to discrete parts manufacturing sector particularly, automobile (this being one of the growing sector) and it appears that it is operating in a sub optimal manner. It is therefore necessary to investigate effective ways and means for coping with the situation. We have presented a normative model, using Volume-Variety model by suggesting three strategies for coping with this uneconomic situation.

In section 2, we present the data collection and discuss Volume- Variety model. Then, we present the triple strategy approach in section 3 and finally draw our conclusions in section 4.

2 Data Collection and Analysis

Annual production figures for major end products of automobiles industries are given in Table 1. These end products assemblers depend on the different parts manufacturing vendors. These parts manufacturers are the major auto parts suppliers to end product assemblers. These parts producer manufacturers (suppliers of the end products assemblers) can be classified into three major

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Dear Mirza Jahanzaib,

Congratulations! Upon review of your very interesting paper by the organizing committee, we feel it will make an important contribution to the conference. We are pleased to announce that the paper titled "Coping with Low Production Volumes and Very Low Variety in Pakistani Automobile Industry – A Normative Model" by Mirza Jahanzaib and Dr. Khalid Akhtar has been accepted for both presentation at the conference and submission into the FAIM 2005 proceedings.

In order to include your paper in the conference proceedings, please complete the following by May 10, 2005.

1. Copyright Transfer
2. Conference Registration

Detailed instructions can be found at http://www.faim2005.deusto.es/ (go to Submission and Registration sections).

The FAIM 2005 organizers committe kindly invites you to attend the conference and present your paper in person as a speaker during July 18-20, 2005 in Bilbao. However, FAIM 2005 organizers will not provide any financial support to your trip.

Thank you again for your participation in what we think will be an outstanding conference. We look forward to seeing you in Bilbao.

Regards,

Esther Alvarez
FAIM 2005 Chairperson

UNIVERSITY of LIMERICK

OLLSCOIL LUIMNIGH

FAIM2006 Paper Notification

16th International Conference on
Flexible Automation & Intelligent Manufacturing
June 25-28, 2006, University of Limerick, Ireland

2? April, 2006

Dear Mirza Jahanzaib,

I am pleased to inform that upon peer review of your very interesting paper by the FAIM2006 program committee and reviewers, we feel it will make an important contribution to this year's FAIM conference. The paper listed below has been accepted for both presentation at the conference and inclusion in the FAIM2006 conference proceedings.

Paper #: Jah-232
Paper Title: Characterization of Performance Measures for Low to Medium Volume- Low Variety Manufacturing Environment in the Wake of WTO Scenario.
Authors: Mirza Jahanzaib and Dr. Khalid Akhtar

The FAIM2006 Organizing Committee kindly invites you to attend the conference and present your paper in person as a speaker during June 25-28, 2006 in University of Limerick, Ireland. However, FAIM2006 organizers will not provide any financial support to your trip. In order to include your paper in the conference proceedings, we request that you complete the following by April 21st 2006.

1. Complete FAIM2006 conference registration
2. Transfer the copyright of your paper to University of Limerick press.
3. On-line accommodation form

This letter also serves as an official invitation for you to apply for a visa to travel to University of Limerick, Ireland for presentation of paper

Yours sincerely

FAIM2006 ORGANISING COMMITTEE

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Dear Author(s),

Thank you for your paper submission and your interest in APIEMS 2005 and its affiliated conferences.

Submission ID:	**2223**
Paper Title:	**ON TESTING MANUFACTURING STRATEGIES FOR COPING WITH LOW TO MEDIUM PRODUCTION VOLUMES -VERY LOW VARIETY ENVIRONMENT FOR AUTOMOBILE INDUSTRY OF PAKISTAN**
Author:	**Mirza Jahanzaib, Dr. Khalid Akhtar**

We are pleased to inform you that based on the comments of the reviewers, your paper has been accepted for oral presentation at the Conference preferably under the following **Thematic Area(s)**:

Business and Economics

and for publication in the electronic Conference Proceedings.

Please submit your paper (up to 10-pages) on or before **August 1, 2005** at the latest. In preparing your paper, we recommend you to use the same attached guidelines of the Journal of Philippine Industrial Engineers.

Please note that we will only accept electronic submission of your paper (in Acrobat PDF or Microsoft Word Format). It should be noted that publication of your paper in the Conference Proceedings is conditional upon Conference registration by at least one of the paper's authors by **August 1, 2005**. Without an author's registration by August 1, 2005, the paper will not appear in the Conference Proceedings. More information about the Registration process will be available online in July 2005.

For hotel information please visit the website www.apiemsmanila.com, Travel and Hotel Section. You are strongly encouraged to book accommodation at your earliest convenience through our secretariat for we have arranged a special rate with the Mandarin Oriental Hotel for the conference participants. Each lecture room will be equipped for PowerPoint presentations.

This notification letter also serves as an official invitation for you to apply for a visa to travel to the Philippines.

Your contribution to APIEMS 2005 and its affiliated Conferences is very much appreciated, and we look forward to welcoming you in Manila where we are confident that you will find your participation rewarding and enjoyable.

Kindest regards,

Dr. Anthony S.F. Chiu
Professor, De La Salle University Manila
APIEMS 2005 Conference Chairman
PIIE Trustee in Charge of APIEMS Conference

On Testing Manufacturing Strategies for Coping with Low to Medium Production Volumes -Very Low Variety Environment for Automobile Industry of Pakistan

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Abstract

Pakistan Manufacturing sector is facing very tough competition after 2005 WTO implementations. Manufacturing is the second largest sector of the economy contributing more than 17% of GDP and engaging 11% of employed labor force in Pakistan. The basic manufacturing industries can be classified into process industry (PI) and discrete parts manufacturing industry (DPMI). Process industries (oil/petrochemical etc) are mass production units with very limited variety. These industries have dedicated product line with fixed processes, routings and planning, whereas, discrete parts manufacturing industries are more flexible in terms of production volumes and varieties. For economic manufacturing, the optimum combination of Volume – Variety exists i.e. job shop, batch production system or mass production. . In this paper, the authors have looked at the typical production volumes and varieties of the discrete part manufacturing in Pakistan and have argued that there exist very low variety and low to medium production volumes for this particular sector. This is obviously uneconomic and calls for investigating ways and strategies to effectively cope with this situation. By taking a case of automobile part vendors (this being a growing sector), we suggest a triple strategy approach. The three strategies are not mutually exclusive – a subsequent strategy assumes that the previous strategy has been executed earlier and its benefits/ results still exist when the subsequent strategy is implemented. The three strategies are: A good governance (cost cutting) strategy, an automation (technology driven) strategy and an export led (value adding) strategy. Using real life data from Pakistani automobile part manufacturers attempt is made to test the three strategies. The results indicate that a major scope for using techniques likes line balancing, activity based costing and value enhancement, exists. The extent of improvement has been shown by case studies of alternative production lines (i.e. comparison of a traditional production line having large number of machines with that of a flexible line involving a much smaller number but versatile machines). Using value analysis has helped in identifying less rewarding operations/ processes and obtaining prioritization of required improvements in the design of product and process.

Key Words: Manufacturing strategies, Production Volume, Product Varieties, Manufacturing Flexibility

1. Introduction

Manufacturing is the second largest sector contributing more than 17% of the GDP and engaging more than 11% of employed labor force in Pakistan. The growth in this sector has picked up during the last couple of years from 1.4% in 1999-2000 to an average of 4.4% during 2003-2004 [1]. Major contributors to this sector include textile, engineering goods, leather and automobiles manufacturers. Since, Industries can be classified into Process Industries (PI) and Discrete Parts Manufacturing Industries (DPMI). Process industries produce dedicated parts with fixed routing; on the other hand discrete parts manufacturing industries can have many parts with flexible routings. Not much attention has been paid to discrete parts manufacturing sector and it appears that this sector is operating in a sub optimal manner. It is therefore necessary to investigate effective ways for coping with this situation.

2. Data Collection and Analysis

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FAIM2004 Paper Notification

14th International Conference on

Flexible Automation & Intelligent Manufacturing

July 12-14, 2004, Ryerson University, Toronto, Canada

March 16, 2004

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Dear Mirza Jahanzaib,

Congratulations! Upon peer reviews of your very interesting paper by the FAIM2004 Program Committee and guest reviewers, we feel it will make important contribution to this year's FAIM conference. We are pleased to announce that the paper listed below has been accepted for both presentation at the conference and inclusion in the FAIM2004 conference proceedings.

Paper #: FAIM04-041
Paper Title: **Production Management for the High-Tech. Products – A Manufacturing Simulation Based Approach**
Authors: Khalid Akhtar and Mirza Jahanzaib

The FAIM2004 Organizing Committee kindly invites you to attend the conference and present your paper in person as a speaker during July 12-14, 2004 in Toronto. However, FAIM2004 organizers will not provide any financial support to your trip. In order to include your paper in the conference proceedings, we request that you complete the following by **April 1, 2004**.

1. Transfer the copyright of your paper to NRC Research Press
2. Complete FAIM2004 conference registration

Please visit http://www.faim2004.org/ for copyright transfer, conference registration, and hotel room reservation. Conference agenda will be posted on this website once finalized.

Thank you for your participation in what we think will be an outstanding conference. We look forward to seeing you at FAIM2004 in Toronto.

Regards,

Dr. Jeff Xi
Dr. Lihui Wang
FAIM2004 Chairpersons