

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

U·M·I

University Microfilms International
A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
313/761-4700 800/521-0600

Order Number 9207141

**Advanced manufacturing technologies, manufacturing strategy,
and economic performance: An empirical investigation**

Youssef, Mohamed A., Ph.D.

City University of New York, 1991

Copyright ©1991 by Youssef, Mohamed A. All rights reserved.

U·M·I

**300 N. Zeeb Rd.
Ann Arbor, MI 48106**

A

**ADVANCED MANUFACTURING TECHNOLOGIES
MANUFACTURING STRATEGY, AND ECONOMIC
PERFORMANCE: AN EMPIRICAL INVESTIGATION**

BY

MOHAMED A. YOUSSEF

**A dissertation submitted to the Graduate Faculty in Business
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy, The City University of New York.**

1991

© 1991

MOHAMED A. YOUSSEF

All Rights Reserved

This manuscript has been read and accepted for the Graduate Faculty in Business in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

5 / 24 / 1991

Date



Chairman of Examining Committee

Dr. Michael N. Chanin

5 / 28 / 1991

Date



Dr. Donald Vredenburg

Executive Officer

Dr. George Sphicas

Dr. Edward Wolf

Dr. Christian Madu

Supervisory Committee

The City University of New York

ABSTRACT

ADVANCED MANUFACTURING TECHNOLOGIES, MANUFACTURING STRATEGY AND ECONOMIC PERFORMANCE: AN EMPIRICAL INVESTIGATION

BY

MOHAMED A. YOUSSEF

ADVISOR: Professor Michael N. Chanin

The contribution of this dissertation to the existing body of knowledge in the area of Advanced Manufacturing Technologies, hereafter AMT, is multifaceted. First, a conceptual model that relates advanced manufacturing technologies, manufacturing capabilities, and economic performance of the firm was developed. Secondly, a technology assessment equation was introduced. The components of this equation were used as taxons or clustering variables to classify business units which have some similarities over these taxons. Thirdly, the relationships stated in our conceptual model were tested empirically.

The term Advanced Manufacturing Technology is defined here as *a group of hardware- and software-based integrated technologies, which if properly implemented, monitored and evaluated, will lead to improving the efficiency and effectiveness of the firm in manufacturing a product or rendering a service.*

Research hypotheses were formulated based on an extensive review of current literature and the results of a pilot study. As it was suggested in our conceptual model, four important groups of hypotheses emerged. First, it was hypothesized that business units with higher levels of technology are more likely to outperform their counterparts on the dimensions of manufacturing capabilities. Secondly, it was also hypothesized that business units with higher overall manufacturing performance are more likely to outperform their counterparts on the following economic variables: (1) Inventory turnover, (2) Return on Sales, (3) Return on Assets, (4) Return on Equity, (5) Return on Investment, and (6) Five years sales growth. Thirdly, it was hypothesized that different levels of technology have some impact upon the economic performance of the business unit. Finally, it was hypothesized that business units with different levels of technologies will exhibit different emphases on structural and infrastructural decisions in their manufacturing strategy.

Three industry groups were targeted for this study. They are industrial machinery equipment, electronics and electric machinery equipment, and transportation equipment. The Standard Industrial Classification Codes (SIC) for these industry groups are 35, 36, and 37. The sample was composed of one hundred and sixty-five business units. A business unit, for the purpose of this research, is defined as an entire company, a division or a subsidiary, or a plant. Eighty-one business units were in SIC 35, fifty-eight in SIC 36, and nineteen in SIC 37.

Factor analysis was used to define the dimensions of manufacturing capabilities. Four factors emerged and were labelled flexibility, responsiveness, quality, and cost. In addition, interitem correlations were computed.

Cluster analysis was used in two phases of the statistical analysis. First, it was utilized to group business units which have some similarities over the components of the AMT assessment equation. Three groups emerged and were identified as **"Superstars," "Major Leaguers,"** and **"Triple A's"** respectively. Analysis of variance and multiple comparisons among clusters assessed the practical utility of these clusters for subsequent analysis.

Cluster analysis was once again used to group business units with similarities over the four dimensions of manufacturing capabilities. Three groups emerged and were labelled **"High Manufacturing Performance Group," "Moderate Manufacturing Performance Group,"** and **"Low Manufacturing Performance Group."** Analysis of variance and multiple comparisons were performed on these clusters to assess their practical utility for subsequent analysis.

Analysis of variance was used to test the hypotheses concerning the differences in performance among groups. In addition, multiple comparisons were used to pinpoint where the differences might be.

Results showed that AMTs have significant impact on the four dimensions of manufacturing capabilities and some impact on a small number of the economic variables. It was also revealed that firms with different levels

of AMT differ in the degree of emphasis on the decision areas of their manufacturing strategy. Manufacturing capabilities demonstrated significant impact on the economic variables. Results also showed that quality, flexibility, responsiveness, and cost are equally important dimensions of competitiveness in the three industries studied.

The technology assessment equation developed in this dissertation has many implications. First, it can be used to evaluate different configurations of AMTs. Secondly, it can be used to assess the degree of emphasis on structural and infrastructural decisions in manufacturing strategy. Finally, it can be used to assess the impact of AMTs on the economic performance.

Recommendations about the relationships proposed in the conceptual model and the impact of the levels of technology on manufacturing and economic performance were offered. Issues for further research were also suggested.

this dissertation is dedicated, with Love and Respect, to

**My Wife HANAA
and My Childern
LOUAY, EYAD, MENNA, HEBBA**

*for their understanding and support during my Doctoral
Studies*

ACKNOWLEDGEMENTS

Thanks to ALLAH who gave me the knowledge, strength and patience to complete this project. The list of people whom I would like to thank is very long. First and foremost, I would like to thank **Dr. Michael Chanin**, the chairman of my examination committee, for providing continual encouragement and motivation. Thanks ,Dr. Chanin, for the constructive suggestions and enlightening ideas you provided for this project . Had it not been for your encouragement, it would have been very difficult to complete this project in this shape and form. It was you who taught me the proper way of conducting an empirical research.

I would like to thank **Dr. George Spficas** who has been my monitor since I started the Ph.D Program. He was always available when I needed him. His support, encouragement, and caring, were unlimited. At many times, when help was needed, he was always the first source I would turn to.

I would like to thank **Dr. Edward Wolf** for his valuable comments on the research instrument, and suggestions for analysis techniques. He was always available for when I needed his help.

I would like to thank **Dr. Christian Madu** for his incisive contribution as an outside reader of my dissertation. Chris has always been a source of motivation and inspiration to me during his graduate studies at C.U.N.Y.

I would like to thank **Dean Donald Vredenburg** the executive officer of the Ph.D Program and the staff of his office, Mrs. Joanne Paitchell

and Mrs. Molevine Karan for all the help and support they provided me with.

I would like to acknowledge the impact of **Dr. Sidney Lirtzman , Dr. Harris J. Shapiro, Dr. Mahmoud Wahba** on my career

I would like to thank my colleagues at S.U.N.Y specially **Dr. Madeline Crocitto, Prof. Ivan Abel, Dr. Barry Armandi, Dr. Al Mickens, and Dr. Patrick O'Sullivan**. I would like to thank the staff of the computer lab, specially **Carl R. Blackman, Marc P. Seybold and Trevor L. Mckenzie** for making the mackintosh lab available to me even at times when they needed it. I would like to thank two special families for their hospitality and generosity, **Azza and Gamal Gad El-Kareem, and Drs. Moein and Gazala Butt**. Their homes have always been opened to me during my travelling back and forth between Huntington, West Virginia and Brooklyn New York.

Special thanks to my brother-in-law **Hesham** and my father-in-law **Mr. Abd El-Wahid Khalil** for their support and caring.

There are five invaluable people to whom I owe a lot. My beloved wife **Hanaa** who is always a source of inspiration and help. She has given me four wonderful children, my sons **Louay, and Eyad** and my daughters Menna and Hebba. **Lou**, I am proud of you for being admitted to Brooklyn Tech. High School, one of the best specialized High schools in U.S.A. **Eyad**, I am also proud of you for always maintaining honor role. My two daughters **Menna and Hebba** whose names translate to the gift of God.

I am ever indebted to **my parents** for their support and love. Special thanks to my father **Mr. Abd El-Hafeez Youssef** and my uncle **Mr. Labeeb Youssef** for their encouragement, and concern. Words cannot truly express my sincere appreciation for what they have done for me. Last but not least, I am indebted to **Egypt** for investing in me all these years. I am sure that their faith will have the highest rate of Return on Investment. I am grateful for all the support and help I was given.

Table of Contents

	Page
ACKNOWLEDGEMENTS.....	ix
LIST OF TABLES	xvi
LIST OF FIGURES	xxi
CHAPTER	
I INTRODUCTION.....	1
I.1 PROBLEM STATEMENT AND RESEARCH QUESTIONS.....	2
I.2 THE CONCEPTUAL MODEL	4
I.3 RESEARCH HYPOTHESES	6
I.3.1 Technology - Overall Manufacturing Hypothesis.....	6
I.3.2 Technology - Responsiveness Hypothesis.....	6
I.3.3 Technology - Flexibility Hypothesis	7
I.3.4 Technology - Quality Hypothesis	7
I.3.5 Technology - Cost Hypothesis	7
I.3.6 Technology - Economic Variables Hypotheses.....	7
I.3.7 Manufacturing - Economic Variables Hypotheses.....	7
I.3.8 Technology - Strategy Variables Hypotheses.....	8
I.4 OUTLINE OF THE REMAINING CHAPTERS	8
II REVIEW OF LITERATURE	10
II.1 Pillars of Manufacturing Excellence	12
II.2 Just-In-Time	13
II.3 Total Quality Control	20
II.4 Computer Integrated Manufacturing	24
II.5 World - Class Manufacturing	33
II.6 Measuring Performance	44
II.7 AMT and Economic Performance.....	48
II.8 Manufacturing Strategy	52
II.8.1 Definitions and Contents	52
II.9 Technology - Strategy Link	67
III RESEARCH METHODOLOGY	70
III.1 THE SAMPLE	70

	Page
III.2 DATA COLLECTION	78
III.3 DATA MATRIX, MODELS, AND STATISTICAL HYPOTHESES	80
III.3.1 Model 1: Technology and Manufacturing Performance	81
III.3.1.1 Overall Manufacturing Performance	82
III.3.1.2 Flexibility	83
III.3.1.3 Responsiveness	83
III.3.1.4 Quality	83
III.3.1.5 Cost	84
III.3.2 Model 2: Manufacturing Performance and Economic Performance	84
III.3.2.1 Return on Sales	85
III.3.2.2 Return on Asset	85
III.3.2.3 Return on Equity	86
III.3.2.4 Return on Investment	86
III.3.2.5 Five Years Sales Growth	87
III.3.2.6 Inventory Turnover	87
III.3.3 Model 3: Technology and Economic Performance	87
III.3.3.1 Return on Sales	88
III.3.3.2 Return on Assets	88
III.3.3.3 Return on Equity	89
III.3.3.4 Return on Investment	89
III.3.3.5 Five Years Sales Growth	89
III.3.3.6 Inventory Turnover	90
III.3.4 Model 4: Technology - Strategy Link	90
III.4 OPERATIONALIZATION OF VARIABLES AND RESEARCH INSTRUMENTATION	91
III.4.1 AMT Variables	92
III.4.2 Economic Variables	96
III.4.3 Manufacturing Capability Variables	96
III.4.4 Manufacturing Strategy Contents	101
III.5 VALIDITY AND RELIABILITY OF THE INSTRUMENT ..	
III.5.1 Validity	104
III.5.2 Reliability	104
III.6 SCHEMATIC PRESENTATION OF STATISTICAL ANALYSIS.....	110
IV ANALYSIS AND RESULTS	112
IV.1 DESCRIPTIVE STATISTICS	112
IV.1.1 Time-Based Technologies	112

IV.1.1.1	Number of Time-Based Technologies	Page 112
IV.1.1.2	Percent of Facility Converted to using Time-Based Technologies	114
IV.1.1.3	Length of Time Since TBT were used	116
IV.1.2	Computer-Based Technologies	119
IV.1.2.1	Number of Computer-Based Technologies	119
IV.1.2.2	Level of Integration	123
IV.1.2.3	Time Since CBT have been used	129
IV.1.2.4	Percent of CAD, CAE used in Designing the Product	131
IV.1.2.5	Percent of Programmable Automation	133
IV.2	EXPLORATORY STATISTICS	135
IV.2.1	INTRODUCTION	135
IV.2.2	Factor Analysis	138
IV.2.3	Cluster Analysis	144
IV.2.3	Analysis of Variance (AMT Index).....	145
IV.2.3.1	One-Way ANOVA Among Clusters.....	145
IV.2.3.2	One-Way ANOVA Model 1 Technology-Manufacturing	146
IV.2.3.2.1	Overall Mfg.	146
IV.2.3.2.2	Flexibility	150
IV.2.3.2.3	Responsiveness.....	153
IV.2.3.2.4	Quality	156
IV.2.3.2.5	Cost	160
IV.2.3.3	One-Way ANOVA Model 2 Technology-Eco. Variables.....	164
IV.2.3.3.1	Inventory Turnover	164

IV.2.3.3.2 Five Years	Page
Sales Growth	166
IV.2.3.3.3 R.O.S	168
IV.2.3.3.4 R.O.A	170
IV.2.3.3.5 R.O.E	172
IV.2.3.3.6 R.O.I.....	174
IV.2.4 Cluster Analysis (MANUFACTURING)	176
IV.2.4.1 One-Way ANOVA Among Clusters.....	176
IV.2.4.2 One-Way ANOVA Model 3 Manufacturing-Eco. Variables.	
IV.2.3.4.1 Inventory Turnover	181
IV.2.3.4.2 Five Years Sales Growth.....	182
IV.2.3.4.3 R.O.S	182
IV.2.3.4.4 R.O.I.....	183
IV.2.3.4.5 R.O.A	184
IV.2.3.4.6 R.O.E	185
IV.2.5 One-Way ANOVA (Contents of Manufacturing Strategy)	189
V SUMMARY, CONCLUSIONS, AND ISSUES FOR FURTHER RESEARCH.....	215
APPENDICES	
A.1 APPENDIX (1) Research Instrument.....	227
A.2 APPENDIX (2) Sample Letter of Contact	236
A.3 APPENDIX (3) Plant Visitation and Interview Forms.....	237
A.4 APPENDIX (4) Performance Charts	238
BIBLIOGRAPHY.....	252

LIST OF TABLES

Table	Page
2.1 The Financial Impact of Fifteen Inventory Turns Plus Thirty Eight Productivity Increase Versus Three Inventory Turns.....	50
2.2 Reductions Due To The Effective Implementation of Tools Such As CIM, JIT, and TQC.....	51
2.3 Manufacturing's Strategic Decision Making Matrix.....	63
3.1 Business Unit.....	71
3.2 Title of The Respondent.....	73
3.3 Industry Group.....	75
3.4 Industries Within Each Industry Group.....	77
3.6 Reliability Analysis (CBT).....	106
3.7 Reliability Analysis (TBT).....	107
3.8 Reliability Analysis (Overall Manufacturing).....	108
3.9 Reliability Analysis (Contents of Manufacturing Strategy).....	109
4.1 Number of TBT.....	112
4.2 Percentage of Facility Converted to using TBT.....	114
4.3 Average Length of Time Since TBT Was Used.....	116
4.4 Number of Firms Using Each Type of CBT Technologies.....	119
4.5 Average Level of Integration Among CBT.....	123
4.6 Firms And The Way They Use CBT Technologies.....	127
4.7 Time Since CBT Have Been Used.....	129
4.8 Percent of CAD, CAE or Other Computer Assisted Technologies Used in Designing The Product.....	131
4.9 Percent of Programmable Automation.....	133
4.10 Varimax Rotated Factor Matrix.....	139
4.11 Factor Transformation Matrix.....	139
4.12 Mean, Standard Deviation and Correlation Among Items Loaded Under Flexibility.....	140
4.13 Mean, Standard Deviation and Correlation Among Items Loaded Under Responsiveness.....	141
4.14 Mean, Standard Deviation and Correlation Among Items Loaded Under Quality.....	142
4.15 Mean, Standard Deviation and Correlation Among Items Loaded Under Cost.....	143
4.16 Final Cluster Centers And Number of Cases In Each Cluster.....	144

Table	Page
4.17 Analysis of Variance And Multiple Comparisons (Advanced Manufacturing Technology Index).....	145
4.18 Tests For Homogeneity of Variance (Overall Manufacturing Performance).....	147
4.19 One-Way ANOVA (Overall Manufacturing Performance).....	147
4.20 Differences in Overall Manufacturing Performance Among The Three Groups.....	148
4.21 Multiple Comparisons of Differences in Overall Manufacturing Among The Three Groups.....	149
4.22 Kruskal-Wallis One-Way ANOVA (Overall Manufacturing Performance).....	149
4.23 Tests For Homogeneity of Variance (Flexibility).....	151
4.24 One-Way ANOVA (Flexibility).....	151
4.25 Differences in Flexibility Among The Three Groups.....	152
4.26 Multiple Comparisons of Differences in Flexibility Among The Three Groups.....	153
4.27 Tests For Homogeneity of Variance (Responsiveness).....	154
4.28 One-Way ANOVA (Responsiveness).....	154
4.33 Differences in Responsiveness Among The Three Groups.....	155
4.29 Multiple Comparisons of Differences in Responsiveness Among The Three Groups.....	156
4.30 Tests For Homogeneity of Variance (Quality).....	157
4.31 One-Way ANOVA (Quality).....	158
4.32 Differences in Quality Among The Three Groups.....	158
4.33 Multiple Comparisons of Differences in Quality Among The Three Groups.....	159
4.34 Kruskal-Wallis One-Way ANOVA (Quality).....	159
4.35 Tests For Homogeneity of Variance (Cost).....	161
4.36 One-Way ANOVA (Cost).....	161
4.37 Differences in Cost Among The Three Groups.....	162
4.38 Multiple Comparisons of Differences in Cost Among The Three Groups.....	162
4.39 Kruskal-Wallis One-Way ANOVA (Cost).....	163
4.40 Kruskal-Wallis One-Way ANOVA (Inventory Turnover).....	165
4.41 Kruskal-Wallis One-Way ANOVA (Five Years Sales Growth).....	167
4.42 Kruskal-Wallis One-Way ANOVA (Return On Sales).....	169
4.43 Kruskal-Wallis One-Way ANOVA (Return On Total Assests).....	171
4.44 Kruskal-Wallis One-Way ANOVA (Return On Common Equity).....	173
4.45 Kruskal-Wallis One-Way ANOVA (Return On Invested Capital).....	175
4.46 Final Cluster Centers And The Number of Cases In Each Cluster.....	176
4.47 Analysis of Variance and Multiple Comparisons (Flexibility).....	177

Table	Page
4.48 Analysis of Variance and Multiple Comparisons (Responsiveness).....	178
4.49 Analysis of Variance and Multiple Comparisons (Quality).....	179
4.50 Analysis of Variance and Multiple Comparisons (Cost).....	180
4.51 Kruskal-Wallis One-Way ANOVA (Inventory Turnover).....	181
4.52 Kruskal-Wallis One-Way ANOVA (Five Years Sales Growth).....	182
4.53 Kruskal-Wallis One-Way ANOVA (Return On Sales).....	182
4.54 Kruskal-Wallis One-Way ANOVA (Return On Total Assests).....	183
4.55 Kruskal-Wallis One-Way ANOVA (Return On Invested Capital).....	184
4.56 Kruskal-Wallis One-Way ANOVA (Return On Common Equity).....	185
4.57 Summary of Hypotheses Testing For All Models.....	186
4.58 Mean and Standard Deviation For Each Program.....	190
4.59 Kruskal-Wallis One-Way ANOVA for Emphasis on Lead Time Reduction.....	191
4.60 Kruskal-Wallis One-Way ANOVA for Emphasis on Preventive Maintenance.....	191
4.61 Kruskal-Wallis One-Way ANOVA for Emphasis on Job Enrichment.....	192
4.62 Kruskal-Wallis One-Way ANOVA for Emphasis on Statistical Process Control - Product.....	193
4.63 Kruskal-Wallis One-Way ANOVA for Emphasis on Statistical Process Control - Process.....	193
4.64 Kruskal-Wallis One-Way ANOVA for Emphasis on Workers Safety.....	194
4.65 Kruskal-Wallis One-Way ANOVA for Emphasis on Zero Defects.....	194
4.66 Kruskal-Wallis One-Way ANOVA for Emphasis on Integrating M.I.S Across Areas.....	195
4.67 Kruskal-Wallis One-Way ANOVA for Emphasis on Integrating M.I.S Within Manufacturing.....	195
4.68 Kruskal-Wallis One-Way ANOVA for Emphasis on Computer Aided Manufacturing.....	196
4.69 Kruskal-Wallis One-Way ANOVA for Emphasis on Giving Workers More Planning Responsibility.....	197
4.70 Kruskal-Wallis One-Way ANOVA for Emphasis on Narrowing Product Lines.....	197
4.71 Kruskal-Wallis One-Way ANOVA for Emphasis on Giving Workers Broader Range of Tasks.....	198
4.72 Kruskal-Wallis One-Way ANOVA for Emphasis on Quality Circles.....	198
4.73 Kruskal-Wallis One-Way ANOVA for Emphasis on Reducing The Size of Manufacturing Workforce.....	199

Table	Page
4.74 Kruskal-Wallis One-Way ANOVA for Emphasis on Developing New Processes For Old Products.....	200
4.75 Kruskal-Wallis One-Way ANOVA for Emphasis on Developing New Processes For New Products.....	200
4.76 Kruskal-Wallis One-Way ANOVA for Emphasis on Defining A Manufacturing Strategy.....	201
4.77 Kruskal-Wallis One-Way ANOVA for Emphasis on VendorLeadTime.....	201
4.78 Kruskal-Wallis One-Way ANOVA for Emphasis on Just-In-Time.....	202
4.79 Kruskal-Wallis One-Way ANOVA for Emphasis on Reducing Setup/Changeover Time.....	203
4.80 Kruskal-Wallis One-Way ANOVA for Emphasis on Flexible Manufacturing Systems.....	203
4.81 Kruskal-Wallis One-Way ANOVA for Emphasis on Introducing Robots.....	204
4.82 Kruskal-Wallis One-Way ANOVA for Emphasis on Group Technology.....	204
4.83 Kruskal-Wallis One-Way ANOVA for Emphasis on Computer Aided Design.....	205
4.84 Kruskal-Wallis One-Way ANOVA for Emphasis on Capacity Expansion.....	206
4.85 Kruskal-Wallis One-Way ANOVA for Emphasis on Reconditioning Physical Facilities.....	206
4.86 Kruskal-Wallis One-Way ANOVA for Emphasis on Automated Jobs.....	207
4.87 Kruskal-Wallis One-Way ANOVA for Emphasis on Reducing The Size of The Manufacturing Units.....	207
4.88 Kruskal-Wallis One-Way ANOVA for Emphasis on Plants Relocation.....	208
4.89 Kruskal-Wallis One-Way ANOVA for Emphasis on Manufacturing Reorganization.....	208
4.90 Kruskal-Wallis One-Way ANOVA for Emphasis on Closing Plants.....	209
4.91 Kruskal-Wallis One-Way ANOVA for Emphasis on Changing Labor/Management Relations.....	210
4.92 Kruskal-Wallis One-Way ANOVA for Emphasis on Management Training.....	210
4.93 Kruskal-Wallis One-Way ANOVA for Emphasis on SupervisorTraining.....	211

Table	Page
4.94 Kruskal-Wallis One-Way ANOVA for Emphasis on Worker Training.....	212
4.95 Kruskal-Wallis One-Way ANOVA for Emphasis on Worker Vendor Quality.....	212
4.96 Kruskal-Wallis One-Way ANOVA for Emphasis on Yield Problems/Rejects.....	213
4.97 Summary of Hypotheses Testing (Contents of Manufacturing Strategy).....	214
5.1 Rank Order of the Importance of the Four Dimensions of Manufacturing Capabilities.....	218
5.2 Rank Order of the Importance of the Four Dimensions of Manufacturing Capabilities (Sample and The Three Industry Groups).....	222

LIST OF FIGURES

Figure	Page
2.1	Opertionalization of JIT.....15
2.2	An Overview of JIT Approach To Manufacturing.....18
2.3	Vertical and Horizontal TQC.....23
2.4	Elements of CIM.....25
2.5	CIM Framework As Used At Arthur Little Inc.....26
2.6	A Typical of CIM Model.....28
2.7	Computer Integrated Manufacturing.....30
2.8	Pillars of Manufacturing Excellence.....32
2.9	Modern Integrated Manufacturing Model.....37
2.10	Spectrum of Understanding About JIT.....41
2.11	Accountability Grid.....47
2.12	Manufacturing Strategy Objectives.....58
2.13	World-Class Manufacturing Product and Process Design.....60
2.14	Manufacturing Productivity.....68
3.1	Geographical Distribution of the Sample.....70
3.2	Business Unit.....72
3.3	Title of The Respondent.....74
3.4	Industry Group.....76
3.5	Time Table For Research Activities.....79
3.6	Data Matrix, and Models.....80
3.7	Scree Plot for Number of Factors.....98
3.8	Varimax Rotated Matrix.....99
3.9	Statistical Analysis And Statistical Techniques Used.....110
4.1	Number of TBT.....113
4.2	Percent of Facility Converted To Using TBT.....115
4.3	Average Length of Time Since TBT Was Used.....118
4.4	Number of CBT.....122
4.5	Average Level of CBT Integration.....126
4.6	Firms and The Way They Use CBT.....128
4.7	Time Since CBT Have Been Used.....130
4.8	Percent of CAD, CAE Used In Designing The Product.....132
4.9	Percent of Programmable Automation.....134
4.10	Analysis of Differences In Performance.....137
4.11	Normal and Detrended Plots (Overall Manufacturing).....146
4.12	Normal and Detrended Plots (Flexibility).....150
4.13	Normal and Detrended Plots (Responsiveness).....153
4.14	Normal and Detrended Plots (Quality).....156
4.15	Normal and Detrended Plots (Cost).....160
4.16	Normal and Detrended Plots (Inventory Turnover).....164

Figure	Page
4.17 Normal and Detrended Plots (Five Years Sales Growth).....	166
4.18 Normal and Detrended Plots (Return On Sales).....	168
4.19 Normal and Detrended Plots (Return On Total Assets).....	170
4.20 Normal and Detrended Plots (Return On Common Equity).....	172
4.21 Normal and Detrended Plots (Return On Invested Capital).....	174
5.1 The Importance of the Four Dimensions of Manufacturing Capabilities (Sample and Industry Groups).....	223

CHAPTER I

INTRODUCTION

The main goal of this dissertation was to examine the relationship among Advanced Manufacturing Technologies, manufacturing capabilities, contents of manufacturing strategy, and economic or financial performance of the firm. To achieve this goal, a conceptual model and a technology assessment equation were developed. The model relates the four the four factors mentioned above. The technology assessment equation relates the hardware and software components of AMT. It serves as an index that measures the level of AMT.

This study then seeks to discover whether or not there are differences in manufacturing and economic performances among business units with different levels of AMTs.

Through A questionnaire and compilation of publicly disclosed financial data, we were able to address the following questions: 1. Which of these computer-based and time-based technologies are employed by various companies? 2. To what extent and for how long have computer-based technologies been used? 3. To what extent and for how long have time-based technologies been used? 4. What are the dimensions of manufacturing capabilities of the companies using these technologies? 5. The degree of emphasis on the structural and infrastructural decisions in manufacturing strategy of companies with different levels of AMTs? 6. The economic

performance of companies with different levels of AMTs?

PROBLEM STATEMENT AND RESEARCH QUESTIONS:

Given the existing plethora of advanced manufacturing technologies,

Do firms that adopt and successfully implement these technologies differ in their manufacturing and economic performance than their counterparts who are less apt to do so.

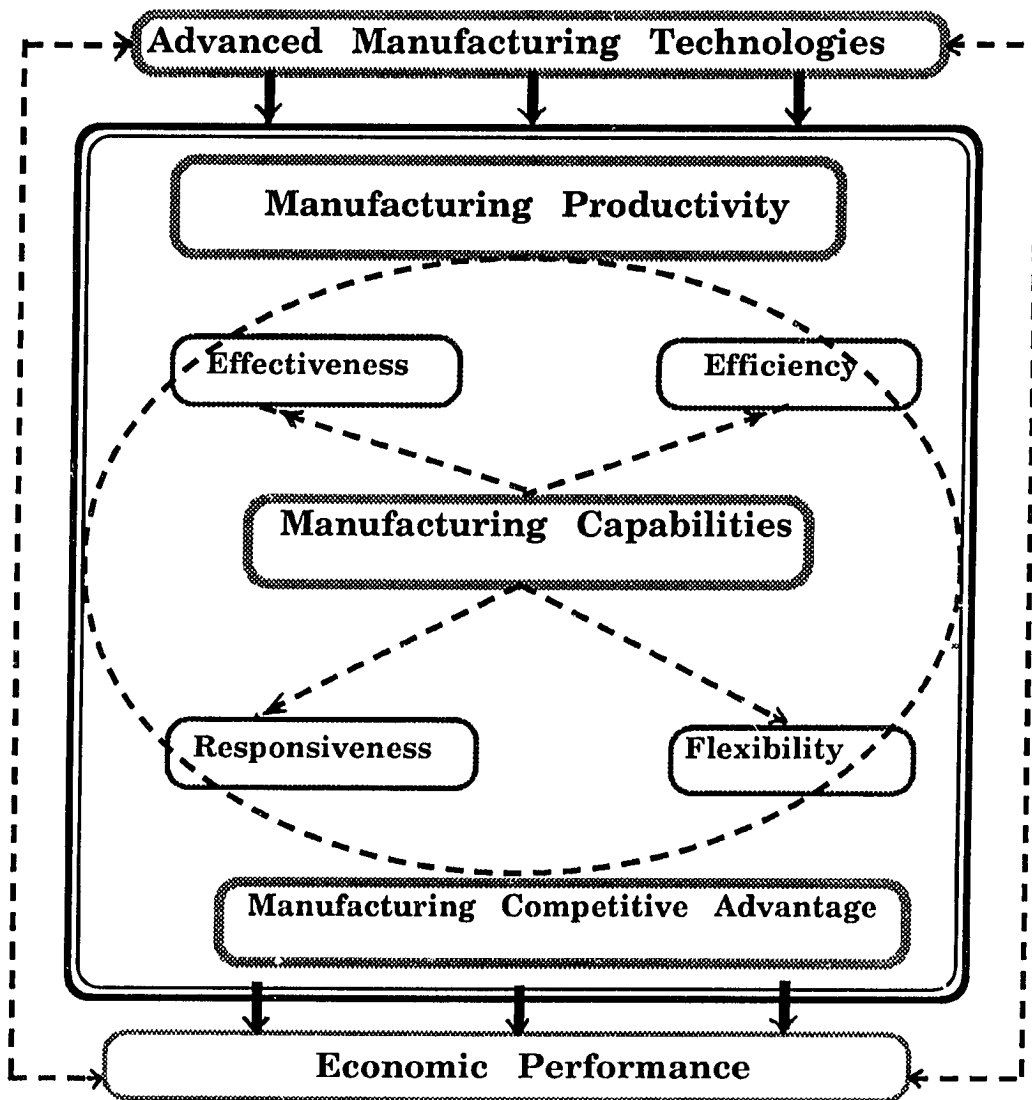
In order to address this problem, the following research questions were formulated:

- 1. To what extent do computer-based and time-based technologies affect firm's overall manufacturing performance?**
- 2. To what extent do these technologies affect responsiveness?**
- 3. To what extent do these technologies affect flexibility?**
- 4. To what extent do these technologies affect Quality?**
- 5. To what extent do these technologies affect cost?**
- 6. To what extent do these technologies affect variables such as inventory turnover, Return on total assets, return on sales, return on common equity, return on invested capital, and growth in sales.**

7. To what extent do Manufacturing capabilities affect Variables such as inventory turnover, Return on total assets, return on sales, return on common equity, return on invested capital, and growth in sales.

The Conceptual Model

Figure (1.1) The Conceptual Model



YOUSSEF 1991

The conceptual model we advance in this thesis relates four important components integrated into a strategic framework. These four components are Advanced Manufacturing Technologies (AMTs), manufacturing capabilities or strength, manufacturing strategy contents and Economic performance. The rationale of the model and the relationships among its components are explained below.

First, adopting and successfully implementing AMTs increases manufacturing productivity which can be evaluated along two dimensions. One is effectiveness as measured by volume. The other is efficiency as measured by cost (Mali, 1987). The literature review has revealed many studies that support this relationship for example, Heizer (1986); Gunn (1987); Ciampa (1988); Schonenberger (1982, 1986); Suzaki (1987); Hayes et al (1984, 1985, 1988); Reid (1990); Hume and Anderson (1987) and Voss (1986).

The second level of the model represents manufacturing capabilities. Variables in this component of the model are derived from the work of Skinner (1969, 1974, 1978, 1985, 1990); Hume and Anderson (1987); Gunn (1987); Hayes et al (1984, 1985, 1988); Roth and Miller (1987, 1988, 1990); Nemetz (1990) and Dean et al (1990). Manufacturing capabilities differ from one firm to another. Therefore, differences in manufacturing and economic performances, as well as emphasis on the components of manufacturing strategy are expected.

The next level in the model is concerned with the economic performance of the firm and its relation to manufacturing capabilities and manufacturing strategy. Based on these relationships, research hypotheses were formulated.

I.3 RESEARCH HYPOTHESIS:

I.3.1 Technology - Overall Manufacturing Hypothesis:

Business Units that make strategic use of their computer-based and time-based technologies are more likely than their counterparts to exhibit high level of overall manufacturing performance.

I.3.2 Technology - Flexibility Hypothesis:

Business Units that make strategic use of their computer-based and time-based technologies are more likely than their counterparts to exhibit high level of flexibility.

I.3.3 Technology - Responsiveness Hypothesis:

Business Units that make strategic use of their computer-based and time-based technologies are more likely than their counterparts to exhibit high level of responsiveness.

I.3.4 Technology - Quality Hypothesis:

Business Units that make strategic use of their computer-based and time-based technologies are more likely than their counterparts to exhibit high level

of quality.

I.3.5 Technology - cost Hypothesis:

Business Units that make strategic use of their computer-based and time-based technologies are more likely than their counterparts to exhibit low level of cost.

I.3.6 Technology - Economic Variables Hypotheses:

Business Units that make strategic use of their computer-based and time-based technologies are more likely to outperform their counterparts on some or all of the following Economic variables:

- A. Inventory Turnover.
- B. Return on Sales.
- C. Return on Assets.
- D. Return on Equity.
- E. Return on Investment.
- F. Five Years Sales Growth.

I.3.7 Manufacturing - Economic Variables Hypotheses:

Business Units with high level of manufacturing performance are more likely to outperform their counterparts on some or all of the following Economic variables:

- A. Inventory Turnover.
- B. Return on Sales.
- C. Return on Assets.

.

D. Return on Equity.

E. Return on Investment.

F. Five Years Sales Growth.

I.3.8 Technology - Strategy Variables Hypotheses:

Business Units that make strategic use of their computer-based and time-based technologies are more likely to place more emphasis on some or all structural and infrastructural decisions of their manufacturing strategy.

I.4 OUTLINE OF THE REMAINDER OF THE DISSERTATION

The remainder of this dissertation will be briefly outlined here. Chapter (II) is an extensive review of literature. The main goal of chapter (II) is to present the state of the art in research on Advanced Manufacturing Technologies, manufacturing strategy and the economic impact of the Advanced Manufacturing Technologies. The main sources for this review were scholarly published materials in various periodicals and journals, audio and video materials presented to meeting and conferences, and insights emerged from personal interviews with various Vice Presidents for manufacturing. In addition, International dissertation abstract was consulted to assess the appropriateness and need for this research.

The focus of Chapter (II) is many-fold. First, different definitions to AMTs were examined. Misconceptions about what constitutes AMTs were

revealed. As a result, a new definition to AMTs was provided. Secondly, pillars of manufacturing excellence were discussed in details. Thirdly, we examined the impact of AMTs on the economic performance of the firm. Finally, several definitions of manufacturing strategy were discussed. The structural and infrastructural decisions in manufacturing strategy as well as strategy-technology link were examined.

Chapter (III) is an outline of the research methodology. To operationalize AMTs variables, a Technology assessment equation was introduced. The equation is unique. We believe that it is a good contribution to the existing body of knowledge in this area of research. Models of interest in this study are schematically presented and explained. Finally, an outline for the statistical analysis and statistical techniques used was also presented schematically.

The focus of chapter (IV) is two-fold. First, data collected for this research were analyzed. secondly, discussions and implications of the analysis of the results were revealed. In Chapter (V) results are summarized, findings are reported, and further issues for research are suggested.

Chapter II

REVIEW OF LITERATURE

The 1980's have witnessed the third major event in the history of manufacturing management (Shonberger, 1986). The other two being Frederick Taylor's scientific management and Elton Mayo's Hawthorne studies at Western Electric. The third major event here refers to the implementation of Advanced Manufacturing Technologies (AMT).

The success of many Japanese companies, Toyota as an example, has convinced many to believe that these advanced manufacturing technologies may be the cure for the problems of productivity in Western societies. Schonberger's 1982 book has opened a new line of research and investigations that resulted in a large number of articles in professional journals and periodicals and a good number of books by practitioners and academicians.

In this part of literature review, we examine some of these advanced manufacturing technologies and their impact on the manufacturing strategy and the economic performance of firms.

There has been many misconceptions about what constitutes AMT. While some researchers looked at AMT from hardware point of view, others looked at it from software point of view. In fact, any definition that ignores either part will be less than complete.

An extensive review of literature has revealed two of the closest

definitions of AMTs. Two definitions were discussed in Slatter and Carven (1988). According to them, the Advisory council for Applied Research and Developed (ACARD) in U.K., defines AMT as ***"Any new technique, which when adopted, is likely to require a change not only in manufacturing practice, but also in management systems and the manufacturer's approach to the design and production engineering of the product."*** Slatter and Carven (1988) also reported that National Economic Development Office (NEDO) recognizes AMTs as Technological aids having an impact in:

1. Automated parts issue and storage,
2. Flexible Manufacturing Systems(FMS),
3. Improved assembly and test,
4. Computer aided manufacture,
5. Computer-aided design and draughting(CAD),
6. Computer numerically controlled machining(CNC),
7. Computerized production control, and
8. Computerized inventory control.

Nori (1990) explains that AMTs refer to **"new technologies which are used directly by the firm in the production of a product (for example, a television set) or in the provision of a service (for example, a hospital operating room).** He indicated that management philosophies are essential part of AMT.

Zeleny (1986) pointed out that technology embraces a lot more than just machines. He identified three equally important components of a technology. They are hardware, software, and brainware. Hardware refers to ***"the physical structure and logical layout of the requirement or machinery that is to be used to carry out the required tasks"***. Software refers to the

"knowledge of how to use the hardware in order to carry out the required tasks". Brainware refers to "the reasons for using the technology in a particular way".

We suggest the following definition for AMT.

Advanced Manufacturing Technologies can be defined as a group of hardware based- and software-based integrated technologies , which if properly implemented, monitored and evaluated, will lead to improving the efficiency and effectiveness of the firm in manufacturing a product or rendering a service.

Our definition is unique in many respects. First, it integrates the previous definitions to reflect the true essence of AMTs. Secondly, it addresses the relationships developed in our conceptual model. Finally, it is applicable to manufacturing organizations as well as service-type organizations.

In the remaining parts of literature review we address the following issues: pillars of manufacturing excellence (JIT, TQC, CIM), World Class Manufacturing, performance measurements, Manufacturing strategy, and technology-strategy linkage.

PILLARS OF MANUFACTURING EXCELLENCE:

Recent Advanced Manufacturing Technologies (AMT) such as JIT, TQC, CIM are viewed by many (Gunn (1987); Ciampa (1988); Hugh and Anderson (1988); Hayes and Wheelwright (1988); Beckamn (1990), Schonenberger (1982, 1986); Hall (1986,1988)) as the pillars of manufacturing excellence. If

successfully implemented, their benefits will be numerous. Customers, firms, and the economy will realize the importance of these technologies as competitive weapons. JIT, TQC, and CIM are not goals in themselves (Suzaki (1987).) They are merely tools to achieve goals. Successful adoption and implementation of these tools give companies a competitive edge, yield synergetic effects for all subsystems of the firm, and increase efficiency and effectiveness of the operations. Below is a detailed examination of these technologies.

JUST-IN-TIME (JIT)

There have been many definitions to JIT since the term became known to Western manufacturers. Schonenberger (1982, 1986); Ed. Hay (1988); Voss (1987); O'Gready (1988); Schroeder (1986); Lubben (1988); Gunn (1987) and Ciampa (1988) are among a long list of practioners and academicians who explicitly defined JIT. A number of books have been written on the subject.

JIT is not an inventory control mechanism nor it is a production planning procedure, says Schroeder (1986). It is a philosophy to achieve manufacturing excellence. A philosophy that aims at minimizing waste in all aspects of production processes. A philosophy that eliminates all non-value added activities, says Ed. Hay (1987). A philosophy that improves the bottom line of the firm and increase Return On Investment, ROI (Schroeder (1986).

Maskell (1987) viewed JIT as a philosophy that involves organizing the production process so that the minimal necessary levels of parts and

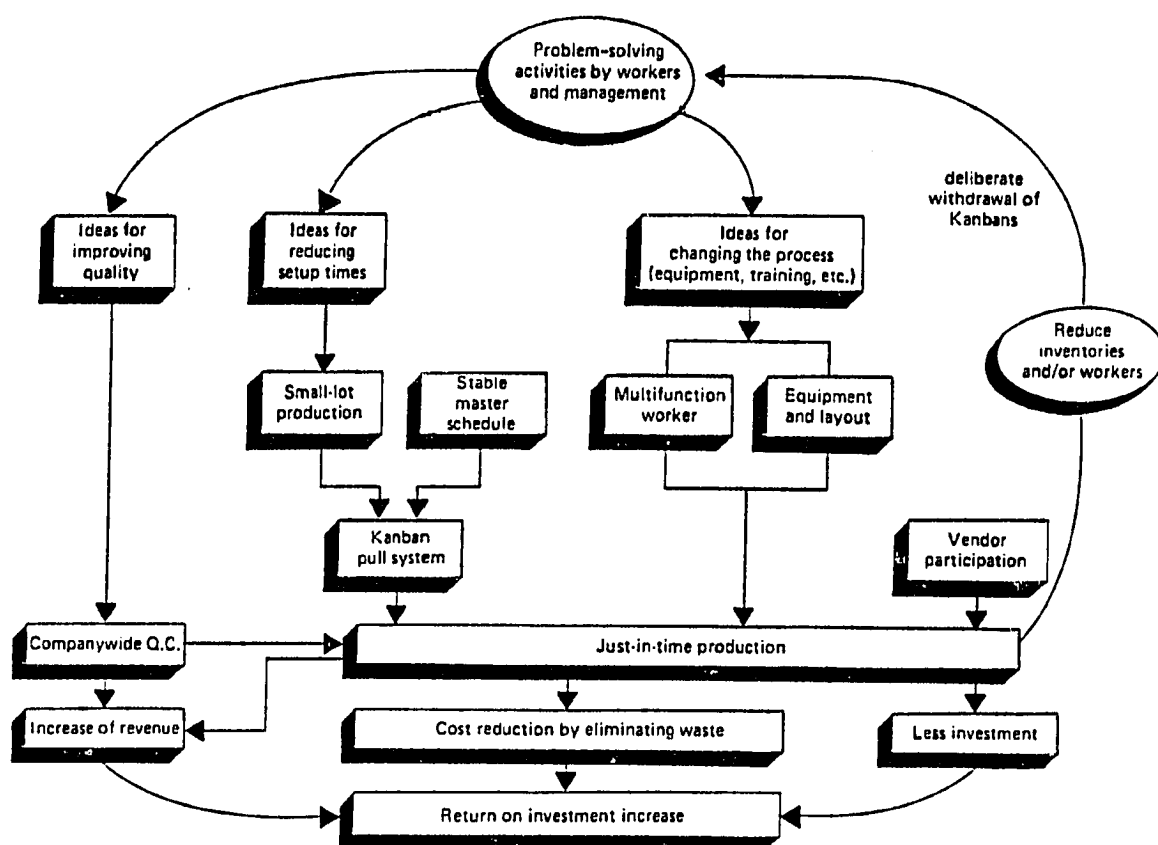
subassemblies-both manufactured and purchased- are available on the shop floor just when they are needed. JIT strategies, in his point of view, must include: 1. building a Customer/Vendor relationship to schedule small deliveries of materials more often, 2. Establishing long-term purchase orders with vendors, 3. Implementing TQC, which requires company wide education and commitment to quality, 4. Implementing production planning that is accurate, timely, flexible, and 5. Reducing setup times.

O'Neal (1986) examined JIT from Firm-supplier relationship. He explained that a growing number of U.S. industries are implementing the JIT/TQC operational philosophy. Firms that adopt JIT/TQC emphasize supplier evaluation and selection techniques. These new techniques include, long-term financial strength, size, and technology. Suppliers are considered partners not adversaries.

Finkel (1986) examined JIT/CIM connection. He stated that JIT is what makes CIM work. However, CIM components such as part routing, order entry, and process planning must work before JIT can be implemented. Combining CIM with JIT will strengthen a manufacturer's competitive position.

Schroder (1986) operationalized many of JIT concepts. He expressed these relationships in a flow chart form. His model is depicted below:

Figure (2.1)
Operatiolization of JIT



Source : Schrodoer, Production and operations management, McGraw Hill, New York, 1986.

JIT production relies on input from workers and management to suggest ideas for quality improvement, reduced setup time, and improved processing. JIT outputs include increased revenue, reduced waste, and reduced investment stemming from lower inventory, and staff levels. The result of these outputs, is an increased return on investment (ROI). The JIT philosophy also provides feedback to workers and management thereby fueling a new cycle of the process.

Myers (1987) Views JIT as a continuous improvement strategy. A strategy that is based on:

1. Mixed or continuous production.
2. Reduction of setup times.
3. Responsive procurement pipeline.
4. Quality-at-the-source.
5. Compression of shop space and flow lines, and
6. People as problem solvers.

Mayers also agrees that the commitment from top management is necessary for the success of adopting and implementing JIT.

JIT was originated in U.S and is now being rediscovered by American Corporations (Musselwhite, 1987). He stated that JIT should not be seen as "quick fix" solution. JIT production relies on a production philosophy in which an operator passes along in-process inventory only when a signal is received from the next operator in the process. Successful implementation of JIT

requires careful, long-range planning and support from high-level management.

These requirements include:

1. Plant-wide quality control.
2. Exposure and examination of every defect.
3. Worker responsibility for repair.
4. Production worker accountability for equipment maintenance.
5. A production environment focusing on one product line.
6. Group technology, and
7. An order quantity of one order or one container.

Lubben (1988) illustrated that the term JIT is meant to convey the idea that the three major elements of manufacturing capital, equipment and labor are made available only in the amount required and at the time required to the job. In his terms, JIT may be described as:

1. A management philosophy that is continually focused on integrating and streamlining the manufacturing system into the simplest possible process.
2. A devotion to the process of continually striving to minimize elements in the manufacturing system that restrain productivity.

Lubben outlined the JIT approach to manufacturing in the following figure.

Figure (2.2)
An Overview of JIt Approach to Manufacturing

Goals				
1	2	3	4	5
Design for optimum quality/cost and ease of manufacturing.	Minimize the resources expended to produce a product.	Be responsive to the customer.	Develop trust and open relationships with both suppliers and customers.	Develop the commitment within each function and employee to improve the total manufacturing system.
Objectives				
1. Design for customer satisfaction. 2. Reduce the costs of manufacturing. 3. Design products for manufacturability.	1. Integrate and optimize every step in the manufacturing process. 2. Build product to specification.	1. Provide customer with the product he wants. 2. Develop manufacturing flexibility.	1. Gain supplier and customer confidence in the company's ability to maintain commitments.	1. Do each job right every time. 2. Use an open systems approach to planning and implementing a JIT system.
Strategies				
1. Use only proven technology. 2. Use design standardization. 3. Simplify product design. 4. Design for ease of fabrication and assembly. 5. Minimize design and production costs. 6. Design for product robustness.	1. Use work cells and pull production processes. 2. Locate and remove sources of excess inventory. 3. Set manufacturing standards at zero defects. 4. Have each function be responsible for its own quality.	1. Design product to meet customer requirements 2. Reduce manufacturing lead time. 3. Provide product on schedule. 4. Provide product at the expected quality level.	1. Develop processes and procedures necessary to keep commitments. 2. Use <i>open kimono</i> policy to develop supplier and customer confidence. 3. Use long-term contracts.	1. Focus on the prevention of problems rather than the resolution of problems after they occur. 2. Continually educate employees with regard to the needs of suppliers, customers, and the production process.
Tactics				
1. Monitor customer application and problems. 2. Use production/supplier involvement in the design process. 3. Have formal design acceptance based on production goals. 4. Set formal goals on production performance. 5. Minimize the cost of labor, materials, and equipment in production.	1. Eliminate redundancy in the production system. 2. Establish goals requiring continuous improvement in the manufacturing system. 3. Remove all forms of gate inspection from the production system. 4. Establish production responsibility for product quality.	1. Continually monitor customer satisfaction. 2. Have engineers meet with customers. 3. Use a <i>kanban</i> system for triggering production requirements. 4. Eliminate all unnecessary inventory. 5. Reduce or eliminate lead time from: suppliers, overhead processes, manufacturing functions. 6. Use flexible production processes and equipment. 7. Train employees to operate a large variety of processes.	1. Stabilize the supplier base. 2. Fail-safe the production process. 3. Give employees the authority to stop the production process if needed. 4. Set a company-wide policy of doing the job right. 5. Deliver quality product on schedule.	1. Design production systems with the intent to prevent problems. 2. Establish a company-wide defect prevention program. 3. Use total quality control and statistical process control techniques.

Source: Lubben, Richard Just-In-Time Manufacturing, McGraw Hill, New York, 1988.

JIT can be implemented successfully if it has the commitment and support from top management. A fully integrated JIT system must consider both customers and suppliers. Gunn (1987), Ciampa (1988), Ed Hay (1988) and many other practitioners realized that suppliers must be considered as part of the production process. Therefore, Suppliers must be treated as partners not as adversaries.

In an empirical study, Ansari and Batoul (1987) studied the potential benefits of JIT purchasing for U.S. manufacturing. Their questionnaire sought information on:

1. Firm characteristics.
2. Relationship with vendors.
3. Methods of inbound freight transportation.
4. Receiving inspection procedure.
5. Benefit of JIT purchasing, and
6. Problems involved in implementing JIT.

Results indicated that firms that implement JIT purchasing realized substantial economic benefits. Inventory turnover almost doubled, the amount of delivery promised rose from 67% to 83%, scrap cost dropped by 40%, and the delivery lead time dropped from 77 days to 64 days.

JIT pays off financially. In a later section of this review we will examine the points of view of Schonberger (1982, 1986), Gunn (1987), Schoreder (1986), Fox (1988), and Reid (1990) to explain their claims.

TOTAL QUALITY CONTROL (TQC)

The second and highly related approach, in the pursuit of production process excellence is Total-Quality-Control. Forgarty et al (1989) based their definition of TQC on the fourteen principles of Quality proposed by Deming (1985). These principles are stated below:

1. Achieve consistency of purpose in the company.
2. Learn a new philosophy.
3. Require statistical evidence in process control on incoming critical parts.
4. Requiring statistical evidence in process control from vendors will require reduction in the number of vendors.
5. Use statistical methods to recognize the sources of trouble.
6. Institute new aids to training on the job.
7. Improve supervision.
8. Drive out fear.
9. Breakdown barriers to communication between departments.
10. Eliminate numerical goals,slogans, pictures, posters, that urge people to increase productivity. Numerical goals have a negative effect through frustration.
11. Look carefully at work standards. Assure that they help people to do a good job.
12. Teach employees to use statistical methods.

13. Train people in new skills.

14. Start at the top. Top management must push every day for TQC.

The definition provided by Fogarty et al for TQC is given as follows:

"TQC is a philosophy of zero defects, which assigns quality responsibility at the source of production by:

- 1. Training in and using established statistical techniques to identify and anticipate quality failure, and**
- 2. By improving equipment reliability through monitoring and preventive maintenance".**

The characteristics of TQC is fourfold. First, TQC ensures zero defects in every aspect of the production process. Secondly, TQC ensures quality at the source before the component parts and raw material arrive to shop-floor. Thirdly, TQC ensures equipment reliability during production process. Finally, TQC ensures reducing scrap and waste. It is obvious that TQC represents an important pillar of manufacturing excellence. If integrated with JIT, and CIM, the three tools will help companies to attain World-class manufacturing status and achieve manufacturing excellence.

To support TQC achieving these goals, tools such as statistical process control (SPC), Stop-line prerogative, preventive maintenance, and fish-bone analysis are used. In addition, top management support, and creating a new culture to appreciate these new technologies, are equally important.

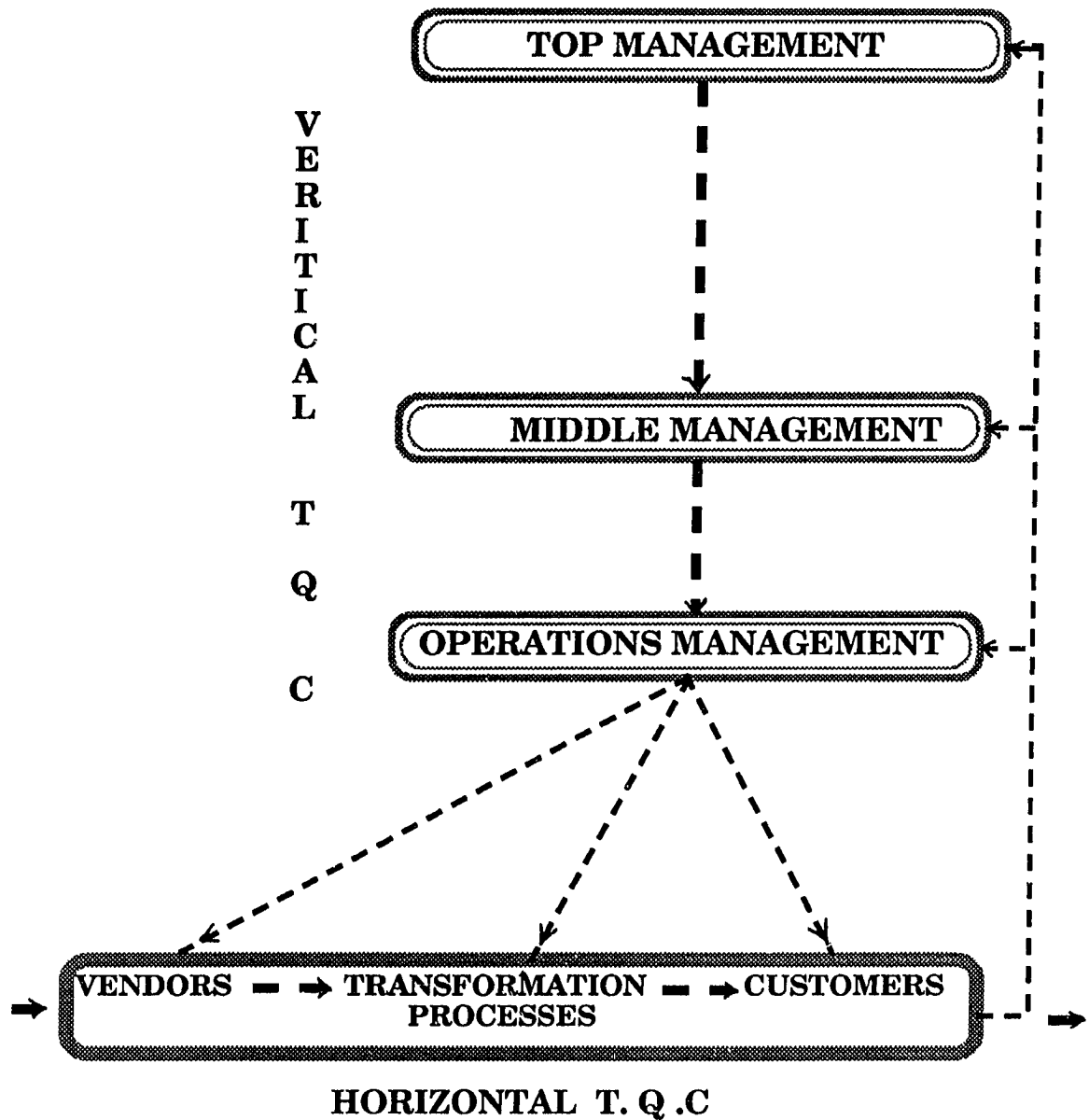
Imai (1986) defined TQC as **"An organized KAIZEN activities involving every one in the company- managers and workers- in a totally integrated effort towards improving performance at every level. This improved process is directed towards satisfying such crossfunctional goals as quality, cost, scheduling, manpower development, and new product development."** It is assumed that these activities ultimately increases customer satisfaction.

Imai compared the perception of TQC in Japan and Western societies, especially United States. In Japan, TQC is a continuous improvement process. Western manufacturers associate quality with inspecting the finished goods. The serious implication of the latter view point is that when the discussion of quality control is brought up top management lose interest immediately.

Recently, TQC in Japan has come to include marketing, sales, and services as well. Western manufacturers look at TQC as the responsibility of the manufacturing department in the firm. TQC in Japan is "customer-oriented" which is also referred to as "market-in". In Western societies, TQC is "market-oriented" which is also referred to as "product-out". The philosophy of "market-in" also looks at next process as a customer which extends the sphere of TQC vertically from top management all the way to supervisors and workers. It also extends the sphere of TQC horizontally from suppliers on one end to customers on the other.

Building on Imai's ideas, one can picture this process as follows:

Figure (2.3)
Vertical and Horizontal TQC



Source: Developed by the Author.

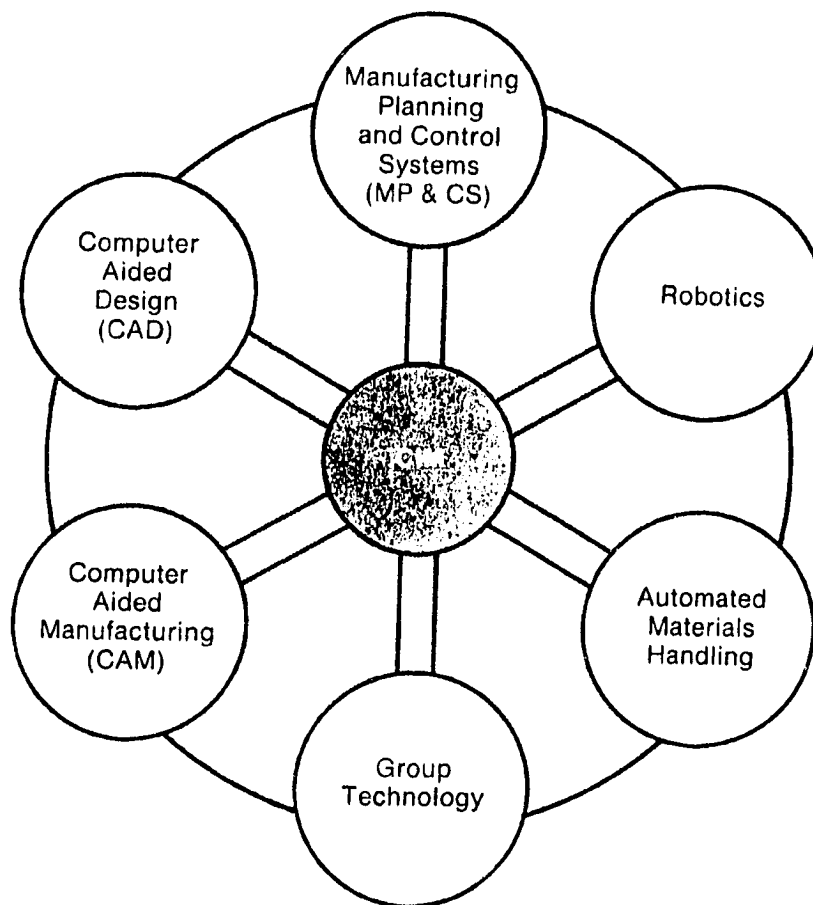
Reid (1990) reported that In 1981 the Ford Motor company announced that their suppliers must implement statistical process control in their manufacturing processes. Pen Fiber, one of Ford suppliers, considered it as an opportunity and started a TQC /JIT programs. Pen Fiber also asked their suppliers to implement SPC in their facilities. The results of implementing TQC /JIT produced impressive benefits including a 45% reduction in returns and improved employee moral. The economic and financial gains of the new programs were recognized everywhere.

COMPUTER INTEGRATED MANUFACTURING (CIM)

There are many definitions of CIM. Sometimes these definitions mean different things to different people. According to Fogarty et al (1988), CIM is defined as **"An application of computer technology to take full advantage of both hardware and software development in conjunction with manufacturing technology and management practice."** To achieve efficiency and effectiveness, CIM integrates two important elements information technology and system concepts. It is difficult to define all components of CIM due to two reasons. First, the dynamic development in the field. Secondly, the numerous different applications of CIM. Fogarty et al (1988) summarized the CIM components into six categories. Their model is depicted below:

Figure (2.4)
Elements of CIM

Elements of a Computer Integrated Manufacturing System

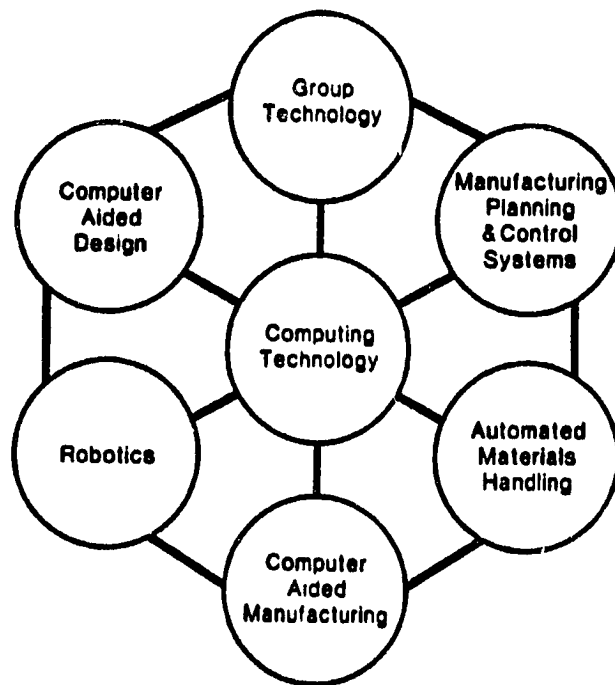


Source: Fogarty et al, Production and Operations Management, South West Publishing Co., 1988.

In 1987 Thomas Gunn developed a CIM model at Arthur D. Little company . This model is also depicted below:

Figure (2.5)
CIM Framework as used at Arthur D. Little Inc.

**Computer Integrated Manufacturing (CIM) Framework, as Used
at Arthur D. Little Inc.**



Source: Thomas Gunn, Manufacturing for Competitive Advantage: Becoming a World-Class Manufacturer, Ballinger Publishing Co., Cambridge, MA, 1987

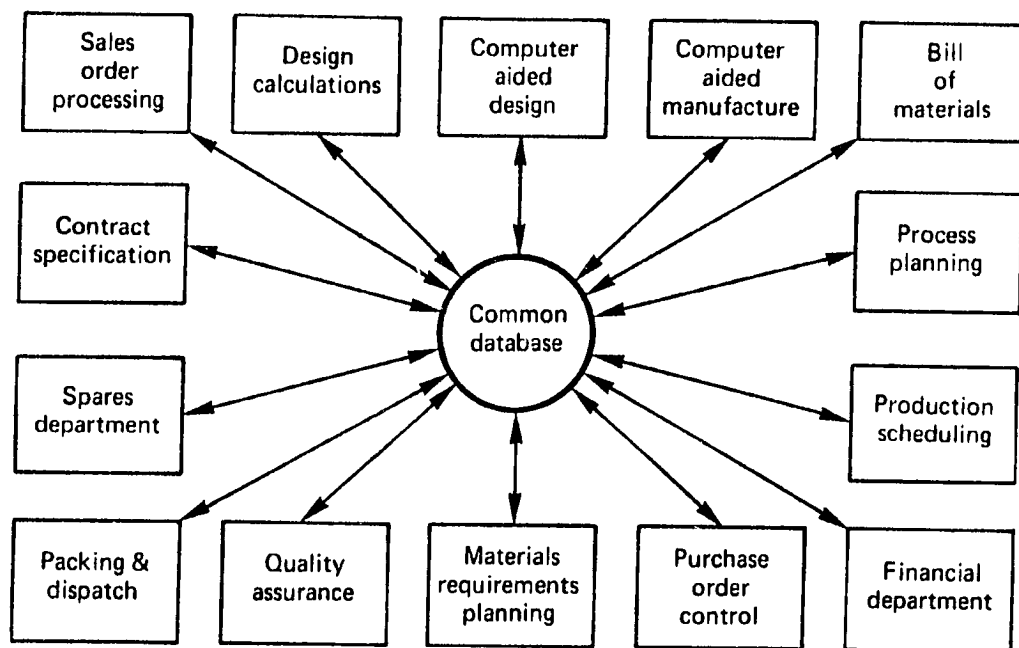
Teicholz and Orr (1988) indicated that there is a bewildering array of CIM technologies, and more are being developed. Among their list are the following technologies:

1. Computer Aided Design / Computer Aided Manufacturing (CAD / CAM).
2. Integrated Manufacturing Centers (IMC).
3. Computer Aided Inspection (CAI).
4. Group Technology (GT).
5. MRP II.
6. Robotics.
7. Computer Numerical Control (CNC).
8. Automated Assembly (AA).
9. Automated Material Handling (AMH).
10. Flexible Manufacturing Systems (FMS).
11. Computer aided Process Planning (CAPP).
12. Direct Numerical Control (DNC).
13. Computer Aided Engineering (CAE).

Carven and Slatter (1988) reviewed some of the current trend in using CIM. They illustrated that the emergence of CIM as a concept reflects the latest stage in what has been described as the trend in manufacturing towards the gradual automation. This process involves three successive stages of automation: intra-activity automation, intra-sphere automation, and inter-

sphere automation. According to Carven and Slatter (1988), a typical CIM model is what Harris (1986) projected. This model is depicted below:

Figure (2.6)
Elements of CIM



Source : Slatter, R. and F.W. Carven, "An Overview of Advanced Manufacturing Technology," Johnson, G.I and J.R WillIn, (Ed.) Ergonomics Matters in Advanced Manufacturing Technology, Butterworths, London, 1988.

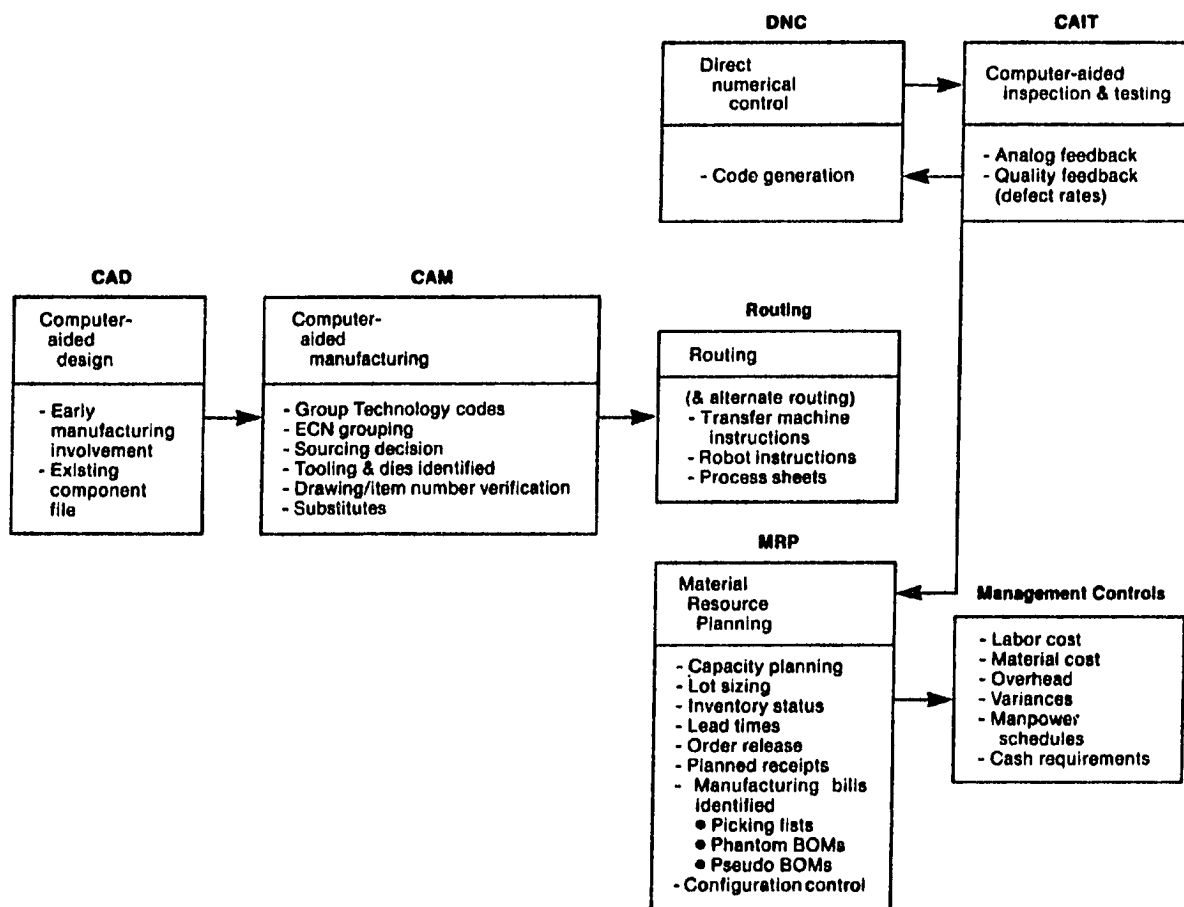
Johnson and Willison (1988) provided a similar list to that of Carven and Slatter. In addition to the components included in Carven and Slatter's article, Johnson and Willison added:

1. Automatically Guided Vehicle (AGV).
2. Application of Computers to Manufacturing Engineering (ACME).
3. Artificial Intelligence (AI).
4. Advanced Manufacturing Technologies (AMT).
5. Computer Aided Planning (CAP).
6. Flexible Manufacturing Cell (FMC).
7. Human Computer Interaction (HCI).
8. Shop-floor Monitoring and Control (SMC).

Heizer considered CIM as the technique for productivity in the 1990's. Among the components of CIM Heizer mentioned are CAD, CAM, MRP, DNC, and Computer Aided Inspection and Testing (CAIT). His model is depicted below:

Figure (2.7)
Computer Integrated Manufacturing

Fig. 2—Computer-Integrated Manufacturing

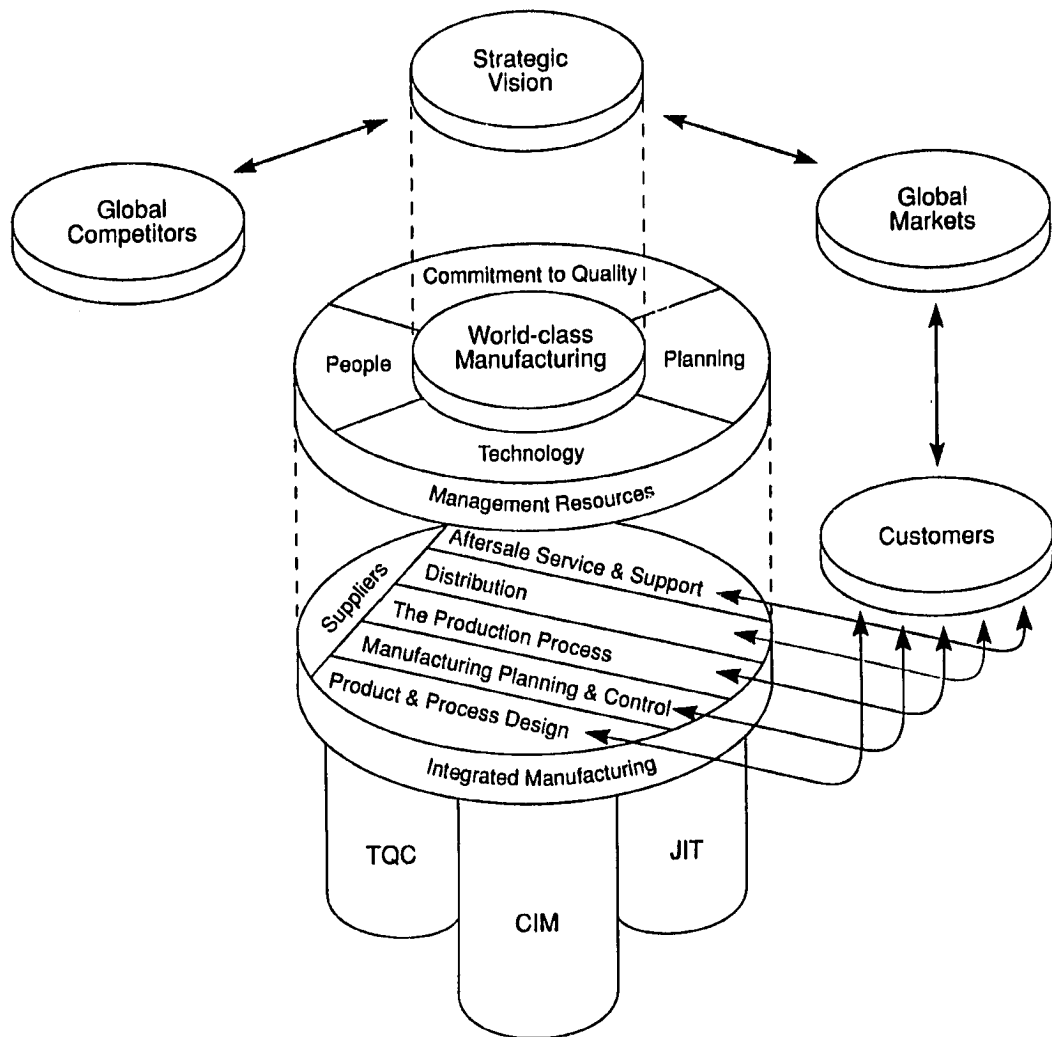


Source: Jay H. Heizer, "Manufacturing Productivity: Japanese Techniques are not Enough," IM, Sept.- Oct., 1986

According to Gunn (1987), There is no single company which can claim that they have a full CIM system. The reasons are simple. First, no one can buy a computer integrated manufacturing plant today. Secondly, No vendor offers a complete CIM-based factory or a complete system to install within the four walls of the facility.

The pillars of manufacturing excellence we reviewed in this chapter are essential tools for defining, planning, and carrying out a successful manufacturing strategy. Gunn (1987) integrated JIT, TQC and CIM and its components in a model. this model is depicted below:

Figure (2.8)
Pillars of Manufacturing Excellence



Source : Thomas Gunn, Ibid

The model provided by Gunn addresses the Total Business Concept (TBC) and the total vision of being in business as a manufacturer in global markets. The model starts with the business unit strategic vision which should be based upon two frames of reference global markets and global competitors. The second level in the model represents the critical management resources necessary to achieve World-class status. These factors are quality, human resource, proven technology, and planning. The third level of the model represents integrated manufacturing, a vision that considers both suppliers and customers as part of the production process. The fourth level of the model is its pillars JIT, TQC, CIM. A top-down or Bottom-up look at this model shows what manufacturing excellence and manufacturing strategy are all about.

WORLD-CLASS MANUFACTURING

The term World-Class Manufacturing has been defined by many academicians and practices. Hayes et al (1988) described what is implied by the term "world-class manufacturing." They said "Basically, this means being better than almost every other company in your industry in at least one important aspect of manufacturing". Hayes' definition has many implications. Companies which fall in this category must decide what kind of competitive advantage they are going to seek, then restructure their decision making process by continuing structural and infrastructural decisions. Structural decisions include: (1) the amount of total production capacity to provide; (2) how this capacity should be broken up into specific

production facilities; (3) what kind of production equipment and systems to provide those facilities with; and (4) which materials, systems, and services should be produced internally and which should be produced from outside the organization. Infrastructure decision refer to management systems and policies that determine how the structural decisions are managed. They include: (1) human resource policies and practices, including management selection and training policies; (2) quality assurance and control policies; (3) production planning and control systems; (4) new product development process; (5) performance measurement and reward systems, including capital allocation systems; and (6) organizational structure and design.

The second implication of Hayes' definition is that world-class companies are, as outlined in his earlier book (1984): *Restoring our Competitive edge: competing through manufacturing*), are Stage IV companies. Stage IV companies are those companies that regard their manufacturing organization as externally supportive. That is, playing a key role in supporting the whole company to achieve an edge over their competitors.

The third implication of Hayes' et al definition is that world-class companies tend to grow faster and are more profitable than their competitors.

In addition to these attributes, Hayes stated some other indicators. Among these indicators are: (1) how workers and managers who are skilled and effective that other companies are continually seeking to attract them away from one's organization; (2) responds quickly to market shifts or pricing

changes, and get new products out into the market faster than they can; (3) design their products in such a way that if their competitors want to produce a comparable product that will not be done without a major retooling and redesign expenses; (4) continuous improvement in facilities, support system . . . etc.; and (5) dislike being dependent on outside organizations for expertise.

Gunn (1987) indicated that for a company to achieve a world-class status the following criteria must exist: (1) an inventory turnovers of at least 25 to 30 per year; (2) fewer than 200 defective parts (for any reason) per million of any product that they manufacture; and (3) the ratio of value added lead time to cumulative manufacturing lead time must be greater than .5.

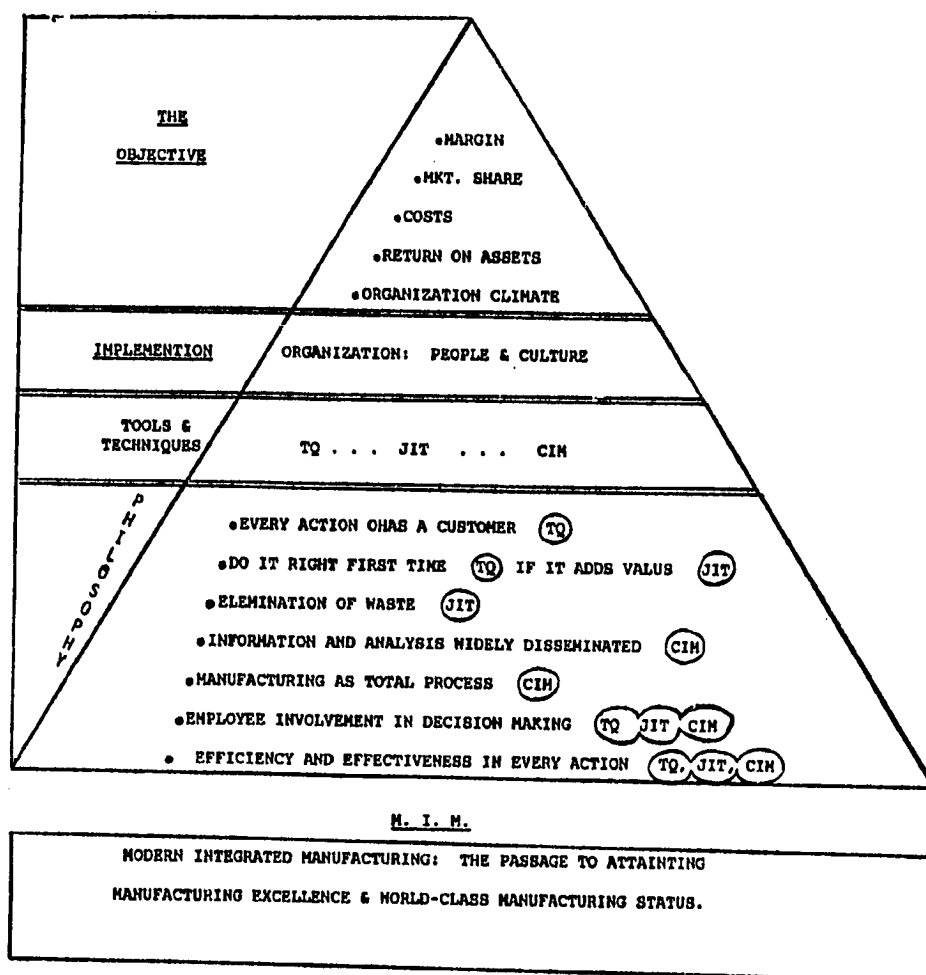
Although the three criteria proposed by Gunn are easy to quantify they are very difficult to achieve. Ford, one of the best managed companies, have inventory turnover of 10.2 times per year (Montgomery 1987). Gunn went further to say that companies with inventory turnover of 25 to 30 times are but a Class C world-class. Class B and Class A companies are , in his opinion, those whose inventory turnover are 50 to 60 times and 80 to 100 times per year respectively.

Gunn also indicated that these measures are far beyond most manufacturers capabilities today and will become even more stringent in the future. Four critical resources are required to achieve world class manufacturing status. These resources are (1) quality; (2) human resources; (3) proven technology; and (4) planning.

Ciampa (1978) agrees that the three main pillars of an integrated manufacturing system are JIT, CIM, and TQC. Although he didn't use the term world-class manufacturing per se, he added a new term. This term is Modern Integrated Manufacturing (MIM) pyramid.

Ciampa's MIM pyramid starts with the objectives that a company is seeking to achieve then creating an environment and proposing tools to help achieve those objectives, and finally stating the philosophy underlying his MIM approach.

Figure (2.9)
A Modified Version of Ciampa's Modern Integrated Manufacturing.



Source of the original Model: Dan Ciampa, Manufacturing's New Mandate: The tools for Leadership, John Wiley & Sons, New York, 1988.

Huge and Anderson (1988) traced the evolution of world-class manufacturing and how the Japanese companies have set an outstanding example of how management and employees, by working together, can overcome gross disadvantages and gain world leadership in manufacturing. In their terms, the new world-class firms must achieve lower cost, higher quality, greater flexibility, and innovative product and process technologies.

Huge and Anderson's definition encompasses two very important facts. First, world-class manufacturers have known that to survive and achieve success, empowering philosophy that efficiently utilize the available resources is a key factor. A philosophy in this context is a set of values and principles that guide the firm's goals and strategies. A powerful philosophy, in their opinion, unites people, gives meaning and purpose to their efforts, and guides the decision making process throughout the firm. A world class firm's philosophy must take precedence over strategic planning. Second, manufacturing strategy must be consistent with the firm's competitive strategy and provide competitive advantages to the company as a whole.

Huge and Anderson, like many other practitioners, believe that the philosophy of manufacturing excellence should include TQC as well as JIT. Furthermore, a cultural change must take place for these two pillars to be successfully implemented. This cultural change must include: (1) stopping production for quality problems; (2) inventory is the "root of the evil" and it masks problems; (3) manufacturing only what is needed, when needed; and

(4) using valid, and appropriate performance measurements that are suitable to their philosophy. In short, this cultural change can be expressed as a function of leadership, knowledge, enthusiasm, will, and energy.

Hayes et al (1984) described the Passage to world-class manufacturing status as a four stage continuum. In Stage I, companies consider their manufacturing organization as internally neutral. The company will produce the product as long as the marketing people are able to sell it. The implications of this philosophy are many. In one hand, the degree of commitment to quality and elimination of waste is low, on the other hand, managerial action and decision will no longer be appropriate when competitors join in and improve themselves on the basis of quality and cost.

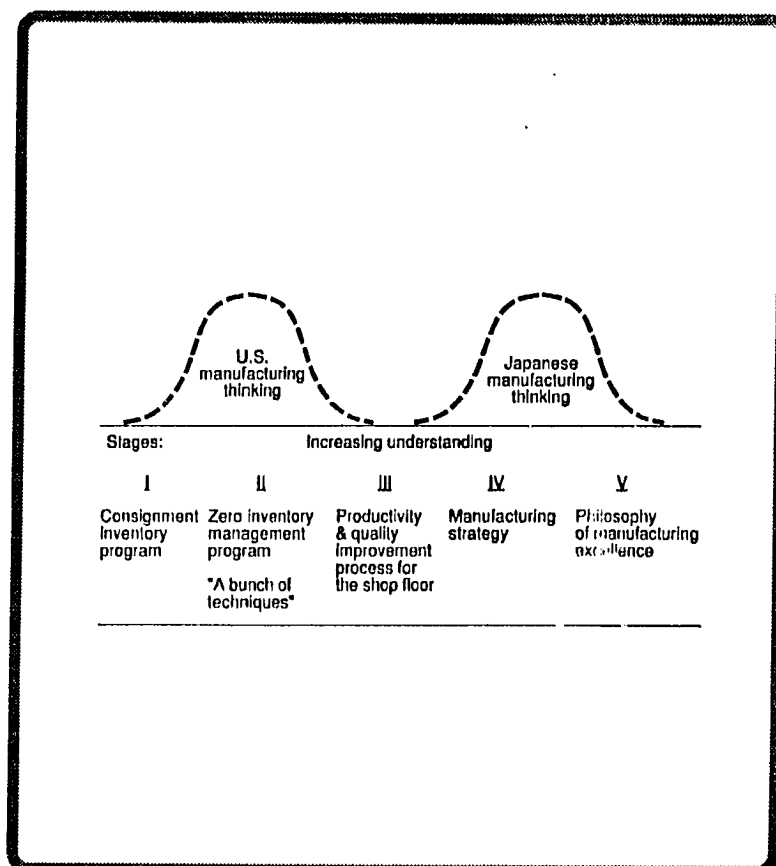
In Stage II, companies view their manufacturing organization as externally neutral. In this stage companies become aware of their competitors and find themselves forced to adhere to standards imposed by their major competitors. The implications of this philosophy are: (1) copycating behavior is no longer appropriate; and (2) to be competitive quality and cost reduction must come into play.

In Stage III manufacturing organizations are thought of as internally supportive of other parts of the company. Management begins to think of the synergetic impact of all parts of organization, manufacturing being one of these parts. The success of the company will be a function of the ability to use the available resources more effectively than their competitors.

In Stage IV, companies view their manufacturing organization as externally supportive in gaining a competitive edge over their competitors. The implication, of this philosophy is more commitment to quality and elimination of waste. The success in this stage becomes a function of creating the proper culture for implementing advanced manufacturing technologies such as JIT, TQC, CIM. A world class status has been achieved and competitors will try to achieve the same status. The overall results will be the benefit to the customer.

Hugh and Anderson (1988) explained the passage toward a philosophy of manufacturing excellence in a different way. First, they consider that the core components of manufacturing excellence are JIT, TQC, and Employee Involvement (EI). Second, they compare United States manufacturing thinking to that of the Japanese. The results of that comparison, and the stages of manufacturing excellence are depicted below:

Figure (2.10)
Spectrum of understanding about JIT



source: Huge and Anderson, The spirit of Manufacturing Excellence: An Executive's Guide to The New Mind Set, DowJones-Irwin/ APICS Series in Production Management, (1988)

Gunn (1988) explained that companies progress by stages toward the desired goal of global competitiveness. For each of the three pillars of WCM, Gunn projected a four stage continuum and explained a set of manufacturing attributes in each stage (Gunn's Model is about eight pages long. Therefore, we refer the reader to the source).

Clark, Hayes, and Lorenz (1985) pointed out that the main factor that is critical to the success of a company is to produce high quality products, efficiently for rapidly changing customer demand. Hayes et al (1988) mentioned that there are certain requirements for a company to be world-class. Among these requirements are: high quality products, minimum inventory, manufacturing technology, work force management policies, new product development policies, and world-wide sourcing.

High quality output can be achieved by: (a) Designing quality into the product, (b) zero-defect goals for both suppliers and internal production, (c) preventive maintenance for equipments rather than equipment repair during unscheduled downtime, and (d) design and manufacturability of new products are developed simultaneously to avoid products that can not be reliably produced.

Minimum inventory can be achieved by (a) reducing set up times to avoid large batch sizes, (b) implementing JIT production, and JIT delivery systems, (c) minimize travel distance and transit time of products in the factory, (d) eliminate safety stocks caused by uncertain quantity and delivery from certain

stages in the production process.

Manufacturing Technology can be achieved by (a) using computer integrated manufacturing techniques such as computer aided design, robotics, flexible manufacturing systems, (b) using technology to enhance flexibility, increase quantity, and reduce inventory, finally, (c) the ultimate goal should always be to make small-batch manufacturing as efficient as mass production.

Work force management policies can be met by (a) more employee participation; (b) company goal-oriented activities through quality circles; (c) eliminating restrictive work rules; (d) more comprehensive job assignment; and (e) bonuses and incentives for enhanced productivity. In the new product development process, the time between launching a new product and the commercial introduction of it must be minimized. Also, products should be available to the customers when needed (JIT with customers).

A world-class manufacturer should explore its capabilities for mass production in low-cost facilities and understand completely the marginal cost of production at each facility to be able to correctly make the buy or make decisions.

MEASURING PERFORMANCE

Traditional business measures are inappropriate for determining the success of a world-class manufacturer (Grieco and Cozzo 1987), Clark et al (1985). A world-class manufacturer strives toward Total Business Concept which integrates all the efforts of subsystems of the company. Synergetic results, therefore, follows and it becomes inappropriate to use traditional measures to evaluate such synergetic results. Synergy is a simple equation in which the sum of the whole is greater than the sum of the parts or in Ansoff's terms Two Plus Two is Five.

Before we elaborate on the purpose of measuring the performance of world-class manufacturers, it is important to mention benefits that a company can gain by being a world-class manufacturer. Benefits can be tangible or intangible. Tangible benefits include, but not limited to, lower cost of parts, greatly improved quality, improved administrative efficiency, and increased productivity. Intangible benefits has to do with the human factor in the company. Motivation, increasing morale, decreasing employees turnover, maximizing employees participation, are just a few of these intangible benefits.

We measure performance simply to be able to tell ourselves where we are now and how far we have deviated from predefined plans (Grieco and Cozzo 1987). A world-class manufacturer should be able not only to tell where are they and how far they have deviated from their plans, but also how they are

doing in comparison to their competitors. The answer to the question of how are we doing must be followed by another follow-on question. This follow-on question should be: compared to what? (Hayes et al 1988). Hayes et al are suggesting that an effective performance measurement system must provide insight into how a company compares with its best competitors with respect to manufacturing capabilities upon which its manufacturing strategy is based.

Fox (1982) in an article entitled "MRP, KANBAN, OPT.: What is best" stated that the real purpose of manufacturing is to make money. Based upon this concept, Fox suggested that the performance of a manufacturing company should be measured in terms of two financial measures net sales and return on total assets. The manufacturing yard stick measures in his opinion are: throughput, inventory, and operating expenses. The goal of a manufacturing company, therefore, should be to maximize throughput, and minimize inventory and operating costs.

Montgomery et al (1987) suggested that the key manufacturing parameters which rank competitors are in order of importance: inventory turnover ratio, manufacturing cycle time, product cost, ability to compete internationally, growth rate, market share, and return on investment. They concluded that these are not the only important financial measures, but they are the engines which drive manufacturing competitiveness.

Myers (1987) listed 35 measures of improving by which one can evaluate the effectiveness of AMT, and the performance of World-Class Manufacturer.

These measures are listed below:

1. Quality of goods produced.
2. Work-In-Process inventory .
3. Flexibility - the number of different items produced per unit of time.
4. Inventory Turnover - times per year.
5. Lead (throughput) time-order entry to completion.
6. Value added time - the amount of time in production during which value is added to the product.
7. Throughput ratio - the ratio of value added time to throughput time.
8. Set up time.
9. Raw material or finished goods inventory.
10. Floor space required to Accommodate operations.
11. Flow distance - material travel through operations.
12. Cycle time to complete a unit - lead time.
13. Transit time from one operation to another.
14. Queue time - how long material waits to be processed.
15. Downtime - percent of planned or unplanned downtime.
16. Inspection delay - any checking time.
17. On time performance.
18. Number of suppliers .
19. Forklifts - number and amount of time in operation.
20. Employee versatility - ability to do many jobs.
21. Number of accepted suggestions from employees.
22. Teamwork.
23. Motivation.
24. Employee turnover.
25. Absenteeism.
26. Morale.
27. Real work - percent of time worked without intrusions by complexities.
28. Cleanliness of work area.
29. Labor costs.
30. Margins.
31. Capital expenditures.
32. Operating expenses.
33. Cash flow from operations.
34. Pretax return on investment.
35. Net profit.

Myers mentioned that just having a list of these measurements leaves an important question unanswered: Who is responsible for defining performance standards and for reporting the results? For the purpose of answering this question, Myers developed an accountability grid. This accountability grid is depicted below.

**Figure (2.11)
Accountability Grid.**

ACCOUNTABILITY GRID		OPERATIONS	SUPPLIERS	MAINTENANCE	QUALITY CONTROL	INTERNAL AUDIT	INDUSTRIAL ENG.	R&D ENGINEER	DESIGN ENGINEER	ACCOUNTING	PERSONNEL	SUPPLIES	MFG. MGR.	PLANT MGR.
✓ Involvement														
⊗ Reporting role														
1. Quality		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
2. WIP		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
3. Manufacturing flexibility		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
4. Turns					⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
5. Lead (or throughput) time			⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
6. Value added (or production) time		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
7. Throughput ratio		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
8. Setup (or changeover) time		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
9. RM/FG inventory					⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
10. Floor space		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
11. Flow distance		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
12. Cycle time		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
13. Transit time		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
14. Queue time		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
15. Downtime		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
16. Inspection delay				⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
17. On-time performance		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
18. Suppliers			⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
19. Forklifts				⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
20. Employee Versatility		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
21. Suggestions		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
22. Teamwork		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
23. Motivation		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
24. Turnover		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
25. Absenteeism		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
26. Morale		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
27. Real work		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
28. Housekeeping		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
29. Labor costs										⊗	⊗	⊗	⊗	⊗
30. Margins										⊗	⊗	⊗	⊗	⊗
31. Capital expense										⊗	⊗	⊗	⊗	⊗
32. Operating expense		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
33. Cash flow										⊗	⊗	⊗	⊗	⊗
34. ROI										⊗	⊗	⊗	⊗	⊗
35. Profit										⊗	⊗	⊗	⊗	⊗

Source: Myers, M. Scott, "Don't Let JIT Become a North American Quick Fix," *Business Quarterly*, March 1987.

From that accountability grid, it is obvious that manufacturing managers, plant managers, and supervisors are responsible for defining most of the standards.

Myers concluded that managers have long used the standard bottom line measures (items 33-35) of cash flow, return on investment and profit to gauge organizational success. While these measures are important indicators of making money, they are too remote in time and linkage to provide relevant feedback to key players (Human factor) in AMT environment.

McNair and Williams (1987) reported that for U.S. companies to be competitive, they must incorporate advanced manufacturing techniques and performance measurement system changes into strategic plans. They added, an organization's performance measurement system should be based on four factors- people, quality, delivery, and cost- as well as on other characteristics that relate to the multiple aspects of the organization. As advances in technology accelerate, companies will have to manage productivity and the process of change in management accounting systems

AMT AND ECONOMIC PERFORMANCE:

JIT philosophy is changing both the behavioral patterns of production cost and how financial executives must measure and control these cost (McIlhattan ,1987). McIlhattan indicated that Manufacturing environment require more innovative means of approaching cost management. JIT philosophy will have significant impact on:

1. Identification of Cost drivers.
2. Number of product cost elements.
3. Application of product costs, and
4. Nature of performance measures.

In JIT environment, management should eliminate the nonvalue-added activities and improve upon the value-added ones.

Beals (1986) reported that In 1983 President Reagan signed a bill prohibiting import of motor cycle over 800cc until 1988. Harley-Davidson took advantage of this opportunity to position itself in the market place and to become a competitive force in that market. Learning from Japanese manufacturers, management at Harley-Davidson realized that productivity triad should consist of (1) employee involvement, (2) a JIT system, and (3) statistical process control. The overall goal was to achieve cost and quality parity with their competitors.

Beals (1986) concluded, over three years period, Harley-Davidson has:

1. Reduced scrap and rework by 66%.
2. Tripled delivery of defect-free motor cycles.
3. Increased productivity by 40%.
4. Increased Inventory turnover by 20 times versus a 3.5 national average, and
5. Implemented cost reductions programs.

Reid (1990) explained the financial impact of JIT at Harley-Davidson. Under a heading "JIT can throw off tremendous amounts of cash", Reid compared the financial impact of "inventory turns" namely: 1)three inventory turns (base); 2) fifteen inventory turns and 3) fifteen inventory turns and 38% productivity increase. His results are summarized below:

Table (2.1) Financial Impact of Different Inventory turns

	Base Three Inv. Turns	fifteen Inv. Turns	fifteen Inv. Turns + 38% Productivity Increase
REVENUE	\$ 100.00	\$ 100.00	\$ 100.00
COST OF SALES	75.00	75.00	65.50
GROSS PROFIT	25.00	25.00	34.50
SELLING, GENERAL AND ADMINISTRATIVE EXPENSES	10.00	10.00	10.00
INVENTORY CARRYING COST AT (20%)	5.00	1.00	.90
RETURN ON INVESTED CASH (AT 10 %)	.00	2.00	2.10
INCOME BEFORE TAX	10.00	16.00	25.70
NET INCOME BEFORE TAX	5.00	8.00	12.80
RAW MATERIALS AND WORK IN PROCESS INVENTORY	25.00	5.00	4.40
CASH THROW-OFF	-----	20.00	20.60

Source: Peter C. Reid, "Made in America: Lessons from Harley-Davidson on being the best." McGraw Hill 1990.

Gunn (1987) indicated that JIT, TQC, and CIM do pay financially and strategically. In his view, reductions due to the effective implementation of world-class manufacturing tools such as CIM, JIT, and TQC have produced the following results:

Table (2.2)

FEATURE	PERCENTAGE REDUCTION
MANUFACTURING COSTS	20 TO 40 %
LEAD TIME	50 TO 75 %
RAW MATERIAL, WIP	30 TO 60 %
QUALITY COSTS	50 % PLUS
FLOOR SPACE	30 TO 60 %
TOTAL MANPOWER	20 TO 50 %
PURCHASING COSTS	5 TO 10 %
NEW PRODUCT DEVELOPMENT LEAD TIME	20 TO 50 %
DESIGN & ENGINEERING COSTS	10 TO 20 %
ENGINEERING CHANGES	10 TO 20 %

Source: Gunn, Thomas "Manufacturing for Competitive Advantages: Becoming a World-Class Manufacturer." Billanger, 1987.

MANUFACTURING STRATEGY

Wickham Skinner of Harvard Business School has been a prominent figure on manufacturing strategy since 1969. His article "Manufacturing: The Missing Link in Corporate strategy" in Harvard Business Review in 1969, has been quoted in almost every piece of research that has to do with manufacturing strategy. The article also opened a new, and much needed, line of research. In this part of literature review we will look at four important concepts. First, we will examine various definitions of manufacturing strategy. Second, we will look at the contents and the various model of manufacturing strategy. Thirdly, we will examine some of the most recent theoretical and empirical research on manufacturing strategy. Finally, we will summarize these current trends in manufacturing strategy.

MANUFACTURING STRATEGY: DEFINITIONS AND CONTENTS

The term strategy in general is of a military origin. It means meeting your enemy in combat under advantageous conditions (Beckman, (1990). In business policy and strategy, the term strategy was tailored to mean a link between a firm and its environment so that the goals and objectives of the firm are achieved. The literature on business strategy is very rich with many versions of that definition.

As there are many definitions of business strategy, there exist many definitions of manufacturing strategy. Skinner(1969, 1974, 1978, 1985, 1990) was the first to coin the term "Operations Strategy." His philosophy is that an

operation should focus on one of the four strategies: (1) be the low-cost producer, (2) offer the best customer service, (3) be the most flexible in terms of schedule and or product changes and product releases, and (4) has the best quality for a given design. The four factors are now considered by many as the major contents of manufacturing strategy (Swamidass (1990), Roth (1990), Dean (1990) Nemtez (1990).

Skinner (1985) proposed the following methodology for developing manufacturing strategy: (1) Start with business strategy. (2) Based upon the business strategy, determine which of the four factors, mentioned above, is appropriate. (3) Evaluate the current operations capability relative to the area selected. (4) Analyze your competitors relative to this focus area. (5) Based upon these competitors analysis decide on the focus area. (6) Determine the "gap" between the current capability versus desired capability. (7) Develop appropriate policies to support manufacturing strategy and close the gap.

Huge and Anderson (1988) stated that in light of Professor Skinner's methodology, manufacturing strategy becomes "implement the philosophy of manufacturing excellence". The manufacturing excellence philosophy, in their view, is very practical. First, it is applicable to continuous process and discrete manufacturers as well as all types of operations (make-to-stock, assemble-to-order, make-to-order, and engineer-to-order). Secondly, It is applicable to all functions within a manufacturing organization. Finally, it is even relevant for service industries (banking, insurance, health care, ... etc). The results of

implementing this philosophy are numerous. Among these results are more responsiveness to schedule changes, more savings and cost reduction, less inventory and higher inventory turnover ratios, more responsiveness to changes in demand patterns, supplier consolidation and above all a quality product and a satisfied customer.

Beckman et al (1990) developed a strategic planning process Hewlett-Packard. According to them, it can help in reestablishing manufacturing's position as a critical contributor to the success of company's business strategy. The strategic planning process is outlined as follows:

1. Start with a business strategy, and understand why customers will prefer your product or service to the competitors'.
2. Create manufacturing strategy that is linked to business strategy. In other words, specify manufacturing's contribution to making customers choose your product or service instead of your competitor's.
3. Identify manufacturing tactics to execute the strategy.
This requires understanding how to manage and control the people, processes, materials, and information needed to deliver products or services in a way that meets the objectives of the strategy.
4. Organize for manufacturing success. Organization design, including structure and performance measurement, must match strategic needs or success will be limited.
5. Measure the results and indicate further change. Strategies must be

continually altered to meet the needs of a constantly changing environment. Feedback loops are critical to the continuous improvement process.

Schmenner (1979) defines manufacturing strategy in simple terms as "A plan that describes the way to produce and distribute a product." Hayes and Wheelwright (1984) defines manufacturing strategy as "A pattern of decisions actually made by manufacturing organization, and the degree to which this pattern supports Business strategy."

In an empirical study, Swamidass (1986) defined manufacturing strategy as "the deployment and development of manufacturing capabilities in total alignment of the firm's goals and strategies. It gives competitive advantage through the best and conscious use of uniqueness of manufacturing function."

In the same study, He concluded that manufacturing strategy is often nonexistent, or misunderstood. Hayes and Wheelwright (1984, 1988) defined manufacturing in terms of the structural and infrastructural decisions. They indicated that manufacturing strategy describes the competitive leverage required of, and made possible by, the production function. It analyzes the entire manufacturing function relative to its ability to provide such leverage, on which task it then focus each element of manufacturing structure. It spells out an internally consistent set of structural decisions design to forge manufacturing into strategic weapon. These structural include:

1. What to make and what to buy.

2. The capacity levels to be provided.
3. The number and size of the plants.
4. Choice of equipment and process technology.
5. The production and inventory system.
6. The quality control system.
7. The cost and other information systems
8. Workforce management policies.
9. Organizational structure.

Gunn (1987) considered Hayes' et al definition as a classical definition and does not offer sufficient basis for creating a manufacturing strategy. Two reasons justify his point of view. First, these factors are suitable for a static world of manufacturing, which no longer exists. Second, these factors fail to emphasis day-to-day manufacturing performance. Thus, they encourage the status quo in manufacturing. Gunn explained that it is necessary to consider new and modern factors for manufacturing strategy. These modern factors must include:

1. Shorter new-product lead time.
2. More inventory turnover.
3. Shorter manufacturing lead time.
4. Highest quality.
5. More flexibility.
6. Better customer service.

7. Less waste.

8. Highest return on assets.

in his words "These new manufacturing strategy objectives are a must for today's dynamic manufacturing environment, where business is becoming increasingly volatile and complex, and where the competition exists today in global market rather than regional or national markets." Other factors pertain to the importance of these new factors are their focus on measuring manufacturing performance, and their emphasis on continuous improvement.

For each strategy objective, three questions must be asked:

1. What is the objective?
2. How will we achieve this objective?
3. What are the necessary tools to achieve this objective?

Gunn examined these three questions as related to two manufacturing strategy objectives: increasing the inventory turnover, and improving quality.

His approach is outlined below:

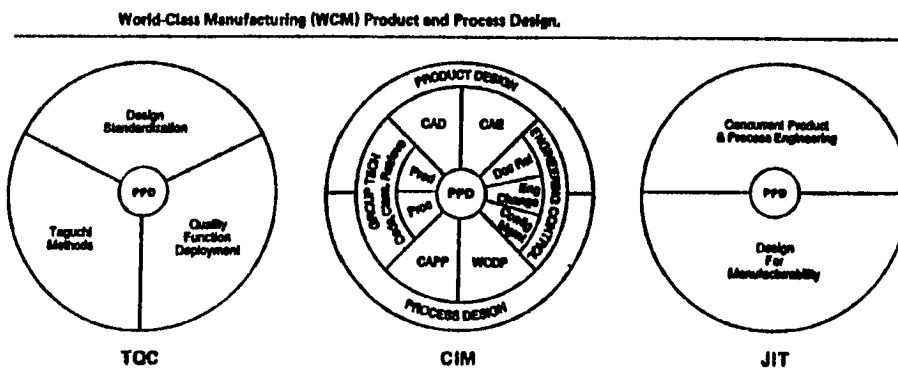
Figure (2.12)

<i>Manufacturing Strategy Objectives</i>	<i>How We Will Achieve Each Objective</i>	<i>Tools to Achieve Each Objective</i>
Increase raw material and work-in-process inventory turns from 2 today to • 10 in 1 year • 50 in 5 years	1a Apply JIT production techniques • Minimize setup times • Minimize lot sizes • Move to pull system • Involve suppliers	1a Standard containers Andon signs Bakayoke & pokayoke devices Multifunctional workers Quick setup machinery JIT education and training program Electronic links to suppliers Supplier education program
	1b Reduce cumulative manufacturing lead time	1b • CIM tools such as • FMS in fabrication • In-process computer aided inspection • AGVS • Parts count reduction in product design
	1c Gain further visibility into finished goods demand	1c Implement distribution resource planning (DRP) at national distribution center level Improve new product forecasting
<i>Manufacturing Strategy Objectives</i>	<i>How We Will Achieve Each Objective</i>	<i>Tools to Achieve Each Objective</i>
Reduce quality costs from 12% of sales today to • 5.0% in 18 months • 1.5% in 5 years	1a Implement statistical quality control program in production	1a • Certify gauging and measuring equipment • SQC education and training program • Visible control charts for all processes • Allow work to stop if quality is not within limits—fix problem before continuing
	1b Improve production equipment capability	1b • CNC production equipment instead of manual • Preventive maintenance program • Standardized tooling • Machining centers to avoid repeat setups • Run equipment at or below standard speeds
	1c Improve product/process design	1c • Taguchi methods • Concurrent product/process engineering • Design for manufacturability • Standardized product/product design rules

Source: Thomas Gunn, Ibid.

To answer these questions, all different aspects of CIM, TQC, and JIT must be considered. Gunn added, "each manufacturing strategy objective must be addressed by some portions of these major tools. In product and process design as part of manufacturing strategy, CIM, TQC, and JIT must be integrated".

Figure (2.13)
World-Class Manufacturing Product and Process
Design.



Source: Thomas Gunn, Ibid

Gunn's approach emphasized two important ingredients of World-class manufacturing: total business concept, and continuous improvement. He showed his approach using the example of increasing the number of inventory turns as one of the manufacturing strategy objectives.

In a recent article , Miller and Hayslip (1988) provided a traditional and a modern definitions to manufacturing strategy. The traditional definition, they provided, was that of Miller and Roth (1987, 1988). The modern definition is:

"A manufacturing strategy is a projected pattern of manufacturing choices formulated to improve fundamental manufacturing capabilities, and to support business and corporate strategy." This view of manufacturing strategy is similar to the definitions by Gunn (1987), and Beckman (1990).

In an aggregate terms, manufacturing strategy contents include: cost, quality, dependability, flexibility / responsiveness, and innovation / technology.

Beckman et al (1990) explained that these five components represent the basis for making further strategic decisions. These decisions fall into number of categories, which may include the following:

1. Capacity / facility

- How many sites?

- How large?

- Where to locate?

- How focused?

2. Work force / organization

Skill sets required?

How measured and compensated?

What composition?

3. Information management systems

How structured?

Who owns?

Degree of automation?

4. Vertical integration / sourcing

How vertically integrated (forward or backward)

How many suppliers?

What type of supplier relationship?

5. Process technology

What types?

How automated?

Make or buy?

6. Quality

What is it?

How measured?

Who's responsible?

For companies to attain a competitive edge, these decisions must be made in conjunction with or relative to business and manufacturing strategy. Bekman

et al proposed the following manufacturer's strategic decision making matrix

Table (2.3)

	COST	QUALITY	AVAIL- ABILITY	FEATURES
CAPACITY / FACILITY	+	+	++	
WORK FORCE ORGANIZATION	+++	+++	++	+
INFORMATION MANAGEMENT	++	++	+++	
VERTICAL INTEGRATION	+++	+++	++	+++
PROCESS TECHNOLOGY	++	++		
QUALITY	+++	+++	+++	+++

Source: Moody, Patricia, "Strategic Manufacturing: Dynamic New Directions for the 1990's, Dow-Jones Irwin, Homewood, Illinois, 1990

Leonard (1990) viewed manufacturing strategy as an integrator. He explained that the real power of the manufacturing strategy can be realized when we look at it from interfunctional rather than interafunctional

perspective. Other parts of the organization, in this perspective, influence manufacturing strategy. Leonard indicated that World-class manufacturing firms have learned the necessity for understanding the nuance of this interfunctional alignment. They are using manufacturing strategy process as an important vehicle to obtain synergistic benefits. This can be achieved by coordinating various parts of the business unit, and strategically position the major elements within manufacturing decision area.

A common thread between these definitions, specially the most recent ones, is that manufacturing strategy should have at least three characteristics (Beckman (1990). First, It must support business strategy to be able to generate synergetic effects. Second, It should describe the process of resource allocation within the manufacturing function so that the goals of the firm are optimally achieved. Finally, manufacturing strategy should reflect the pattern of actual decisions (example, capacity, expansion, automation, e.t.c.) made in the manufacturing function. Roth's (1990) definition reflects these facts. She defined Manufacturing strategy as a "pattern stream" of first order manufacturing decisions. The basis of Roth's definition is Hayes and Wheelwright (1985) schema for manufacturing strategy. A schema in which Hayes and Wheelwright indicated that the content of manufacturing strategy should be expressed in terms of Structural "(brick and mortar)" and infrastructure "(soft)" decisions. McGaughey (1988, 1989) defined manufacturing strategy as "the means to achieve business goals or mission

through effective use of manufacturing strength as a competitive weapon. It is not the unconditional pursuit of efficiency, it is rather the continuous drive for effectiveness (doing the right thing). For maximum effectiveness, the entire production system ought to be aligned with the strategies of other functions and the overall strategies of the firm." McGaughey stated that the choice of manufacturing strategy should be based on a clear set of decisions. Among these decisions are:

1. What are we going to do differently?
2. What change in emphasis will we make?
3. What are our new priorities?
4. What new policies will we adopt?
5. What resources (People, finance) will we allocate to each manufacturing element?
6. Can we implement this strategy given the available resources?

The process of developing a manufacturing strategy must be tailored to the culture and needs of particular business. This process must entails at least four elements. First, Manufacturing strategy must be consistent with overall business strategy. Secondly, it must support the corporate goals and objectives. Thirdly. The process itself must employ creative thinking and analytical tools. Finally, the development of manufacturing strategy must be an iterative process.

On January 8th, 1990 I attended a two-day conference on manufacturing strategy at the University of Michigan. The conference included participants from academia and industry. The main concerns, when it comes to defining manufacturing strategy, was a complete definition to the term manufacturing strategy is not yet at hand. Although this conclusion might sound strong, the following reasons, in my opinion, obviates the need to such a definition. First, if one is to define manufacturing strategy from systems perspective, one should consider some important factors. Among these factors are the customer, the other subsystems of the firm, and the external environment. Second, Manufacturing strategy is not just manufacturing problem, or just the responsibility of manufacturing organization in the firm, it should be an interfunctional problem. Therefore, the definition should be broaden to include and be integrated with other functional strategies.

Skinner (1969, 1974, 1978, 1985, 1990) considered the following four factors as the major components of any manufacturing strategy: cost, quality, flexibility, and dependability. The many research papers by Miller and Roth (1987, 1988, 1989, and 1990) examines the contents of manufacturing strategy in terms of the structural and infrastructural decisions proposed by Hay and Wheelwright (1984).

TECHNOLOGY STRATEGY LINK.

Technology and manufacturing strategy link is poorly formulated and defined. Skinner (1986) mentioned the importance of adopting and successfully implementing manufacturing technologies such as CAD/CAM, Robotics, Flexible machining centers on productivity. Professor Skinner warned that failures in small companies and crises in big ones are, in fact, inability of one or more of the key managers to understand and to manage the technological component of their business.

Kantrow (1980) reviewed the literature on strategic implications of technological decisions. He indicated that the critical link between technology and strategy exists. The only real choice is whether managers want to see it. He also explained that technology bears an integral relation to company's strategic thinking by helping to define the range of its possibilities. At the same time, it provides a good portion of the means by which strategy, once decided on, is to be carried into effect. In his opinion, it is sheer foolishness for managers to leave the technological dimensions of manufacturing operations out of their strategic thinking.

Heizer (1986) addressed the issue of "A manufacturing strategy for U.S." In his opinion, "to achieve excellence, an organization should think in strategic terms, not in terms of yesterday's innovation. Eliminating waste is not the only solution to pursue productivity". Manufacturing strategic strength should be considered as one of the most important factor in this regard. Heizer

continues to say " that strategic strength is for many manufacturers, Utilization of Computer-oriented information systems which are now available. Such strategy will use information systems skills and technology to move toward Computer Integrated Manufacturing". Heizer evaluated past and current techniques for improving productivity and projected that CIM will be the technique for the 1990's. His evaluation is illustrated below:

Figure (2.14)
Manufacturing Productivity

Manufacturing Productivity		
Fig. 1—Productivity Techniques		
Historically	Currently	The Future—Computer Integrated Manufacturer
Plants that Grew but Were Not Reorganized	Focused Factory (Manufacturing Cells)	Layout Design Via —Systematic layout planning & computer-aided layout planning Flexible Manufacturing —To maximize benefits of group technology —Electronic rather than mechanical or manual machine control
Job Lot Production	Group Technology	Computer-Aided Design to Ensure Comprehensive Code Generation Computer-Aided Process Planning (Routing) Enhanced Support for Production and Inventory Control from Design Engineering and Manufacturing Staff
Just-in-Case Inventory	Just-in-Time Inventory	Improved Data Processing Network —Intra plant to aid in —Maintenance (Analog feedback) —Inventory control —Scheduling —Inter plant to aid in —Suppliers scheduling —O.C. feedback (Quality at the source) —Clerical functions
Quality Control via Inspectors	Quality Control at the Source	Quality Control Enhanced via Computer Aided Design Early and Continuing Manufacturing Involvement in Design Analog-to-Digital Feedback to Machines and Management Adopt —Statistical process control —Deming's 14 points —Shop training & discipline
Variations in Plant Load	Stable & Uniform Plant Load	Capacity Planning/MRP
Push Through Production	Pull Through Production (Kanban)	Utilization of Group Technology Data Scheduled Production/MRP
EDO as a Given (Set-Up Time Limited by Restrictive Work Rules)	EDO as a Variable (Set-Up Time Reduced by Innovation & Teamwork)	Flexible Manufacturing System (FMS) —Reduced set-up costs —Progressive set-ups —Very small lot sizes Recognize That —Lot size greater than 1 may hide problems —Carrying costs are typically understated

Source: Jay H. Heizer, Ibid

Ebner and Vollmann (1988) traced the history of manufacturing strategy, the competitive thrust, and manufacturing systems from 1960's to the 1980's and projected the trends for these three elements in the 1990's. Their views are summarized below:

Table (2.4)

	1960's	1970's	1980's	1990's
Competitive Thrust	Cost	Market	Quality	Time
Manufacturing Strategy	High Volume Cost Minimization Stabilize Product Focus	Functional Integration Closed Loop	Process Control Material Velocity World Class Mfg. Overhead Cost	New Product Introduction Responsiveness Manufacturing Metrics New Organization Forms
Manufacturing Systems	PICS NC	MRP MPS FFC CNC	MRP II JIT OPT DNC SPC, TQC CAD, CAM	CIM Supervisory Systems Scenario Generation Selective Intervention Decentralization Simplification

Source: Ebner, Miller L, Thomas Vollmann, "Manufacturing Systems for the 1990's." In *Intelligent Manufacturing: Proceedings from the first International Conference on Expert Systems and the Leading Edge in Production Planning and Control*, Michael Oliff (Ed.), the Benjamin / Cummings Publishing Company Inc., Reading, May, 1988.

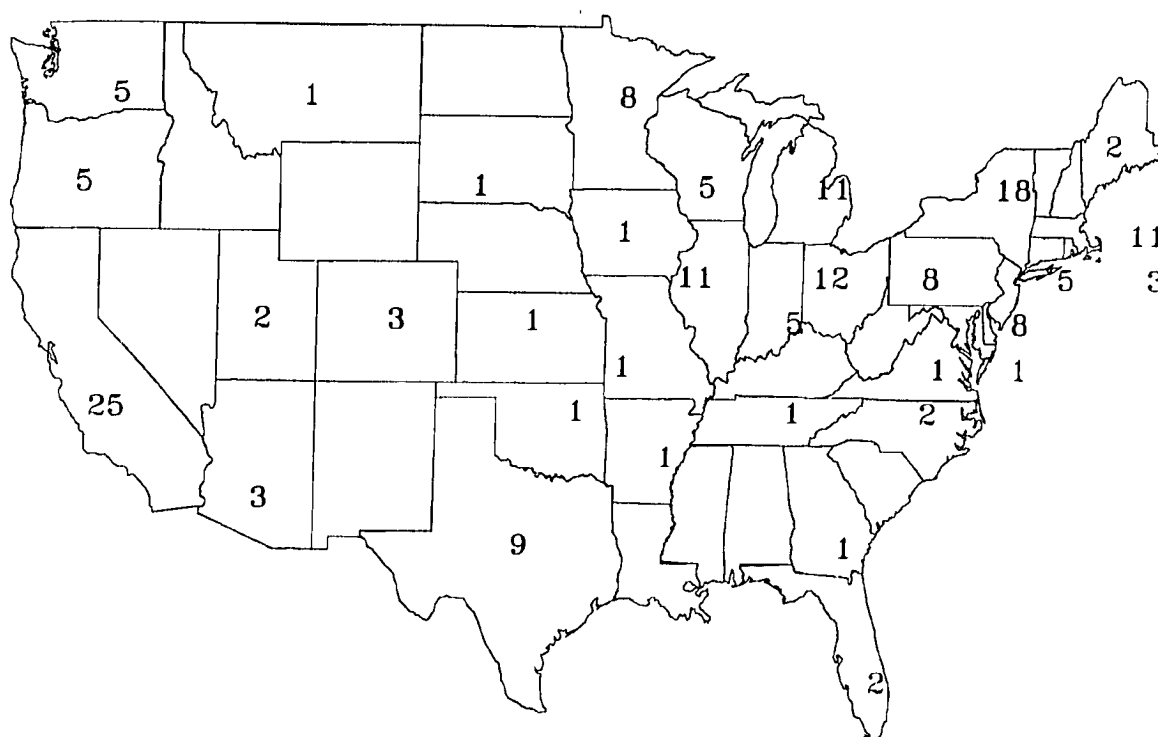
CHAPTER (III)

RESEARCH METHODOLOGY

The Sample:

The data is based on information from 165 manufacturing business units in the United States. Figure (3.1) Below shows the geographical distribution of the sample.

Figure (3.1) Geographical Distribution of the Sample



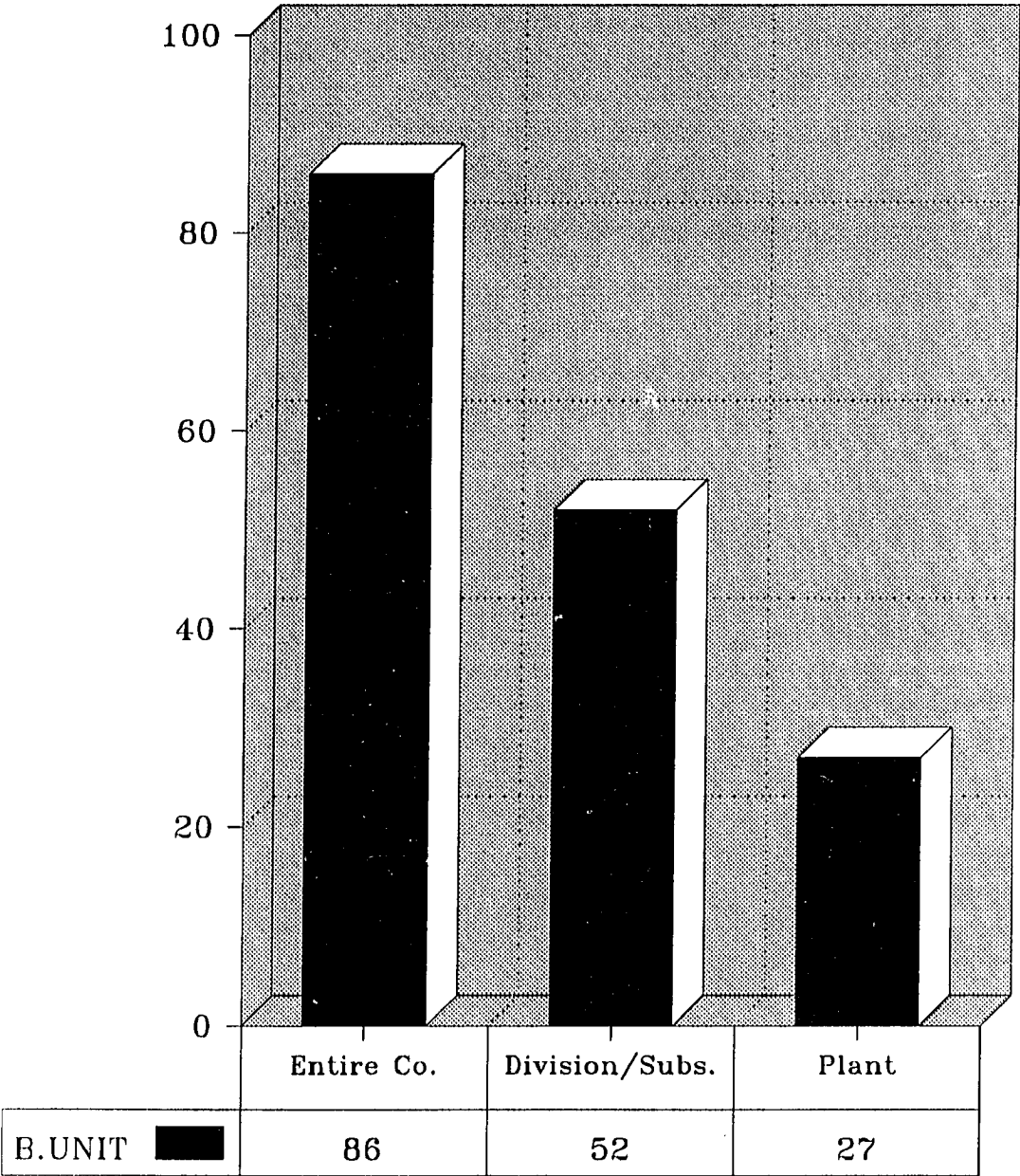
A manufacturing business unit, for the purpose of this research, is either an entire company, division or subsidiary, or a plant. Table (3.1) below shows the percentage of respondents in each category.

Table (3.1)

Business Unit

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Entire Company	1	86	52.1	52.1	52.1
Division or Subsidiary	2	52	31.5	31.5	83.6
Plant/Production Facility	3	27	16.4	16.4	100.0
		-----	-----	-----	
	Total	165	100.0	100.0	

Figure (3.2) Business Unit

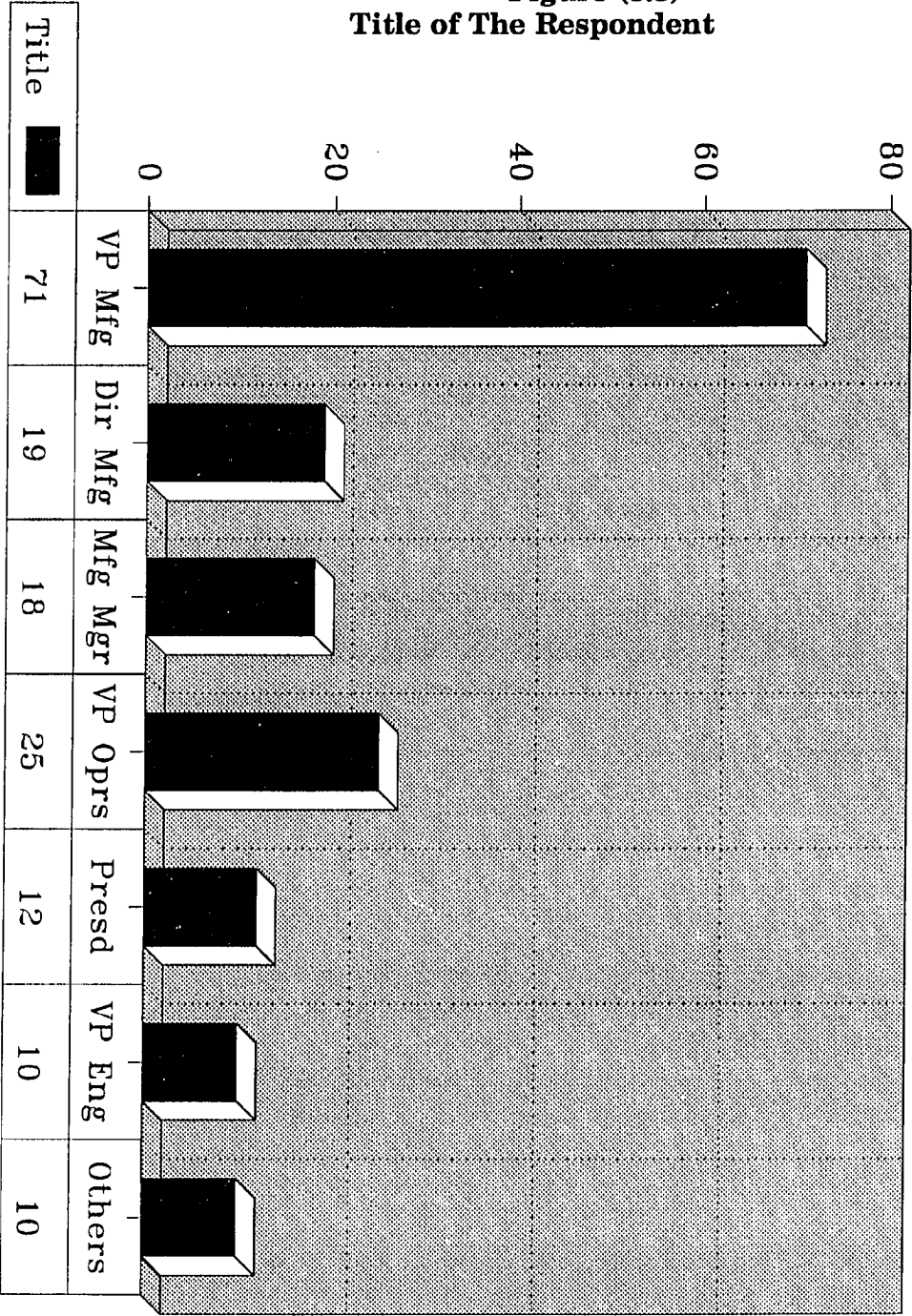


The questionnaire was sent to the Vice Presidents of manufacturing. Valid questionnaires that were received, completed by Vice Presidents for manufacturing, Vice Presidents for operations, Vice Presidents for engineeringg, Vice President for technology, or Directors of these functions. Table (3.2) below shows the percentage of the respondents in each category.

Table (3.2)
Title of the Respondent

Variable Label	Freq- uenc	Percent
Dir. of Engineering	2	1.2
Dir. of Manufacturing	19	11.5
Engineering Manager	1	.6
General Manager	1	.6
Manufacturing Manager	18	10.9
President	12	7.3
Vice President Eng.	10	6.1
Vice President Mfg.	71	43.0
Vice President Oprs.	25	15.2
Vice President Tech.	6	3.6
	----	----
Total	165	100.0

Figure (3.3)
Title of The Respondent



The distribution of the questionnaires was restricted to companies within Standard Industrial Classification (SIC) codes 35, 36, and 37. The industry groups for these SIC codes are industrial machinery and equipment, electronic and other electric equipment, and transportation equipment respectively. Table (3.3) shows the percentage of respondents in each category

Table (3.3)
Industry Group

Value Label	Value	Freq- uency	Percent	Valid Percent	Cum Percent
Sic 3500 To 3599	1	81	49.1	51.3	51.3
Sic 3600 To 3699	2	58	35.2	37.3	88.6
Sic 3700 To 3799	3	19	11.5	11.4	100.0
	.	7	4.2	Missing	
	-----	-----	-----		
Total	165	100.0	100.0		

Figure(3.4)
Industry Group

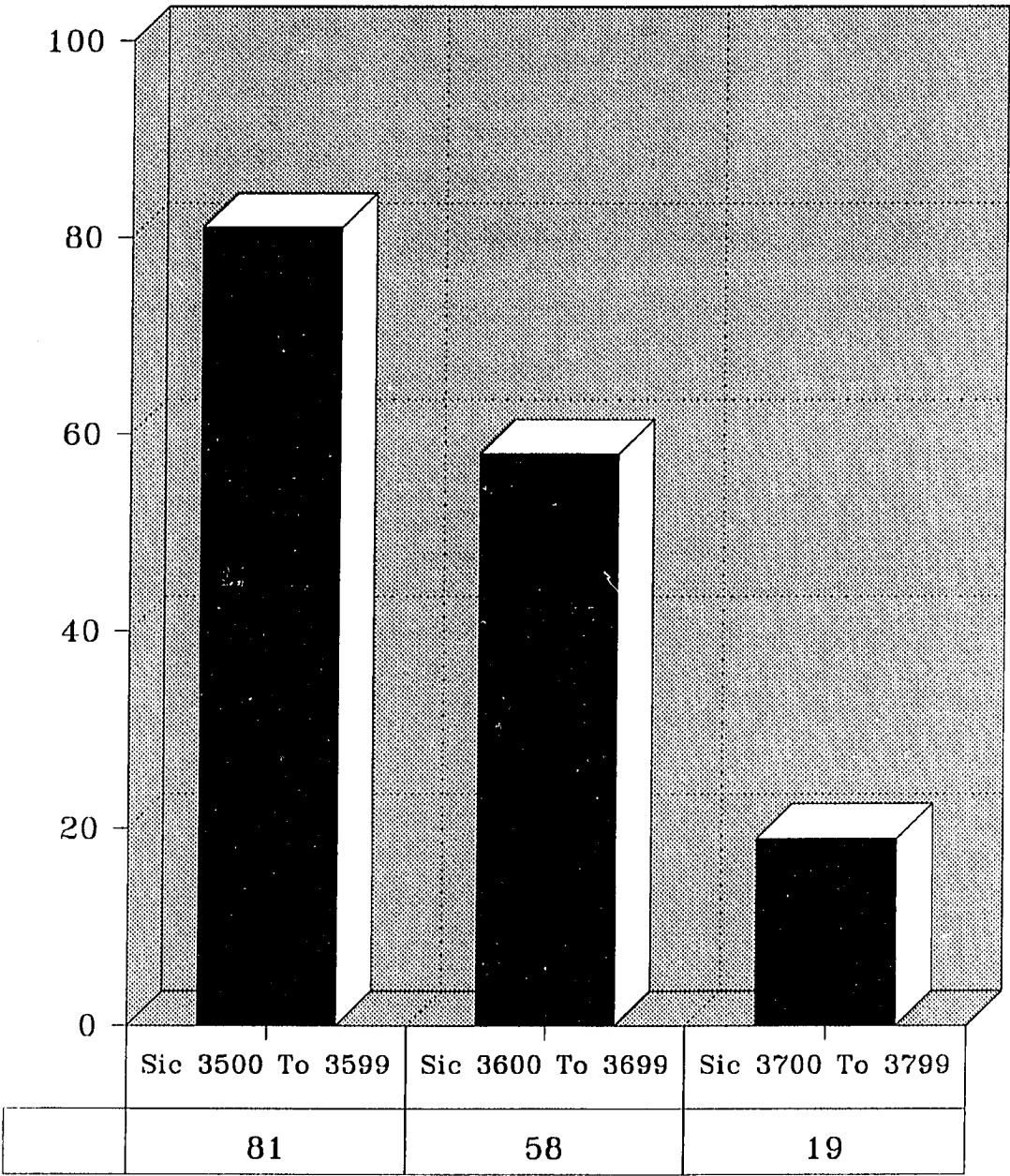


Table (3.4)
Industries Within Each Industry Group

	Frequency	Percent
INDUSTRIAL MACHINERY AND EQUIPMENT		
351 Engines and Turbines	4	2.4
352 Farm and Garden Machinery	3	1.8
353 Construction and Related Machinery	6	3.6
354 Metal Working Machinery	4	2.4
355 Special Industry Machinery	2	1.2
356 General Industrial Machinery	14	8.5
357 Computer and Office Equipment.	42	25.5
358 Refrgration and Service Machinery	3	1.8
359 Industrial Machinery (NEC)	3	1.8
TOTAL	81	
ELECTRONIC AND OTHER ELECTRIC EQUIPMENT		
361 Electric Distribution Equipment	2	1.2
362 Electrical Industrial Apparatus	3	1.8
363 Household Appliances.	3	1.8
364 Electric Lighting & Wiring Equip.	3	1.8
365 Household Audio & Video Equipment.	1	.6
366 Communication Equipment.	16	9.7
367 Electronic Components & Accessories.	20	12.1
369 Misc. Electrical Equip. & Supplies.	10	6.1
TOTAL	58	
TRANSPORTATION EQUIPMENT		
371 Motor Vehicles & Equipment.	6	3.6
372 Aircraft and Parts.	6	3.6
373 Ships & Boat Building & Repairing.	1	.6
375 Motorcycles & Bicycles and Parts.	1	.6
376 Guided missiles & Space Vehicle.	4	2.4
379 Misc. Transportation Equipment.	1	.6
TOTAL	19	
Missing .	7	4.2
Total Valid Cases	165	100.0

DATA COLLECTION

Data pertinent to economic performance were collected from the Compact disclosure system and compustat tapes. The main segments of the financial data for each firm in the sample are balance sheets, operating statements, key financial ratios, profitability reports, segments of business, primary products, description of business, and other demographic data.

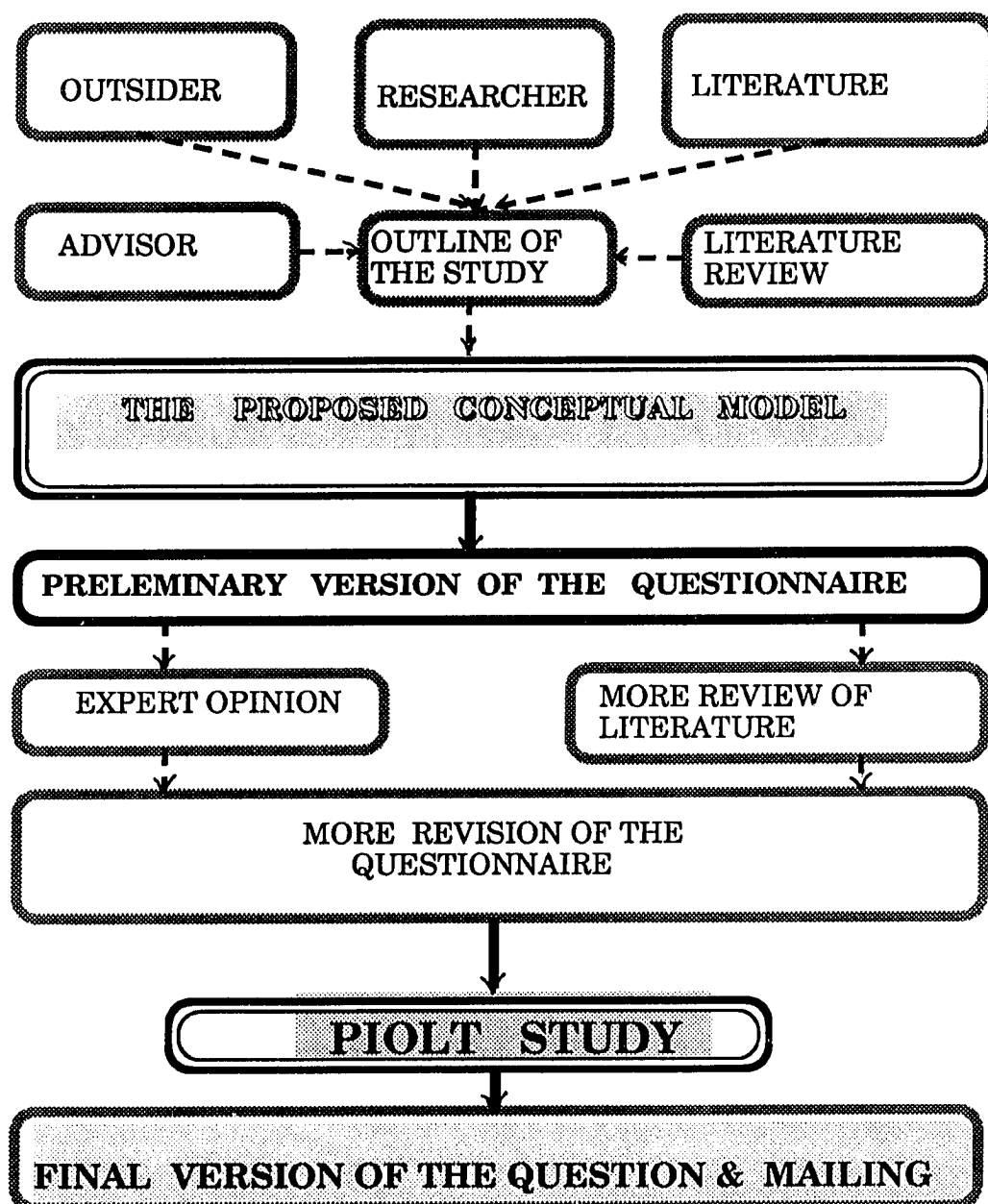
Data pertinent to manufacturing performance were collected through the questionnaire. The questionnaire is presented in Appendix (1). The Questionnaire was based on survey instruments developed by Nemetz (1990); American Electronics Association Productivity Survey (1989); Sharma (1987) and Swamidass (1986). Few changes were introduced to suit our research problem and the conceptual model we developed.

The questionnaire was divided into five segments. Part one of the questionnaire was designed to reflect the profile of the participating business units. Part two was designed to assess the existence, utilization, and the length of time since time based- and computer-based technologies were used. Part three of the questionnaire was designed to assess the manufacturing capabilities of the participating business units. Part four was designed to assess the importance of the dimensions of manufacturing capabilities as related to business strategy. Part five was designed to assess the emphasis of participating business units on structural and infrastructural decisions of their manufacturing strategy.

Research activities up to the mailing of the questionnaire is depicted below.

Figure (3.5)

Research activities in the pilot study stage



MODEL (1): Technology and Manufacturing Performance:

In model (1) we study the relationship between manufacturing performance and computer based- and time based technologies. The dependent variable in this model is manufacturing performance while the independent variable is the level of technology. To operationalize this relationship, the following technology assessment equation was developed:

$$AMTINDEX = \alpha_1 \sum_{n1=1, t}^{all \in n_1} \delta_i T_i + \alpha_2 \sum_{n2=1, d}^{all \in n_2} \delta_i I_i + \alpha_3 \sum_{n3=1, d}^{all \in n_3} \delta_i I_i + \alpha_4 \sum_{n4=1, d}^{all \in n_4} \delta_i I_i \quad (1)$$

Where:

- α_1 Percent of facility converted to using TBT.
- α_2 Percent of product design done using CAD.
- α_3 Percent of programmable automation.
- α_4 Percent of administrative and control work done on a computer.
- δ_i Response to the question "Is TBT or CBT of type (i) being used?"

$$\delta_i = \begin{cases} 0 & \text{if the answer is "NO".} \\ 1 & \text{if the answer is "YES".} \end{cases}$$

- I_i Level of integtation of CBT (i) with other technologies.
- T_i Time since TBT (i) has been used.
- n_1 A set of TBT's.
- n_2 A set of CBT's used int he design of the product.

- n_3 A set of CBT's used in planning, adminstarting and controlling the activities related to the product.
- n_4 A set of CBT's used in manufacturing the product.

Using technology assessment index as a clustering variable, cluster analysis produced three distinct groups of firms. The first group consists of firms with high technology assessment index. The second and third groups consist of firms with medium to low technology assessment index respectively. Borrowing from baseball terminologies, the groups were named "Superstars," "Major leaguer," and "Triple A's" respectively.

In model (1.1) we examined the overall manufacturing performance of the three groups. In models (1.2), (1.3), (1.4) , and (1.5) we examined quality, flexibility, responsiveness, and cost performances of the three groups.

Model (1.1) Overall manufacturing performance

Statistical Hypothesis: There is No statistically significant difference in overall manufacturing performance among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

$$H_1 \text{ At least one } \mu_j \text{ is different (} j = 1,2,3 \text{)}$$

where:

μ_1 is the mean score of overall manufacturing performance for group (1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model(1.2) Flexibility.

Statistical Hypothesis: there is No statistically significant difference in flexibility performance among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of flexibility for group (1).

μ_2 is the mean score of flexibility for group (2).

μ_3 is the mean score of flexibility for group (3).

Models (1.3) Responsiveness

Statistical Hypothesis: There is No statistically significant difference in responsiveness performance among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of responsiveness for group (1).

μ_2 is the mean score of responsiveness for group (2).

μ_3 is the mean score of responsiveness for group (3).

Model (1.3) Quality

Statistical Hypothesis: There is no significant difference in quality performance among the three groups. Statistically speaking,

Where:

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of quality for group(1).

μ_2 is the mean score of quality for group (2).

μ_3 is the mean score of quality for group (3).

Model (1.4) Cost

Statistical Hypothesis: There is No statistically significant difference in cost performance among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of cost for group (1).

μ_2 is the mean score of cost for group (2).

μ_3 is the mean score of cost for group (3).

MODEL (2): Manufacturing performance and Economic Performance

In model (2) we study the relationship between manufacturing performance and economic performance of the firms sampled. The dependent variable in this model is economic performance and the independent variable is

manufacturing performance. Economic performance is measured by the following objective measures: Return On Sales (ROS), Return On Assets (ROA), Return On Equity (ROE), Inventory Turnover (IT), Return On Investment (ROI), and Five Year Sales Growth (FYSG). Wheelwright (1978) considered efficiency as one of the most important criteria on which manufacturing strategy should be based. Evans et al (1990) suggested that efficiency can be measured with indexes such as ROS, IT, and ROA.

Model (2.1) Return On Sales

Statistical Hypothesis: There is no statistically significant difference in return on sales among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

$$H_1 \text{ At least one } \mu_j \text{ is different (} j = 1,2,3 \text{)}$$

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (2.2) Return On Assets

Statistical Hypothesis: There is no statistically significant difference in return on assets among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

$$H_1 \text{ At least one } \mu_j \text{ is different (} j = 1,2,3 \text{)}$$

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (2.3) Return on Equity

Statistical Hypothesis: There is no statistically significant difference in return on common equity among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (2.4) Return On Investment

Statistical Hypothesis: There is no statistically significant difference in return on invested capital among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (2.5) Five Years Sales Growth

Statistical Hypothesis: There is no statistically significant difference in five years sales growth among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (2.6) Inventory Turnover

Statistical Hypothesis: There is no statistically significant difference in Inventory turnover among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

MODEL (3) Technology and Economic performance .

In model (3) we study the relationship between the economic performance of the firms in the sample and the level of AMT. The dependent variable in

this model is economic performance and the independent variable is technology level.

Model (3.1) ROS and Technologies.

Statistical Hypothesis: There is no statistically significant difference in return on sales among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

$$H_1 \text{ At least one } \mu_j \text{ is different (} j = 1,2,3 \text{)}$$

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (3.2) Return On Assets

Statistical Hypothesis: There is no statistically significant difference in return on assets among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

$$H_1 \text{ At least one } \mu_j \text{ is different (} j = 1,2,3 \text{)}$$

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (3.3) Return On Equity

Statistical Hypothesis: There is no significant difference in return on equity among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (3.4) Return on Investment

Statistical Hypothesis: There is no statistically significant difference in return on investment among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (3.5) Five Years Sales Growth

Statistical Hypothesis: There is no statistically significant difference in the five years sales growth among the three groups.

Where:

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

Model (2.6) Inventory Turnover

Statistical Hypothesis: There is no statistically significant difference in Inventory turnover among the three groups.

$$H_0 \mu_1 = \mu_2 = \mu_3$$

H_1 At least one μ_j is different ($j = 1,2,3$)

where:

μ_1 is the mean score of overall manufacturing performance for group(1).

μ_2 is the mean score of overall manufacturing performance for group (2).

μ_3 is the mean score of overall manufacturing performance for group (3).

MODEL (4): Technology - Strategy Link

In this model we examine if there are any difference on the degree of emphasis on the contents of manufacturing strategy among firms with different levels of technology. The dependent variables in this model are the structural and infrastructural decisions in manufacturing strategy while independent variable is technology level.

Statistical Hypotheses: there is no statistically significant difference in the degree of emphasis on structural and infrastructural decisions in manufacturing Strategy among the three groups.

$$H_0 \quad \mu_{1,i} = \mu_{2,i} = \mu_{3,i}$$

H_1 At least one μ_{ji} is different ($j=1,2,3$ $i=1,2,3$)

Where:

$\mu_{1,i}$ is the mean score for the degree of emphasis on action program (i),
Group (1).

$\mu_{2,i}$ is the mean score for the degree of emphasis on action program (i),
Group (2).

$\mu_{3,i}$ is the mean score for the degree of emphasis on action program (i),
Group (3).

OPERATIONALIZATION OF VARIABLES AND RESEARCH INSTRUMENTATION:

Four groups of Variables in accordance with the level of our conceptual model were formulated. These groups of variables are : AMT variables, Dimensions of manufacturing capabilities, Economic variables, and contents of manufacturing strategy. Operationalization of the variables in each group is discussed in detailed.

1. AMT VARIABLES

These variables were compiled from published materials on advanced manufacturing technologies and consulting with major users and developers of these technologies. Among the groups consulted, is the electronics group of the American Inventory and Control Society (APICS). The list was also presented to a group of practitioners and academicians attending a conference on manufacturing strategy (Jan. 8 - 10th, 1990) at the University of Michigan .One part of the questionnaire, the question relates to the use of one or more of these technologies and the extent to which they were used. These technologies and their abbreviations are shown below:

1. Computer Aided Design (CAD).
2. Computer Aided Manufacturing (CAM).
3. Group Technology (GT).
4. Manufacturing Resource Planning (MRP II).
5. Robotics (ROBT).
6. Computer Numerical Control (CNC)
7. Automated Assembly (AA).
8. Automated Material Handling (AMH).
9. Flexible Manufacturing Systems (FMS).
10. Computer Aided Process Planning (CAPP).
11. Direct Numerical Control (DNC).
12. Computer Aided Engineering (CAE).
13. Automatically Guided Vehicle (AGV).
14. Flexible Manufacturing Cell (FMC).
15. Shop-floor Monitoring and Control (SMC).
16. Just-In-Time (JIT).
17. Statistical Process Control - Product (SPC-P).
18. Statistical Process Control - Process (SPC-R).
19. Design For Manufacturability (DFM).
20. Vendor Quality (VQ).
21. Zero Defects (ZD).
22. Quality at the Source (QAS).
23. Preventive Maintenance (PM).

In this research we classify these variables into two groups: Computer-Based Technologies (CBT), Time-Based Technologies (TBT). To develop the CBT and TBT indices,

let

$$\{ N = n_1 , n_2 , n_3 , n_4 \} \quad (2)$$

Where :

N = A set of AMTs variables in this paper.

$n_1 = \{ X_{231} , X_{231t} , \dots , X_{239} , X_{239t} \}$ is a set of TBT technologies.

$n_2 = \{ X_{211} , X_{211d} , X_{211t} , X_{211d} \}$ is a set of CBT pertinent to the design of the product.

$n_3 = \{ X_{213} , X_{213d} , X_{219} , X_{219d} , X_{2114} , X_{2114d} \}$ is a set of CBT pertinent to the planning, administrating, and controlling the activities related to the product.

$n_4 = \{ X_{212} , X_{212d} , X_{214 \text{ to } 218} , X_{214d \text{ to } 218d} , X_{2110} , X_{2110d} , X_{2112 \text{ to } 2113} , X_{2112d \text{ to } 2113d} \}$ is a set of CBT pertinent to the manufacturing of the product.

These independent variables were addressed in the set of questions posed in part II of the questionnaire.

For computer-based technology variables, respondents were asked to indicate whether or not these technologies have been used. If a specific

technology is being used, to what extent has this technology been integrated with all other technologies. The following equation is developed to calculate the score for computer based technologies for each firm in the sample.

Let:

(i) be an index representing the technology

δ_i be the response to the question "is this CBT being used?"

$$\delta_i = \begin{cases} 0 & \text{if the response is "NO".} \\ 1 & \text{if the response is "YES".} \end{cases}$$

I(i) be the degree of integrating this technology with other technologies

α_2 be The percentage of product design done on CAD.

α_3 be The percentage of programmable automation.

α_4 be The percentage of Administrative and control work done on a computer.

Then:

$$CBT (SCORE) = \alpha_2 \sum_{n2=1, d}^{all \in n_2} (\delta_i I_i) + \alpha_3 \sum_{n3=1, d}^{all \in n_3} (\delta_i I_i) + \alpha_4 \sum_{i=1}^{all \in n_4} (\delta_i I_i) \quad (3)$$

For time-based technologies, respondents were asked to indicate whether or not these technologies have been used, for how long has the technology been used, and what percentage of their facilities has been converted to using these

technologies. The following equation is developed to calculate the score for time based technologies.

Let

(i) be an index representing the TBT technology.

δ_i be the response to the question "is this TBT (i) being used?"

$$\delta_i = \begin{cases} 0 & \text{if the response is "NO".} \\ 1 & \text{if the response is "YES".} \end{cases}$$

T_i be time since TBT technology (i) has been used.

α_i be the percentage of the facility converted to using these technologies.

Then:

$$TBT \text{ (SCORE)} = \alpha_1 \sum_{n1=1, t}^{all \in n_1} (\delta_i) T_i \quad (4)$$

A review of the questionnaire items used by Mecimore and Weeks (1987), Nemetz (1989), and PRT & M (1990) necessitate the modified and more representative measure for computer based and time based technologies. the rationale of our modification is many-fold. First, Firms may have an arsenal of technology but they are not integrated the way they should be. Secondly, firms may claim that they have adopted and implemented JIT, TQC, CIM, DFM, and GT, but their facilities are nor fully converted to using these technologies. Finally, to distinguish users and nonusers of these technologies

accurately, we considered time factor since the technology has been implemented. Firms that have used these technologies longer than their counterparts, one may hypothesize, are more likely to exhibit higher performance levels.

2. ECONOMIC PERFORMANCE VARIABLES:

The group of variables which will be investigated here include:

1. Return On Sales (ROS).
2. Return On Assets (ROA).
3. Return On Equity (ROE).
4. Return On Investment (ROI).
5. Five Years Sales Growth (FYSG).
6. Inventory Turnover.

For each firm in the sample , the value of these economic performance variables was downloaded from Disclosure system or compustat tapes. A computer file for each firm is generated and as soon as responses were received, this file along with the responses to the questionnaire were incorporated before data analysis started.

3. MANUFACTURING CAPABILITIES VARIABLES:

These variables are represented in our conceptual model by boxes labelled manufacturing performance, responsiveness to demand changes, and flexibility to product changes. These variables were compiled from published materials, Skinner (1969, 1978, 1985, 1990); Gunn (1987); Roth and Miller (1990); Nemetz (1990), Beckman et al (1990); Huge and Anderson (1987); Voss (1987, 1988); Hayes at al (1984, 1988). A list of variables relating to our

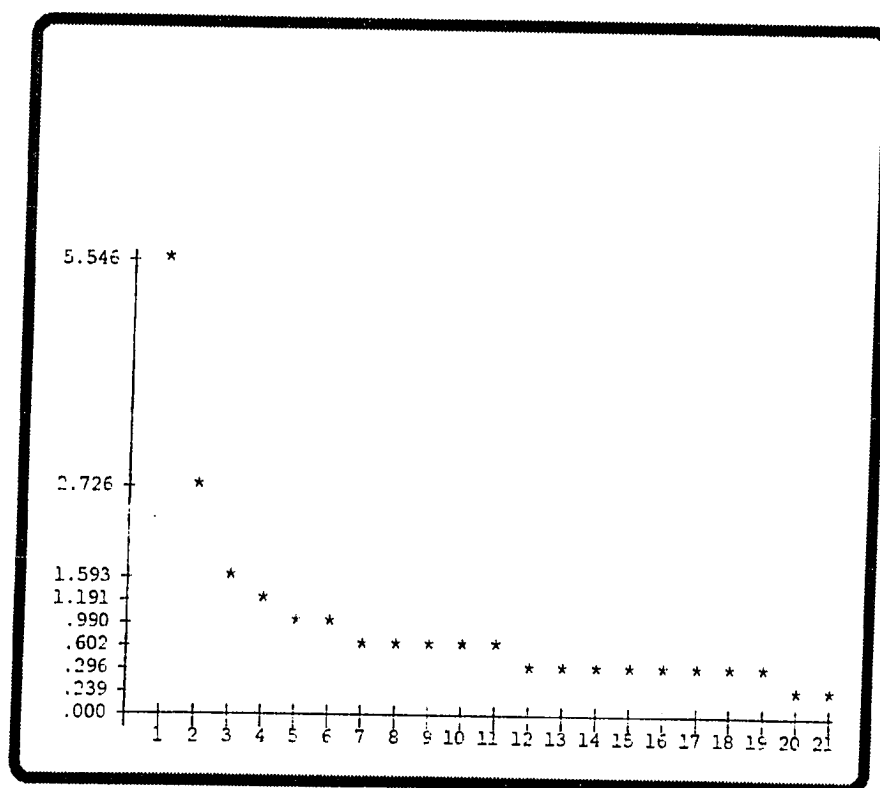
conceptual model is shown below:

1. New Product Introduction.
2. Introducing new Production Process.
3. Product Varieties.
4. Product Features.
5. R & D Efforts
6. Lead Times of Orders.
7. Time to Market.
8. Speed in Changing Product Volume.
9. Speed in Developing New Products.
10. Speed in Making Product Change-Overs.
11. Response to Short Term Customer Requirements.
12. Ability to meet Production Schedule and Delivery Dates.
13. Product Quality.
14. Vendor Quality.
15. Design and Engineering Quality.
16. Manufacturing Workmanship.
17. Cost of Quality.
18. Product R & D cost.
19. Unit Material Cost.
20. Unit Labor Cost.
21. Unit Overhead Cost.

To operationalize the manufacturing performance variables, part (III) of the questionnaire was developed.

Principle component of factor analysis with varimax rotation produced four factors that accounted for almost sixty percent of variation in the data. The factors were named flexibility, Responsiveness, quality, and cost.

Figure (3.6)
Scree Plot for Rotated Factors.



Varimax converged in 6 iterations.

	Responsiveness	Cost	Flexibility	Quality
X37	.62886			
X310	.62175			
X311	.61114			
X36	.58752			
X38	.53731			
X39	.47870			
X312	.47501			
X319		.74622		
X321		.72790		
X317		.64249		
X320		.63480		
X318		.57625		
X31			.64297	
X33			.57743	
X35			.54181	
X34			.53797	
X32			.49650	
X313				.66926
X316				.61933
X315				.59311
X314				.51188

Items X_{31} , X_{32} , X_{33} , X_{34} ,and X_{35} loaded on what was defined as flexibility.

Raw score of these items and equation (5) were used to calculate a measure of flexibility.

$$Flex. (score) = (\sum_{i=1}^5 X_{3i}) / 5 \quad (5)$$

Items X_{36} , X_{37} , X_{38} , X_{39} , X_{310} , X_{311} ,and X_{312} loaded on what was defined as responsiveness. Raw score of these items and equation (6) were used to calculate a measure of responsiveness.

$$Resp. (Score) = (\sum_{i=6}^{12} X_{3i}) / 7 \quad (6)$$

Items X_{313} , X_{314} , X_{315} ,and X_{316} loaded on what was defined as quality. Raw scores for these items and equation (7) were used to calculate a measure of quality.

$$Qual. (Score) = (\sum_{i=13}^{16} X_{3i}) / 4 \quad (7)$$

Items X_{17} , X_{318} , X_{319} , X_{320} ,and X_{321} loaded on what was defined as cost. Raw scores for these items and equation (8) were used to calculate a measure of cost.

$$Cost (Score) = (\sum_{i=17}^{21} X_{3i}) / 5 \quad (8)$$

To measure the overall all manufacturing performance, there are at least two approaches. First, one can take the grand average of flexibility, responsiveness, quality, and cost responses for each firm. However, this approach assumes that the four dimensions are equally important for all firms. A second approach would be to use the question (1) of Part (IV) of the questionnaire to formulate a weight for each of the four dimensions as it relates to the firm's

business strategy. An overall score for the manufacturing performance will be calculated as follows:

$$Mfg_{all} = \beta_1 \left(\sum_{i=1}^5 X_{3i}/5 \right) + \beta_2 \left(\sum_{i=6}^{12} X_{3i}/7 \right) + \beta_3 \left(\sum_{i=13}^{16} X_{3i}/4 \right) + \beta_4 \left(\sum_{i=17}^{21} X_{3i}/5 \right)$$

Where:

β_1 is the importance of flexibility as a competitive factor.

β_1 is the importance of responsiveness as a competitive factor.

β_1 is the importance of quality as a competitive factor.

β_1 is the importance of cost as a competitive factor.

4. MANUFACTURING STRATEGY CONTENTS:

To study the variables of the manufacturing strategy contents, we reviewed three important definitions, of manufacturing strategy (see literature review): Hayes et al (1984), Gunn (1987), Miller and Hayslip (1989).

According to Hayes et al (1984), structural decisions in manufacturing strategy include:

1. What to make and what to buy.
2. The capacity level to be provided.
3. Number and size of plants.
4. Choice of equipment and process technology.
5. Production and inventory system.
6. The quality control system.
7. Cost and other information system.

- 8. Workforce management policies.**
- 9. Organization structure.**

Gunn (1987), and Miller and Hayslip (1989) considered Haye's definition as classical definition, and modern factors must be considered in defining manufacturing strategy. Gunn (1987) indicated that among these modern factors:

- 1. Shorter new product lead time.**
- 2. More inventory turnover.**
- 3. Shorter manufacturing lead time.**
- 4. Highest quality.**
- 5. More flexibility.**
- 6. Less waste.**
- 7. Highest return on assets.**

The definition provided by Miller and Hayslip's (1989) focused on manufacturing choice in actionable terms and ties it to two crucial areas; key capability development and strategic plan development. Their definition is shown below:

"A manufacturing strategy is a projected pattern of manufacturing choices formulated to improve fundamental manufacturing capabilities, and to support business and corporate strategy."

The work of Hayes et al (1988); Roth (1988, 1989, 1990); Ward et al (1989); Ebner and Vollmann (1988) represent this modern view of manufacturing strategy. Based upon the definitions and works mentioned above, the following structural and infrastructural variables will be studied:

- 1. Manufacturing lead time reduction.**
- 2. Vendor lead time reduction.**
- 3. Just-In-Time.**
- 4. Reducing setup/changeover Time.**
- 5. Flexible Manufacturing Systems.**
- 6. Group Technology.**

7. Introducing Robots.
8. Computer Aided Design.
9. Capacity Expansion.
10. reconditioning of Physical Facility.
11. Automating Jobs.
12. Reducing size of Manufacturing Units.
13. Plant Relocation.
14. Manufacturing Reorganization.
15. Closing Plants.
16. Changing Labor/Management relation.
16. Supervisor Training.
17. Management Training.
18. Worker Training.
19. Preventative maintenance.
20. Job Enrichment.
21. Worker Safety.
22. SPC- Product.
23. SPC- Process.
24. Vendor Quality.
25. Zero Defects.
26. Integrating Information Systems Across Areas.
27. Integrating Information Systems within Manufacturing.
28. Yield problems, rejects.
29. Computer Aided Manufacturing.
30. giving workers more planning responsibility.
31. giving workers a broader range of tasks.
32. Narrowing product lines.
33. Manufacturing reorganization.
34. defining a manufacturing strategy
35. Quality Circles
36. Reducing the size of the Manufacturing workforce.
37. Devolving new processes for old products.
38. Developing new processes for new products.

To operationalize these variables, respondents were asked to indicate the degree of their emphasis on each issue on a scale of 1(no emphasis) to 5(critical emphasis). These issues were analyzed using multivariate and univariate statistics. The rationale behind this is two fold. First, We want to see indepth analysis of the differences if they exist. Secondly, our sample is so diverse that

studying these issues individually, will give us some insights of the differences between different industry groups.

VALIDITY AND RELIABILITY OF THE INSTRUMENT:

VALIDITY:

One of the important property of the empirical measurement is validity. Validity is defined as the extent to which any measuring instrument measures what it is intended to measure (Carmines and Zeller(1979)). Cronbach (1971) cautioned that one validates, not a test, but the interpretation of the data arising from a specific procedure. According to Carmines and Zeller (1985), there are three types of validity tests:

1. Criterion related validity.
2. Content validity. and
3. Construct validity.

Factor analysis was utilized to assess the face validity of the manufacturing capability items in part three of our instrument. The four factors emerged were in a general agreement with the current literature of AMTs. Therefore, they have a high degree of face validity.

RELIABILITY

In this part of the study we ask how can we evaluate the degree to which the items used to measure Computer Based Technology and Time Based Technology accurately represent these two concepts. In essence the

question here is what are the desirable characteristics or quality of the measurement procedure when it comes to the two concepts advanced above.

Carmines and Ziller (1975) stated that there are two basic properties of any empirical measurement. These two properties are validity and reliability.

Reliability concerns the extent to which an experiment , test, or measure procedure yields the same results on repeated trials. Since it is difficult, if not impossible, to replicate the same results in repeated measures especially in social science, there is always a chance for errors. A good design should minimize that error. Mathematically speaking, the observed value of a variable should equal to its true value plus or minus an error. The lower the value of the error the more reliable the instrument is.

Grosov and Sardy (1985) indicated that an instrument is reliable if it yields measurement which are: (1) consistent and predictable, and (2) Accurate and precise.

According to Grosov and Sardy (1985) , there are four tests of reliability. These test are:

1. Test reliability.
2. Internal consistency reliability.
3. Item reliability, and
4. Equivalent forms reliability.

Tables (3.6, 3.7, 3.8, 3.9) show the internal consistency of four scales used in the analysis.

Table (3.6)
Reliability Analysis (CBT)

#	Variable	Variable Label
1.	X21	Computer Aided Design (CAD).
2.	X211D	CAD Linkage to Other Technologies.
3.	X212	Computer Aided Manufacturing (CAM).
4.	X212D	CAM Linkage to Other Technologies.
5.	X213	Manufacturing Resource Planning (MRPII).
6.	X213D	MRPII Linkage to Other Technologies.
7.	X214	Robotics.
8.	X214D	Robotics Linkage to Other Technologies.
9.	X215	Computer Numerical Control (CNC).
10.	X215D	CNC Linkage to Other Technologies.
11.	X216	Automated Assembly.
12.	X216D	Automated Assembly Linkage to Other Technologies.
13.	X217	Flexible Manufacturing Systems (FMS).
14.	X217D	FMS Linkage to Other Technologies.
15.	X218	Automated Material Handling.
16.	X218D	Automated Material Handling Linkage to Other Technologies.
17.	X219	Computer Aided Process Planning (CAPP).
18.	X219D	CAPP Linkage to Other Technologies.
19.	X2110	Direct Numerical control (DNC).
20.	X2110D	DNC Linkage to Other Technologies.
21.	X2111	Computer Aided Engineering (CAE).
22.	X2111D	CAE Linkage to Other Technologies.
23.	X2112	Automated Guided Vehicle (AGV).
24.	X2112D	AGV Linkage to Other Technologies.
25.	X2113	Flexible Manufacturing Cell (FMC).
26.	X2113D	FMC Linkage to Other Technologies.
27.	X2114	Shop Floor Monitoring and Control (SFMC).
28.	X2114D	SFMC Linkage to Other Technologies.
29.	X25	% of CAD CAE or any Other Computer Assisted Technologies used in Designing the Product.
30.	X26	% of Programmable Automation.
31.	X27	% of Administrative Work done on a Computer.

RELIABILITY COEFFICIENTS

N OF CASES = 157

N OF ITEMS = 31

ALPHA = .9169

Table (3.7)
Reliability Analysis (TBT)

#	Variable	Variable Lable
1.	X231	Just-In-Time (JIT).
2.	X231T	Time Since JIT has been Used.
3.	X232	Group technology (GT).
4.	X232T	Time Since GT has been used.
5.	X233	Statistical Process Control(SPC) - Product.
6.	X233T	Time Since SPC - Product has been used.
7.	X234	Statistical Process Control(SPC) - Process.
8.	X234T	Time Since SPC - Process has been used.
9.	X235	Vendor Quality.
10.	X235T	Time Since Vendor Quality has been used.
11.	X236	Zero Defects.
12.	X234T	Time Since Zero Decfects has been used.
13.	X235	Quality At the Source.
14.	X235T	Time Since Quality at the Source has been used.
15.	X236	Preventive Maintenance.
16.	X236T	Time Since Preventive Maintenance has been used.
17.	X24	% of Facility Converted to using TBT.

RELIABILITY COEFFICIENTS

N OF CASES = 157

N OF ITMES = 17

ALPHA = .8528

Table (3.8)
Reliability Analysis (Manufacturing Capabilities)

(Manufacturing Capabilities))

#	Variable	Variable Lable
1.	X31	New Product Introduction.
2.	X32	Introducing New Production Processes.
3.	X33	Product Varities.
4.	X34	Product Features.
5.	X35	Research and Development Efforts.
6.	X36	Lead Time of Orders.
7.	X37	Time to Market.
8.	X38	Speed in Changing Product Volume.
9.	X39	Speed in Developing New Products.
10.	X310	Speed in Making Product Changeover.
11.	X311	Response to Short Term Customer Requirments.
12.	X312	Ability to Meet Production Schedule and Delivery.
13.	X313	Product Quality.
14.	X314	Vendor Quality.
15.	X315	Design and Engineering Quality.
16.	X316	Manufacturing Workmanship.
17.	X317	Cost of Quality.
18.	X318	Product R&D Cost.
19.	X319	Unit Material Cost.
20.	X320	Unit Labor Cost.
21.	X321	Unit Overhead Cost.

RELIABILITY COEFFICIENTS

N OF CASES = 157

N OF ITMES = 21

ALPHA = .7592

Table (3.9)
Emphasis on Contents of Manufacturing Strategy

Variable listed below are the items in part (V) of the research instrument

#	Var.	#	Var.	#	Var.	#	Var.
1.	X51	2.	X51E	3.	X52	4.	X52E
5.	X53	6.	X53E	7.	X54	8.	X54E
9.	X55	10.	X55E	11.	X56	12.	X56E
13.	X57	14.	X57E	15.	X58	16.	X58E
17.	X59	18.	X59E	19.	X510	20.	X510E
21.	X511	22.	X511E	23.	X512	24.	X512E
25.	X513	26.	X513E	27.	X514	28.	X514E
29.	X515	30.	X515E	31.	X516	32.	X516E
33.	X517	34.	X517E	35.	X518	36.	X518E
37.	X519	38.	X519E	39.	X520	40.	X520E
41.	X521	42.	X521E	43.	X522	44.	X522E
45.	X523	46.	X523E	47.	X524	48.	X524E
49.	X525	50.	X525E	51.	X526	52.	X526E
53.	X527	54.	X527E	55.	X528	56.	X528E
57.	X529	58.	X529E	59.	X530	60.	X530E
61.	X531	62.	X531E	63.	X532	64.	X532E
65.	X533	66.	X533E	67.	X534	68.	X534E
69.	X535	70.	X535E	71.	X536	72.	X536E
73.	X537	74.	X537E	75.	X538	76.	X538E

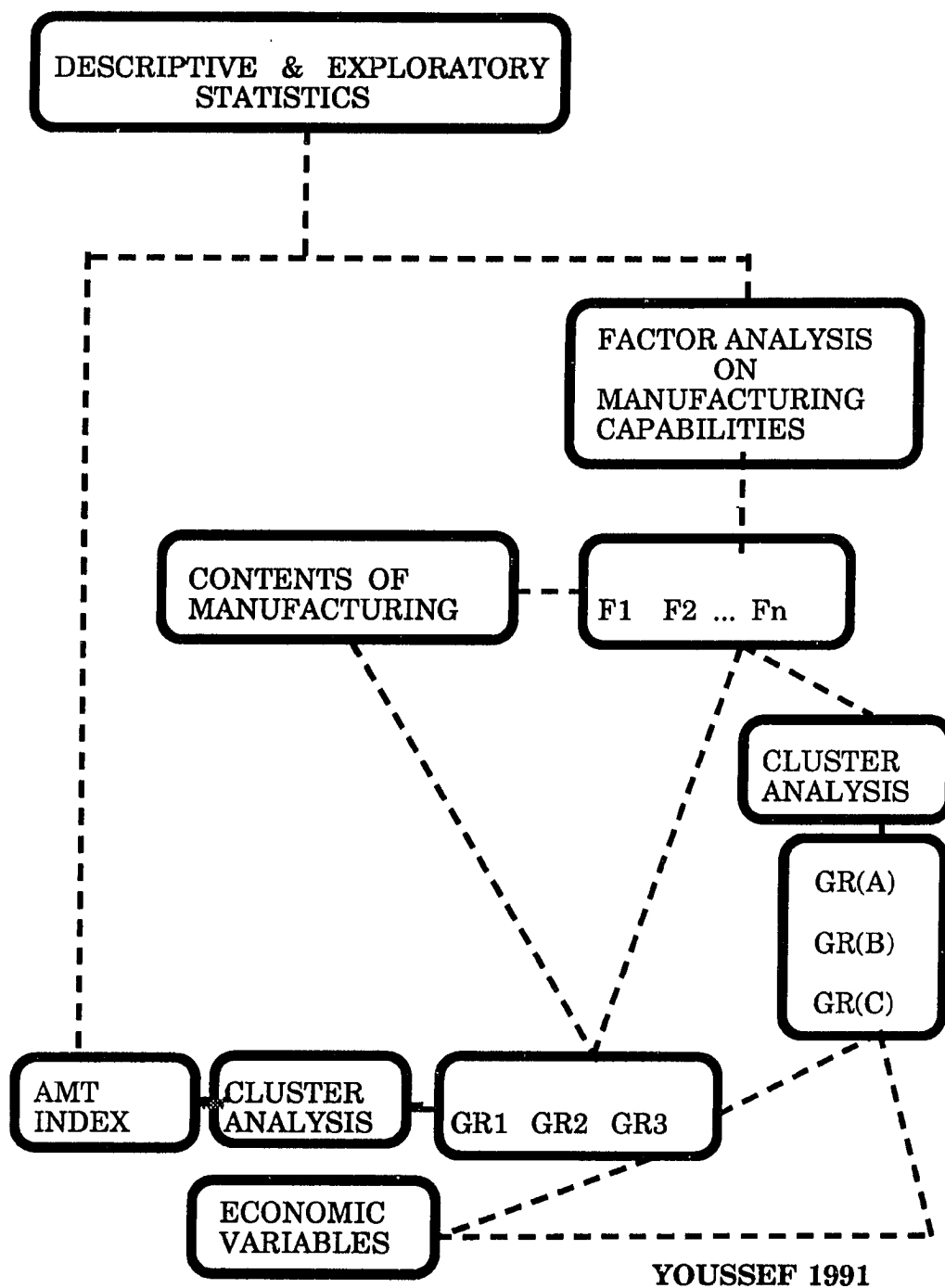
RELIABILITY COEFFICIENTS

N OF CASES 157.0

N OF ITEMS 76.0

ALPHA = .9256

Figure (3.8)
Analysis Strategy



Statistical analysis in the next chapter will proceed in the following order:

PART (I) Descriptive Statistics.

PART (II) Exploratory Statistics.

II.1 Factor Analysis

II.2 Cluster Analysis (AMTINDEX)

II.3 Analysis of Variance among Clusters of II.2

II.3.1 Model (1) (Technology - Manufacturing)

II.3.2 Model (2) (Technology - Eco. Variables)

II.4 Cluster Analysis (Manufacturing)

II.5 Analysis of Variance among Cluster of II.4

II.5.1 Model (4) (Manufacturing - Eco.
Variables)

II.6 Analysis of Variance (Startegt-Technology)

CHAPTER (IV)

ANALYSIS OF THE RESULTS.

The analysis of the data collected in this study is presented according to the diagram depicted at the end of the previous chapter. We will proceed with the analysis in the following order: Descriptive statistics, followed by inferential statistics.

PART (I) DESCRIPTIVE STATISTICS:

I.1. TIME-BASED TECHNOLOGIES (TBT)

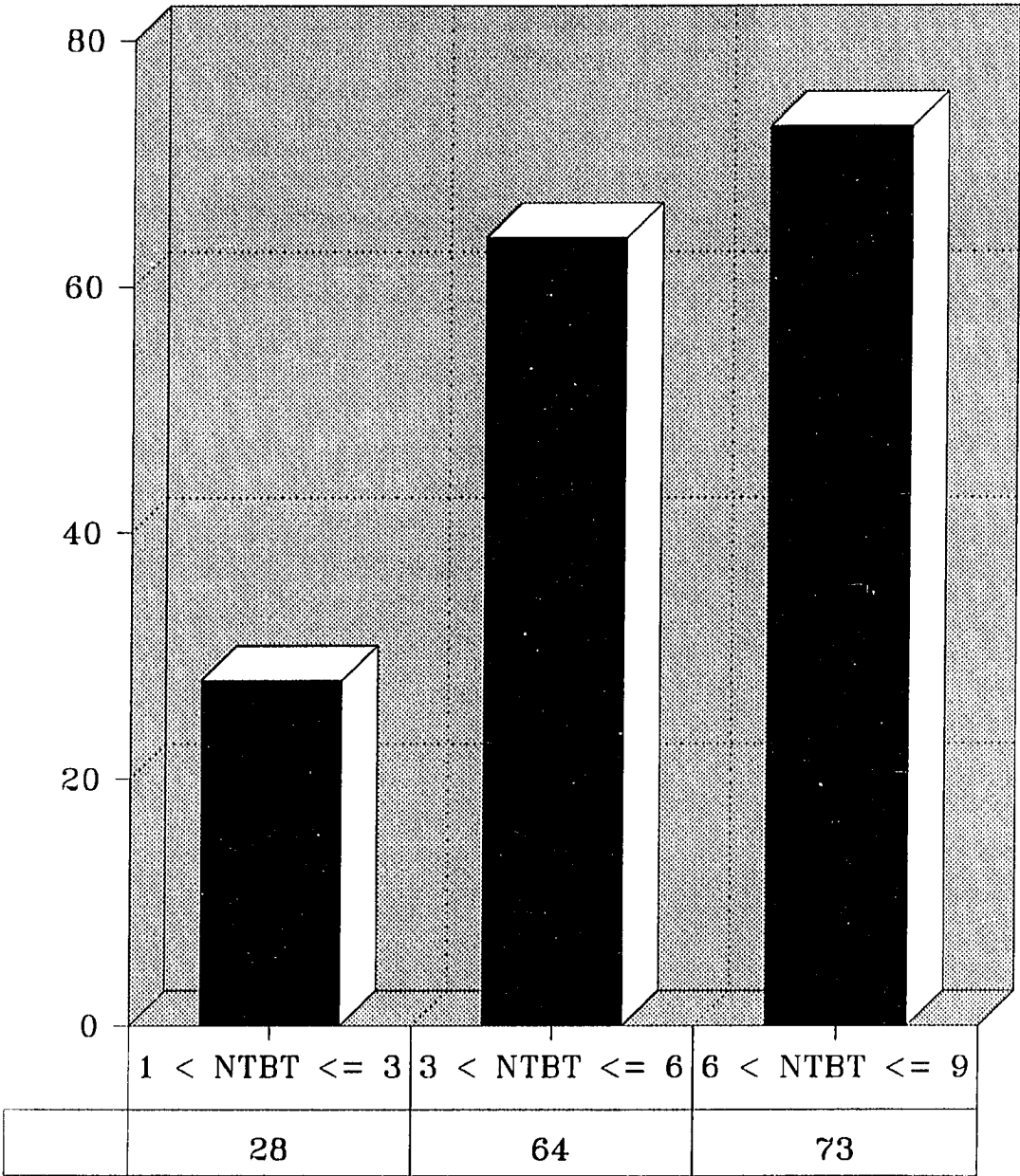
I.1.1 Number of TBT (NTBT)

Respondents were asked about their use of nine time-based technologies. The following Frequency table shows the distribution of the number of these technologies and the percentage of firms using them.

Table (4.1)
Number of Time-Based Technologies

Value Label	Value	Freq- uency	Percent	Valid Percent	Cum. Percent
1 < NTBT <= 3	1.00	28	17.0	17.0	17.0
3 < NTBT <= 6	2.00	64	38.8	38.8	55.8
6 < NTBT <= 9	3.00	73	44.2	44.2	100.0
		-----	-----	-----	
	Total	165	100.0	100.0	

Figure (4.1)
Number of Time-Based Technologies



Among the firms sampled, seventeen percent had fewer than three of these technologies, forty-nine percent had between three and six of these technologies, and forty-four percent had more than six of these technologies.

I.1.2 Percentage of facilities converted to TBT

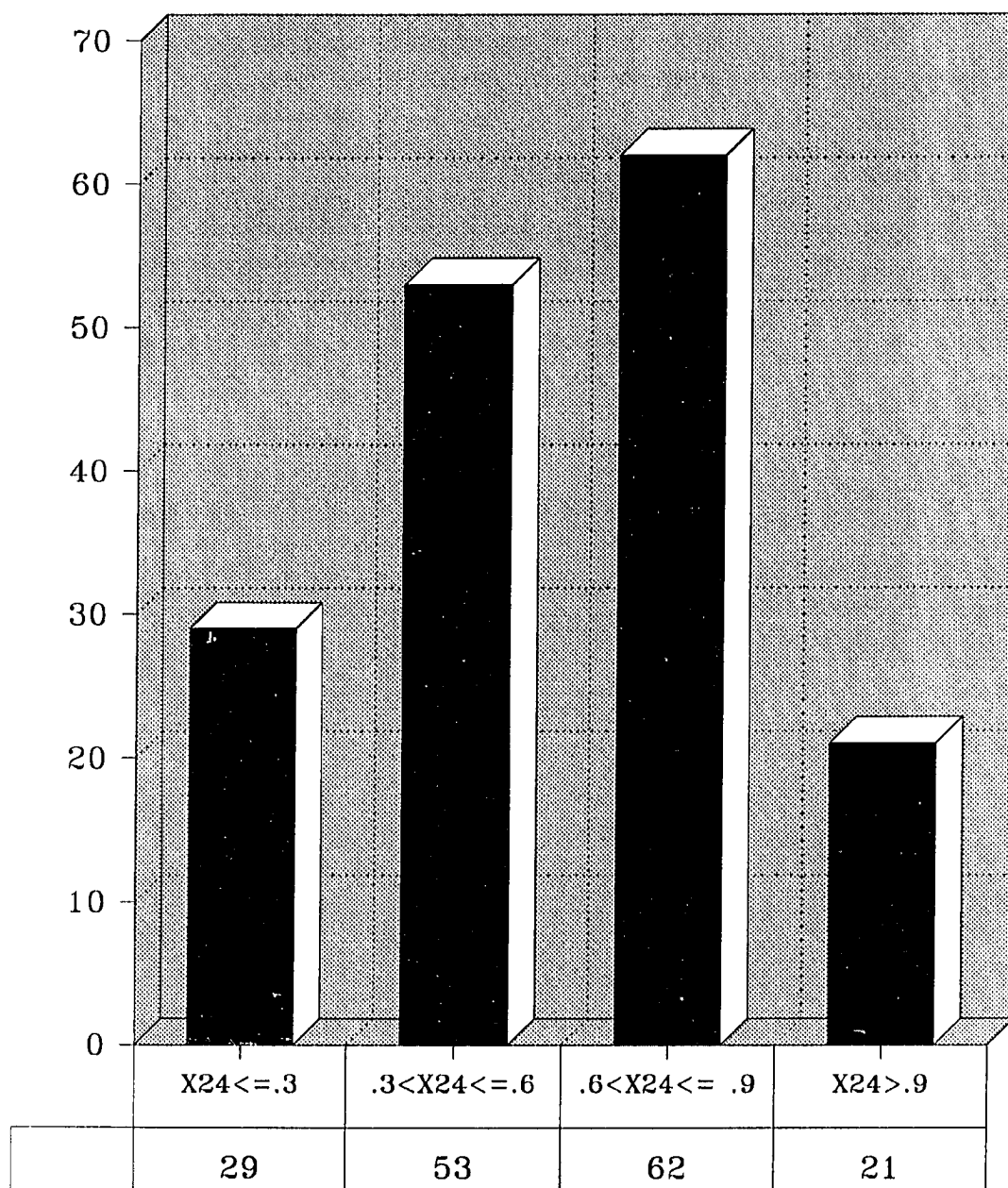
Respondents were also asked about the percentage of their facilities that have been converted to using these technologies. The following frequency table shows the distribution of these percentages.

Table (4.2)
Percentage of Facilities converted to using time-based technologies.

Value Label	Value	Freq- uency	Valid Percent	Cum. Percent	Percent
X24 >= 90 %	1	21	12.7	12.7	12.7
60% < X24 <= 90 %	2	62	37.6	37.6	50.3
30% < X24 <= 60 %	3	53	32.1	32.1	82.4
X24 <= 30 %	4	29	17.6	17.6	100.0
		-----	-----		
	Total	165	100.0	100.0	

Table (4.2) shows that about thirteen percent of the firms sampled have more than ninety percent of their facilities converted to using these technologies, about thirty-eight percent have between sixty and ninety percent of their facilities converted to using these technologies. Figure (4.2) below shows the percentage of facility converted to TBT.

Figure (4.2)
Percentage of Facility Converted to Using TBT



I.1.3 Length of Time TBT have been in use

Respondents were asked to indicate for how long have time-based technologies been used. The following table shows the average length of time since each type of TBT has been used.

Table (4.3)
Average Length of Time Since Each
Time-Based Technology Has Been Used

Variable	Mean	Std Dev	Minimum	Maximum	N
X231T	1.24	1.01	0	3	165
X232T	.71	1.06	0	3	165
X233T	1.08	1.00	0	3	165
X234T	1.23	1.07	0	3	165
X235T	1.18	1.04	0	3	165
X236T	1.87	.97	0	3	165
X237T	1.05	1.15	0	3	165
X238T	1.28	1.10	0	3	165
X239T	1.90	1.10	0	3	165

Scale:

- 0 = the technology is not use
- 1 = the technology has been used but for less than two years.
- 2 = the technology has been used between two to five years.
- 3 = the technology has been used for more than five years.

Where:

X_{231t} is mean time since just-in-time has been used.

X_{232t} is mean time since group technology has been used.

X_{233t} is mean time since design for manufacturability has been used.

X_{234t} is mean time since statistical process control - product has been used.

X_{235t} is mean time since statistical process control - process has been used.

X_{236t} is mean time since vendor quality program has been used.

X_{237t} is mean time since zero defects program has been used.

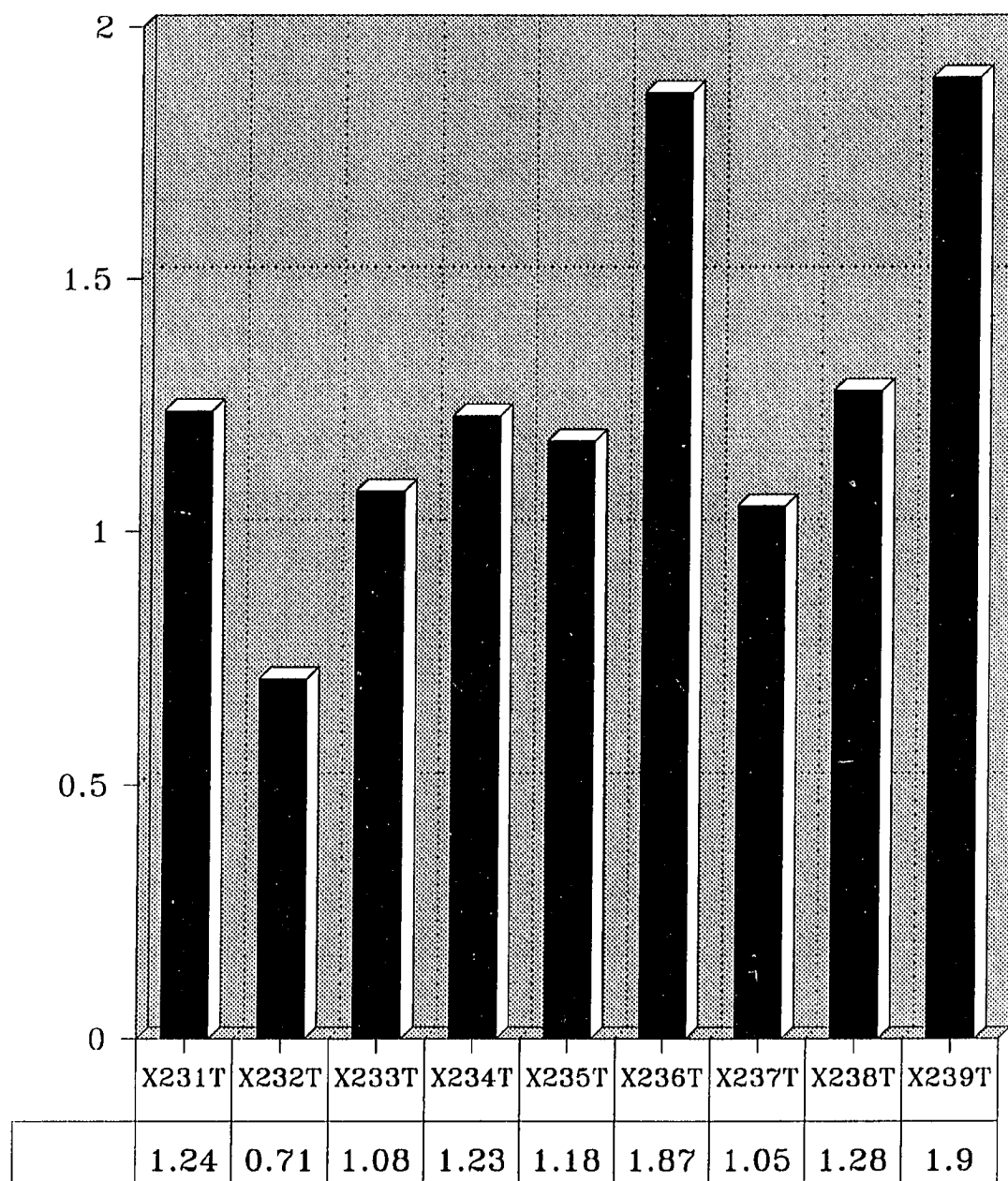
X_{238t} is mean time since quality at the source program has been used.

X_{239t} is mean time since preventive maintenance has been used.

Table (4.3) shows that ,on average, preventive maintenance, vendor quality programs, just-in-time, design for manufacturability, and statistical process control have been used longer than other time based technologies.

Figure (4.3) Below shows time since TBT have been used.

Figure (4.3)
Time Since TBT have been Used



I.2. COMPUTER-BASED TECHNOLOGIES (CBT):

I.2.1 Number of CBT

Respondents were asked about their use of fourteen computer-based technologies. The following frequency table shows the distribution of the number of computer-based technologies and the percentage of firms using them.

Table (4.4)
Number of firms using each
type of technology

Technology	N	NO	YES 1	NONE 2	FEW 3	ALL
X211	165	11	154	43	91	20
X212	165	64	101	20	68	13
X213	165	33	132	17	68	47
X214	165	103	62	29	31	2
X215	165	68	97	36	46	15
X216	165	117	48	13	30	5
X217	165	95	70	16	47	7
X218	165	121	44	11	25	8
X219	165	101	64	13	39	12
X2110	165	120	45	15	19	11
X2111	165	54	111	38	62	11
X2112	165	139	26	8	16	2
X2113	165	92	73	28	37	8
X2114	165	72	93	15	61	17

Where:

X₂₁₁ is Computer Aided Design (CAD).

X₂₁₂ is Computer Aided Manufacturing.

X₂₁₃ is Manufacturing Resource Planning.

X_{214} is Robotics.

X_{215} is Computer Numerical Control (CNC).

X_{216} is Automated Assembly (AA).

X_{217} is Flexible Manufacturing Systems (FMS)

X_{218} is Automated Material Handling (AMH).

X_{219} is Computer Aided Process Planning (CAPP).

X_{2110} is Direct Numerical Control (DNC).

X_{2111} is Computer Aided Engineering (CAE).

X_{2112} is Automatically Guided Vehicle (AGV).

X_{2113} is Flexible Manufacturing Cells (FMC).

X_{2114} is Shop Floor Control by Personal computers.

Table (4.4) shows that the most commonly used technologies are computer aided design, manufacturing resource planning, computer aided engineering, computer aided manufacturing, and computer numerical control. Ninety three percent of the firms sampled used computer aided design, eighty percent used manufacturing resource planning, sixty-seven percent used computer aided engineering, sixty-one percent used computer aided manufacturing, and fifty-nine percent used computer numerical control.

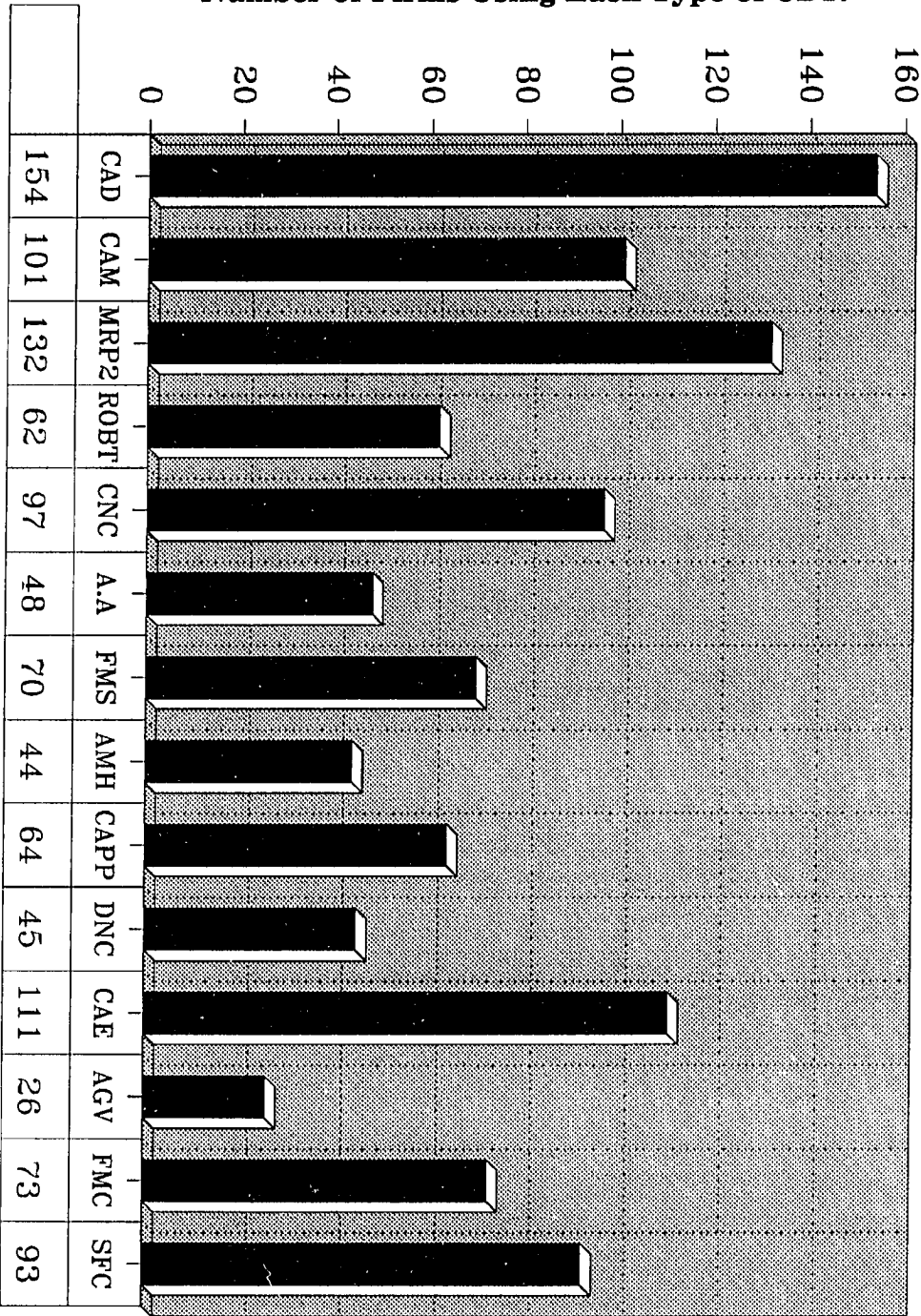
Table (4.4) also shows that the least commonly used technologies are automated guided vehicles, automated material handling, direct numerical control, automated assembly, and robotics. Only sixteen percent of the firms sampled used automated guided vehicle, twenty-six percent used automated

material handling, twenty-seven percent used direct numerical control, twenty-nine percent used automated assembly, and thirty seven percent used robotics.

Table (4.4) also shows that most of the firms used these technologies as stand-alone technologies, or islands of automation. This finding can be seen from the clustering of firms under the columns labeled "None", or "Few" of that table.

The findings from table (4.4) leads us to two conclusions. First, the most commonly used technologies are the ones basically used for the design and planning processes of the product. Secondly, the type of the least commonly used technologies is an indicative of the fact that workerless factory is not yet to exist. These conclusions motivated us to examine the level of integration in depth. Figure (4.4) below shows the number of firms using each type of Computer-Based Technologies.

Figure (4.4)
Number of Firms Using Each Type of CBT.



1.2.2 LEVEL OF INTEGRATION

Respondents were asked to indicate the linkage of each to the other technologies. The following table shows the mean of integration score for each of the fourteen computer-based technologies.

Table (4.5)
Average Level of Integration

Variable	Mean	Std Dev	Minimum	Maximum	N
X211D	1.73	.76	0	3	165
X212D	1.18	1.04	0	3	165
X213D	1.78	1.07	0	3	165
X214D	.59	.83	0	3	165
X215D	1.05	1.03	0	3	165
X216D	.53	.89	0	3	165
X217D	.79	1.00	0	3	165
X218D	.52	.92	0	3	165
X219D	.77	1.05	0	3	165
X2110D	.52	.94	0	3	165
X2111D	1.18	.97	0	3	165
X2112D	.28	.69	0	3	165
X2113D	.76	.96	0	3	165
X2114D	1.14	1.10	0	3	165

Scale

- 0: is not used
- 1: stand alone
- 2: linked to few other technologies
- 3: linked to all other technologies.)

Where:

X_{211d} is the average level of integration of Computer Aided Design (CAD) with other computer-based technologies.

X_{212d} is the average level of integration of Computer Aided Manufacturing (CAM) with other computer-based technologies.

X_{213d} is the average level of integration of Manufacturing Resource

Planning (MRPII) with other computer-based technologies.

X_{214d} is the average level of integration of Robotics with other computer-based technologies.

X_{215d} is the average level of integration of Computer Numerical Control (CNC) with other computer-based technologies.

X_{216d} is the average level of integration of Automated Assembly (AA) with other computer-based technologies.

X_{217d} is the average level of integration of Flexible Manufacturing Systems (FMS) with other computer-based technologies.

X_{218d} is the average level of integration of Automated Material Handling (AMH) with other computer-based technologies.

X_{219d} is the average level of integration of Computer Aided Process Planning (CAPP) with other computer-based technologies.

X_{2110d} is the average level of integration of Direct Numerical Control (DNC) with other computer-based technologies.

X_{2111d} is the average level of integration of Computer Aided Engineering (CAE) with other computer-based technologies.

X_{2112d} is the average level of integration of Automatically Guided Vehicle (AGV) with other computer-based technologies.

X_{2113d} is the average level of integration of Flexible Manufacturing Cells (FMC) with other computer-based technologies.

X_{2114d} is the average level of integration of Shop Floor Control by

Personal Computers (SFCPC) with other computer-based technologies.

Table (4.5) shows the average level of integration for each type of the technologies. Manufacturing resource planning, computer aided design, computer aided manufacturing, computer aided engineering, shop floor monitoring and control by personal computers, and computer numerical control are the main technologies that are most likely linked to few other technologies. The average level of integration for the rest of the technologies is an indicative of the fact that they are being used as stand-alone technologies. Furthermore, we examined the number of firms in conjunction with the level of integration. The average level of integration was calculated using the following equation

$$Avg.L_j = (\sum_{i=1}^{14} Y_i I_i) / 14 \quad (1)$$

Figure (4.5) below shows the Level of Integration of each to the other CBT.

Figure (4.5)
Average Level of Integration of Each Type of CBT

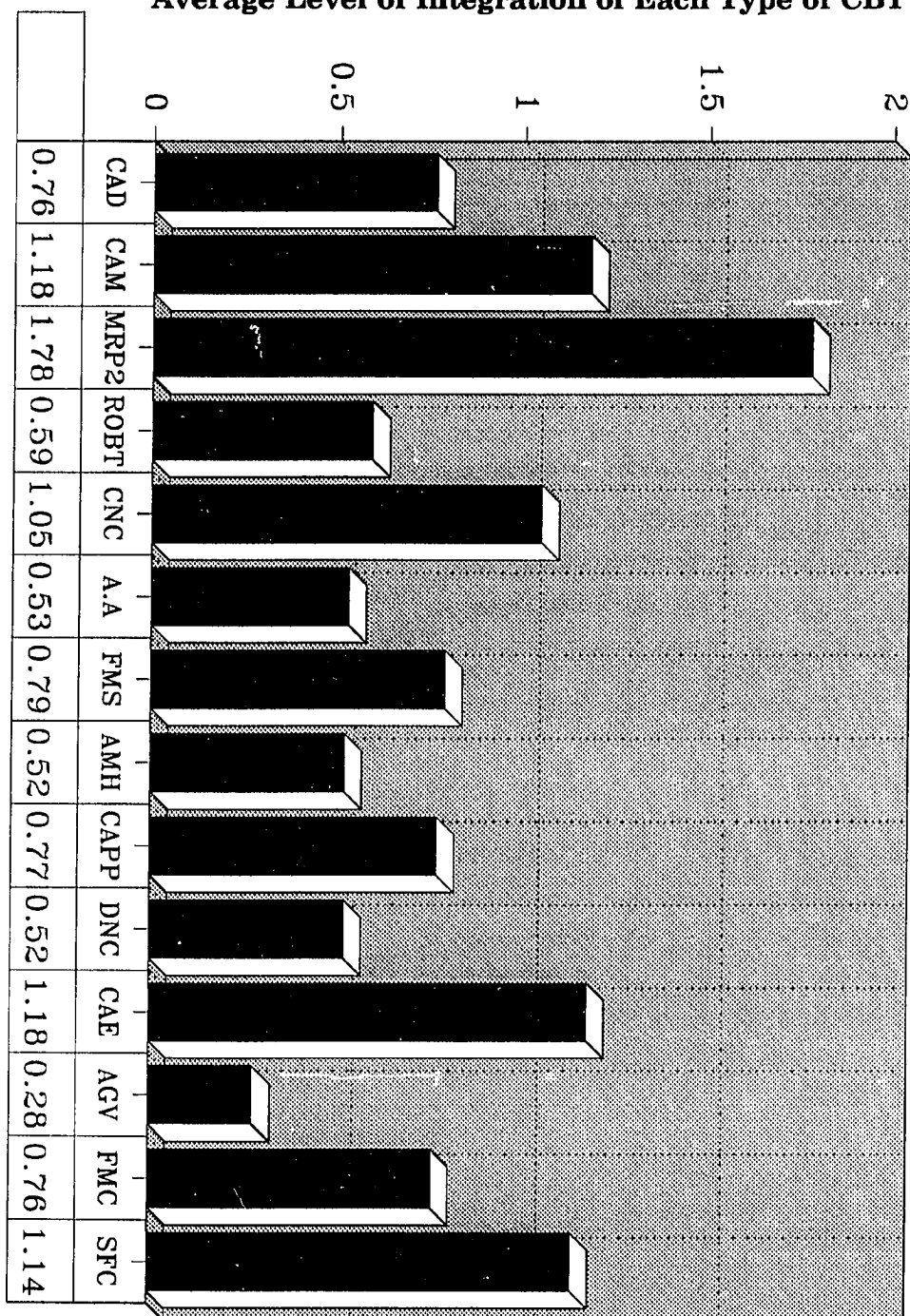
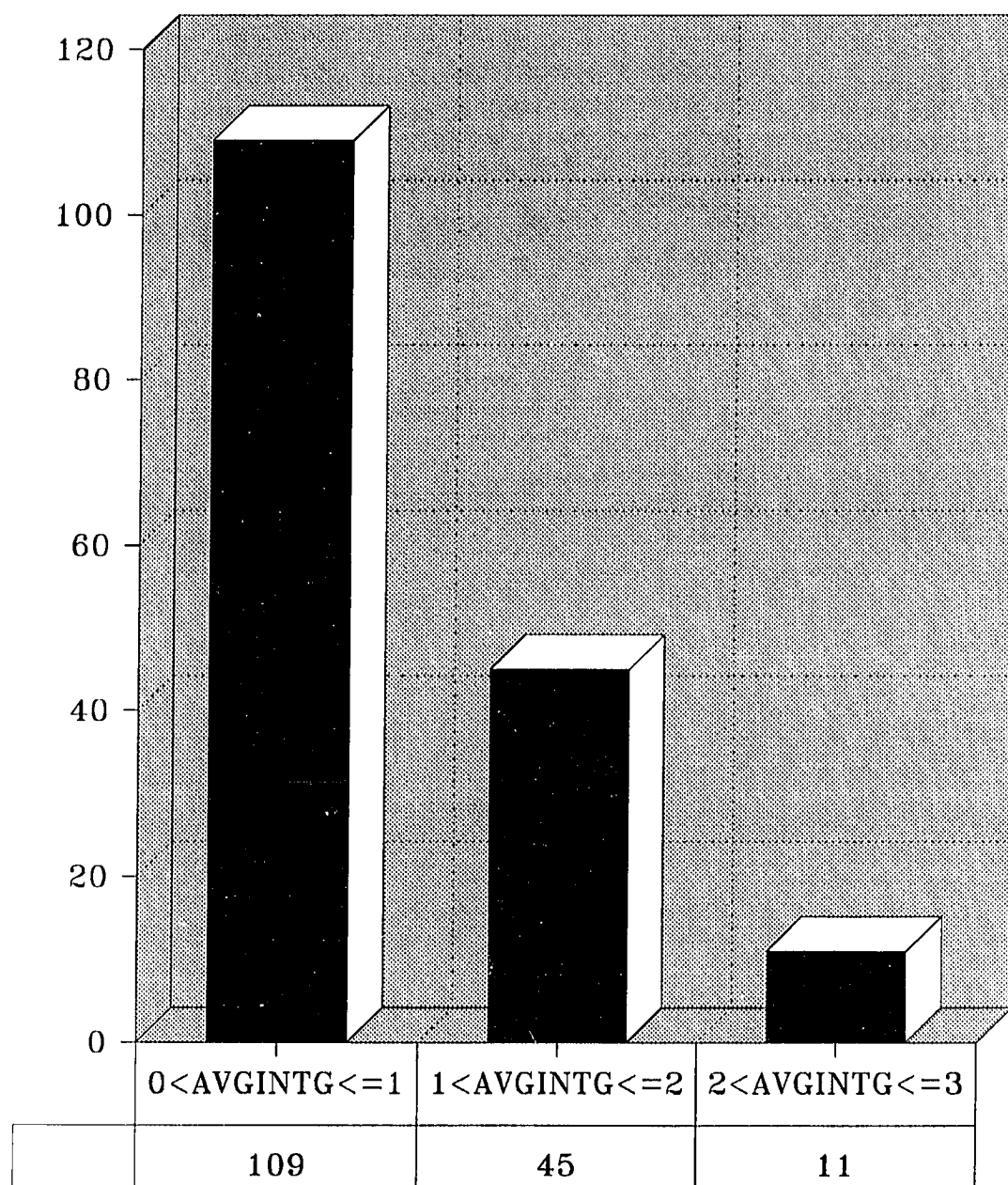


Table (4.6)
Average Integration Level In Business Units.

Value Label	Value	Freq- uency	Percent	Valid Percent	Cum. Percent
0 < AVGINETG <= 1	1.00	109	66.1	66.1	66.1
1 < AVGINTEG <= 2	2.00	45	27.3	27.3	93.3
2 < AVGINTEG <= 3	3.00	11	6.7	6.7	100.0
		-----	-----	-----	
	Total	165	100.0	100.0	
Valid cases		165	Missing cases	0	

Table (4.6) shows that sixty-six percent of the firms sampled use stand-alone technologies. Twenty-seven percent use few of the technologies as integrated to one another. Almost seven percent of the firms sampled use these technologies in a fully integrated way. The third group can said to be CIM users. Figure (4.6) below shows the average level of technology integration in each firm in the sample.

Figure (4.6)
Average Level of CBT integration in each firm



I.2.3 Time since CBT have been used

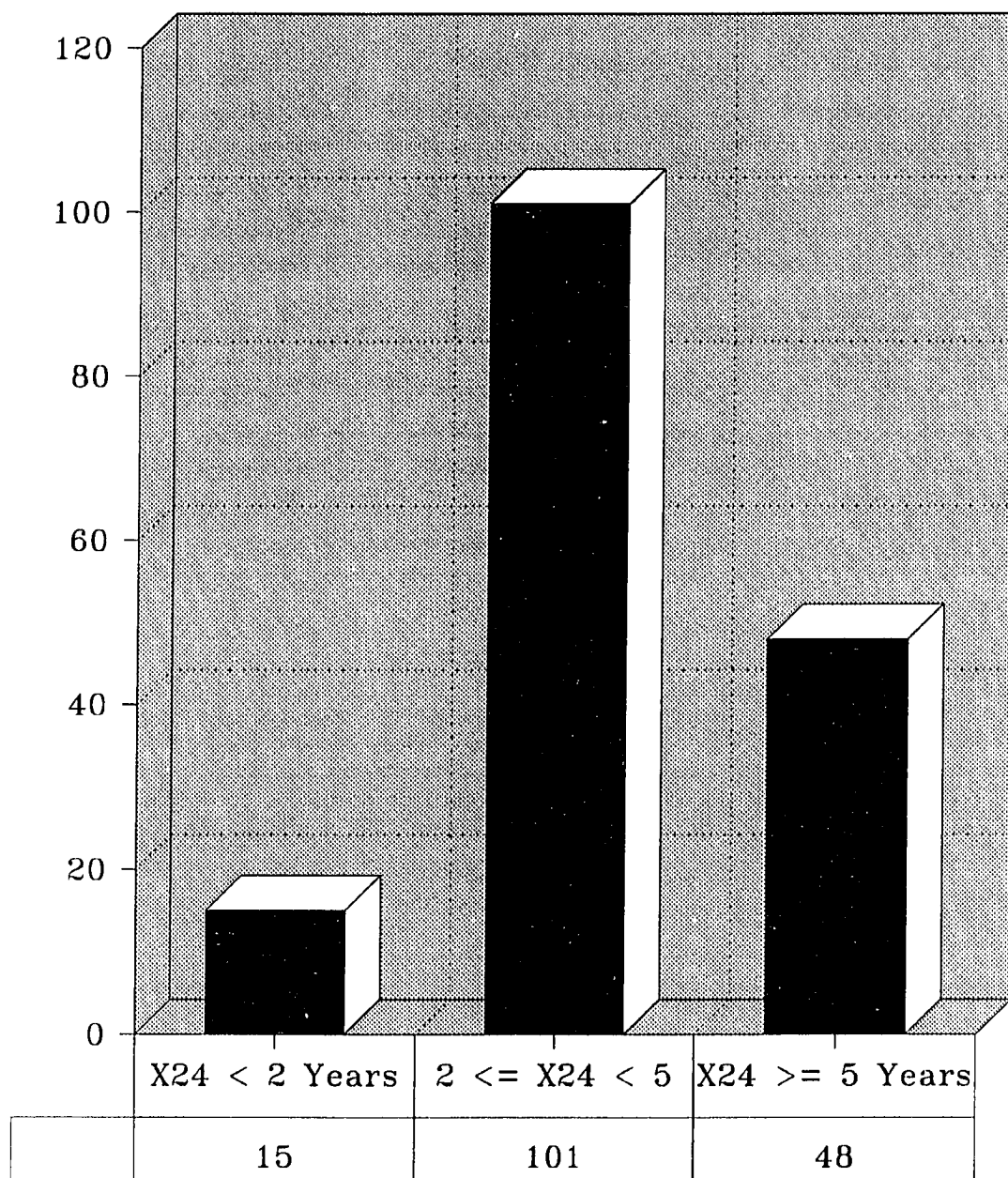
Respondents were asked about how long CBT have been used. Table (4.7) below indicates that about nine percent of the sample use the technologies for less than two years. Sixty-one percent of the firms have been using the technologies between two and five years. Twenty-nine percent of the firms have been using the technologies for more than five years.

Table (4.7)
Time Since The Technologies have been used

Value Label	Value	Freq- uency	Percent	Percent	Percent
OTHER	1	1	.6	.6	.6
X24 < TWO YEARS	2	15	9.1	9.1	9.7
2 YEARS < X24 < 5 YEARS	3	101	61.2	61.2	70.9
X24 > FIVE YEARS	4	48	29.1	29.1	100.0
		-----	-----	-----	
Total		165	100.0	100.0	
Valid cases	165	Missing cases	0		

Figure (4.7) below shows the length of time since CBT have been used.

Figure (4.7)
Time Since CBT Have Been Used



I.2.4 The Use of CAD, CAE and Other Design Technologies.

Respondents were asked about how much of the design of the product is done using CAD, CAE, or other types of computer assisted technologies. Sixty percent of the respondents reported that more than sixty percent of the design of the product is done utilizing computer assisted technologies (Last two classes of Table (4.8) Below). In fact, one hundred and fifty four (93%) of the respondents use CAD in their facilities.

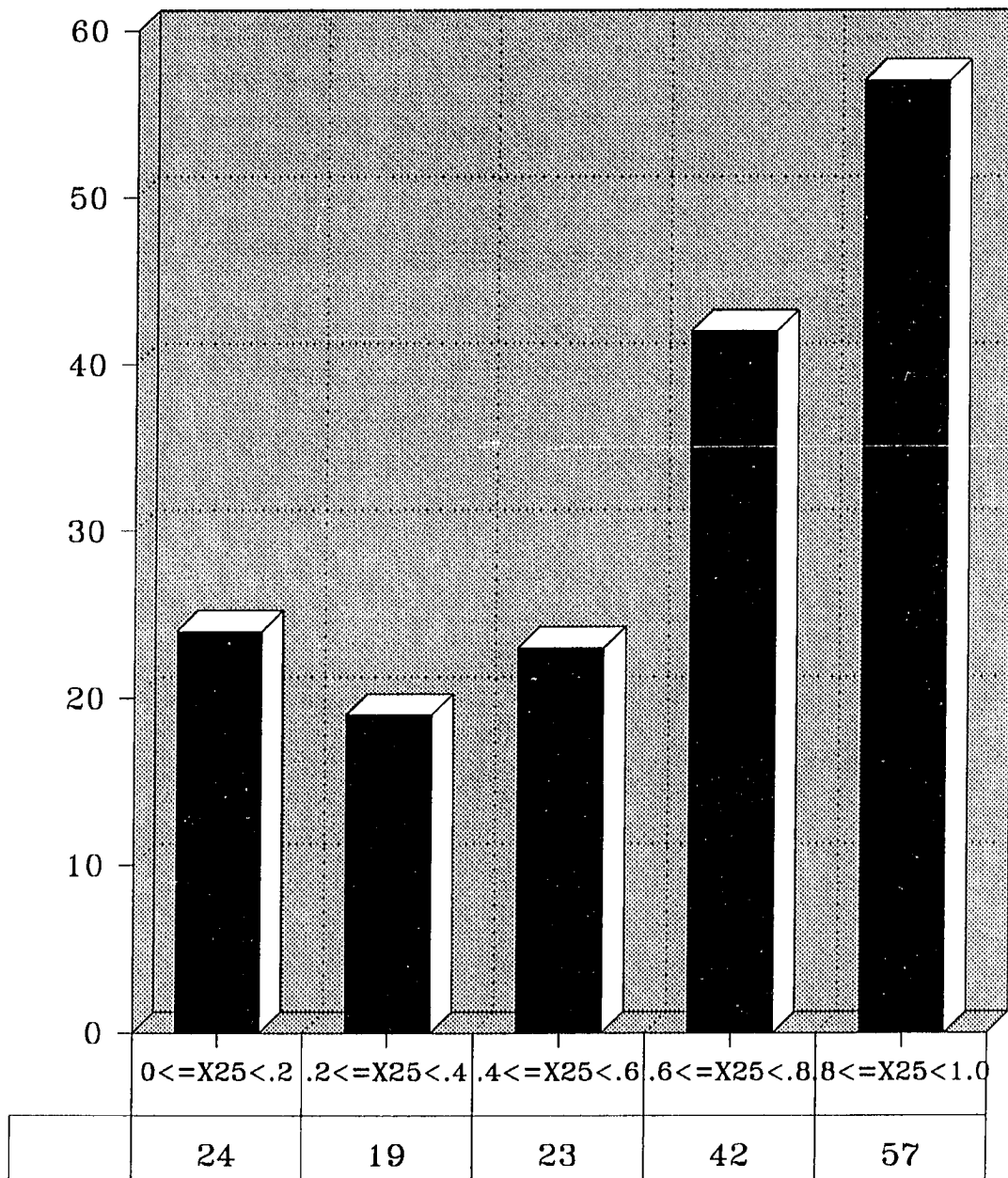
Table (4.8)
% of CAD, CAE or Other Computer Assisted
Technologies used in Designing the product

X25 % OF CAD, CAM, OR OTHER COMPUTER ASSISTED TECHNOLOGIES

Value Label	Value	Freq- uency	Percent	Percent	Percent
0 < X25 <= .20	1.00	24	14.5	14.5	14.5
.20 < X25 <= .40	2.00	19	11.5	11.5	26.1
.40 < X25 <= .60	3.00	23	13.9	13.9	40.0
.60 < X25 <= .80	4.00	42	25.5	25.5	65.5
.80 < X25 <= 1.0	5.00	57	34.5	34.5	100.0
		-----	-----	-----	
Total		165	100.0	100.0	
Valid cases 165 Missing cases 0					

Figure (4.8) below shows the percentage of CAD, CAE, or other computer assisted Technologies in the design of the product.

Figure (4.8)
% of CAD, CAE in the Design of the Product.



I.2.5 Percent of programmable Automation

Respondents were asked about how much of their equipment are programmable. Our survey showed fairly low use of computer-automated equipments. Only five percent of the respondents reported that their level of "programmable automation" is higher than eighty percent. Six percent have between sixty to eighty percent computer-automated equipment.

Table (4.9) below demonstrates that the factory of the future is not yet at hand. Our extensive literature review indicated many findings that support our statement, for example, Gunn (1987).

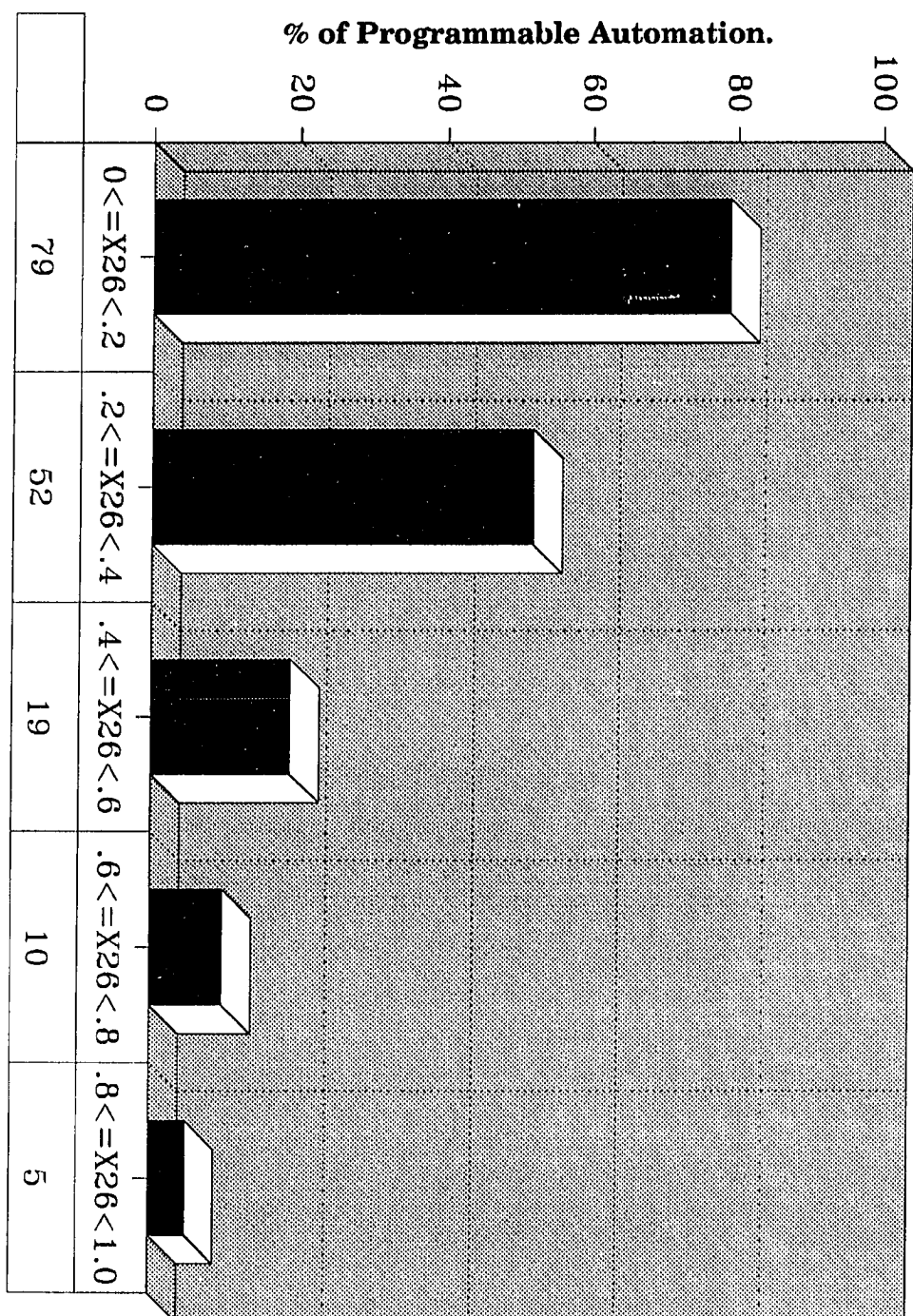
Table (4.9)
Percent of Programmable Automation

X26 % of Programmable Automation

Value Label	Value	Frequ- ency	Percent	Valid percent	Cum percent
.00 <X26<= .20	1.00	79	47.9	47.9	47.9
.20 <X26<= .40	2.00	52	31.5	31.5	79.4
.40 <X26<= .60	3.00	19	11.5	11.5	90.9
.60 <X26<= .80	4.00	10	6.1	6.1	97.0
.80 <X26<= 1	5.00	5	3.0	3.0	100.0

Figure (4.9) below shows the percentage of programmable automation.

Figure (4.9)



PART (II) EXPLORATORY STATISTICS:

INTRODUCTION

Factor analysis was used to define the dimensions of manufacturing capabilities. To study the strength of association between the items loaded on each factor, interitem Correlation analysis was performed.

Cluster analysis was used to group homogeneous business units that have similarities over a variable or a set of variables. Cluster analysis is statistically known as segmentation or topology technique or numerical taxonomy. Norusis (1990, SPSSPC 4.0 manual) indicated that three question must be addressed when one uses cluster analysis. These three question are:

- (1) Which variable or variables will serve as the basis for cluster formation?***
- (2) How will the distances between cases be measured?, and***
- (3) What criteria will be used to for combining cases into clusters.***

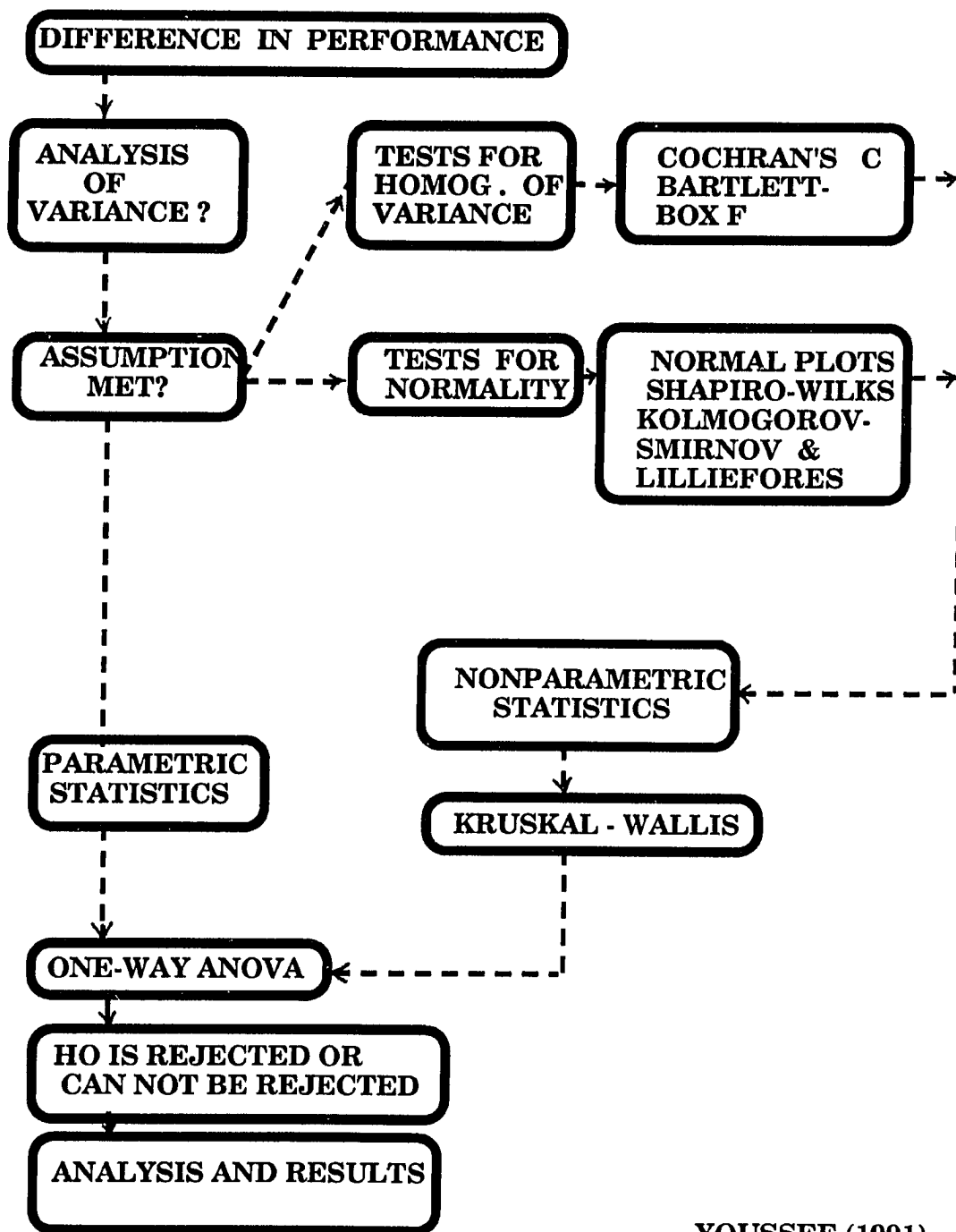
Cluster analysis was used first to cluster firms on the basis of the level of Advanced Manufacturing Technologies. Using the clusters emerged, we analyzed the differences in manufacturing and economic performances among theses clusters.

Cluster analysis was , once again, used to cluster the firms on the basis of their manufacturing performance. Using the cluster emerged, we analyzed the differences in economic performances among these clusters.

In both cases, One-Way ANOVA was used among the clusters themselves to assure the practical utility of these clusters in subsequent analysis. Summary of hypotheses testing is provided at the end of this chapter.

Analysis of variance was the technique used to test the hypotheses that deals with the difference in performance among the three groups. In order for us to use the ANOVA technique properly, We conduct the analysis according to the flow chart depicted below.

Figure (4.10)
Analysis of Difference in Performance



YOUSSEF (1991)

II.1 FACTOR ANALYSIS.

The principle component of factor analysis with varimax rotation was performed to define the dimensions of manufacturing capability. Our goal was to represent the relationships among manufacturing capability items parsimoniously. That is, to explain the observed correlations using a few factors as possible. In the main time, we would like the factors to be meaningful. Therefore, the decision rules we used to decide upon the number of factors are: (1) Factor solution must be simple and interpretable, (2) Retain factors with at least 1.0 eigenvalue, and (3) Retained factors should explain a good portion of variability in the data. These decision rules were based on two things. First, the results we got in the pilot study stage. Secondly, a different number of runs with different number of factors using all observations.

Four factors interpreted our data most. Naming the factors was remarkably clear. The factors emerged were in general agreement with current literature on Advanced Manufacturing Technologies. Therefore, they have high face validity. Tables (4.14), (4.15) below shows the varimax rotated matrix and factor transformation matrix respectively.

Table (4.10)
Varimax Rotated Factor Matrix

F A C T O R A N A L Y S I S

Varimax Rotation 1, Extraction 1, Analysis 1 - Kaiser Normalization.

Varimax converged in 6 iterations.

Rotated Factor Matrix:

	Responsiveness	Cost	Flexibility	Quality
X31	.21481	-.06346	.67335	.14969
X32	.22503	-.08996	.42935	.24497
X33	.04999	-.00161	.53546	.11497
X34	.07881	.07350	.55774	.12213
X35	.27239	.01355	.56523	.10373
X36	.58085	-.18294	.06524	.21932
X37	.62243	-.13849	.11424	.18568
X38	.55265	-.04173	.26212	.05907
X39	.46154	-.21606	.41510	.11943
X310	.61943	-.21903	.15096	.03781
X311	.64387	.07549	.18816	.11202
X312	.49978	-.07714	.07779	.33328
X313	.30600	.05613	.14684	.68791
X314	.12146	-.18506	.22289	.51518
X315	.03713	-.10505	.28701	.59418
X316	.18810	-.02117	.08538	.58708
X317	-.01981	.63920	.03803	-.10247
X318	.00690	.58427	.08943	-.07590
X319	-.20453	.74231	-.17965	-.02008
X320	-.16182	.63196	-.03525	.00037
X321	-.12569	.73693	-.04401	-.03946

Table (4.11)
Factor Transformation Matrix

Factor Transformation Matrix:

	Responsiveness	Cost	Flexibility	Quality
Responsiveness	.64254	-.31925	.53167	.45006
Cost	.02716	.90645	.40056	.13102
Flexibility	.76094	.25043	-.52327	-.29057
Quality	-.08587	.11711	-.53204	.83418

CORRELATION ANALYSIS AMONG ITEMS LOADED ON EACH FACTOR

Tables (4.16), (4.17), (4.18), and (4.19) below show the mean and standard deviation and the correlation among items loaded under each factor. It is obvious that items loaded under one factor are highly correlated, as they are supposed to be.

FLEXIBILITY

Table (4.12)
Mean & Standard Deviation and Correlation
Among Items Loaded Under "Flexibility"

Variable	Cases	Mean	Std Dev
X31	165	3.3333	.9195
X32	165	3.2606	.9233
X33	165	3.8424	.9103
X34	165	3.9212	.8553
X35	165	3.3212	1.0240

Correlations:	X31	X32	X33	X34	X35
X31	1.0000	.3711**	.3327**	.3437**	.5461**
X32	.3711**	1.0000	.2015*	.2655**	.4075**
X33	.3327**	.2015*	1.0000	.5087**	.2312*
X34	.3437**	.2655**	.5087**	1.0000	.2727**
X35	.5461**	.4075**	.2312*	.2727**	1.0000

N of cases: 165 1-tailed Signif: * - .01 ** - .001
 ". " is printed if a coefficient cannot be computed

RESPONSIVENESS

Table (4.13)
Mean & Standard Deviation and Correlation
Among Items Loaded Under "RESPONSIVENESS"

Variable	Cases	Mean	Std Dev				
X36	165	3.4545	.8443				
X37	165	3.2303	.8739				
X38	165	3.5818	.8343				
X39	165	3.1152	.8512				
X310	165	3.4303	.7980				
X311	165	3.9515	.8250				
X312	165	3.7576	.8845				

Corr.	X36	X37	X38	X39	X310	X311	X312
X36	1.0000	.5349**	.3321**	.3255**	.3776**	.3908**	.4016**
X37	.5349**	1.0000	.2751**	.5544**	.4166**	.4554**	.3330**
X38	.3321**	.2751**	1.0000	.3258**	.4368**	.4311**	.3989**
X39	.3255**	.5544**	.3258**	1.0000	.4473**	.3380**	.1912*
X310	.3776**	.4166**	.4368**	.4473**	1.0000	.4301**	.3387**
X311	.3908**	.4554**	.4311**	.3380**	.4301**	1.0000	.4183**
X312	.4016**	.3330**	.3989**	.1912*	.3387**	.4183**	1.0000

N of cases: 165 1-tailed Signif: * - .01 ** - .001
" . " is printed if a coefficient cannot be computed

QUALITY

Table (4.14)
Mean & Standard Deviation and Correlation
Among Items Loaded On "QUALITY"

Variable	Cases	Mean	Std Dev
X313	165	4.1576	.6803
X314	165	3.5818	.7163
X315	165	3.7636	.7800
X316	165	3.9758	.6980

Correlations: X313		X314	X315	X316
X313	1.0000	.4238**	.4613**	.5089**
X314	.4238**	1.0000	.4004**	.2967**
X315	.4613**	.4004**	1.0000	.4038**
X316	.5089**	.2967**	.4038**	1.0000

N of cases: 165 1-tailed Signif: * - .01 ** - .001
". " is printed if a coefficient cannot be computed

COST

Table (4.15)
Mean & Standard Deviation and Correlation
Among Items Loaded On "COST"

Variable	Cases	Mean	Std Dev		
X317	165	2.8000	.8848		
X318	165	2.9152	.9902		
X319	165	2.8485	.9147		
X320	165	2.6667	.8506		
X321	165	2.9273	.9788		
Correlations:					
	X317	X318	X319	X320	X321
X317	1.0000	.4537**	.4897**	.3970**	.4618**
X318	.4537**	1.0000	.4368**	.2703**	.4025**
X319	.4897**	.4368**	1.0000	.5381**	.5393**
X320	.3970**	.2703**	.5381**	1.0000	.5785**
X321	.4618**	.4025**	.5393**	.5785**	1.0000

N of cases: 165 1-tailed Signif: * - .01 ** - .001
 ". " is printed if a coefficient cannot be computed

II.2 CLUSTER ANALYSIS (Clustering variable AMTINDX)

In this part of the analysis, Advanced Manufacturing Technology Assessment Index was used as a taxon or clustering variable. Three clusters were formed and were named "Superstars," "Major leaguers," and "Triple A's".

Table (4.16) below shows the final cluster centers and the number of cases in each cluster.

Table (4.16)
Final Cluster Centers and Number of Cases in each Cluster

Final Cluster Centers.

Cluster	AMTINDX	
1	56.2245	Major Leaguers.
2	98.0292	Superstars.
3	23.5278	Triple A's.

Number of Cases in each Cluster.

Cluster	unweighted cases	weighted cases
1	47.0	47.0
2	12.0	12.0
3	106.0	106.0
Missing	0	
Total	165.0	165.0

II.3 ANALYSIS OF VARIANCE

II.3.1 One-Way ANOVA Among Clusters

Oneway ANOVA over each taxon shows that Superstars outperform the other two groups on Advanced Manufacturing Technology Index. The following tables of analysis of variance and multiple comparisons illustrate this point.

Table (4.17)
Analysis of Variance and Multiple Comparisons
(Advanced Manufacturing Technology Index)

Analysis of Variance					
Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	81042.0824	40521.0412	309.0142	.0000
Within Groups	162	21243.0659	131.1300		
Total	164	102285.1483			

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean
Grp 1	47	56.2245	11.3783	1.6597	52.8837 To 59.5653
Grp 2	12	98.0292	15.2660	4.4069	88.3296 To 107.7287
Grp 3	106	23.5278	11.0082	1.0692	21.4078 To 25.6479
Total	165	38.2597	24.9738	1.9442	34.4208 To 42.0986
Fixed Effects Model			11.4512	.8915	-56.8508 To 133.3758
Random Effects Model - Estimate of Between Component Variance					977.4619

Multiple Range Test Scheffe Procedure

Mean	Group	G G G
23.5278	Grp 3	r r r
56.2245	Grp 1	p p p
98.0292	Grp 2	3 1 2
		*
		**

The multiple comparison part of table (4.17) above shows that differences exist between any two groups. Indeed, the groups are clearly

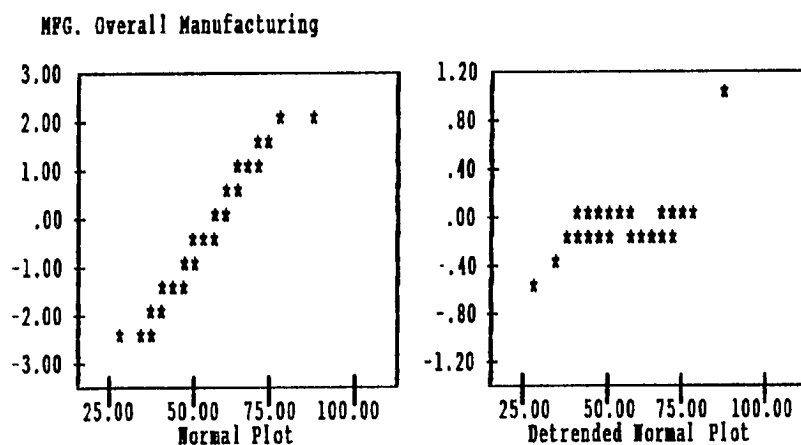
distinguished from one another. This asserts the practical utility of these clusters for subsequent analysis.

II.3.2 One-Way ANOVA : Model (1) Technology - Manufacturing

II.3.2.1 Overall Manufacturing Performance.

1. Test for Normality

Figure (4.11)
Normal and detrended normal plots(Overall
Manufacturing Performance).



	Statistic	df	Significance
K-S (Lilliefors)	.0428	159	> .2000

Figure (4.11) shows that the observed values for the variable overall manufacturing performance fall ,more or less, on a straight line in the normal

plot. It also shows that the values are clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a high Lilliefors significance level shows that the observed values for overall manufacturing is normally distributed .

2. Test for Homogeneity of Variance

Table (4.18)
Tests for Homogeneity of Variance
(Overall Manufacturing)

Cochrans C = Max. Variance/Sum(Variations) = .4855, P = .009 (Approx.)
Bartlett-Box F = 2.512 , P = .081
Maximum Variance / Minimum Variance 3.004

Table (4.18) shows that the significance level for Cochrans C and Bartlett-Box F are small, the null hypothesis that the three population have the same variance must be rejected. Since the normality assumption was not violated, but homogeneity of variance assumption was, one should resort to nonparametric ANOVA. However, we prefer to conduct the parametric as well as the nonparametric tests.

Parametric ANOVA

Table (4.19)
One-Way ANOVA (Overall Manufacturing)

Variable Overall Manufacturing By Variable CLUST1					
Analysis of Variance					
Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	1728.1128	864.0564	10.8892	.0000
Within Groups	156	12378.5765	79.3498		
Total	158	14106.6892			

At a significance level of ($P < .00001$), the hypothesis that the mean overall manufacturing scores for the three groups are equal is therefore rejected. Table (4.20) below shows that superstars outperform triple A's . However superstars do not differ significantly from the major leaguers on overall manufacturing.

Table (4.20)
Differences in Overall Manufacturing
Among the Three Groups

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean	
Grp 1	45	59.7746	8.0956	1.2068	57.3424	To 62.2068
Grp 2	11	59.3916	5.4779	1.6516	55.7115	To 63.0717
Grp 3	103	52.8000	9.4945	.9355	50.9444	To 54.6556
Total	159	55.2300	9.4490	.7494	53.7499	To 56.7100
Fixed Effects Model			8.9079	.7064	53.8345	To 56.6254
Random Effects Model				3.2481	41.2544	To 69.2055
Random Effects Model - Estimate of Between Component Variance						19.9215

To pinpoint where the difference are, Scheffe multiple comparisons procedure was used. Table (4.21) below shows significant differences in overall manufacturing exist between major leaguers and triple A's . Also differences in overall manufacturing exist between superstars and triple A's.

Table (4.21)
Multiple Comparisons of Differences in Overall
Manufacturing Among the Three Groups

Variable MFG
 By Variable CLUST1
 Multiple Range Test
 Scheffe Procedure
 Ranges for the .050 level -
 3.50 3.50

The ranges above are table ranges.

The value actually compared with Mean(J)-Mean(I) is..

$$6.2988 * \text{Range} * \text{Sqrt}(1/N(I) + 1/N(J))$$

(*) Denotes pairs of groups significantly different at the .050 level

Variable MFG
 (Continued)

		G G G
		r r r
		p p p
Mean	Group	3 2 1
52.8000	Grp 3	
59.3916	Grp 2	
59.7746	Grp 1	*

Nonparametric ANOVA

Table (4.22)
Kruskal-Wallis One-Way AMOVA
(Overall Manufacturing)

Variable Overall Manufacturing
 by CLUST1

Mean Rank	Cases			
103.29	45	CLUST1 = 1 :	Major Leaguers	
105.27	11	CLUST1 = 2 :	Superstars	
67.13	103	CLUST1 = 3 :	Triple A's	

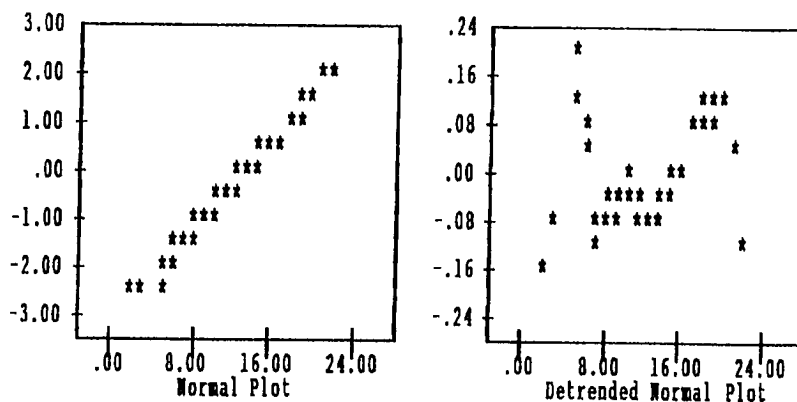
	159	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
159	22.8789	.0000	Chi-Square	Significance
			22.8791	.0000

At a significance level of ($P < .00001$), The null hypothesis that there are no differences in overall manufacturing performance among the three groups is, therefore, rejected. Table (4.23) shows that mean rank for superstars is far higher than those of major leaguers and Triple A's. It is also obvious that differences exist between major leaguers and triple A's. The conclusions are consistent with those obtained from the parametric ANOVA.

II.3.2.2 Flexibility

1. Test for Normality.

Figure (4.12)
Normal and detrended normal plots.



	Statistic	df	Significance
K-S (Lilliefors)	.0497	165	> .2000

Figure (4.12) shows that the observed values for the variable flexibility fall ,more or less, on a straight line in the normal plot. It also shows that the values are clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a high Lilliefors significance level shows that the observed values for flexibility are normally distributed.

Table (4.23)
Tests for Homogeneity of Variance (Flexibility)

2.Tests for Homogeneity of Variances

Cochrans C = Max. Variance/Sum(Variances) = .4097, P = .226 (Approx.)
Bartlett-Box F = .702 , P = .496
Maximum Variance / Minimum Variance 1.675

Table (4.23) shows that the significance level for Cochrans C and Bartlett-Box F tests are large (P = .226 and .496 respectively), so the hypothesis that the populations have the same variance cannot be rejected.

Since the assumptions of normality and homogeneity of variance were not violated, we will proceed with the parametric one-way ANOVA.

Table (4.24)
One-Way ANOVA (Flexibility).

Variable FLEX : Flexibility					
By Variable		CLUST1			
		Group (2) Superstars, Group (1) Major leaguers Group (3) Triple A's.)			
Analysis of Variance					
Source	D.F	Sum of Squqres	Mean Squares	F Ratio	F Prob.
Between Groups	2	559.8316	279.9158	19.6919	.0000
Within Groups	162	2302.7929	14.2148		
Total	164	2862.6245			

At a significance level of ($P < .00001$), the hypothesis that the mean flexibility scores for the three groups are equal is therefore rejected. Table (4.25) below shows that superstars obviously outperform their counterparts on the dimension of flexibility.

Table (4.25)
Differences in Flexibility Among the Three Groups

Group	Count	Standard		Standard Error	95 Pct Conf Int for Mean		
		Mean	Deviation				
Grp 1	47	14.5915	3.5942	.5243	13.5362	To	15.6468
Grp 2	12	16.3167	3.0241	.8730	14.3952	To	18.2381
Grp 3	106	11.1981	3.9133	.3801	10.4445	To	11.9518
Total	165	12.5370	4.1779	.3253	11.8948	To	13.1792
Fixed Effects Model			3.7702	.2935	11.9574	To	13.1166
Random Effects Model				1.8154	4.7259	To	20.3481
Random Effects Model - Estimate of Between Component Variance							6.4301

To pinpoint where the difference are, Scheffe multiple comparisons procedure was used. Table (4.30) below shows that differences in flexibility exist between superstars and triple A's . Also differences in flexibility exists between Major leaguers and triple A's.

Table (4.26)

Multiple Comparison Among groups (Flexibility).

Multiple Range Test

Scheffe Procedure

Ranges for the .050 level -

3.49 3.49

The ranges above are table ranges.

The value actually compared with $\text{Mean}(J) - \text{Mean}(I)$ is.. $2.6660 * \text{Range} * \text{Sqrt}(1/N(I) + 1/N(J))$

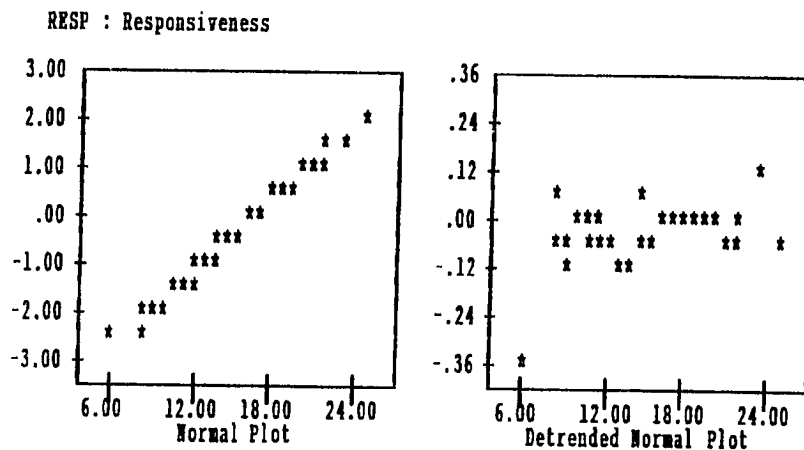
(*) Denotes pairs of groups significantly different at the .050 level

		G G G
		r r r
		p p p
Mean	Gr	p 2 1
11.1981	Grp 3	
14.5915	Grp 1	*
16.3167	Grp 2	*

II.3.2.3 Responsiveness**1. Test for Normality**

Figure (4.13)

Normal and detrended normal plot for Responsiveness



	Statistic	df	Significance
K-S (Lilliefors)	.0458	165	> .2000

Figure (4.13) shows that the observed values for the variable Responsiveness fall ,more or less, on a straight line in the normal plot. It also shows that the values are clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a high lilliefors significance level Shows that the observed values for responsiveness are normally distributed population.

2. Test for Homogeneity of Variances

Table (4.27)
Tests for Homogeneity of Variance (Responsiveness)

Cochrans C = Max. Variance/Sum(Variiances) = .4007, P = .304 (Approx.)
Bartlett-Box F = .547 , P = .579
Maximum Variance / Minimum Variance 1.522

Table (4.27) shows that the significance level for Cochrans C and Bartlett-Box F tests are large (P = .304, .579 respectively), so the hypothesis that the populations have the same variance cannot be rejected.

Since the assumptions of normality and homogeneity of variance were not violated, we proceed with the parametric one-way ANOVA.

Table (4.28)
One-Way ANOVA (Responsiveness)

Variable RESP : Responsiveness

Source	D.F.	Analysis of Variance		F	F
		Sum of Squares	Mean Squares		
Between Groups	2	393.6567	196.8284	15.4628	.0000
Within Groups	162	2062.1239	12.7292		
Total	164	2455.7806			

At a significance level of ($P < .00001$), the null hypothesis that the mean responsiveness scores for the three groups are equal is therefore rejected. Table (4.29) below shows that superstars outperform both major leaguers and triple A's on the dimension of responsiveness.

Table (4.29)
Differences in Responsiveness Among the Three Groups

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean
Grp 1	47	17.1581	3.3863	.4939	16.1638 To 18.1523
Grp 2	12	19.5952	2.9971	.8652	17.6910 To 21.4995
Grp 3	106	14.6725	3.6979	.3592	13.9603 To 15.3847
Total	165	15.7385	3.8697	.3013	15.1437 To 16.3334
Fixed Effects Model			3.5678	.2778	15.1900 To 16.2870
Random Effects Model				1.5169	9.2118 To 22.2653
Random Effects Model - Estimate of Between Component Variance					4.4553

To pinpoint where the differences are, Scheffe multiple comparisons procedure was used. Table (4.30) below shows that differences in responsiveness superstars and triple A's and between major leaguers and triple A's.

Table (4.30)
Multiple Comparisons Among Groups (Responsiveness)

Scheffe Procedure

Ranges for the .050 level -

3.49 3.49

The ranges above are table ranges.

The value actually compared with Mean(J)-Mean(I) is..

$$2.5228 * \text{Range} * \text{Sqrt}(1/N(I) + 1/N(J))$$

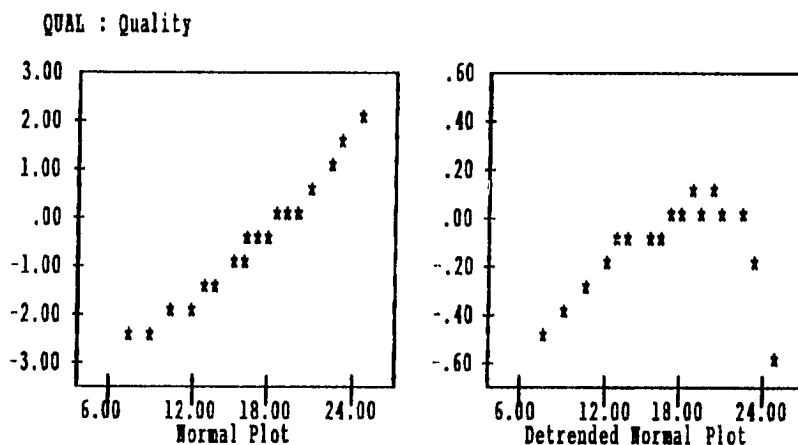
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	G G G r r r p p p 3 1 2
14.6725	Grp 3	
17.1581	Grp 1	*
19.5952	Grp 2	*

II.3.2.4 QUAL: Quality

1. Test of Normality

Figure (4.14)
Normal and detrended normal plots (Quality)



	Statistic	df	Significance
K-S (Lilliefors)	.0588	165	> .2000

Figure (4.14) shows that the observed values for the variable quality fall ,more or less, on a straight line in the normal plot. It also shows that the values are clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a high lilliefors significance level Shows that the observed values for quality are normally distributed.

2. Test for Homogeneity of Variance

Table (4.31)
Tests for Homogeneity of Variance (Quality)

Cochrans C = Max. Variance/Sum(Variances) = .5051, P = .003 (Approx.)
Bartlett-Box F = 3.760 , P = .023
Maximum Variance / Minimum Variance 4.036

Table (4.31) shows that the significance level for Cochrans C and Bartlett-Box F are small, the null hypothesis that the three population have the same variance must be rejected. Norusis (1990) stated that many of these tests are not very useful since they are influenced by the characteristics of the data other than the variance. We prefer to conduct the parametric as well as the nonparametric tests.

Parametric ANOVA.

Table (4.32)
One-Way ANOVA (Quality)

Analysis of Variance					
Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	500.0719	250.0359	19.9903	.0000
Within Groups	162	2026.2766	12.5079		
Total	164	2526.3485			

At a significance level of ($P < .00001$), The null hypothesis that the mean quality scores for the three groups are equal is therefore rejected. Table (4.33) below shows that superstars outperform their counterparts on the dimension of quality.

Table (4.33)
Differences in Quality Among the Three Groups.

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean
Grp 1	47	18.9894	3.2391	.4725	18.0383 To 19.9404
Grp 2	12	22.8542	1.8843	.5440	21.6569 To 24.0514
Grp 3	106	16.7052	3.7854	.3677	15.9762 To 17.4342
Total	165	17.8030	3.9249	.3056	17.1997 To 18.4063
Fixed Effects Model		3.5366		.2753	17.2593 To 18.3467
Random Effects Model		1.7161			10.4192 To 25.1869
Random Effects Model - Estimate of Between Component Variance					5.7483

To pinpoint where the differences are, Scheffe multiple comparisons procedure was used. Table (4.34) below shows that differences in quality exist between any two groups (Superstars and major leaguers, Superstars and Triple A's, Maor leaguers and Triple A's).

Table (4.34)
Multiple Comparisons of Differences in Quality Among the Three Groups

Multiple Range Test

Scheffe Procedure

Ranges for the .050 level -

3.49 3.49

The ranges above are table ranges.

The value actually compared with Mean(J)-Mean(I) is..

$2.5008 * \text{Range} * \text{Sqrt}(1/N(I) + 1/N(J))$

(*) Denotes pairs of groups significantly different at the .050 level

		G G G
		r r r
		p p p
Mean	Group	3 1 2
16.7052	Grp 3	
18.9894	Grp 1	*
22.8542	Grp 2	**

Nonparametric ANOVA

Table (4.35)
Kruskal-Wallis One-Way AMOVA (Quality)

QUALITY				
Mean Rank		Cases		
96.89	47	CLUST1 = 1 : Major Leaguers		
147.00	12	CLUST1 = 2 : Superstars		
69.59	106	CLUST1 = 3 : Triple A's		

	165	Total		
	Corrected for Ties			
CASES	Chi-Square	Significance	Chi-Square	Significance
165	33.8550	.0000	34.0934	.0000

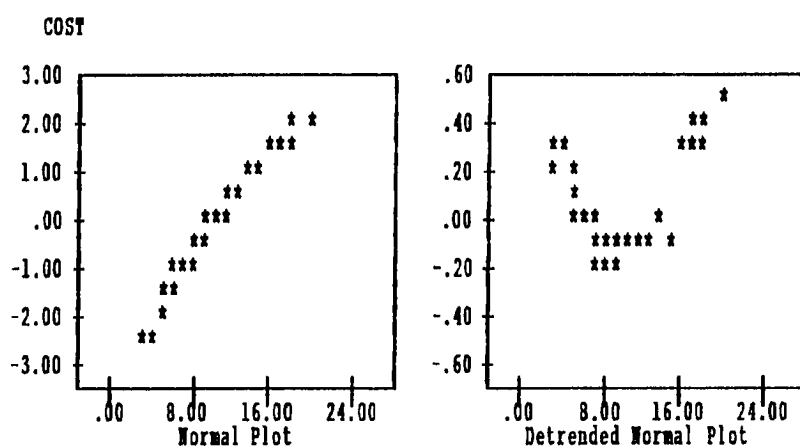
At a significance level of ($P < .00001$), The null hypothesis that there are no differences in quality among the three groups is therefore rejected. Table (4.35) shows that mean rank for superstars is far higher than those of major leaguers and Triple A's. It is also obvious that differences exist between major leaguers and triple A's. The conclusions are consistent with those

obtained from the parametric ANOVA.

II.3.2.5 COST

1. Test for Normality

Figure (4.15)
Normal and detrended normal plots (Cost)



	Statistic	df	Significance
K-S (Lilliefors)	.0736	165	.0292

Figure (4.15) shows that the observed values for the variable cost fall, more or less, on a straight line in the normal plot. It also shows that the values are clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a lilliefors significance level of ($P = .0292$) shows that the observed values for cost are normally distributed .

2. Test for Homogeneity of Variance

Table (4.36)
Tests for Homogeneity of Variance (Cost)

Cochrans C = Max. Variance/Sum(Variations) = .4945, P = .005 (Approx.)
 Bartlett-Box F = 3.015 , P = .049
 Maximum Variance / Minimum Variance 3.747

Table (4.36) shows that the significance level for Cochrans C and Bartlett-Box F are small, the null hypothesis that the three population have the same variance must be rejected. Norusis (1990) stated that many of these tests are not very useful since they are influenced by the characteristics of the data other than the variance. Since the normality assumption was not violated, but the homogeneity of variance was, one should resort to nonparametric ANOVA. For this variable we conduct the parametric as well as the nonparametric tests.

Table (4.37)
One-Way ANOVA (Cost)

Source	Analysis of Variance				
	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	183.5309	91.7654	8.8837	.0002
Within Groups	162	1673.4049	10.3297		
Total	164	1856.9358			

At a significance level of (P = .0002), the null hypothesis that the mean cost score for the three groups are equal is therefore rejected. Table (4.38) below shows that superstars outperform Triple A's on the dimension of cost. Not so significant difference exist between either superstars and major

leaguers or major leaguers and Triple A's.

Table (4.38)
Differences in cost Among the Three Groups.

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean
Grp 1	47	9.5234	3.6124	.5269	8.4628 To 10.5841
Grp 2	12	6.2333	1.8661	.5387	5.0477 To 7.4190
Grp 3	106	10.3075	3.1393	.3049	9.7030 To 10.9121
Total	165	9.7879	3.3649	.2620	9.2706 To 10.3051
Fixed Effects Model			3.2140	.2502	9.2938 To 10.2820
Random Effects Model			1.0229		5.3867 To 14.1891
Random Effects Model - Estimate of Between Component Variance					1.9708

To pinpoint where the differences Scheffe multiple comparisons procedure was used. Table (4.39) below shows that superstars outperforms Triple A's on the dimensions of cost.

Table (4.39)
Multiple Comparisons of Differences in Cost Among the Three Groups.

Scheffe Procedure
Ranges for the .050 level -
3.49 3.49

The ranges above are table ranges.

The value actually compared with Mean(J)-Mean(I) is..

$2.2726 * \text{Range} * \text{Sqrt}(1/N(I) + 1/N(J))$

(*) Denotes pairs of groups significantly different at the .050 level

Variable COST
(Continued)

Mean	Group	G G G r r r p p p 2 1 3
6.2333	Grp 2	
9.5234	Grp 1	*
10.3075	Grp 3	*

Nonparametric ANOVA

Table (4.40)
Kruskal-Wallis One-Way AMOVA (Cost)

COST				
Mean Rank	Cases			
77.51	47	CLUST1 = 1	Major Leaguers	
29.96	12	CLUST1 = 2	Superstars	
91.44	106	CLUST1 = 3	Triple A's	

	165	Total		
		Corrected for Ties		
CASES	Chi-Square	Significance	Chi-Square	Significance
165	18.7188	.0001	18.7755	.0001

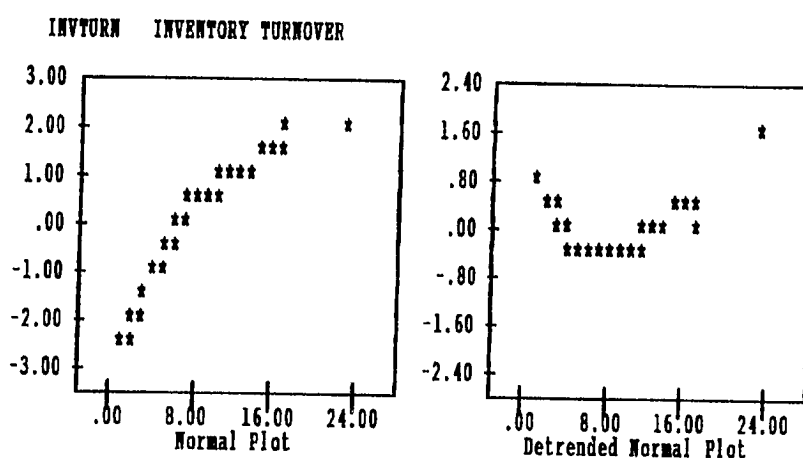
At a significance level of ($P = .0001$), The null hypothesis that there are no differences in cost among the three groups is therefore rejected. Table (4.40) shows that mean rank for superstars is way lower than those of major leaguers and Triple A's. It is also obvious that differences exist between superstars and major leaguers, superstars and triple A's, major leaguers and triple A's . The conclusions are consistent with those obtained from the parametric ANOVA.

II.3.3 One-Way ANOVA: Model (2) Technology - Eco. Performance

II.3.3.1 INVENTORY TURNOVER

1. Test fro Normality

Figure (4.16)
Normal and Detrended Plots (Inventory Turnover)



	Statistic	df	Significance
K-S (Lilliefors)	.1201	159	.0000

Figure (4.16) shows that the observed values for the variable inventory turnover do not fall on a straight line in the normal plot. It also shows that the values are not clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a Lilliefors significance level of ($P = .0000$) shows that the observed values for inventory turnover are not normally distributed. Therefore, we resorted to using the nonparametric ANOVA.

Table (4.41)
Kruskal-Wallis One-Way ANOVA (Inventory Turnover)
INVTURN INVENTORY TURNOVER
by CLUST1

Mean Rank	Cases			
103.07	46	CLUST1 = 1 : Major Leaguers		
137.50	11	CLUST1 = 2 : Superstars		
63.40	102	CLUST1 = 3 : Triple A's		

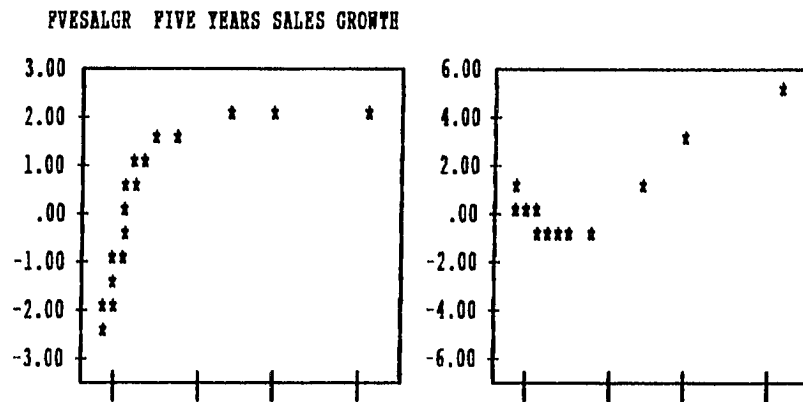
	159	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
159	41.9613	.0000	41.9621	.0000

Table (4.41) shows that the mean ranks for the three groups are different. At a significance level of ($P < .00001$), the null hypothesis was rejected. Indeed, there are differences in inventory turnover among the three groups. Superstars outperform both major leaguers and Triple A's. It is also obvious that major leaguers outperform Triple A's.

II.3.3.2 Five Years Sales Growth

1. Test for Normality

Figure (4.17)
Noral and Detrended Plots (Five Years Sales Growth)



	Statistic	df	Significance
K-S (Lilliefors)	.2586	145	.0000

Figure (4.17) shows that the observed values for the variable five years sales growth do not fall on a straight line in the normal plot. It also shows that the values are not clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a Lilliefors significance level of ($P = .0000$) shows that the observed values for five years sales growth are not normally distributed. Therefore, we resorted to using the nonparametric ANOVA.

Table (4.42)
Kruskal-Wallis One-Way ANOVA (Five Years Sales Growth)

FVESALGR				
FIVE YEARS SALES GROWTH				
Mean Rank	Cases			
71.58	42	CLUST1 = 1 : Major Leaguers		
77.92	12	CLUST1 = 2 : Superstars		
73.01	91	CLUST1 = 3 : Triple A's		

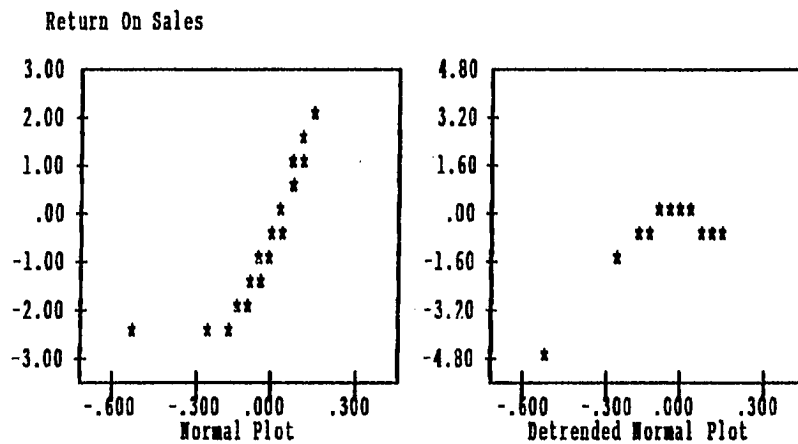
145	Total			
CASES	Chi-Square	Significance	Corrected for Ties	
145	.2122	.8993	Chi-Square	Significance
			.2122	.8993

Table (4.42) shows that the mean ranks for the three groups are not significantly different. At a significance level of ($P = .8993$), the null hypothesis cannot be rejected. There are no significant differences in five years sales growth among the three groups.

II.3.3.3 Return On Sales

1. Test for Normality

Figure (4.18)
Normal and Detrended Plots (Return on Sales)



	Statistic	df	Significance
K-S (Lilliefors)	.1118	146	.0001

Figure (4.18) shows that the observed values for the variable return on sales do not fall on a straight line in the normal plot. It also shows that the values are not clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a Lilliefors significance level of ($P = .0001$) shows that the observed values for return on sales are not normally distributed. Therefore, we resorted to using the nonparametric ANOVA.

Table (4.43)
Kruskal-Wallis One-Way ANOVA (Return on Sales)

Return on Sales				
by CLUST1				
Mean Rank	Cases			
83.50	43	CLUST1 = 1 : Major Leaguers		
77.29	12	CLUST1 = 2 : Superstars		
68.27	91	CLUST1 = 3 : Triple A's		

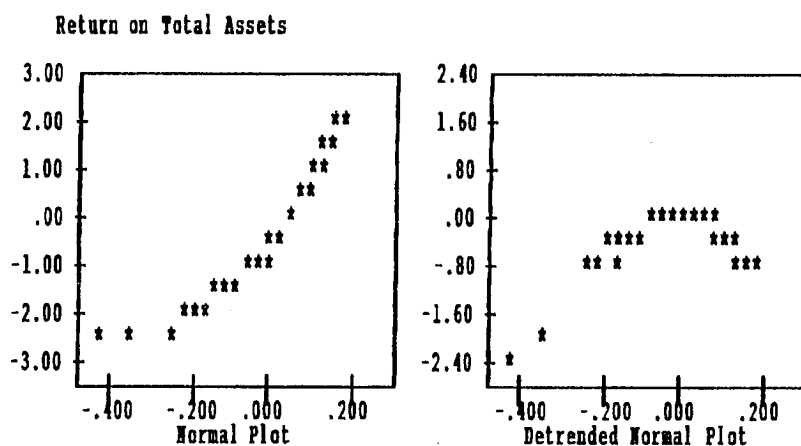
	146	Total		
CASES	Chi-Square	Sig.	Corrected for Ties	
			Chi-Square	Sig.
146	3.8899	.1430	3.9030	.1421

Table (4.43) shows that the mean ranks for the three groups are not significantly different. The mean rank for major leaguers seem to be different from that of triple A's. At a significance level of ($P = .1421$), the null hypothesis cannot be rejected. There are no significant differences in return on sales among the three groups.

II.3.3.4 Return on Total Assets

1. Test for Normality

Figure (4.19)
Normal and Detrended Plots (Return on Total Assets)



	Statistic	df	Significance
K-S (Lilliefors)	.0964	145	.0022

Figure (4.19) shows that the observed values for the variable return on total assets do not fall on a straight line in the normal plot. It also shows that the values are not clustered around the horizontal line through zero in the detrended plot. Kolmogorov-Smirnov statistics with a lilliefors significance level of ($P = .0001$) shows that the observed values for return on total assets are not normally distributed. Therefore, we resorted to using the nonparametric ANOVA.

total assets do not fall on a straight line in the normal plot. It also shows that the values are not clustered around the horizontal line through zero in the detrended plot. Kolmogorove-Smirnov statistics with a lilliefors significance level of ($P = .0001$) shows that the observed values for return on total assets are not normally distributed. Therefore, we resorted to using the nonparametric ANOVA.

Table (4.44)
Kruskal-Wallis One-Way ANOVA (Return on Total Assets)

RETURN ON TOTAL ASSETS				
Mean Rank	Cases			
80.34	43	CLUST1 = 1 : Major Leaguers		
71.08	12	CLUST1 = 2 : Superstars		
69.75	90	CLUST1 = 3 : Triple A's		

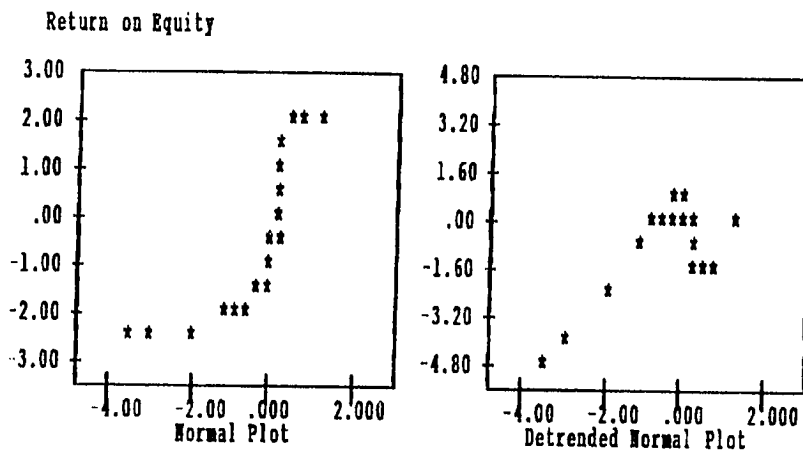
	145	Total		
CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
145	1.8760	.3914	1.8805	.3905

Table (4.44) shows that the mean ranks for the three groups are not significantly different. The mean rank for major leaguers seem to be different from that of triple A's. At a significance level of ($P = .3905$), the null hypothesis cannot be rejected. There are no significant differences in return on total assets among the three groups.

II.3.3.5 RETURN ON COMMON EQUITY

1. Test for Normality

Figure (4.20)
Normal and Detrended Plots (Return on Common Equity)



	Statistic	df	Significance
K-S (Lilliefors)	.2537	145	.0000

Figure (4.20) shows that the observed values for the variable return on return on common equity do not fall on a straight line in the normal plot. It also shows that the values are not clustered around the horizontal line through zero and seem to have a trend in the detrended plot. Kolmogorove-Smirnov statistics with a Lilliefors significance level of ($P = .0001$) shows that the observed values for return on common equity are not normally distributed. Therefore, we resorted to using the nonparametric ANOVA.

Table (4.45)
Kruskal-Wallis One-Way ANOVA
(Return on Common Equity)

Return on Equity				
by CLUST1				
Mean Rank		Cases		
80.49	43	CLUST1 = 1 : Major Leaguers		
75.00	12	CLUST1 = 2 : Superstars		
69.16	90	CLUST1 = 3 : Triple A's		

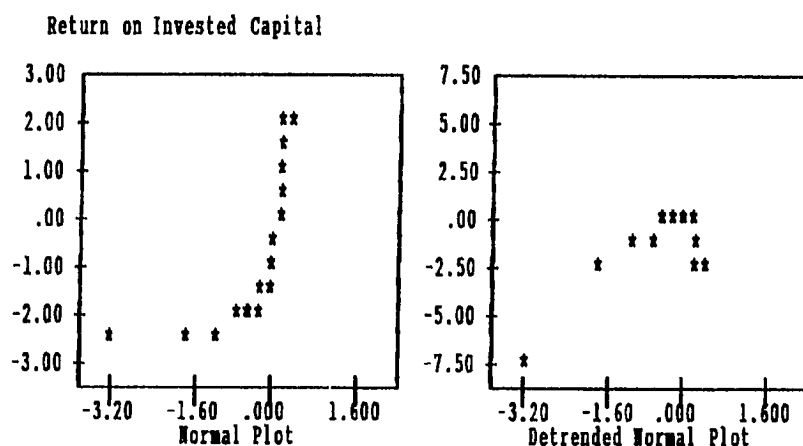
	145	Total		
		Corrected for Ties		
CASES	Chi-Square	Significance	Chi-Square	Significance
145	2.1480	.3416	2.1500	.3413

Table (4.45) shows that the mean ranks for the three groups are not significantly different. The mean rank for major leaguers seem to be different from that of triple A's. At a significance level of ($P = .3905$), the null hypothesis cannot be rejected. There are no significant differences in return on common equity among the three groups.

II.3.3.6 Return on Invested Capital

1. Test for Normality

Figure (4.21)
Normal and Detrended Plots (Return On Capital)



	Statistic	df	Significance
K-S (Lilliefors)	.2463	145	.0000

Figure (4.21) shows that the observed values for the variable return on return on invested capital do not fall on a straight line in the normal plot. It also shows that the values are not clustered around the horizontal line through zero and seem to have a trend in the detrended plot. Kolmogorove-Smirnov statistics with a Lilliefors significance level of ($P < .0001$) shows that the observed values for return on invested capital is not normally distributed. Therefore, we resorted to using the nonparametric ANOVA.

Table (4.46)
Kruskal-Wallis One-Way ANOVA (Return on Invested Capital)

Variable: Return on Capital by CLUST2				
Mean Rank	Cases			
62.38	33	CLUST2 = 1 : Major Leaguers		
61.45	11	CLUST2 = 2 : Superstars		
77.73	101	CLUST2 = 3 : Triple A's		

	145	Total		
	Corrected for Ties			
CASES	Chi-Square	Significance	Chi-Square	Significance
145	4.2210	.1212	4.2259	.1209

Table (4.46) shows that the mean ranks for the three groups are not significantly different. The mean rank for triple A's seem to be different from that of major leaguers and superstars. At a significance level of ($P = .1209$), the null hypothesis cannot be rejected. There are no significant differences in return on invested capital among the three groups.

II.4 CLUSTER ANALYSIS

In this part of the analysis we use the four dimensions of manufacturing capabilities as taxons or clustering variables. Three manufacturing capabilities clusters were formed. The clusters were named "High manufacturing performance", "Moderate manufacturing performance", and "Low manufacturing performance". Table (4.47) below shows the final cluster centers and the number of cases in each cluster.

Table (4.47)
Final Cluster centers and the Number of Cases in Each Cluster

Final Cluster Centers.				
Cluster	FLEX	RESP	QUAL	COST
1	9.5550	11.2607	13.3938	10.8450
2	19.1167	19.4762	21.6667	13.5000
3	12.8938	16.9267	18.9535	9.0195
Cluster	unweighted cases		weighted cases	
1	40.0		40.0	
2	12.0		12.0	
3	113.0		113.0	
Missing	0			
Total	165.0		165.0	

II.5 ANALYSIS OF VARIANCE

II.5.1 One-Way ANOVA Among Clusters

Oneway ANOVA over each taxon shows that groups with high manufacturing performance outperforms the other two groups on every manufacturing capabilities dimensions except on cost. The following tables of analysis of variance and multiple comparisons illustrate this point.

Table (4.48)
Analysis of Variance and Multiple Comparisons
(Flexibility)

Variable FLEX : Flexibility							
Analysis of Variance							
Source	D.F.	Sum of Squares	Mean Squares	F Ratio		F Prob.	
Between Groups	2	889.5832	444.7916	36.5204		.0000	
Within Groups	162	1973.0413	12.1793				
Total	164	2862.6245					

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean		
Grp 1	40	9.5550	2.9259	.4626	8.6192	To	10.4908
Grp 2	12	19.1167	1.7341	.5006	18.0149	To	20.2184
Grp 3	113	12.8938	3.7868	.3562	12.1880	To	13.5996
Total	165	12.5370	4.1779	.3253	11.8948	To	13.1792
Fixed Effects Model		3.4899	.2717		12.0005	To	13.0735
Random Effects Model			2.4618		1.9445	To	23.1294
Random Effects Model - Estimate of Between Component Variance							11.2305

Multiple Range Test

		G G G
		r r r
		p p p
Mean	Group	1 3 2
9.5550	Grp 1	
12.8938	Grp 3	*
19.1167	Grp 2	**

Table (4.49)
Analysis of Variance and Multiple Comparisons (Responsiveness)

Variable RESP: Responsiveness		Analysis of Variance					
Source		D.F.	Sum of Squares	FMMmn Mea Squares	F Ratio		F Prob.
Between Groups		2	1129.1954	564.5977	68.9476		.0000
Within Groups		162	1326.5851	8.1888			
Total		164	2455.7806				

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean		
Grp 1	40	11.2607	2.1960	.3472	10.5584	To	11.9630
Grp 2	12	19.4762	2.9133	.8410	17.6252	To	21.3272
Grp 3	113	16.9267	3.0548	.2874	16.3573	To	17.4961
Total	165	15.7385	3.8697	.3013	15.1437	To	16.3334
Fixed Effects Model			2.8616	.2228	15.2986	To	16.1784
Random Effects Model				2.7838	3.7607	To	27.7164
Random Effects Model - Estimate of Between Component Variance					14.4442		

Multiple Range Test

		G G G
		r r r
		p p p
Mean	Group	1 3 2
11.2607	Grp 1	
16.9267	Grp 3	*
19.4762	Grp 2	**

Table (4.50)
Analysis of Variance and Multiple Comparisons (Quality)

Variable QUAL

			Analysis of Variance			
Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.	
Between Groups	2	1106.3773	553.1886	63.1115	.0000	
Within Groups	162	1419.9712	8.7653			
Total	164	2526.3485				

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean		
Grp 1	40	13.3938	3.2269	.5102	12.3617	To	14.4258
Grp 2	12	21.6667	2.2822	.6588	20.2166	To	23.1167
Grp 3	113	18.9535	2.9225	.2749	18.4088	To	19.4983
Total	165	17.8030	3.9249	.3056	17.1997	To	18.4063
Fixed Effects Model			2.9606	.2305	17.3479	To	18.2582
Random Effects Model				2.7545	5.9514	To	29.6547
Random Effects Model - Estimate of Between Component Variance							14.1331

Multiple Range Test

		G G G
		r r r
		p p p
Mean	Group	1 3 2
13.3938	Grp 1	
18.9535	Grp 3	*
21.6667	Grp 2	* *

Table (4.51)
Analysis of Variance and Multiple Comparisons (Cost)

Variable COST					
Source	D.F.	Analysis of Variance		F Ratio	F Prob.
		Sum of Squares	Mean Squares		
Between Groups	2	276.7796	138.3898	14.1879	.0000
Within Groups	162	1580.1562	9.7541		
Total	164	1856.9358			

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean		
Grp 1	40	10.8450	2.8144	.4450	9.9449	To	11.7451
Grp 2	12	13.5000	3.6507	1.0539	11.1805	To	15.8195
Grp 3	113	9.0195	3.1688	.2981	8.4288	To	9.6101
Total	165	9.7879	3.3649	.2620	9.2706	To	10.3051
Fixed Effects Model			3.1231	.2431	9.3078	To	10.2680
Random Effects Model				1.3562	3.9526	To	15.6231
Random Effects Model - Estimate of Between Component Variance						3.3393	

Multiple Range Test

		G G G
		r r r
		p p p
Mean	Group	3 1 2
9.0195	Grp 3	
10.8450	Grp 1	*
13.5000	Grp 2	* *

It is important to mention that the purpose of conducting the One-Way ANOVA and projecting the tables showing the results of such analysis is to assert the practical utility of these clusters in subsequent analysis.

II.5.2 One-Way ANOVA:

Model (4) Manufacturing - Economic Performance of the Three groups

II.5.2.1 Inventory Turnover

Table (4.52)
One-Way ANOVA (Inventory Turnover)

INVTURN INVENTORY TURNOVER				
by CLUST2				
Mean Rank	Cases			
63.01	38	CLUST2 = 1 Moderate Manufacturing Performance		
121.92	12	CLUST2 = 2 High Manufacturing Performance		
81.31	109	CLUST2 = 3 Low Manufacturing Performance		

	159	Total		
CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
159	15.2054	.0005	15.2056	.0005

Table (4.52) shows that the mean ranks of inventory turnover for the three groups are different. At a significance level of ($P = .0005$), the null hypothesis was rejected. Indeed, there are differences in inventory turnover among the three groups. High manufacturing performance group outperform their counterparts on inventory turnover.

II.5.2.2 Five Years Sales Growth

Table (4.53)
One-Way ANOVA (Five Years Sales growth)

FVESALGR FIVE YEARS SALES GROWTH
by CLUST2

Mean Rank	Cases	
60.42	33	CLUST2 = 1 Moderate Manufacturing performance
77.68	11	CLUST2 = 2 High Manufacturing Performance
76.60	101	CLUST2 = 3 Low Manufacturing performance

	145	Total
Corrected for Ties		
CASES	Chi-Square	Significance
145	3.8365	.1469
	Chi-Square	Significance
	3.8368	.1468

Table (4.53) shows that the mean ranks for the three groups are not significantly different. At a significance level of ($P = .1468$), the null hypothesis cannot be rejected. There are no significant differences in five years sales growth among the three groups. However, Table (4.53) also shows that high manufacturing performance group outperform moderate manufacturing performance group.

II.5.2.3 Return on Sales

Table (4.54)
One-Way ANOVA (Return on Sales)

Return on SALES
by CLUST2

Mean Rank	Cases	
59.59	34	CLUST2 = 1 : Moderate Manufacturing Performance
58.18	11	CLUST2 = 2 : High Manufacturing Performance
79.85	101	CLUST2 = 3 : Low Manufacturing Performance

	146	Total
Corrected for Ties		
CASES	Chi-Square	Significance
146	7.4005	.0247
	Chi-Square	Significance
	7.4254	.0244

Table (4.54) shows that the mean ranks of Return on sales for the three groups are not quite different. At a significance level of ($P = .0244$), the null hypothesis was rejected. one can conclude that there are differences in return on sales between high manufacturing performance group and low manufacturing performance group. surprisingly, high manufacturing performance group came last ,as compared to their counterparts, on return on sales.

Table (4.55)
One-Way ANOVA (Return on Total Assets)

II.5.2.4 Return on Total Assets

NTINTAST RETURN ON TOTAL ASSETS
by CLUST2

Mean Rank	Cases	
61.17	33	CLUST2 = 1 Moderate Manufacturing Performance
63.14	11	CLUST2 = 2 High Manufacturing performance
77.94	101	CLUST2 = 3 Low Manufacturing performance

	145	Total

CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square	Significance
145	4.6234	.0991		4.6346	.0985

Table (4.55) shows that the mean ranks of Return on total assets for the three groups are not quite different. At a significance level of ($P = .0985$), the null hypothesis can not be rejected. one can conclude that there are no significant differences in return on total assets between high manufacturing performance group and moderate manufacturing performance group. surprisingly, high manufacturing performance group came second ,as compared

to their counterparts, on return on total assets.

Table (4.56)
One-Way ANOVA (Return on Invested Capital)

II.5.2.5 Return on Invested Capital

NTININCP RETURN ON INVESTED CAPITAL
by CLUST2

Mean Rank	Cases	
62.38	33	CLUST2 = 1 Moderate Manufacturing performance
61.45	11	CLUST2 = 2 High manufacturing performance
77.73	101	CLUST2 = 3 Low manufacturing performance

	145	Total

CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
145	4.2210	.1212	4.2259	.1209

Table (4.56) shows that the mean ranks for the three groups are not significantly different. At a significance level of ($P = .1209$), the null hypothesis cannot be rejected. There are no significant differences in return on Invested Capital among the three groups. surprisingly, that high manufacturing came last ,as compared to their counterparts, on return on invested capital.

Table (4.57)
One-Way ANOVA (Return on Common Equity)

II.5.2.6 Return on Common Equity

NTINCOEQ NET INCOME TO COMMON EQUITY

Mean Rank	Cases	
64.97	33	CLUST2 = 1 : Moderate Manufacturing Performance
59.23	11	CLUST2 = 2 : High Manufacturing Performance
77.12	101	CLUST2 = 3 : Low Manufacturing Performance

	145	Total

CASES		Chi-Square		Corrected for Ties	
				Significance	Significance
145	3.3626	.1861		3.3657	.1858

Table (4.57) shows that the mean ranks for the three groups are not significantly different. At a significance level of ($P = .1858$), the null hypothesis cannot be rejected. There are no significant differences in return on common equity among the three groups. surprisingly, that high manufacturing came last ,as compared to their counterparts, on return on common equity.

Table (58)
Summary of Hypotheses Testing for All Models

SUMMARY OF HYPOTHESIS TESTING

MODEL # AND HYPOTHESIS	NULL HYPOTHESIS	SIG. LEVEL
1. Technology - Manufacturing		
Overall Manufacturing	Rejected	P < .0001
Flexibility	Rejected	P < .0001
Responsiveness	Rejected	P < .0001
Quality	Rejected	P < .0001
Cost	Rejected	P = .0002
2. Technology - Eco.		
Inventory Turnover	Rejected	P < .0001
Five Years Sales Growth	Can not be Rejected	P = .8993
Return on Sales	Can not be rejected	P = .1421
Return on total assets	Can not be Rejected	P = .3905
Return on Common Equity	Can not be Rejected	P = .3413
Return on Invested Capital	Can not be Rejected	P = .1209
3. Technology - AMT Clusters		
	Rejected	P < .0001
4. Manufacturing - Mfg. Clusters		
Flexibility	Rejected	P < .0001
Responsiveness	Rejected	P < .0001
Quality	Rejected	P < .0001
Cost	Rejected	P < .0001
5. Manufacturing - Eco.		
Inventory turnover	Rejected	P = .0005
Five years Sales Growth	Can not be Rejected	P = .1468
Return on Sales	Rejected	P = .0244
Return on Total Assets	Can not be Rejected	P = .0985
Return on Common Equity	Can not be Rejected	P = .1858
Return on Invested Capital	Can not be Rejected	P = .1209

Table (4.59)
MANOVA Tests of Significance Among The Three
Groups

MANOVA X51EMPH TO X538EMPH BY CLUST1 (1,3) /DESIGN.

**** ANALYSIS OF VARIANCE -- DESIGN 1 ****

EFFECT .. CLUST1

Multivariate Tests of Significance (S = 2, M = 17 1/2, N = 56)

Test Name	Value	Approx. F	Hypoth. DF	Error DF	Sig. of F
Pillais	.71506	1.68413	76.00	230.00	.002
Hotellings	1.34911	2.00591	76.00	228.00	.000
Wilks	.38367	1.84334	76.00	228.00	.000
Roys	.52812				

Table (4.59) contains the value of Hotelling's T^2 statistics for the test of hypothesis that "Superstars", "Major Leaguers", and "Triple A's" do not differ on their emphasis on manufacturing strategy contents. With a significant level of ($P < .0001$), The null hypothesis that the three groups do not differ in their emphasis on the contents of manufacturing strategy, is therefore, rejected

To pinpoint where the differences might be, the univariate tests for the individual variables was examined. Tables (4.60) below shows the results of univariate tests. These results are almost the same obtained from the one-way ANOVA.

Table (4.60)
Univariate F-tests for each variable.

Univariate F-tests with (2,151) D. F.						
Variable	Hypoth. SS	Error SS	Hypoth. MS	Error MS	F	Sig. of F
X51EMPH	13.50571	278.05922	6.75286	1.84145	3.66714	.028
X52EMPH	45.01256	239.32510	22.50628	1.58493	14.20013	.000
X53EMPH	67.17622	400.38871	33.58811	2.65158	12.66720	.000
X54EMPH	39.90798	391.80631	19.95399	2.59474	7.69016	.001
X55EMPH	47.59400	404.30860	23.79700	2.67754	8.88763	.000
X56EMPH	13.12847	172.63777	6.56423	1.14330	5.74150	.004
X57EMPH	37.59579	563.02759	18.79789	3.72866	5.04146	.008
X58EMPH	11.01317	314.83748	5.50659	2.08502	2.64103	.075
X59EMPH	55.50085	378.89525	27.75042	2.50924	11.05929	.000
X510EMPH	64.26987	350.58728	32.13493	2.32177	13.84070	.000
X511EMPH	38.50038	419.26586	19.25019	2.77660	6.93302	.001
X512EMPH	2.37649	422.09754	1.18824	2.79535	.42508	.654
X513EMPH	23.51690	329.16492	11.75845	2.17990	5.39403	.005
X514EMPH	42.72346	533.17264	21.36173	3.53094	6.04986	.003
X515EMPH	32.46595	478.39119	16.23298	3.16815	5.12380	.007
X516EMPH	35.15097	393.47241	17.57548	2.60578	6.74481	.002
X517EMPH	37.22197	414.31699	18.61098	2.74382	6.78287	.002
X518EMPH	45.44856	314.81768	22.72428	2.08489	10.89953	.000
X519EMPH	26.97680	235.51670	13.48840	1.55971	8.64800	.000
X520EMPH	81.10085	390.50954	40.55043	2.58616	15.67981	.000
X521EMPH	39.44613	405.59283	19.72306	2.68605	7.34279	.001
X522EMPH	80.22113	440.27238	40.11056	2.91571	13.75670	.000
X523EMPH	35.58945	218.67029	17.79473	1.44815	12.28792	.000
X524EMPH	47.37311	332.21130	23.68656	2.20007	10.76625	.000
X525EMPH	20.33089	289.59768	10.16544	1.91787	5.30040	.006
X526EMPH	30.42421	446.69917	15.21210	2.95827	5.14223	.007
X527EMPH	16.02846	428.62738	8.01423	2.83859	2.82331	.063
X528EMPH	36.20207	269.77196	18.10104	1.78657	10.13173	.000
X529EMPH	7.45516	460.81108	3.72758	3.05173	1.22146	.298
X530EMPH	8.77951	352.83088	4.38976	2.33663	1.87867	.156
X531EMPH	5.72968	538.60799	2.86484	3.56694	.80316	.450
X532EMPH	2.44296	297.32327	1.22148	1.96903	.62035	.539
X533EMPH	7.51628	496.02268	3.75814	3.28492	1.14406	.321
X534EMPH	27.11168	342.99871	13.55584	2.27151	5.96775	.003
X535EMPH	26.46765	322.44144	13.23383	2.13537	6.19743	.003
X536EMPH	21.84208	242.70337	10.92104	1.60731	6.79462	.001
X537EMPH	18.77381	221.62229	9.38691	1.46770	6.39567	.002
X538EMPH	17.48039	288.37026	8.74019	1.90974	4.57665	.012

II. 6 ANALYSIS OF VARIANCE

II.6.1 One-Way ANOVA : Model (4) Degree of Emphasis on Action Programs.

In this part of the analysis we study the differences among the three groups in terms of the degree of emphasis on the thirty eight action programs (Part VI of the questionnaire). Table (4.61) below shows the mean and standard deviation for each action program for the three groups.

Table (4.61)
Mean and Standard Deviation for each action Program

Variable	Group (1) (N = 46)		Group (2) (N = 12)		Group (3) (N = 103)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
X51EMPH	3.76	1.18	4.25	.62	3.25	1.47
X52EMPH	3.07	.74	3.75	.75	2.17	1.44
X53EMPH	2.77	1.64	3.83	1.03	1.70	1.66
X54EMPH	2.70	1.63	4.08	.90	2.17	1.66
X55EMPH	3.17	1.50	4.08	.90	2.24	1.73
X56EMPH	3.93	1.00	4.50	.52	3.49	1.14
X57EMPH	3.00	1.83	2.75	2.14	1.89	1.94
X48EMPH	3.11	1.30	3.00	1.13	2.49	1.51
X59EMPH	3.39	1.27	3.75	.97	2.19	1.72
X510EMPH	2.72	1.50	3.08	1.16	1.39	1.59
X511EMPH	3.20	1.61	3.58	1.31	2.33	1.71
X512EMPH	1.72	1.50	1.58	1.73	1.40	1.71
X513EMPH	3.61	.95	3.58	1.38	2.78	1.63
X514EMPH	2.52	1.86	3.08	1.83	1.61	1.88
X515EMPH	2.80	1.64	2.92	1.83	1.83	1.82
X516EMPH	2.78	1.51	3.25	1.36	1.95	1.70
X517EMPH	3.76	1.40	4.33	.78	2.87	1.79
X518EMPH	3.85	.97	4.00	1.04	2.81	1.63
X519EMPH	3.57	.86	4.33	.49	2.96	1.42
X520EMPH	3.67	1.32	4.00	.74	2.34	1.81
X521EMPH	3.20	1.39	3.92	1.00	2.36	1.76
X522EMPH	2.76	1.67	2.92	1.56	1.30	1.70
X523EMPH	1.46	1.59	1.83	1.47	.50	.96
X524EMPH	1.84	1.52	2.50	1.45	.83	1.44
X525EMPH	3.59	1.11	4.00	.60	2.97	1.51
X526EMPH	2.28	1.81	2.25	1.60	1.46	1.71

Table (4.61) Continued

X527EMPH	2.37	1.62	2.00	1.28	1.67	1.72
X528EMPH	1.57	1.59	2.17	1.47	.71	1.23
X529EMPH	1.91	1.66	1.33	1.72	1.39	1.76
X530EMPH	1.09	1.64	1.33	1.44	.65	1.46
X531EMPH	2.43	1.78	1.83	1.75	2.04	1.93
X532EMPH	.91	1.66	.83	1.27	.57	1.30
X533EMPH	1.46	1.83	1.58	2.11	1.07	1.80
X534EMPH	2.93	1.37	3.83	.58	2.44	1.64
X535EMPH	3.15	1.28	4.00	.60	2.58	1.56
X536EMPH	3.57	1.05	4.33	.49	3.05	1.39
X537EMPH	3.83	1.08	4.58	.67	3.34	1.30
X538EMPH	4.02	1.20	4.25	.62	3.34	1.49

Table (4.61) shows that the second group, "Superstars", placed moderate to critical emphasis on sixty three percent of the action programs. The first group, "Major leaguers", places moderate to critical emphasis on fifty percent of the action programs. The third group, "Triple A's", places moderate to critical emphasis on only thirteen percent of the action programs. These results indicate that business units with higher level of technology places more emphasis on structural and infrastructural decisions of their manufacturing strategy. In addition to these preliminary results Kruskal-Wallis one way analysis of variance was conducted.

II.6.1.1 Emphasis on Lead Time Reduction

Table (4.62)
Degree of emphasis on Lead Time Reduction

Mean Rank	Cases			
90.27	46	CLUST1 = 1	(Major Leaguers)	
108.88	12	CLUST1 = 2	(Superstars)	
73.61	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
161	8.6962	.0129	Chi-Square	Significance
			9.5390	.0085

Table (4.62) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0085$), the null hypothesis was rejected and in fact the three groups differ in their emphasis on reducing lead time. Table (4.62) also shows that superstars indeed outperform their counterparts on this action program.

II.6.1.2 Emphasis on Preventive Maintenance.

Table (4.63)
Emphasis on Preventive Maintenance

Mean Rank	Cases			
96.29	46	CLUST1 = 1	(Major Leaguers)	
123.92	12	CLUST1 = 2	(Superstars)	
69.17	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
161	21.7511	.0000	Chi-Square	Significance
			23.4418	.0000

Table (4.63) shows that the mean ranks for the three groups are different. At a significance level of ($P < .00001$), The null hypothesis was rejected . Indeed the three groups differ on their emphasis on preventive maintenance. Table (4.63) also shows that superstars outperformed their counterparts on this action program.

II.6.1.3 Emphasis on Job Enrichment.

Table (4.64)
Emphasis on Job Enrichment

Mean Rank	Cases			
94.42	44	CLUST1 = 1	(Major Leaguers)	
122.00	12	CLUST1 = 2	(Superstars)	
68.06	102	CLUST1 = 3	(Triple A's)	

	158	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
158	21.4047	.0000	Chi-Square	Significance
			22.8012	.0000

Table (4.64) shows that the mean ranks for the three groups are different. At a significance level ($P < .00001$), the null hypothesis was rejected. The implication of this fact is that inspite of the high level of technology they attain, superstars emphasized this aspect of human resource in their organization. They also outperform their counterparts in this regard.

II.6.1.4 Emphasis on SPC - Product.

Table (4.65)
Emphasis on Statistical Process Control - Product

Mean Rank	Cases			
87.34	46	CLUST1 = 1	(Major Leaguers)	
126.00	12	CLUST1 = 2	(Superstars)	
72.93	103	CLUST1 = 3	(Triple A's)	

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	15.1184	.0005	15.9302	.0003

Table (4.65) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0003$), the null hypothesis was rejected. Indeed, the three groups differ in their emphasis on SPC-Product. Table (4.65) also shows that superstars outperform their counterparts in the emphasis on this action program.

II.6.1.5 Emphasis on SPC - Process.

Table (4.66)
Emphasis on Statistical Process Control - Process.

Mean Rank	Cases			
94.99	46	CLUST1 = 1	(Major Leaguers)	
120.21	12	CLUST1 = 2	(superstars)	
70.18	103	CLUST1 = 3	(Triple A's)	

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	18.1725	.0001	19.1554	.0001

Table (4.66) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0001$), the null hypothesis was

rejected. Indeed, the three groups differ in their emphasis on this action program. Table (4.68) also shows that superstars outperform their counterparts in this regard.

II.6.1.6 Emphasis on Worker Safety.

Table (4.67)
Emphasis on Worker Safety.

Mean Rank	Cases			
90.41	46	CLUST1 = 1	(Major Leaguers)	
115.50	12	CLUST1 = 2	(Superstars)	
72.78	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
161	11.6512	.0030	12.5596	.0019

Table (4.67) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0019$), the null hypothesis was rejected. Indeed, the three groups differ in their emphasis on worker safety. Table (4.69) also shows that superstars outperform their counterparts on this action program.

II.6.1.7 Emphasis on Zero Defects.

Table (4.68)
Emphasis on Zero Defects.

Mean Rank	Cases			
96.54	46	CLUST1 = 1	(Major Leaguers)	
91.96	12	CLUST1 = 2	(Superstars)	
72.78	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
161	8.9770	.0112	9.6979	.0078

Table (4.68) shows that slight difference between superstars and major leaguers exists. Both groups differ significantly from the third group. At a significance of ($P = .0078$), the null hypothesis was rejected. However, Major leaguers outperform both superstars and triple A's.

II.6.1.8 Emphasis on Integrating M.I.S Across Areas.

Table (4.69)
Emphasis on integrating M.I.S Across Areas.

Mean Rank	Cases			
94.40	46	CLUST1 = 1 (Major Leaguers)		
90.04	12	CLUST1 = 2 (Superstars)		
73.96	103	CLUST1 = 3 (Triple A's)		

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
161	6.6007	.0369	Chi-Square	Significance
			6.9683	.0307

Table (4.69) shows that slight difference between superstars and major leaguers exists. Both groups differ significantly from the third group. At a significance level of ($P = .0307$), the null hypothesis was rejected. However, major leaguers outperform both superstars and triple A's.

II.6.1.9 Emphasis on Integrating M.I.S within Manufacturing.

Table (4.70)
Emphasis on Integrating M.I.S Within Manufacturing

Mean Rank	Cases			
101.16	46	CLUST1 = 1 (Major Leaguers)		
110.29	12	CLUST1 = 2 (Superstars)		
68.58	103	CLUST1 = 3 (Triple A's)		

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
161	20.6484	.0000	Chi-Square	Significance
			21.6512	.0000

Table (4.70) shows that the mean ranks for the three groups are different. At a significance level of ($P < .00001$), the null hypothesis was rejected. Indeed, the three groups differ in their emphasis on integrating information systems within manufacturing. Table (4.72) shows that superstars outperform both major leaguers and triple A's on this action program.

II.6.1.10 Emphasis on CAM.

Table (4.71)
Emphasis on Computer Aided Manufacturing.

Mean Rank	Cases			
102.67	46	CLUST1 = 1	(Major Leaguers)	
113.67	12	CLUST1 = 2	(Superstars)	
67.51	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
161	24.4516	.0000	26.5855	.0000

Table (4.71) shows that the mean ranks for the three groups are different. At a significance level of ($P < .00001$), the null hypothesis was rejected. Indeed, the three groups differ in their emphasis on using computer aided manufacturing. Superstars outperform major leaguers and Triple A's on this action program.

II.6.1.11 Emphasis on Giving Workers More Planning Responsibility.

Table (4.72) Emphasis on Giving Workers More Planning Responsibility

Mean Rank	Cases			
95.80	46	CLUST1 = 1	(Major Leaguers)	
106.54	12	CLUST1 = 2	(Superstars)	
71.41	103	CLUST1 = 3	(Triple A's)	

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	12.5962	.0018	13.3074	.0013

Table (4.72) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0013$), the null hypothesis was rejected. Indeed, the three groups differ on giving workers more planning responsibility. Table (4.74) also shows that superstars outperform their counterpart on this action program.

II.6.1.12 Emphasis on Narrowing Product Lines.

**Table (4.73)
Emphasis on Narrowing Product Lines.**

Mean Rank	Cases			
88.35	46	CLUST1 = 1	(Major Leaguers)	
82.46	12	CLUST1 = 2	(Superstars)	
77.55	103	CLUST1 = 3	(Triple A's)	

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	1.7189	.4234	1.9400	.3791

Table (4.73) shows that the mean ranks for the three groups are not really different. A significance level of ($P = .3791$) enables one not to reject the null hypothesis. As a result, one can conclude that the three groups do not

differ among themselves on narrowing product lines.

II.6.1.13 Emphasis on Giving Worker Broader Range of Tasks.

Table (4.74)
Emphasis on giving Workers Broader range of Tasks.

Mean Rank	Cases			
94.08	46	CLUST1 = 1	(Major Leaguers)	
100.17	12	CLUST1 = 2	(Superstars)	
72.93	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
161	8.7353	.0127	9.4276	.0090

Table (4.74) shows that the mean rank for the three groups are different. At a significance level of ($P = .0090$), the null hypothesis was rejected. Indeed, the three groups differ on giving workers broader range of tasks. Table (4.76) also shows that superstars outperform their counterparts on this action program.

II.6.1.14 Emphasis on Quality Circles.

Table (4.75)
Emphasis on Quality Circles.

Mean Rank	Cases			
93.67	46	CLUST1 = 1	(Major Leaguers)	
105.92	12	CLUST1 = 2	(Superstars)	
72.44	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
161	10.3021	.0058	11.3736	.0034

Table (4.75) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0034$), the null hypothesis was rejected indicating that the three groups differ in their emphasis on quality circles. Table (4.75) also shows that superstars outperform their counterparts on this action program.

II.6.1.15 Emphasis on Reducing the Size of Manufacturing Workforce.

Table (4.76)
Emphasis on Reducing the Size of Manufacturing Workforce.

Mean Rank	Cases			
96.04	46	CLUST1 = 1	(Major Leaguers)	
100.33	12	CLUST1 = 2	(Superstars)	
72.03	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
161	10.6669	.0048	Chi-Square	Significance
			11.4917	.0032

Table (4.76) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0032$), the null hypothesis was rejected indicating that the three groups differ in their emphasis on reducing the size of their manufacturing workforce. Table (4.76) also shows that superstars outperform their counterparts on this action program.

11.6.1.16 Emphasis on Developing New process for Old Products.

Table (4.77)
Emphasis on Developing New Processes for Old Products.

Mean Rank	Cases			
92.62	45	CLUST1 = 1	(Major Leaguers)	
106.21	12	CLUST1 = 2	(Superstars)	
72.21	103	CLUST1 = 3	(Triple A's)	

	160	Total		
CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
160	10.0735	.0065	10.7359	.0047

Table (4.77) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0047$), the null hypothesis was rejected. The three groups differ in their emphasis on developing new processes for old products. Table (4.77) also indicates that superstars outperform their counterparts on this action programs.

II.6.1.17 Emphasis on Developing new processes for new products.

Table (4.78)
Emphasis on Developing New Processes for New Products.

Mean Rank	Cases			
95.62	46	CLUST1 = 1	(Major Leaguers)	
111.50	12	CLUST1 = 2	(Superstars)	
70.92	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
161	14.4768	.0007	15.4702	.0004

Table (4.78) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0004$), the null hypothesis was

rejected. The three groups differ in their emphasis for developing new processes for new products. Table (4.78) also shows that superstars outperform their counterparts on this action program.

II.6.1.18 Defining a Manufacturing Strategy.

Table (4.79)
Emphasis on Defining a Manufacturing Strategy.

Mean Rank	Cases			
99.42	46	CLUST1 = 1	(Major Leaguers)	
105.00	12	CLUST1 = 2	(Superstars)	
69.98	103	CLUST1 = 3	(Triple A's)	

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	16.1235	.0003	17.0985	.0002

Table (4.79) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0002$), the null hypothesis was rejected. The three groups differ in their emphasis on defining a manufacturing strategy. Table (4.79) also show that superstars outperformed their counterparts on this action program.

II.6.1.19 Emphasis on Vendor Lead Time.

Table (4.80)
Emphasis on Vendor Lead Time.

Mean Rank	Cases			
89.57	46	CLUST1 = 1	(Major Leaguers)	
125.00	12	CLUST1 = 2	(Superstars)	
72.05	103	CLUST1 = 3	(Triple A's)	

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	16.0386	.0003	17.4882	.0002

Table (4.80) shows that the mean ranks for the three groups are different. At a significance level ($P = .0002$), the null hypothesis was rejected. The three groups differ in their emphasis on Vendor lead time. Table (4.80) also shows that superstars outperformed their counterparts on this action program.

II.6.1.20 Emphasis on JIT.

Table (4.81)
Emphasis on Just-In-Time.

Mean Rank	Cases			
103.01	46	CLUST1 = 1	(Major Leaguers)	
110.50	12	CLUST1 = 2	(Superstars)	
67.73	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	
161	23.3993	.0000	Chi-Square	Significance
			24.6473	.0000

Table (4.81) shows that the mean ranks for the three groups are different. At a significance level of ($P < .00001$), the null hypothesis was rejected. The three groups differ in their emphasis on Just In Time. Table (4.81) also show that superstars outperformed their counterparts on this action program.

II.6.1.21 Emphasis on Reducing Setup/Changeover Time.

Table (4.82)
Emphasis on Reducing Setup/Changeover Time.

Mean Rank	Cases			
91.64	46	CLUST1 = 1	(Major Leaguers)	
113.96	12	CLUST1 = 2	(Superstars)	
72.41	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
161	11.8924	.0026	12.4358	.0020

Table (4.82) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0020$), the null hypothesis was rejected. The three groups differ in their emphasis on reducing setup/changeover time. Table (4.82) also show that superstars outperformed their counterparts on this action program.

II.6.1.22 Emphasis on FMS.

Table (4.83)
Emphasis on Flexible Manufacturing Systems

Mean Rank	Cases			
102.64	45	CLUST1 = 1	(Major Leaguers)	
104.79	12	CLUST1 = 2	(Superstars)	
68.00	103	CLUST1 = 3	(Triple A's)	

	160	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
160	21.0812	.0000	23.5217	.0000

Table (4.83) shows that the mean ranks for the three groups are different. At a significance level of ($P < .00001$), the null hypothesis was

rejected. The three groups differ in their emphasis on Flexible manufacturing systems. Table (4.83) also show that superstars outperformed their counterparts on this action program.

II.6.1.23 Emphasis on Introducing Robots.

Table (4.84)
Emphasis on introducing Robots.

Mean Rank	Cases			
97.38	46	CLUST1 = 1	(Major Leaguers)	
110.00	12	CLUST1 = 2	(Superstars)	
70.31	103	CLUST1 = 3	(Triple A's)	

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	15.7416	.0004	21.9371	.0000

Table (4.84) shows that the mean ranks for the three groups are different. At a significance level of ($P < .00001$), the null hypothesis was rejected. The three groups differ in their emphasis on introducing robots. Table (4.84) also show that superstars outperformed their counterparts on this action program.

II.6.1.24 Emphasis on Group Technology.

Table (4.85)
Emphasis on Group Technology.

Mean Rank	Cases			
96.90	44	CLUST1 = 1	(Major Leaguers)	
114.13	12	CLUST1 = 2	(Superstars)	
68.81	103	CLUST1 = 3	(Triple A's)	

	159	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
159	18.6059	.0001	23.1434	.0000

Table (4.85) shows that the mean ranks for the three groups are different. At a significance level of ($P = .00001$), the null hypothesis was rejected. The three groups differ in their emphasis on group technology. Table (4.85) also show that superstars outperformed their counterparts on this action program.

II.6.1.25 Emphasis on CAD.

Table (4.86)
Emphasis on Computer Aided Design.

Mean Rank	Cases			
90.85	46	CLUST1 = 1	(Major Leaguers)	
106.58	12	CLUST1 = 2	(Superstars)	
73.62	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
161	8.2461	.0162	8.9521	.0114

Table (4.86) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0114$), the null hypothesis was rejected. The three groups differ in their emphasis on computer aided design. Table (4.86) also show that superstars outperformed their counterparts on this action program.

II.6.1.26 Emphasis on Capacity Expansion.

Table (4.87)
Emphasis on Capacity Expansion.

Mean Rank	Cases				
94.28	46	CLUST1 = 1 (Major Leaguers)			
93.08	12	CLUST1 = 2 (Superstars)			
73.66	103	CLUST1 = 3 (Triple A's)			

	161	Total			
			Corrected for Ties		
CASES	Chi-Square	Significance	Chi-Square	Significance	
161	7.0930	.0288	7.9029	.0192	

Table (4.87) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0192$), the null hypothesis was rejected. The three groups differ in their emphasis on capacity expansion. Table (4.87) also show that major leaguers outperformed their counterparts on this action program.

II.6.1.27 Emphasis on Reconditioning Physical facilities.

Table (4.88)
Emphasis on Reconditioning Physical facilities.

Mean Rank	Cases			
94.49	46	CLUST1 = 1 (Major Leaguers)		
83.13	12	CLUST1 = 2 (Superstars)		
74.73	103	CLUST1 = 3 (Triple A's)		

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	5.7400	.0567	6.2358	.0442

Table (4.88) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0442$), the null hypothesis was rejected. The three groups differ in their emphasis on reconditioning physical

facilities. Table (4.88) also show that major leaguers outperformed their counterparts on this action program.

II.6.1.28 Emphasis on Automated Jobs.

Table (4.89)
Emphasis on Automated Jobs.

Mean Rank	Cases			
95.64	46	CLUST1 = 1	(Major Leaguers)	
112.50	12	CLUST1 = 2	(Superstars)	
70.79	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
161	14.9539	.0006	19.4844	.0001

Table (4.89) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0001$), the null hypothesis was rejected. The three groups differ in their emphasis on automated jobs. Table (4.89) also show that superstars outperformed their counterparts on this action program.

II.6.1.29 Emphasis on reducing the Size of the Manufacturing Units.

Table (4.90)
Emphasis on Reducing the Size of Manufacturing Units

Mean Rank	Cases			
90.65	46	CLUST1 = 1	(Major Leaguers)	
75.79	12	CLUST1 = 2	(Superstars)	
77.30	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties Chi-Square	Significance
161	2.7716	.2501	3.2718	.1948

Table (4.90) shows that the mean ranks for the three groups are different. At a significance level of ($P = .1948$), the null hypothesis can not be

rejected. The three groups do not significantly differ in their emphasis on reducing the size of the manufacturing units. Table (4.90) also show that major leaguers outperformed their counterparts on this action program. In fact, superstars came last on this action programs.

II.6.1.30 Emphasis on Plants relocation.

Table (4.91)
Emphasis on Plants Relocation.

Mean Rank	Cases			
88.71	46	CLUST1 = 1	(Major Leaguers)	
97.42	12	CLUST1 = 2	(Superstars)	
75.65	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
161	4.1035	.1285	6.7807	.0337

Table (4.91) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0337$), the null hypothesis was rejected. The three groups differ in their emphasis on plants relocation. Table (4.91) also show that superstars outperformed their counterparts on this action program.

II.6.1.31 Emphasis on Manufacturing Reorganization.

Table (4.92)
Emphasis on Manufacturing Reorganization.

Mean Rank	Cases			
87.95	46	CLUST1 = 1	(Major Leaguers)	
72.88	12	CLUST1 = 2	(Superstars)	
78.84	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
161	1.8056	.4481	1.7486	.4171

Table (4.92) shows that the mean ranks for the three groups are different. At a significance level of ($P = .4171$), the null hypothesis can not be rejected. The three groups do not significantly differ in their emphasis on manufacturing reorganization. Table (4.92) also show that major leaguers outperformed their counterparts on this action program. In fact, superstars came last on this action program.

II.6.1.32 Emphasis on Closing Plants.

Table (4.93)
Emphasis on Closing Plants.

Mean Rank	Cases			
84.97	46	CLUST1 = 1	(Major Leaguers)	
88.00	12	CLUST1 = 2	(Superstars)	
78.41	103	CLUST1 = 3	(Triple A's)	

	161	Total		
			Corrected for Ties	
CASES	Chi-Square	Significance	Chi-Square	Significance
161	.9209	.6310	1.7329	.4204

Table (4.93) shows that the mean ranks for the three groups are different. At a significance level of ($P = .4204$), the null hypothesis can not be rejected. The three groups do not significantly differ in their emphasis on closing plants. Table (4.93) also show that superstars outperformed their counterparts on this action program.

II.6.1.33 Emphasis on Changing Labor/Management Relation.

Table (4.94)
Emphasis on Changing Labor/Management Relation.

Mean Rank	Cases			
86.83	46	CLUST1 = 1	(Major Leaguers)	
88.21	12	CLUST1 = 2	(Superstars)	
76.74	102	CLUST1 = 3	(Triple A's)	

	160	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
160	1.8614	.3943	2.6660	.2637

Table (4.94) shows that the mean ranks for the three groups are different. At a significance level of ($P = .2637$), the null hypothesis can not be rejected. The three groups do not significantly differ in their emphasis on changing labor/management relations. Table (4.94) also show that superstars outperformed their counterparts on this action program.

II.6.1.34 Emphasis on Management Training.

Table (4.95)
Emphasis on Management Training.

Mean Rank	Cases			
86.05	46	CLUST1 = 1	(Major Leaguers)	
117.21	12	CLUST1 = 2	(Superstars)	
74.52	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
161	9.7663	.0076	10.3346	.0057

Table (4.95) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0057$), the null hypothesis was rejected. The three groups differ in their emphasis on management training. Table (4.95) also show that superstars outperformed their counterparts on this action program.

II.6.1.35 Emphasis on Supervisor Training.

Table (4.96)
Emphasis on Supervisor Training.

Mean Rank	Cases			
88.48	46	CLUST1 = 1	(Major Leaguers)	
120.33	12	CLUST1 = 2	(Superstars)	
73.08	103	CLUST1 = 3	(Triple A's)	

	161	Total		
CASES	Chi-Square	Significance	Corrected for Ties	Chi-Square
161	12.6996	.0017	13.6206	.0011

Table (4.96) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0011$), the null hypothesis was rejected. The three groups differ in their emphasis on supervisor training. Table (4.96) also show that superstars outperformed their counterparts on this action program.

II.6.1.36 Emphasis on Worker Training.

Table (4.97)
Emphasis on Worker Training.

Mean Rank		Cases		
88.82		46	CLUST1 = 1	(Major Leaguers)
122.67		12	CLUST1 = 2	(Superstars)
72.66		103	CLUST1 = 3	(Triple A's)

		161	Total	
CASES	Chi-Square	Significance	Corrected for Ties	
161	14.1777	.0008	Chi-Square	Significance
			15.5288	.0004

Table (4.97) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0004$), the null hypothesis was rejected. The three groups differ in their emphasis on worker training. Table (4.97) also show that superstars outperformed their counterparts on this action program.

II.6.1.37 Emphasis on Vendor Quality.

Table (4.98)
Emphasis on Vendor Quality.

Mean Rank		Cases		
89.61		46	CLUST1 = 1	(Major Leaguers)
122.29	12		CLUST1 = 2	(Superstars)
72.34		103	CLUST1 = 3	(Triple A's)

		161	Total	
CASES	Chi-Square	Significance	Corrected for Ties	
161	14.5320	.0007	Chi-Square	Significance
			15.7405	.0004

Table (4.98) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0004$), the null hypothesis was rejected. The three groups differ in their emphasis on vendor quality. Table (4.98) also show that superstars outperformed their counterparts on this action program.

II.6.1.38 Emphasis on Yield problems/Rejects.

Table (4.99)
Emphasis on Yield Problems/Rejects.

Mean Rank	Cases	
96.15	46	CLUST1 = 1 (Major Leaguers)
99.79	12	CLUST1 = 2 (Superstars)
72.04	103	CLUST1 = 3 (Triple A's)

	161	Total
CASES	Chi-Square	Significance
161	10.6100.0050	11.6322.0030
		Corrected for Ties
		Chi-Square
		Significance

Table (4.99) shows that the mean ranks for the three groups are different. At a significance level of ($P = .0030$), the null hypothesis was rejected. The three groups differ in their emphasis on yield problems/rejects. Table (4.99) also show that superstars outperformed their counterparts on this action program.

SUMMARY OF THE HYPOTHESES:

ACTION PROGRAM	Null Hypothesis	Group
1. Lead Time Reduction.	Rejected	$g2 > g1 > g3$
2. Preventive Maintenance.	Rejected	$g2 > g1 > g3$
3. Job enrichment.	Rejected	$g2 > g1 > g3$
4. SPC - Product.	Rejected	$g2 > g1 > g3$
5. SPC - Process.	Rejected	$g2 > g1 > g3$
6. Worker Safety.	Rejected	$g2 > g1 > g3$
7. Zero Defects.	Rejected	$g1 > g2 > g3$
8. M.I.S Across Areas.	Rejected	$g1 > g2 > g3$
9. M.I.S Within Manufacturing.	Rejected	$g2 > g1 > g3$
10. CAM.	Rejected	$g2 > g1 > g3$
11. Giving Workers More Planning Responsibility.	Rejected	$g2 > g1 > g3$
12. Narrowing Products Lines.	Can not be Rejected	$g1 > g2 > g3$
13. Giving Workers Broader Range of Tasks.	Rejected	$g2 > g1 > g3$
14. Quality Circles.	Rejected	$g2 > g1 > g3$
15. Reducing the Size of Manufacturing Workforce.	Rejected	$g2 > g1 > g3$
16. Developing New Processes for Old Products.	Rejected	$g2 > g1 > g3$
17. Developing New Processes for New Products.	Rejected	$g2 > g1 > g3$
18. Defining a Manufacturing Strategy.	Rejected	$g2 > g1 > g3$
19. Vendor Lead Time.	Rejected	$g2 > g1 > g3$
20. JIT.	Rejected	$g2 > g1 > g3$
21. Reducing Setup/Changeover Time.	Rejected	$g2 > g1 > g3$
22. FMS.	Rejected	$g2 > g1 > g3$
23. Robotics.	Rejected	$g2 > g1 > g3$
24. Group Technology.	Rejected	$g2 > g1 > g3$
25. CAD.	Rejected	$g2 > g1 > g3$
26. Capacity Expansion.	Rejected	$g1 > g2 > g3$
27. Reconditioning Physical Facilities.	Rejected	$g1 > g2 > g3$
28. Automated Jobs.	Rejected	$g2 > g1 > g3$
29. Reducing the Size of Manufacturing Units.	Can not be Rejected	$g1 > g2 > g3$
30. Plant Relocation.	Rejected	$g2 > g1 > g3$
31. Manufacturing Reorganization.	Can not be Rejected	$g1 > g3 > g2$
32. Closing Plants.	Can not be Rejected	$g2 > g1 > g3$
33. Changing Management/Labor Relation.	Can not be Rejected	$g2 > g1 > g3$
34. Management Training.	Rejected	$g2 > g1 > g3$
35. Supervisor Training.	Rejected	$g2 > g1 > g3$
36. Worker Training.	Rejected	$g2 > g1 > g3$
37. Vendor Quality.	Rejected	$g2 > g1 > g3$
38. Yield Problems/Rejects.	Rejected	$g2 > g1 > g3$

Hint: Group 2 are the Superstars.
 Group 1 are the Major Leaguers.
 Group 3 are the Triple A's.

CHAPTER (V)

SUMMARY, CONCLUSIONS AND AVENUES FOR FURTHER RESEARCH

The contribution of this research and the results emerged from the statistical analysis in chapter IV can be discussed under the following headings:

1. Definitions.
2. Conceptual and theoretical contribution.
3. Empirical results.
4. Areas for further research.

1. DEFINITIONS

In the last decade alone there have been many writings on the subject of Advanced Manufacturing Technologies. Extensive review of literature enabled us to pinpoint some of the misconceptions about what constitutes AMT. AMT was defined in this dissertation as follows: ***Advanced manufacturing Technology is a group of integrated hardware- and software-based technologies that if properly implemented, monitored and evaluated, will result in a higher efficiency and effectiveness in manufacturing a product or rendering a service.***

The definition is unique in many respects.

1. It can be applied to manufacturing organizations as well as service type organization.

2. It emphasizes the integration of these technologies to achieve synergetic and strategic competitive advantage.
3. It emphasizes that implementing these technologies is just as important as monitoring and evaluating it. Many of the companies fail to realize the synergetic results mainly because they fail to monitor and evaluate these technologies.

CONCEPTUAL AND THEORETICAL CONTRIBUTION

The conceptual model we introduced in chapter (I) is a step toward integrating manufacturing strategy decisions into a business strategy. The relationship between manufacturing and finance as well as that between manufacturing and other functional areas in the firm must be in harmony and must be integrated in a holistic approach. The integration of these functional strategies will enable firms to achieve synergetic results.

When we studied the financial performance of the participating business units, it was not just downloading and analyzing publicly disclosed data. Our intention was to go one step further and look at available qualitative data. For each business unit that responded to our questionnaire, a complete file was downloaded from the Compact Disclosure System and other publicly accessible data bases. In addition to the financial data, The file shows valuable qualitative information. This information ranges from the president letter to shareholders to the management discussions and strategies. In some cases the file was fifty to sixty pages long. Reading into the components of the file , in

addition to the empirical findings, enabled us to get a clear picture of what is going on.

Our model suggests that financial performance should be analyzed in conjunction with manufacturing performance. The bottom line in manufacturing is to maximize profit says Fox (1987). Heard (1990), Beckman (1990), Hayes et al (1988), and Schroeder (1986) addressed that relationship.

The AMT assessment equation we developed in this dissertation is the first of its kind. The equation is consistent and in accordance with the conceptual model we developed. Our contribution to the existing body of literature in this regard is explained below.

The equation relates the four critical factors to the success in using AMT. These four factors are: the existence of the technology, the utilization of the technology, the integration of the technology with other available technologies, and time since the technology has been used. These four components of the equation are necessary to evaluate the impact of the technology on manufacturing and economic performance of the firm.

The equation can be used in two scenarios. First, a manager can use it to evaluate different configurations of the above mentioned factors and decide upon the technology-strategy decisions in his or her firm. Secondly, It can be used as an assessment for competitive advantage when information about competitors is available.

The list of AMT used in this research is not collectively exhaustive since

it is always expanding and new technologies are always introduced.

EMPIRICAL RESULTS

The indepth analysis undertaken in chapter (IV) reveals that Advanced Manufacturing Technologies indeed have an impact on firms's manufacturing performance. Firms with higher score on the equation of "AMTINDEX," were found to outperform their counterparts in overall manufacturing performance as well as each dimension of manufacturing capabilities individually. Firms with higher level of AMT are more flexible, responsive, produce high quality products at a lower cost in general.

In responding to the question of how important is each and every one of these four dimension,as they relate to business strategy, respondents indicated that quality, responsiveness, flexibility and cost are in that order of importance. The following table clearly shows just that.

**Table (5.1) Rank order of the Importance of the Four
Dimensions of Manufacturing Capability**

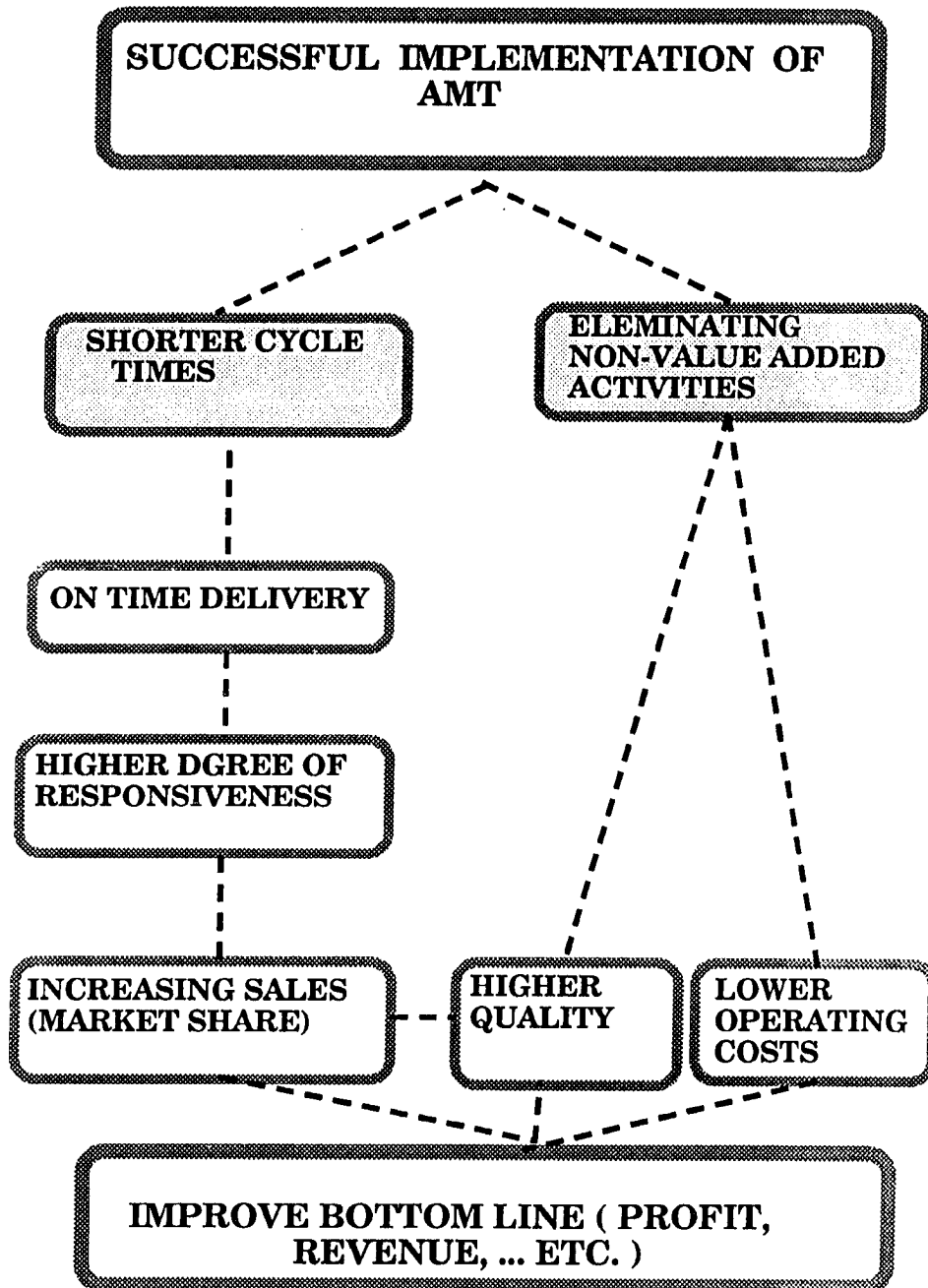
Variable	Mean	Std Dev	Min.	Max.	N	Label	Rank
X411	3.50	.91	1	5	165	COST	4
X412	4.57	.66	2	5	165	QUALITY	1
X413	4.47	.70	2	5	165	RESPONSIVENESS	2
X414	3.52	.91	1	5	165	FLEXIBILITY	3

It was not a surprise to see that quality is still "job one". The second most important dimension was responsiveness. It was not also a surprise

finding. Firms are beginning to realize that the next battle field is "Time-based competition". Firms that will beat their competitors to the market place will stay there for a long time. The third most important dimension was flexibility in providing a variety of products as often as requested by customers. Although for a long time American manufacturers were blaming failure to compete in international markets on lower cost of production, they start to realize that cost-quality, cost-responsiveness, and cost-flexibility can be achieved simultaneously. Cost is a factor but no longer the determining factor in completion.

Our view based on these findings is schematically depicted below:

Figure (5.1)

Impact of Successful Implementation of AMT

To the contrary of what we expected, we found that the percent of programmable automation is very low. Except for few companies, who are leaders in their industries, the percent of programmable automation was mainly between thirty to forty percent. The existence of time-based and computer-based technologies, in terms of their number, was moderate. These two finding coupled with low level of technology integration enabled us to conclude the following: (1) The factory of the future is not yet at hand. (2) What most of the companies have is really islands of automation not full automation or CIM users. Only seven percent of the sample can be said to be a CIM user.

Number of CBT and the size of the firm (as measures by total assets) are not independent. Larger firms were found to have acquired a large number of these technologies.

Level of technology integration was also found to be associated with the number of CBT. Our conclusion was: as the firm acquires more of these technologies, they tend to use them in an integrated way. This conclusion is highly supported by the existing body of literature.

The time since the technology was adopted and implemented was not really a discriminating factor since most of the firms sampled have the technology between two and five years. The three industry groups we studied here do not differ significantly in evaluating the four dimension of their

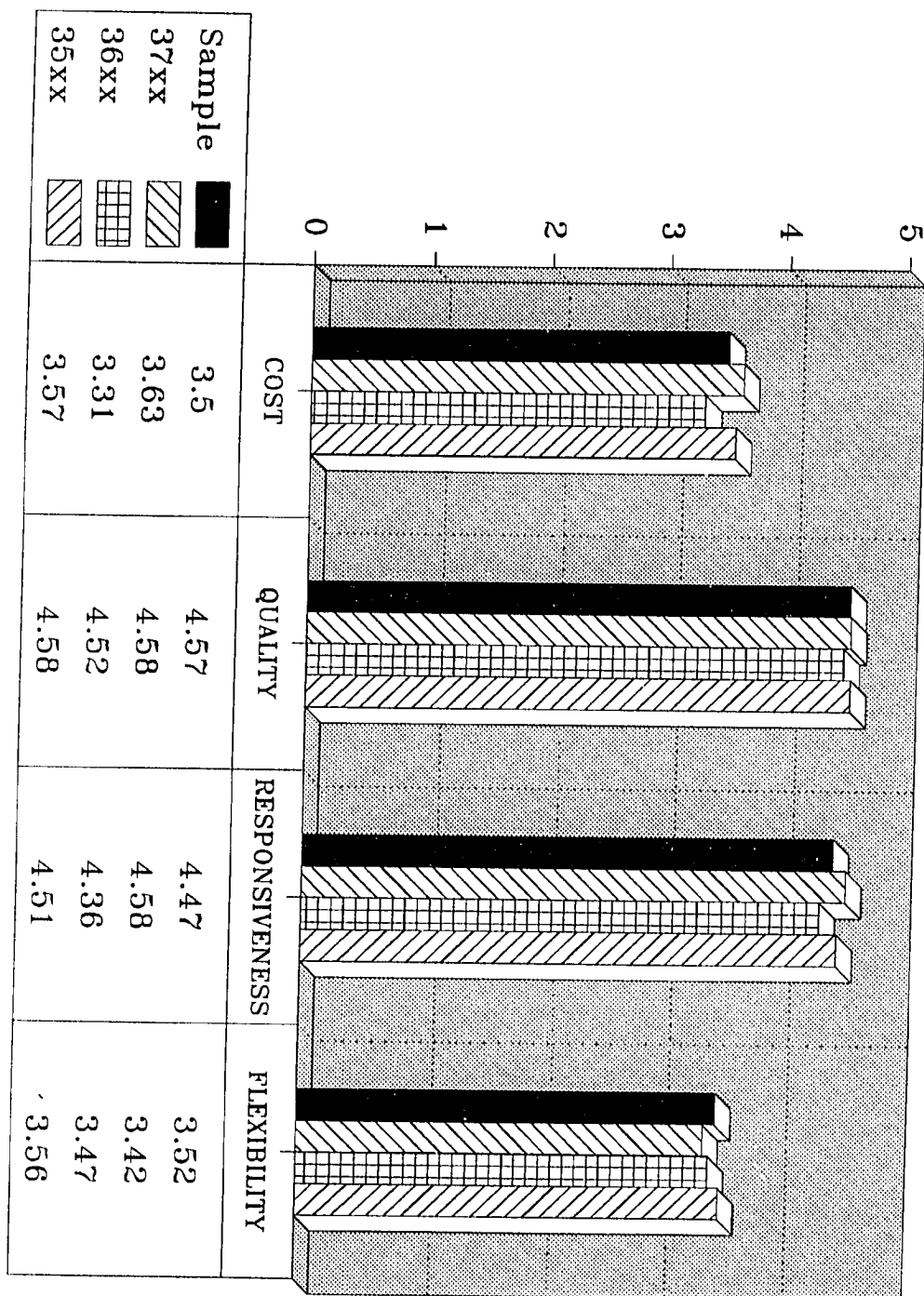
manufacturing capabilities as they relate to their business strategy. Table (5.2) and Figure (5.2) show the mean score for each item in the sample and in each industry group.

Table (5.2)
Rank Order of the Importance of the Four Dimensions of
Manufacturing Capabilities

Number of Valid Observations (Listwise) = 158.00

Variable	all 158 Mean	37X 19 mean	36X 58 mean	35X 81 mean	
X411	3.50	3.63	3.31	3.57	Cost
X412	4.57	4.58	4.52	4.58	Quality
X413	4.47	4.58	4.36	4.51	Responsiveness
X414	3.52	3.42	3.47	3.56	Flexibility

Figure (5.2)
Importance of the four Dimensions of Manufacturing Capabilities
(Sample and the Three Industry Groups)



AREAS FOR FURTHER RESEARCH

Our research has answered many questions we raised at the beginning of carrying out this research project. In addition to answering the main question of do firms with higher level of AMT differ in their manufacturing and economic performance, other questions were answered as well. Among these questions are the following:

1. What Constitute Advanced Manufacturing Technologies.
 2. Do sampled firms have Computer Integrated Manufacturing (CIM) or just Islands of automation?
 3. What constitute Computer-Based and Time-Based Technologies?
 4. For how long have these technologies been used?
 5. For these technologies used, what are the percentages of utilizing them in the designing, manufacturing, and administrative activities related to manufacturing a product?
 6. What percentage of facility has been converted to using these technologies.
- In other words, Do firms create the proper environment for these technologies?

In addition, our research has raised many more questions. These questions may be answered by further research. Therefore, we suggest the following avenues for future research.

1. Other CBT and TBT, when they emerge, can be added to the list of Advanced Manufacturing Technologies and this study can be replicated.

2. In addition to the economic variables studied here, other economic variables can be investigated as well.
3. A longitudinal study of the impact of AMT on the economic performance of the firm can be carried out. This can be done by tracing the economic performance of the firm few years before and few years after AMT was implemented. A Comparison of the performance in these two states may show the real impact of these technologies.
4. A study of the impact of AMT in conjunction with financial justification of investing in these technologies may also reveal if the AMT is for every one. In other words, does it pay to invest in these technologies regardless of the size of the firm?
5. A More focused study on the size of the firm and the level of integrating these technologies.
6. In addition to the reasons for implementing these technologies from manufacturing viewpoint, what other strategic reasons does top management consider when implementing these technologies?
7. A study of the human resource in the firms with different levels of technology to see if the technology affects variables such as job satisfaction, employee moral, work environment... etc.
8. Different industries may be targeted to study the relationships proposed in our conceptual model.

Six of these eight proposed avenues for further research are currently under formulation. Questionnaire are being developed, and frameworks for investigation are being outlined.

APPENDIX (1) Research Instrument

227

I would like to send you a copy of the findings of this research. Please indicate your mailing address below. If you do not wish to receive a copy of the findings, please leave this part blank and proceed to the next section.

NAME:	
TITLE:	
COMPANY:	
ADDRESS:	
PHONE:	()

The Information furnished by you about your company will be kept strictly confidential

PART (1)

1. Business Unit for which this questionnaire is being completed is best described as:

- | | |
|--|--|
| ☐ A. Entire Company. | ☐ B. Division or Subsidiary |
| ☐ C. Plant or Production Facility | ☐ D. Other |

2. Please describe the line that best describes your manufacturing process.

- | | |
|--|---|
| ☐ A. Repetitive, High Volume. | ☐ B. Discrete Batch. |
| ☐ C. Repetitive, High Dollar, Low to Medium Volume. | |
| ☐ D. Made-To-Order, Low Volume. | ☐ E. Other. |

PART (II)

1. Listed Below are several elements of Computer-Based Technology. Please indicate whether or not these technologies are being used in your facility. If "YES", please use the following scale to describe the linkage of each to the other technologies by placing an (X) inside the appropriate **BOX** under the description heading

- 1 ■ IT IS NOT LINKED TO ANY OF THE OTHER TECHNOLOGIES WE HAVE. IT PRETTY MUCH STANDS ALONE.
- 2 ■ IT IS LINKED TO FEW OTHER TECHNOLOGIES WE HAVE.
- 3 ■ IT IS LINKED TO ALMOST ALL TECHNOLOGIES WE HAVE THROUGH A THOROUGHLY INTEGRATED SYSTEM OF COMPUTER ASSISTED DESIGN, MANUFACTURING, ENGINEERING, MATERIAL HANDLING, AND / OR ORDER ENTRY.

TECHNOLOGY	YES NO		DESCRIPTION		
			NONE	FEW	ALL
1. Computer Aided Design (CAD)	☐	☐	1 ☐	2 ☐	3 ☐
2. Computer Aided Manufacturing (CAM)	☐	☐	1 ☐	2 ☐	3 ☐
3. Manufacturing Resource Planning (MRP II)	☐	☐	1 ☐	2 ☐	3 ☐
4. Robotics.	☐	☐	1 ☐	2 ☐	3 ☐
5. Computer Numerical Control (CNC).	☐	☐	1 ☐	2 ☐	3 ☐
6. Automated Assembly (AA).	☐	☐	1 ☐	2 ☐	3 ☐
7. Flexible Manufacturing Systems (FMS).	☐	☐	1 ☐	2 ☐	3 ☐
8. Automated Material Handling (AMH).	☐	☐	1 ☐	2 ☐	3 ☐
9. Computer Aided Process Planning (CAPP).	☐	☐	1 ☐	2 ☐	3 ☐
10. Direct Numerical Control (DNC).	☐	☐	1 ☐	2 ☐	3 ☐
11. Computer Aided Engineering (CAE).	☐	☐	1 ☐	2 ☐	3 ☐
12. Automatically Guided Vehicle (AGV).	☐	☐	1 ☐	2 ☐	3 ☐
13. Flexible Manufacturing Cell (FMC).	☐	☐	1 ☐	2 ☐	3 ☐
14. Shop Floor Monitoring and Control by Personal Computers.	☐	☐	1 ☐	2 ☐	3 ☐

2. For those technologies checked "YES" in the previous question, Approximately how long have these technologies been used:

- ☐ More than FIVE years ☐ Between TWO and FIVE years
☐ Less than TWO years ☐ Other

3. Listed below are several elements of Time-Based Technologies. Please indicate whether or not these technologies are being used in your facility. If "YES", please use the following scale to describe the length of time these technologies have been used by placing an (X) inside the appropriate BOX under the description heading.

- 1 = LESS THAN TWO YEARS.
 2 = BETWEEN TWO AND FIVE YEARS.
 3 = MORE THAN FIVE YEARS.

TECHNOLOGY	YES	NO	DESCRIPTION		
1. Just-In-Time (JIT)	☐	☐	1 ☐	2 ☐	3 ☐
2. Group Technology (GT).	☐	☐	1 ☐	2 ☐	3 ☐
3. Design for Manufacturability (DFM).	☐	☐	1 ☐	2 ☐	3 ☐
4. Statistical Process Control - Product (SPC-P).	☐	☐	1 ☐	2 ☐	3 ☐
5. Statistical Process Control - Process (SPC-R).	☐	☐	1 ☐	2 ☐	3 ☐
6. Vendor Quality.	☐	☐	1 ☐	2 ☐	3 ☐
7. Zero Defects.	☐	☐	1 ☐	2 ☐	3 ☐
8. Quality at the Source.	☐	☐	1 ☐	2 ☐	3 ☐
9. Preventive maintenance.	☐	☐	1 ☐	2 ☐	3 ☐

4. For those technologies checked "YES" in question, (3) approximately what percentage of your facility have been converted to using them:

- ☐ More than 90 % ☐ 60 to 90 %
☐ 30 to 60 % ☐ Less than 30 %

5. Consider the product development, engineering and design work done in your facility. Approximately how much is done with Computer Aided Design (CAD), Computer Aided Engineering (CAE) or other types of computer assisted technology? How much is done manually or without computer assistance?

Your Answer Must Total 100 %

A. PERCENT OF WORK DONE WITH CAD, CAE, OR OTHER COMPUTER ASSISTED TECHNOLOGY.	_____ %
B. PERCENT OF WORK DONE MANUALLY OR WITHOUT COMPUTER ASSISTED TECHNOLOGY.	_____ %
TOTAL	100 %

6. How much of your entire equipment consists of Fixed Automation or manual production? Programmable Automation?

Your Answer Must Total 100 %

A. FIXED AUTOMATION OR MANUAL PRODUCTION.	_____ %
B. PROGRAMMABLE AUTOMATION.	_____ %
TOTAL	100 %

7. Consider the following Administrative work related to managing and controlling Manufacturing activities : (1) Inventory Control. (2) Accounting, and (3) Shop Floor Tracking System. Approximately how much is done on a computer? How much is done manually?

Your Answer Must Total 100 %

A. PERCENT OF WORK DONE ON A COMPUTER	_____ %
B. PERCENT OF WORK DONE MANUALLY.	_____ %
TOTAL	100 %

PART (III)

Comparing your manufacturing performance to that of your competitors on the items below, please place an "(X)" inside the BOX that most closely describes your evaluation.

1. New Product Introduction
2. Introducing New Production Processes

3. Product Varities.
4. Product Features.

5. Resenrch and Development Efforts

6. Lead Time of Orders
7. Time-To-Market.

8. Speed in Changing Product Volume.
9. Speed in Developing New Products.
10. Speed in Making Product Changeover
11. Response to Short Term Customer Requirements.

LEAST FREQUENT IN INDUSTRY					MOST FREQUENT IN INDUSTRY				
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐
NARROWEST RANGE IN INDUSTRY					WIDEST RANGE IN INDUSTRY				
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐
LEAST AGGRESSIVE IN INDUSTRY					MOST AGGRESSIVE IN INDUSTRY				
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐
LONGEST IN INDUSTRY					SHORTEST IN INDUSTRY				
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐
SLOWEST IN INDUSTRY					QUICKEST IN INDUSTRY				
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐

12. Ability to meet Production

Schedules and delivery dates.

13. Product Quality.

14. Vendor Quality.

15. Design and Engineering Quality.

16. Manufacturing Workmanship.

17. Cost of Quality.

18. Product R & D Cost.

19. Unit Material Cost.

20. Unit Labor Cost.

21. Unit Overhead Cost.

PART (IV)

1. Based on how each and every one of the following competitive factors relate to your business strategy, please place an (X) inside the BOX that most closely describes your evaluation.

1. Cost of the Product.

2. Quality and Reliability of the Product

3. Service and Responsiveness to Customer needs.

4. Flexibility and Number of Options, and Wide Range of Products.

LEAST
RELIABLE
IN INDUSTRYMOST
RELIABLE
IN INDUSTRY1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐LOWEST
QUALITY
IN INDUSTRYHIGHEST
QUALITY
IN INDUSTRY1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐WORST
IN INDUSTRYBEST
IN INDUSTRY1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐LEAST
EXPENSIVE
IN INDUSTRYMOST
EXPENSIVE
IN INDUSTRY1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2. To what extent does unexpected change in the Product Mix affect the following Competitive Factors. Please place an (X) inside the BOX that most closely represents your evaluation.

NOT AT ALL	TO A GREAT EXTENT
------------------	-------------------------

1. Quality of the Product.
2. Cost of the Product.
3. Delivery Performance.

1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐

3. To what extent does unexpected change in the Product Volume affects the following Competitive Factors. Please place an (X) inside the BOX that most closely represents your evaluation.

NOT AT ALL	TO A GREAT EXTENT
------------------	-------------------------

1. Quality of the Product
2. Cost of the Product.
3. Delivery Performance.

1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐
1	☐	2	☐	3	☐	4	☐	5	☐

(PART (V))

Listed below are several action programs. Please indicate whether or not they are underway in your facility. If "YES", please use the following scale to describe the degree of emphasis on each by placing an (X) inside the appropriate **BOX** under the heading of Degree of emphasis.

1. NO EMPHASIS**2. LITTLE EMPHASIS****3. MODERATE EMPHASIS****4. LARGE EMPHASIS****5. CRITICAL EMPHASIS****ACTION PROGRAM****YES NO****DEGREE OF EMPHASIS**

1. Manufacturing Lead Time Reduction.
2. Preventive Maintenance.
3. Job Enrichment.
4. Statistical Process Control - Product.
5. Statistical Process Control- Process
6. Worker Safety.
7. Zero Defects.
8. Integrating Information Systems Across Areas.
9. Integrating Information Systems Within Manufacturing.
10. Computer Aided Manufacturing.
11. Giving Workers More Planning Responsibility.
12. Narrowing Product Lines.
13. Giving Workers a broader Range of Tasks.
14. Quality Circles.
15. Reducing the Size of Manufacturing Workforce.
16. Developing a New Process for Old Products.
17. Developing a New Process for New Products.

☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

ACTION PROGRAM**YES NO****DEGREE OF EMPHASIS**

18. defining a manufacturing strategy
19. Vendor Lead Time Reduction
20. Just-In-Time
21. Reducing setup/ changeover time.
22. Flexible Manufacturing Systems.
23. Introducing Robots.
24. Group Technology.
25. Computer Aided Design.
26. Capacity Expansion
27. Reconditioning of physical Facilities.
28. Automated Jobs.
29. Reducing the Size of the Manufg. unit.
30. Plant Relocation.
31. Manufacturing Reorganization.
32. Closing Plants.
33. Changing Labor Management Relation.
34. Management Training.
35. Supervisor Training.
36. Worker Training.
37. Vendor Quality.
38. Yield Problems/ Rejects.

☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
☐	☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

APPENDIX (2)
Sample Letter of Contact

Mr. Excellence in Mfg., VP Manufacturing
XYZ Company
NQ 1 Quality Street
Responsiveness City
Flexibility State ZIP 95035

Dear Mr. *Excellence*.

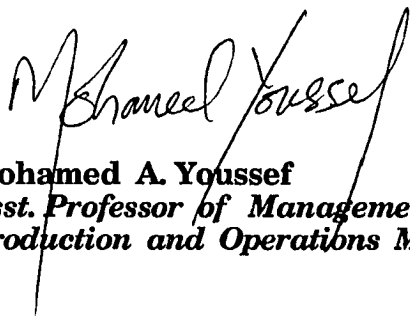
I am writing to ask you to participate in an important study dealing with Advanced Manufacturing Technologies (AMT), manufacturing strategy, Manufacturing capabilities, and Economic performance of the firm. We have devised a new conceptual model that relates these forces into a strategic framework. The model and its empirical validation will help decision makers in many areas related to structural and infrastructural decisions in manufacturing.

To do the study, we need your assistance. Would you please complete and return this questionnaire. Your responses will be treated as highly confidential, and the report which results from this study will not associate any of the findings with the responding firms. A copy of the report will be sent to you at your request.

We have attempted to minimize the effort which is required to provide the needed data by designing the questionnaire in the form of a checklist. The entire questionnaire will require only a few minutes to answer.

We would very much appreciate your co-operation. Would you please return the questionnaire in the enclosed envelope at your earliest convenience?

Sincerely yours,



Mohamed A. Youssef
*Asst. Professor of Management Science and
Production and Operations Management*

State University of New York / College at Old Westbury .
Old Westbury, New York 11568-0210

APPENDIX (3)

PLANT VISITATION AND INTERVIEW FORMS

PROF. MOHAMED A. YOUSSEF

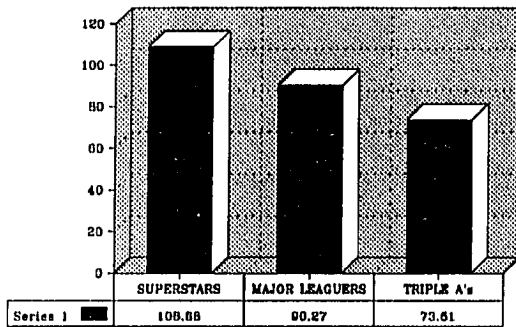
STATE UNIVERSITY OF NEW YORK AT OLD WESTBURY &

Ph.D. CANDIDATE AT C.U.N.Y

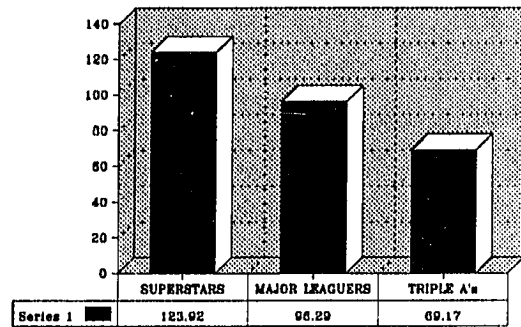
[illegible]

Performance Charts

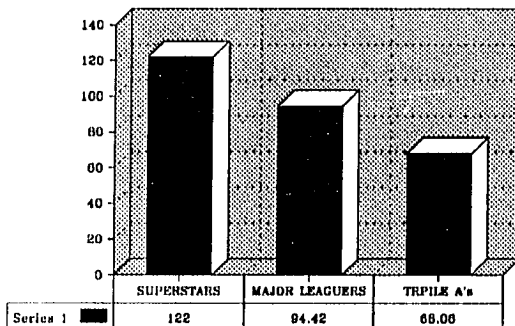
Emphasis on lead time reduction
Ranked Means



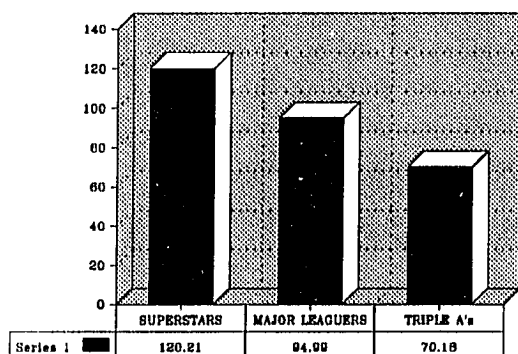
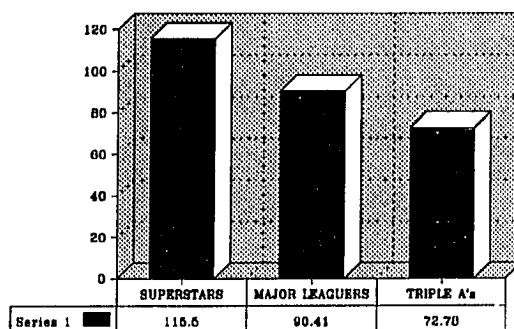
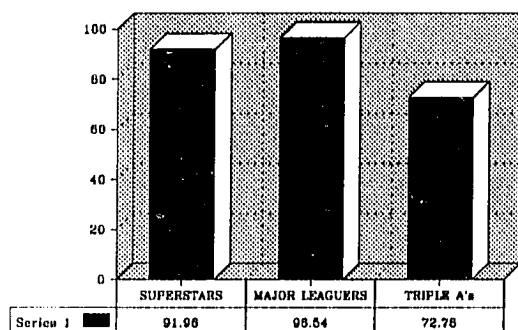
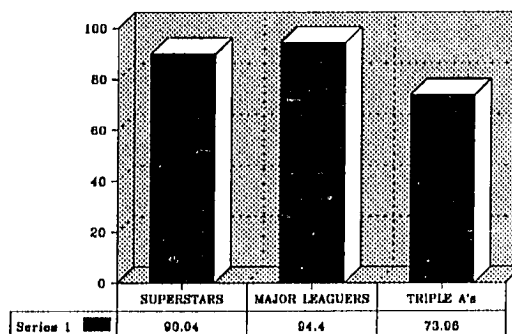
Emphasis on Preventive maintenance
Ranked Means



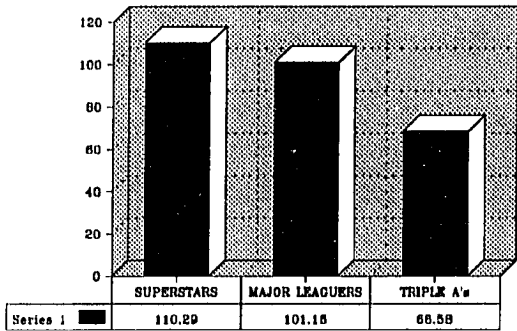
Emphasis on Job Enrichment
Ranked Means



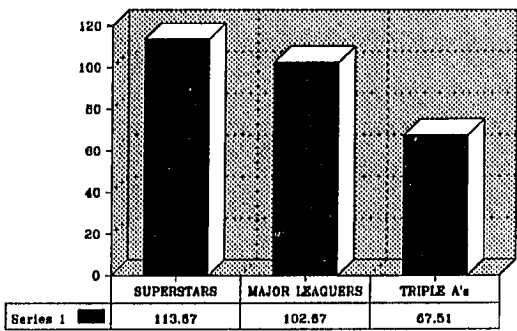
Emphasis on SPC - Process

Emphasis on Worker Safety
Ranked MeansEmphasis on Zero Defects
Ranked MeansEmphasis on Integrating MIS Across Areas
Ranked Means

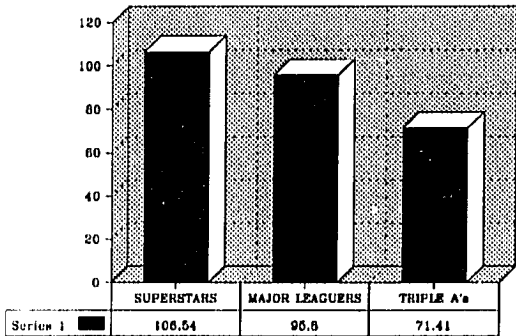
Emphasis on Integrating MIS within Mfg.
Ranked Means



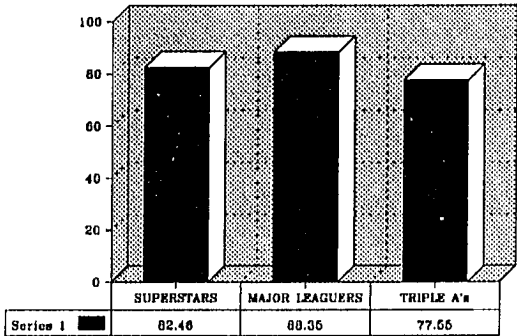
Emphasis on CAM
Ranked Mean



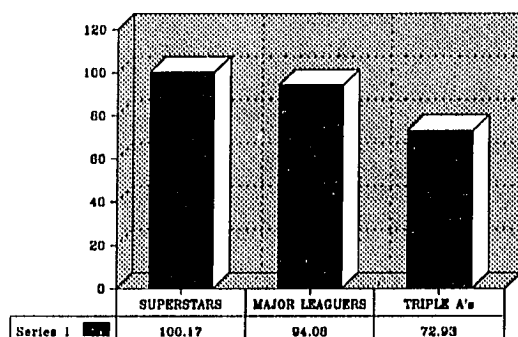
Emphasis on Giving Workers more planning
Responsibility (Ranked Means)



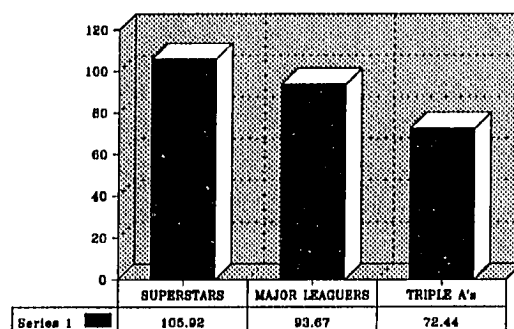
Emphasis on Narrowing Product Lines
Ranked Means



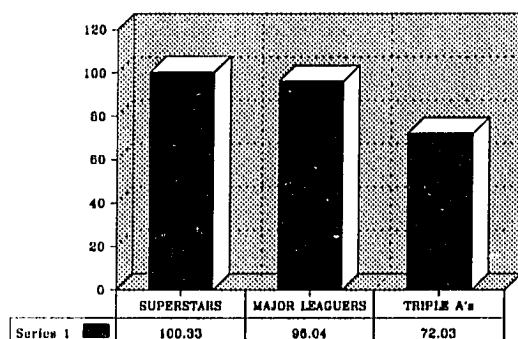
Emphasis on Giving Worker Broader range
of Tasks (Ranked Means)



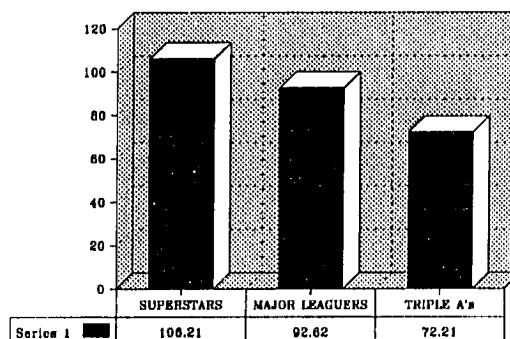
Emphasis on Quality Circles
Ranked Means



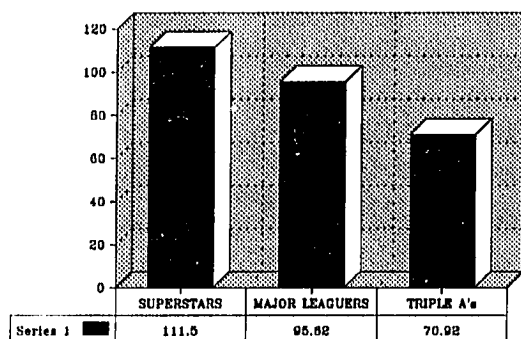
Emphasis on Reducing the Size of
Mfg. Workforce (Ranked Means)



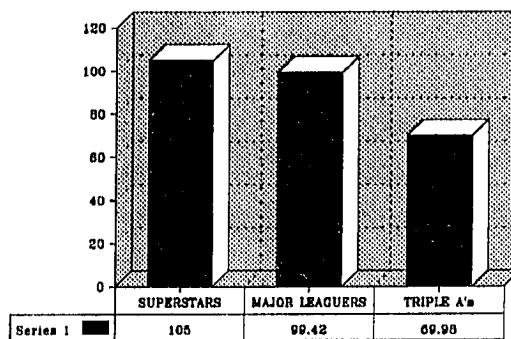
Emphasis on Developing New Processes
for old Products (Ranked Means)



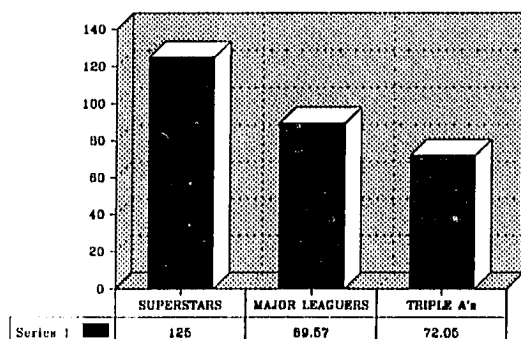
**Emphasis on Developing New Processes
for New Products (Ranked Means)**



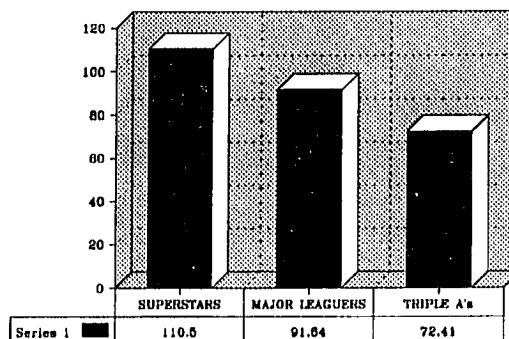
**Emphasis on Defining Manufacturing
Strategy (Ranked Means)**



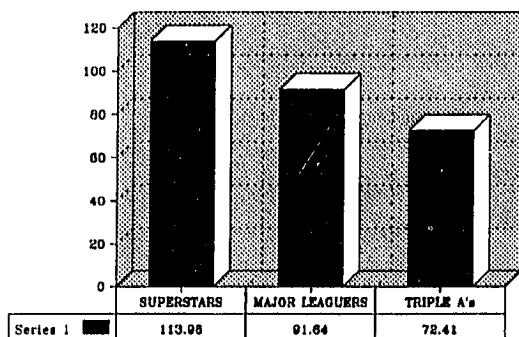
**Emphasis on Vendor Lead Time
(Ranked Means)**



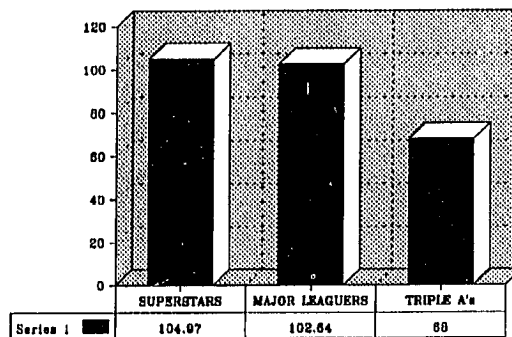
**Emphasis on JIT
(Ranked Means)**



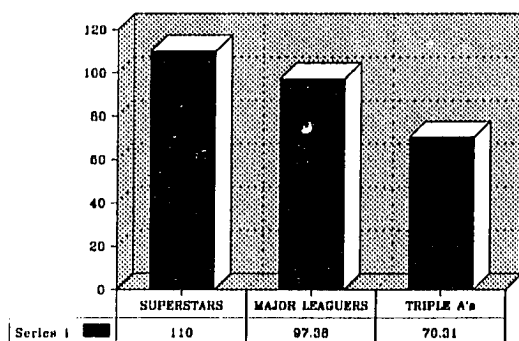
Emphasis on Reducing Setup/Changeover .
(Ranked Means)



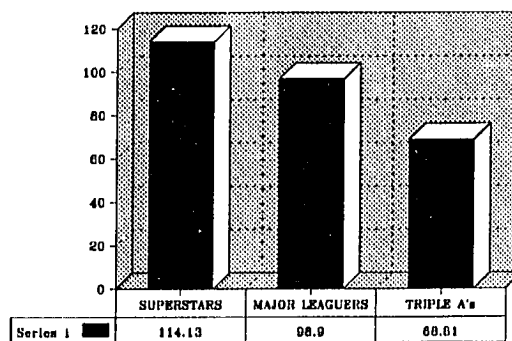
Emphasis on FMS
(Ranked Means)



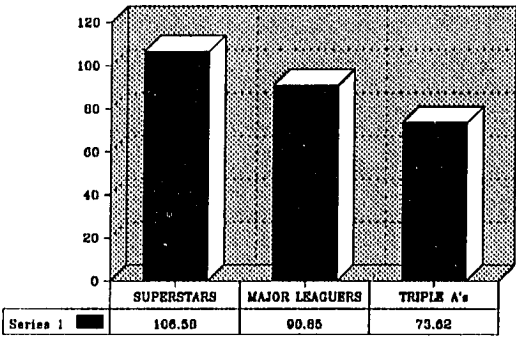
Emphasis on Robotics
(Ranked Means)



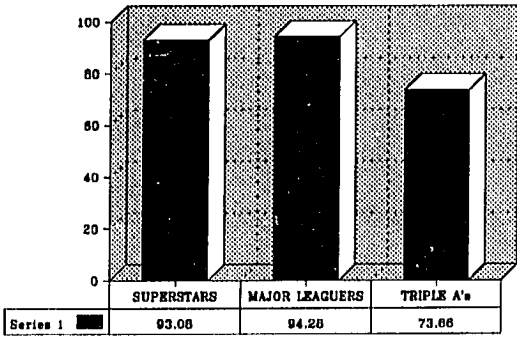
Emphasis on Group Technology
(Ranked Means)



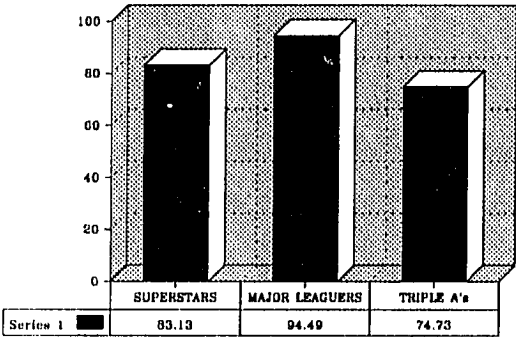
Emphasis on CAD
(Ranked Means)



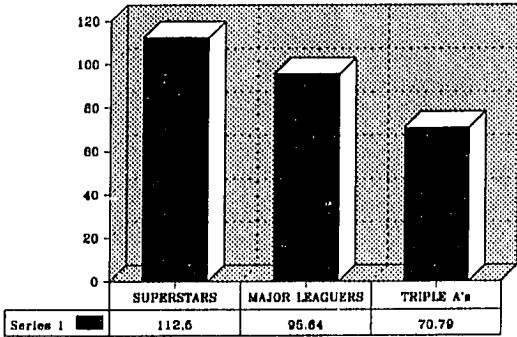
Emphasis on Capacity Expansions
(Ranked Means)



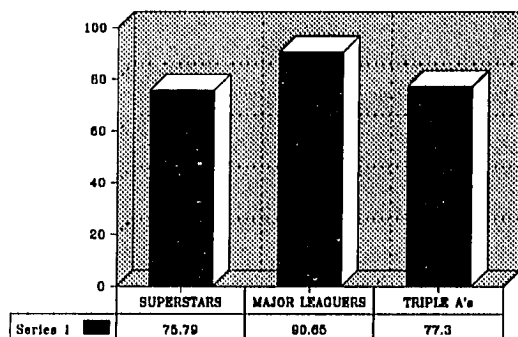
Emphasis on Reconditioning Physical
Facilities (Ranked Means)



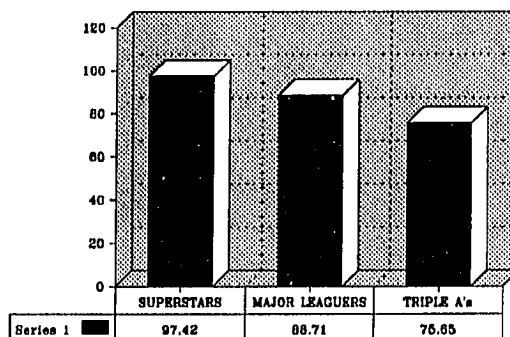
Emphasis on Automated Jobs
(Ranked Means)



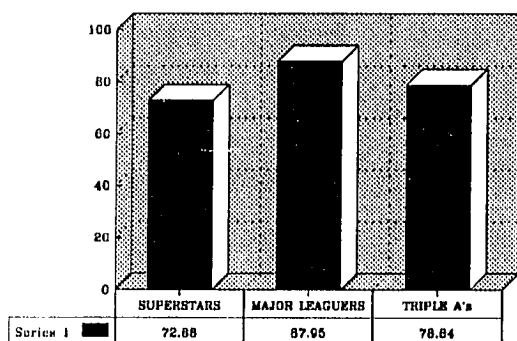
Emphasis on Reducing The Size of Mfg. Units (Ranked Means)



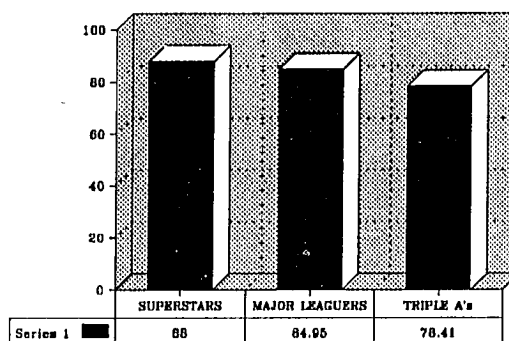
Emphasis on Plant Relocation (Ranked Means)



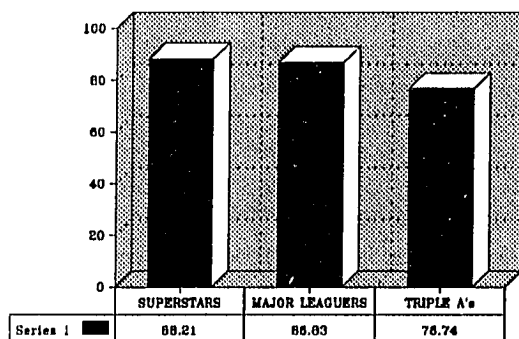
Emphasis on Manufacturing Reorganization (Ranked Means)



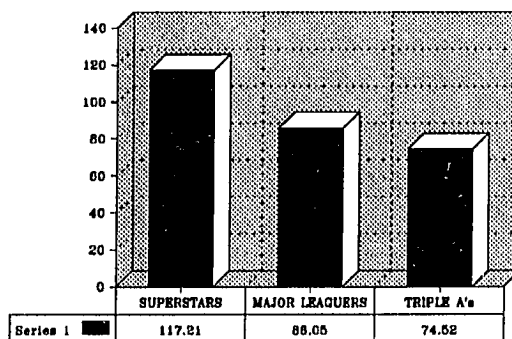
Emphasis on Plant Closing (Ranked Means)



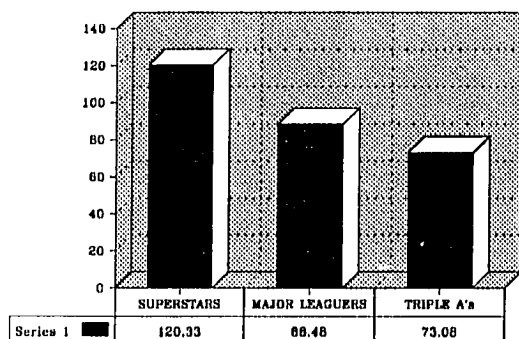
Emphasis on Changing Labor/Mgt.
Relation (Ranked Means)



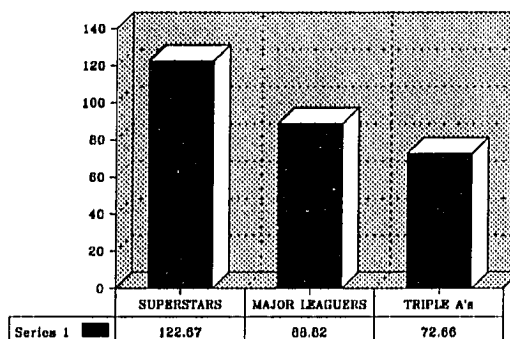
Emphasis on Management Training
(Ranked Means)



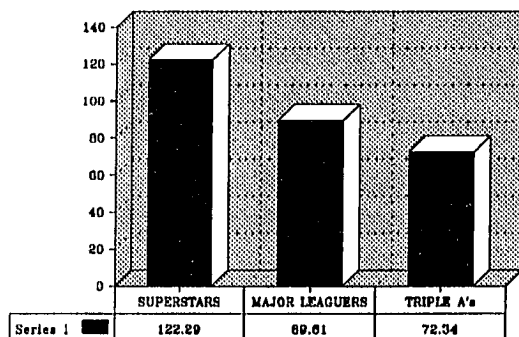
Emphasis on Supervisor Training
(Ranked Means)



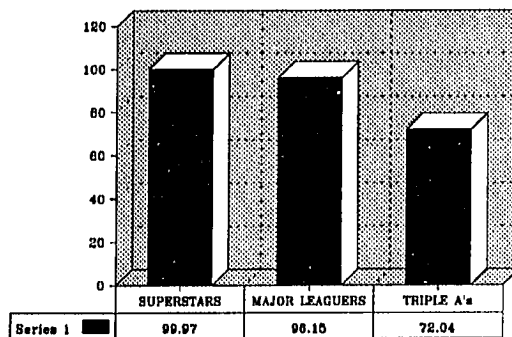
Emphasis on Worker Training
(Ranked Means)



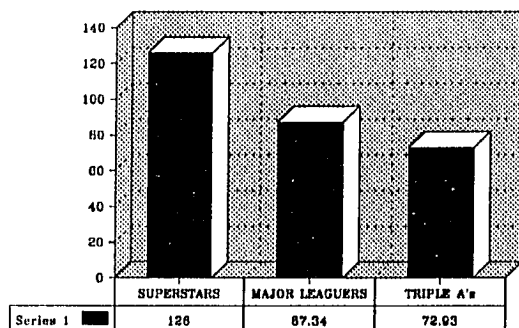
**Emphasis on Vendor Quality
(Ranked Means)**



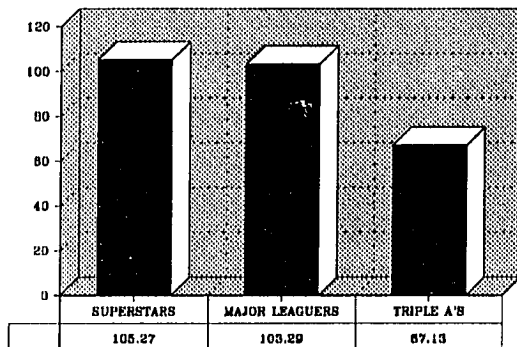
**Emphasis on Yield Problems/Rejects
(Ranked Means)**



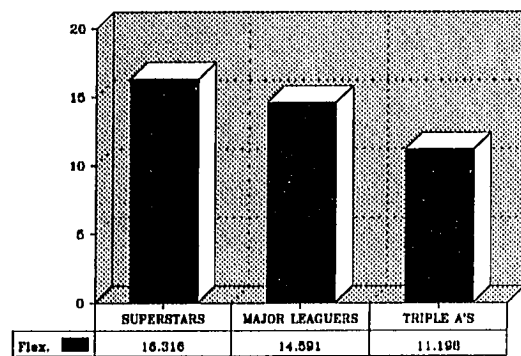
**Emphasis on SPC - Product
Ranked Means**



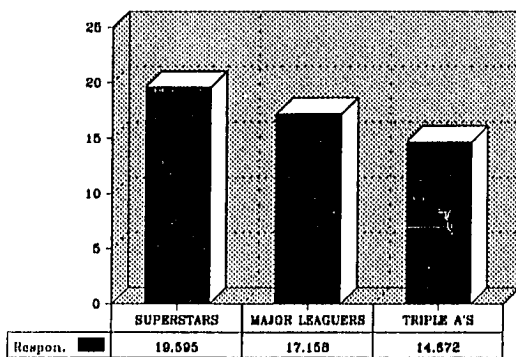
Ranked Means, Overall Mfg.



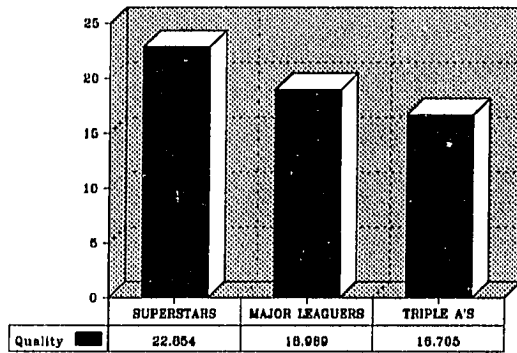
Means (Flexibility)



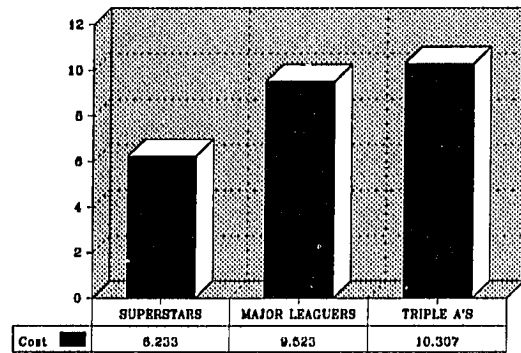
Means (Responsiveness)



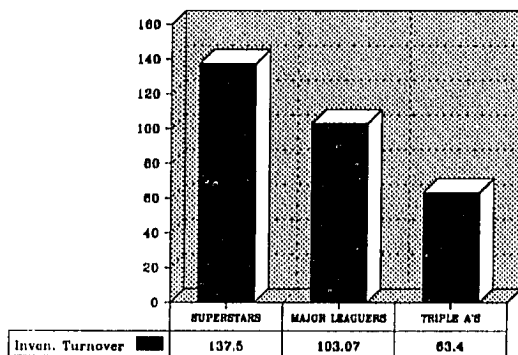
Means (Quality)



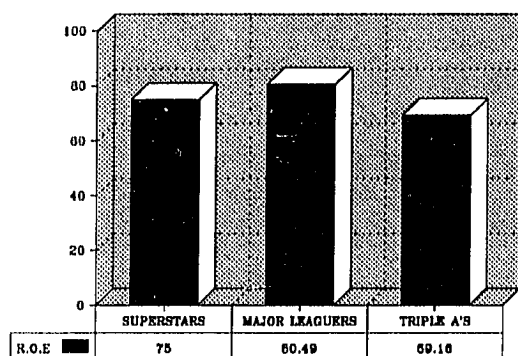
Means (Cost)



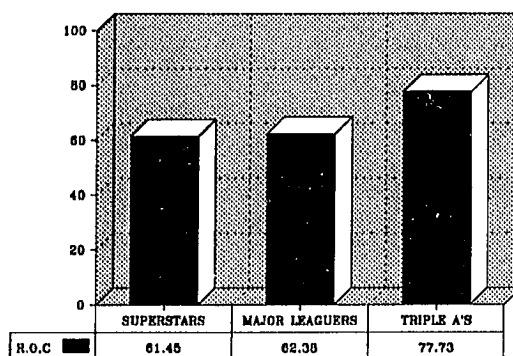
Ranked Mean(Inventory Turnover)



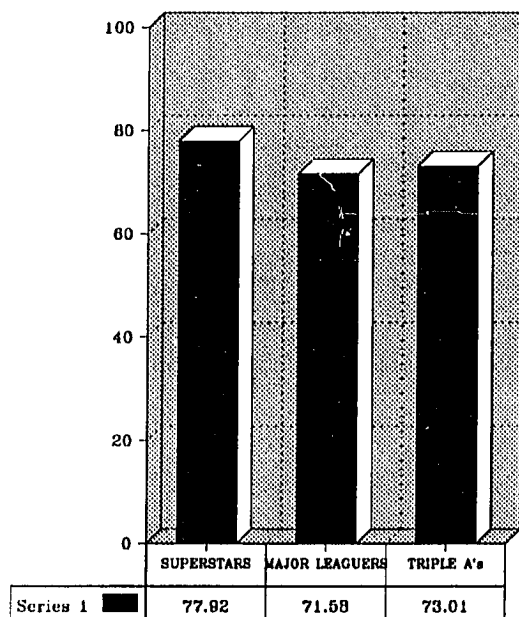
Ranked Means (ROE)



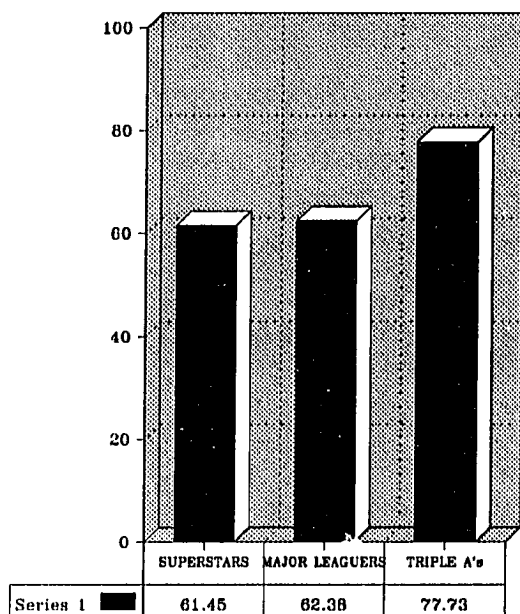
Ranked Means (ROC)



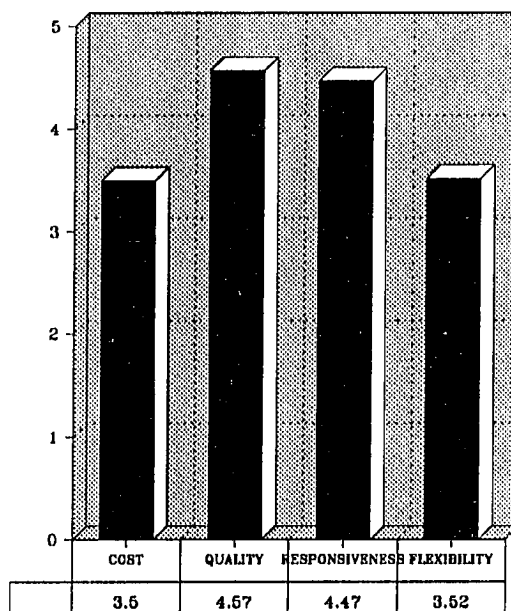
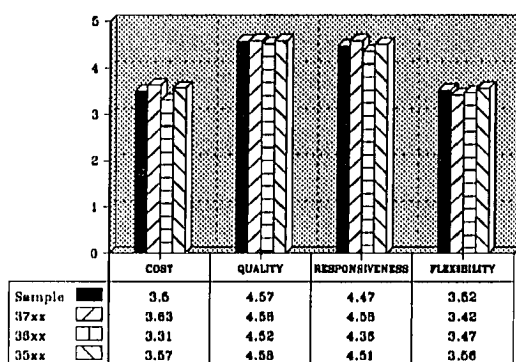
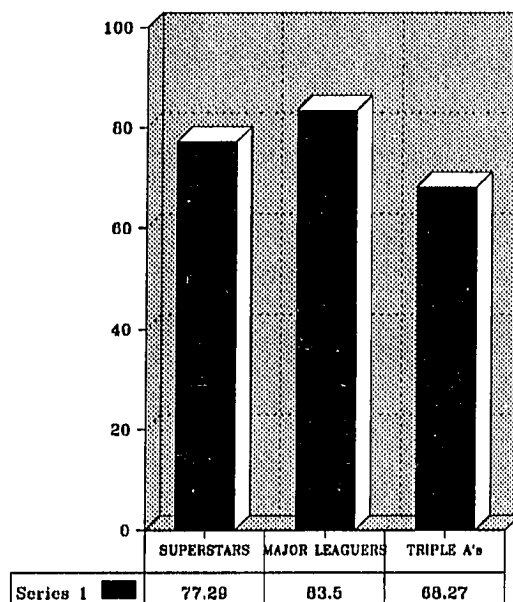
Ranked Mean (5 Years Sales Growth)



Ranked Mean (ROIC)



Ranked Mean (ROS)



BIBLIOGRAPHY

Alexander, David C., "Managing Technical Change." In Blache (Ed.) Success Factors for Implementing Change : A Manufacturing Viewpoint. Dearborn , Michigan, Society of Manufacturing Engineers, 1988.

Allaire, Paul, "Quality : A Competitive Strategy." In Robson (Ed.) The quality and Productivity Equation. Cambridge, Massachusetts, Productivity Press, 1990.

Allen, Mary J. ; and Yen, Wendy, J. Introduction to Measurement Theory. Monterey, CA: Brooks/Cole Publishing Company, 1979.

Ansoff, H. Igor; Richard G. Brandenburg; Fred E. Portner; Raymond Radosevich Acquisition Behavior of U.S. Manufacturing Firms, 1946-1965. Nashville, TN, Vanderbilt University Press, 1971.

Ayres, Robert U., "Computer-Integrated Manufacturing and the next Industrial Reveloution." In Dermer (Ed.) Competitiveness Through Technology : What Business Needs from Government. Lexington, Massachusetts. Lexington Books, 1986.

----- , "Future trends in factory automation," Manufacturing Review , (12), 93-103, 1988.

Ayres, Robert U. ; and Miller, "Steve Industrial robots on the line," In Tom Forrester (Ed.) The Information Technology Revolution , Cambridge, MA: The MIT Press, 1985.

Baily, Martin Neil; and Alok K. Chakrabarti Innovation and the Productivity Crisis. Washington D.C., The Brookings Institution, 1988.

Bancroft, Carol E., "Design for manufacturability: Half speed ahead," Manufacturing Engineering , 101(3), 67-69, 1988.

Banks, Jerry , "Management of Quality," In Cleland and Bidanda (Ed.) The Automated Factory Handbook: Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Banks, Jerry, Principles of Quality Control. New York, John Wiley & Sons, 1989.

Banks, Robert L. ; and Wheelwright, Steven C., "Operations vs. strategy: trading tomorrow for today," Harvard Business Review , 573, 112-120, 1979.

Barley, Stephen R., "Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments," Administrative Science Quarterly , 31, 78-108, 1986.

Beckman, Sara L., "Manufacturing Flexibility: The next Source for Competitive Advantage," In Strategic Manufacturing Dynamic: New Directions for the 1990's, (Patricia E. Moody Ed), Homewood, Illinois: Dow Jones-Irwin, 1990.

Bedworth, David D.; and James Bailey Integrated Production Control Systems: Management, Analysis, and Design (Second Ed.) New York, John Wiley and Sons, 1987.

Beer, Michael; Russell A. Eisenstat; and Bert Spector, The Critical Path to Corporate Renewal. Boston Massachusetts, Harvard Business School Press, 1990.

Bentley, David A., "Emphasis on total quality management for JIT success." APICS Proceedings , 20-23, 1987.

Bills, Daniel, "Putting Shingo Methods to Work in U.S. Business." In Shetty and Buehler (Ed.) Competing Through Productivity and Quality. Cambridge, Massachusetts, Productivity Press, 1988.

Blache, Klaus M., Success Factors for Implementing Change : A Manufacturing Viewpoint. Dearborn Michigan, Society of Manufacturing Engineers, 1988.

Boothroyd, Geoffrey, "Making it simple: Design for assembly," Manufacturing Engineering , 110(2), 28-31, 1988.

Boothroyd, Geoffrey ; and Dewhurst, P., "Product design for manufacture and assembly," Manufacturing Engineering , 100(4), 42-46, 1988.

Bossert, James L., (Ed.) Procurement Quality Control, Milwaukee, ASQC Quality Press, 1988.

Bowersox, Donald J.; Patricia J. Daugherty; Cornelia L. Droge; Dale S. Rogers; and Daniel L. Wardlow, Leading Edge Logistics Competitive Positioning for the 1990's: Comprehensive Research on Logistics Organization Strategy and Behavior in North America, 1989. Oak Brook, Illinois, The Council of Logistics Management (Prepared by Michigan State University.)

Brody, Herb, "Overcoming barriers to automation," High Technology , May, 1985, 41-46, 1985.

Brody, Herb, "CAD meets CAM," High Technology , May, 12-18, 1987.

Browne, Jimmie; John Harhen; and James Shivnan, Production Management : A CIM Prespective. Reading, Massachusetts, Addison - Wesley, 1988.

Buffa, E. S., Meeting the Competitive Challenge. Homewood, IL: Dow Jones-Irwin, 1984.

Bylinsky, Gene, "The race to the automatic factory," Fortune , February 21, 52-64, 1983.

Byrd jr, Jack, "Automated Technologies: Thew Strategic Issues." In Cleland abd Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Cariapa, Vikram, "Value Analysis in Flexible Manufacturing Systems." In Cleland and Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Chang, Chao-Hwa, "A new perspective on realization of computer integrated manufacturing." Manufacturing Review , 2(2), 82-90, 1989.

Chang, Tien-Chien, "Computer-Aided Process Planning." In Cleland and Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Charles, David; Peter Monk; and Ed Sciberras, Technology and Competition in the International Telecommunications Industry. London UK, Pinter Publishers, 1989.

Ciampa, Dan., Manufacturing's New Mandate: Tools for Leadership, New York Jhon Wiley & Sons, 1988.

Clark, Kim B.; Robert H. Hayes; and Christopher Lorenz, The Uneasy Alliance: Managing Productivity-Technology Dilemma, Boston, MA HBS Press, 1985.

Cleland, David I. and Bopaya Bidanda The Automated Factory Handbook: Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Cohen, J. ; and Cohen, P., Applied Multiple Regression and Correlation Analysis for the Behavioral Sciences, 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates, 1983.

Compact Disclosure., Disclosure, Inc., Bethesda, MD, March, 1988.

Compton, W. Dale, Design and Analysis of Integrated Manufacturing Systems. Washington D.C. National Academy of Engineering Press, 1988.

Crocker, Olga; Cyril Charney; and Johnny Sik Leung Chiu. , Quality Circles: A Guide to Participation and Productivity. New York: Methuen Publications, 1984.

Daniel, Wayne W., Workplace Industrial Relations and Technical Change. London, UK. Frances Pinter Publishers in Association with The Policy Studies Institute, 1987.

-----; and James C. Terrel., Business Statistics: Basic Concepts and Methodology. 6th Ed. Boston, MA Houghton Mifflin Co., 1986

Das, Biman, "Ergonomics and New Technology Implementation." In Blache (Ed.) Success Factors for Implementing Change : A Manufacturing View point. Dearborn, Michigan, Society of Manufacturing Engineers, 1988.

Datamation. , "Manufacturing technology: A report to management," February, 102A-102Z, 1984.

Davis, Dwight B., "Renaissance on the factory floor," High Technology, 25-25, May 1984.

Davis, Donald D., "Technological Innovation and Organizational Change," In Donald D. Davis (Ed.) Managing Technological Innovation: Organizational Strategies for Implementing Advanced Manufacturing Technologies, London, Jossey-Bass Publishers, 1986.

-----, "Integrating Technological, Manufacturing, Marketing, and Human Resource Strategies," In Donald D. Davis (Ed.) Managing Technological Innovation: Organizational Strategies for Implementing Advanced Manufacturing Technologies, London, Jossey-Bass Publishers, 1986.

Dean jr, James W., Deciding to Innovate : How Firms Justify Advanced Technology. Cambridge, Massachusetts, Ballinger Publishing Company, 1987.

Dermer, Jerry, Competitiveness Through Technology : What Business need from Government. Lexington, Massachusetts, Lexington Books, 1986.

Dewey, Bruce R., "Computer-Aided Design and Drafting." In Cleland and Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Dixon, J. Robb; Alfred J. Nanni; and Thomas E. Vollmann , The New Performance Challenge : Measuring Operations for World-Class Competition. Homewood, Illinois, Dow Jones-Irwin, 1990.

Eade, Robert, "For flexibility, you can't beat them," Manufacturing Engineering, 102(5), 49-52, 1989.

Edmondson, Harold E., "Manufacturing Excellence at HP in an Autonomous Environment." In Shetty and Buehler, Quality, Productivity and Innovation, New York, Elsevier, 1987.

Edosomwan, Johnson, Integrating Innovation and Technology Management. New York, John Wiley & Sons, 1989.

-----, "The Meaning and Measurment of Productivity." In Cleland and Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Englert. Robert D., Winning at Technological Innovation. New York, McGraw-Hill, 1990.

Ernst and Young Quality Improvement Consulting Group, Total Quality: An Executive's Guide for the 1990s. Homewood, Illinois, Dow Jones-Irwin, 1990.

Ettlie, John E., "Implementing Strategies for Discrete Parts Manufacturing Innovations." In M. Warner (Ed.) Microelectronics, Manpower, and Society. Brookfield, Vt., Gower Press, 1984.

-----, "Implementing Manufacturing Technologies: Lessons from Experience." In Donald D. Davis, (Ed.) Managing Technological Innovation: Organizational Strategies for Implementing Advanced Manufacturing Technologies, London, Jossey-Bass Publishers, 1984.

Evans, Bill, "Simultaneous engineering," Manufacturing Engineering, 110(2), 38-39, 1988.

Foster, George, and Charles T. Horngren., "JIT: Cost accounting and cost management issues." Management Accounting, 19-25, (June 1987).

Fry, Louis W., "Technology=structure research: Three critical issues," Academy of Management Journal, 25(4), 532-551, 1982.

Fry, Louis W. Slocum, John W., "Technology, structure, and workgroup effectiveness: A test of a contingency model," Academy of Management Journal, 27, 224-246, 1984.

Galbraith, Jay R., "Organizing the 1990's in the New Competitive Environment." In Robson (Ed.) The quality and Productivity Equation. Cambridge, Massachusetts, Productivity Press, 1990.

Garvin, David, A., "Quality on the line," Harvard Business Review, 51(5), 65-75, 1983.

-----, "What does "product quality" really mean?," Sloan Management Review , Fall, 25-43, 1984.

-----, "quality problems, policies, and attitudes in the United States and Japan: An exploratory study," Academy of Management Journal, 29(4), 653-673, 1986.

Gerelle, Eric G. R. ; and John Stark, Integrated Manufacturing : Strategy, Planning, and Implementation. New York, McGraw-Hill, 1988.

Gerwin, Donald, "Do's and don'ts of computer-aided manufacturing," Harvard Business Review, 62(2), 58-67, 1982.

Gitlow, Howard S. Planning for Quality, Productivity, and Competitive Position. Homewood, IL, Dow Jones-Irwin, 1990.

Glazer, Sarah, "The automation industry: Integrating for success," High Technology, May, 46-47, 1985.

Goddard, Walter E., "How to measure performance beyond class A." APICS Proceedings, 488-90, 1987.

Goldstein, Gina, "Integrating product and process design," Manufacturing Engineering, 111(4), 48-51, 1989.

Gould, Leroy C.; Gerald T. Gardner; Ronald E. Deluca; Adrian R. Tiemann; Leonard W. Doob; and Jan A. J. Stolwijk Perceptions of Technological Risks and Benefits. New York, Russell Sage Foundation, 1988.

Greene, James H. Production and Inventory Control Handbook, (Second Ed.) New York, McGraw-Hill Book Company, 1987.

Greenwood, Nigel R., Implementing Flexible Manufacturing Systems, New York: Halsted Press, 1988.

Grieco, Peter L., "The role TQC plays in our business," APICS Proceedings, 27-28, 1987.

Grieco, Peter L., and Michael W. Gozzo, Made in America: The total Business Concept, Plantsville, CT: PT Publications, Inc., 1987.

Groover, Mikell, Automation, Production Systems, and Computer-Aided Manufacturing, Englewood Cliffs, NJ: Prentice-Hall, Inc, 1980.

Groover, Mikel P. and Wigington, C., "CIM and the flexible automated factory of the future," Industrial Engineering, January, 75-85, 1986.

Grosov, Miriam Schapiro; and Hyman Sardy, A Research Primer for the Social and Behavioral Sciences. Orlando, FL, Academic Press, 1985.

Gunn, Thomas., Manufacturing for Competitive Advantage: Becoming a World Class Manufacturer , Cambridge, MA Ballinger Publishing Company, 1987.

Hagedorn, Homer J., "The factory of the future: What about the future?," Journal of Business Strategy , 5(1), 38-45, 1985.

Halberstam, David, "The Reckoning : Made in America or Japan." In Shetty and Buehler, Competing Through Productivity and Quality. Cambridge, Massachusetts, 1988.

Hall, R. W., Zero Inventories, Homewood, IL: Dow Jones-Irwin, 1983.

-----, Attaining Manufacturing Excellence, Homewood, Ill, Dow Jones-Irwin, 1987.

-----, H. Thomas Johnson; and Peter B. B. Turney , Measuring Up : Charting Pathways to Manufacturing Excellence. Homewood, Illinois, Business One Irwin, 1990.

Harrington Jr, Joseph ,(5th printing) Computer Integrated Manufacturing. Malbar, FL, Robert E. Krieger Publishing Company, 1985.

Hatakeyama, Yoshio, Manager Revolution ! : A Guide to Survival in Today's Changing Workplace. Cambridge, Massachusetts, Productivity Press, 1985.

Hayes, Robert H., "Why Japanese factories work," Harvard Business Review, 59(4), 56-66, 1981.

Hayes, Robert H. ; and Abernathy, W. J., " Managing Our Way to Economic Decline," Harvard Business Review, 58(1), 67-77, 1980.

Hayes, Robert W. and Schmenner, R. W., " How should you organize manufacturing?," Harvard Business Review, 56(1), 106-118, 1987.

Hayes, Robert, H. ; and Wheelwright, Steven C., " Link manufacturing process and product life cycles," Harvard Business Review, 57(1), 133-140, 1979a.

Hayes, Robert H. ; and Wheelwright, Steven C. (1979b), "The dynamics of process-product life cycles," Harvard Business Review, 1979b.

Hayes, Robert H. ; Wheelwright, Steven C.; and Clark, Kim B. , Dynamic Manufacturing. New York: The Free Press, 1988.

Heard, Ed. "Competing in Good Times and Bad," in Strategic Manufacturing: Dynamic New Directions for the 1990's, (Patricia E. Moody, Ed). Homewood, Illinois. Dow-Jones Irwin, 1990.

Hendricks, James A., "Accounting for automation," Mechanical Engineering, 111(2), 64-69, 1989.

Heizer, Jay H., "Manufacturing Productivity: Japanese Techniques Not Enough," IM, Sept. - Oct. 1986.

Hill, Terry Manufacturing Strategy : Text and Cases. Homewood, IL, Irwin, 1989.

Hoerr, John, and Pollock, Michael A., "Management discovers the human side of automation," Business Week, September 29, 70-75, 1986.

Holtry, Julie , "Toatal Quality Control : A Breakthrough Approach to Teamwork at Hewlett Packard." In Shetty and Buehler (Ed.) Competing Through Productivity and Quality. Cambridge, Massachusetts, Productivity Press, 1988.

Huber, George P., "The nature of design of post-industrial organizations," Management Science, 30(8), 928-951, 1984.

Hudson, C. A., "Computers in Manufacturing," In T. Forrester (Ed.), The Information Technology Revolution, Cambridge, MA: The MIT Press, 260-271, 1985.

Huge, Ernest C., The spirit of Manufacturing Excellence: An Executive's Guide to the new Mind Set, Homewood, Ill. The Dow Jones - Irwin, 1989.

Hunt, V. Danial Computer Integrated Manufacturing Handbook. New York, Chapman and Hall, 1988.

Inman, Bobby, "Exploiting Technology to Regain Markets." In Shetty and Buehler, Competing Through Productivity and Quality. Cambridge, Massachusetts, Productivity Press, 1988.

Ishikawa, Kaoru, What is Total Quality Control: The Japanese Way. Englewood Cliffs, New Jersey, Printice Hall, 1985.

Jacobs, James A., "TQC's role in world-class manufacturing." APICS Proceedings, 24-26, 1987.

Jaikumar, Ramchandran, "Postindustrial manufacturing," Harvard Business Review, 64(6), 69-76, 1986.

Japanese Management Association, Canom Production System: Creative Involvement of the Total Workforce. Stamford, Connecticut, Productivity Press, 1987.

Jelinek, Mariann and Joel D. Goldhar, "Maximizing Strategic Opportunities in Implementing Advanced Manufacturing Systems," in Donald D. Davis (Ed.) Managing Technological Innovation: Organizational Strategies for Implemeniting Advanced Manufacturing Technologies, London, Jossey-Bass, 1986.

----- and C. B. Schoonhoven Innonvation Marathon: Lessons from High Technology Firms. Cambridge Massachusetts, Basil Blackwell Inc., 1990

Johnson, H. Thomas, "Managing Costs: An outmoded philosophy," Manufacturing Engineering, 102(5), 42-46, 1989.

Jones, James V., "Integrated Logistics Support for the Automated Factory." In Cleland and Bidanda (Ed.) The Automated Factory Handbook: Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Julian, Ken , "Westinghouse: Building a better board," High Technology, May, 36-38, 1985.

Kaplan, Robert S., "Accounting lag: the obsolescence of cost accounting systems," in The Uneasy Alliance, (Kim B. Clark, Robert H. Hayes, and Christopher Lorenz, Ed.) Boston: Harvard Business School Press, 195-226, 1985.

Karatsu, Hajime, Though Words for American Industry. Cambridge, Massachusetts, productivity Press, 1986.

Keats, J. Bert, "Quality Control Issues in Automated Manufacturing." In Cleland and Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Keown, Arthur J., et. al. (1985), Basic Financial Management, 3rd ed., Englewood Cliffs, NJ, Prentice-Hall, Inc., 1985.

Klahorst, H. Thomas, "How to plan your FMS," Manufacturing Engineering, 96(9), 52-54, 1983.

Kleinbaum, David G.; Lawrence L. Kupper; and Keith E. Muller Applied Regression Analysis and Other Multivariable Methods, Boston, PWS-KENT Publishing Company, 1988.

Kleiner, Brian M. and Colin G. Dury, "Implementation of Industrial Ergonomics in an Aerospace Company." In Blache (Ed.) Success Factors for Implementing Change : A Manufacturing Viewpoint. Dearborn, Michigan, Society of Manufacturing Engineers, 1988.

Kobayashi, Iwao, 20 Keys to Workplace Improvement. Cambridge, Massachusetts, Productivity Press, 1990.

Koenig, Wes., "News economic realities take new purchasing practices." Electronic Business, 146-50,(Nov 1, 1986)

Krauskopf, Bruce, "Defining FMS: the concept, the users, the builders," Manufacturing Engineering, 96(6), 41, 1984.

Krepchin, Ira P. "How MRP II and JIT work together at DuPont." Modern Materials Handling, 73-76,(Dec 1986).

Krepchin, Ira P., "FMS, JIT drive this plant's efficiency." Modern Materials Handling, 93-98,(Nov. 1987).

Krepchin, Ira P., "Linking MRP II with product design." Modern Materials Handling, 99-101,(March 1987).

Krismann, Carol, Quality Control: An Annotated Bibliography, White Plains, New York, Quality Resources, 1990.

Krouse, John K., "Engineering without paper," High Technology, March, 38-46, 1986.

Kuilman, Martin, "Manufacturing Without a Human Face," High Technology, January 10, 1987.

Kengnick-Hall, Cynthia A., "Technology advances in batch production and improved competitive position," Journal of Management, 12(1), 75-90, 1986.

Lincoln, James R., Hanada, Mitsuyo, and McBride, Kerry, "Organizational structures in Japanese and U. S. Manufacturing," Administrative Science Quarterly, 31, 338-364, 1986.

Ling, Richard C.; and Walter E. Goddard Orchasterating Sucess : Improve Control of the Business with Sales and Operations Planning. Essex Junction, VT, Oliver Wright Limited Publications, Inc., 1988.

Link, Albert N.; and Gregory Tasse, Strategies for Technology-Based Competition: Meeting the New Global Challenge. Lexington, Massachusetts, Lexington Books, 1987.

Macbeth, Douglas K., Advanced Manufacturing : Strategy and Management. London, UK, IFS Publications, 1989.

Magee, John F., "SMR Forum: What information technology has in store for managers," Sloan Management Review, Winter, 45-49, 1985.

Mali, P., Improving Total Productivity. New York ,John Wiley & Sons, 1987.

Manchuk, Stan, "CIM project may be doomed to failure if key building blocks are missing," Industrial Engineering, July, 34-43, 1984.

Majchrzak, Ann, "Effect of CAD on the jobs of drafters and engineers: A quantitative case study," Proceedings of the Academy of Management, 335-339, 1988.

-----; and Mansour Rahimi, "Transitioning to CIM Systems : Effects on Human Factors and Resources Management." In Blache (Ed.) Success Factors for Implementing Change : A Manufacturing Viewpoint. Dearborn, Michigan, Society of Manufacturing Engineers, 1988.

-----; Nieva, Veronica; Newman Paul, "Adoption and use of Computerized Manufacturing Technology: A National Survey," In Donald D. Davis (Ed.) Managing Technological Innovation: Organizational Strategies for Implementing Advanced Manufacturing Technologies, London, Jossey-Bass Publishers, 1986.

Martin, John M., "Strategic Planning for Manufacturing," Manufacturing Engineering, 99(5), 45-50, 1987a.

Martin, John M., "CAD/CAM in the year 2000," Manufacturing Engineering, 99(6), 44-49, 1987b.

Martin, John M., "Cells drive manufacturing strategy," Manufacturing Engineering, 102(1), 49-54, 1989.

Matzner, Egon; and Michael Wagner, The Employment Impact of New Technology. Brookfield USA, Avebury, 1990.

Mayer, Raymond R., "A critical look at Kanban, Japan's just-in time inventory system." Management Review, 48-51, (Dec, 1984).

Meredith, Jack, Hyer, Nancy H., Gerwin, Donald, Rosenthal, Stephen R. and Weemmerloev, Urgan, "Research needs in factory automation," Journal of Operations Management, 6(2) 203-218, 1986.

Meredith, Jack and Green, Stephen, "Managing the introduction of advanced manufacturing technologies," Manufacturing Review, 1(2), 87-92, 1988.

Miller, J. G., " Fit production systems to tasks," Harvard Business Review, 59(1), 145-164, 1981.

Miller, J. G., "Report on the 1982 Manufacturing Future Survey," Manufacturing roundtable Research Report Series, Boston University, 1982.

Miller, J. G., and W. Hayslip, "Implementing Manufacturing Strategic Planning," Planning Review, 43-49, (July - August 1989).

-----, and A.V.Roth, "Manufacturing Strategies," Operations Management Review, 8-20, (1988-a).

-----, and -----, "Manufacturing Strategies," Manufacturing Roundtable Research Report Series, Boston University, (1988-b).

-----, and -----, "A Taxonomy of Manufacturing Strategies," Manufacturing Roundtable Research Report Series, Boston University, 1989.

Mitchell, Terence, "An evaluation of the validity of correlational research conducted in organizations," Academy of Management Review, 19(2), 192-205, 1985.

Mize, Joe H., "Success Factors for Advanced Manufacturing Systems." In Blache (Ed.) Success Factors for Implementing Change : A Manufacturing Viewpoint. Dearborn, Michigan, Society of Manufacturing Engineers, 1988.

Monden, Yasuhiro, "Charactristics of Performance Control Systems In Japanese Corporations." In Monden and Sakurai (Ed.) Japanese Management Accounting : A World Class Approach to Profit Management. Cambridge, Massachusetts, Productivity Press, 1989.

Montgomery, David, James Gooch, and Michael George, America can compete: the new method to become competitive in quality and cost worldwide, Dalls, TX, The Institute of Business Technology, 1987.

Musselwhite, W. Christopher, "The just-in-time production challenge," Training and Development Journal, 27-29, (Feb. 1987).

Myers, M. Scott, "Don't let JIT become a North American quick- fix." Business Quarterly, 28-38, (March 1987).

Myers, Raymond H. Classical and Modern regression with Applications (Second Ed.) Boston, PWS-KENT Publishing Company, 1990.

Nakajima, Seiichi, TPM : An Introduction to Total Productive Maintenace. Cambridge, Massachusetts, Productivity Press, 1988.

Nemetz, Patricia L. and Fry, Louis W., "Flexible manufacturing organizations: Implications for strategy formulation and organization," Academy of Management Review, 13(4), 627-638, 1988.

-----, "Bridging the Strategic Outcome Measurement Gap in Manufacturing Organizations," In Manufacturing Strategy, Proceedings of the Joint Industry University Conference on Manufacturing Strategy held in Ann Arbor, Michigan January 8-10, 1990. John E. Etlie et al (Editors), 63-74, 1990.

Nemoto, Masao, Total Quality Control for Management: Strategies and Techniques from Toyota and Toyoda Gosei. Englewood Cliffs, N.J, Prentice Hall Inc, 1987.

Noble, David F., "Social choice in machine design: The case of automatically controlled machine tools," In Case Studies on the Labor Process, A. Zimbalist (Ed.) New York: Monthly Review Press, 1979.

Nolen, James A., "Capitalizing on CAPP," Manufacturing Engineering, 102(5), 70-72, 1989.

Noori, Hamid, Managing the Dynamics of New Technology : Issues in Manufacturing Management. Englewood Cliffs, New Jersey, Printice Hall, 1990.

O'Guin, Michael; and A. T. Kearney, "Strategic and Financial Planning for the Automated Factory." In Cleland and Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

O'Neal, Charles; and Kate Bertrand, Developing a Winning J.I.T. Marketing Strategy : The Industrial Marketer's Guide. Englewood Cliffs, New Jersey, Prentice Hall, 1991.

Ohno, Taiichi, Toyota Production System: Aiming at an Off-Scale Management, New York: Diamond Publishing Company, 1978.

-----, Workplace Management. Cmbridge, Massachusetts, Productivity Press, 1988.

-----, and Setsuo Mito, Just-In-Time for Today and Tomorrow. Cambridge, Massachusetts, Productivity Press, 1988.

Oliff, Michael D., "Intelligent Manufacturing," Proceedings from the First International Conference on Expert Systems and the Leading Edge in Production Planning and Control, The Benjamin/Cummings Publishing Company, Inc., Melno Park, CA, 1988.

O'Neal, Charles, "New operational philosophy means smart supplier selection is a must." Marketing News 31, (Nov 7, 1986).

Palframan, Diane, "FMS: Too Much, too soon," Manufacturing Engineering, 98(3), 35-39, 1987.

Pannesi, Ronald, "Focus on material efficiency and productivity," APICS Proceedings, 475-77, 1987.

Phillips, Edward J., "FMS: Advantages, problems and opportunities," Mechanical Engineering, June, 31-33, 1985.

Piore, Michael J., "Computer technologies, market structure, and strategic union choices," In Challenges and Choices Facing American Labor, (Thomas Kochan, Ed.)Cambridge, MA: The MIT Press, 193-204, 1985.

Plossi, George W., "Manage by the numabers--but which numbers?" APICS Proceedings, 499-502, 1987.

Porter, Michael E., Competitive Strategy, New York: The Free Press, 1980.

Porter, Michael E. and Millar, Victor E., "How information gives you competitive advantage," Harvard Business Review, 63(4), 149-160, 1985.

-----, Competitive Advantages of Nations. New York, The Free Press, 1990.

Quinn, James B., "Managing strategic change," Sloan Management Review, 21(4), p. 3-20, 1980.

Raffi, F., "Upgrading the manufacturing function's strategic role," Operations Management Review, Fall, 42-47, 1984.

Raffi, F. and Miller, J. G., "Integrating manufacturing into strategic decision making," Boston University Working Paper, 1983.

Raia, Ernest, "Four Execs are champions of JIT cause," Purchasing 23-24, (Nov. 21, 1985).

Ria, Ernest, "Journey to world class," Purchasing 48+, (Sept. 24, 1987).

Ray, Jodie, "Computer Integrated Manufacturing: The Continuous Journey." In Shetty and Buehler (Ed.) Competing Through Productivity and Quality. Cambridge, Massachusetts, Productivity Press, 1988.

Reid, Peter C., Made in America: Lessons from Harley-Davidson on being the best, New York: McGraw Hill, 1990.

Reischauer, Edwin O., The Japanese Today, Cambridge, MA: The Belknap Press, 1988.

Robson, Ross E., (Ed.), The Quality and Productivity Equation : American Corporate Strategies for the 1990's. Cambridge, Massachusetts, Productivity Press, 1990.

-----; and Karen Richards, "Corporate Strategies for the Quality and Productivity Equations." In Robson (Ed.) The Quality and Productivity Equation : American Corporate Strategies for the 1990's. Cambridge, Massachusetts, Productivity Press, 1990.

Roth, A.V., "Linking Manufacturing Strategy and Performance: An Empirical Investigation," Manufacturing Roundtable Research Report Series. Boston University, 1989.

-----, A. Demyer, and A. Amano, "International Manufacturing Strategies: A Comparative Analysis," In Managing International Manufacturing, (K. Ferdows, Ed.). North Holland, Amsterdam, 1988.

-----, J. G. Miller, "Market, Manufacturing Strategy, and Technology Acquisition: An Interactive Development Approach," Proceeding of the Joint Industry University Conference on Manufacturing Strategy held in Ann Arbor, Michigan on January 8th-10th, 1990, (John Etlie, et al Ed.), 1990.

-----, Strategic Planning for the Optimal Acquisition of Flexible Manufacturing Systems Technology, Unpublished Ph.D Dissertation, Ohio State University, 1986.

Rouse, William B., "The Human Role in Advanced Manufacturing Systems." In W. Dale Compton (Ed.) Design and Analysis of Integrated Manufacturing Systems. Washington D. C., Academy of Engineering Press, 1988.

Rubinger, Bruce, Competing Through Technology : The Success Factor. In Dermer (Ed.) Competitiveness through Technology : What Business Needs from Government. Lexington, Massachusetts, Lexington Books, 1986.

Rumelt, R. P., Strategy, Structure, and Economic Performance, Cambridge, MA: Harvard Graduate School of Business Administration, 1974.

Ryan, Nancy E., "CAD/CAM integration yields quality, control," Manufacturing Engineering, 98(2), 43-47, 1987.

Rydz, John S., " Strategic Planning: Productivity's keystone," Production Engineering, June, 46-48, 1984.

Sakurai, Michiharu; and Philip Y Huang, "A Japanese Survey of Factory Automation and Its Impact on Management Control Systems. In Monden and Sakurai (Ed.) Japanese Management Accounting: A World Class Approach to Profit Management. Cambridge, Massachusetts, Productivity Press, 1989.

-----; Larry N. Killough; and Robert M. Brown, "Performance Measurement Techniques and Goal Setting : A Comparison between U.S. and Japanese Practices." In Monden and Sakurai (Ed.) Japanese Management Accounting : A World Class Approach to Profit Management. Cambridge, Massachusetts, Productivity Press, 1989.

Sandras, William A. Just-In-Time : Making it Happen. Essex Junction, VT, Oliver Wright Limited Publications, Inc., 1989

Sato, Kazuo; and Yasuo Hoshino (Ed.), The Anatomy of Japanese Business. Armonk, New York, M.E. Sharpe Inc., 1984.

Savage, Charles M., "CIM management of the future: FGM," Manufacturing Engineering, 112(1), 59-63, 1989.

Schlie, Theodore W. and Goldhar Joel, D., "Product variety and time based manufacturing and business management: achieving competitive advantage through CIM," Management Review, 2(1), 32-42, 1989.

Schonberger, Richard, J., Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity. London: Free Press, 1982.

Schonberger, Richard, J., World Class Manufacturing: The Lessons of Simplicity Applied. London: Free Press, 1986.

Schreiber, Rita R., "Building a case for CIM, " Manufacturing Engineering, 98(2), CT31-CT33, 1987.

Schroeder, Roger G., Anderson, John C., and Cleveland, G. , "The Content of Manufacturing Strategy: An Empirical Study," Journal of Operations Management--Special Combined Issue, 6(4), 405-415, 1986.

Shaiken, Harley, Work Transformed: Automation and Labor in the Computer Age. New York: Holt, Rinehart, and Winston, 1984.

Shaiken, Harley, Herzenberg, Stephen, and Kuhn, Sarah, "The work process under more flexible production," Industrial Relations, 25(2), 167-183, 1986.

Sharma, Devem., Manufacturing Strategy: An Empirical Analysis, Unpublished Ph.D Dissertation, Ohio State University, 1987.

Shetty, Y. K. and Vernon M. Buehler, (Ed.), Quality , Productivity , and Innovation: Strategies for Gaining Competitive Advantage. New York, Elsevier, 1987.

-----, (Ed.), Competing Through Productivity and Quality. Cambridge, Massachusetts, Productivity Press, 1988.

Shibakawa, Rinya, "Financial Characteristics of Japanese Corporations." In Monden and Sakurai (Ed.) Japanese Management Accounting : A World Class Approach to Profit Management. Cambridge, Massachusetts, Productivity Press, 1989.

Shingo, Shigeo , Study of Toyota Production System from an Industrial Engineering Viewpoint. Tokyo, Japan: Japan Management Association, 1981.

----- , The Sayings of Shigeo Shingo: Key Strategies for Plant Improvement. Cambridge Massachusetts, Productivity Press, 1987.

-----, Non-Stock Production System for Continuous Improvement. Cambridge, Massachusetts, Productivity Press, 1988.

----- , "SMED : The Heart of JIT Production." In Shetty and Buehler, Competing Through Productivity and Quality. Cambridge, Massachusetts, Productivity Press, 1988.

Skinner, Wickham, "Manufacturing--missing link in corporate strategy," Harvard Business Review, 47(3), 136-145, 1969.

-----, "The focused factory," Harvard Business Review, 52(3), 113-121, 1974.

-----, Manufacturing in Corporate Strategy. New York, John Wiley, 1978.

-----, "The Taming of the Lions : How Manufacturing Leadership Evolved 1780 - 1984." In Clark et al (Ed.) The Uneasy Alliance : Managing the Productivity- Technology Dilemma. Boston, Massachusetts, Harvard Business School Press, 1985.

-----, "The Productivity Paradox Explained." In Robson (Ed.) The Quality and Productivity Equation. Cambridge, Massachusetts, Productivity Press, 1990.

Smeltzer, Larry R. and Karen J. Gritzmacher, "The use of Quality Circles for Implementing Automated Manufacturing." In Cleland and Bidanda (Ed.) The Automated Factory Handbook: Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Snead, Charles S. Group Technology : Foundation for Competitive Manufacturing. New York, Van Nostrand Reinhold, 1989.

Spechler, Jay W., Case Studies in Service Quality : When America Does it Right. Norcross, Georgia, Industrial Engineering and Management Press (Institute of Industrial Engineers, 1988.)

Stalk Jr., George and Thomas M. Hout, Competing Against Time: How Time-Based Competition is Reshaping Global Markets. New York, The Free Press, 1990.

Starr, Martin K., "How"Fast Response Organization" Achieve Global Competitiveness." In Robson (Ed.) The Quality and Productivity Equation. Cambridge, Massachusetts, Productivity Press, 1990.

Stasey, Robert and Carol J. McNair, Crossroads : A JIT Success Story. Homewood, Illinois, Dow Jones-Irwin, 1990.

Stauffer, Robert N., "Managing the fifth-generation enterprise," Manufacturing Engineering, 98(2), CT19-CT21, 1987.

Suri, Rajan , "A New Prespective on Manufacturing Systems Analysis." In W. Dale Compton (Ed.) Design and Analysis of Integrating Manufacturing Systems. Washington D.C., Academy of Engineering Press, 1988.

Suzaki, Kiyoshi, The New Manufacturing Challenge, Techniques for Continuous Improvement. New York: The Free Press, 1987.

Swamidass, Paul M., "Manufacturing strategy: its assessment and practice," Journal of Operations Management--Special Combined Issue, 6(4), 471-484, 1986.

Swamidass, Paul M. and Newell, William J., "Manufacturing strategy, environment uncertainty, and performance: A path-analytic model," Management Science, 33, 509-524, 1987.

Szakonyl, Robert, "Worlds apart--Bridging R & D and manufacturing," Management Engineering, 99(6) 67-70, 1987.

Teicholz, Eric and Joel N. Orr Computer-Integrated Handbook. New York, McGraw-Hill Book Company, 1987.

Tepsic, Rudy M., "How to justify your FMS," Manufacturing Engineering, September, 50-52, 1983.

Thamhain, Hans J., "Production Teams in Manufacturing." In Cleland and Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Thorndike, Robert M. Correlational Procedures for Research. New York, Gardner Press, Inc., 1978

----- Data Collection and Analysis : Basic Statistics. New York, Gardner Press, Inc., 1982

Tipnis, Vijay A., "Process and Economic Models for Manufacturing Operations." In W. Dale Compton (Ed.) Design and Analysis of Integrated Manufacturing Systems. Washington D.C., National Academy of Engineering Press, 1988.

Todd, Henry, "Managing Quality/Productivity Improvement at McDonnell Douglas." In Shetty and Buehler, (Ed.) Competing Through Productivity and Quality. Cambridge, Massachusetts, Productivity Press, 1988.

Tonkay, Gregory L., "Taxonomy of Manufacturing Operations." In Cleland and Bidanda (Ed.) The Automated Factory Handbook : Technology and Management. Blue Ridge Summit, PA, TPR, 1990.

Torvinen, James, "Ford's Use of Shingo's Methods." In Shetty and Buehler (Ed.) Competing Through Productivity and Quality. Cambridge, Massachusetts, Productivity Press, 1988.

Udoka, S. J. and John W. Nazemetz, "Structuring A Survey Instrument for Assessing Success Factors in Automation Projects." In Blache (Ed.) Success Factors for Implementing Change : A Manufacturing Viewpoint. Dearborn, Michigan, Society of Manufacturing Engineers, 1988.

Unterweger, Peter, "The Human Factor in The Factory of the Future." In Blache (Ed.) Success Factors for Implementing Change : A Manufacturing Viewpoint. Dearborn, Michigan, Society of Manufacturing Engineers, 1988.

Vollmann, Thomas E.; William L. Berry; and Clay Whybark
Manufacturing Planning and Control Systems (Second Ed.) Homewood, IL, Irwin., 1988.

Voss, C. A. Just-In-Time Manufacture, IFS(Publication) Ltd. Uk., 1987

Wantuck, Kenneth A. Just-In-Time for America : A Common Sense Production Strategy. Milwaukee, WI, The Forum Ltd., 1989

Warner, Malcolm , "New technology work organizations, and industrial relations," OMEGA International Journal of Management Science, 12(3), 203-210, 1984.

Wheelwright, Steven C., "Japan -- Where operations really are strategic," Harvard Business Review, 59(4), 67-74, 1981.

Wheelwright, Steven, C., "Manufacturing strategy: Defining the missing link," Strategic Management Journal, 5, 77-91, 1984.

----- and Hayes, R. H., "Competing through manufacturing," Harvard Business Review, 63(1), 99-109, 1984.

-----, "Building Excellence in Manufacturing." In Shetty and Buehler, Quality, Productivity and Innovation : Strategies for Gaining Competitive Advantage, New York, Elsevier, 1987.

Wilson, John W. and Dobrzynski, Judith H., "And now, the post-industrial corporation," Business Week, March 3, 64-71, 1986.

Young, Clifford; and Alice Greene Flexible Manufacturing Systems : AMA Management Briefing. New York, N.Y., American Management Association, 1986.

Zammuto, R. F., "A comparison of multiple constituency models of organizational effectiveness," Academy of Management Review, 9(4), 606-616, 1984.

Zygmunt, Jeffrey , "Guided vehicles set manufacturing in motion," High Technology, 16-21, Dec. 1986.

Zygmunt, Jeffrey, "Manufacturers move toward computer integration," High Technology, February, 1987.