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The impact of computer integrated manufacturing, flexible manufacturing systems, and group technology on product quality

Elahmady, Bassam Mohamed, Ph.D.

City University of New York, 1993

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THE IMPACT OF COMPUTER INTEGRATED MANUFACTURING, FLEXIBLE MANUFACTURING SYSTEMS, AND GROUP TECHNOLOGY ON PRODUCT QUALITY

by

BASSAM M. ELAHMADY

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

1993

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ABSTRACT

THE IMPACT OF COMPUTER INTEGRATED
MANUFACTURING, FLEXIBLE MANUFACTURING SYSTEMS,
AND GROUP TECHNOLOGY ON PRODUCT QUALITY

by

BASSAM M. ELAHMADY

ADVISOR: Professor Michael N. Chanin

Recently, the success of advanced manufacturing technologies (AMTs) has drawn worldwide attention to the quality issue as a competitive edge in manufacturing strategy implementation. This dissertation investigates the impact of the intensity level of three forms of advanced manufacturing technologies i.e. Computer Integrated Manufacturing , Flexible Manufacturing Systems and Group Technology on four major quality aspects. These are quality costs, market and customer, total employee involvement, and quality techniques. Hypothesis testing with analyses of variance (ANOVA) was performed to determine whether there are statistically significant differences in these four aspects of quality among business units with different levels of AMTs. The sample of business units was drawn from five industries. These are: Electronics, Aerospace, Industrial Equipment, Metal Products, and Automotive. The survey response rate was 23%.

An intensity index was developed for the purpose of this study. The index is the multiplicative impact of:

1- (CIM) Computer Integrated Manufacturing

2- (FMS) Flexible Manufacturing Systems

3- (GT) Group Technology

on quality.

Based on this index, cluster analysis was utilized. The results of cluster analysis showed that our data are best interpreted by three clusters that define different intensities of AMTs. ANOVA results reveal that significant

differences in the four aspects of quality exist among business units with different intensity levels of AMTs.

The contribution of this study is apparent in the development of the Intensity Index of AMTs. The index is a unique way of quantifying the concept of levels of AMTs.

The implications of the study are multifaceted. First, the higher the levels of AMTs, the more likely that business units will outperform their counterparts with low intensity levels of AMTs. Second, managers or practitioners may use the concept of the intensity levels to benchmark the performance of their companies against that of their competitors.

The findings of this study are limited by the following factors:

1 - It is applicable to the five industries mentioned in our study.

2 -It deals with just three forms of Advanced Manufacturing Technologies, that is Computer Integrated Manufacturing, Flexible Manufacturing Systems and Group Technology.

3 - It concentrates on four aspects of quality management. These are quality costs; marketing and consumer; total employee involvement and quality tools.

this dissertation is dedicated to

My Parents, My Wife,
and My Son

for their devotion during my studies

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Chapter 1

INTRODUCTION

In recent years, U.S. companies have faced competition from high quality products coming from Japan and Europe. They started to realize that quality is a strategic weapon and can determine survival in the business world. Many contributions in this field have been established by Deming, Juran, Crosby, and Taguchi.

Quality is a fusion of technical, economical, behavioral, and managerial issues. Quality, thus, is an interdisciplinary topic. This research will be restricted to the combination of those aspects related to quality and automated business units. Those aspects are: Quality Costs, Market and Customer, Employee Involvement, and Quality Tools. Restricting the research to these aspects will help reduce the possibility of encroaching on other research domains such as organizational structure, psychology, and technical details in automated quality control systems.

The main assumption is that these quality aspects differ considerably from one selected Advanced Manufacturing Technology (AMT) to another. Through a designed questionnaire, it is hoped that this study will provide information that is useful in investigating the impact on quality of Computer Integrated Manufacturing (CIM), the Flexible Manufacturing System (FMS), and Group Technology (GT).

During the 1980s, manufacturing strategies have undergone dramatic change. A major factor that has contributed to this change is the advance in computer technology as it is applied to manufacturing systems. In order to compete effectively, companies are increasing their computer utilization degree.

The following have been discussed in the literature as some of the results of applying Advanced Manufacturing Technologies (AMTs):

1. Increased costs through jamming and production delays due to feeding defective parts and components.
2. The worker's responsibility shifts to performing adjustments and maintenance activities.
3. More emphasis on interpretation of data, disposition of product and reporting rather than on regular procedures and visual inspections.
4. More emphasis on consumer and market issues in addition to reliability and performance.
5. More emphasis on diagnosing the causes of instability and variations than on corrective actions.
6. More emphasis on empowering employees to integrate quality into their daily work activities.

7. More emphasis on international standards and specifications designed to satisfy the needs of the international marketplace.

Unfortunately, economic growth has recently slowed down, and competition has become fierce. Product life cycles are now shorter than in the 1970s and 1980s. The increasing product market shares are being divided into more segments as the number of firms now participating in a global economy increase. To meet these threats, companies must find ways for their production to achieve a higher degree of integration, flexibility, productivity and quality. Advanced Manufacturing Technologies can contribute in making a significant effort to achieve these strategic goals.

The main purpose of this study is to determine whether there are statistically significant differences in certain quality aspects among groups with different levels of AMTs.

In order to achieve this objective, a questionnaire was designed and pilot tested. Among the questions asked:

1. For how long AMTs have been used in each business unit?
2. What percentage of each business unit has been using AMTs?
3. To what extent do AMTs affect each of the following quality aspects:
    (a) marketing and customers
    (b) cost

(c) measurements

(d) total employee involvement

This study relates the intensity level of the three forms of Advanced Manufacturing Technologies (AMTs) and the four aspects of quality. The two areas are considered by many researchers to be complex and ill-structured. The review of literature showed that measuring the impact of AMTs on quality , in a quantitative manner, has not been fully investigated.

Udoka and Nazemetz (1990) stated that by reason of the complex nature of the factors affecting AMT systems implementation performance, firms implementing such projects have been unable to determine factors responsible for successful implementation of AMTs. Another difficulty in the time gap between implementation and the achievement of benefits. Sohal (1991) concluded that one of the main difficulties is determining the impact of the AMTs on the organization as a whole. He added, "The real benefits from AMT investments can be measured only after the equipment has been fully commissioned and running for a reasonable period of time."

Son (1991) examined some of the difficulties related to measuring the predicted economic benefits of AMTs. Son's contribution to this area was that quality costs are considered important factors in justifying AMTs.

Foden (1989) argued that the impact of new technologies on the conditions of work affects product quality. In addition, the rate of growth of labor productivity is not determined solely by the technical characteristics of the innovation.

Jain (1989) and Noble (1989) draw a similar conclusion about the difficulties of implementing Computer Integrated Manufacture (CIM). They considered quality as a strategic benefit of CIM. However, it was difficult to quantify CIM's impact on the ability of a company to survive in the dynamic marketplace. Other equally unmeasurable but important intangible benefits are better customer relations, higher employee morale, and higher sales and profits.

Chen and Adam (1991) concluded that there is a modest empirical relationship between Flexible Manufacturing System (FMS) and quality improvement. While demonstrating that quality improves somewhat with FMS implementation, they recommended that FMS impact on quality should be fully explored, in order to provide critical input into a company's strategic decision-making process.

The rest of this dissertation includes four chapters. Chapter 2 contains an overview and discussion of the various definitions, components and advantages of CIM, GT and FMS. In addition a discussion of the importance of these technologies to quality is addressed.

Chapter 3 lays the foundation for the discussion of the research methodology. It includes research objectives, research hypotheses, data collection, and measurement.

Chapter 4 is divided into two parts. Part I includes the statistical analysis performance. Part II focuses on an explanation of these results and their implications.

In chapter 5, findings are reported and recommendations for future research are proposed.

Chapter 2

REVIEW OF LITERATURE

2.1 INTRODUCTION:

This chapter provides an overview of the significant prior research on definition, components, and benefits of both Advanced Manufacturing Technologies and Quality. The review includes: Computer Integrated Manufacturing (CIM), Flexible Manufacturing System (FMS), and Group Technology (GT) as the selected forms of AMTs. Also, the review includes a framework and operational definitions of AMTs and Quality terms.

2.2 ADVANCED MANUFACTURING TECHNOLOGIES (AMTs):

Hornsby and Williams (1990), emphasized the importance of AMTs as a driving force in domestic and international competition. They indicated that promoting firms are willing to explore and invest in various types of computer assisted processes and equipment. They defined AMTs as an array of process technologies, including Computer Aided Manufacturing (CAM), Computer Aided Design (CAD), Manufacturing Resource Planning (MRP), Computer Aided Process Planning (CAPP), and Computer Integrated Manufacturing (CIM). Computer Aided Manufacturing (CAM) encompasses Flexible Manufacturing Systems. Merdith and Hill (1987) reported that the new manufacturing technologies can be considered to span the continuum in terms of level of integration from stand-alone equipment to full Computer Integrated Manufacturing (CIM).

Fuchs (1988) broke down the integrity issue into: the integrity of the material that goes into the process, and the integrity of the process that achieves maximum possible control of variability. Carol (1990) through an empirical study of 10 firms starting to use AMTs projects, found that one of the implementation factors that have a significant bearing on the degree to which the goals of AMTs will be met is how many systems are integrated.

Canada and Sullivan (1989) defined the term Advanced Manufacturing System (AMS) as any automated (usually computer-oriented) technology used in design, manufacturing/service, and decision support. Some refer to it simply as automation, which traditionally has been applied to hardware and equipment to facilitate manufacturing. They focused on computer and automation beside the possible availability to include a joined management information system to support decision making process. According to Youssef (1991), AMTs may 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 rending a service". This definition includes main components: hardware and software; and main benefits such as efficiency and effectiveness.

The benefits of using advanced manufacturing technologies vary depending on the type of product and its manufacturing process, the particular applications of new technology, the number of business units that use computer aids, and extent to which database are a shared resource. The integration of Advanced Manufacturing Systems can provide further benefits. AMTs can achieve strategic benefits such as increasing quality, productivity, and market share. Also, AMTs can assure operational benefits such as decreasing production run time, eliminating waste, and increasing equipment utilization.

The literature is rich in books, articles, cases, and applications of AMTs which explain and discuss the technical benefits on production lines. Therefore, in the following part of the literature review the emphasis will be on the strategic benefits of AMTs as related to product quality.

Many researchers explained that AMTs can achieve the following advantages:

1. improve quality and productivity,
2. increase flexibility,
3. making design stage easier and faster,
4. cut production costs,
5. increase market share,
6. increase consumer satisfaction,

7. speed new model development, and

8. increase material handling capabilities.

McNair and Mosconi (1987) and McReynolds and Fern (1990) discussed the areas in which AMTs can achieve progress. McReynolds and Fern (1990) studied the following four areas: 1. cost analysis, 2. inventory control, 3. cost control, and 4. performance measures. McNair and Mosconi analyzed the fourth area by including people, delivery, cost, and quality as critical success factors in an organization's performance measurement system. Brooks and Patterson (1988) stated that failure to invest in factory modernization will affect quality, cost efficiency, and flexibility. Park and Son (1988) stated similar benefits such as quality, and flexibility. Maji (1991) addressed the following strategic benefits of AMTs: the flexibility to manufacture multiple products; the ability to manufacture complex products; increased responsiveness in meeting market demand; and improved product reliability.

Shingler (1986) and Krepchon (1986) focused on the effect of AMTs on the product design and manufacturing specifications which achieve significant gains in market share and reduce costs and work-in-process times. Hoffer (1985) analyzed the impact of technological advances on the defect prevention systems. He explained that the inspection that test devices needed to maintain ongoing process control are being integrated into the manufacturing assembly process. To be effective, these devices must feature adaptive feedback mechanisms, such as automatic tool adjustment, based on the statistically determined process variability rather than the part print specification.

Ryan (1984) described the impact of advances in computer assisted automated metrology on widespread use of variable data, which have advantages over attributes data in the decision-making information that they can covey. He explained that attributes data are not useful when the specified quality level for a process is described in terms of parts per million nonconforming, unless sample sizes are large. Technologically, AMTs have the capability to produce within these rigid quality levels.

2.2.1 Computer Integrated Manufacturing (CIM):

There are numerous definitions of Computer Integrated Manufacturing. The linkage between CIM and other techniques such as flexible manufacturing system (FMS), have created confusion. In this segment of the review, some of these definitions and their strengths will be considered.

According to Merdith (1987), when the design, planning, materials handling, manufacturing, and support systems (e.g. order entry, cost accounting, purchasing) are all linked together through computer, the factory is considered to be fully integrated, commonly known as CIM. Merdith focused on how manufacturing interacts with other areas. Meister (1987) stated that CIM cannot be defined in terms of products or services. Rather, CIM is an environment in which companies can more effectively implement solutions to critical business problems. Meister also focused on the computer as only a tool to aid in implementation. He distinguished between automation and integration. Automation represents a change in how a process is done. Integration represents a change in what is done. According to Bonsack (1998), CIM refers to a complex network of machines, computers, and people developing and producing products with greater efficiency.

Asghar (1991) considered CIM as a vertical integration of computerized manufacturing system. The reason is the interchangeable activities throughout the organization. CIM can easily be a link between management and shop floor inside firms. Wilder (1991) claimed that CIM facilitates more stringent control of the process, and provides the manufacturing accountability necessary to meet increasing quality requirements.

Ciampa (1988) emphasized the concept of integration. According to him, CIM stresses the integration of automatic systems that provide information for decision making throughout the manufacturing process.

Reed (1991) explained that CIM can be a major contributing factor to world class performance. For a manufacturer, world class performance means running faster and smarter than the competition and never letting up. CIM is gradually reshaping the U.S. industrial sector. The giants such as International Business Machines, General Motors, General Electric and Ford Corporations have spent billions of dollars to implement CIM technologies. Feldman (1991) stated that in addition to making large organizations more competitive, IBM's CIM Production Planning Series program addresses head-on such critical success factors as being able to improve or maintain high levels of quality. The program provides for both horizontal and vertical communication of information. It incorporates requirements for electronic data interchange among the variety of programmable factory floor devices.

Eyrich (1991) explained how one of the IBM subsidiaries (Rochester, Minnesota) demonstrates world class manufacturing. He cited that IBM Rochester sought to be the undisputed leader in customer satisfaction; first with the best products. These goals were accomplished through a team of enabled, empowered, excited, and rewarded people. Consistent with this vision is the goal of IBM Rochester to be the best CIM site. Goldhar, Jelinek, and Schlie (1991) described the overall benefits of CIM from the manufacturing competitive advantage point of view. They state that CIM makes it possible to create a factory and a product realization system that has high levels of economy of scope as well as scale. This challenges traditional trade-offs between volume, flexibility-variety and quality costs. In brief, CIM can provide solutions to trade-offs followed by a wide range of new marketing tactics and business strategies.

Many writers discussed CIM's benefits from different points of view. Some have concentrated on the role of CIM as an information system. Badiru (1990) stated that CIM determines the data needed in automated manufacturing systems. Data categories should be selected on the basis of their relevance and the level of likelihood that they will be needed for future functions of the system and whether they contribute to the enhancement of those functions. Nowak (1988) introduced the concept of an Integrated Quality System (IQS) as a means of controlling the quality of information processed within a CIM system. Others (Boudette (1990) and King, and Freedman (1988)) focused on a shortened cycle time and lowering the minimum production level.

For aspects related to quality, Powers (1988) stated that CIM includes tighter quality control at each operational stage. King and Freedman (1988), Rohan (1987), and Badiru (1990) included improving the product's quality as one of the major benefits to CIM. Wilder (1991) stated that CIM links management, equipment, and the shop floor. This link facilitates more stringent control of processes and provides the manufacturing accountability necessary to meet increasing quality requirements. According to Kahan (1991), a shop floor CIM system enables parameter tracking so that manufacturers can decrease the number of rejects and accurately analyze quality result. In short, CIM reduces time and costs, and increases quality and integration.

2.2.2 Flexible Manufacturing System (FMS):

Much has been written about flexible manufacturing systems. Definitions, components, implementation, justification, and advantages represent major areas in FMS literature. For the purpose of this research, definitions and benefits will be given more attention. According to Chen and Adam (1991), the origin of FMS started in the mid to late 1960s as a logical growth of numerical control (NC) applications. Ouellette (1983) reported that manufacturers started to integrate NC and Computer Numerical Control (CNC) by linking them to a computer that provides for greater power of computation as well as for control and communication capability between the operator and the machine tools. Some machines can change their tools automatically to carry out many machine operations on the same piece. These machining centers bring additional diversity to the manufacturing process. FMS is a further step toward technology integration. Machine centers are linked together such that a piece being worked on can travel from one machining center to another in direct sequence, under the control of one or more control computers.

Buffa (1985) explained the importance of using FMS applications for U.S. industries. Buffa reported that 75% of machined parts in the U.S. are produced in a lots of 50 or less. Assembly-line techniques for which U.S. manufacturing is so famous are not applicable to the kind of batch production. In the past these automation techniques have been even less applicable. However, FMS promises changes. In FMS, NC machines on the line are controlled by a computer; robots handle the parts; and automatically-guided carts carry finished products to their next locations. Automatic tool-changing systems are incorporated and product changeover is included in the computer program. Thus, a wide variety of parts can be produced on the same flexible equipment.

Yau and Buzacott (1986, P. 894) have another definition (quoted from Collins 1980):

> *FMS combines the existing technology of NC manufacturing, automated material handling, and computer hardware and software to create an integrated system for the automatic random processing of different parts across various work stations in the systems.*

Chen and Adam (1991, P. 33) defined FMS (quoted from Draper 1984) as:

> *A computer-control configuration of semi-independent work stations and material handling system designed to efficiently manufacture more than one part type at low to medium volumes.*

Ramchandarn and Jaikumar (1986) interpret FMS as a computer-controlled grouping of semi independent work stations linked by automated material-handling system. It is similar to Draper's definition. Briefly, many writers focus on the major elements or components of FMS which could be summarized as flexible machines or work stations; automated material handling system; and computerized network that directs and links all the related processes.

The following part concerns with FMS's benefits. Rembold, Blume, and Dillmann (1985) summarized the possible benefits of FMS as:

1. *Operate equipment around the clock: During the two day shifts, the equipment will be supplied with raw parts and properly maintained by personnel. Scheduling and supervision is done by the computer under operator observance. During the night shift (ghost shift) a*

computer supervises the operation independently and if necessary, turns the system off when problems arise.

2. *Minimize direct labor: Machining, toll changing, fixturing, measuring, and material moving and handling are controlled automatically by the computer. Labor may be used during day shifts for observance functions, loading, unloading, and maintenance.*
3. *Minimize lead time: This is performed by the computer, which knows the production schedule and the machine status.*
4. *Reduction of in-process inventory: Since a FMS operates on the flow line production principle, in-process inventory buffers are reduced to a minimum. They may only be maintained to provide parts during a possible equipment failure.*
5. *Reduce tolls and fixture requirements: Since FMS produce a larger part spectrum, universal tools and fixtures are used. This results in shorter retooling and setup times.*
6. *Obtain a high flexibility: The part spectrum for which a FMS is conceived has a major influence on the flexibility and utilization of the equipment. Future product variants, engineering changes, and manufacturing methods should be anticipated when such a system is conceived.*

Source: Rembold, Blume, and Dillmann (1985, P 748)

Canada and Sullivan (1989) indicated that FMS allows the continuous manufacture of different items within a family of parts in small batches within a dedicated machining facility. FMS can achieve low-volume high variety end of the manufacturing spectrum. FMS allows additional models to be added to the company's product range at only marginal cost.

Weintraub (1988) stated that FMS has become viable option in apparel production because the group system reduces conflicts in areas such as rates and quotes, good work and bad work, favoritism, and quality. Yost (1987) cited that FMS can be valuable quality tool if the product and process are designed together.

Empirically, Tombak (1988) concluded that firms which plan to implement an FMS were concerned more about vendor quality and lead times than non-FMS firms. Nemetz and Fry (1988) showed that FMS firms synthesize unit and batch production, mass production, and continuous process production, thus allowing them to exploit the advantages of each. Hill (1985) compared the advantages of FMS and conventional manually-operated machines and numerically controlled machine tools. His major conclusions were decreased times, costs, and inventory; and increased utilization, market share, profit, quality, and responsiveness.

2.2.3 Group Technology (GT):

This section deals with Group Technology (GT) as the third form of the selected Advanced Manufacturing Technologies (AMTs). GT represents a logical change in manufacturing systems development. The reason is the increased attention to the concept of process-focused production. According to this concept, all operations that have similar technical processes must be grouped together in order to form a specific production facility.

Canada and Sullivan (1989) defined GT as a method of classifying parts into families according to similar shapes, or common manufacturing process operations. This is implemented by assigning codes that are combined to form specific numbers of families. In more details, Rembold, Blume, and Dillmann

(1985) explained the criteria of grouping parts. Grouping could be either according to the geometric similarities or to similar fabrication methods. Fry, Willson, and Breen (1987) considered that GT is a manufacturing practice which harnesses manufacturing resources for small lot production in much the same way as is done for mass production. However, instead of producing identical parts, a family of similar parts with similar process is manufactured. Merdith and Hill (1987) related GT to the second level of integration in Advanced Manufacturing Systems.

All the previous writers, except Merdith and Hill, where their emphasis was on justification issues, explained the benefits and advantages of using GT. By reviewing the efforts of the previous writers, benefits of GT could be summarized as:

1. improved routing, handling, and machine loading,
2. reduced set up, and process time,
3. reduced working process and number of scheduled operations,
4. reduced cycle times from vendors to customers,
5. reduced manual inventory,
6. reduced design proliferation,
7. improved plant layouts,

8. and allows sorting part families according to codes or attributes and features.

Rembold, Blume, and Dillmann (1985) explained in detail the benefits of a well-conceived classification system. They divided the main benefits into groups. Each deals with one issue such as: engineering, equipment and facility planning, process planning, production control, and quality control. For the quality issue, they indicated that GT reduces sampling and inspection times, improves utilization of measuring instruments, reduces time to locate defects, and it is easier to install quality inspection procedures.

2.3 QUALITY:

Nowadays, quality has become the most critical and sensitive issue to business progress than ever before in history. Therefore, many academics and practitioners have been writing about quality issues. There are many reasons to clarify the importance of quality definition. Ryan (1987) concluded that while companies recognize the need for product quality, they are less certain about what to do to bring about quality. Robertson (1991) cited that the first step in understanding how quality can be applied to industrial companies is to construct a definition of quality. Monty (1990) explained a common misconception about quality. This misconception is related to a popular view that product or service excellence is an expensive luxury. In fact, doing things right the first time is less costly than something that has to be reworked or corrected. Both Robertson (1991) and Langevin (1984) stated the same idea about "getting the right things the first time".

This section briefly reviews the definition of quality and identifies the key words of the quality concept. According to Juran (1988), the word quality has many meanings. Quality consists of those product features which meet the needs of customers and provides satisfaction; and freedom from deficiencies. He explained in detail the related key words such as: product features, customer, product satisfaction, conformance to specification or requirements, and product deficiency. Garvin (1987) discussed five approaches to defining quality: (1) the transcendent approach of philosophy, (2) the product-based approach of economics, (3) the user-based approach of economics, marketing, and operations management, (4) the manufacturing-based and (5) value-based approaches of operations management. He also identified eight dimensions as a framework for basic elements of product quality. These dimensions are: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. He cited that a product can be ranked high on one dimension while being low on another. These dimensions are similar to Juran's key words; except Garvin focused on reliability, durability, and serviceability.

Freund (1985) defined quality by citing the necessity of recognizing activities such as product or process design, production and service operations, and maintenance. These activities interact and influence the degree of satisfaction with quality. In contrast, Mayo (1986) explained the major areas of quality in terms of its' impact. He analyzed the impact of quality on efficiency, attitude, cost control, and customer satisfaction. He also reported that the major point about the real meaning of quality is the customer's definition which is much more all-encompassing than the traditional supplier's definition. Akers (1991), Donnelly (1991), Dumas (1989), Diminnie (1989), and Ebrahimpour (1986) stated that consumer expectations are major element in quality definition. Kitchenham and Redmill (1990), Crosby (1989), and Bognossian (1988) focused on quality as conformance to requirements. Deming (1988) took the statistical approach to quality. He believes that the reduction of variation is the foundation of philosophy of quality. Supporting this approach, Anderson (1990) defined quality as total acceptable variation divided by total actual variation. Clearly, it is a narrow and statistical definition; it focuses on variation theory. In the service area, while the benefits of quality are obvious, quality is not an easy concept to define.

Tierno (1989) defined quality as user-based which means aiming at performing the maximum useful quality to customers. Much has been written about defining quality in service businesses particularly in health care and banking systems. The main dimensions in quality related service could be summarized as: accessibility, continuity, coordination, appropriateness, efficiency, and effectiveness. For more details, see Aguilina (1989), Power (1991), and Brown(1988). This study considers the manufacturing perspective of quality. In this study, the American Society for Quality Control (1976) definition of quality is adopted. It states that quality is "The totality of features and characteristics of a product or service that bears on its ability to satisfy given needs". This definition applies to almost all the dimensions of quality. It considers the whole or the overall specifications, output, and user's requirements. It supports the definition of "fitness of use" where all users (external and external) and their expectations must be considered.

Chapter 3

RESEARCH METHODOLOGY

3.1 RESEARCH OBJECTIVE:

The contribution of this study to the existing body of literature on AMTs is the development of an intensity level of the three forms of AMTs. In addition this intensity level is expected to affect certain aspects of quality.

In this study we consider the following three forms of AMTs:

1. Computer Integrated Manufacturing (CIM),
2. Flexible Manufacturing Systems (FMS),
3. Group Technology (GT).

It is important to notice that these three forms of AMTs are not necessarily mutually exclusive.

The main objective of this study is to determine:

whether the intensity level of these three forms of AMTs affects the four quality aspects.

This study is carried out to address this research objective. A questionnaire was designed to answer the following questions:

1. For how long have AMTs been used in each business unit?

2. What percentage of each business unit has been converted to using AMTs?

3. Do business units with different intensity levels of AMTs differ in their emphasis on the following objectives?

   (a) public image,

   (b) market share,

   (c) sales revenue,

   (d) cost reduction,

   (e) quality,

   (f) productivity,

   (g) profit.

4. Are there any differences in the following aspects of quality among business units with different intensity levels of AMTs, and to what extent does using AMTs affect each of the following aspects of product's quality:

   (a) Marketing and customers,

   (b) costs,

   (c) quality tools, and total employees involvement.

3.2 RESEARCH HYPOTHESES:

3.2.1 Overall Quality:

The first hypothesis examines the relationship between the intensity levels of the three forms of AMTs and the relative importance of quality as a strategic objective. This hypothesis can be stated as follows:

> **There is no statistically significant difference in the degree of emphasis on quality as a strategic objective among business units with different intensity levels of AMTs.**

The intensity of AMTs is measured by the existence of the technology, the length of time since the technology has been in use, and the percentage of utilization of these technologies.

3.2.2 Quality Tools:

Quality tools provide the concrete data needed to improve upon the manufacturing processes. With the expansion of the international business and large scale applications of automated testing, improving quality is essential. Using AMTs requires that quality tools focus on design and process stages and apply variable data more than attribute data.

Juran (1988) explained that variable data is usually measured by the mean and standard deviation of some specific characteristics of the product inspected. On the other hand, attribute data can be measured in proportion or percent defective.

The following hypothesis examines if there are any significant differences in using quality tools among business units with different intensity levels of AMTs, namely;

> **There are no statistically significant differences in using quality tools among business units with different intensity levels of AMTs.**

3.2.3 Quality Costs:

According to American Society for Quality Control (ASQC), the most common four categories of quality costs are: preventive costs, appraisal costs, internal failure costs, and external failure costs.

Quality costs may be reduced by identifying and avoiding hidden quality costs, and changing the process due to quality demands. The hypothesis to be tested is whether:

> **There are no statistically significant differences in quality cost items among business units with different intensity levels of AMTs.**

3.2.4 Marketing & Consumer Related Quality:

Consumer and marketing issues have become very critical aspects in the quality filed. Through quality improvements, AMTs help increase market share, consumer satisfaction, and product safety and liability. The use of AMTs enable companies to achieve higher flexibility and higher quality. Both dimensions are necessary for competing in global markets. The hypothesis to be tested here is whether:

> **There are no statistically significant differences in marketing and consumer items among business units with different intensity levels of AMTs.**

3.2.5 Total Employee Involvement:

As manufacturing products become more complex and interdependent, employee competence, commitment, and involvement become increasingly important. Hence, special skills have become necessary for employees to be adapted to the AMTs requirements.

The literature review discloses that AMTs are believed to influence the following points:

1. The shift from skill of feeding to skill of adjustment, communication, and solving problems.

2. More consideration to quality assurance over quality control.
3. More consideration to work smarter over work harder.
4. More focus on "group think" prevention.
5. Every employee in the business unit has his or her own customers, either inside or outside the organization, who use the output of his or her job.
6. AMTs can create a motivational environment which plays a major role to improve quality through empowering and commitment rather than control and command. The hypothesis to be tested is:

   There are no statistically significant differences in total employee involvement items among business units with different intensity levels of AMTs.

3.3 The Sample:

A random sample of 490 companies was drawn from Aerospace, Electronics, Industrial and Farm Equipment, Metal products, and Motor Vehicles industries. The corporations are Fortune 500 companies. For the purpose of this study, a business unit is either an entire company, division, or a plant.

3.4 Data Collection:

The questionnaire was sent to vice presidents of manufacturing. They were asked to fill it out or direct it to whom it may concern. Received questionnaires were signed by:

1. Vice President Operations
2. Senior Manufacturing Engineer
3. Quality Control Manager
4. General Director Quality Assurance
5. Director Quality Improvement and Statistical Methods
6. Quality Assurance and Manufacturing Eng. and Mgr.
7. Quality Manager

Four hundred and ninety questionnaires were mailed. After the cut off date of response, a follow up attempt was made to secure a response. One hundred and sixteen questionnaires were received, representing a twenty three percent response rate. That response rate is considered fairly good in this type of research. Fourteen questionnaires were excluded from the analysis. The reason for exclusion was that a major portion of the questionnaire was unanswered. The remaining questionnaires were used throughout the analysis.

The questionnaire was divided into two main parts. The first part is designed to collect data pertinent to the existence and utilization of AMTs in participating business units. The second part is designed to assess the importance of various quality aspects such as costs, techniques, market and consumers, and total employment involvement in participating business units.

3.5 Measurements:

A scale is a continuous spectrum or series of categories (Zikmund 1988). For the purpose of this study, ordinal, and interval scales were used to measure responses.

Ordinal scale is a scale that arranges objects or alternatives according to their magnitude. Interval scale is a scale that distinguishes the ordered arrangement in units of equal intervals.

3.6 Independent Variables:

Respondents were asked to indicate which technologies are used, for how long, and what percentage of facilities have been using these technologies. These variables were used to formulate a technology intensity index. This index is formulated as follows:

(CIM * time CIM has been used * percentage of facility using CIM) + (FMS * time FMS has been used * percentage of facility using FMS) +(GT * time GT has been used * percentage of facility using GT)

The concept of formulating the intensity index of technology utilization is attributed to Youssef (1991).

The index can take on a value of zero if the three technologies are not used. Otherwise, it can take on any value up to forty-five. The sample was clustered on the basis of this index into three groups: G1, G2, and G3.

3.7 Dependent Variables:

Dependent variables are classified into five groups. These are:

1. Quality as a strategic objective:

   Respondents were asked about the importance of quality as a strategic objective. The question was scaled on a 5 point Likert-type scale (5 being most important and 1 being least important).

2. Quality Costs:

   Respondents were asked about the effect of using AMTs on some quality costs. The question was scaled on a 5 point Likert-type scale (5 being a strong positive effect and 1 being a strong negative effect).

   2.1 Rework

   2.2 Scrap

   2.3 Extra inventory

   2.4 Warranty

2.5 Field down-time

2.6 Lost orders

2.7 R&D expenditures

2.8 Inspection

2.9 Quality training

3. Marketing and consumer:

Respondents were asked about the effect of using AMTs on some market and consumer items related to quality. The question was scaled on a 5 point Likert-type scale (5 being a strongly positive effect and 1 being a strong negative effect).

3.1 Market share

3.2 Multinational markets

3.3 Number of complaints

3.4 Number of returns

3.5 Warranty period

3.6 Ability to meet deliveries

3.7 Loss of customers

3.8 Product safety

3.9 Maintainability

4. Total employee involvement:

Respondents were asked about the effect of using AMTs on some work force items related to quality. The question was scaled on a 5 point Likert-type scale (5 being a strong positive effect and 1 being a strong negative effect).

4.1 Responsibility

4.2 Worker participation

4.3 Worker loyalty

4.4 Skill variety

4.5 Autonomy

4.6 Feedback

5. Quality tools:

Respondents were asked about the effect of using AMTs on some quality tools. The question was scaled on a 5 point Likert-type scale (5 being a strong positive effect and 1 being a strong negative effect).

5.1 Pareto analysis

5.2 Statistical process control

5.3 Statistical quality control

5.4 Taguchi's approach

5.5 P chart

5.6 C chart

3.8 Data Analysis:

The study seeks to determine whether there are differences in quality aspects among business units with differing intensity levels of AMTs. To do so, an analysis of variance (ANOVA) procedure was used. However, it was essential to test for normality and homogeneity of variance assumptions.

3.8.1 Quality as a strategic objective:

H_1 There are no statistically significant differences in quality as a strategic objective among business units with different intensity levels of AMTs.

Statistically speaking:

H_0: $\mu_{11} = \mu_{12} = \ldots = \mu_{ij}$

H_1: At least one of μ_{ij} is different.

Where:

j = group number (j = 1,2,3)

i = quality aspect as strategic objective

3.8.2 Quality costs:

The purpose of this part is to examine if there are differences in quality costs among the three groups.

H_2 There are no statistically significant differences in quality cost items among business units with different intensity levels of AMTs.

Statistically speaking:

H_0: $\mu_{11} = \mu_{12} = \ldots = \mu_{ij}$

H_1: At least one of μ_{ij} is different.

Where:

j = group number (j = 1,2,3)

i = quality cost item number

$H_{2.1}$ There are no statistically significant differences in rework costs among business units with different intensity levels of AMTs.

$H_{2.2}$ There are no statistically significant differences in scrap costs among business units with different intensity levels of AMTs.

$H_{2.3}$ There are no statistically significant differences in extra inventory costs among business units with different intensity levels of AMTs.

$H_{2.4}$ There are no statistically significant differences in warranty costs among business units with different intensity levels of AMTs.

$H_{2.5}$ There are no statistically significant differences in down time costs among business units with different intensity levels of AMTs.

$H_{2.6}$ There are no statistically significant differences in lost order cost among business units with different intensity levels of AMTs.

$H_{2.7}$ There are no statistically significant differences in research and development expenditures costs among business units with different intensity levels of AMTs.

$H_{2.8}$ There are no statistically significant differences in inspection tools costs among business units with different intensity levels of AMTs.

$H_{2.9}$ There are no statistically significant differences in quality training costs among business units with different intensity levels of AMTs.

3.8.3 Marketing & Consumers:

The purpose of this part of the analysis is to examine if there are differences in marketing and consumer items related to quality among the three groups.

H_3 There are no statistically significant differences in marketing and consumers items among business units with different intensity levels of AMTs.

Statistically speaking:

H_0: $\mu_{11} = \mu_{12} = \ldots = \mu_{ij}$

H_1: At least one of μ_{ij} is different.

Where:

j = group number (j = 1,2,3)

i = marketing and consumers number

$H_{3.1}$ There are no statistically significant differences in market share among business units with different intensity levels of AMTs.

$H_{3.2}$ There are no statistically significant differences in multinational markets among business units with different intensity levels of AMTs.

$H_{3.3}$ There are no statistically significant differences in complaints among business units with different intensity levels of AMTs.

$H_{3.4}$ There are no statistically significant differences in returns among business units with different intensity levels of AMTs.

$H_{3.5}$ There are no statistically significant differences in warranty periods among business units with different intensity levels of AMTs.

$H_{3.6}$ There are no statistically significant differences in ability to meet deliveries among business units with different intensity levels of AMTs.

$H_{3.7}$ There are no statistically significant differences in loss of customers among business units with different intensity levels of AMTs.

$H_{3.8}$ There are no statistically significant differences in product safety among business units with different intensity levels of AMTs.

$H_{3.9}$ There are no statistically significant differences in maintainability among business units with different intensity levels of AMTs.

3.8.4 Total Employee Involvement:

The purpose of this part of the analysis is to examine if there are differences in total employee involvement related quality among the three groups.

H_4 There are no statistically significant differences in work force items among business units with different intensity levels of AMTs.

Statistically speaking:

H_0: $\mu_{11} = \mu_{12} = \ldots = \mu_{ij}$

H_1: At least one of μ_{ij} is different.

Where:

j = group number (j = 1,2,3)

i = worker total employee involvement number

$H_{4.1}$ There are no statistically significant differences in worker responsibility among business units with different intensity levels of AMTs.

$H_{4.2}$ There are no statistically significant differences in worker participation business units with different intensity levels of AMTs.

$H_{4.3}$ There are no statistically significant differences in worker loyalty among business units with different intensity levels of AMTs.

$H_{4.4}$ There are no statistically significant differences in skill variety among business units with different intensity levels of AMTs.

$H_{4.5}$ There are no statistically significant differences in autonomy among business units with different intensity levels of AMTs.

$H_{4.6}$ There are no statistically significant differences in feedback among business units with different intensity levels of AMTs.

3.8.5 Quality Tools:

The purpose of this part of the analysis is to examine if there are differences in quality tools among the three groups.

H_5 There are no statistically significant differences in use of quality tools among business units with different intensity levels of AMTs.

Statistically speaking:

H_0: $\mu_{11} = \mu_{12} = \ldots = \mu_{ij}$

H_1: At least one of μ_{ij} is different.

Where:

j = group number (j = 1,2,3)

i = Quality techniques number

$H_{5.1}$ There are no statistically significant differences in Pareto analysis among business units with different intensity levels of AMTs.

$H_{5.2}$ There are no statistically significant differences in statistical process control among business units with different intensity levels of AMTs.

$H_{5.3}$ There are no statistically significant differences in statistical quality control among business units with different intensity levels of AMTs.

$H_{5.4}$ There are no statistically significant differences in Taguchi's approach among business units with different intensity levels of AMTs.

$H_{5.5}$ There are no statistically significant differences in P chart among business units with different intensity levels of AMTs.

$H_{5.6}$ There are no statistically significant differences in C chart among business units with different intensity levels of AMTs.

3.9 Validity:

Instruments are usually evaluated in terms of reliability and validity. Zikmund (1988) defined validity as the degree to which the instrument measures the concept the researcher wants to measure. There are three types of validity tests:

1. Criterion validity which is the ability of some measure to correlate with other measures of the same construct. Criterion validity can be classified into two types: concurrent validity and predictive validity, Zikmund (1988) and Carmines and Zeller (1985).

2. Construct validity which is the ability of measure to confirm a network of related hypotheses generated from a theory based on concepts, Zikmund (1988).

3. Content validity which refers to the extent to which an empirical measurement reflects a specific domain of content Carmines and Zeller (1985).

3.10 Reliability:

To evaluate the questionnaire reliability, a pilot study containing 37 cases was conducted. Each case included 70 variables divided into 7 groups as following:

GROUP 1	6 VARIABLES (ITEMS)
EXISTENCE OF	V1: COMPUTER INTEGRATED
TECHNOLOGIES	MANUFACTURING = CIM
AND TIME IT	V2: GROUP TECHNOLOGY = GT
HAS BEEN IN	V3: FLEXIBLE MANUFACTURING
USE	SYSTEM = FMS
	V4: COMPUTER INTEGRATED
	MANUFACTURING1 = CIM1
	V5: GROUP TECHNOLOGY1 = GT1

	V6: FLEXIBLE MANUFACTURING SYSTEM = FMS1
GROUP 2	**7 VARIABLES (ITEMS)**
STRATEGIC OBJECTIVES	V7: PUBLIC IMAGE = PUBIMG
	V8: MARKET SHARE = MKTSHR
	V9: SALES REVENUE = SALREV
	V10: COST REDUCTION = COSTRE
	V11: QUALITY = QUALIT
	V12: PRODUCTIVITY = PRODUC
	V13: PROFIT = PROF
GROUP 3	**9 VARIABLES (ITEMS)**
MARKET & CONSUMER	V37: MARKET SHARE = MKTSH1
	V38: MULTINATIONAL MARKETS = NATMKT
	V39: NUMBER OF COMPLAINTS = NOCOMP
	V40: NUMBER OF RETURNS = NORETU
	V41: WARRANTY PERIOD = WARPER

V42: ABILITY TO MEET DELIVERIES = METDLV

V43: LOSS OF CUSTOMERS = LOSCUS

V44: PRODUCT SAFETY = PRDSAF

V45: MAINTAINABILITY DEGREE = MAINTA

GROUP 4	**9 VARIABLES (ITEMS)**
QUALITY COSTS	V46: REWORK = REWORK
	V47: SCRAP = SCRAP
	V48: EXTRA INVENTORY = EXTINV
	V49: WARRANTY = WARRAN
	V50: FIELD DOWN TIME = DOWTIM
	V51: LOST ORDERS = LOSORD
	V52: R&D EXPENDITURES = RDEXPE
	V53: INSPECTION = INSPEC
	V54: QUALITY TRAINING = QUTRAI

GROUP 5	**6 VARIABLES (ITEMS)**
TOTAL	V64: RESPONSIBILITY = RESPON
EMPLOYMENT	V65: WORKER PARTICIPATION = PARTICI
INVOLVEMENT	V66: WORKER LOYALTY = LOYALT
	V67: SKILL VARIETY = SKIVAR
	V68: AUTONOMY = AUTONO
	V69: FEEDBACK = FEEBAC

GROUP 6	**13 VARIABLES (ITEMS)**
QUALITY	V88: CONTROL LIMITS = CONLIM1
TECHNIQUES	V89: TOLERANCE LIMITS = TOLLIM1
	V90: PARETO ANALYSIS = PARETO1
	V91: ATTRIBUTE INSPECTION = ATTINS1
	V92: VARIABLE INSPECTION = VARINS1
	V93: NUMBER OF SAMPLES = NUMSAM1
	V94: SAMPLE SIZE = SAMSIZ1

V95: INSPECTION FREQUENCY =
INSFRE1

V96: STATISTICAL PROCESS
CONTROL = SPC1

V97: STATISTICAL QUALITY
CONTROL = SQC

V98: TAGUCHI'S APPROACH =
TAGUCH

V99: P CHART = PCHART

V100: C CHART = CCHART

GROUP 7	**20 VARIABLES (ITEMS)**
GENERAL STATEMENTS	V101 - V120

Thirty seven questionnaires were distributed and used to assess the reliability of the construct.

Table (3.1)

Reliability Cronbach's Alpha

Group	Variables Included	Alpha
1	V1 - V6	.8528
2	V7 - V13	.7114
3	V37 - V45	.9803
4	V46 - V54	.9567
5	V64 - V69	.9514
6	V88 - V100	.9449
7	V101 - V120	.8734
	OVERALL ALPHA =	.8958

Table (3.1) shows that the coefficient alphas vary from .71 to .98, indicating that some scales are more reliable than others. Cronbach (1951), showed that coefficient of .7 or more are judged to be reliable. As a result, our instrument is highly reliable.

Chapter 4

Results and Discussion

To analyze the data collected in this study, we will proceed in the following manner:

Part (1) Results:

1.1 Descriptive analysis and profile of respondents.

1.2 Cluster analysis.

1.3 Analysis of variance.

1.1 Descriptive Analysis:

1.1.1 Type of Industry:

In general it is necessary to recognize the number and percentage for each industry sampled in this study.

Table (4.1)

Type of Industry

Industry	Frequency	Percent	Cum Percent
Electronics	31	30.4	30.4
Aerospace	13	12.7	43.1
Industrial Equipment	15	14.7	57.8
Metal Products	12	11.8	69.6
Automotive	31	30.4	100.0
	102	100.00	

Table (4.1) shows that 30.4% of the respondents are in the electronics industry, 12.7% are in the space industry, 14.7% are in industrial equipment, 11.8% are in the metal products industry, and 30.4% are in the automotive industry.

1.1.2 Length of time using CIM:

Respondents were asked about the number and percentage for each interval of time since Computer Integrated Manufacturing (CIM) has been used.

Table (4.2)

For How Long Has CIM Been Used?

Time	Frequency	Percent	Cum Percent
None	38	37.3	37.3
Less than 2 years	13	12.7	50.0
2 to 4 years	21	20.6	70.6
More than 4 years	30	29.4	100.0
	102	100.00	

Table (4.2) shows that almost 37% of the respondents do not use CIM technology. For those who are using CIM, 12.7% have been using it for less than two years, 20.6% have been using it for a time period between two and four years and 29.4% have been using it for more than four years.

1.1.3 Length of time using GT:

Respondents were asked about the number and percentage of each interval of time since Group Technology (GT) has been used.

Table (4.3)

For How Long Has GT Been Used?

Time	Frequency	Percent	Cum Percent
None	47	46.1	46.1
Less than 2 years	17	16.7	62.7
2 to 4 years	16	15.7	78.4
More than 4 years	22	21.6	100.0
	102	100.00	

Table (4.3) shows that over 46% of the respondents do not use GT. For those using GT, 16.7% have been using it for less than two years, 15.7% have been using it for a period of time between two and four years, and 21.6 have been using it for more than four years.

1.1.4 Length of time using FMS:

The sample respondents were asked about the number and percentage for each interval of time since Flexible Manufacturing System (FMS) has been used.

Table (4.4)

For How Long Has FMS Been Used?

Time	Frequency	Percent	Cum Percent
None	52	51.0	51.0
Less than 2 years	13	12.7	63.7
2 to 4 years	18	17.6	81.4
More than 4 years	19	18.6	100.0
	102	100.00	

Table (4.4) shows that 51% of the respondents do not use FMS technology. For those using FMS, 12.7% have been using it for less than two years, 17.6% have been using it for a time period between two and four years, and 18.6% have been using it for more than four years.

1.1.5 Percentage of Business unit using CIM:

The respondents were asked about the percentage of their business facilities using Computer Integrated Manufacturing (CIM), the size is represented by interval percentages.

Table (4.5)

Percentage of Facilities Using CIM

Percent	Frequency	Percent	Cum Percent
None	37	36.3	36.3
Less than 25%	21	20.6	56.9
25% - 50%	18	17.6	74.5
50% - 75%	6	5.9	80.4
75% - 90%	15	14.7	95.1
More than 90%	5	4.9	100.0
	102	100.00	

Table (4.5) shows that over 36% are not using CIM technology. For those who are using it, 20.6% are using it in less than 25% of their facilities, 17.6% are u;sing it in 25% to 50% of their facilities, 5.9% are using it in 50% to 75% of their facilities, 14.7% are using it in 75% to 90% of their facilities, and 4.9% are using it in more than 90% of their facilities.

1.1.6 Percentage of Business units using GT:

The respondents were asked about the percentage of their facilities using Group Technology (GT). The size is represented by interval percentages.

Table (4.6)

Percentage of Facilities using GT

Percent	Frequency	Percent	Cum Percent
None	48	47.1	47.1
Less than 25%	17	16.7	63.7
25% - 50%	15	14.7	78.4
50% - 75%	12	11.8	90.2
75% - 90%	8	7.8	98.0
More than 90%	2	2.0	100.0
	102	100.00	

Table (4.6) shows that 47.1% are not using GT. For those who are using it, 16.7% are using it in less than 25% of their facilities, 14.7% are using it in 25% to 50% of their facilities, 11.8% are using it in 50% to 75% of their facilities, 7.8% are using it in 75% to 90% of their facilities, and 2% are using it in more than 90% of their facilities.

1.1.7 Percentage of Business units using FMS:

The respondents were asked about the percentage of their facilities using Flexible Manufacturing System (FMS). The size is represented by interval percentages.

Table (4.7)

Percentage of Facilities using FMS

Percent	Frequency	Percent	Cum Percent
None	52	51.0	51.0
Less than 25%	23	22.5	73.5
25% - 50%	14	13.7	87.3
50% - 75%	7	6.9	94.1
75% - 90%	4	3.9	98.0
More than 90%	2	2.0	100.0
	102	100.00	

Table (4.7) shows that 51% are not using FMS technology. For those who are using it, 22.5% are using it in less than 25% of their facilities, 13.7% are using it in 25% to 50% of their facilities, 6.9% are using it in 50% to 75% of their facilities, 3.9% are using it in 75% to 90% of their facilities, and 2% are using it in more than 90% of their facilities.

1.2 Cluster Analysis:

Cluster Analysis was utilized to group observations which have similarities over the intensity level of advanced manufacturing technologies. Quick Cluster procedures of SPSS was used. Three clusters emerged and were named GI, GII, and GIII, or moderate, high and low groups.

The following table shows the number of observations in each cluster, and cluster centers which are the intensity level for each group.

Table (4.8)

AMTs Intensity

Cluster	Cases	Index[1]
1	30	14.9667
2	7	32.7143
3	65	3.1231

Table (4.8) shows that 6.86% of the sample has a high advanced manufacturing technologies intensity (32.7 out of maximum 45). Almost 30% of the sample achieved moderate intensity level (14.9 out of a maximum 45). Almost 63% of the sample have a very low intensity level of advanced manufacturing technologies (3 out of 45 maximum). Generally speaking, a majority of firms in the sample have a low level of intensity of advanced manufacturing technologies . This is supported in the literature by Youssef's study (1991).

[1]Level of AMTs Intensity

1.3 Analysis of variance:

In this study, we examine the differences in quality aspects among the three groups that represent the intensity of Advanced Manufacturing Technologies (AMTs).

The dependent variables are:

(1) Quality as strategic objective adopted by business units(QUALIT).

(2) Rework costs (REWORK).

(3) Scrap costs (SCRAP).

(4) Extra Inventory costs (EXTINV).

(5) Warranty costs (WARRAN).

(6) Down time costs (DOWTIM).

(7) Lost orders costs (LOSORD).

(8) R&D expenditures costs (RDEXPE).

(9) Inspection costs (INSPEC).

(10) Quality training costs (QUTRAI).

(11) Market share (MKTSH1).

(12) Multinational Markets (NATMKT).

(13) Number of complaints (NOCOMP).

(14) Number of returns (NORETU).

(15) Warranty period (WARPER).

(16) Ability to meet deliveries (METDLV).

(17) Loss of customers (LOSCUS).

(18) Product safety (PRDSAF).

(19) Maintainability (MAINTA).

(20) Responsibility (RESPON).

(21) Worker participation (PARTICI).

(22) Worker loyalty (LOYALT).

(23) Skill variety (SKIVAR).

(24) Autonomy (AUTONO).

(25) Feedback (FEEBAC).

(26) Pareto analysis (PARETO1).

(27) Statistical process control (SPC1).

(28) Statistical quality control (SQC).

(29) Taguchi's approach (TAGUCH).

(30) P chart (PCHART).

(31) C chart (CCHART).

The independent variables are levels of AMT's intensity representing as three groups of responses such as:

(1) Group 1. (Moderate Level)

(2) Group 2. (High Level)

(3) Group 3. (Low Level)

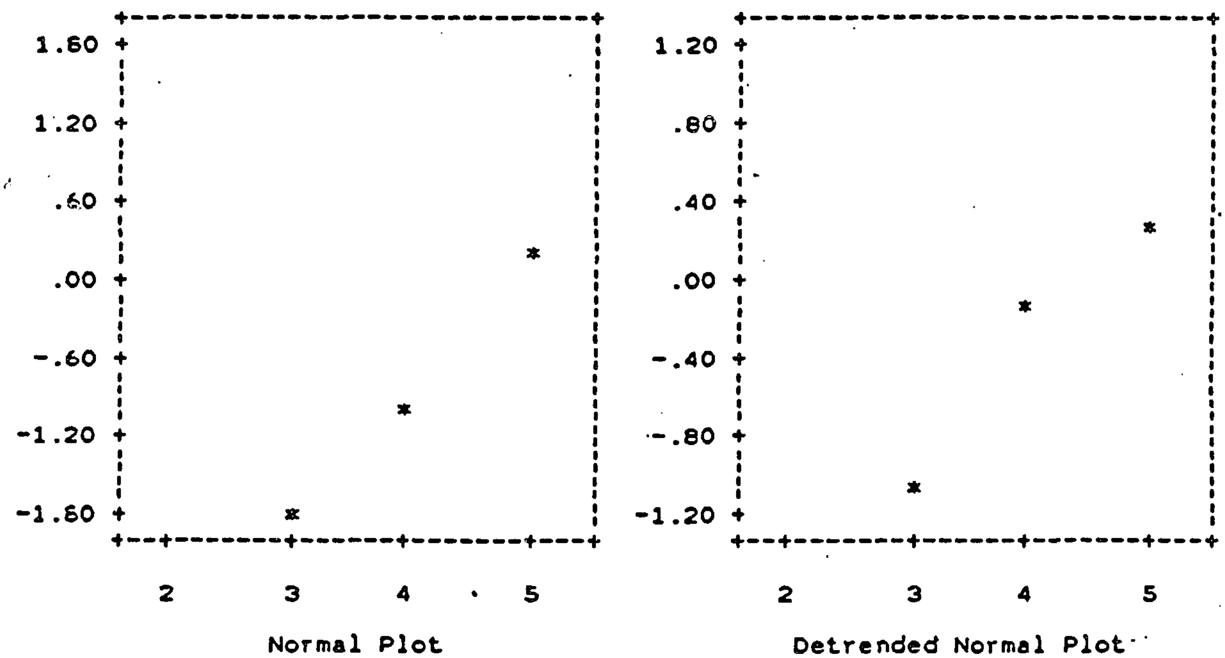
It is essential to test for normality and homogeneity for each dependent variable followed by the suitable type of analysis of variance.

1.3.1 Quality:

1. Test for Normality and Homogeneity of Variance

Figure (4.1)

Normal and Detrended Plots (Quality)



	Statistic	df	Significance
K-S (Lilliefors)	.3091	102	.0000

Figure (4.1) presents the values for quality as a strategic objective do not form a straight line in the normal plot. It shows that the values are not grouped around the zero line in the detrended plot. With P = .0000, the values of quality as strategic objective violate the normality assumption. We resort nonparametric statistics. We use Kruskal Wallis One-way ANOVA.

Table (4.9)

Test for Homogeneity of Variance (Quality)

Cochrans C=Max. Variance/Sum(Variances) =	.4213,	P=	.293 (Approx.)
Bartlett-Box F =	.548 ,	P=	.578
Maximum Variance/Minimum Variance	1.642		

As shown in table (4.9), the significance level for Cochrans C is P = .293 and Bartlett-Box F tests is P = .578, the assumption of homogeneity is not violated. This should be supported by not to reject the null hypothesis that no differences among the three groups in considering quality as a strategic objective.

2. ANOVA

Table (4.10)

Kruskal-Wallis One-Way ANOVA (QUALITY)

Mean Rank	Cases	
48.37	30	CLUST3 = 1 M
49.43	7	CLUST3 = 2 H
53.17	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = .5776	SIGNIFICANCE = .7492
CORRECTED FOR TIES:	CHI-SQUARE = 1.0872	SIGNIFICANCE = .5807

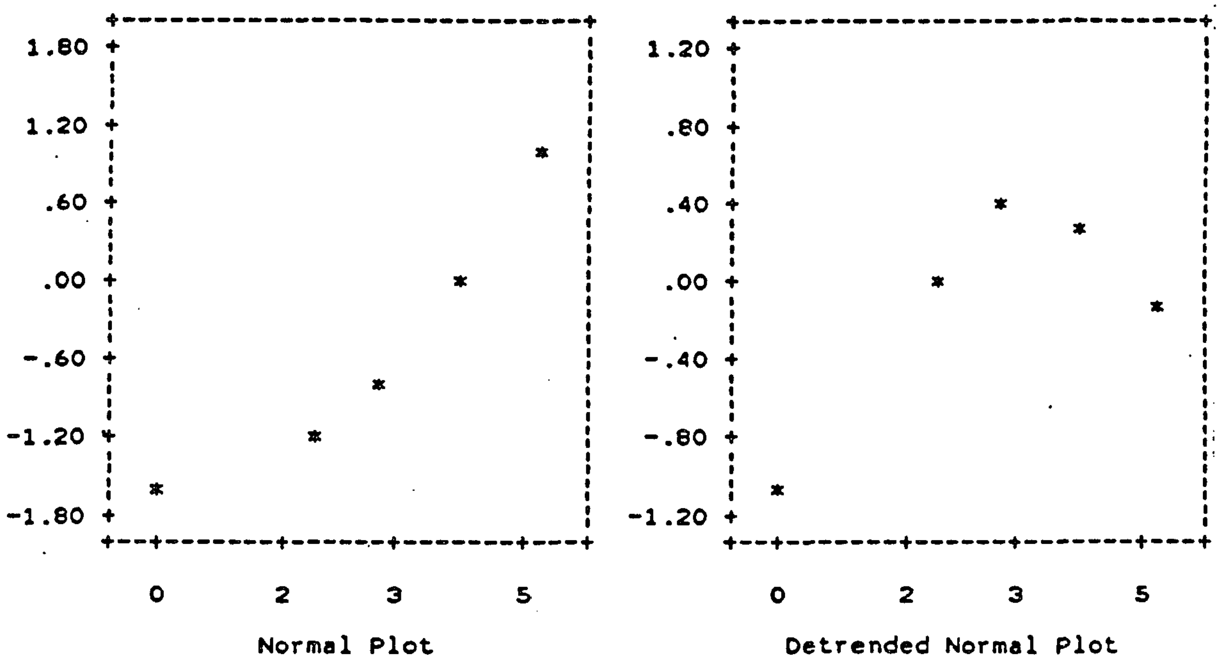
Table (4.10) shows that the mean ranks for group 1, group 2, and group 3 are not exactly different. At significance level of .5807, the null hypothesis cannot be rejected. Therefore, there are no significant differences in Quality as a strategic objective among the three groups.

1.3.2 Rework:

1. Test for Normality and Homogeneity of Variance

Figure (4.2)

Normal and Detrended plots (Rework)



	Statistic	df	Significance
K-S (Lilliefors)	.1808	102	.0000

Figure (4.2) shows that the values of rework costs do not form a straight line in the normal plot. In the detrended plot, the values are not grouped around the zero line. With significance level P = .0000, the values for rework costs is not normally distributed.

Table (4.11)

Test for Homogeneity (Rework)

Cochrans C=Max. Variance/Sum(Variances) =	.6431,	P=	.000 (Approx.)
Bartlett-Box F =	12.828 ,	P=	.000
Maximum Variance/Minimum Variance	6.400		

As shown in the table (4.11), the significance level for Cochrans C and Bartlett-Box are zero. Therefore, the homogeneity assumption was violated.

2. ANOVA

Table (4.12)

Kruskal-Wallis One-Way ANOVA (REWORK)

Mean Rank	Cases	
67.22	30	CLUST3 = 1 M
55.57	7	CLUST3 = 2 H
43.81	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 12.9898	SIGNIFICANCE = .0015
CORRECTED FOR TIES:	CHI-SQUARE = 15.0009	SIGNIFICANCE = .0006

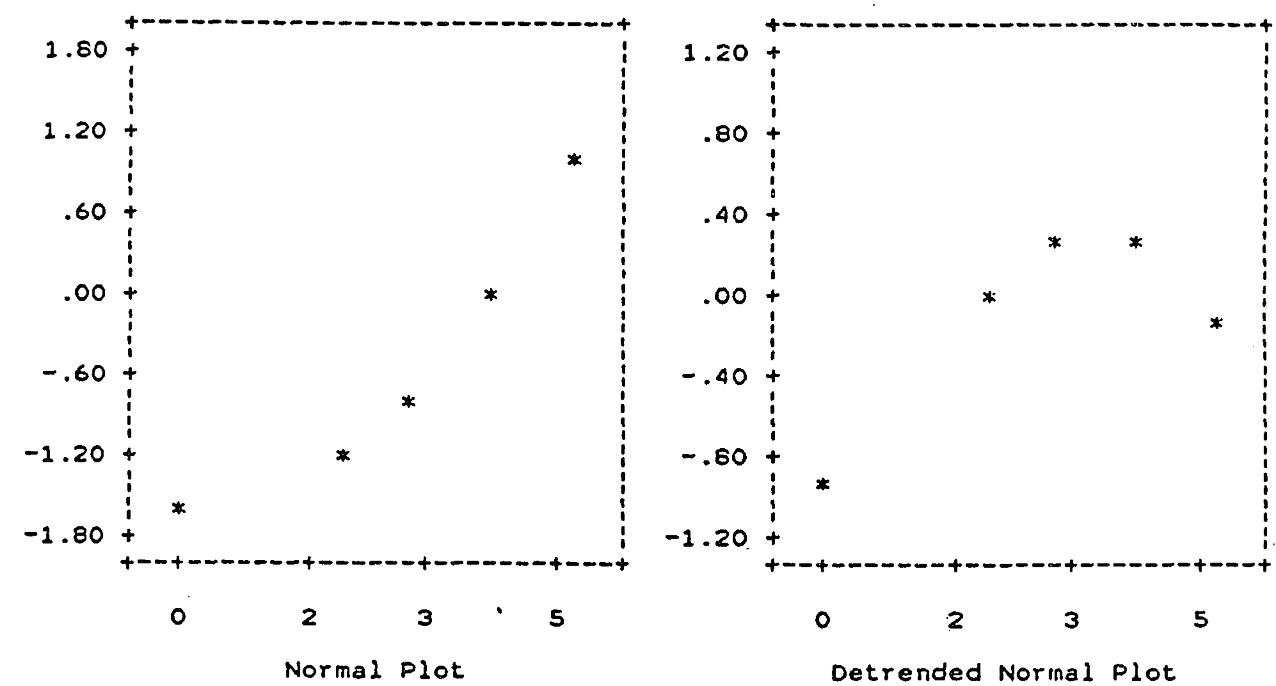
Table (4.12) shows that the mean ranks for the three groups are different. At significance level of .0006, the null hypothesis is rejected. There is a significant difference in Rework, as an item of quality costs, among the three groups.

1.3.3 Scrap:

1. Test for Normality and Homogeneity of Variance

Figure (4.3)

Normal and Detrended Plots (Scrap)



	Statistic	df	Significance
K-S (Lilliefors)	.1940	102	.0000

Figure (4.3) shows that the values for scrap costs do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of scrap costs violate the normality assumption.

Table (4.13)

Test for Homogeneity (Scrap)

Cochrans C=Max. Variance/Sum(Variances) =	.6148,	P=	.000 (Approx.)
Bartlett-Box F =	12.948 ,	P=	.000
Maximum Variance/Minimum Variance	6.594		

Table (4.13) shows that the significance level for Cochrans C and Bartlett-Box F are zero. The Homogeneity assumption was violated.

2. ANOVA

Table (4.14)

Kruskal-Wallis One-Way ANOVA (SCRAP)

Mean Rank	Cases	
66.17	30	CLUST3 = 1 M
64.29	7	CLUST3 = 2 H
43.35	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 13.6048	SIGNIFICANCE = .0011
CORRECTED FOR TIES:	CHI-SQUARE = 15.2086	SIGNIFICANCE = .0005

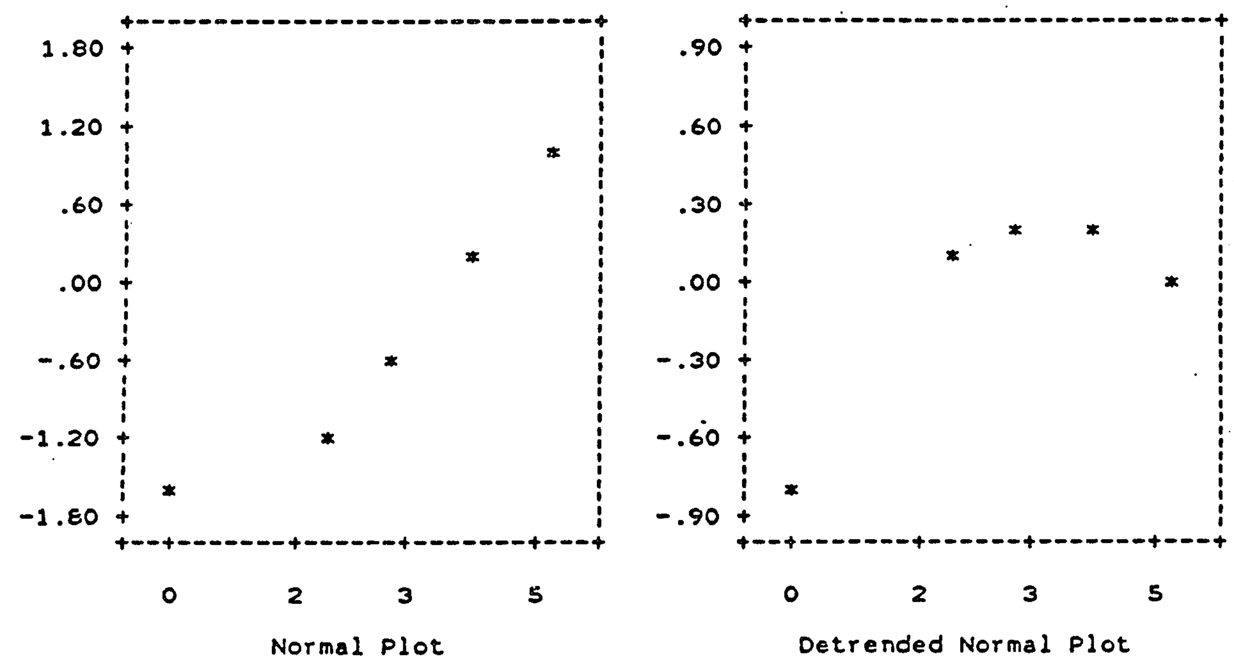
Table (4.14) shows that the mean ranks for group 1, group 2, and group 3 are different. However, at significance level of .0005, the null hypothesis is rejected. There is a significant difference in Scrap as an item of quality costs among the three groups.

1.3.4 Extra Inventory costs:

1. Test for Normality and Homogeneity of Variance

Figure (4.4)

Normal and Detrended Plots (Extinv)



	Statistic	df	Significance
K-S (Lilliefors)	.1601	102	.0000

Figure (4.4) shows that the values for extra inventory costs variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of extra inventory costs violate the normality assumption.

Table (4.15)

Test for Homogeneity (Extinv)

Cochrans C=Max. Variance/Sum(Variances) =	.5342,	P=	.006 (Approx.)
Bartlett-Box F =	6.217 ,	P=	.002
Maximum Variance/Minimum Variance	3.444		

Table (4.15) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .006 and .002 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.16)

Kruskal-Wallis One-Way ANOVA (EXTRA INVENTORY)

Mean Rank	Cases	
64.65	30	CLUST3 = 1 M
55.50	7	CLUST3 = 2 H
45.00	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 9.1901	SIGNIFICANCE = .0101
CORRECTED FOR TIES:	CHI-SQUARE = 9.9606	SIGNIFICANCE = .0069

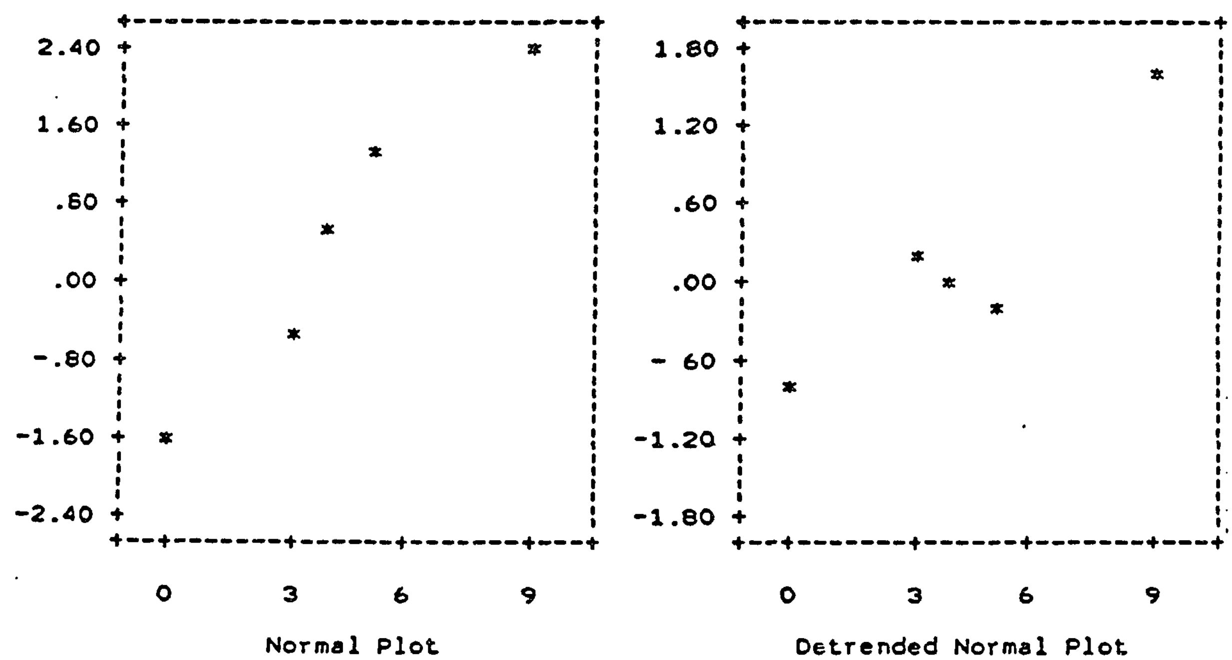
Table (4.16) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0069, the null hypothesis is rejected. There is a significant difference in this item of quality costs among the three groups.

1.3.5 Warranty costs:

1. Test for Normality and Homogeneity of Variance

Figure (4.5)

Normal and Detrended Plots (Warran)



	Statistic	df	Significance
K-S (Lilliefors)	.1746	102	.0000

Figure (4.5) shows that the values for warranty costs variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of warranty costs violate the normality assumption.

Table (4.17)

Test for Homogeneity (Warran)

Cochrans C=Max. Variance/Sum(Variances) =	.5706,	P=	.001 (Approx.)
Bartlett-Box F =	5.575 ,	P=	.004
Maximum Variance/Minimum Variance	15.750		

Table (4.17) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .001 and .004 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.18)

Kruskal-Wallis One-Way ANOVA (WARRAN)

Mean Rank	Cases	
62.42	30	CLUST3 = 1 M
40.00	7	CLUST3 = 2 H
47.70	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 6.2131	SIGNIFICANCE = .0448
CORRECTED FOR TIES:	CHI-SQUARE = 7.0848	SIGNIFICANCE = .0289

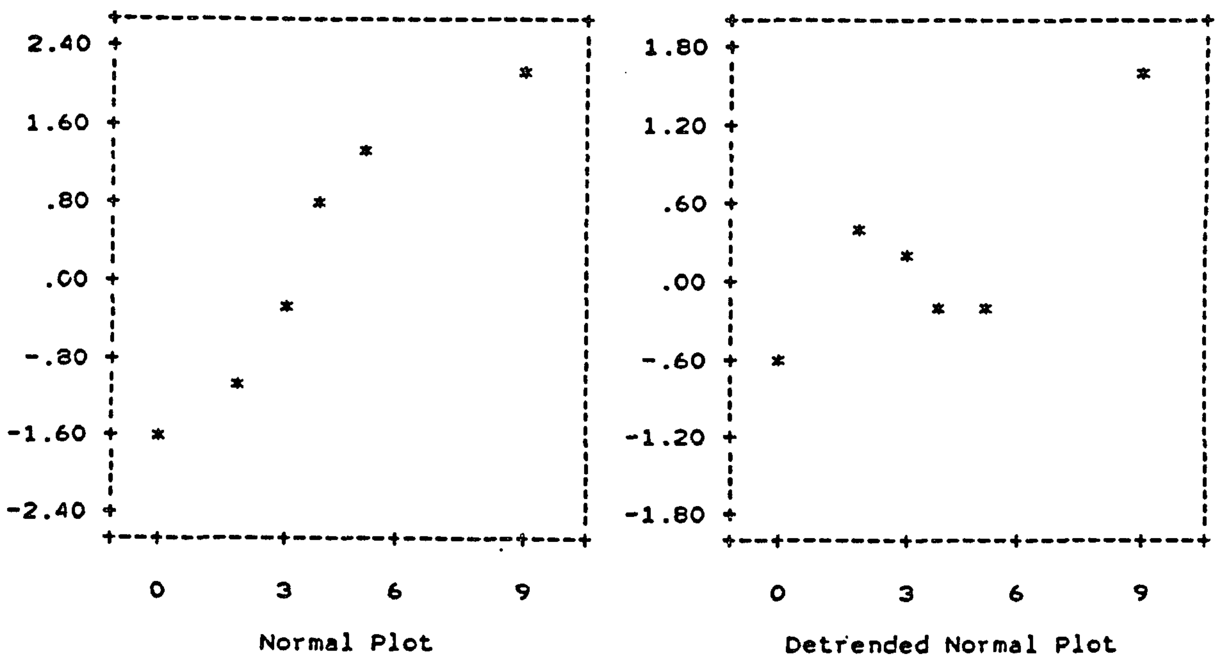
Table (4.18) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0289, the null hypothesis is rejected. There is a significant difference in warranty costs among the three groups.

1.3.6 Down time costs:

1. Test for Normality and Homogeneity of Variance

Figure (4.6)

Normal and Detrended Plots (Dowtim)



	Statistic	df	Significance
K-S (Lilliefors)	.2083	102	.0000

Figure (4.6) shows that the values for down time costs variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of down time costs violate the normality assumption.

Table (4.19)

Test for Homogeneity (Dowtim)

Cochrans C=Max. Variance/Sum(Variances) =	.5799,	P=	.001 (Approx.)
Bartlett-Box F =	4.473 ,	P=	.012
Maximum Variance/Minimum Variance	8.955		

Table (4.19) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .001 and .012 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.20)

Kruskal-Wallis One-Way ANOVA (DOWN TIME)

Mean Rank	Cases	
63.80	30	CLUST3 = 1 M
57.00	7	CLUST3 = 2 H
45.23	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 8.3440	SIGNIFICANCE = .0154
CORRECTED FOR TIES:	CHI-SQUARE = 9.9568	SIGNIFICANCE = .0069

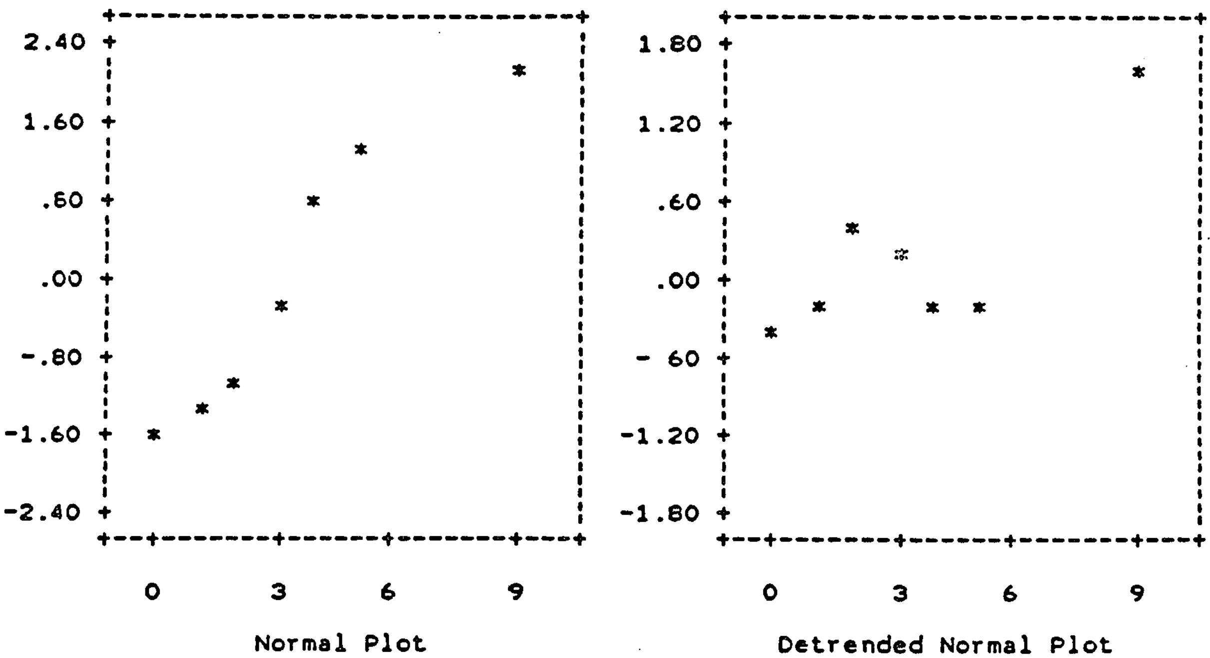
Table (4.20) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0069, the null hypothesis is rejected. There is a significant difference in down time costs among the three groups.

1.3.7 Lost orders costs:

1. Test for Normality and Homogeneity of Variance

Figure (4.7)

Normal and Detrended Plots (Losord)



	Statistic	df	Significance
K-S (Lilliefors)	.2083	102	.0000

Figure (4.7) shows that the values for lost orders costs variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P - .0000, the values of lost orders costs violated the normality assumption.

Table (4.21)

Test for Homogeneity (Losord)

Cochrans C=Max. Variance/Sum(Variances) =	.5233,	P=	.010 (Approx.)
Bartlett-Box F =	2.342 ,	P=	.096
Maximum Variance/Minimum Variance	4.000		

Table (4.21) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .010 and .096 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.22)

Kruskal-Wallis One-Way ANOVA (LOST ORDERS)

Mean Rank	Cases	
63.38	30	CLUST3 = 1 M
59.71	7	CLUST3 = 2 H
45.13	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 8.3902	SIGNIFICANCE = .0154
CORRECTED FOR TIES:	CHI-SQUARE = 9.8098	SIGNIFICANCE = .0074

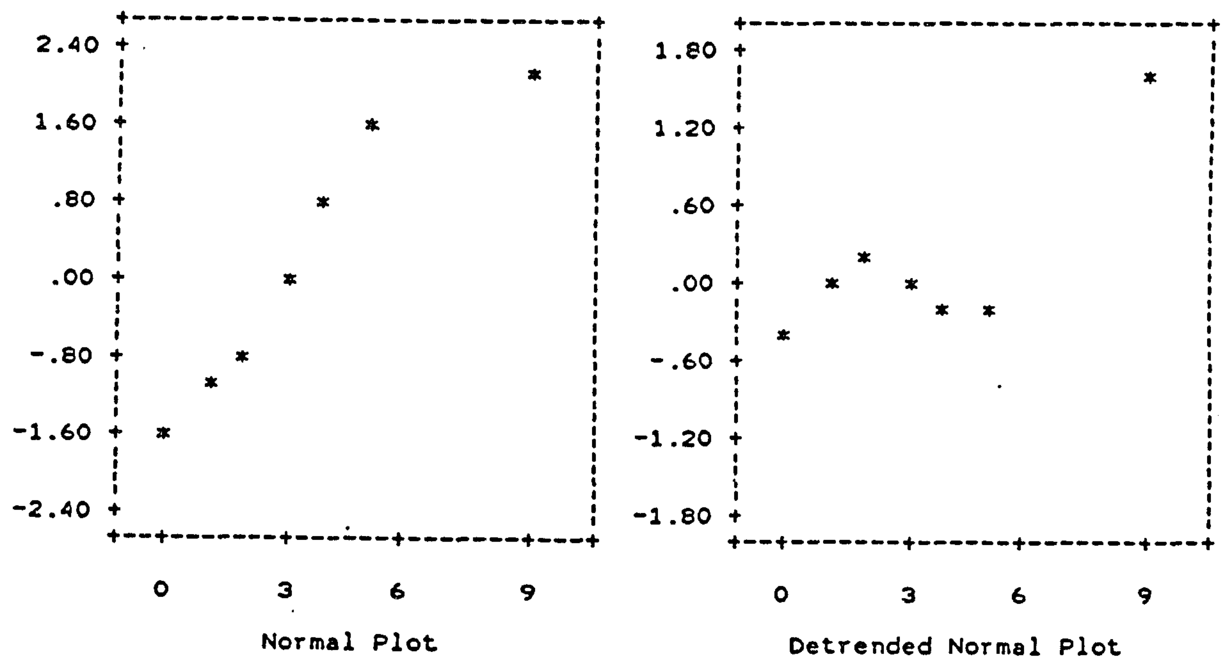
Table (4.22) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0074, the null hypothesis is rejected. There is a significant difference in the cost of lost orders among the three groups.

1.3.8 Research and development expenditures:

1. Test for Normality and Homogeneity of Variance

Figure (4.8)

Normal and Detrended Plots (Rdexpe)



	Statistic	df	Significance
K-S (Lilliefors)	.2008	102	.0000

not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of R&D expenditures violated the normality assumption.

Table (4.23)

Test for Homogeneity (Rdexpe)

Cochrans C=Max. Variance/Sum(Variances) =	.4851,	P=	.044 (Approx.)
Bartlett-Box F =	1.470 ,	P=	.230
Maximum Variance/Minimum Variance	2.681		

Table (4.23) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .044 and .230 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.24)

Kruskal-Wallis One-Way ANOVA (R & D EXPENDITURES)

Mean Rank	Cases	
63.72	30	CLUST3 = 1 M
66.29	7	CLUST3 = 2 H
44.27	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 10.7438	SIGNIFICANCE = .0046
CORRECTED FOR TIES:	CHI-SQUARE = 11.8257	SIGNIFICANCE = .0027

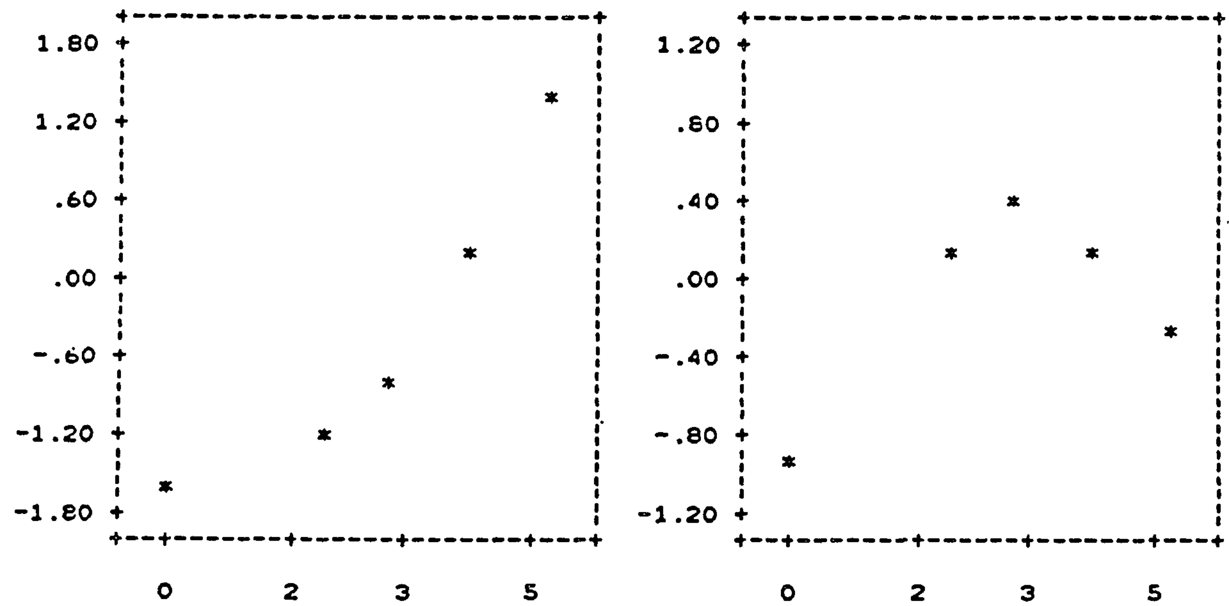
Table (4.24) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0027, the null hypothesis is rejected. There is a significant difference in research and development costs among the three groups.

1.3.9 Inspection costs:

1. Test for Normality and Homogeneity of Variance

Figure (4.9)

Normal and Detrended Plots (Inspec)



Normal Plot   Detrended Normal Plot

	Statistic	df	Significance
K-S (Lilliefors)	.1985	102	.0000

Figure (4.9) shows that the values for inspection costs variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of inspection costs violate the normality assumption.

Table (4.25)

Test for Homogeneity (Inspec)

Cochrans C=Max. Variance/Sum(Variances) =	.7918,	P=	.000 (Approx.)
Bartlett-Box F =	14.277 ,	P=	.000
Maximum Variance/Minimum Variance	3.803		

Table (4.25) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .000 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.26)

Kruskal-Wallis One-Way ANOVA (INSPECTION)

Mean Rank	Cases	
67.70	30	CLUST3 = 1 M
60.50	7	CLUST3 = 2 H
43.05	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 14.9368	SIGNIFICANCE = .0006
CORRECTED FOR TIES:	CHI-SQUARE = 17.4897	SIGNIFICANCE = .0002

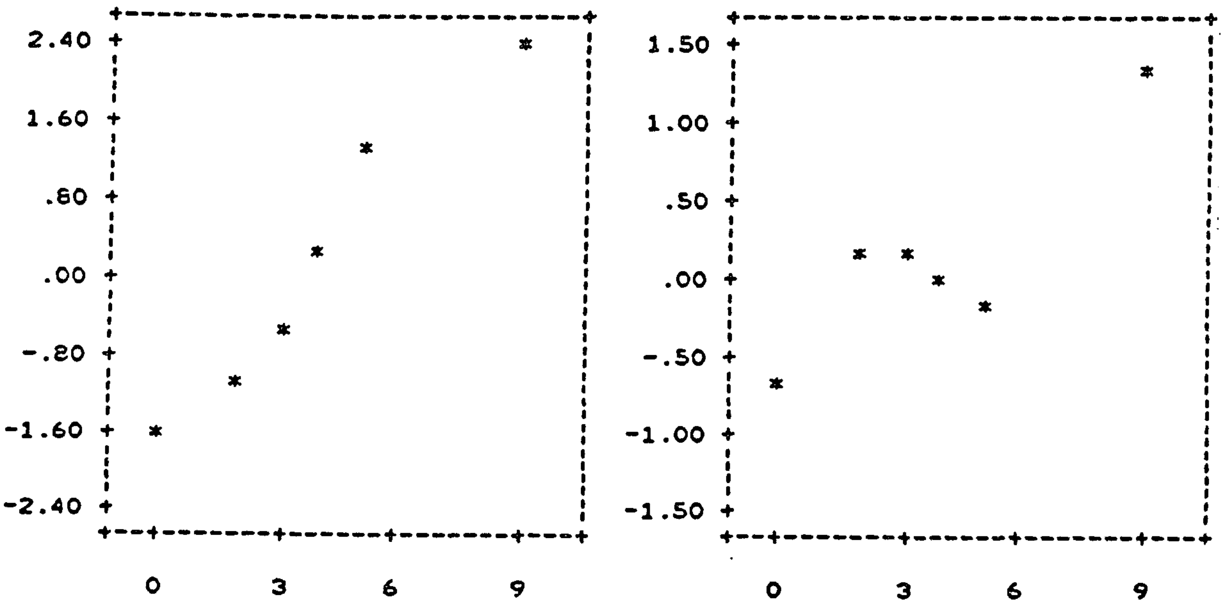
Table (4.26) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0002, the null hypothesis is rejected. There are significant difference in inspection cost among the three groups.

1.3.10 Quality training costs:

1. Test for Normality and Homogeneity of Variance

Figure (4.10)

Normal and Detrended Plots (Qutrai)



Normal Plot   Detrended Normal Plot

	Statistic	df	Significance
K-S (Lilliefors)	.1691	102	.0000

Figure (4.10) shows that the values for quality training costs variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of quality training costs violate the normality assumption.

Table (4.27)

Test for Homogeneity (Qutrai)

Cochrans C=Max. Variance/Sum(Variances) =	.7641,	P=	.000 (Approx.)
Bartlett-Box F =	14.844 ,	P=	.000
Maximum Variance/Minimum Variance	6.561		

Table (4.27) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .000 respectively). The homogeneity assumption was violated.

2.·ANOVA

Table (4.28)

Kruskal-Wallis One-Way ANOVA (QUALITY TRAINING)

Mean Rank	Cases	
58.55	30	CLUST3 = 1 M
58.36	7	CLUST3 = 2 H
47.51	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 3.2624	SIGNIFICANCE = .1957
CORRECTED FOR TIES:	CHI-SQUARE = 3.5668	SIGNIFICANCE = .1681

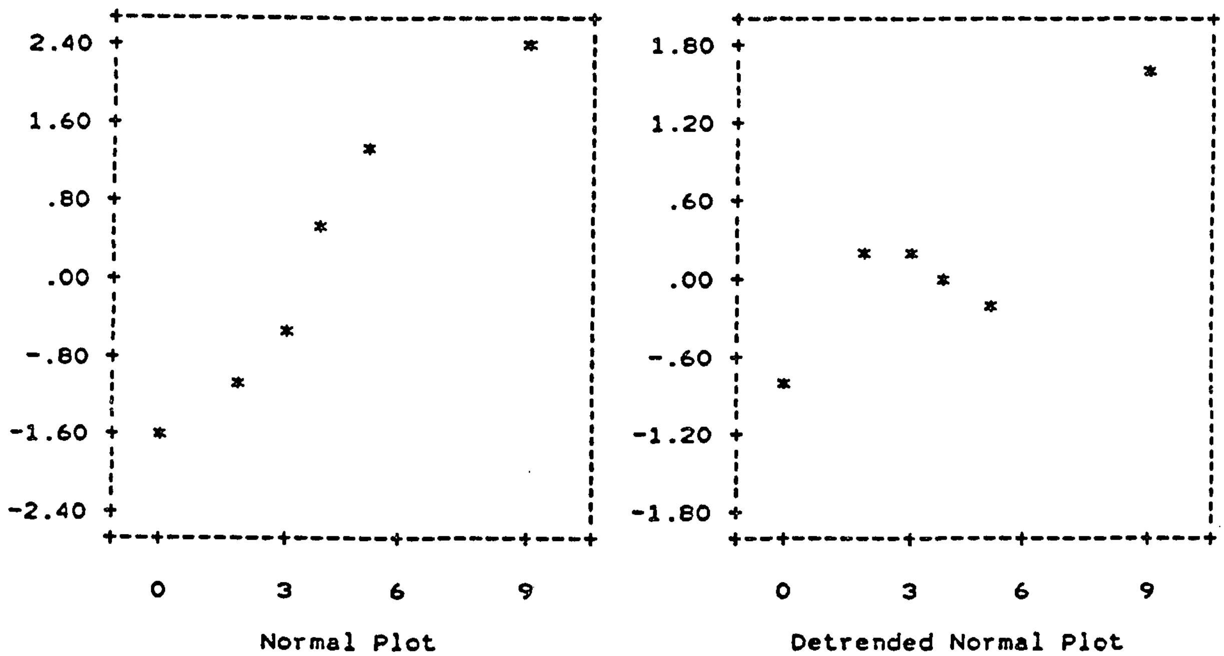
Table (4.28) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .1681, the null hypothesis is rejected. There are significant difference in training for improving quality among the three groups.

1.3.11 Market share:

1. Test for Normality and Homogeneity of Variance

Figure (4.11)

Normal and Detrended Plots (Mktsh1)



	Statistic	df	Significance
K-S (Lilliefors)	.1908	102	.0000

Figure (4.11) shows that the values for market share variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0C00, the values of market share violate the normality assumption.

Table (4.29)

Test for Homogeneity (Mktsh1)

Cochrans C=Max. Variance/Sum(Variances) =	.5078,	P=	.019 (Approx.)
Bartlett-Box F =	1.963 ,	P=	.141
Maximum Variance/Minimum Variance	3.454		

Table (4.29) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .019 and .141 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.30)

Kruskal-Wallis One-Way ANOVA (MARKET SHARE)

Mean Rank	Cases	
66.83	30	CLUST3 = 1 M
51.43	7	CLUST3 = 2 H
44.43	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 11.7666	SIGNIFICANCE = .0028
CORRECTED FOR TIES:	CHI-SQUARE = 13.1714	SIGNIFICANCE = .0014

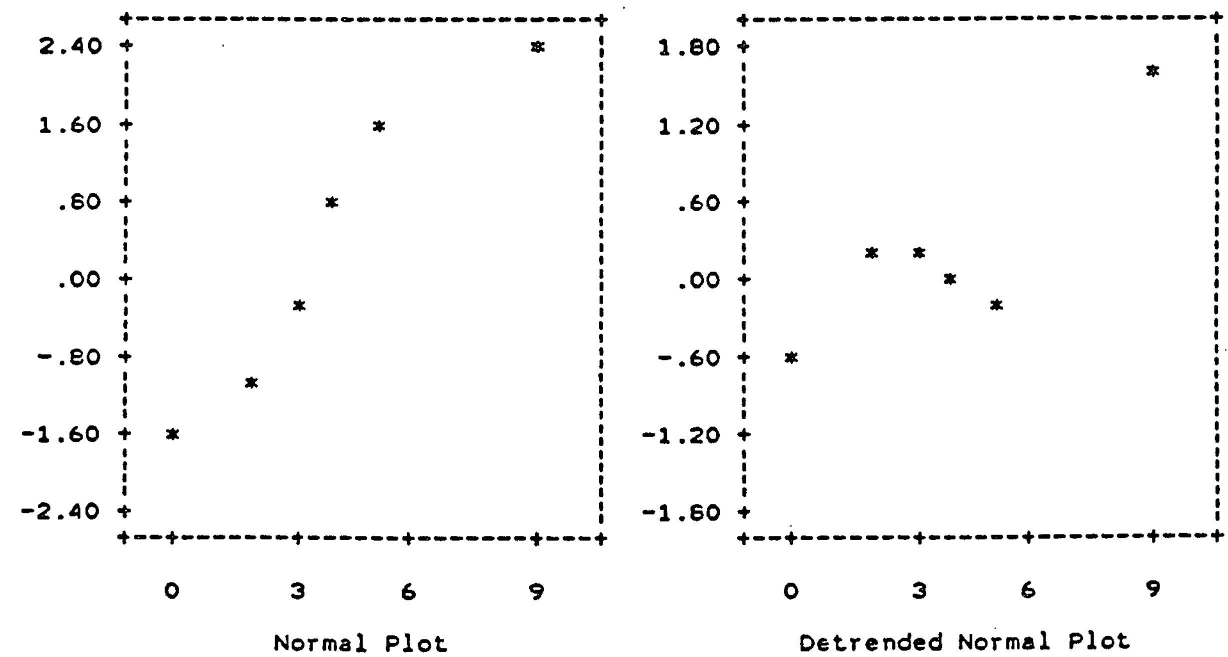
Table (4.30) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0014, the null hypothesis is rejected. There are significant difference in market share among the three groups.

1.3.12 Multinational markets:

1. Test for Normality and Homogeneity of Variance

Figure (4.12)

Normal and Detrended Plots (Natmkt)



	Statistic	df	Significance
K-S (Lilliefors)	.1626	102	.0000

Figure (4.12) shows that the values for multinational markets variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of multinational markets violated the normality assumption.

Table (4.31)

Test for Homogeneity (Natmkt)

Cochrans C=Max. Variance/Sum(Variances) =	.5161,	P=	.014 (Approx.)
Bartlett-Box F =	2.420 ,	P=	.089
Maximum Variance/Minimum Variance	4.672		

Table (4.31) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .014 and .089 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.32)

Kruskal-Wallis One-Way ANOVA (MULTINATIONAL MARKETS)

Mean Rank	Cases	
65.73	30	CLUST3 = 1 M
46.93	7	CLUST3 = 2 H
45.42	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 9.8507	SIGNIFICANCE = .0073
CORRECTED FOR TIES:	CHI-SQUARE = 11.1844	SIGNIFICANCE = .0037

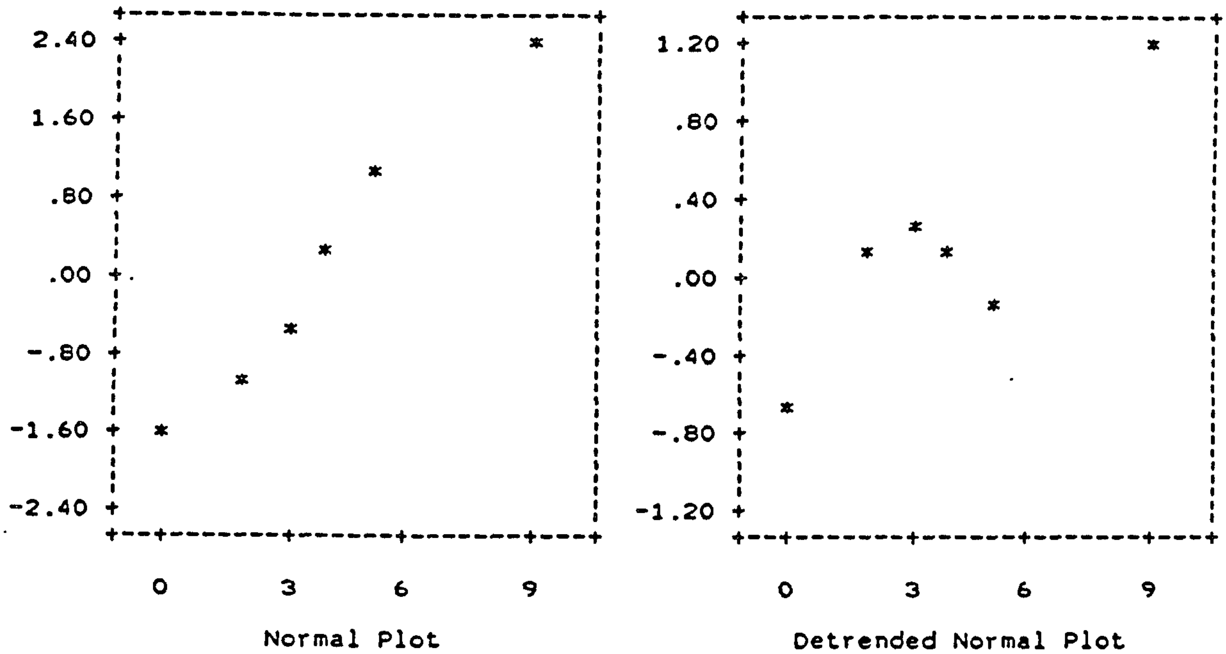
Table (4.32) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0037, the null hypothesis is rejected. There are significant difference in multinational markets among the three groups.

1.3.13 Complaints:

1. Test for Normality and Homogeneity of Variance

Figure (4.13)

Normal and Detrended Plots (Nocomp)



	Statistic	df	Significance
K-S (Lilliefors)	.1595	102	.0000

Figure (4.13) shows that the values for complaints variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of complaints violate the normality assumption.

Table (4.33)

Test for Homogeneity (Nocomp)

Cochrans C=Max. Variance/Sum(Variances) =	.4985,	P=	.027 (Approx.)
Bartlett-Box F =	1.887 ,	P=	.152
Maximum Variance/Minimum Variance	2.355		

Table (4.33) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .027 and .152 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.34)

Kruskal-Wallis One-Way ANOVA (NUMBER OF COMPLAINTS)

Mean Rank	Cases	
64.13	30	CLUST3 = 1 M
54.86	7	CLUST3 = 2 H
45.31	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 8.4059	SIGNIFICANCE = .0150
CORRECTED FOR TIES:	CHI-SQUARE = 9.1103	SIGNIFICANCE = .0105

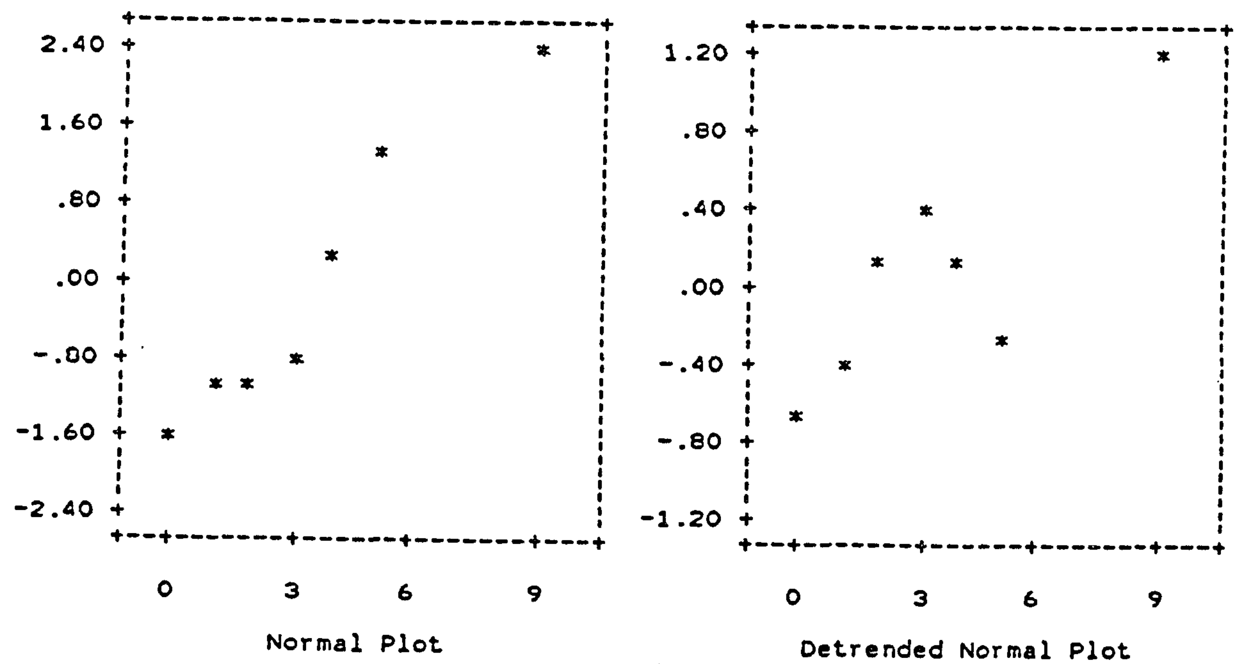
Table (4.34) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0105, the null hypothesis is rejected. There are significant difference in number of complaints among the three groups.

1.3.14 Returns:

1. Test for Normality and Homogeneity of Variance

Figure (4.14)

Normal and Detrended Plots (Noretu)



	Statistic	df	Significance
K-S (Lilliefors)	.1717	102	.0000

Figure (4.14) shows that the values for returns variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of returns violate the normality assumption.

Table (4.35)

Test for Homogeneity (Noretu)

Cochrans C=Max. Variance/Sum(Variances) =	.5492,	P=	.003 (Approx.)
Bartlett-Box F =	3.102 ,	P=	.045
Maximum Variance/Minimum Variance	3.070		

Table (4.35) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .003 and .045 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.36)

Kruskal-Wallis One-Way ANOVA (NUMBER OF RETURNS)

Mean Rank	Cases	
63.98	30	CLUST3 = 1 M
49.07	7	CLUST3 = 2 H
46.00	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 7.6328	SIGNIFICANCE = .0220
CORRECTED FOR TIES:	CHI-SQUARE = 8.5604	SIGNIFICANCE = .0138

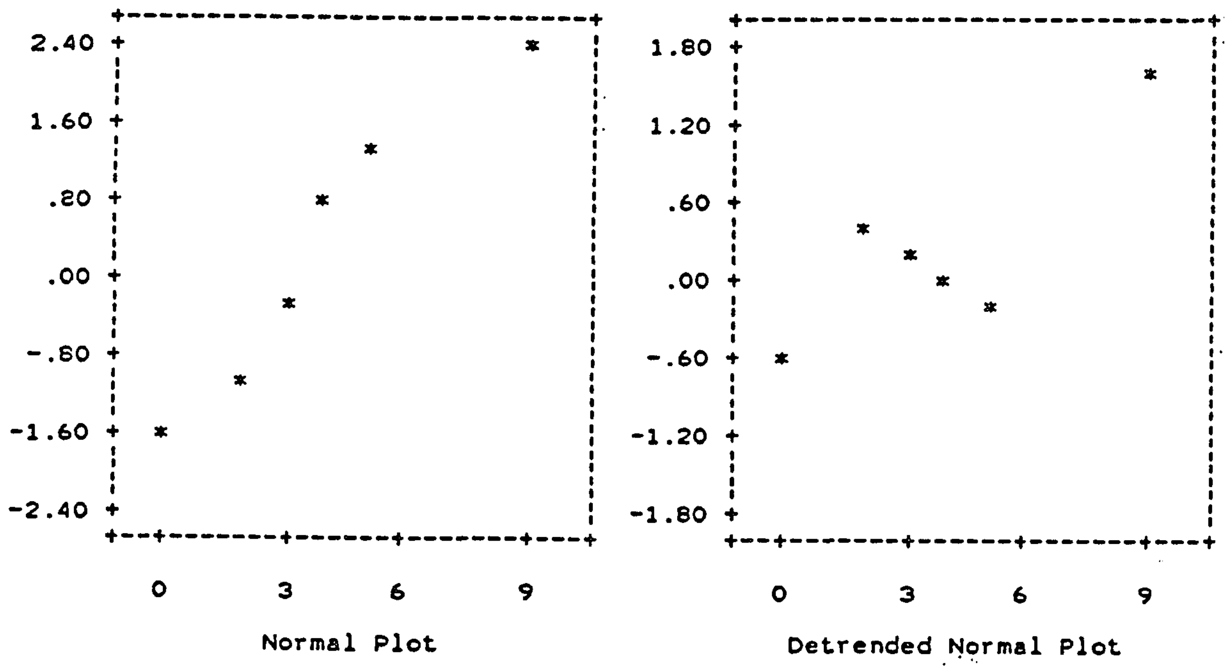
Table (4.36) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0138, the null hypothesis is rejected. There are significant difference in number of returns among the three groups.

1.3.15 Warranty period:

1. Test for Normality and Homogeneity of Variance

Figure (4.15)

Normal and Detrended Plots (Warper)



	Statistic	df	Significance
K-S (Lilliefors)	.1806	102	.0000

Figure (4.15) shows that the values for warranty period variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of warranty period violate the normality assumption.

Table (4.37)

Test for Homogeneity (Warper)

Cochrans C=Max. Variance/Sum(Variances) =	.5130,	P=	.015 (Approx.)
Bartlett-Box F =	2.234 ,	P=	.107
Maximum Variance/Minimum Variance	4.198		

Table (4.37) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .015 and .107 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.38)

Kruskal-Wallis One-Way ANOVA (WARRANTY PERIOD)

Mean Rank	Cases	
63.28	30	CLUST3 = 1 M
49.07	7	CLUST3 = 2 H
46.32	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 6.7947	SIGNIFICANCE = .0335
CORRECTED FOR TIES:	CHI-SQUARE = 7.8200	SIGNIFICANCE = .0200

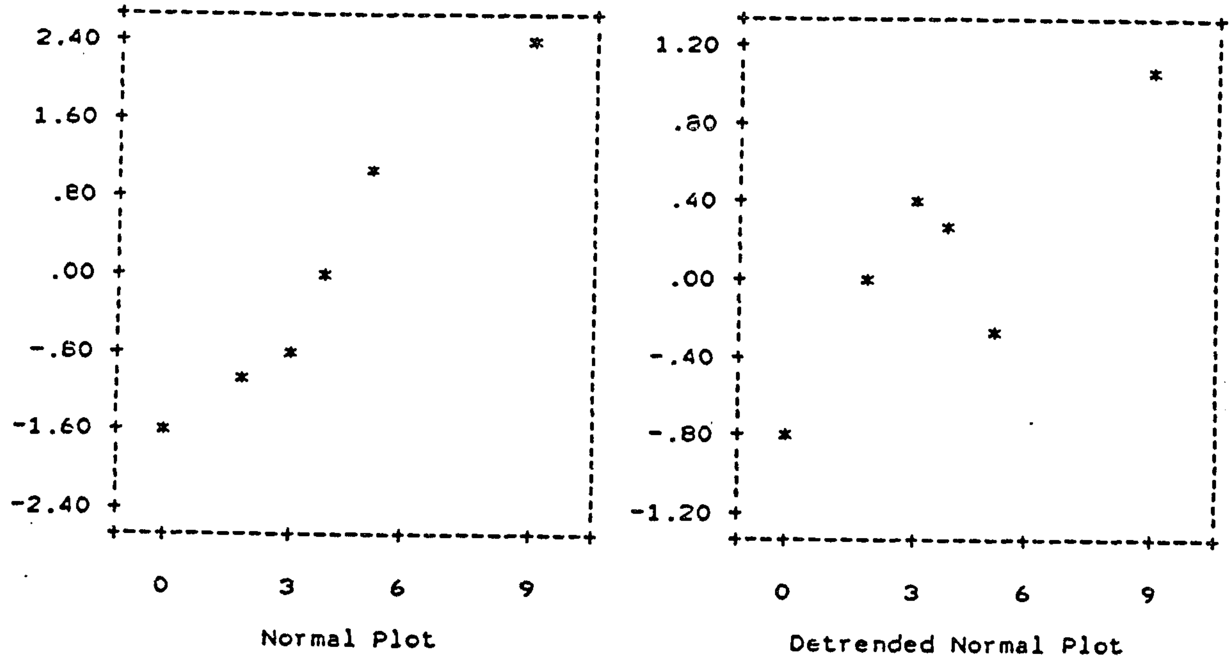
Table (4.38) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0200, the null hypothesis is rejected. There are significant difference in warranty period among the three groups.

1.3.16 Meet deliveries:

1. Test for Normality and Homogeneity of Variance

Figure (4.16)

Normal and Detrended Plots (Metdlv)



	Statistic	df	Significance
K-S (Lilliefors)	.1955	102	.0000

Figure (4.16) shows that the values for meet deliveries variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of meet deliveries violate the normal assumption.

Table (4.39)

Test for Homogeneity (Metdlv)

Cochrans C=Max. Variance/Sum(Variances) =	.6270,	P=	.000 (Approx.)
Bartlett-Box F =	5.501 ,	P=	.004
Maximum Variance/Minimum Variance	4.873		

Table (4.39) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .004 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.40)

Kruskal-Wallis One-Way ANOVA (ABILITY TO MEET DELIVERIES)

Mean Rank	Cases	
63.48	30	CLUST3 = 1 M
61.79	7	CLUST3 = 2 H
44.86	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 9.0384	SIGNIFICANCE = .0109
CORRECTED FOR TIES:	CHI-SQUARE = 10.2915	SIGNIFICANCE = .0058

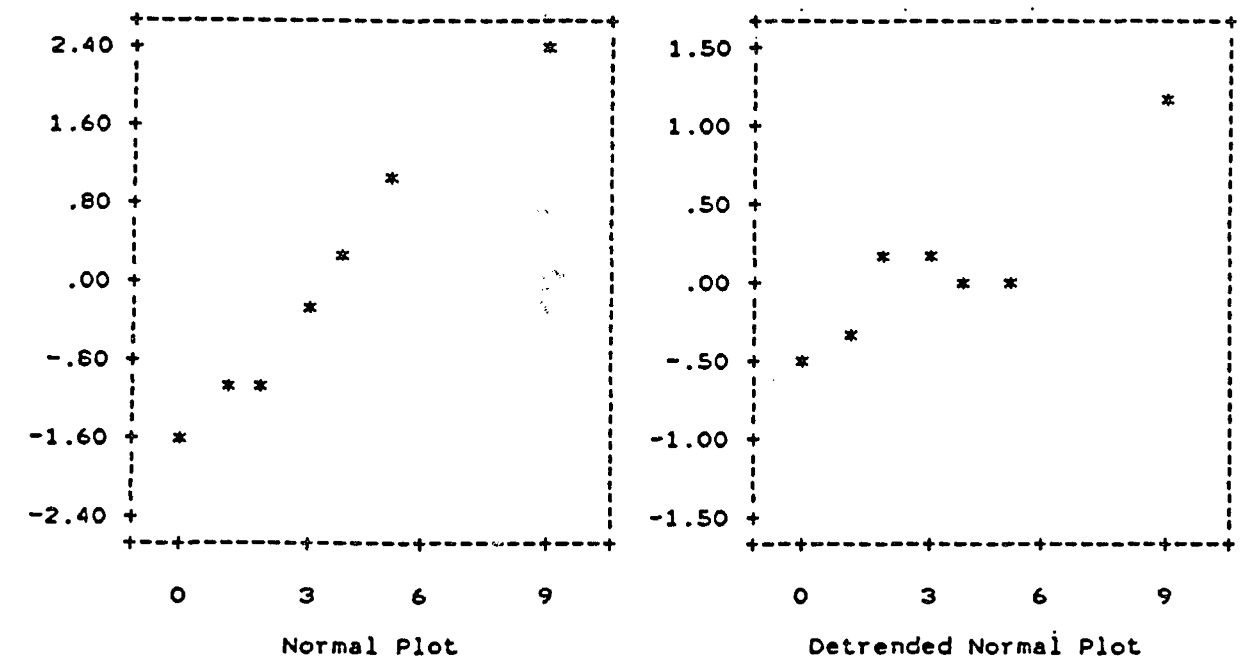
Table (4.40) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0058, the null hypothesis is rejected. There are significant difference in ability to meet deliveries among the three groups.

1.3.17 Loss of customers:

1. Test for Normality and Homogeneity of Variance

Figure (4.17)

Normal and Detrended Plots (Loscus)



	Statistic	df	Significance
K-S (Lilliefors)	.1381	102	.0001

Figure (4.17) shows that the values for loss customers variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0001, the values of loss customers violated the normal assumption.

Table (4.41)

Test for Homogeneity (Loscus)

Cochrans C=Max. Variance/Sum(Variances) =	.4975,	P=	.028 (Approx.)
Bartlett-Box F =	1.709 ,	P=	.181
Maximum Variance/Minimum Variance	2.886		

Table (4.41) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .028 and .181 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.42)

Kruskal-Wallis One-Way ANOVA (LOSS OF CUSTOMERS)

Mean Rank	Cases	
70.27	30	CLUST3 = 1 M
67.93	7	CLUST3 = 2 H
41.07	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 22.3038	SIGNIFICANCE = .0000
CORRECTED FOR TIES:	CHI-SQUARE = 24.3393	SIGNIFICANCE = .0000

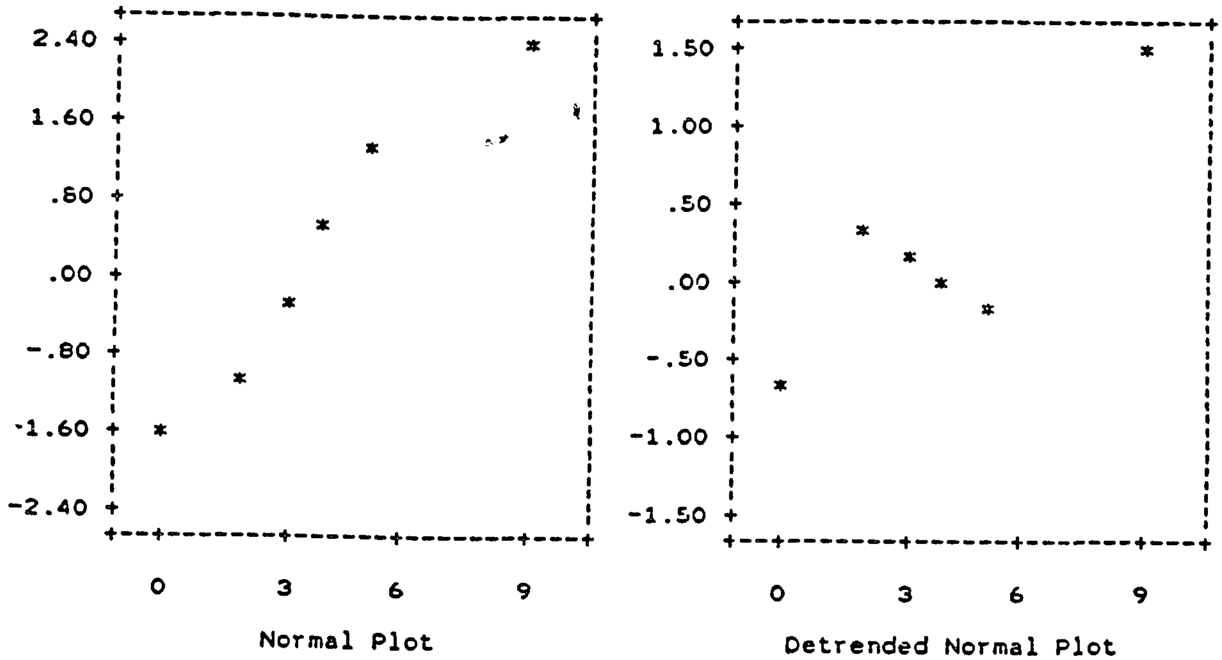
Table (4.42) shows that the mean ranks for group 1, group 3 are different. At significance level of zero, the null hypothesis is rejected. There are significant difference in loss of customers among the two groups.

1.3.18 Product safety:

1. Test for Normality and Homogeneity of Variance

Figure (4.18)

Normal and Detrended Plots (Prdsaf)



	Statistic	df	Significance
K-S (Lilliefors)	.1591	102	.0000

Figure (4.18) shows that the values for product safety variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of product safety violate the normality assumption.

Table (4.43)

Test for Homogeneity (Prdsaf)

Cochrans C=Max. Variance/Sum(Variances) =	.5628,	P=	.002 (Approx.)
Bartlett-Box F =	3.985 ,	P=	.019
Maximum Variance/Minimum Variance	8.040		

Table (4.43) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .002 and .019 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.44)

Kruskal-Wallis One-Way ANOVA (PRODUCT SAFETY)

Mean Rank	Cases	
69.27	30	CLUST3 = 1 M
59.07	7	CLUST3 = 2 H
42.48	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 17.3089	SIGNIFICANCE = .0002
CORRECTED FOR TIES:	CHI-SQUARE = 19.7232	SIGNIFICANCE = .0001

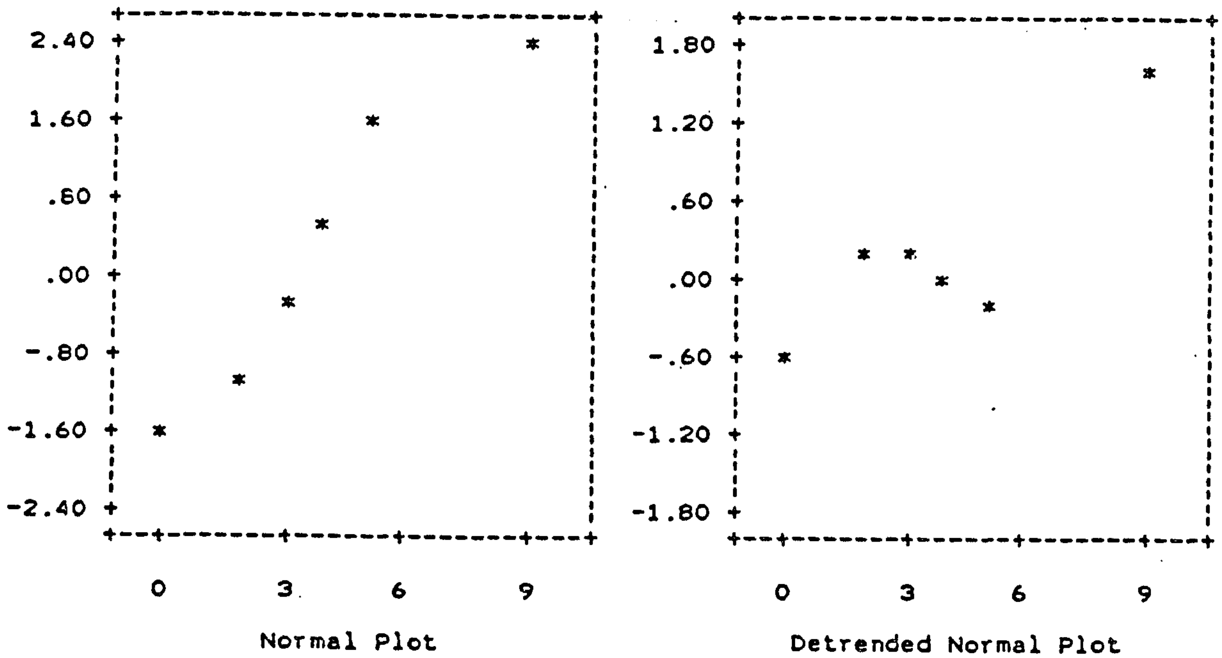
Table (4.44) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0001, the null hypothesis is rejected. There are significant difference in product safety among the three groups.

1.3.19 Maintainability:

1. Test for Normality and Homogeneity of Variance

Figure (4.19)

Normal and Detrended Plots (Mainta)



	Statistic	df	Significance
K-S (Lilliefors)	.1726	102	.0000

Figure (4.19) shows that the values for maintainability variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of maintainability violated the normality assumption.

Table (4.45)

Test for Homogeneity (Mainta)

Cochrans C=Max. Variance/Sum(Variances) =	.5366,	P=	.006 (Approx.)
Bartlett-Box F =	2.646 ,	P=	.071
Maximum Variance/Minimum Variance	4.281		

Table (4.45) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .006 and .071 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.46)

Kruskal-Wallis One-Way ANOVA (MAINTAINABILITY)

Mean Rank	Cases	
64.73	30	CLUST3 = 1 M
59.07	7	CLUST3 = 2 H
42.48	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 8.7989	SIGNIFICANCE = .0123
CORRECTED FOR TIES:	CHI-SQUARE = 9.6163	SIGNIFICANCE = .0082

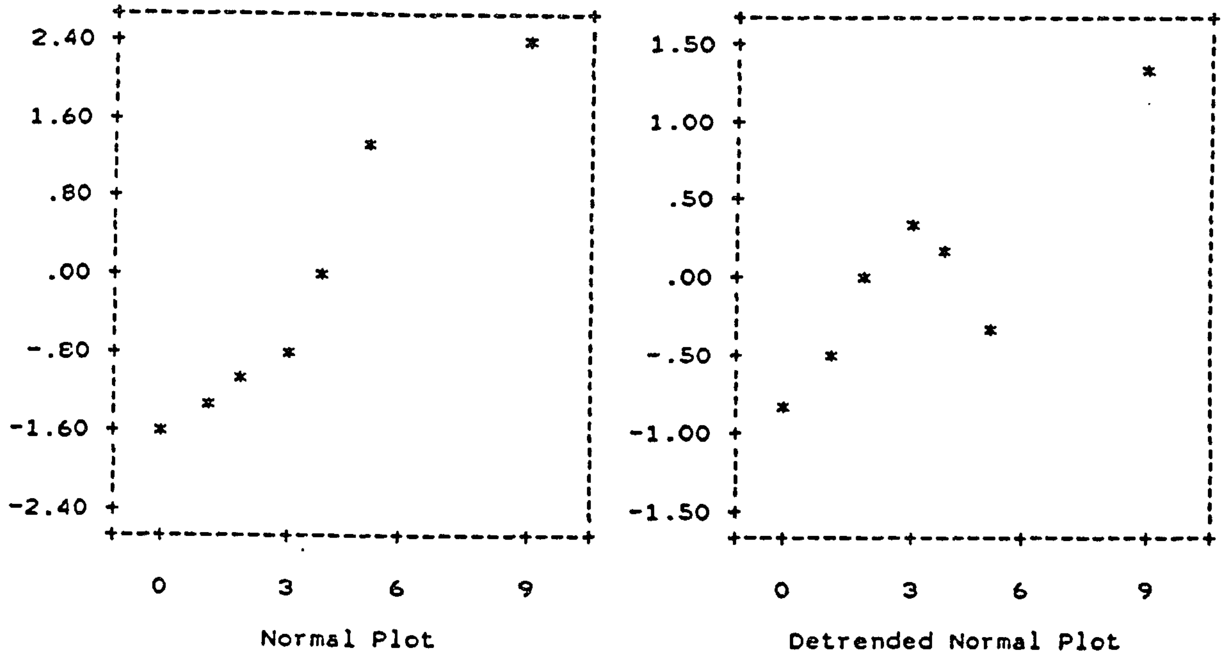
Table (4.46) shows that the mean ranks for group 1, group 2, and group 3 are different. At significance level of .0082, the null hypothesis is rejected. There are significant difference in maintainability among the three groups.

1.3.20 Responsibility:

1. Test for Normality and Homogeneity of Variance

Figure (4.20)

Normal and Detrended Plots (Respon)



	Statistic	df	Significance
K-S (Lilliefors)	.2080	102	.0000

Figure (4.20) shows that the values for responsibility variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of responsibility violate the normality assumption.

Table (4.47)

Test for Homogeneity (Respon)

Cochrans C=Max. Variance/Sum(Variances) =	.6788,	P=	.000 (Approx.)
Bartlett-Box F =	11.338 ,	P=	.000
Maximum Variance/Minimum Variance	5.320		

Table (4.47) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .000 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.48)

Kruskal-Wallis One-Way ANOVA (RESPONSIBILITY)

Mean Rank	Cases	
60.67	30	CLUST3 = 1 M
50.93	7	CLUST3 = 2 H
47.33	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 4.1725	SIGNIFICANCE = .1242
CORRECTED FOR TIES:	CHI-SQUARE = 4.9632	SIGNIFICANCE = .0836

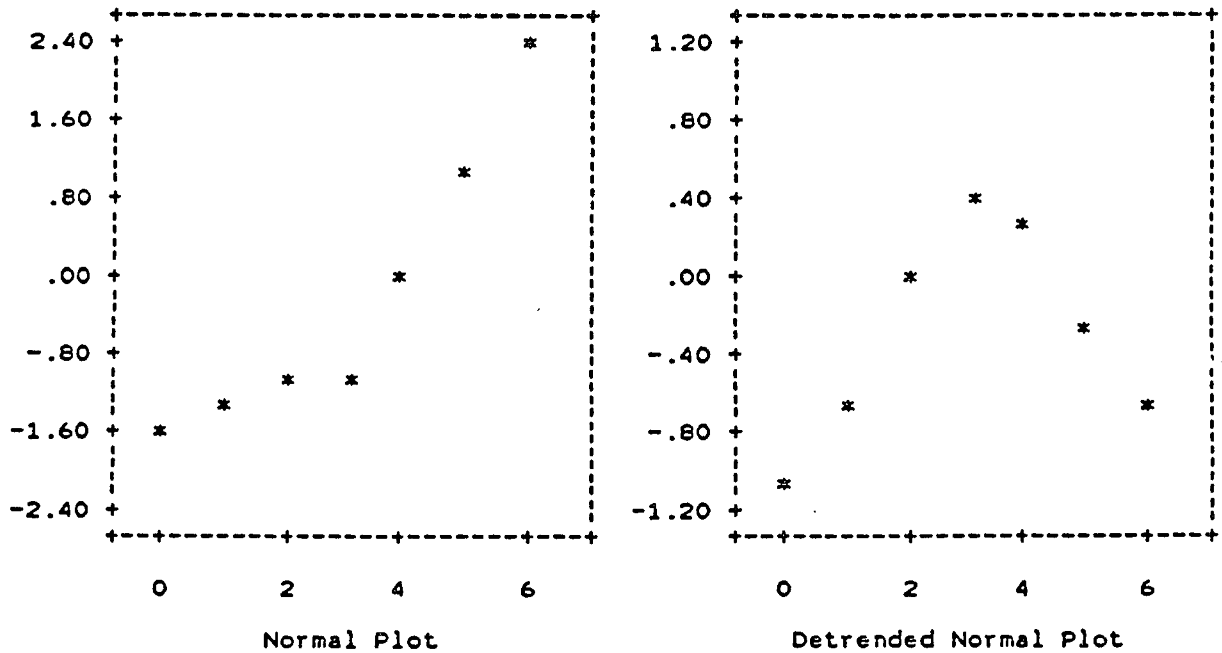
Table (4.48) shows that the mean ranks for group 1, group 2 are different. At significance level of .0835, the null hypothesis can not be rejected. There is no significant difference in responsibility among the two groups.

1.3.21 Participation:

1. Test for Normality and Homogeneity of Variance

Figure (4.21)

Normal and Detrended Plots (Partici)



	Statistic	df	Significance
K-S (Lilliefors)	.1970	102	.0000

Figure (4.21) shows that the values for participation variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0C00, the values of participation violate the normality assumption.

Table (4.49)

Test for Homogeneity (Partici)

Cochrans C=Max. Variance/Sum(Variances) =	.7679,	P=	.000 (Approx.)
Bartlett-Box F =	12.866 ,	P=	.000
Maximum Variance/Minimum Variance	10.163		

Table (4.49) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .000 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.50)

Kruskal-Wallis One-Way ANOVA (WORKER PARTICIPATION)

Mean Rank	Cases	
62.95	30	CLUST3 = 1 M
62.79	7	CLUST3 = 2 H
45.00	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 8.6475	SIGNIFICANCE = .0133
CORRECTED FOR TIES:	CHI-SQUARE = 10.7309	SIGNIFICANCE = .0047

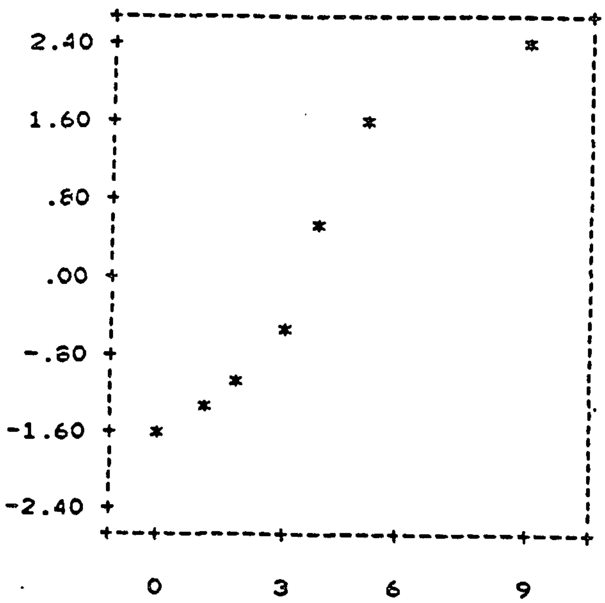
Table (4.50) shows that the mean ranks for group 1 and group 3 are different. At significance level of .0047, the null hypothesis is rejected. There are significant differences in worker participation among the two groups.

1.3.22 Loyalty:

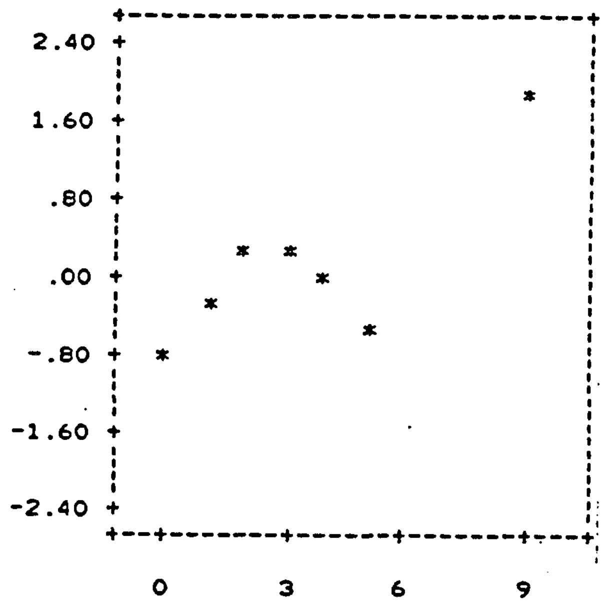
1. Test for Normality and Homogeneity of Variance

Figure (4.22)

Normal and Detrended Plots (Loyalt)



Normal Plot



Detrended Normal Plot

	Statistic	df	Significance
K-S (Lilliefors)	.2198	102	.0000

Figure (4.22) shows that the values for worker loyalty variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of loyalty violate the normality assumption.

Table (4.51)

Test for Homogeneity (Loyalt)

Cochrans C=Max. Variance/Sum(Variances) =	.6525,	P=	.000 (Approx.)
Bartlett-Box F =	13.072 ,	P=	.000
Maximum Variance/Minimum Variance	6.508		

Table (4.51) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .000 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.52)

Kruskal-Wallis One-Way ANOVA (WORKER LOYALTY)

Mean Rank	Cases	
57.90	30	CLUST3 = 1 M
58.07	7	CLUST3 = 2 H
47.84	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 2.7442	SIGNIFICANCE = .2536
CORRECTED FOR TIES:	CHI-SQUARE = 3.1247	SIGNIFICANCE = .2096

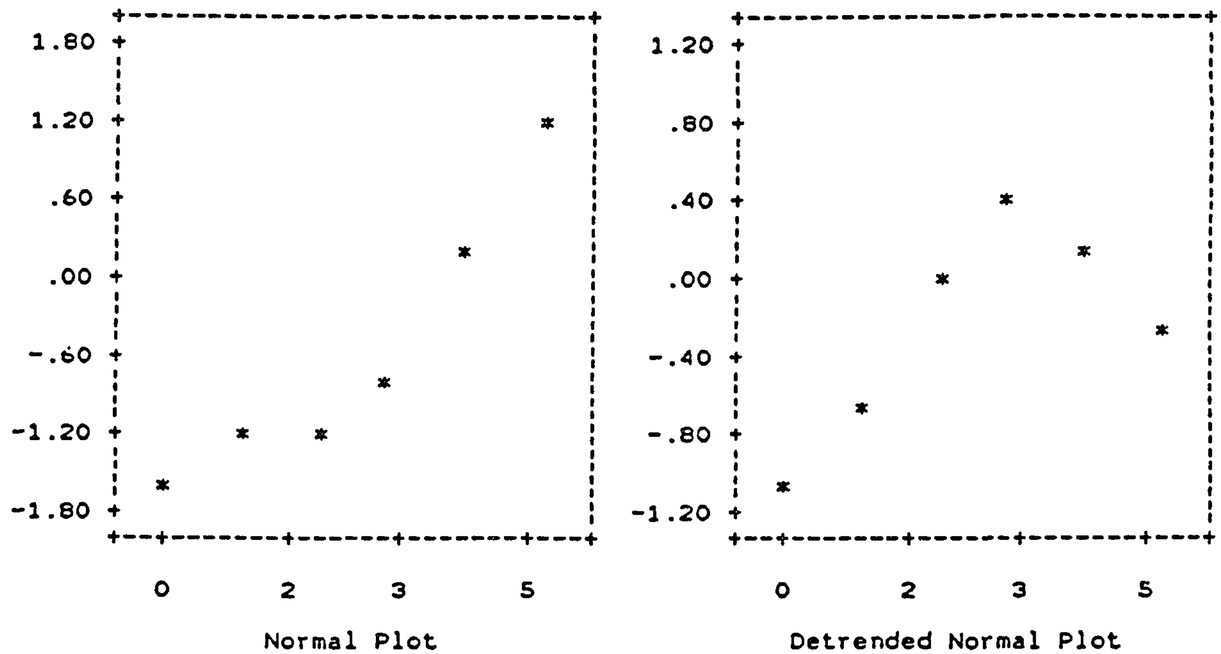
Table (4.52) shows that the mean ranks for group 1 and group 3 are different. At significance level of .2096, the null hypothesis can not be rejected. There is no significant differences in worker loyalty among the two groups.

1.3.23 Skill variety:

1. Test for Normality and Homogeneity of Variance

Figure (4.23)

Normal and Detrended Plots (Skivar)



	Statistic	df	Significance
K-S (Lilliefors)	.1830	102	.0000

Figure (4.23) shows that the values for skill variety variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of skill variety violate the normality assumption.

Table (4.53)

Test for Homogeneity (Skivar)

Cochrans C=Max. Variance/Sum(Variances) =	.7373,	P=	.000 (Approx.)
Bartlett-Box F =	11.395 ,	P=	.000
Maximum Variance/Minimum Variance	7.151		

Table (4.53) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .000 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.54)

Kruskal-Wallis One-Way ANOVA (SKILL VARIETY)

Mean Rank	Cases	
58.55	30	CLUST3 = 1 M
57.43	7	CLUST3 = 2 H
47.61	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 3.1089	SIGNIFICANCE = .2113
CORRECTED FOR TIES:	CHI-SQUARE = 3.5927	SIGNIFICANCE = .1659

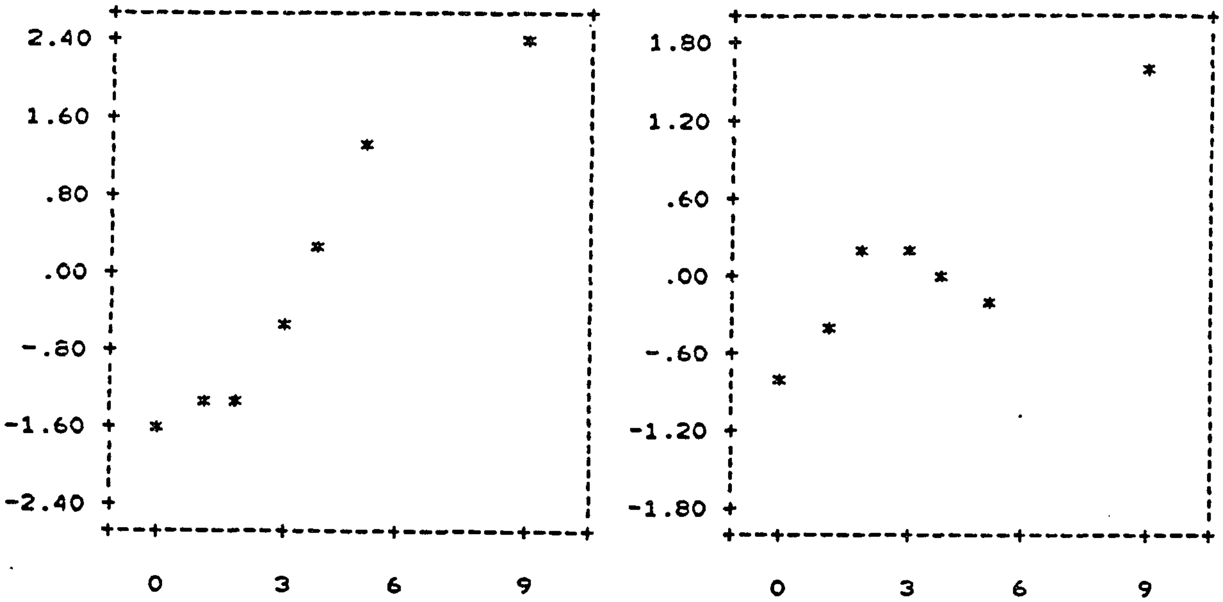
Table (4.54) shows that the mean ranks for group 1 and group 3 are different. At significance level of .1659, the null hypothesis can not be rejected. There is no significant differences in worker's skill variety among the two groups.

1.3.24 Autonomy:

1. Test for Normality and Homogeneity of Variance

Figure (4.24)

Normal and Detrended Plots (Autono)



Normal Plot

Detrended Normal Plot

	Statistic	df	Significance
K-S (Lilliefors)	.1801	102	.0000

Figure (4.24) shows that the values for autonomy variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of autonomy violate the normality assumption.

Table (4.55)

Test for Homogeneity (Autono)

Cochrans C=Max. Variance/Sum(Variances) =	.7367,	P=	.000 (Approx.)
Bartlett-Box F =	10.492 ,	P=	.000
Maximum Variance/Minimum Variance	10.968		

Table (4.55) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .000 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.56)

Kruskal-Wallis One-Way ANOVA (AUTONOMY)

Mean Rank	Cases	
58.03	30	CLUST3 = 1 M
74.57	7	CLUST3 = 2 H
46.00	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 7.9644	SIGNIFICANCE = .0186
CORRECTED FOR TIES:	CHI-SQUARE = 8.8486	SIGNIFICANCE = .0120

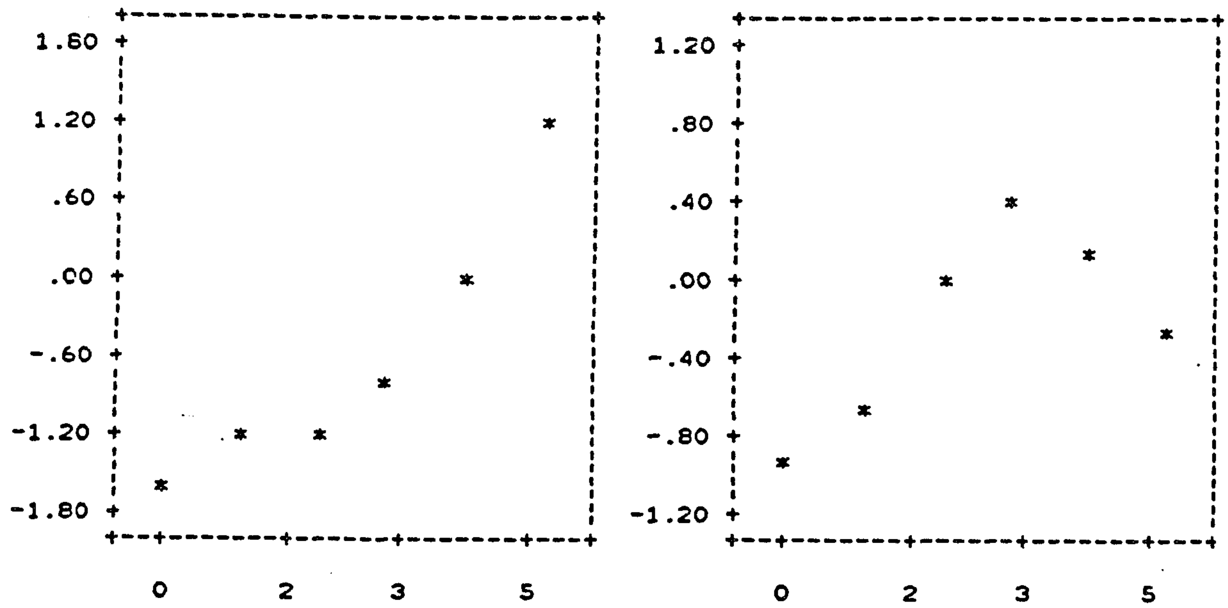
Table (4.56) shows that the mean ranks for group 2 and group 3 are different. At significance level of .0120, the null hypothesis is rejected. There are significant differences in worker's autonomy among the two groups.

1.3.25 Feedback:

1. Test for Normality and Homogeneity of Variance

Figure (4.25)

Normal and Detrended Plots (Feebac)



Normal Plot   Detrended Normal Plot

	Statistic	df	Significance
K-S (Lilliefors)	.1740	102	.0000

Figure (4.25) shows that the values for feedback variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of feedback violate the normality assumption.

Table (4.57)

Test for Homogeneity (Feebac)

Cochrans C=Max. Variance/Sum(Variances) =	.6828,	P=	.000 (Approx.)
Bartlett-Box F =	10.051 ,	P=	.000
Maximum Variance/Minimum Variance	4.562		

Table (4.57) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .000 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.58)

Kruskal-Wallis One-Way ANOVA (FEEDBACK)

Mean Rank	Cases	
63.50	30	CLUST3 = 1 M
65.86	7	CLUST3 = 2 H
44.42	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 10.3088	SIGNIFICANCE = .0058
CORRECTED FOR TIES:	CHI-SQUARE = 11.9804	SIGNIFICANCE = .0025

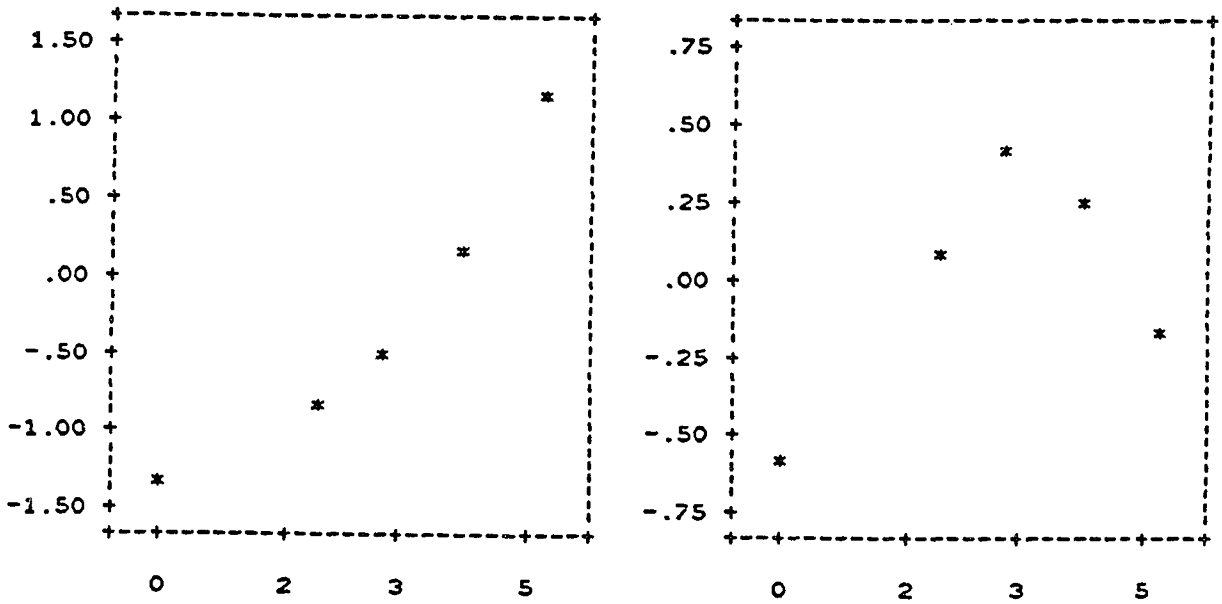
Table (4.58) shows that the mean ranks for group 2 and group 3 are different. At significance level of .0025, the null hypothesis is rejected. There are significant differences in feedback among the two groups.

1.3.26 Pareto analysis:

1. Test for Normality and Homogeneity of Variance

Figure (4.26)

Normal and Detrended Plots (Pareto1)



Normal Plot   Detrended Normal Plot

	Statistic	df	Significance
K-S (Lilliefors)	.1592	102	.0000

Figure (4.26) shows that the values for pareto analysis variable do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of pareto analysis violate the normality assumption.

Table (4.59)

Test for Homogeneity (Pareto1)

Cochrans C=Max. Variance/Sum(Variances) =	.5314,	P=	.007 (Approx.)
Bartlett-Box F =	2.739 ,	P=	.065
Maximum Variance/Minimum Variance	5.042		

Table (4.59) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .007 and .065 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.60)

Kruskal-Wallis One-Way ANOVA (PARETO ANALYSIS)

Mean Rank	Cases	
64.77	30	CLUST3 = 1 M
72.86	7	CLUST3 = 2 H
43.08	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 14.9654	SIGNIFICANCE = .0006
CORRECTED FOR TIES:	CHI-SQUARE = 16.2762	SIGNIFICANCE = .0003

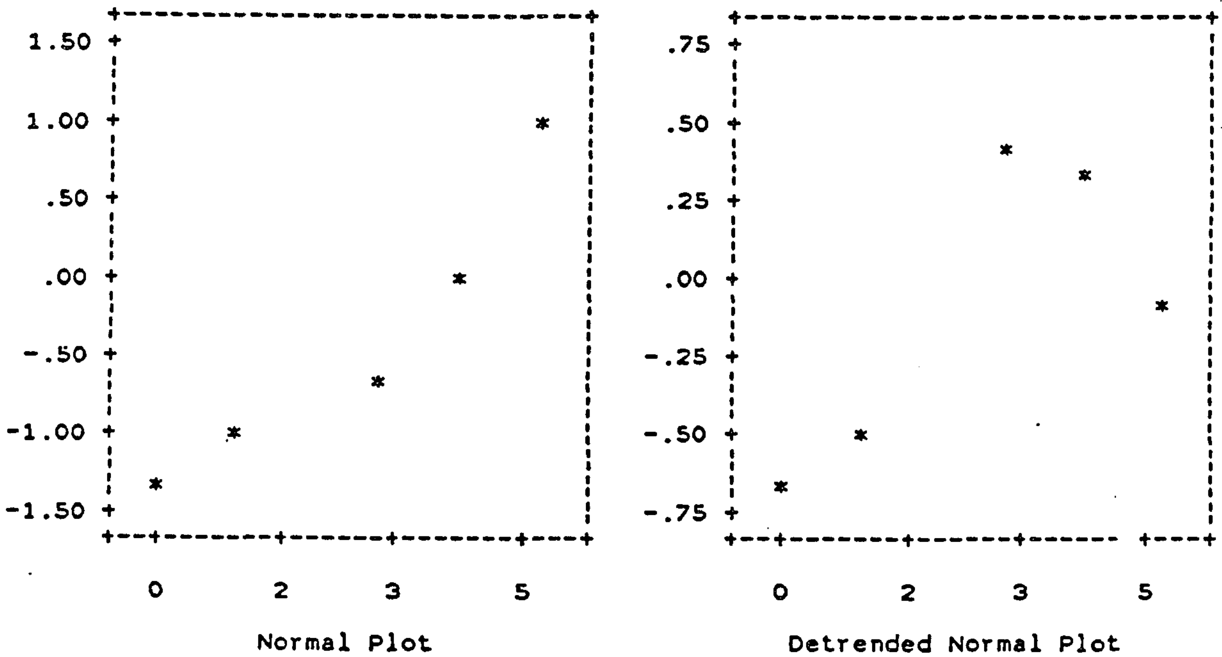
Table (4.60) shows that the mean ranks for group 1 group 2, and group 3 are different. At significance level of .0003, the null hypothesis is rejected. There are significant differences in using pareto analysis among the three groups.

1.3.27 Statistical process control:

1. Test for Normality and Homogeneity of Variance

Figure (4.27)

Normal and Detrended Plots (Spc1)



	Statistic	df	Significance
K-S (Lilliefors)	.1958	102	.0000

Figure (4.27) shows that the values for using statistical process control do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of statistical process control violate the normality assumption.

Table (4.61)

Test for Homogeneity (Spc1)

Cochrans C=Max. Variance/Sum(Variances) =	.6387,	P=	.000 (Approx.)
Bartlett-Box F =	6.343 ,	P=	.002
Maximum Variance/Minimum Variance	12.045		

Table (4.61) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .000 and .002 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.62)

Kruskal-Wallis One-Way ANOVA (STATISTICAL PROCESS CONTROL)

Mean Rank	Cases	
63.35	30	CLUST3 = 1 M
70.36	7	CLUST3 = 2 H
44.00	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 11.8310	SIGNIFICANCE = .0027
CORRECTED FOR TIES:	CHI-SQUARE = 13.1452	SIGNIFICANCE = .0014

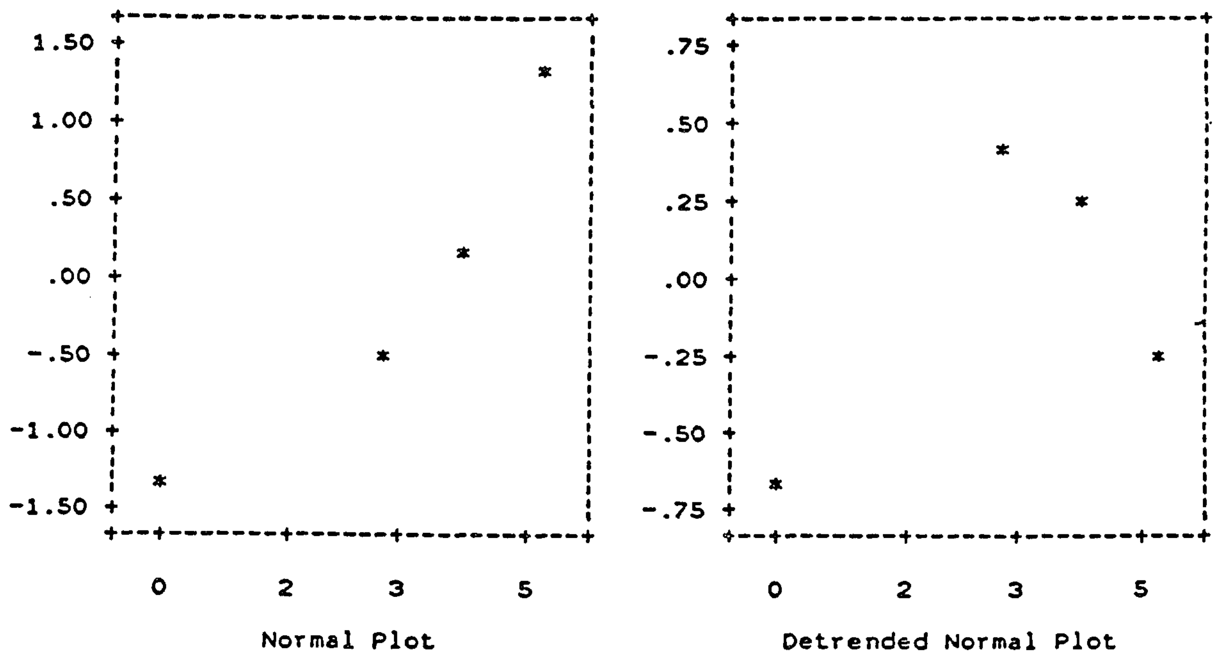
Table (4.62) shows that the mean ranks for group 1 group 2, and group 3 are different. At significance level of .0014, the null hypothesis is rejected. There are significant differences in using statistical process control among the three groups.

1.3.28 Statistical quality control:

1. Test for Normality and Homogeneity of Variance

Figure (4.28)

Normal and Detrended Plots (Sqc)



	Statistic	df	Significance
K-S (Lilliefors)	.1597	102	.0000

Figure (4.28) shows that the values for using statistical quality control do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of statistical quality control violate the normality assumption.

Table (4.63)

Test for Homogeneity (Sqc)

Cochrans C=Max. Variance/Sum(Variances) =	.4874,	P=	.040 (Approx.)
Bartlett-Box F =	2.382 ,	P=	.093
Maximum Variance/Minimum Variance	5.189		

Table (4.63) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .040 and .093 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.64)

Kruskal-Wallis One-Way ANOVA (STATISTICAL QUALITY CONTROL)

Mean Rank	Cases	
62.33	30	CLUST3 = 1 M
69.71	7	CLUST3 = 2 H
44.54	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 10.2721	SIGNIFICANCE = .0059
CORRECTED FOR TIES:	CHI-SQUARE = 11.4217	SIGNIFICANCE = .0033

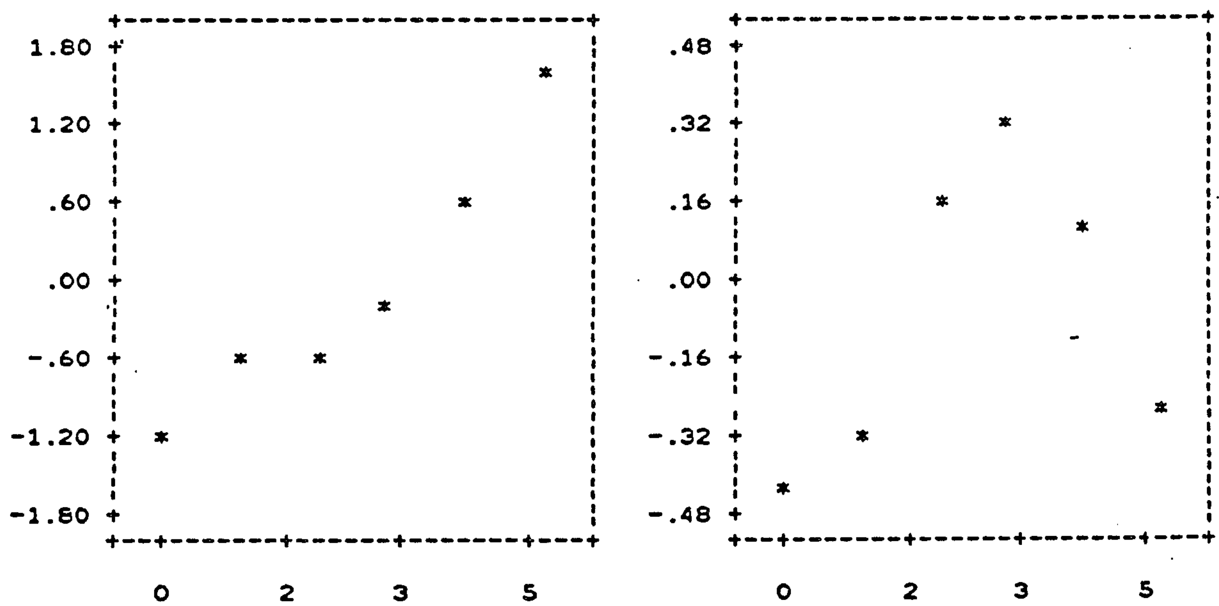
Table (4.64) shows that the mean ranks for group 1 group 2, and group 3 are different. At significance level of .0033, the null hypothesis is rejected. There are significant differences in using statistical quality control among the three groups.

1.3.29 Taguchi's approach:

1. Test for Normality and Homogeneity of Variance

Figure (4.29)

Normal and Detrended Plots (Taguch)



Normal Plot

Detrended Normal Plot

	Statistic	df	Significance
K-S (Lilliefors)	.1943	102	.0000

Figure (4.29) shows that the values for using Taguchi's approach do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of Taguchi's approach violate the normality assumption.

Table (4.65)

Test for Homogeneity (Taguch)

Cochrans C=Max. Variance/Sum(Variances) =	.4732,	P=	.065 (Approx.)
Bartlett-Box F =	2.418 ,	P=	.089
Maximum Variance/Minimum Variance	5.343		

Table (4.65) shows that the significance level for Cochrans C and Bartlett-Box F are small (P = .065 and .089 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.66)

Kruskal-Wallis One-Way ANOVA (TAGUCHI'S APPROACH)

Mean Rank	Cases	
57.88	30	CLUST3 = 1 M
67.57	7	CLUST3 = 2 H
46.82	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 5.0854	SIGNIFICANCE = .0787
CORRECTED FOR TIES:	CHI-SQUARE = 5.4880	SIGNIFICANCE = .0643

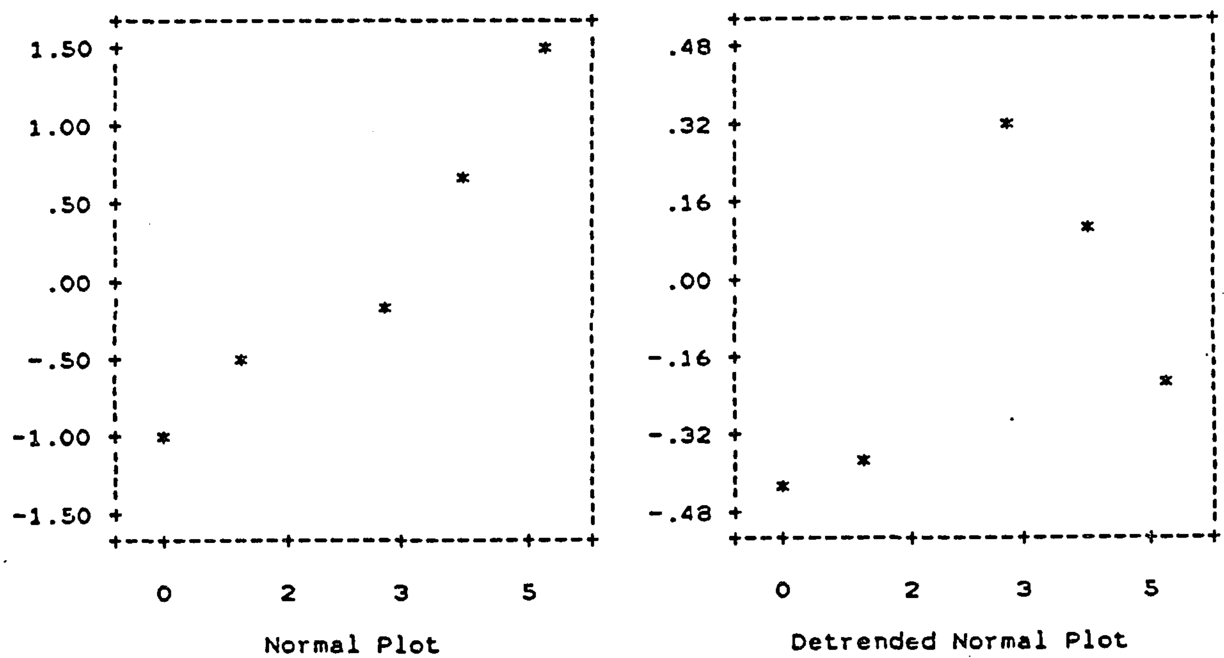
Table (4.66) shows that the mean ranks for group 1 group 2, and group 3 are different. At significance level of .0643, the null hypothesis is rejected. There are significant differences in using Taguchi's approach among the three groups.

1.3.30 P chart:

1. Test for Normality and Homogeneity of Variance

Figure (4.30)

Normal and Detrended Plots (Pchart)



	Statistic	df	Significance
K-S (Lilliefors)	.2128	102	.0000

Figure (4.30) shows that the values for using P chart do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of Pchart violate the normality assumption.

Table (4.67)

Test for Homogeneity (Pchart)

Cochrans C=Max. Variance/Sum(Variances) =	.3488,	P=	1.000 (Approx.)
Bartlett-Box F =	.034 ,	P=	.966
Maximum Variance/Minimum Variance	1.087		

Table (4.67) shows that the significance level for Cochrans C and Bartlett-Box F are large (P = 1.000 and .966 respectively). The homogeneity assumption was violated.

2. ANOVA

Table (4.68)

Kruskal-Wallis One-Way ANOVA (P CHART)

Mean Rank	Cases	
64.70	30	CLUST3 = 1 M
68.21	7	CLUST3 = 2 H
43.61	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 12.8287	SIGNIFICANCE = .0016
CORRECTED FOR TIES:	CHI-SQUARE = 13.8448	SIGNIFICANCE = .0010

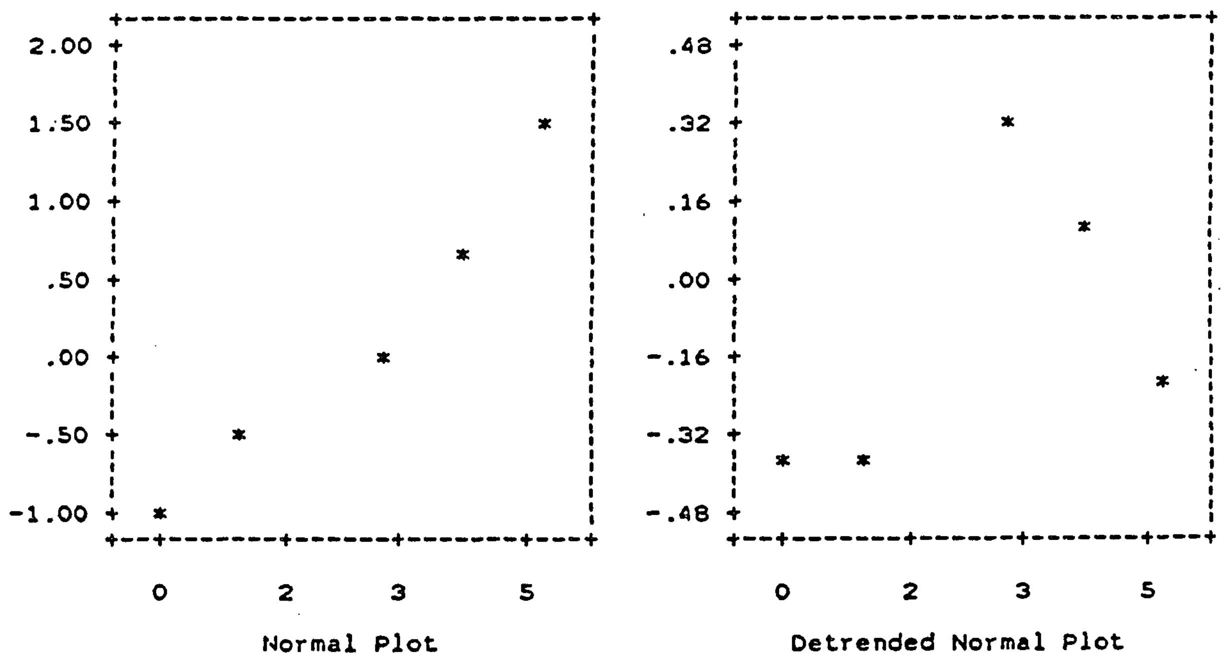
Table (4.68) shows that the mean ranks for group 1 group 2, and group 3 are different. At significance level of .0010, the null hypothesis is rejected. There are significant differences in using P chart among the three groups.

1.3.31 C chart:

1. Test for Normality and Homogeneity of Variance

Figure (4.31)

Normal and Detrended Plots (Cchart)



	Statistic	df	Significance
K-S (Lilliefors)	.2287	102	.0000

Figure (4.31) shows that the values for using C chart do not form a straight line in the normal plot. It also shows that the values are not grouped around the zero line in the detrended plot. With significance level P = .0000, the values of Cchart violate the normality assumption.

Table (4.69)

Test for Homogeneity (Cchart)

Cochrans C=Max. Variance/Sum(Variances) =	.4068,	P=	.412 (Approx.)
Bartlett-Box F =	.313 ,	P=	.732
Maximum Variance/Minimum Variance	1.636		

Table (4.69) shows that the significance level for Cochrans C and Bartlett-Box F are large (P - .412 and .732 respectively). The homogeneity assumption was violated.

1.3.31.2 ANOVA

Table (4.70)

Kruskal-Wallis One-Way ANOVA (C CHART)

Mean Rank	Cases	
63.27	30	CLUST3 = 1 M
64.71	7	CLUST3 = 2 H
44.65	65	CLUST3 = 3 L

CASES = 102	CHI-SQUARE = 9.6280	SIGNIFICANCE = .0081
CORRECTED FOR TIES:	CHI-SQUARE = 10.4318	SIGNIFICANCE = .0054

Table (4.70) shows that the mean ranks for group 2, and group 3 are different. At significance level of .0054, the null hypothesis is rejected. There are significant differences in using C chart among the two groups.

Table (4.71)

Summary of the hypotheses:

Quality Aspects	Null Hypothesis H_0	Group Ranks
I. Quality as a strategic objective	Can not be rejected	L>H>M
II. Quality cost:		
1. Rework	rejected	M>H>L
2. Scrap	rejected	M>H>L
3. Extra inventory	rejected	M>H>L
4. Warranty	rejected	M>H>L
5. Down time	rejected	M>H>L
6. Lost orders	rejected	M>H>L
7. Research and Development	rejected	H>M>L
8. Inspection	rejected	M>H>L
9. Quality training	rejected	M>H>L
III. Market & Consumer:		
1. Market share	rejected	M>H>L
2. Multinational market	rejected	M>H>L
3. Complaints	rejected	M>H>L
4. Returns	rejected	M>H>L
5. Warranty period	rejected	M>H>L
6. Meet deliveries	rejected	M>H>L
7. Loss of customers	rejected	M>H>L
8. Product safety	rejected	M>H>L
9. Maintainability	rejected	M>H>L
IV. Total Employee Involvement:		
1. Worker responsibility	not rejected	M>H>L
2. Worker participation	not rejected	M>H>L
3. Worker loyalty	not rejected	H>M>L
4. Skill variety	not rejected	M>H>L
5. Autonomy	not rejected	H>M>L
6. Feedback	not rejected	H>M>L
V. Quality Tools:		
1. Pareto analysis	rejected	H>M>L
2. Statistical process control	rejected	H>M>L
3. Statistical quality control	rejected	H>M>L
4. Taguchi's approach	rejected	H>M>L
5. P chart	rejected	H>M>L
6. C chart	rejected	H>M>L

1.4 Multiple Comparison Tests:

To pinpoint which two groups differ on each of the dependent variables, multiple comparison procedure was utilized. The test utilized here is due to Steel (1960). Miller (1986) indicated that this test is easiest to describe in its Mann-Whitney form. Using Miller's notations, we let

$$U_{ii'} = \sum_{j=1}^{n_i} \sum_{k=1}^{n_{i'}} I\,(y_{ij} > y_{i'k}) \tag{1}$$

Where:

$$I\,(y_{ij} > y_{i'k}) = \begin{cases} 1 & \text{if } y_{ij} > y_{i'k} \\ 1/2 & \text{if } y_{ij} = y_{i'k} \\ 0 & \text{if } y_{ij} < y_{i'k} \end{cases} \tag{2}$$

Equations 1 and 2 are (3.28, 3.29) in Miller (1986, pp 85-86). Our three groups do not have equal sample size. Therefore, to studentize for unequal sample size, we let

$$\hat{U}_{ii'} = U_{ii'} / n_i n_{i'} \tag{3}$$

The Steel test compares

$$|\hat{U}_{ii'} - .5| \tag{4}$$

with the following critical value:

$$q^{\infty} I, \infty [(n_i + n_{i'} + 1)/24 n_i n_{i'}]^{1/2} \tag{5}$$

Where $q^{Inf.}$ I, Inf. is the upper 100 (alpha) percentile of a studentized range distribution for *I* variables in the numerator and infinite degrees of freedom in the denominator. Equations 3,4, and 5 are (3.30, 3.31, and 3.32) in Miller (1986, p86). The. Equations 4 and 5 are used to determine whether significant difference between any pairs exist. If the value obtained from equation (4) equals or exceeds the critical value in equation (5), the null hypothesis that no significant differences between these two groups will be rejected. Two tables representing the

$$\hat{U}_{ii'} \quad and \quad |\hat{U}_{ii'} - .5|$$

are located in the appendix.

Table (4.72)

Group Comparisons:

Quality Aspects	M Vs H	M Vs L	H Vs L
I. Quality as a strategic objective	N. S.[1]	N. S.	N. S.
II. Quality cost:			
1. Rework	N. S.	S.[2]	N. S.
2. Scrap	N. S.	S.	N. S.
3. Extra inventory	N. S.	S.	N. S.
4. Warranty	N. S.	N. S.	N. S.
5. Down time	N. S.	N. S.	N. S.
6. Lost orders	N. S.	N. S.	N. S.
7. Research and Development	N. S.	S.	N. S.
8. Inspection	N. S.	S.	N. S.
9. Quality training	N. S.	N. S.	N. S.
III. Market & Consumer:			
1. Market share	N. S.	S.	N. S.
2. Multinational market	N. S.	S.	N. S.
3. Complaints	N. S.	N. S.	N. S.
4. Returns	N. S.	N. S.	N. S.
5. Warranty period	N. S.	S.	N. S.
6. Meet deliveries	N. S.	S.	N. S.
7. Loss of customers	N. S.	S.	N. S.
8. Product safety	N. S.	S.	N. S.
9. Maintainability	N. S.	S.	N. S.
IV. Total Employee Involvement:			
1. Worker responsibility	N. S.	N. S.	N. S.
2. Worker participation	N. S.	S.	N. S.
3. Worker loyalty	N. S.	N. S.	N. S.
4. Skill variety	N. S.	S.	N. S.
5. Autonomy	N. S.	N. S.	N. S.
6. Feedback	N. S.	S.	N. S.
V. Quality Tools:			
1. Pareto analysis	N. S.	S.	N. S.
2. Statistical process control	N. S.	S.	S.
3. Statistical quality control	N. S.	S.	N. S.
4. Taguchi's approach	N. S.	N. S.	N. S.
5. P chart	N. S.	S.	N. S.
6. C chart	N. S.	S.	N. S.

[1] N. S. = Not Significant

[2] S. = Significant

PART (2) DISCUSSION:

This part presents the analysis of the statistical results based on the hypotheses developed earlier in Chapter 3.

The analysis depends on a combination of variables under study and their statistical results in order to provide some practical implementation suggestions.

2.1 Overall Quality:

The respondents were asked about the relative importance of quality as a strategic objective in their business units.

Statistically, there is no difference among the business units with high, moderate or low levels of advanced manufacturing technology (AMT) intensity. In other words, it seems that regardless of the level of AMT use, quality is a key business objective in a firm's long range strategy. Each business unit needs to develop a long range quality strategy that covers at least five years. Also, each unit should consider quality as a whole system approach by applying Total Quality Management.

2.2 Quality Costs:

In quality costs section respondents were asked about the relative influence of the use of advanced manufacturing technologies (AMTs) on some specific cost items. These rework costs, scrap, extra inventory, warranty costs, down-time and lost order costs represent the most important internal failure costs.

The impact of using advanced manufacturing technologies (AMTs) on these items was examined by testing H2.1 through H2.9. Statistically speaking, there are significant differences in these items among the three groups.

In the rework cost item there are significant differences among the three groups. However, there is a remarkable difference between the high and moderate level groups when compared with the low level one. Both the high and moderate level groups set more emphasis on scrap costs as one of the main internal failure costs. The literature has shown that total operating costs decrease as defects decrease. Cost savings result from the reduced rework and reduced scrap. The conclusion appears to be that the use of AMTs with high levels of automation and integration results in fewer defects, thereby decreasing costs due to poor quality.

In extra inventory cost item, there are differences between the high and moderate level groups when compared to the low level group. It seems that using AMTs can result in fewer material handling and needing less inventory provided that processed items do not have to be recycled back through the manufacturing process.

For the warranty cost item there is no significant difference between the three groups.

In the down-time cost item there are differences among the high, moderate and low level business units when one examines the effect of AMTs on decreasing down time costs. Specifically, there are significant differences between high and low groups. It appears that the high level unit suffers more non-operative time due to diagnosis time, repair time, and waiting time for paper work preparation, for parts and the loss of skilled team work. It seems that solutions to down-time problems are more complicated in the high level groups than low level groups because the low level groups are more simplistic and flexible in their responses to these problems.

In the lost orders cost item, there is a significant difference between high and low level units. The high level group has more success in decreasing lost orders by reason of high quality.

Units with a high level of AMTs can recognize customer needs and fulfill customer satisfaction due to their ability to communicate and receive feedback from customers. In addition, a lost order can affect other strategic objectives, such as public image and market share, which can be just as costly for the high level units that have invested millions to establish their AMTs.

In research and development cost, there is a significant difference between high and moderate level groups on one hand and the low level group on the other hand. It appears that both high and moderate level units pay the same attention to the influence of the AMTs system on research and development expenditures. This is explained by the use of continuous quality improvement programs. High and moderate groups spend more on research and development. This seems to enable them to achieve exemplary standards of design, manufacturing, diagnosis, adjustment, and quality measurement.

In the case of the inspection cost, there is a significant difference between the low group and the other two groups. This is certainly the case with highly automated inspection techniques, ones that not only measure production but also record, summarize and display the data of line production. With these techniques, feedback to the workers can be immediate, thus providing an early warning of possible trouble. This is what high technology units need to achieve in order to utilize their expensive investments.

In the quality training cost, there is no difference between the high level and moderate level units. However, there is a significant difference between the low level group and the other units. It appears that the higher and moderate level units are equally emphasizing the importance of quality. These training programs will usually offer training for different categories of personnel, using the most advanced audio-visual systems. The literature shows that major corporations have extensive programs for quality training. From this, one concludes that given today's advances in AMT high technology companies should intensify the training of their employees by updating them on all current aspects related to quality.

2.3 Marketing and Consumer:

In this part of the study, respondents were asked about the relative influence of using AMTs on some specific market and customer items. These items were examined by testing hypotheses H3.1 through H3.9.

In the market share item high and moderate level units place more emphasis on how high intensities of an AMT system affects the size of market. This is supported by the literature which claims that the use of AMTs achieves more competitive advantages. Some of these advantages include be higher flexible products, higher speed of development, lower operational costs and higher accuracy of finished products. By using AMTs there will be a greater opportunity to achieve potential competitive advantages which indirectly can contribute to increased market share.

In the multinational market, there is no significant difference between the high level group and the low level one. Both of them show that AMTs have almost equal impact on multinational markets, while the moderate level group shows a higher AMT impact on multinational markets. It seems that both the high level group and low level one have some hesitancy in marketing their products overseas. A high level firm could meet tough competition when facing low labor costs, low prices or restrictive regulations in multinational markets.

Low level units consider that AMTs have low impact in increasing multinational markets. Their position seems to be that it is more risky when dealing with overseas markets because of possible problems in meeting varying customer needs and satisfying them from outside your domestic market base. In addition, there could be problems in the areas of transportation and communication.

In the area concerning the number of complaints and returns, H2.3 and H2.4. The differences between the high level groups and the low level groups are quite large. The high level group feels that AMTs have a greater capacity to decrease the number of customer complaints and returns due to product defects. This may be so because the higher level units have a greater ability to achieve improved design through the use of Computer Aided Design (CAD) techniques and thus a better chance to reduce process variations.

Moderate level units also believe that using AMTs will result in large reductions in the number of complaints and returns. It appears that these units achieve progress in this area at a greater rate than both the high level units, which are relatively stable, and the low level units, which seem unaware of the impact of AMTs on the number of complaints and returns.

In examining the product warranty periods of the different groups, there is only a small gap between the high level and low level units in their consideration of the impact of AMTs on warranty periods. On the other hand, the management of moderate level units thinks that AMTs can help extend the warranty periods. The reason seems to be attributable to short-term comparisons of the payoffs furnished by increased product reliability before and after applying AMTs.

When compared with high and moderate level units, low level units display less ability to meet delivery schedules. It appears that the two higher-end groups have a greater capacity to respond rapidly to customer demands, and also have more efficient means of communication and transportation. On the other hand, the low level units must realize that the market will shift toward those suppliers that can best meet delivery schedules, which often will be disrupted by quality control problems. They should realize that customers now have a wider choice among markets with more companies vying for their attention in those markets.

In the loss-of-customer item there is a significant difference between the high and moderate level advanced manufacturing technologies on one hand and the low level group on the other hand. The higher quality products can decrease the number of lost customers by achieving zero defects, and thus achieving a high level of customer satisfaction followed by a steady increase in market share.

Units with a low level of AMTs, however, must adapt to the concept of service through market-driven manufacturing. The essential factor in maintaining a steady customer base is the development of an understanding of one's customer's orientation.

A considerable difference is found between the high, moderate and low level groups when examining product safety as a marketing and customer factor. Those units with an intense degree of AMTs consider the technology to have a great effect on the increase of product safety. Using a higher level of technology in the design stage results in a greater ease of installation and use of the product by potential customers. Computer Aided Design (CAD) certainly can help to achieve this goal. In addition AMTs can have a high level of automated inspection techniques that should reduce the opportunities for human error.

Only a slight difference is found between the high and low level units when examining increased maintainability as a result of using AMTs. At all levels of use of AMTs, the units depend on human effort to carry out the maintenance functions. Both high and moderate units find that there is no direct impact by AMTs on their maintenance duties.

The moderate level group, though, believes that there is a large impact by AMTs on maintenance. This impact could, however, be due to the shift stage in going from the low to high levels of technology.

2.4 Total Employee Involvement:

Respondents were asked about the impact of AMTs on the work force. Total employee involvement areas were tested by hypotheses H4.1 through H4.6.

In examining employee responsibility, very little difference was found between the high and low level groups. Support for this response comes from the idea that quality is a function of people and the key to achieving a successful quality environment rests with worker involvement. The moderate level group focuses more on the use of AMTs as a means of increasing worker responsibility through greater diagnostic reporting and increased adjustments by taking specific corrective actions. Briefly, AMTs have redefined the roles and responsibilities of both managers and workers.

A significant difference appears between the high and moderate level groups and the low level units when we considered their perceptions about the impact of AMTs on quality improvement as a result of increased employee participation. In this connection Teresko (1991) reported the Ernst and Young studies and results of these studies about human integrated manufacturing (HIM). It appears that this may be attributable to the fact that the high level units have the resources to invest in team work and quality circle programs. A conclusion that one may reach is that the low level units should create joint quality efforts and explore the manner in which their employees fit into all processes the manufacturing cycle.

When examining employee loyalty, only slight differences were found between the high and moderate groups when considering the impact of AMTs. The low level group, though, showed a somewhat larger variation. It seems that the high and moderate level units, seeing the impact of AMTs on their workers, consider the workers to be a valuable asset and an added value factor. Through Total Quality Management improvement programs these groups can achieve a good interaction between the worker and his or her work station through the integrated network. This, in turn, causes an increase in quality awareness by the worker.

No differences exist between the high and moderate level groups when the item concerning skill variety is examined although there are differences between the low level group and the other two. The use of AMTs produces a shift from a work environment of machine operation to one of increased report, analysis, and adjustment functions. This is supported by the fact that high technology units consider and require a work force with more skill variety to meet and satisfy the new jobs that the use and application of AMTs require.

In items concerning employee autonomy there are significant differences among the three groups. The high level units consider AMTs to have a great impact on the amount of worker control over planning and performing the work which, in turn, results in higher quality performance followed by a high quality product. This could result both in higher worker motivation and in fewer defects, eliminating the need for corrective action.

There are significant differences among the three groups when feedback is examined. The high level units consider that AMTs can provide a greater degree of direct knowledge of results to employees. AMTs can offer more direct communication and improved management information systems. These systems can assist the high level units to take rapid and correct reactions to problems, particularly in the new design or development stages. As we have also seen, units with a high degree of technology can be very flexible in responding to any changes in market and customer needs and preferences.

2.5 Quality Tools

We asked the respondents about some quality tools and the degree to which these are influenced by using AMTs. These tools were examined through tested hypotheses H5.1 through H5.6.

Considerable differences in the three groups were found when the Pareto analysis technique was examined. The high level group believes that AMTs have a great impact on increasing the use of Pareto analysis.

Units with a high level of AMT use should also find those critical few customers and suppliers which can affect the product's quality and the unit's quality improvement efforts.

In items concerning statistical process control (SPC) and statistical quality control (SQC), there is a significant difference among the three groups as AMT use relates to techniques that improve product quality. Essentially, these two statistical tools measure and analyze both process variations and sampling plans. A high technology unit can apply these techniques because of the varied skills of its employees along with its greater ability to invest in quality training programs, even including the use of advanced statistical measures. Also these tools aid in determining process variations by using an advanced integrated computer base. This base can send information to all participants inside the business unit, such as design engineers, marketing staff, production staff, quality staff, and senior management.

When Taguchi's approach is examined there are considerable differences among the three groups on the impact of AMTs use on the application of this approach. Taguchi's approach is a quality improvement method which cannot only improve the product but its design process as well. It seems that the high technology group places more emphasis on the process during the design stage of a product's life. This approach helps in detecting problems early when product research and design are being examined. The high level units apparently realize that competitive design is a powerful manufacturing strategy. Design itself should be considered as a vital flow factor because of its huge influence on the following stages of a product's life cycle. High level units can effectively use their automated facilities to design fewer pieces which will result in a less expensive assembly process and fewer opportunities for manufacturing flaws.

There are significant differences among the three groups when evaluating the degree of implementation of P charts and C charts to monitor variations in the manufacturing process. These charts play an extremely important role in product acceptance. High technology units have a tremendous capacity to communicate, monitor and use statistical methods. They give more attention to the timely evaluation of the performances of processes so that necessary corrective action can be taken before problems occur. High technology level units expend more effort in attempting to attain zero defects than the low level units and it appears that the high level units make wide use of automated statistical quality control systems to achieve these results.

Chapter 5

Conclusions

5.1 The Study's Findings:

The primary focus of the literature dealing with the relationship between advanced manufacturing technologies (AMTs) and quality issues is the technical impact on a product's quality. This study has related three levels of AMTs use intensity (high, moderate and low) with four quality aspects (quality costs, markets and consumers, total employee involvement, and quality tools). It was hypothesized that the different levels of AMT use are more likely to reflect different effects on quality aspects.

Based on the statistical results (explained in chapter 4), the main findings are:

1.1 All groups with different levels of AMT use consider quality a strategic objective for the business unit.

1.2 Among those items which represent quality aspects, there are some which are significantly influenced by the use of AMT. The other items are less significantly influenced by AMTs usage.

1.3 The majority of the quality aspects have been influenced differently among the three levels of AMTs use.

1.4 There are no, or perhaps only insignificant, differences among the three levels of AMT use in terms of quality training costs, warranty periods, market and customer factors, worker responsibility, worker loyalty, and skill variety among the workers.

1.5 It is obvious that Computer Integrated Manufacturing (CIM), Group Technology (GT), and Flexible Manufacturing System (FMS) have not yet matured in terms of length of time of use and percentage of use in manufacturing facilities.

1.6 Based on some telephone conversations with the staffs of some organizations, who are involved in quality functions (questionnaire follow-up stage), it seems that these quality aspects and their improvement can not be isolated for measurement due to the integration and complexity of factories and assembly lines.

1.7 In the moderate level AMTs group, it seems that more consideration is given to the impact of AMT use than in the high level units. The moderate level units are very interested in finding the payoffs from investing in AMT systems. This is particularly true of the units that have used AMT for only a few years and which are in the mid-range of usage percentage. The units with a high level of AMT use seem to be more confident and stable in their attention to some quality cost items which have already been reduced by AMTs use.

1.8 In the AMT justification stage, this study enables managers to evaluate to what extent their companies display quality aspects. Also in the AMT implementation stage, this study helps establish the relative importance of those quality aspects.

1.9 This study devotes more attention in attempting to quantify the role of using AMTs to achieve quality improvements.

5.2 The Study's Limitations:

2.1 This study examined only five different industries, so its results may not be applicable to all industries.

2.2 This study examined only three different forms of AMTs: CIM, GT and FMS, and the four quality aspects, which is what the literature discusses, so the findings may not apply to all advanced manufacturing systems.

5.3 Recommendations For Future Research:

This study can be expanded in many ways:

3.1 Similar studies with different industries and different strategic manufacturing concerns such as, location, operations layout, aggregate planning, inventory management, and scheduling.

3.2 Comparative studies between industries that use AMTs in terms of one of the concerns referred to in 3.1 above, including quality as a competitive advantage.

3.3 Empirical studies to investigate the impact of AMTs on the organizational structure of the managerial unit in charge of quality.

APPENDICES

THE IMPACT OF ADVANCED MANUFACTURING TECHNOLOGIES (AMTs) ON QUALITY IMPROVEMENT IN MAJOR U.S. INDUSTRIAL ORGANIZATIONS

RESPONDENT DATA

NAME: ______________________________

COMPANY: ______________________________

DIVISION: ______________________________

PLANT: ______________________________

TITLE: ______________________________

TELEPHONE ______________________________

BRIEF DESCRIPTION OF YOUR RESPONSIBILITIES: ______________

____

____

LENGTH OF TIME ON THIS JOB: ____________________

1. Listed below are some stages of Advanced Manufacturing techniques. Please indicate whether or not these techniques are being used in you business unit. If "YES", please use the following scale to describe the length of using those techniques.

TECHNOLOGY	YES	NO	LESS THAN 2 YEARS	BETWEEN 2 AND 4 YEARS	MORE THAN 4 YEARS
1. Computer Integrated Manufacturing (CIM).	---	---	-----	------	------
2. Group Technology (GT).	---	---	-----	------	------
3. Flexible Manufacturing System (FMS).	---	---	-----	------	------

2. For those technologies checked "YES" in the previous question, approximately what percentage of your business unit has been using them.

TECHNOLOGY	LESS THAN 25%	BETWEEN 25% AND 50%	BETWEEN 50% AND 75%	BETWEEN 75% AND 90%	MORE THAN 90%
1. Computer Integrated Manufacturing (CIM).	---	---	---	---	---
2. Group Technology (GT)	---	---	---	---	---
3. Flexible Manufacturing System (FMS).	---	---	---	---	---

3. Please indicate how important each of the following strategic points are for your business unit's objective.

	NOT IMPORTANT	SLIGHTLY IMPORTANT	MODERATELY IMPORTANT	REASONABLY IMPORTANT	EXTREMELY IMPORTANT
1. Public image	1	2	3	4	5
2. Market share	1	2	3	4	5
3. Sales revenue	1	2	3	4	5
4. Cost reduction	1	2	3	4	5
5. Quality	1	2	3	4	5
6. Productivity	1	2	3	4	5
7. Profit	1	2	3	4	5
8. Other (please specify)	1	2	3	4	5

4. Do you think your business unit considers planning for quality improvement as a part of strategic planning?

----yes ----no ----don't know

5. Please indicate the quality policy adopted by our business unit

(1) Defect-prevention oriented ----yes ----no

(2) Defect-detection oriented ----yes ----no

(3) Other (please specify)

6. Does your business unit utilize an acceptable quality level (AQL) for major products?

----yes If YES what is the (AQL) in part per million (PPM)

----------ppm OR ----------range

----no

----don't know

7. Please indicate to which degree the following quality-related technical aspects have been influenced by using AMTs.

	STRONG NEGATIVE EFFECT	MODEST NEGATIVE EFFECT	NO EFFECT	MODEST POSITIVE EFFECT	STRONG POSITIVE EFFECT
1. Speed of design processing *	1	2	3	4	5
2. Speed of manufacturing	1	2	3	4	5
3. Reliability degree**	1	2	3	4	5
4. Flexibility degree	1	2	3	4	5
5. Percentage of defects ***	1	2	3	4	5
6. Speed of diagnosis	1	2	3	4	5
7. Speed of adjustment	1	2	3	4	5
8. Speed of measurement	1	2	3	4	5
9. Conformance to specifications	1	2	3	4	5

* Very high speed refers to strong positive effect.

** Reliability refers to the probability that an item will perform a required function under stated conditions for a stated period of time.
Highest degree refers to strong positive effect.

*** Very low percentage refers to strong positive effect.

8. Please indicate to the degree of FREQUENT CAUSES of poor quality in your business unit:

	VERY OFTEN	OFTEN	SOMETIMES	RARELY	NEVER
1. Poor design standards	1	2	3	4	5
2. Lack of training programs	1	2	3	4	5
3. Lack of quality programs	1	2	3	4	5
4. Material standards	1	2	3	4	5
5. Low commitment with quality	1	2	3	4	5
6. Concerns about decreased costs	1	2	3	4	5
7. Concerns about decreased prices	1	2	3	4	5
8. Inefficient measurements	1	2	3	4	5
9. Lack of monitoring	1	2	3	4	5
10. Defectives late reporting	1	2	3	4	5
11. Lack of top management support	1	2	3	4	5
12. Lack of quality training	1	2	3	4	5
13. Lack of quality knowledge	1	2	3	4	5
14. Lack of communication	1	2	3	4	5
15. Other (please specify)					

9. Please indicate to which degree the following MARKETING & CONSUMER items have been influenced by using AMTs with regard to product's quality.

	STRONG NEGATIVE EFFECT	MODEST NEGATIVE EFFECT	NO EFFECT	MODEST POSITIVE EFFECT	STRONG POSITIVE EFFECT
1. Market Share *	1	2	3	4	5
2. Multi-national markets	1	2	3	4	5
3. Number of complaints**	1	2	3	4	5
4. Number of returns***	1	2	3	4	5
5. Warranty period #	1	2	3	4	5
6. Ability to meet deliveries	1	2	3	4	5
7. Loss of customers ##	1	2	3	4	5
8. Product safety	1	2	3	4	5
9. Maintain-ability degree ###	1	2	3	4	5

* Very large market share refers to strong positive effect.

, * Very low number of complaints and returns refers to strong positive effect.

Longer warranty period refers to strong positive effect.

Smallest loss of customers refers to strong positive effect.

Maintainability refers to the ease with which maintenance can be conducted. Very easy refers to strong positive effect.

10. Please indicate to which degree the following COST items* have been influenced by AMTs with regard to quality:

	STRONG NEGATIVE EFFECT	MODEST NEGATIVE EFFECT	NO EFFECT	MODEST POSITIVE EFFECT	STRONG POSITIVE EFFECT
1. Rework	1	2	3	4	5
2. Scrap	1	2	3	4	5
3. Extra inventory	1	2	3	4	5
4. Warranty	1	2	3	4	5
5. Field down time	1	2	3	4	5
6. Lost orders	1	2	3	4	5
7. R & D expenditures	1	2	3	4	5
8. Inspection	1	2	3	4	5
9. Quality training	1	2	3	4	5

* For all of these cost items, reduction costs refers to a positive effect.

11. Listed below are several quality control techniques. Please indicate whether or not these techniques are being used in your business unit. Please indicate which workers implement them.

	YES	NO	OPERATION WORKER	QUALITY WORKER	OTHERS
1. Determination of sample size.	---	---	------	-----	---
2. Control limits.	---	---	------	-----	---
3. Tolerance limits.	---	---	------	-----	---
4. Pareto analysis.	---	---	------	-----	---
5. Number of samples.	---	---	------	-----	---
6. Attribute inspection.	---	---	------	-----	---
7. Variable inspection.	---	---	------	-----	---
8. Inspection frequency.	---	---	------	-----	---
9. Statistical process control.	---	---	------	-----	---
10. Others	---	---	------	-----	---

12. Please indicate to which degree the following WORK FORCE items have been influenced by using ATMs with regard to product's quality.

	STRONG NEGATIVE EFFECT	MODEST NEGATIVE EFFECT	NO EFFECT	MODEST POSITIVE EFFECT	STRONG POSITIVE EFFECT
1. Responsibility	1	2	3	4	5
2. Worker Participant	1	2	3	4	5
3. Worker loyalty	1	2	3	4	5
4. Skill variety	1	2	3	4	5
5. Autonomy	1	2	3	4	5
6. Feedback	1	2	3	4	5

* For all of these items, high degree refers to strong positive effect.

(4) Skill variety refers to the degree to which the job has a sufficient variety of activities to require a diversity of employee skills and talents.

(5) Autonomy refers to the amount of employee self control in planning and doing the work.

(6) Feedback refers to the degree to which direct knowledge of results is provided to employee. Juran (1988, p. 10-37)

13. Does your business unit have a quality control or quality assurance department?

----yes ----no

Please indicate to the importance of the following items as responsibilities of your business unit's quality department.

	NOT IMPORTANT	SLIGHTLY IMPORTANT	MODERATELY IMPORTANT	REASONABLY IMPORTANT	EXTREMELY IMPORTANT
1. Promoting quality ideas	1	2	3	4	5
2. Setting up quality policies	1	2	3	4	5
3. Inspection planning	1	2	3	4	5
4. Defect prevention programs	1	2	3	4	5
5. Analysis of causes of defects	1	2	3	4	5
6. Quality cost analysis	1	2	3	4	5
7. Preparing executive reports	1	2	3	4	5
8. Training for quality	1	2	3	4	5
9. Inspecting incoming parts	1	2	3	4	5
10. Inspecting finished products	1	2	3	4	5
11. Inspecting shipment of products	1	2	3	4	5
12. Reviewing customer feedback	1	2	3	4	5

14. Listed below are several quality improvement programs.
Please indicate whether or not these methods are being used in your business unit.
If "YES", please use the following scale to describe the importance of these methods.

	not important	slightly important	moderately important	reasonably important	extremely important
1. Quality training program.	1	2	3	4	5
2. Quality team program.	1	2	3	4	5
3. Quality control circle.	1	2	3	4	5
4. Defect prevention program.	1	2	3	4	5
5. Quality cost analysis.	1	2	3	4	5
6. Zero defect team.	1	2	3	4	5
7. Other (please specify).	1	2	3	4	5

15. Please indicate to which degree the following MEASURABLE AND METHODOLOGICAL items have been influenced by AMTs with regard to product's quality:

	STRONG NEGATIVE EFFECT	MODEST NEGATIVE EFFECT	NO EFFECT	MODEST POSITIVE EFFECT	STRONG POSITIVE EFFECT	NOT APPLICABLE
1. Control limits	1	2	3	4	5	
2. Tolerance limits	1	2	3	4	5	
3. Pareto analysis	1	2	3	4	5	
4. Attribute inspection	1	2	3	4	5	
5. Variable inspection	1	2	3	4	5	
6. Number of samples	1	2	3	4	5	
7. Sample size	1	2	3	4	5	
8. Inspection frequency	1	2	3	4	5	
9. Stat. process control *	1	2	3	4	5	
10. Stat. quality control	1	2	3	4	5	
11. Taguchi's approach	1	2	3	4	5	
12. P chart	1	2	3	4	5	
13. C chart	1	2	3	4	5	

*** Stat. = STATISTICAL**

(1) Control limits based on the statistical variation of the process can be established at some specific parameters.

(2) Tolerance limits refer to the range of values in which individual units of output must fall in order to be acceptable.

(3) Pareto analysis states that a few contributors to the cost of poor quality are responsible for the bulk of the cost. These vital few contributors need to be identified so that quality improvement resources can be reviewed.

(4) Attribute inspection refers to go and no-go information.

(5) Variable inspection refers to the measurement information.

(9) STATISTICAL PROCESS CONTROL (spc) refers to the application of statistical techniques for measuring and analyzing the variation in processes.

(10) Statistical quality control (SQC) refers tot he application of statistical techniques for measuring and improving the quality of processes. SQC includes SPC, diagnostic tolls, sampling plans, and other statistical methods.

(11) Taguchi approach is a system of steps:
a. develop product specifications,
b. incorporate the specifications into process and/or a product,
c. Obtain output that actually surpasses those specifications.
Quality costs are measured relative to society rather than to just the producer.

(12) P chart is control chart to monitor the proportion of defectives generated by a process. The center line is the average fraction defective in the population.

(13) C chart is a control chart to monitor the number of defectives generated by a process. The center line is the number of defects per number of samples.

16. For the following statements, please show the degree of your agreement:

(1) Strongly Disagree	(2) Mildly Disagree	(3) No Effect	(4) Mildly Agree	(5) Strongly Agree
___	___	___	___	___

(1) AMT techniques can discover early causes of instability.
1 2 3 4 5

(2) Applying AMT techniques reduces the time required from the conceptual stage to commercial introduction. 1 2 3 4 5

(3) Applying AMT techniques eases the identification and solution of quality problems. 1 2 3 4 5

(4) Applying AMT techniques considers preventive costs much than failure costs.
1 2 3 4 5

(5) AMT techniques achieve unity of product design and manufacturing process.
1 2 3 4 5

(6) AMT techniques contribute to prevent quality problems during customer usage. 1 2 3 4 5

(7) AMT techniques contribute to establishing sufficient tolerance limits considering flexibility systems and interchangeable parts.
1 2 3 4 5

(8) AMT Techniques enlarge worker participation in quality performance.
1 2 3 4 5

(9) AMT techniques reduce the inspection frequency.
1 2 3 4 5

(10) AMT techniques contribute to quality policies getting closer to considering international an multiple markets.
1 2 3 4 5

(11) AMT techniques affect the belief that product price could be considered as quality rating.
1 2 3 4 5

(1) Strongly Disagree	(2) Mildly Disagree	(3) No Effect	(4) Mildly Agree	(5) Strongly Agree
_____	_____	_____	_____	_____

(12) AMT techniques ease the performance of computerized inspection techniques. 1 2 3 45

(13) AMT techniques require good communication between production and design departments.
1 2 3 45

(14) AMT techniques implement the required changes in the product design without compromising the quality.
1 2 3 45

(15) AMT techniques achieve high speed in responding to the changes in customer attitude toward quality.
1 2 3 45

(16) AMT techniques support the selling policy which emphasize quality rather than price.
1 2 3 45

(17) AMT techniques is considered wasted investment without hiring well trained and skilled work force.
1 2 3 45

(18) AMT techniques achieve less reliance on inspection and more use of statistical quality control.
1 2 3 45

(19) AMT techniques have created demand for different types of quality specialist in the manufacturing systems.
1 2 3 45

(20) AMT techniques have created demand for different types of quality cost measure and reports.
1 2 3 45

GLOSSARY

Availability: It is time-related and is measured by the extent to which the user can secure service when he or she wants it.

C. Chart: It is a control chart to monitor the number of detectives generated by a process. The center line is the number of defects per number of samples.

Cause: Is a proved reason for the existence of the defect.

Computer-Aided Design (CAD): Provides interactive graphics that assist in the development of product and part designs, tool designs, and specifications.

Computer-Aided Manufacturing (CAM): Means the use of computers directly to control the processing equipment or material-handling equipment or indirectly to support manufacturing operations.

Computer Aided Tolerance Analysis (CITY): Is a method of analyzing the effects of tolerance build up due to the manufacturing process.

Computer-Integrated Manufacturing: A group of modular subsystems, each of which are controlled by computers that are interconnected to form a distributed manufacturing system.

Computer Limits: Are statistical limits that reflect the extent to which sample statistics such as means ranges can vary due to randomness alone.

Defect: Is any state of unfitness from use, or non conformance to specifications. A defect also goes by other names, e.g., error, discrepancy, non conformance.

Diagnosis: Is the process of studying symptoms, theorizing as to causes, testing theories, and discovering causes.

Fixed-alternative questions: A question in which the respondent is given specific limited alternative responses and asked to choose the one closest to his or her own viewpoint.

Flexible Manufacturing System (FMS): Is a group of general computer controlled machine tool linked by a materials handling system and a mainframe computer to completely process a group of parts.

Group Technology (GT): Is the analysis and comparison of items to group them into families with similar characteristics.

P Chart: Is a control chart to monitor the proportion of detectives generated by a process. The center line is the average fraction defective in the population.

Pareto Analysis: States that a few contributors to the cost of poor quality are responsible for the bulk of the cost. These vital few contributors need to be identified so that quality, improvement resources can be concentrated in those areas.

Process Variability: Reflects the natural or inherent variability in a process.

Quality: The totality of features and characteristics of a product or service that bear on its ability to satisfy given needs.

Quality Circles: Are quality improvement and self-improvement study groups. A circle is usually composed of workers and their supervisors who function as leaders.

Quality Information Management System (QIMS): A system that provides automated data gathering and analysis of inspection results and manufacturing work center performance to determine the part numbers that are to be modified, full mandatory, or problem inspection candidates.

Quality teamwork: The entire enterprise can be viewed as a network of people in interdependent supplier (Produces) customer relationships.

Statistical Process Control (SPC): The application of statistical techniques for measuring and analyzing the variation in processes.

Statistical Quality Control (SQC): The application of statistical techniques for measuring and improving the quality of processes.

Taguchi approach: A system of steps: (1) develop product specifications, (2) incorporate the specifications into a process and/or a product and (3) obtain output that actually surpasses those specifications. Quality costs are measured relative to society rather than to just the producer.

Summary of Multiple Comparisons

$U_{ii'}$

Variable	M Vs H	M Vs L	H Vs L
Quality	0.52339181	0.53564593	0.51212121
Mktsh1	0.45175439	0.30382775	0.34343434
Natmkt	0.30555556	0.28636364	0.45353535
Nocomp	0.51900585	0.38325359	0.37070707
Noretu	0.45760234	0.37320574	0.41010101
Warper	0.37134503	0.31770335	0.43232323
Metdlv	0.52777778	0.32870813	0.3040404
Loscus	0.51608187	0.25598086	0.23232323
Prdsaf	0.50292398	0.29210526	0.26262626
Mainta	0.40204678	0.33564593	0.4040404
Rework	0.4751462	0.334689	0.35353535
Scrap	0.51461988	0.31602871	0.32323232
Extinv	0.36403509	0.30645933	0.43838384
Warran	0.3625731	0.38923445	0.51414141
Dowtim	0.49415205	0.35406699	0.35151515
Losord	0.45175439	0.35741627	0.39090909
Rdexpe	0.52046784	0.33133971	0.30505051
Qutrai	0.45175439	0.36220096	0.38787879
Respon	0.36988304	0.35143541	0.47272727
Partici	0.48830409	0.33229665	0.33232323
Loyalt	0.48976608	0.37488038	0.38585859
Skivar	0.40497076	0.32464115	0.3979798
Autono	0.60964912	0.37033493	0.26161616
Feebac	0.5248538	0.32344498	0.3
Pareto1	0.51900585	0.26698565	0.27979798
Attins1	0.55994152	0.32727273	0.26464646
Spc1	0.64473684	0.30861244	0.19393939
Sqc	0.48976608	0.28684211	0.3010101
Taguch	0.53362573	0.35191388	0.31919192
Pchart	0.52046784	0.30191388	0.3040404
Cchart	0.50730994	0.3076555	0.2979798

$| U_{ii'} - .5 |$

Variable	M Vs H	M Vs L	H Vs L
Quality	0.023391813	0.035645933	0.012121212
Mktsh1	0.048245614	0.19617225	0.15656566
Natmkt	0.19444444	0.21363636	0.046464646
Nocomb	0.019005848	0.11674641	0.12929293
Noretu	0.042397661	0.12679426	0.08989899
Warper	0.12865497	0.18229665	0.067676768
Metdlv	0.027777778	0.17129187	0.1959596
Loccus	0.016081871	0.24401914	0.26767677
Prdsaf	0.0029239766	0.20789474	0.23737374
Mainta	0.097953216	0.16435407	0.095959596
Rework	0.024853801	0.165311	0.14646465
Scrap	0.014619883	0.18397129	0.17676768
Extinv	0.13596491	0.19354067	0.061616162
Warran	0.1374269	0.11076555	0.014141414
Dowtim	0.0058479532	0.14593301	0.14848485
Losord	0.048245614	0.14258373	0.10909091
Rdexpe	0.020467836	0.16866029	0.19494949
Qutrai	0.048245614	0.13779904	0.11212121
Respon	0.13011696	0.14856459	0.027272727
Partici	0.011695906	0.16770335	0.16767677
Loyalt	0.010233918	0.12511962	0.11414141
Skivar	0.09502924	0.17535885	0.1020202
Autono	0.10964912	0.12966507	0.23838384
Feebac	0.024853801	0.17655502	0.2
Parto1	0.019005848	0.23301435	0.22020202
Attins1	0.05994152	0.17272727	0.23535354
Spc1	0.14473684	0.19138756	0.30606061
Sqc	0.010233918	0.21315789	0.1989899
Taguch	0.033625731	0.14808612	0.18080808
Pchart	0.020467836	0.19808612	0.1959596
Cchart	0.0073099415	0.1923445	0.2020202

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