DATA VISUALIZATION &

TQM IMPLEMENTATION

A STUDY OF THE IMPLEMENTATION OF DATA VISUALIZATION IN TOTAL QUALITY MANAGEMENT IN VICTORIAN MANUFACTURING INDUSTRY

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EXECUTIVE SUMMARY

Introduction

Data visualisation (DV) is the process of creating and presenting a chart given a set of active data and sets of attribute and entity constraints. It rapidly and interactively investigates large multivariate and multidisciplinary data sets to detect trends, correlations, and anomalies.

Data Visualisation is the latest analytical tool for both technical computer users and business computer users. Total Quality Management (TQM) is continuous improvement in the performance of *all processes and the products and services* that are the outcomes of those processes. In quality management, DV is one of the three new tools that complement the existing seven, which are flow charts, Ishikawa or cause and effect diagrams, Pareto charts, histograms, run charts and graphs, scattergrams and control charts. It lets quality control engineers readily see the real reasons for quality problems by presenting the data in up to six dimensions.

Methodology

A survey by mail questionnaire was conducted to collect data from one hundred Victorian manufacturing companies. Responses were received from 52 companies out of the total of 100. The sample size for each analysis may vary from 52 to 49.

The source for company information was Kompass Australia 1994/1995. The statistical analysis tool used was Statistica.

Major Findings

The TQM program implementation tends to be more complete in companies with more employees.

Wordprocessing software is adopted by all companies in TQM practice, mostly for producing a quality instructional manual. Spreadsheet and database packages are the second and the third most commonly used software.

Companies that have completed their formal TQM program implementation generally use computer software in more aspects of their TQM practice than companies at lower TQM stages though not always.

Two-dimensional DV techniques are more commonly used than three-dimensional ones with the 2-D colour and 2-D shade the most widely used by all. The 3-D animation tool needs to be explored.

DV features are generally important for all the users. The ability to handle complex data is more important for companies at a higher stage of TQM program implementation than companies at lower stages.

CHAPTER ONE

INTRODUCTION

1.1 Background of Research

In the United States and the United Kingdom, Visual Data Analysis (VDA) software business has been booming for the last couple of years.

Carl Machover, industry analyst and president of Machover Associates Corp., White Plains, NY, says that VDA is a blossoming business - a robust $1.5 million market in 1992 and growing at a healthy 18% per year. Machover projects that by 1998, the industry will mushroom into a $4.9 million market.

Both technical and business computer users are turning to VDA software for data analysis. The users said that what VDA software did to technical computing equals what the spreadsheet had done to business computing.

However, up to now there has been little formal research into the implementation of Data Visualisation technology in Australia. There has been little information about whether Australian industries are using Data Visualisation software or how Data Visualisation technologies are serving Australian Business. An interest to fill a gap in the development of Data Visualisation has led to this research.

1.2 Introduction to Data Visualisation (DV)

Presenting information in visual terms is a practice that is as old as the human race.

Data visualisation is the latest data presentation technique which contributes tremendously to complex data analysis.

1.1.1 What is Data Visualisation?

Parsaye & Chignell (1992) explain:

> Data visualisation is the process of creating and presenting a chart given a set of active data and sets of attribute and entity constraints. Data visualisation is concerned with understanding the patterns, trends, and relationships that exist in groups of numbers, which must be related to some model of the domain of interest. They are then used to close the knowledge gap between the user's understanding of the current situation and the situation as it actually is (p.22).

Bourne (1993) defines data visualisation in another way: Visualisation is 'the ability to gather the largest amount of information in the least amount of time from a particular set of views. Those views can range from simple text to the representation of a set of data points in some graphical way to a digitised image that can be manipulated in real-time' (p.38).

Thus, data visualisation is part of a cybernetic (feedback) process of knowledge acquisition about situations and systems. It is a tool for presenting the trends and relationships that are implicit in numerical data. Numerical data represents snapshots in time about different aspects of systems. Understanding of the situation can be gained by viewing charts that summarise these numerical snapshots in a meaningful way. For instance, in a marketing application, the system could be products, advertising expenditures, customers, and the demographic and lifestyle attributes that differentiate the response of different market segments to different products. In quality control, the system might be the production process and the causes of defects, along with the workers who monitor the system and the customers who react to the quality of the product over time (Parsaye & Chignell 1992, p. 22).

1.1.2 Data Visualisation Techniques

Data visualisation involves a range of techniques that enable the display of abstract numerical data and statistics in graphical form to provide a way of identifying and analysing underlying patterns in data.

Many elements combine to make up data visualisation technology. Among them are animation (rapidly changing still images used to create the illusion of movement), 3-D graphics (an illusion of depth produced by using perspective), and rendering (computer images created to represent the surfaces of 3-D objects, complete with shading and texture) (Weber 1993, p. 121).

Virtual reality (VR) is a natural extension of data visualisation. VR increases the number of dimensions in which information can be displayed and allows the user to "enter" and explore the information as if it were a physical environment. The first VR product for market traders, Metaphor Mixer from Maxus Systems International of New York, appeared in 1993. It represents financial instruments as animated 3D objects in market "terrain". The shape, colour and movement of the objects indicates factors such as price and volume and volatility of sales (Davidson 1994, p. 28).

1.1.3 Hardware Requirements

Until recently, only super-computer users had access to visualisation's full potential. Now anyone with a Personal Computer (PC) or a Macintosh (Mac) can produce sophisticated and meaningful visualisations with "off-the -shelf "software.

Whether it is a Mac, a PC, or a workstation, the main requirements for visualisation are fast maths-processing capabilities and high-quality graphics. A 66-Mhz 486 PC with VGA graphics or a PowerMac is able to perform most kinds of visualisation. The more powerful the machine, the more sophisticated the visualisation application can be. In order to conduct animation, a video-out card may be needed to transfer the sequences to the videotape (Weber 1993, p. 122).

CHAPTER TWO

LITERATURE REVIEW

2.1 Visual Data Analysis (VDA) Software

Data visualisation systems can be general or they may be customised to deal with particular application areas (eg. project management or quality control). For instance, in project management, data visualization provides decision makers with a high level view of project status using 3D colour pictures and network diagrams. The visual representation of the project network makes it easy to understand the schedule of the project as well as the complexity, cost, and risk involved in each project.

Data Visualisation technologies have integrated graphical user interfaces (GUI) with presentation graphics software. GUIs simplify the process of creating presentation graphics. Products such as Precision Visuals Inc's and IMSL Inc's PV-Wave Advantage application development software, SAS Institute Inc's SAS/Insight database management system (DBMS) and DSP Development's DADisp DBMS represent great strides in the visualisation area.

A notable example of a data visualisation GUI builder is SL Graphical Modeling System from SL Corp. in Corte Madera, California. SL-GMS develops dynamic graphics screens for real-time and highly interactive applications. Non-programmers can design application screens in standard drawing-tool modes, connect them to real-time data sources and animate screen objects to visualise changing data values (Miles 1993, p. 18).

PV-Wave

One example of commonly used VDA software is PV-Wave. PV Wave from Precision Visuals is an interactive Visual Data Analysis (VDA) software for the Sun, DEC, IBM RS/6000, HP/Apollo, and Silicon Graphics environments running UNIX, ULTRIX, or VMS. It is available in two formats - a command language version and a point-and-click version. The Point & Click version eliminates the need to learn syntax or commands while keeping most of the power of the command language version. PV-Wave point and click provides convenient access to various kinds of files. Data Visualisation is the program's strength, and data can be visually interpreted and analysed in various ways (Francis 1992, p. 55).

A list of common VDA software names and contact addresses is presented in Appendix 1.

2.2 Functions of VDA Software

Brian Ritchie, IBM's vice president of marketing, says visual data analysis software normally consists of four component functions. The first is data access, which is the importing and exporting of information to and from the visualisation program, including links to external data sources. The second function is data management, which is the ability to save, restore and manage data once it is in the system, including utilities for reading and writing data from formats generated by simulation programs, test instruments or real-time data acquisition devices, and support for standard industry file formats. The third is data analysis, which includes most mathematical, statistical, time series and data modeling algorithms, and support of common image processing operations and functions. The final function is visualisation, or the display techniques that add the graphic elements to the image, which includes 2-D and 3-D surface displays, colour, shading and animation (Dickey 1992, p. 20).

2.3 VDA Software Application Area

Data visualisation is important in all applications for which large amounts of data must be sifted and interpreted. Visualisation provides a picture of the data and its internal relationships to make it easier to understand complex information. For instance, medical researchers (epidemiologists) gather reams of data daily from hospitals across the country. This data is collected for analysis, the goal of which might be to improve diagnostic capabilities or to prevent disease. For instance, a striking relationship is found between average per capita consumption of fat and incidence of cancer. Data visualisation can illustrate such relationships by graphically demonstrating the correlation among variables (Parsaye & Chignell 1992, p.22).

Data Visualisation can assist in the analysis of numerical data by presenting it graphically, and assist the comprehension of complex information more easily. What is more, today's data visualisation software is easy to learn, simple to use and, quite cheap to buy. All these features are leading to a wide implementation of data visualisation software.

VDA application areas currently include scientific research, test engineering, engineering for design, medical imaging, experimental analysis, simulation, energy exploration, financial analysis, and quality control. Here are some examples.

2.3.1 Medical Imaging

In his article 'Visual analysis software opens windows on medicine', Baum (1993) told a very interesting story about how VDA software helped a medical doctor with his research.

Dr. Roger Pierson is an associate professor in the Department of Obstetrics and Gynecology at the University of Saskatatchewan in Saskatoon, Canada, and director of the school's Reproductive Biology research unit, which is mainly concerned with the study of infertility.

Like many clinics of this type, the reproductive Biology unit relies heavily on ultrasound technology to generate pictures of internal body tissues. These are black and white images which are studied against a light board, similar to x-rays. Because most people can only discern a dozen or so shades of grey through this visual inspection, medical diagnoses, as well as research efforts, are marked to some degree by uncertainty and guess-work.

Pierson hoped to make his science more exact by bringing computers into the process. He worked with engineers from the company producing the unit's ultrasound equipment to devise a way to capture the images. Now, instead of being fed to a video processor, the images are directed to a digitiser, and then posted to a Sun Microsystems Inc. workstation. Then the images are interrogated by visual data analysis (VDA) software.

The package Pierson and his team use is PV-Wave, from Visual Numerics Inc. of Houston. PV-Wave integrated all the key components of image processing: accessing, manipulating, and analysing the data, displaying it visually; and outputting it as an image or as numerical data. The end result is that the Sun workstation can distinguish 256 shades of grey in an ultrasound image; by using PV-Wave's bandwidth filters, superimposed colours, and three-dimensional visualisation techniques, even finer distinctions and variations can be observed (p. 66).

2.3.2 Quality Control (QC)

According to Parsaye & Chignell (1993), Data Visualisation is 'the ninth' QC tool that complements the existing seven tools of quality together with the eighth tool, information discovery, and the tenth tool, hypermedia..

Most diagramming techniques used within the seven existing tools of QC are 2-D and do not reflect state-of-art developments in computer technology. Three dimensional (3-D) visualisation adds the critical third dimension to graphical views of data, giving depth of charts and graphs and more fully exploiting human perception capability. Graphic visualisation of large data bases can represent up to six dimensions: the three Euclidean dimensions (height, width, and depth), plus box size, colour, and shading. This lets QC engineers readily see the real reasons for quality problems (p. 109).

Data visualisation is essential for understanding data and interpreting information. People are highly visual and see patterns in well-presented figures that are less noticeable in corresponding tables of numbers. Here are some data visualisation capabilities that are particularly useful in QC:

- The 2-D box plot lets analysts view the range of values on one variable that are associated with a specific range of values on another variable.
- The 3-D bar chart displays the relative frequencies (scaled along the z axis) of groups identified as falling within specific ranges on two variables (plotted along the x and y axis). The 3-D bar chart provides a 3-D representation of the data and represents the relative frequencies of variate range combinations in terms of the heights of bars as opposed to the size of boxes.
- The 3-D box diagram is similar in concept to the 2-D box plot. Each box is centred at a point that represents its mean value within a combination of ranges along the x, y, and z axes. Whereas the area of each box in a box plot indicates the relative frequency of its combination of field values (Parsaye & Chignell 1993, pp. 111-112).

2.4 Total Quality Management

2.4.1 Definition

Total Quality Management can be defined in many ways. Bruce Irwin (1990), the founding Chief Executive of Enterprise Australia, defined total quality management as 'continuous improvement in the performance of *all processes and the products and services* that are the outcomes of those processes'.

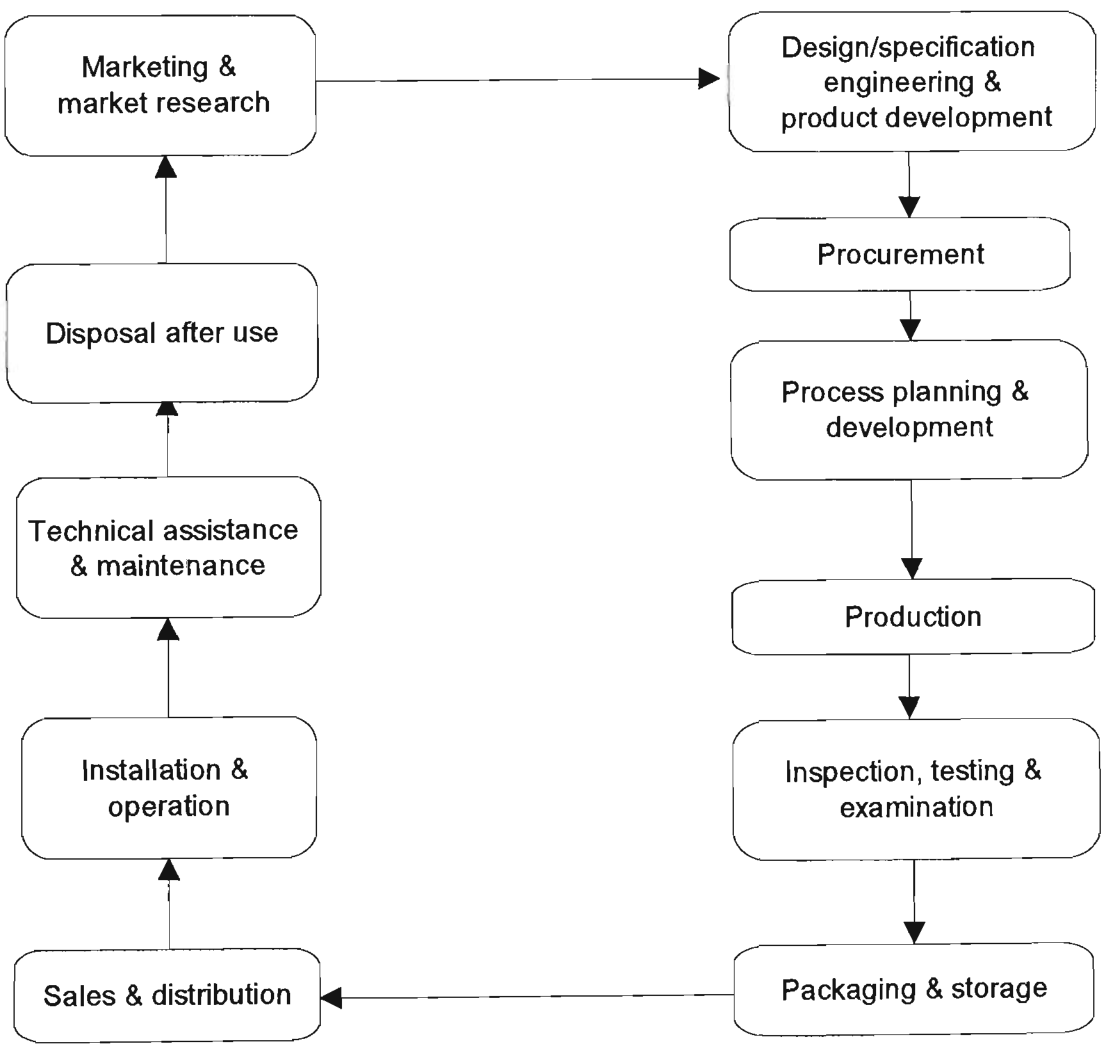
The main difference between the traditional approach to quality and Total Quality Management is the word 'Total'. A totality of involvement which has transformed Quality Management from being at best the monitor of manufacturing mistakes to being at the center of the drive to improve its total operations performance (Slack 1991, p. 24)

This means that TQM involves all functional areas in an organisation, from product design and development, to manufacturing, to marketing and to administration.

2.4.2 Quality System in an Manufacturing Organisation

The interrelationship of all the activities through which the goods or services are produced is often described as a 'quality loop'. A quality loop described by Standards Association of Australia (1987) for a manufacturing company is reproduced in Figure 2.4.2. All possible activities associated with a particular product are included in the loop, from initial design to final disposal. Implementing TQM involves the improvement of all of these activities and their inter-relationships with each other. In addition, the relationship of the manufacturing company and its suppliers for a number of the activities on the right hand side of the loop offers potential for the application of TQM, as do the relationships of the activities on the left hand side of the loop with the customers. The whole process keeps circling as product improvements are continuously designed and implemented with the aim of exceeding current customer requirements (Gilmour & Hunt, 1995, p. 3).

Figure 2.4.2 The Manufacturing Quality Loop



2.4.3 Basic TQM Tools

According to McConnell(1986), there are seven basic techniques for total quality management. They are flow charts, Ishikawa or cause and effect diagrams, Pareto charts, histograms, run charts and graphs, scattergrams and control charts.

Flow charts

Constructing a flow chart is an effective way to understand a process quickly and clearly. A complete understanding of the process is a prerequisite to use this tool. McConnell(1986) suggests a technique as 'imagineering'. With imagineering, the user draws a flow chart of the real process and another flow chart of an ideal process. The difference between the two flow charts is the area to be improved.

Ishikawa or cause and effect diagrams

The cause and effect diagrams are used to define the relationship between a particular quality characteristic (the effect) and the factors which impact it (the cause). The quality to be controlled is a measurable characteristic such as diameter, length, or hardness of an item, or the completion time, defective percentage of a process.

Pareto charts

A Pareto chart is a bar chart with the horizontal axis showing the variable of interest (the type of errors, factors contributing to the problem, types of products) and the vertical axis showing the number of occurrences of each factor. It is used to determine the significance of quality problem factors and hence determine how improvement efforts can be prioritized.

Histograms

A histogram is a chart (usually a simple column chart) that plots a distribution analysis which reports the number of items in a data range that fall between specified boundaries.

Run charts and graphs

A run chart shows the trends or unusual movements in the process over time. It can be a line diagram or a graph or a bar chart, with time on the horizontal axis and variable of interest (percentage of defective or production volume, etc.).

Scattergrams

Scattergrams are typically used to determine what kind of relationship - if any - exists between two data series. On both axes of a scattergram are values of variables. Data is collected in pairs and each pair is represented by a dot or point on the scattergram. As more pairs are plotted, the relationship between the two variables becomes apparent.

Control charts

Control charts are usually constructed to determine if and when the operation is out of control. It sets a target value and upper and lower control limits. If a subsequent observation of the process falls outside the control limits it is identified as abnormal.

2.5 Summary

The main types of Data Visualisation tools are colour, size, shade, shape and animation. These tools can appear in two dimensional form or three dimensional form.

The main benefits of Data Visualisation technologies can be summarised as

- analysing numerical data graphically;
- viewing data multidimensionally;
- revealing the effects of multiple factors on each other clearly;
- displaying data changes over time; and
- comprehending complex information more easily.

Data Visualisation is one of the three new quality management tools that complement the existing seven.

CHAPTER THREE

RATIONALE

3.1 Purpose of Study

The purpose of the study is to find out how Data Visualisation technology has been implemented in Australia. However, due to limitations of resources and time, the research area is narrowed down to the implementation of Data Visualisation technology in the total quality management (TQM) in Victorian manufacturing industry. This includes

- what DV techniques have been adopted for TQM purpose; and
- in what aspects of TQM DV technologies are implemented.

Users' perception of the importance of DV technology and their future expectation of DV technology for the purpose of TQM are also explored.

In this research, the subject is general Data Visualisation technology and not any particular VDA software. There are two reasons for this:

1) the term of 'VDA software' is not commonly used in Australia. An uncommon term in a questionnaire might bias the responses of the survey.
2) Nowadays, most software has Data Visualisation features and can be used for Data Visualisation purpose to some extend.

The findings of this research will give direction to future research on Data Visualisation so as to improve the techniques of Data visualisation and better serve Victorian manufacturing industry's use of TQM.

3.2 Theoretical Framework

Since the main object of this research is to find out to what extend Data Visualisation (DV) technology has been implemented in Victorian manufacturing industry, ***the implementation of DV technology*** is the main factor of interest of the study and varies according to other factors, hence it is the dependent variable.

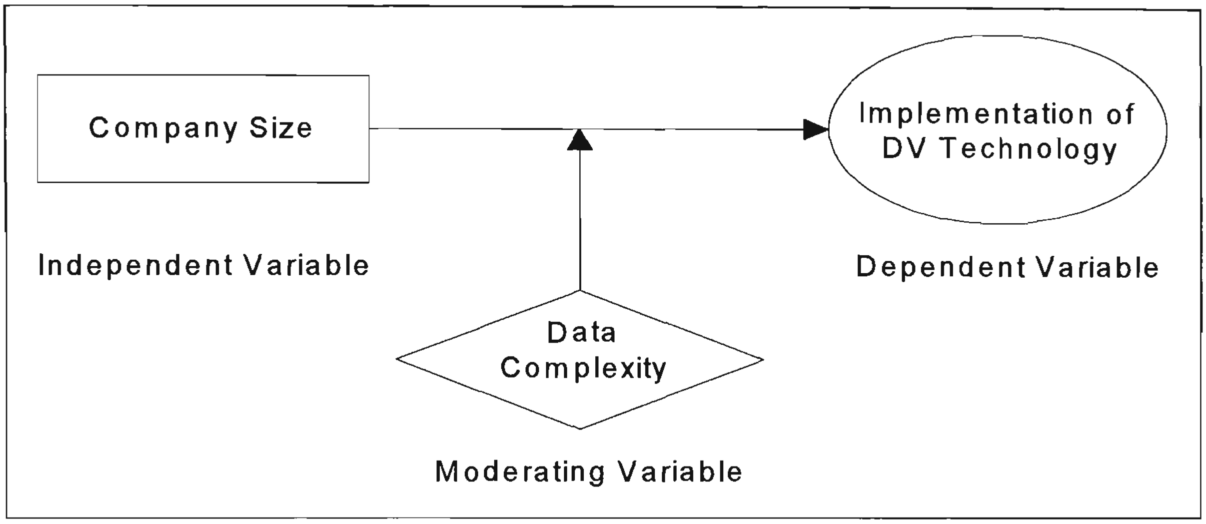
The two most important independent variables that are hypothesised to influence the dependent variable are ***company size*** and ***stage of TQM program implementation***. The moderating variable of ***data complexity*** modifies the relationship between the independent variable of firm size and the dependent variable. The intervening variable of *aspects of quality management* surfaces between the time the independent variable ***stage of TQM program implementation*** operates to influence the dependent variable and its impact on the dependent variable. The independent variable of company size also influences the other independent variable of stage of TQM program implementation. The interrelationships hypothesised among the variables are explained as below.

3.2.1 Company Size and the Implementation of DV Technology

In the literature review, all the examples of companies which have adopted VDA software are large companies. For example, Fourgen Software Inc and IBM have introduced new tools for analysing data stored on multiple SQL database servers (Bowen 1994, p33). To exploit the “bandwidth” of our visual sense to interpret complex high volume data, organisations such as Morgan Grenfell, Lehman Brothers and Barclays BZW are now using data visualisation products originally developed for scientific application (Davidson 1994, p28). It can thus be argued that there is a relationship between the independent variable: firm size, and the dependent variable: implementation of DV technology.

Although this relationship can be said to hold true, it is the complex data the large companies have that impels the large companies to use DV technology, for complex data analysis is one of the main features of DV technology. With small quantities of data, numerical data analysis will serve the purpose easily. Thus complex data moderates the relationship between company size and implementation of DV technology. To put it differently, the relationship between company size and the implementation of DV technology is contingent upon data complexity. The judgement of 'data complexity' is subject to respondents' perception, for no explicit definition of the term could be identified from the literature review. The influence of data complexity on the relationship between the independent variable and the dependent variable can be diagrammed as Figure 3.2.1.

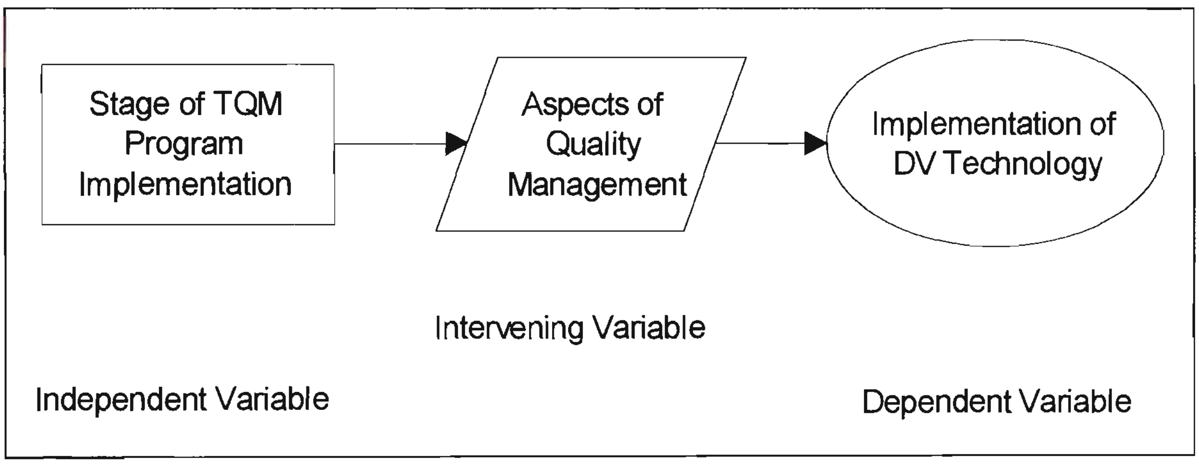
Figure 3.2.1 Diagram of the relationship between the independent variable (company size) and the dependent variable (implementation of DV technology) as moderated by the moderating variable (data complexity)



3.2.2 Stage of TQM Program Implementation and the Implementation Of DV Technology

The stage of TQM program implementation influences the implementation. If a company has started implementing a TQM program, it would have considered or started implementing DV technology to most or all of the aspects of its quality management in order to assist the implementation of the TQM program. Likewise, if a company has completed the implementation of a TQM program, it would have implemented DV techniques in all aspects of its TQM. Thus the intervening variable, aspects of quality management, surfaces as a function of the stage of TQM program implementation. This is how the stage of TQM program implementation influences the implementation of Data Visualisation technology. The dynamics of these relationships are illustrated in Figure 3.2.2.

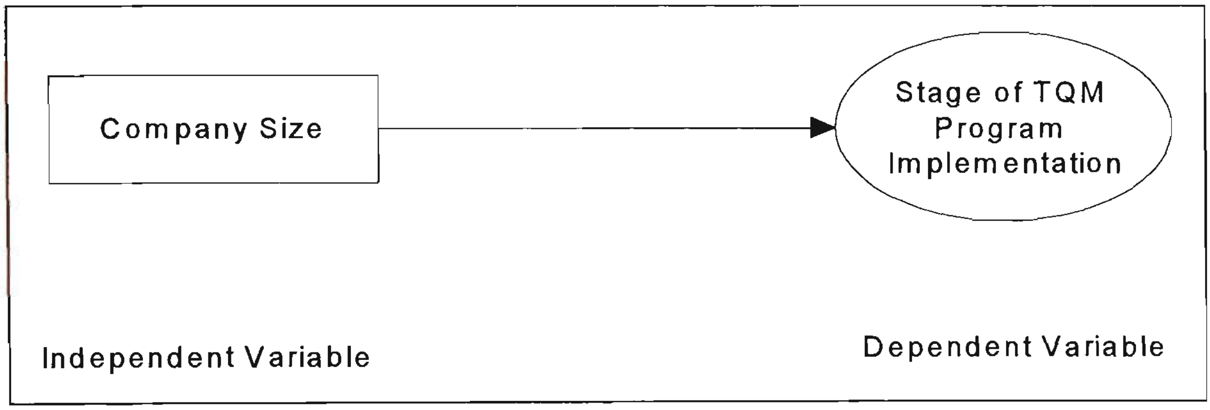
Figure 3.2.2 Diagram of the relationships among the independent (stage of TQM program implementation), intervening variable (aspects of quality management) and the dependent variable (implementation of DV technology)



3.2.3 Company Size and Stage of TQM Program Implementation

Company size also influences the stage of TQM program implementation. The quality operation in large companies is more complicated than that in small companies. Large companies need a formal program to manage their quality operations more urgently than small companies. In addition, large companies have higher capacity to adopt new techniques such as TQM to improve their management. This relationship is diagrammed in Figure 3.2.3.

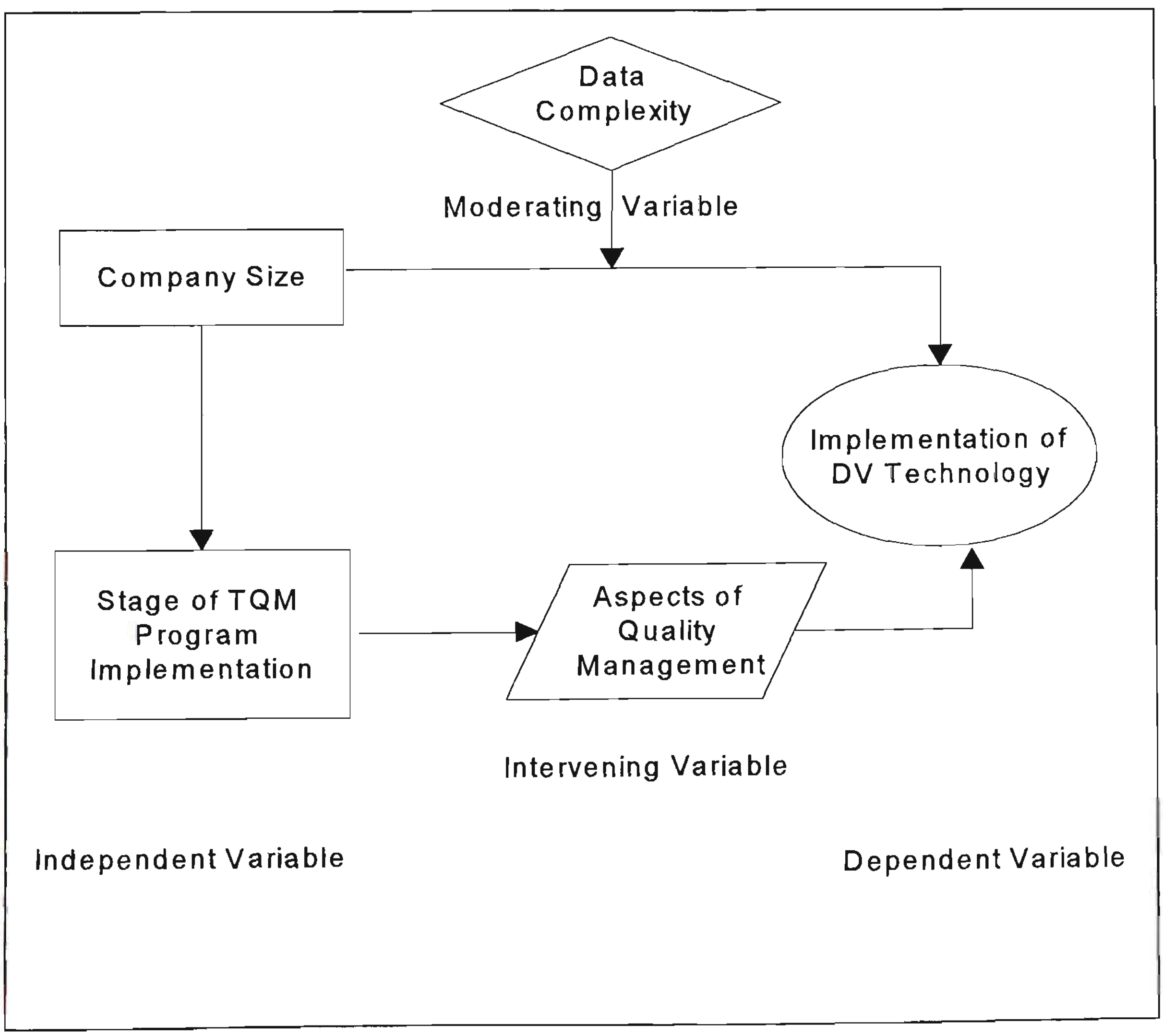
Figure 3.2.3 Relationship between the independent variable (company size) and the independent variable (stage of TQM program implementation)



3.2.4 Summary

In sum, company size and stage of TQM program implementation significantly influence the implementation of DV technology and explain the variance in it. In the mean time, data complexity moderates the relationship between company size and DV implementation. Aspects of quality management intervene between the stage of TQM program implementation and the implementation of DV technology. Company size also influences the stage of TQM program implementation. The relationships between these factors are schematically diagrammed in Figure 1.4.4.

Figure 3.2.4 Schemetic diagram of the theoretical framework



3.3 Hypothesis Statements

To test whether the relationships that have been theorised among the variables do in fact hold true, five hypotheses have been developed. By testing these hypotheses scientifically, we will be able to obtain some reliable information on what kinds of relationships exist among the variables and thus figure out what factors are involved and how the factors influence the implementation of Data Visualisation technology in the TQM practice in Victorian manufacturing industry. The results of these tests will offer us some clues as to what could be done to improve the implementation of DV technology. The hypothesis statements are as follows.

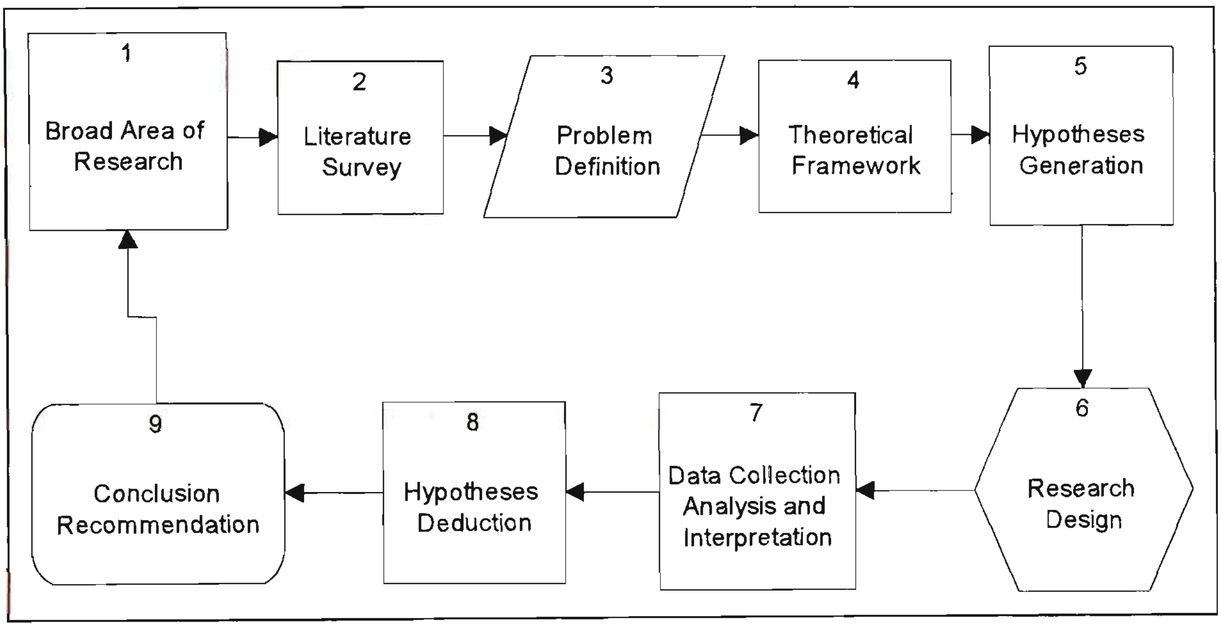
1. Large companies have more complex data than small companies.
2. Companies which report they are ahead with TQM implementation use DV techniques to a more advanced level.
3. Companies which have completed TQM programs implementation use DV techniques in more aspects than companies that have not implemented TQM programs.
4. DV techniques are more important to companies that have implemented TQM programs than companies that have not implemented TQM programs.
5. There is a positive correlation between the size of a company and the stage of TQM program implementation the company is at.

CHAPTER FOUR

METHODOLOGY

The approach of this research is survey. It adopts the hypothetico-deductive method. This method starts with a theoretical framework, and formulating hypothesis, and makes logical deductions from the results of the study (Uma 1992, p. 15). The process of the research is diagrammed in Figure 4.0.

Figure 4.0 Diagram of the research process



4.1 Population and Sampling

4.1.1 Population

Due to the limitation of research resource, the survey is geographically restricted within Victoria and classically restricted among manufacturing organisations. The population of the research is the quality managers of Victorian manufacturing organizations. This population is considered to be practical for the research work and also valuable in respect of outcomes.

4.1.2 Sampling

It is practically impossible for a sole researcher to collect data from the entire population within the given time limit, therefore sampling is necessary. Stratified random sampling is used to reduce the number of elements.

The companies are stratified into three groups according to their employee numbers. These three groups are companies with employee number less than one hundred, between one hundred and five hundred and more than five hundred. They are referred to as small-size firms, medium-size firms and large-size firms. After stratifying the elements, a disproportionate sampling method is used to decide the final subjects for the survey. The proportions of the subjects from each stratum is forty per cent from large-size companies and thirty per cent from each of the medium and small-size companies. This sampling method is in line with hypothesis 5, which hypothesizes the stage of TQM program implementation has a positive correlation with the difference of the company sizes. It is easier to test this hypothesis when the population of the survey is stratified by company size. In addition, companies at higher stages of TQM program implementation are hypothesized to be more likely ahead with the implementation of data Visualization technology as opposed to medium or small-size companies. Assuming these hypotheses substantiate, company size and the implementation of Data Visualization technology will be positively correlated. Thereby in order to explore the application of data Visualization technology in Victorian manufacturing industry, it is useful to assign an excess proportion of the subjects from the large-size companies over the subjects from medium and small size companies.

4.2 Data Collection Method

The data collection method used in this research is mail questionnaire. Kompass Australia 1994/1995 was used to identify specific organizations according to activity classification for *manufacturing* and both postcode and telephone number beginning with '3'. One copy of the questionnaire was mailed to each of the quality managers in the sampled one hundred Victoria manufacturing organisations.

The respondents are assumed to be highly educated and have no problem with understanding the questions addressed in the questionnaire. As managers, the respondents do not usually have flexible schedules so that it is good for them to have a choice of arranging their time to fill in the questionnaire. In this case, mail questionnaire is the most suitable means to collect data for this survey.

The questionnaire itself comprises four sections numbered as A, B, C and D. Section A examines the variables of company size and stage of TQM program implementation. This section tests hypothesis five (H5). It answers the questions of 'whether large companies are at a higher stage of TQM implementation than smaller companies.' Section B examines the relationship between the stage of TQM program implementation and aspects of quality management, the relationship of which was hypothesized in hypothesis three (H3). Hypothesis two (H2) is also tested in this section. It answers the questions 'whether companies which are ahead with TQM implementation use DV techniques to a more advanced level'; and 'whether companies which have completed TQM program implementation use DV techniques in more aspects than companies that have not implemented a TQM program'. Section C examines the participants' perception regarding the importance of the main data Visualization features to their total quality management. Section D offers the participants a copy of the results of the survey.

The questionnaire had been tested by five random companies before it was administered to the survey population. This pilot study gathered valuable information for further refinement. A copy of the final questionnaire is attached in Appendix 4.

4.3 Data Processing and Analysis

Fifty-two companies responded to the survey, however the sample size in each analysis may slightly vary due to the fact that not all respondents answered all the questions.

Data were processed and analyzed using Statistica, a Microsoft package for statistical analysis. Frequency Tables, stub-and-banner Tables, correlation Matrix and ANOVA/MANOVA modules were utilized to carry out the analysis of sample distribution, correlations between different variables and variance among different variables against a certain criterion. The significance of the statistical analysis was also taken into consideration.

4.4 Limitations of Study

The applicability of the findings may be constrained due to the following reasons:

- The sample size was limited by the limited resource of time and funds.
- The industry applicable area is constrained within manufacturing companies.
- The reference materials are limited because the topic of DV has not emerged for long.
- No work in the area of this research could be identified from the available literature.
- The sources of reference materials for DV are limited within U.S.A. and U.K..

CHAPTER FIVE

FINDINGS

5.1 The Sample Profile

5.1.1 Distribution According to Size of Companies

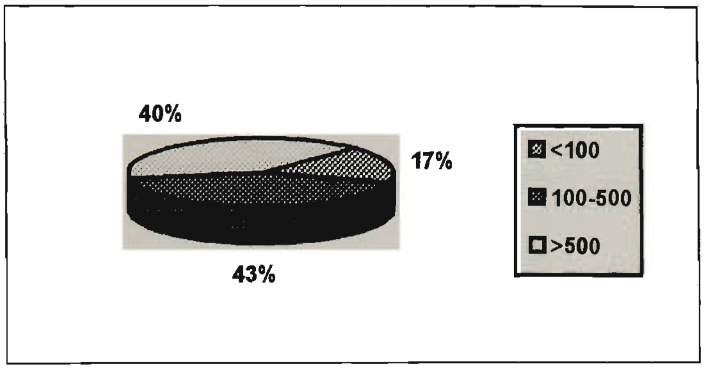
The size of companies is categorised in two ways. One method used is to categorise the companies by the number of employees. The other method used is to classify the companies by their turnover volume.

5.1.1.1 Distribution According to Employee Level

The normal employee levels used to classify manufacturing companies are less than one hundred, between one hundred and five hundred and over five hundred. The companies that fall within these three levels are categorised as small, medium and large companies.

Using this classification the sample had unequal numbers of companies of different sizes. With a total number of fifty-two, twenty-one of them are classified as large companies, twenty-two as medium companies and nine of them are classified as small companies. The percentage of the sample is shown in Figure 5.1.1.1.

Figure 5.1.1.1 Distribution of Sample According to Employee Level



5.1.1.2 Distribution According to Turnover Volume

With classification of turnover volume, small companies are defined as those with less than \$10 million turnover per year. Companies with yearly turnover between \$10 million and \$100 million are classified as medium-size companies. Large companies are those with yearly turnover more than \$100 million.

Table 5.1.1.2 Distribution According to Turnover Volume

Turnover of Company	No of Companies	%
< \$10m	2	3.8
\$10m - \$100m	26	50.0
>\$100m	24	46.2

From Table 5.1.1.2 we can see that 50% of the sample can be classified as medium-sized companies, and 46.2% and 3.8% of the sample are large and small companies respectively.

5.1.1.3 Relationship between Turnover Volume and Employee Level

Table 5.1.1.3a Correlation between Turnover Volume and Employee Level

Correlation Coefficient (r)	p	N
.84	.0000	52

The correlation coefficient is close to +1, which means that the turnover volume of the company is highly positively correlated to the employee level of the company, but the relationship is not always perfect. The p value is zero, which indicates that this test result is significant.

Table 5.1.1.3b Turnover Volume vs Employee Level

	< $10m	$10m - $100m	> $100m	Total
< 100	22.2 %	77.8 %	0.0 %	9
100 - 499	0.0 %	86.4 %	13.6 %	22
≥ 500	0.0 %	0.0 %	100.0 %	21
Total	3.9 %	50.0 %	46.2 %	52

Most of the small companies and medium companies (77.8% of the small companies and 86.4% of the medium ones) have turnover volume between $10 million and $100 million while all the large companies have turnover above $100 million. Only 22.2% of the small companies have a low volume of turnover, which makes the correlation between the employee level and turnover volume imperfect.

5.1.2 Distribution According to Structure of Companies

5.1.2.1 Distribution According to the Existence of a Separate Quality Management Department

Table 5.1.2.1 shows that a high percentage (80.8%) of the sample have a separate quality management department in the company. The percentage of companies with a separate quality department increases from small companies to large companies accordingly. All large companies had a separate quality department.

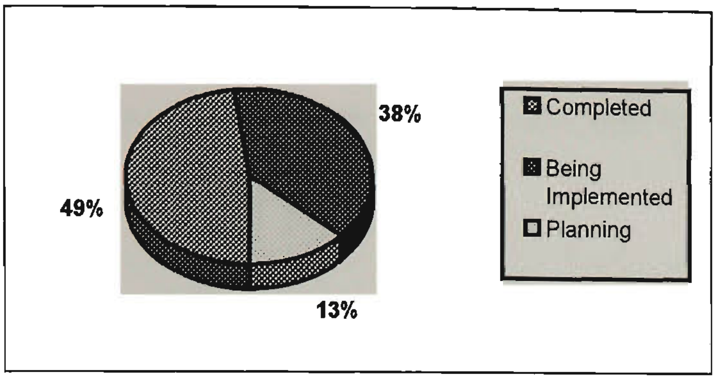
Table 5.1.2.1 Company Structure in Respect of Separate Quality Department According to Size of Company

	Has Separate Quality Department	Does not Have a Separate Quality Department	Total
<100	55.6 %	44.4 %	9
100 - 499	72.7 %	27.3 %	22
>500	100.0 %	0.0 %	21
Total	80.8 %	19.2 %	52

5.1.2.2 Distribution According to the Stage of Implementation of a Formal Total Quality Management (TQM) Program

All the companies have taken actions on TQM programs. Nearly half of them have actually completed the TQM program implementation, as demonstrated in Figure 5.1.2.2.

Figure 5.1.2.2 Distribution of Sample According to the Stage of Implementation of a Formal TQM Program



5.1.2.3 Correlation between Stage of TQM and Size of Companies

Table 5.1.2.3 Correlation between Stage of TQM and Size of Company

Variable x & Variable y	r (x, y)	p	N
Employee & Stage of TQM	.79	.0000	52
Turnover & Stage of TQM	.69	.0000	52

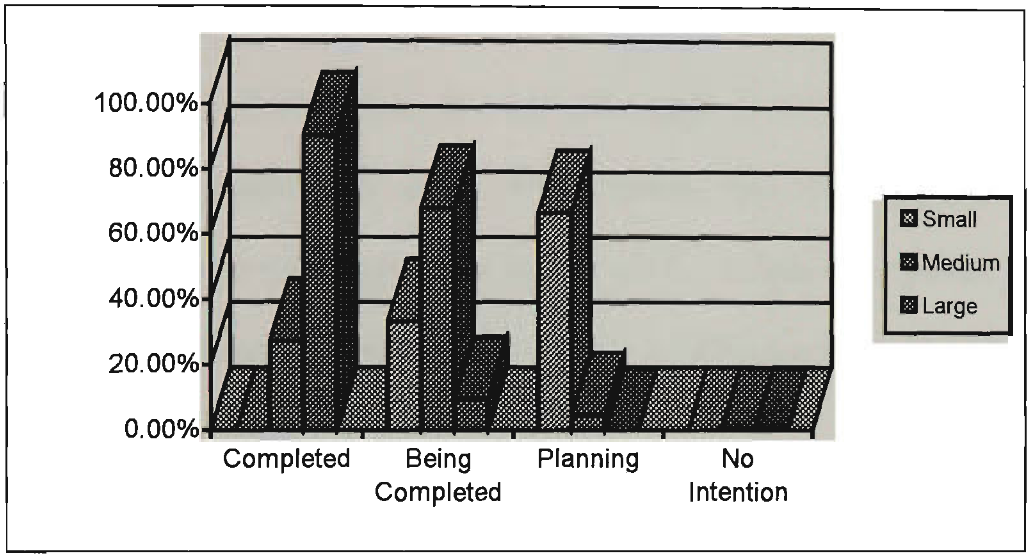
In Table 5.2.1.3, employee level is from low to high. Stage of TQM is from planning to completion or in other words, from low to high as well.

Both correlation coefficients, r values are high, so that both the relation between employee level and the stage of TQM implementation and the relation between the turnover volume and the stage of TQM implementation are positive.

Since r(Turnover & Stage of TQM) > r(Employee & Stage of TQM), employee level is more closely related to the stage of TQM program implementation and hence is chosen as the criterion for company size classification.

5.1.2.4 Stage of the Implementation of a TQM Program According to Size of Companies

Figure 5.1.2.4 Stage of the Implementation of a TQM Program According to Size of Company



According to Figure 5.2.1.3, over 90% of the large companies have completed the implementation of a formal TQM program. Nearly 70% of the medium-sized companies are implementing the program and about 70% of the small companies are still at the planning stage. This pattern conforms with the correlation result in 5.2.1.3.

5.2 The Adoption of Data Visualisation Tools

Wordprocessors, spreadsheets, databases, statistics and quality-documenters are the types of computer software that were set up to check which type of software is the most commonly used and which type is the least commonly used in the total quality management of the sample companies. It is assumed that there are differences between the frequencies of the software application among the three different sizes of companies.

5.2.1 Test of the Hypothesis of Frequency Differences of the Software Application among Different Sizes of Companies

In order to determine whether there are any differences in the frequencies of the computer software application among the three different sizes of companies, a one-way analysis of variance (ANOVA) was carried out to compare the means of the software application frequencies in the three groups of different sizes of companies. The null and alternative hypotheses are as follows:

Null hypothesis(*H0*): There is no difference in the frequencies of the computer software application among the three different sizes of companies.

Alternative hypothesis (*H1*) : There are differences in the frequencies of the computer software application among the three different sizes of companies.

The F statistic values were computed and compared with the appropriate F critical values at 95% confidence interval. The group size varies from 52 to 46 , which leads to the within group degree of freedom (df_w) varying from 49 to 46. However, with the same between group degree of freedom (df_b) of 2, the critical values for df_w=40 (3.23) and the critical value for df_w=60 (3.15) are not much different. Likewise, the critical values for df_w=49 and df_w=46 with the same df_b=2 would be almost the same. Therefore, the critical value for this test is decided to be the value which is close to the median of critical values for df_w=40 and df_w=60 with df_b=2 , which is 3.20, for the ease of analysis.

The statistical significance was also tested. In this test, the effects are significant at $p < .0500$. The results are regarded to be highly statistically significant if $p < .0100$.

Table 5.2.1 One-way Analysis of the Frequency Differences of the Software Application among Different Sizes of Companies

Type of software	F statistic	f critical $df_b = 2$, $df_w = 49$ $\alpha = .05$	Accepted Hypothesis	p Level	Statistical Significance
Wordprocessor	- -	3.20		- -	
Spreadsheet	6.34	3.20	F > f, *H1*	.004	Highly significant
Database	11.04	3.20	F >f, *H1*	.0001	Highly significant
Statistics	10.90	3.20	F >f, *H1*	.0001	Highly significant
Quality-Documenter	.79	3.20	F < f, *H0*	.46	Not significant

The above table reveals that spreadsheet, database and statistical packages are used at significantly different frequencies by the three different sizes of companies whereas there is not much difference on the adoption of a Quality-documenter or a wordprocessor. The detailed differences are explained in the following section.

5.2.2 Types of Computer Software Adopted by Different Size of Companies

Table 5.2.2 Types of Computer Software Used in Total Quality Management According to Size of Companies

	Word-processor	Spread-sheet	Database	Statistics	Quality-Documenter
Small	100.0 %	55.6 %	33.3 %	11.1 %	11.1 %
Medium	100.0 %	86.4 %	72.7 %	50.0 %	27.3 %
Large	100.0 %	100.0 %	100.0 %	0.0 %	14.3 %
Total	100.0 %	86.5 %	76.9 %	23.1 %	19.2 %

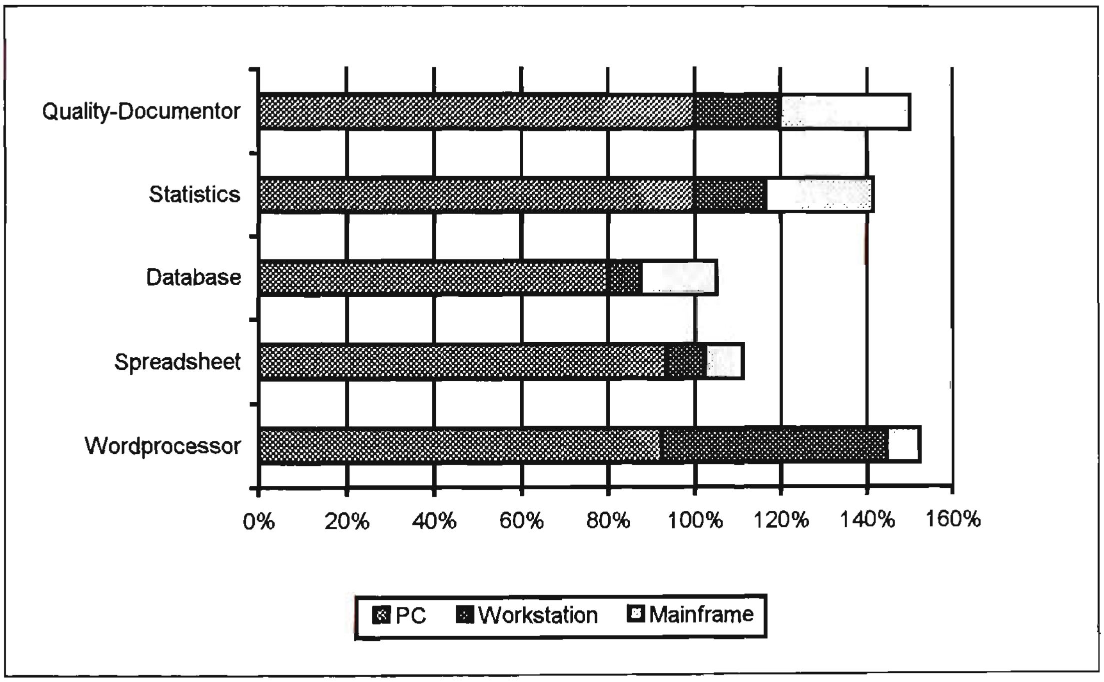
Wordprocessor, spreadsheet and database software are the most commonly used computer software in the total quality management of the sample companies. The percentage of applications for these three types of software are 100%, 86.5% and 76.9% respectively. Statistical packages and quality-documenter packages are much less commonly used, with only around twenty percent users.

With regard to the differences in the software adoption by different sizes of companies, wordprocessing packages are used by all companies while quality-documenter packages are not highly used by any group of companies. The adoption of spreadsheet, database and statistical packages varies significantly for different sizes of companies. Among the three types of software, the frequency of the application of spreadsheet and database packages increases with the increase of company size. The frequency of statistical packages applications has a rather strange pattern. It increases from the small companies to medium companies but stops this increasing trend suddenly with a zero frequency of application by large sized companies.

5.2.3 Hardware Support for the Software Adopted

The distribution of different types of hardware support for different types of software adopted is shown in Figure 5.2.3.

Figure 5.2.3 Hardware Support for Different Types of Software Adopted



PC is the dominant hardware support for the software adopted in TQM. The lowest percentage base of PC is 80%, for database packages. One hundred percent of quality-documenter and statistics packages are base on PCs.

All types of software in use are also located on workstations and mainframes, although rarely.

The bar length exceeds 100% means that the particular type of software is located on more than one type of hardware. In this case, all types of software adopted are located on PCs plus both or either of workstations and/or mainframes.

Detailed percentages are provided in Table 5.2.3.

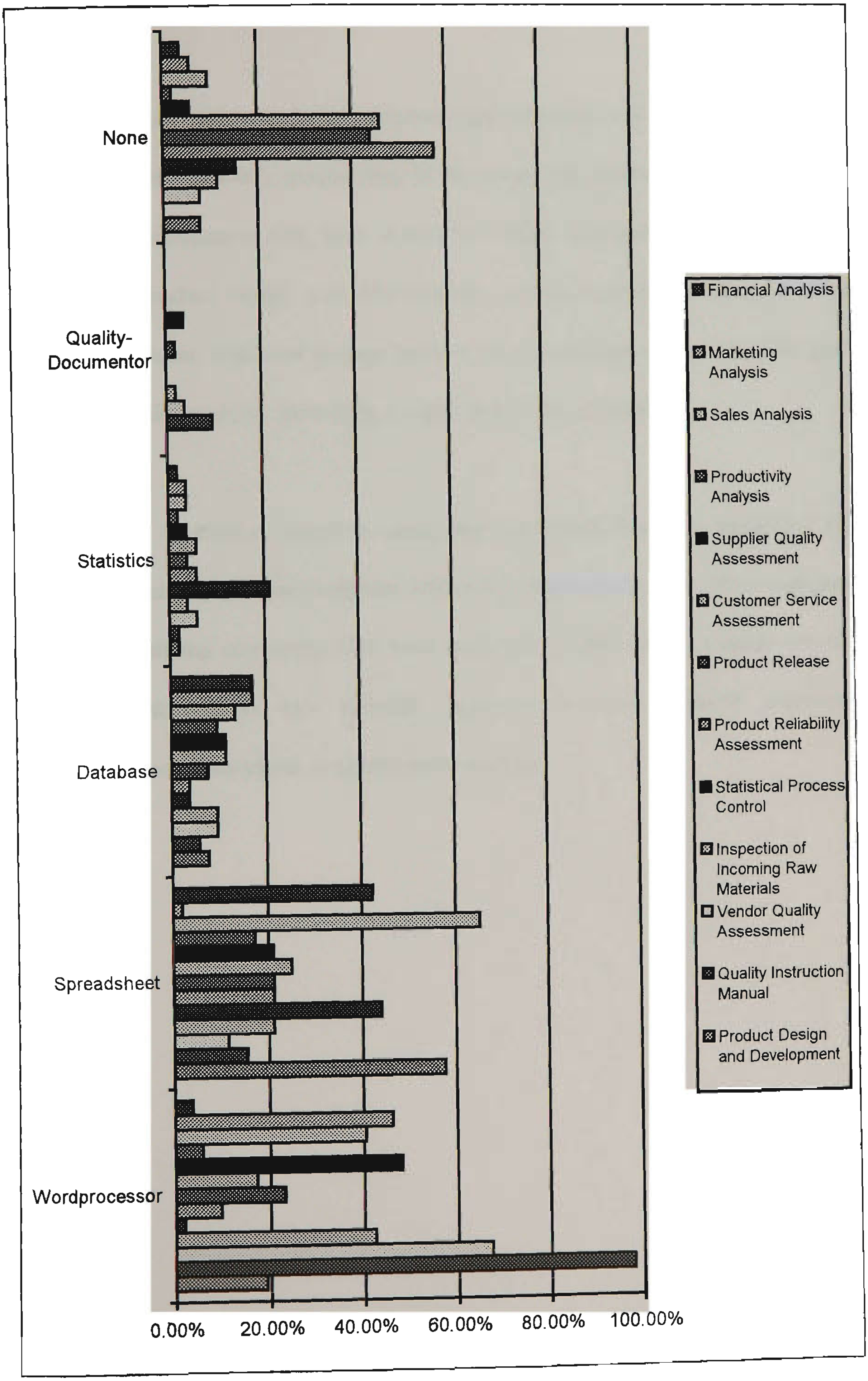
5.2.4 The Application of Different Types of Computer Software in Different Aspects of TQM

The aspects of TQM that were surveyed for the use of the computer software are: production design and development, quality instruction manual, vendor quality assessment, inspection of incoming raw materials, statistical process control, product reliability assessment, product release, customer service assessment, supplier quality assessment, productivity analysis, sales analysis, marketing analysis and financial analysis.

5.2.4.1 General Pattern of the Application of Different Types of Computer Software in Different Aspects of TQM

Figure 5.2.4.1 reveals that almost all (98%) of the companies use wordprocessing packages to produce their quality instruction manuals. Wordprocessing software is also the most commonly used software for vendor quality assessment, recording of the inspection of incoming raw materials, recording of product release, supplier quality assessment and marketing assessment. Spreadsheet software is commonly used for sales analysis (65.4%) as well as product design and development. It is also the most commonly used type of software for statistical process control, product reliability assessment, customer service assessment, productivity analysis, and financial analysis. Database, statistics and quality-documenter packages are not commonly used for TQM at all. The detailed percentages for Figure 5.2.3.1 are presented in Table 5.2.4.1 in Appendix 3.

Figure 5.2.4.1 The Application of Different Types of Software in Different Aspects of TQM



5.2.4.2 Companies That Use Computer Software in Different Aspects of TQM According to Their Stage of TQM Program Implementation

Companies at all stages of TQM program implementation use computer software in TQM very often. The only outstanding difference among companies at different TQM stages is all companies that have completed TQM implementation use computer software in product design and development, quality instructional manual, vendor quality assessment, statistical process control, product release record, supplier quality assessment, sales analysis, marketing analysis and financial analysis.

However, the conclusion cannot be made that companies that have completed TQM program implementation use computer software in more aspects than other companies, because not all the companies that have completed TQM implementation are using computer software for raw material inspection, product reliability assessment, customer service assessment or productivity analysis.

Table 5.2.4.2 Companies That Use Computer Software in Different Aspects of TQM According to Their Stage of TQM Program Implementation

	Completed %	Being Implemented %	Planning %
Product Design & development	*100.00*	85.00	85.71
Quality Instructional Manual	*100.00*	100.00	100.00
Vendor Quality Assessment	*100.00*	100.00	71.43
Inspection of Incoming Raw Material	96.00	80.00	85.71
Statistical Process Control	*100.00*	75.00	57.14
Product Reliability Assessment	20.00	65.00	57.14
Product Release	*100.00*	75.00	71.43
Customer Service Assessment	32.00	70.00	32.00
Supplier Quality Assessment	*100.00*	90.00	85.71
Productivity Analysis	76.00	60.00	24.00
Sales Analysis	*100.00*	80.00	85.71
Marketing Analysis	*100.00*	90.00	85.71
Financial Analysis	*100.00*	90.00	100.00

N varies from 49 to 52.

5.2.5 The Adoption of Data Visualisation Techniques in TQM

The Data Visualisation techniques that were surveyed were two dimensional and three dimensional tools with the five same aspects, which are colour, shade, size, shape and animation. The general pattern of the use of Data Visualisation tools and the deference in the Data Visualisation tools application among different size of companies are explored.

5.2.5.1 The General Pattern of the use of Data Visualisation Tools in TQM

Figure 5.2.5.1 General Pattern of the use of Data Visualisation Tools

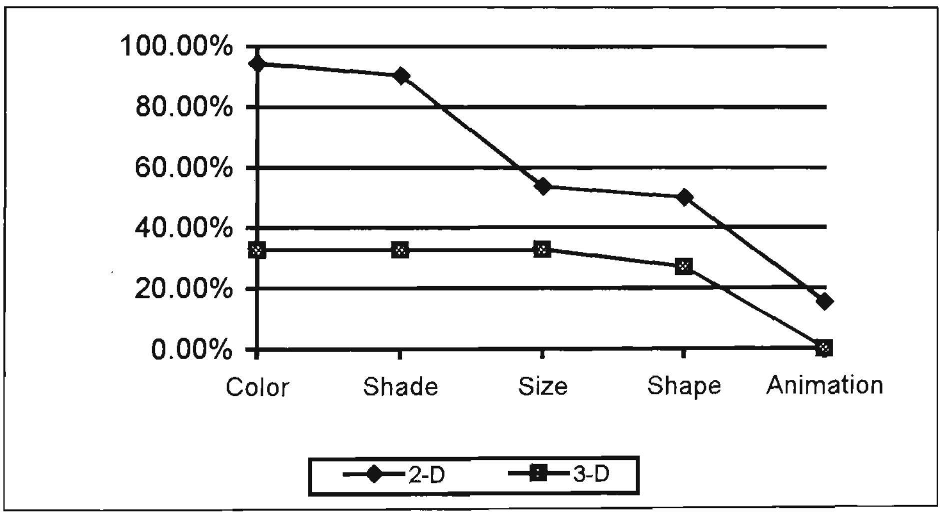


Figure 5.2.4.1 demonstrates explicitly different patterns for the adoption of 2-D techniques and 3-D techniques. Two-dimensional tools are much more widely used than the three-dimensional ones. Within the two-dimensional tools, colour and shade are the most commonly used, being used by nearly one-hundred percent of users. Meanwhile, 2-D size and 2-D shape are also commonly used with over half of the

users. As a contrast to the two-dimensional tools, none of the three-dimensional tools are commonly used, especially the 3-D animation tool which has not been adopted by any of the sample companies.

Three-dimensional tools are regarded as more advanced than two-dimensional tools. Unfortunately more advanced tools are generally less commonly used. How are the tools used in different sizes of companies? The answer is provided in the next section.

5.2.5.2 ANOVA Test on the Level of Data Visualisation Tools Application in TQM among Different Sized Companies

It is assumed that there are differences in the use of the Data Visualisation tools among different size companies. In order to determine whether this assumption is true, a ANOVA test was carried out to compare the means of the each of the tools' application frequencies in the three groups of different sizes of companies. The null and alternative hypotheses are as follows:

Null hypothesis(*H0*): There is no difference in the frequencies of the Data Visualisation Tools application among the three different sizes of companies.

Alternative hypothesis (*H1*) : There are differences in the frequencies of Data Visualisation Tools application among the three different sizes of companies.

The confidence interval, degrees of freedom and statistical significance criteria are the same as those applied in the ANOVA test in 5.2.1.

Table 5.2.5.2 One-way Analysis of the Frequency Differences of the Data Visualisation Tools Application among Different Sizes of Companies

DV Tools	F statistic	f critical $df_b = 2$, $df_w = 49$ $\alpha = .05$	Accepted Hypothesis	p Level	Statistical Significance
2-D Colour	3.09	3.20	F < f, *H0*	.054	Not Significant
2-D Shade	2.20	3.20	F < f, *H0*	.121	Not significant
2-D Size	8.23	3.20	F >f, *H1*	.0008	Highly significant
2-D Shape	6.14	3.20	F >f, *H1*	.0004	Highly significant
2-D Animation	.13	3.20	F < f, *H0*	.877	Not Significant
3-D Colour	5.76	3.20	F > f, *H1*	.006	Highly Significant
3-D Shade	5.76	3.20	F > f, *H1*	.006	Highly Significant
3-D Size	4.15	3.20	F > f, *H1*	.022	Significant
3-D Shape	6.55	3.20	F > f, *H1*	.003	Highly Significant
3-D Animation	- -	3.20		- -	

The above table reveals that there is not significant difference in the use of two-dimensional colour and two-dimensional shade tools among the three different sizes of companies, though the effects are not very significant.. However, the table reveals that there are significant differences in the use of two-dimensional size, shape, and three dimensional colour, shade, size and shape among the three different size of companies. And the effects are highly significant. The detailed differences are explained in the following section.

5.2.5.3 The Usage of Data Visualisation Tools According to Size of Companies

Table 5.2.5.3 Data Visualisation Tools Application According to Size of Companies

	2 - Dimension				
	Colour %	Shade %	Size %	Shape %	Animation %
Small	77.8	77.8	66.7	55.6	11.1
Medium	95.5	86.4	77.3	72.7	18.2
Large	100.0	100.0	23.8	23.8	14.3
n = 52					

	3 - Dimension				
	Colour %	Shade %	Size %	Shape %	Animation %
Small	0.0	0.0	0.0	0.0	0.0
Medium	54.6	54.6	50.0	50.0	0.0
Large	23.8	23.8	28.6	14.3	0.0
n = 51					

The percentage figures in the table tell us that 2-D colour and 2-D shade tools are very commonly used by all size of companies with an increasing trend from small to large companies (from 77.8% to 100%). 2-D size and 2-D shape are also commonly used by small companies and medium-sized companies (over 50%) but not the large companies (23.8% for both tools). In fact, the large companies are only favourable to 2-D colour and 2-D shade. All the other tools are only used by a small proportion of the large companies with the percentage use being between fourteen and thirty except a zero for 3-D animation tool. None of the small companies has introduced three-dimensional tools into their total quality management, whilst over half of the medium-sized companies are using three-dimensional colour, shade, size and shape.

In general, Data Visualisation tools are more commonly used in large companies than in small-sized companies for TQM purpose, and large companies use the Data Visualisation tools to more advanced levels than the small companies. These tools, however, are most commonly used in the medium-sized companies at all levels. This non-linear relationship between the level of DV tools implementation and the size of companies could be due to two reasons. Firstly, the 2-D tools are powerful enough. Secondly, it is not easy to change software or adopt more advanced tools due to lack of training opportunities for the user or high cost of software, etc. Nevertheless, further research is needed to identify the causes of this relationship.

5.2.6 Rating of the Importance of Data Visualisation Features

The main Data Visualisation features are summarised as :

- Handle complex data easily
- Display periodic data changes in one graph
- Recognise the effects of multiple factors on each other
- Analyse data quickly
- Analyse data accurately

The importance is scaled at three levels as very important, important and not important. Missing data are deleted casewise and the percentage of missing data is summarised in the column of 'no comments'.

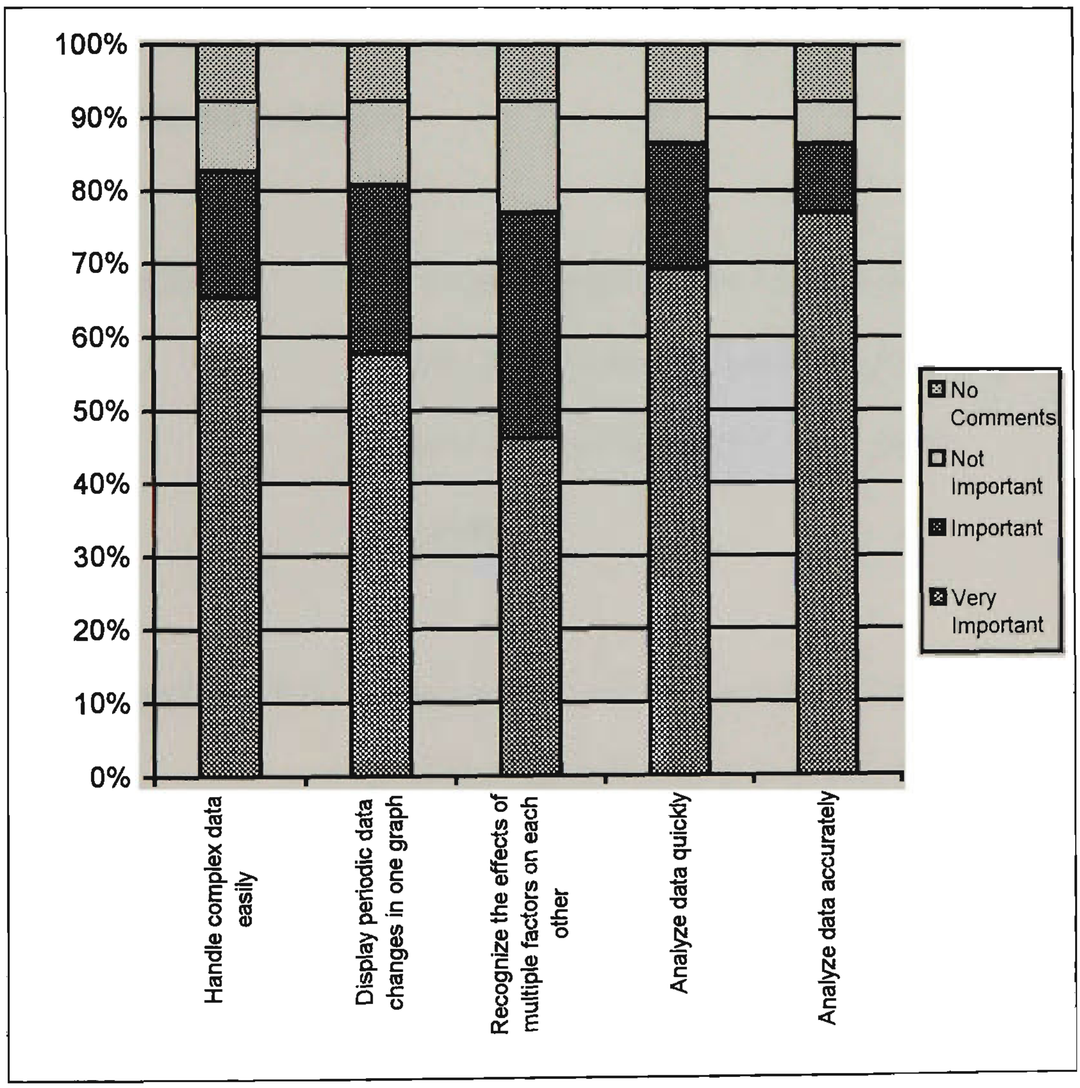
The general rating for the importance of these Data Visualisation features and specific rating for each of these features by each group of companies are analysed as follows.

5.2.6.1 General Rating of the Importance of Data Visualisation Features

The importance of the five Data Visualisation features are highly recognised, as shown in Figure 5.2.5.1. Each of these features is rated as very important or important by more than eighty percent of the respondents. Accurate analysis of data was rated as the most important feature with nearly eighty percent of the respondents rated it as 'very important' and only about twelve percent of the rating is 'not important' or 'no comments'. The speed of the data analysis is also rated highly important with about eighty-eight percent of the respondents rating it as very important or important.

In general, all the five main Data Visualisation features are important to the users. Detailed percentages of the rating are presented in Table 5.2.6.1 in Appendix 3.

Figure 5.2.6.1 General Rating of the Importance of Data Visualisation Features



5.2.6.2 Specific Rating of the Importance of Data Visualisation Features by Different Groups of Companies According to Stage of TQM Program Implementation

Before we go down to the specific rating by specific groups of companies, a test of the difference on the rating among different groups is carried out to determine the necessity of breaking down the analysis into particular features by different groups. As previous tests, ANOVA is the tool used to perform this task. The null and alternative hypotheses are set out as follows:

Null hypothesis(*H0*): There is no difference in the rating of the importance of the Data Visualisation features among the companies at the three different stages of TQM program implementation.

Alternative hypothesis (*H1*) : There are differences in the rating of the importance of the Data Visualisation features among the companies at the three different stages of TQM program implementation.

The confidence interval, degrees of freedom and statistical significance criteria are the same as those applied in the ANOVA test in 5.2.1.

The result of this test is presented in Table 5.2.5.2.

Table 5.2.6.2 One-way Analysis of the Rating Differences on the Importance of the Data Visualisation Features among Companies at Different Stages of TQM Implementation

DV Features	F statistic	f critical $df_b = 2$, $df_w = 49$ $\alpha = .05$	Accepted Hypothesis	p	Statistical Significance
Handle complex data easily	8.96	3.20	F > f, *H1*	.0005	Highly Significant
Display periodic data changes in one graph	10.69	3.20	F > f, *H1*	.0001	Highly significant
Recognise the effects of multiple factor on each other	13.49	3.20	F > f, *H1*	.00002	Highly significant
Analyse data quickly	4.45	3.20	F >f, *H1*	.017	Significant
Analyse data accurately	5.37	3.20	F > f, *H1*	.008	Highly Significant

For all the variables tested, H1 is the hypothesis accepted. These results tell us that for the five main Data Visualisation features, companies at different stages of TQM program implementation rated the importance differently. And the test effects are either significant or highly significant. This leads to a further breakdown analysis on the detail rating on the importance of the features by different groups of companies.

5.2.7. Rating of the Importance of the Data Visualisation Features by Companies at Different Stages of TQM Implementation

Since section 5.2.5 has analysed rating for each of the features, this section is going to conduct an analysis for different groups of companies according to their stage of TQM program implementation.

5.2.7.1 Rating of the Importance of the Data Visualisation Features by Companies at TQM Planning Stage

Table 5.2.7.1 The Importance of DV Features to Companies at Planning Stage

	Very Important %	Important %	Not Important %	No Comments %
Handle complex data easily	14.29	14.29	57.14	14.29
Display periodic data changes in one graph	14.29	28.57	42.86	14.29
Recognise the effects of multiple factors on each other	0.00	42.86	42.86	14.29
Analyse data quickly	42.86	0.00	42.86	14.29
Analyse data accurately	100.00	0.00	0.00	
n = 7				

The accuracy of data analysis is the most important among the five DV features to all of the companies at planning stage. On the other hand, to 'handle complex data' is the least important to this group of companies with over half of them rating this feature as 'not important'.

The abilities to display periodic data changes in one graph and to recognise the effects of multiple factors on each other are not so outstanding as being important and not important to the same proportion of the users.

To be different, 'to analyse data quickly' is rated as 'not important by half of the respondents to this question. But on the other hand, it is tremendously important to the other half.

5.2.7.2 Rating of the Importance of the Data Visualisation Features by Companies That are Implementing TQM Program

With progress in the stage of TQM implementation, the importance of 'handling complex data easily' rises sharply. To be able to analyse data accurately and quickly is definitely very important to the companies at this stage. The abilities to display periodic data changes in one graph and to recognise the effects of multiple factors on each other are also important.

Generally, nothing is not important to companies that are carrying out the TQM program implementation.

Table 5.2.7.2 The Importance of DV Features to Companies That are Implementing TQM Program

	Very Important %	Important %	Not Important %	No Comments %
Handle complex data easily	52.63	42.11	5.26	0.00
Display periodic data changes in one graph	42.11	42.11	15.79	0.00
Recognise the effects of multiple factors on each other	21.05	52.63	26.32	0.00
Analyse data quickly	73.68	26.32	0	0
Analyse data accurately	94.74	5.26	0	0
n = 20				

5.2.7.3 Rating of the Importance of the Data Visualisation Features by Companies That Have Completed TQM Program Implementation

All the five main DV features are 'very important' to almost all of the companies that have completed their TQM program implementation, as Table 5.2.6.3 reveals.

Table 5.2.7.3 The Importance of DV Features to Companies That Have Completed TQM Program Implementation

	Very Important %	Important %	Not Important %	No Comments %
Handle complex data easily	92	0	0	8
Display periodic data changes in one graph	84	8	0	8
Recognise the effects of multiple factors on each other	80	12	0	8
Analyse data quickly	92	0	0	8
Analyse data accurately	96	4	0	0
n = 21				

5.2.8 Future Expectation

Open-ended comments were sought from respondents on their future expectations of DV techniques for their TQM purposes. The responses are summarised as follows:

- Ease of use in converting data to graph form;
- More pointer or free-form labelling in graphs, especially SPC charts;
- Prompt accuracy checks in order to minimise mistakes; and
- Adaptability.

CHAPTER SIX

CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

Fifty-two companies took part in this survey on the implementation of DV technology in TQM in Victorian manufacturing industry.

The respondents were classified into three categories with unequal group size according to their employee levels. The companies were also identified into four groups but fall into three groups according to the stage of a formal TQM program implementation they are at. The survey showed an explicit trend that with increase of employee level, the stage of TQM implementation approaches completion. This trend supports hypothesis five.

Wordprocessing software is used by all companies in TQM practice, and ninety-eight percent of the companies use wordprocessing packages for producing their quality instructional manuals. Spreadsheet and database packages are also highly used and the frequency has an increasing trend with the increase of company size. Statistical software is used by half of the medium-size companies but very few small or large companies. Spreadsheet software is commonly used for sales analysis as well as product design and development. Quality-documenter software is rarely used by any group of companies.

Companies that have completed their formal TQM program implementation generally use computer software in more aspects of their TQM practice than companies at lower TQM stages though not always. Hypothesis three does not always hold true.

Two-dimensional DV techniques are more commonly used than three-dimensional ones with the 2-D colour and 2-D shade the most widely used by all. Three-dimensional tools are only used by medium-size and large companies but the increasing trend of usage is the reverse of that of the size of companies. Hypothesis two has been partially proved. The use of animation generally needs to be increased, especially the 3-D animation needs to be explored.

The importance of Data Visualisation features to their TQM is highly recognised by all the companies. The accuracy of data analysis is very important to companies at all stages of TQM implementation. The ability to handle complex data is significantly more important to companies at higher stages than companies at lower stages of TQM implementation. Since the stage of TQM program implementation is possitively related to the size of company, the ability to handle complex data is significantly more important to large companies than small ones. The respondents' perception of the importance of the ability to handle complex data reveals their perception of the data complexity in their work. From the different perceptions held by respondents from different sized companies, a conclusion or judgment could be made that large companies have more complex data than small companies, which conforms with hypothesis one. The importance of displaying periodic data changes in one graph, recognising the effects of multiple factor on each other and analysing data quickly also increases with the upgrading of the stage of TQM implementation. Hypothesis four sustains.

6.2 Recommendations

That DV technology be implemented into more companies at lower stages of TQM program implementation.

That three-dimensional DV techniques implementation be increased in all companies.

That attention be given to exploring the application of animation tools.

That DV techniques be adapted for the total quality management in different sizes of companies.

That attention be given to manipulating data and graphs easily, and analysing data accurately.

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APPENDICES

APPENDIX 1 Where to Find VDA Software (Beem 1992, p. 203)

Data visualiser

Wavefront Technologies 530 E. Montecito St., Suite 106 Santa Barbera, CA 93103

(805) 962-8117 Fax (805) 963-0410

Fingraph II

Graphic M*I*S P.O. Box A3389 Chicago, IL 60690

(312) 786-1330 Fax (312) 786-1324

Interactive Data Language Research Systems 777 29th St. Suite 302 Boulder, Co 80301 (303) 786-9900 Fax (303) 786-9909

PV-Wave Command Language and PV-Wave Point & Click

Precision Visuals 6260 Lookout Rd. Boulder, Co 80301

(303) 530-9000 (800) 447-7147 Fax (303) 530-9329

Iris Explorer

Silicon Graphics Inc. 2011 N. Shoreline Blvd. Mountain View, CA 94039

(415) 960-1980 Fax (415) 961-0595

SAS

SAS Institute Campus Dr. Cary, NC 27513 (919) 677-8000 Fax (919) 677-8166

Spyglass Transform and Spyglass Dicer

Spyglass 1800 Woodfield Dr. Savoy, IL 61874 (217) 355-6000 Fax (217) 355-8925

Unigraph + 2000 and agx/Toolmaster

Uniras 5429 LBJ Freeway Suite 650 Dallas, Tx 75240

(214) 980-1600 (800) 886-4727 Fax (214) 991-1860

APPENDIX 2 LIST OF SOFTWARE ADOPTED BY SAMPLE COMPANIES

ABC Flowchart
Access
Allin 1
Ami Pro
Approach
AS 400
Bravo
DAPS 6.1
dBase III
dBase IV
Excel 5
Excel 3
Excel 5 Statpak
Foxpro
GAUGB Pack(Calibration s/w)
Jender Analyst
Labtam
Lotus 123
Lotus 123 R4
Ms Graph
Ms Project
Organise
Paradox
Prime
Prometheus
Q&A D-Base
QIS 2000
Quality Analyst
Quatto Pro
Smart
SPC +
SPC 2000
SQC Pack
TIMS
Win Worx
Word 2
Word 6
WordPerfect

Table 5.1.1.1 Distribution of Sample According to Employee Level of Companies

No of Employees	No of Companies	%
< 100	9	17.3
100 - 499	22	42.3
≥ 500	21	40.4

Table 5.1.2.2 Distribution of Sample According to the Stage of Implementation of a Formal Quality Management Program

Stage of Implementation	No of Company	%
Completed	25	49
Being Completed	20	38
Planning	7	13
No Intention	0	0

Table 5.1.2.4 Stage of TQM program Implementation According to Size of Company

	Completed %	Being Completed %	Planning %	No Intention %
<100	0	33.33	66.67	0
100 - 500	27.27	68.18	4.55	0
≥ 500	90.48	9.52	0	0

Table 5.2.4.1 The Application of Different Types of Computer Software in Different Aspects of TQM

	Word-processor	Spread-sheet	Data-base	Statistics	Quality-documenter	none
Product Design & development	19.2	57.7	7.7	1.9	0	7.7
Quality Instructional Manual	98	15.4	5.8	1.9	9.6	0
Vendor Quality Assessment	67.3	11.5	9.6	5.8	3.8	7.7
Inspection of Incoming Raw Material	42.3	21.1	9.6	3.8	1.9	11.5
Statistical Process Control	1.9	44	3.8	21.2	0	15.4
Product Reliability Assessment	9.6	21.2	3.8	5.8	0	57.7
Product Release	23.8	21.2	7.7	3.8	1.9	44.2
Customer Service Assessment	17.3	1.9	11.5	5.8	0	46.2
Supplier Quality Assessment	48.1	21.1	11.5	3.8	3.8	5.8
Productivity Analysis	5.8	1.9	9.6	1.9	0	55.8
Sales Analysis	40.4	65.4	13.5	3.8	0	9.6
Marketing Analysis	46.2	1.9	17.3	3.8	0	5.8
Financial Analysis	3.8	42.3	17.3	1.9	0	3.8
N varies from 49 to 52.						

Table 5.2.3 Type of Hardware Support for the Software Used

Software Type	Hardware Support		
	PC %	Workstation %	Mainframe %
Wordprocessor	92.3	53.8	7.7
Spreadsheet	80.8	7.7	7.7
Database	61.5	5.8	13.5
Statistics	23.1	3.8	5.8
Quality Documenter	19.2	3.8	5.8
Others	3.8	0	3.8

Table 5.2.5.1 General Pattern of the Use of DV Tools

Tools		Usage %
	Colour	94.2
	Shade	90.4
2-D	Size	53.8
	Shape	50
	Animation	15.4
	Colour	32.7
	Shade	32.7
3-D	Size	32.7
	Shape	26.9
	Animation	0

Table 5.2.6.1 General Rating of the Importance of DV Features

	Very Important %	Important %	Not Important %	No Comments %
Handle complex data easily	65.4	17.3	9.6	7.7
Display periodic data changes in one graph	57.7	23.1	11.5	7.7
Recognise the effects of multiple factor on each other	46.2	30.8	15.3	7.7
Analyse data quickly	69.2	17.3	5.8	7.7
Analyse data accurately	76.9	9.6	5.8	7.7

APPENDIX 4 *QUESTIONNAIRE*

1 Circle the number of your choice. More than one choice to one question is possible.

2 The answers to this questionnaire will be kept in strict confidence.

3 The names of participating companies and individuals will not be released.

A1 What is the total number of employees in your company?

Less than 100	01
100 - 499	02
500 - 1000	03
More than 1000	04

A2 What is the approximate turnover of your company?

Less than $10M	01
$10M - $100M	02
More than $100 M	03

A3 Is there a separate quality control/assurance department in your company?

Yes	01
No	02

A4 Is your company practising a formal quality management programme (e.g. TQM, QA..)?

Implementation completed	01
Being implemented	02
At planning	03
No	04

B1 What software is used in your quality management (circle as many as appropriate) ?

Software Type		Software Name (Please state)		Hardware Support		
				PC	Workstation	Mainframe
Wordprocessor	01			02	03	04
Spreadsheet	01			02	03	04
Database	01			02	03	04
Statistics	01			02	03	04
Quality Documenter	01			02	03	04
Others (please state)						
1	01			02	03	04
2	01			02	03	04
3	01			02	03	04

B2 Referring to the previous question, how is the software used? (Circle as many as appropriate.)

	Wordprocessor	Spreadsheet	Database	Statistical	Quality Documento	Others	None
Product Design and Development	01	02	03	04	05	06	07
Quality Instruction Manual	01	02	03	04	05	06	07
Vendor Quality Assessment	01	02	03	04	05	06	07
Inspection of Incoming Raw Materials	01	02	03	04	05	06	07
Statistical Process Control	01	02	03	04	05	06	07
Product reliability Assessment	01	02	03	04	05	06	07
Product Release	01	02	03	04	05	06	07
Customer Service Assessment	01	02	03	04	05	06	07
Supplier Quality Assessment	01	02	03	04	05	06	07
Productivity analysis	01	02	03	04	05	06	07
Sales Analysis	01	02	03	04	05	06	07
Marketing Analysis	01	02	03	04	05	06	07
Financial Analysis	01	02	03	04	05	06	07
Others (Please State):							
1	01	02	03	04	05	06	07
2	01	02	03	04	05	06	07
3	01	02	03	04	05	06	07

B3 What features of Data Visualisation are available in the above software ?
(Circle as many as appropriate.)

Two Dimension	Colour	Shade	Size	Shape	Animation
	01	02	03	04	05
Three Dimension	**Colour**	**Shade**	**Size**	**Shape**	**Animation**
	06	07	08	09	10

B4 How many variables (e.g. sales, production, rejects, etc.) can be presented in one graphic using each of the software ? (Please state)

Software Type		Software Name	Number of Variables
Wordprocessor	01		
Spreadsheet	02		
Database	03		
Statistics	04		
Quality Documenter	05		
Other (please state)			
1	06		
2	07		
3	08		

C1 Are the following Data Visualisation features important to you?

	Very Important	Important	Not Important
Handle complex data easily	01	02	03
Display periodic data changes in one graph	01	02	03
Recognise the effects of multiple factors on each other	01	02	03
Analyse data quickly	01	02	03
Analyse data accurately	01	02	03
Others (please state) 1	01	02	03

2	01	02	03
3	01	02	03

C2 If you have any further comments about the benefits, or necessary improvements of Data Visualisation, please state them in the following space.

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D1 Please provide your name and address *only if you are interested in:*

Further Participation	01	Results of this research	02	(Circle either or both)

Name	----------------------------
Position	----------------------------
Address	----------------------------

	____________________________
Telephone Number	----------------------------
Fax. Number	----------------------------

(End of Questionnaire)

THANK YOU VERY MUCH FOR YOUR CO-OPERATION.