An empirical investigation into the effectiveness of statistical process control techniques, with management data from a product development environment.

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Table of Contents ---- Volume 1

Table of Figures

Chapter 6.

Table of Tables.

Abstract

The study reported on in this thesis was an empirical investigation into the implementation and use of, Statistical Process Control (SPC) techniques and tools in a product development environment. The data used originated from four different business units in the European flavour division of a large International company, belonging to the Flavour and Fragrance industry. The study highlights many of the problems related to the use of real data, and working with individuals throughout an organisation.

The data distributions were positively skewed, and a comparison of the effectiveness of various methods for calculating the position of both the center line and the process control limits, on individual measurements control charts was made. The author was able to show empirically that SPC is a useful project management tool. Additionally, the author demonstrated that the use of either the median or trimmed mean approaches, were more effective in use when dealing with these types of skewed data distributions.

Additionally, it was possible to define the relationship between the numbers of outside out-of-control signals and the numbers of run out-of-control signals. The study also provided some interesting insights into possible barriers to the transfer of the techniques, from the manufacturing floor into more traditional management areas. It also highlighted some areas for improvement in the product development laboratories of the company and potentially the industry.

Acknowledgements

Four years ago when I enrolled in the PhD programme I could not have imagined this moment, in fact just one year ago it still seemed to be a distant almost unattainable goal. In addition to my innate stubbornness that kept me plodding on and on, there are many people who provided me with the support and inspiration that fuelled my drive to finish.

Looking back, the influence of Dr. Howard Gitlow during my Masters programme had a lot to do with my decision to pursue a PhD. In actual fact, it was through him and his association with the Deming Institute that I made my first contact with Dr. Henry Neave, who was then a Faculty member here at the University of Nottingham. Dr. Neave was responsible for my introduction to Dr. Phillip Willey who ultimately agreed to supervise me!

For the first half of the PhD I worked under the supervision of Dr. Phillip Willey, however, midway through the study when he opted to take early retirement and I was assigned a new supervisor. Despite this, he has remained an important source of advice and support throughout the duration of the programme. Dr. James Tannock had the dubious pleasure of inheriting me and acted as my supervisor for the remainder of the study. In spite of the slight hiccup caused by the changeover, it proved to be a fortuitous event. As my two supervisors have different approaches and viewpoints which while conflicting at times, in general succeeded in challenging me and pushing me down new avenues that I had not previously considered. I think that despite the added complexity of having two different supervisors, both the thesis and myself benefited from the experience.

I owe a huge debt to the Professors that I work with at IMD (International Institute for the Development of Management), as they have exposed me to many new ideas and constantly challenged me to learn and develop intellectually. I am also grateful to IMD itself for providing me with access to facilities such as, the library without which I would have been lost.

On a personal level this has been one of the more demanding periods of my life. Since registering we have moved country, had our daughter -- Rebecca, I started working part time, endured a second pregnancy and will have the newest addition to the family in a couple of weeks. Needless to say fitting a PhD into this schedule necessitated many sacrifices, on the part of both my family and myself. In all honesty I have my husband Andre to thank for finishing this work, as without his constant support it would have been impossible to cope with the myriad of demands placed upon my time. I will not even attempt to articulate how much I appreciate him as it would by default be inadequate. As for the little monster -- Rebecca, I hope that we succeeded in shielding her, and that apart from the odd occasion when I was unable to spend time with her because of work, that she did not suffer from a lack of attention from me. In reality, I suffered more on those occasions than she did! As for the bump, I can only imagine how much he/she suffered as it was impossible to shield him/her from my bad moods, fatigue, and inability to relax and *'enjoy this pregnancy'*!

The last person that I need to thank for instilling in me from a very young age the desire to learn and grow is my mother. She has always believed in our (my siblings and I) ability and encouraged us to test our boundaries.

After four guilt ridden years I am looking forward to the moment when I can read a novel, watch TV, or just relax without a piece of my mind telling me to get up and do some work!

"Education's purpose is to replace an empty mind with an open one."

- **Malcolm Forbes**

Chapter 1.

Introduction and Objectives

1.1 Background on Social Trends

As we near the end of the 20th Century and prepare to enter into the third millennium, there is naturally a certain nervousness about what the future holds. In light of the tremendous changes during the last century, in particular over the last twenty years, as parents, friends, managers, customers, and suppliers we are faced with a breath of choices the consequences of which can only be guessed at.

Globalisation and de-regulation are having profound effects on domestic markets, opening the doors to international competition, changing the business landscape permanently. In parallel with this consumers are becoming ever more discerning and are demanding more value, where value added is shifting more and more to the services being provided with the product purchased (Struebing, 1996, Feigenbaum, 1996, McCutcheon, Raturi and Meredith, 1994).

> "A firm's ability to identify, package and deliver value-added service capabilities will determine its success in contemporary markets." (Vandermerwe, 1993).

Additionally, many of the social artefacts that are taken for granted are being challenged. Bridges (1994) in his article predicts the end of "the job" as a way of organising work.

> "What is disappearing is the very thing itself: the job. That much sought after, much maligned social entity, a job, is vanishing like a species that has outlived its evolutionary time." (Bridges, 1994).

Originally, “the job” emerged as a way to package the work that needed to be done. In today’s fast moving world it is proving to be too inflexible and rigid to cope with the demands being placed on organisations. In the “de-jobbed” organisations of the future, the work will be more project based with freer movement of people between projects and companies as their particular skills are required. Both social and organisational structures will need to change in order to cope with the new demands placed on the systems (Bridges, 1994).
Information technology is considered to be the key driver behind many of the changes observed. The increased sophistication of information and communication technologies in the last decade has made possible the observed trends towards more telecommuting, with over fifty-two per cent of companies surveyed recently by International Data Corp. (Network World, 1996) reporting that they had employees that worked from home part of the time.
In his book titled "The End of Work", Rifkin predicts a growing gap between the technically literate and the technically illiterate, with increasing numbers of un-employable world-wide.

> "The Third Industrial Revolution is a powerful force for good and evil. The new information and telecommunication technologies have the potential to both liberate and de-stabilise civilisation in the coming century." (Rifkin, 1996).

Against this backdrop of turmoil and change in the global marketplace, and the predicted social disturbances, the implications for managers today in their role as decision makers are enormous. Managers are complaining of information overload as a significant problem influencing their ability to manage. Time, or rather the lack of it, is considered to be a barrier preventing them from achieving their goals. Finally, managers are searching for solutions to the problem of managing a dispersed workforce.

The competencies required of managers are evolving from the 80's approach of functional excellence, to a much broader based competency -- where managers will need to develop an *"enterprise process expertise"* (Roth, 1996) in which the development of economies of knowledge are crucial to their ability to manage effectively. If as predicted by numerous researchers (Roth, 1996, Boynton, Jacobs and Zmud, 1992, Drucker, 1985) -- the knowledge worker is key to the future of business, then an issue that should be addressed by managers today is how to obtain the information that is vital, and then how to translate that into useful knowledge. The plethora of tools and techniques that are specifically designed to help managers sort through the mass of information appears to be compounding the problem.

A managerial technique represents an approach or methodology that is implemented to achieve the business objectives, some examples of different techniques are; Total Quality Management (TQM), Activity Based Management, Benchmarking, and Concurrent Engineering. Whereas managerial tools are the specific instruments used by the workforce under each of the approaches. Continuing with the above examples some of the tools used to implement the various methodologies are; statistical process control charts, Ishikawa diagrams, process flowcharts, activity analysis, cost driver analysis, process maps, diagnostic surveys, cycle time analysis, Gantt charts, and PERT charts.

The different techniques target different functional groups within the organisation, that, combined with the jargon used, constructs barriers to managers from different areas outside the target group. Euske and Player (1996) suggest that instead of limiting the use of the various tools to separate functional areas, using a mix of tools could be a way of leveraging the techniques.

The product development laboratories under study had very high throughput levels of projects, the projects on average had durations of thirty days, the project tasks that needed to be performed and their individual durations were very subjective, and numerous projects were running in parallel. The traditional tools used in project management such as, critical path methods (CPM), PERT charts and Gantt charts were too unwieldy and were considered to be inappropriate by the managers. The end result being that the managers were in essence managing by intuition, because of the absence of an appropriate tool. Not intending to underestimate the importance of intuition in management, the author considered this an ideal opportunity to experiment with various non-conventional tools for this area.

1.2 Objective of this research

The main objective of this study was:

- To investigate the effectiveness of and also the problems encountered in the cross functional implementation of Statistical Process Control (SPC).

Specifically the study:

- Applied SPC techniques to project management data from four product development laboratories of a large Fragrance and Flavour company.
- Provided an ideal opportunity to test the usefulness and appropriateness of SPC, as a tool to manage projects in an environment where the traditional tools proved to be too cumbersome.
- Allowed the author to make some recommendations with respect to the use of SPC in this specific product development environment.

The work described in this study used the project turnaround times as the key measure of project performance.

1.3 Rationale behind the choice of SPC

Despite the uniqueness of the product development laboratories under study, the factors that affected the project duration were many of the commonly acknowledged problems encountered on all projects. For example, issues related to inadequate resources (chemists and technicians) for the volume of projects moving through the system were commonplace. Additionally, issues related to equipment needed in the laboratories; time to receive approval for purchase of new equipment, deciding on a particular product, delivery time, set-up time and training on the new equipment were prevalent. Problems related to the product specifications also proved to be widespread; incomplete/unclear initial product specifications, and changes to the product specifications during the project.

Unlike the traditional tools of PERT charts and CPM which do not attempt to isolate problems with the actual process, using SPC charts to track the project turnaround times, should allow the author to identify many of the problems affecting the system through special cause analysis. In fact, if SPC proves to be useful in this area of project management, it could potentially have broader applications in more general areas of project management. The intent being to complement the existing tools which concentrate on scheduling and resource levelling.

1.4 Background on SPC

Managers today have an interesting dilemma. They are expected to make decisions and act upon the information that they receive from different sources. However, the volume of information that they receive threatens to completely inundate them, and cripples their ability to make timely decisions. In addition to the volume of information, is the problem of conflicting reports. Managers have developed different coping mechanisms to resolve this problem, whether the approach involves an assistant screening incoming information, or a policy of dumping unopened mail from certain sources, the manager runs the risk of losing vital information needed to be effective at his/her job.

Statistical process control charts are decision making tools that can be used by managers as filters of noise and as a provider of timely and accurate information. Traditionally the Quality Assurance Managers, Quality Engineers, etc. are the functional group who use these tools, with the goal of identifying and eliminating defects and waste on the manufacturing floor.

The author has worked with employee involvement teams on the manufacturing floor of an Electronics firm in the United States of America, using different SPC tools and techniques as a way to improve the process. During that time numerous difficulties in their use by the team members were apparent to the author. The author considers the various statistical quality control tools to be useful to today's managers, but in her experience has found them to be much maligned and consequently under utilised, by managers in areas other than on the production floor.

A unique feature of this study was the origin of the data. The author worked with a company and was able to use the data from their product development laboratories as the basis for the study. The use of real data as opposed to simulated data, highlighted many of the practical problems that managers would be faced with when trying to use the tools in an organisation.

A crucial component of the control chart is the control limits placed on it. The limits become the triggers for action by a manager, and help to focus the manager's attention on the real problems existing in the process. Once a manager has identified a problem then there are numerous other problem solving tools that can be used to find the root cause of the problem and eliminate it from the system.

Research by Alwan and Roberts (1995) has indicated that the large majority of examples related to control charts quoted in the literature suffer from the problem of misplaced limits. The problem arises because of the violation of one of the key theoretical assumptions to the use of control charts and the calculation of the limits -- that the underlying distribution of the data being plotted is normal. The usefulness and accuracy of control charts is questioned by numerous researchers and the economic impact to companies because of missed signals and or false alarms is discussed extensively in the literature (Caulcutt 1995, Tannock 1997, Wood 1995, Wood and Preece 1992, Levi and Mainstone 1987, Dale and Shaw 1991).

The debate surrounding the underlying distribution of the data was particularly relevant to this study as, on reviewing the data accumulated from the company, the distributions proved to be positively skewed. Given that there is no one right way to calculate the control limits in this situation, the author took the opportunity to experiment with several different approaches to calculating the limits.

1.5 Background of project

This project involved the author working with managers, food chemists/technologists, and support staff in the product development area in the European flavour division of a Flavour and Fragrance Company.

1.5.1 Organisational context of project:

- Both the industry and the company are extremely secretive. Therefore, as part of the agreement of being able to work with the company was the mandate that the identity of the company must at all times remain unknown.
- The company, like many others had been struggling with the issue of how best to meet the needs of a global marketplace, and had undergone several

structural changes in the preceding three years and continued to make changes throughout the duration of this study.

- Permission was granted to access the project management database for four business units (BU's) operating at the site.
- Finally, it was requested that there would be no significant disruption of either the work or the individuals in any of the BUs.

1.5.2 General goals of project

Many practitioners working in industry see an increasing focus on work structured around a project, (Rifkin, 1996, Bridges 1994). These predictions were supported by a large scale study, looking at the meaning and motivation of work into the 20^{th} century conducted by IMD in 1997 (Julien, Boynton, and Fischer, 1997). The results indicate strong support for the predicted trend towards companies organised around projects. Clearly, an essential skill for managers in the coming years will be their ability to effectively manage projects.

As previously noted the origin of the data used in this study was from four different BUs, and was related to the internal management of projects. Additionally, the environment was a multi-project one, that is, the resources in the four BUs were assigned to more than one project at a time. This complicates the task of managing and scheduling projects within the BUs. Given the growing interest in the project management area the author considered this an ideal opportunity to experiment with a variety of tools in this environment.

The author recognised that there could be certain limitations to the generalisability of the results related to the fact that the it was a single industry study. However, a key factor adding to the rigour of the results was that the data was received from four different business units within the company, where each BU developed different types of products and interfaced with very different segments of the market. In essence the BUs could be considered as four different businesses, with the advantage of a common database that allowed for comparison between them.

1.6 Methodology

The dominant approach taken would be that of a case study approach, where a case study is defined as follows:

> "The case study is a research strategy which focuses on understanding the dynamics present within single settings." (Eisenhardt, 1989).

A case study can fulfil several different goals: to provide description, test theory, generate theory, develop skills, and increase understanding. This particular investigation involved building theory from the case study data, and providing a better description and understanding of a traditionally closed industry.

A case study also typically involves a combination of different data collection methods such as; archives, interviews, questionnaires and observation, the result being a mix of both quantitative and qualitative data. This particular project collected a substantial amount of data from the project management database, complemented by some in-depth sessions with the marketing assistants to understand the data being collected. Additionally, over a period of time several other individuals were questioned about the observations of the author and to provide additional insight into the workings of the product development process and the BUs.

> "Despite their stereotype as being a weak method of performing research, they are used extensively in field research in a wide range of disciplines. Additionally, it is frequently used for thesis and dissertation work." (Yin, 1994).

While an initial definition of the research question is necessary, it should initially be broad. When starting theory-building research it is ideal to have no theory under consideration, as it would introduce biases and also limit the findings. However, an initial definition of the research question is useful as it provides guidelines for the type of data that needs to be collected. Without one it would be very easy to become overwhelmed by the volume of data.

Theory-building research normally combines multiple data collection methods. The combination of qualitative and quantitative data can be highly synergistic. The quantitative data can bolster the qualitative findings by corroborating it.

When shaping the hypotheses the original constructs need to be sharpened up by refining their definition and building evidence that measures the construct in each case. Then the emergent relationships between constructs are verified using the evidence from each case. The qualitative data can provide understanding of the relationships between the constructs.

It is essential to compare the results with the extant literature, both conflicting and similar. By doing so the researcher builds confidence in the results, the end result being a theory that has stronger internal validity, wider generalisability and higher conceptual level.

There are several conditions that should be considered when choosing among the five major research strategies; experiments, surveys, archival analysis, histories, and case studies. First, the type of research question posed, second, the extent of control that the researcher has over the actual behavioural events and finally, the degree of focus on contemporary as opposed to historical events.

Yin (1994) develops the following two part definition of a case study:

1. A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.
2. The case study inquiry

- copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
- benefits from prior development of theoretical propositions to guide data collection benefits.

Stake (1995) develops on the idea of triangulation as a means of validating the work, as it increases the credence of the results. There are several different protocols for triangulation; data source triangulation, investigator triangulation, theory triangulation, and methodological triangulation

"This research approach is especially appropriate in new topic areas. The resultant theory is often novel, testable, and empirically valid." (Eisenhardt, 1989).

1.7 Overview of results

The study showed empirically that SPC is a useful management tool in this particular product development environment. Additionally, that when working with positively skewed distributions, the use of the data's mean or resampled mean as the centre line is less effective than using either the median or the trimmed mean of the data as the centre line for the control chart.

Regression models were developed to explain the relationship between the number of outside out-of-control signals and the number of run out-of-control signals. Which could provide practitioners in the field with a means of estimating the number of run signals that would be produced by the process under study.

In addition, the author was able to document many of the softer issues related to the implementation of the techniques. Finally, the results from several analyses related to the performance of the product development laboratories under study are presented. These results highlight the huge potential for improvement in the BUs under study and the need for a technique such as SPC to improve the management of projects.

1.8 Layout of the dissertation

Chapter 2 reviews previously published material about quality and process improvement. It commences with an overview of the different approaches to quality as described by several experts in the quality movement, this then feeds into a discussion around the current disillusionment with Total Quality Management (TQM). The chapter then briefly touches on some of the different quality awards and certification programmes available, followed by a review of some of the quality tools in use today. The last section reviews some of the background material related to project management.

Chapter 3 reviews material specifically related to statistical process control (SPC) charts. It begins with a general discussion about the use of SPC followed by a section providing some background to the tools. This leads into the next section that discusses the problems associated with the use of SPC charts and techniques.

Chapter 4 provides background on the industry, the company structure, and the research project. The chapter also describes in detail the type of data collected and the work processes under study. A description of the sample used in the analyses is provided. The chapter concludes with a detailed outline of the methodology used and the different analyses performed.

Chapter 5 presents the results of the different analyses performed as outlined in the preceding chapter.

Chapter 6 discusses the findings of the study. Chapter 7 concludes the dissertation with a discussion of the contribution of knowledge made by the author, along with a critique of the study, it also provides an outline of possible future research as suggested by this dissertation.

Chapter 2.

Review of Quality and Process Improvement Material.

2.1 Introduction to the Approaches to Quality

The numbers of people and organisations which have contributed in different ways to the evolution of quality are numerous. This section reviews the approaches of some of the more influential in order to provide an appropriate backdrop for the work reported on in this study. The following is not meant to be an exhaustive list, and the selection presented is more a reflection of the authors own biases towards the importance of the individuals to the quality movement.

2.1.1 Walter Shewhart

Walter Shewhart has been called the father of quality. His ideas helped to revolutionise modern quality control and practice. Based on his work at Bell Laboratories in the early 1920s Shewhart defined two types of variation that affect a process; Controlled variation which is due to the process itself, and uncontrolled variation which comes from sources outside the process. He developed the control chart as a tool for process improvement. It displays pictorially how the process is performing and alerts you when there has been some special cause that has affected the process. He also developed the Shewhart Plan Do Check Act (PDCA) cycle. This acts as a basis for quality activities and training programmes.

2.1.2 *Dr. W. Edwards Deming*

Deming worked with Shewhart whose work he respected and was influenced by. Deming built on his ideas and applied them universally to all types of businesses. Throughout his life Deming was continually developing and improving his own ideas, in keeping with his philosophy on continuous improvement.

Deming became famous for his role in developing Japan's quality image after the second World war. On his visits to Japan he spoke to them about his ideas on profound knowledge, statistical quality control, respect for the people, customer orientation, and visionary leadership. The Japanese Deming Prize is one of the most prestigious of quality awards and is a good indication of how much the Japanese respected his contribution to their development . Dr. Deming himself received numerous awards during his lifetime, one of the most prestigious being the Second Order Medal of the Sacred Treasure. This was bestowed on him by Emperor Hirohito in 1960, for his contributions to Japan's economy (Gitlow, et. al. 1987).

He developed the Shewhart cycle (Gitlow, et. al. 1987) further and it is more often now referred to as the Deming or PDSA (Plan Do Study Act) cycle. It is a way to systematically solve problems as a vehicle for continuous improvement, see Figure 2.1.

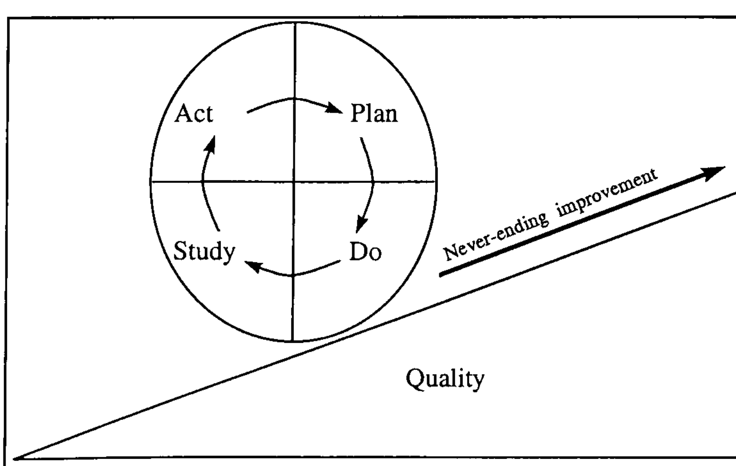


Figure 2.1. Deming's PDSA cycle.

Another important development of Deming was his chain reaction (Figure 2.2), which links quality with reduction in costs, productivity improvements, market share, competitiveness and ultimately to stay in business and provide jobs.

Improve quality

Costs decrease because of less rework, fewer mistakes, fewer delays, snags; better use of machine-time and materials

Productivity improves

Capture the market with better quality and lower price

Stay in business

Provide jobs and more jobs

Figure 2.2. Deming's Chain Reaction (Deming 1992)

Deming viewed production as a system and insisted that quality improvement would have to envelop the entire production line, this would include improving incoming materials through developing partnerships with your suppliers, right through to the consumer of the product. Deming was very clear in expressing his opinion about the importance of the consumer:

> "The consumer is the most important part of the production line. Quality should be aimed at the needs of the consumer, present and future." (Deming 1992).

Towards the end of his life Deming encapsulated the core of his teachings under the title of "The System of Profound Knowledge". The System of Profound Knowledge comprised four parts (Deming, 1994, Neave, 1997):

- Appreciation for a system;
- Some knowledge about variation;
- Some theory of knowledge; and

- Some knowledge of psychology.

As with any system the parts are not independent of each other, they interact with each other and work together to try to accomplish the aim of the system.

> "One need not be eminent in any part nor in all four parts in order to understand and to apply it." (Deming, 1994).

Elaborating briefly on each of the four elements of profound knowledge which are the cornerstone of Deming's lifelong work (Deming, 1994, Beedon, 1996).

A system must have an overall aim that the interdependent components of the system work towards. Additionally, the individual components have to work together to achieve the aim which is of benefit to all the components, the individual components must resist the temptation to work towards their own local optimum as it may not be to the benefit of the overall system.

Variation is a fact of life, it is present in everything; people, outputs, processes, etc.. It is important for management to recognise that variation exists and to understand what the variation is trying to tell them. Even if a process is stable there will still be variation present, but it will be predictable.

Information of itself is not knowledge. It needs to be used and applied to become knowledge forming, the process of systematically revising and extending theory, based on a comparison of prediction and observation allows for rational predictions by management. Deming (1994) considers all management to be a form of prediction.

Some understanding of psychology is necessary as it helps managers to understand people and the interactions between them. The recognition that people are unique, that they have different motivators, and that they learn in different ways is vital to a manager's ability to get the most from his people.

Deming considers his system of profound knowledge, to be a way for managers to understand the environment that they work in.

Contrary to popular belief that Deming's 14 points are a summary of his teachings, Deming considers them merely to follow naturally from his System of Profound Knowledge and so may assist in the transformation of management.

Deming's 14 Points are listed below (Deming 1992).

1. Create constancy of purpose toward improvement of product and service, with the aim to become competitive and to stay in business, and to provide jobs.
2. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.
3. Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.
4. End the practice of awarding business on the basis of price tag. Instead, minimise total cost. Move toward a single supplier for any one item, on a long term relationship of loyalty and trust.
5. Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.
6. Institute training on the job.
7. Institute leadership. The aim of supervision should be to help people and machines and gadgets to do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.

8. Drive out fear, so that everyone may work effectively for the company.

9. Break down barriers between departments. People in research, design, sales, and production must work as a team, to foresee problems of production and in use, that may be encountered with the product or service.

10. Eliminate slogans, exhortations, and targets for the workforce asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the workforce.

11. a. Eliminate work standards (quotas) on the factory floor. Substitute leadership.

b. Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute leadership.

12. a. Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.

b. Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, inter alia, abolishment of the annual or merit rating and of management by objective.

13. Institute a vigorous programme of education and self-improvement.

14. Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

Since his death in 1993, his work continues because of the time and efforts of many individuals and organisations, world-wide.

2.1.3 Dr. Joseph M. Juran

Juran, like Deming played a major role in the development of Japanese quality after the war. Like Deming he has received many awards and medals throughout his life, and has also received the Second Order Medal of the Sacred Treasure from the Emperor of Japan.

Juran uses a very simple definition of quality "fitness for use" (March, et. al. 1986), his definition of fitness of use has five key dimensions: quality of design, quality of conformance, availability, safety, and field use. Juran does not concentrate solely on the end customer, but includes in his definition of customer, all persons who are impacted by our processes and products. This would encompass both internal and external customers.

One of Juran's core ideas is his trilogy (Juran and Gryna, 1993), which provides the basis of his philosophy on quality assurance. The three themes are quality planning, quality control and quality improvement.

To assist in the implementation of the quality planning steps Juran developed a flowchart of the various steps that he considers necessary to achieve a process ready to produce quality products. The steps are as follows (Bendell, 1993):

1. Identify who are the customers.
2. Determine the needs of those customers.
3. Translate those needs into our language.
4. Develop a product that can respond to those needs.
5. Optimise the product features so as to meet our needs as well as customers needs.
6. Develop a process which is able to produce the product.
7. Optimise the process.

8. Prove that the process can produce the product under operating conditions.
9. Transfer the process to Operations.

Juran recommends that the introduction of companywide quality management starts at the top. However he recognised that the language of quality improvement (i.e. defect rates, failure modes, etc.) would not catch the much needed attention and also commitment of the top managers. To combat this problem he advocated the use of a Cost of Quality accounting system which would report on the cost in dollars associated with making, finding, repairing or avoiding defects.

Companywide Quality Management (CWQM) is a systematic approach for setting and meeting quality goals throughout the company. The introduction of CWQM into a company involves a lot of work, changes to the corporate culture and dealing with the associated resistance to the change. The upper management must not try to delegate the responsibility for the quality drive to their subordinates, as this is a signal to the workers of a lack of top-management commitment to the programme. The upper managers in the firm must (Juran and Gryna, 1993):

- Establish policies and goals for quality.
- Establish plans for meeting those quality goals.
- Provide the resources needed to carry out the plans.
- Establish controls to evaluate progress against goals and to take appropriate action.
- Provide motivation to stimulate the personnel to meet the quality goals.

Juran accepts that this approach succeeds in irritating many top managers who believe that they do not need to be involved.

"Their instinctive belief is that upper managers already know what needs to be done, and that training is for others - the workforce, the supervision, the engineers. It is time to re-examine this belief" (Bendell, 1993).

2.1.4 Dr. Kaoru Ishikawa

Ishikawa provided a great deal of leadership in shaping the Japanese quality movement through his vision and other activities. Ishikawa paid particular attention to ensuring that the statistical techniques used, were accessible to the workers. He developed the Cause-and-Effect Diagram in 1943 which is a technique used to aid problem solving. Cause-and-Effect Diagrams are also known as Ishikawa diagrams, or Fishbone Diagrams because of their appearance. He developed the technique as a method for dealing with the overwhelming number of factors that can influence a process, with the goal of solving problems.

He is also well known as a pioneer of the Quality Circle movement in Japan in the early 1960's. He considered this to be one of the most effective ways to reach the workers and to educate them in the ideas of Quality Control. The members of the circle must master statistical quality control and the related methods and use them to achieve improvements in the following areas; quality, cost reductions, productivity, and safety.

2.1.5 Armand V. Feigenbaum

Feigenbaum had a great impact on the evolution of quality from a narrow, reactive view, concerned with measuring conformance to specifications to the broad companywide approach now being practised. Feigenbaum stressed a systems approach to quality by defining a quality system as follows:

> "A quality system is the agreed on, company-wide and plant-wide operating work structure, documented in effective, integrated technical and managerial procedures, for guiding the co-ordinated actions of the work force, the machines, and the information of the company and the plant in the best and most practical ways to assure customer quality satisfaction and economical costs of quality." (Feigenbaum, 1983).

Quality is considered essential to the proper managing of the organisation, and he defines total quality control as spanning all the functional divisions of the organisation.

To maintain effective control over the product quality it is necessary to introduce quality controls at all of the main areas of the production process. Starting with new design control, then incoming material control, product control and finally, special process control.

2.1.6 Philip B. Crosby

Crosby is well known for his concept of "Zero defects". His interpretation of this is not that people do not make mistakes but rather that the company does not start out expecting them to make mistakes. His quality philosophy is characterised by his five quality absolutes (Bendell, 1993), which are the foundation of his quality improvement process:

1. Quality is defined as conformance to requirements, not as 'goodness' nor 'elegance'.
2. The system for causing quality is prevention, not appraisal.

3. The performance standard must be zero defects, not "that's close enough".
4. The measurement of quality is the price of non-conformance, not indices.
5. There is no such thing as a quality problem.

Once a company knew where it stood on his management maturity grid, his fourteen steps provided it with a framework to achieve the goal of quality improvement. The emphasis is on prevention rather than detection, and is focused on changing the company culture and does not stress statistical techniques. It is thought to be a good way to gain commitment to the programme. Crosby's 14-point programme is as follows (Bendell, 1993):

1. Establish management commitment.
2. Form the quality improvement team from representatives from each department.
3. Establish quality measurement throughout the company.
4. Evaluate the cost of quality.
5. Establish quality awareness by the employees.
6. Instigate corrective action.
7. Establish an ad hoc committee for the zero defects programme.
8. Supervisor/Employee training.
9. Hold a zero defects day to establish the new attitude.
10. Employee goal setting should take place; usually on a 30-, 60- and 90-day basis.
11. Error cause removal should be set up to follow the collection of problems.
12. Establish recognition of those who meet goals or perform outstandingly by (non-financial) award programmes.

13. Quality councils composed of quality professionals and team chairpersons should meet regularly.
14. Do it all over again.

2.2 Factors affecting the implementation of TQM programmes

Recent studies are reporting disillusionment with Total Quality Management (TQM) programmes by many individuals world-wide. They point to the lack of concomitant results for the amount of investment in time and money made by organisations. In a survey by Arthur D. Little of 500 manufacturing and service companies in the US only one third felt that their total quality programmes had improved their competitiveness. In a similar study by A.T. Kearney of 100 British firms only one fifth reported that they had achieved tangible results (The Economist, April 18, 1992).

Sharman (1992) from McKinsey offers the following suggestions to jump start some of the stalled programmes. Firstly, he recommends that in businesses that require drastic changes, shut down the total quality programme as it will yield incremental improvements, where tougher measures are needed. Otherwise the programme needs to be linked to the strategic decision making process, the focus of the programme must be outwards on market breakpoints. Additionally, there needs to be a single theme for the entire programme with the emphasis placed on results as opposed to process. In actual fact an over emphasis on the process has been sited as one of the problems with total quality programmes as it shifts the focus away from the customer. Florida Power & Light is often referenced as a prime example of a quality programme gone mad, with a huge amount of resources committed to the improvement of quality but very few benefits felt by the customers (The Economist, April 18, 1992, Choi & Behling 1997).

Choi and Behling (1997) suggest that the source of the problem with many TQM programmes lies in the orientations of top managers to time, market and customers. They identify three types of orientations: Developmental, Tactical and Defensive. Based on the results of their study they link successful TQM programmes with managers who have moved beyond the defensive and tactical orientations to embrace a developmental orientation. In their article Nasierowski and Coleman (1997) consider the country's culture where the company is located, to also be a major impediment to the transfer of managerial techniques. The problem arises as the managerial techniques are always developed within the context of potentially unique local conditions which creates a problem when trying to transfer the techniques to a different culture or economic condition.

Despite the disillusionment with TQM, Davis (1997) still considers TQM to be the most popular approach to organisational improvement. Davis considers that TQM programmes are difficult to implement and very often do not produce the desired results, mainly as a result of a failure to execute the six fundamentals of any TQM programme:

1. Top management commitment and leadership,
2. Identification of customer's requirements and needs,
3. Improvements in core processes,
4. Employee training and empowerment,
5. Performance measurement and evaluation,
6. Employee feedback, recognition and rewards.

The difficulty of implementing each of these fundamentals is a key challenge to the success or failure of the TQM programme. Davis (1997) highlights some practices that he considers to be instrumental to the success of the implementation:

1. Tailor the TQM approach to fit the company situation.
2. Integrate TQM with strategic planning and set clear objectives.
3. Pay careful attention to the design, scope and implementation structure.
4. Make customer satisfaction the focus of organisational improvement.
5. Evaluate internal customer improvements against external customer service measures.
6. Form cross-functional, quality improvement teams with the goal of serving customers.
7. Capture and share information vertically and horizontally.
8. Integrate process quality measures from operations with financial results.
9. Benchmark performance in comparison to the best.

Paying attention to these nine areas improves, says Davis, the probability of success of the TQM implementation, but is not meant to be a guarantee. Mann and Kehoe (1995) support many of the arguments put forward by Davis and add that organisations must not allow themselves to stagnate as the quality activities which are important today may change with time; or the area of implementation.

Lack of identifiable results is often defended by the claim that TQM programmes are long term projects and that they need time and investment over a period of several years before real progress is observed. However, in a recent study Ahire (1996) was able to show that the length of time that a company had been involved with the implementation of TQM was not correlated to the performance of the programme. The results indicate that the more successful the company the more likely it is that they will begin to reap benefits in the first couple of years

At the same time, it is reported by Malhotra, Steele, and Grover (1994) that the top-ranked strategic issues, chosen by senior managers from over seventy five companies in the US, which need to be addressed to achieve competitiveness on a global scale are: Quality management, manufacturing strategy and process technology. Additionally, the top tactical issues reported were: Quality control, manufacturing planning and control systems, and work force supervision. Based on the results presented from both a ranking analysis and a factor analysis they conclude that :

> "It is easy to see that strategically or tactically, quality is the most critical manufacturing issue for the 1990s." (Malhotra, Steele, and Grover, 1994)

The dissatisfaction with many TQM programmes is not so much a criticism of the ideas underlying the process of continuous improvement but stems more from the ways by which different organisations have tried to implement such improvement. Some of the common barriers to the successful implementation of TQM as outlined by Nesbit (1992) are: a misalignment of the strategy with the company culture, unrealistic expectations of teams, lack of middle management support, and no facilitators. In an empirical study (Ittner & Larcker, 1997), using a sample of some two hundred and fifty companies spread across four countries and from two industries, they concluded the following:

> "Our results indicate that organisations placing greater emphasis on quality in their strategic plans do tend to make greater use of quality-related strategic control practices." (Ittner & Larcker, 1997)

Their analyses provided mixed support for the hypothesis that organisations aligning their strategic control practices and competitive strategies more closely achieve higher performance. There was agreement across the sample about the importance of management participation, while for the other factors there was some variation across industry. One interesting result was the negative correlation achieved between several strategic control practices and performance, the implication being that too formal or rigid strategic plans limit the flexibility of the organisation which hinders better performance.

Part of the difficulty with TQM implementation programmes, has been the lack of an instrument for measuring the critical factors of quality performance. Interestingly, in a study carried out in the UK, it was found that the weak link in many TQM programmes was the lack of measurement (Claret, J., 1993, Coulson-Thomas, C., 1992, Cottrell, J., 1992). Cottrell (1992) adds that many TQM programmes falter and lose momentum because of a lack of direction. He proposes that this is a direct result of the absence of a solid foundation in facts as provided by the appropriate use of statistics. In another study the researchers were able to demonstrate that both measuring and displaying results, increases the chance of success of the TQM programme (Capon, et. al., 1995).

Saraph, Benson and Schroeder (1989) identify what they consider to be the eight critical factors of quality management, and develop operational measures of the eight factors. The eight factors that they consider to be good indicators of the quality performance of a business unit are as follows:

1. The role of management leadership and quality policy.
2. Role of the quality department.
3. Training.
4. Product/service design.
5. Supplier quality management.
6. Process management.
7. Quality data and reporting.
8. Employee relations.

It is important to recognise that TQM programmes result in significant changes in how we do business and the manner in which the change is communicated is crucial to their success. Guaspari (1996) elaborates on a way to achieve buy-in from your employees through an analogy with marketing approaches to selling a product on the marketplace. Three key issues discussed are: Do you really know why the change is best for your employees? Can you deliver on those claims? Can you communicate "*best*", clearly and compellingly? Developing on his third issue, communication,

> "If there's one thing that everyone agrees on, it's that communications are an essential part of achieving buy-in." Guaspari (1996).

The way in which the message is communicated is vital. Additionally, he states that there is no time when you are not communicating. In fact what you don't say can send as loud a (if not louder) message as what you actually say. How you allocate your time, your actions, can often provide the hidden message of the importance that you place on the particular issue.

Clearly, the debate surrounding quality management, continuous improvement, and statistical process control (SPC), will continue for some time yet. The need to continuously improve the quality of your product and processes is considered to be a requirement to sustain growth and profitability in today's global markets, the disagreement appears to focus more on the how it is achieved.

2.3 Quality Certification and Award Programmes

A large percentage of companies in business today will have participated in some form of certification, of their processes and/or their products. In fact, many executives consider certification to be practically a requirement to do business nowadays.

Whether it is an internationally recognised programme, for example the ISO 9000 series, or an individual supplier certification programme the final goal is not much different - a documented quality management system. Doubts have been raised about the effectiveness of the implementation of ISO 9000 standards as a way of infusing quality within an organisation. However, because of its universal acceptance and potential to provide a common basis for comparison, ISO 9000 standards do represent a major international quality initiative (ISO website, 1998, Skrabec, et. al., 1997, Rao, et. al., 1997).

This increase in company certification is a reflection of the increasing awareness of people to quality and quality related issues. This improved awareness is in itself beneficial. However, when the certification is treated as an end in itself the full extent of the value to be gained is lost. Unfortunately, this activity dominates and diverts attention from what ought to be going on all the time and in every part of the organisation. That effort ought to bring incremental, small, continuous but nevertheless real improvements. That should not be overshadowed by having to prepare a submission for a "prize". The ultimate goal should be to become more competitive and thus stay in business. As was shown in the Made in Switzerland (Julien, et. al. 1996) study there was no significant difference between the companies that were ISO 9000 certified and those that were not, when it came to their quality performance. Skrabec et. al. (1997) document many improvements to the system as a result of ISO 9000 registration. Their study suggests that many companies expect that the improvements to their systems will produce long-term benefits in the form of competitive advantage. This assumption is not supported in their study. However, in other studies reported on in the literature, linkages between ISO 9000 and quality management practices have been confirmed through increased quality orientation, leadership and results (Withers, et. al., 1997, Rao, et. al., 1997)

The sad truth is that being certified to ISO 9000 or any similar quality certification does not guarantee success, increased market share nor delighted customers. These expectations have led to disillusionment, fairly or unfairly, with all such programmes.

2.3.1 European Foundation for Quality Management

The European Foundation for Quality Management (E.F.Q.M.) was founded in 1988 to promote Total Quality Management in Europe. Their objective is to:

> "Create conditions to enhance the position of European industry by strengthening the role of management in quality strategies". (E.F.Q.M. 1994).

To assist in the achievement of this, the EFQM has developed a Model of Total Quality Management (E.F.Q.M. Guidelines 1994), which provides a generic framework that adapts to different organisations, business units, despite the uniqueness of every organisation, see Figure 2.3.

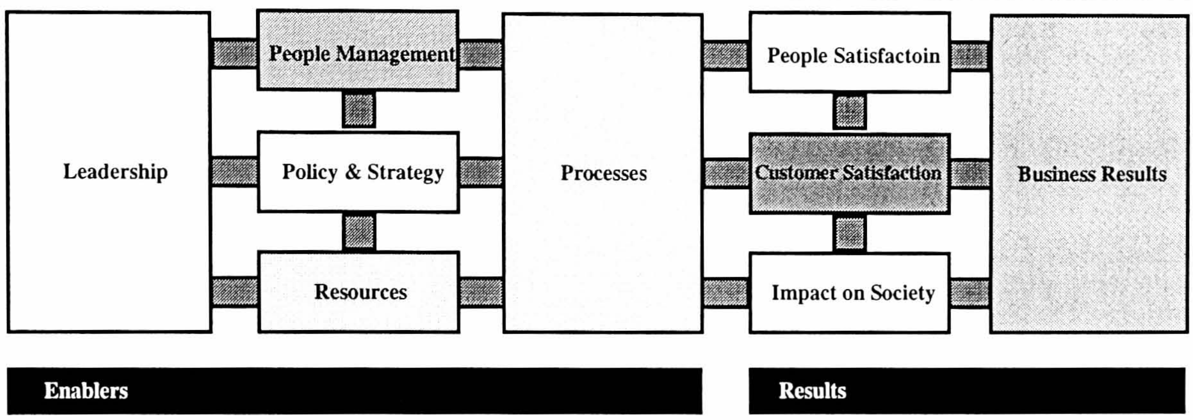


Figure 2.3. The European Model for Total Quality Management.

The basic premise of the E.F.Q.M. Model as stated is that:

> "Customer satisfaction, people (employee) satisfaction, and impact on society are achieved through leadership, which drives the policy and strategy, people management, resources and processes, leading to excellence in business results." (E.F.Q.M. 1994).

The EFQM is responsible for The European Quality Award which is the European equivalent to the Malcolm Baldridge Award in the US. The assessment process follows the guidelines set down by the model and assigns a score for the company in each of the nine elements of the model, where the overall score is split 50:50 between the enablers and the results. The results are an indication of what the company has achieved and is achieving, while the enablers indicate how the company is achieving those results.

E.F.Q.M.'s mission is to:

- Support the management of European companies in accelerating the process of making quality a decisive influence for achieving global competitive advantage;
- Stimulate and, where necessary, assist all segments of the European community to participate in quality improvement activities and to enhance the quality culture. (E.F.Q.M. 1994).

In keeping with the EFQM Mission statement their activities are not limited to the European Quality Award, they organise numerous activities throughout the year, as a means of increasing the awareness and promoting quality as a decisive influence. Many companies use the qualification process solely as a way of benchmarking their performance on a regular basis, which provides the focus for their process improvement programmes. Where the different types of benchmarking can provide invaluable information related to the current norms in the industry, and also the *'best in class'*.

2.4 Information Tools

Regardless of the approach used, the underlying requirement is that the people working within the system have timely and accurate information about the processes. Given the information overload being experienced by most managers today, finding and using the tools best suited to the individual situation could be the key to improving the quality of information available and consequently knowledge and organisational learning. The goal of this section is not to provide an in-depth description of all the tools available to managers, but instead briefly reviews a handful of tools that are relevant to this study. The section includes details related to the seven basic tools of quality control, with the exception of control charts which are dealt with separately in Chapter 3, the seven new quality tools, process flowcharts and the house of quality.

2.4.1 The Seven Basic Tools of Quality Control

2.4.1.1 Check Sheets

Check sheets are used for collecting data. The most important purpose of the check sheet is that it allows the user to collect and organise data in a format that facilitates analysis. There are different types of check sheets, depending on the needs of the user. Three of the more common types are; Attribute check sheets, variables check sheet and defect location check sheets (Gitlow, et. al., 1989).

2.4.1.2 Histograms

A histogram is a type of bar chart which is a useful way of graphically representing a frequency distribution or a relative frequency distribution (Daniel and Terrell, 1989). The variable under consideration is plotted on the horizontal axis and the frequency (or relative frequency) plotted on the vertical axis. The shape of the histogram provides useful information about the state of the population. The mean and standard deviation are the measures most often used to describe the distribution.

2.4.1.3 Stratification

The process of dividing the sample into two or more sub-populations is called stratification, and the sub-populations are called strata. The systematic decomposition of the population or process data allows for the development of a detailed understanding of the underlying structure. When used in combination with other techniques it is a useful approach to problem solving and can help to identify the root causes.

2.4.1.4 Scatter Diagrams

Scatter diagrams are a useful way to study the relationship between two variables. A simple X-Y plot of the two variables produces the scatter diagram, which can reveal whether or not a strong, weak, positive or negative relationship exists between the variables. The absence of any correlation between the two variables can be as revealing as discovering the presence of a relationship.

2.4.1.5 Pareto Analysis

This type of analysis allows for the identification and prioritisation of problems. It's origin is the work of an Italian economist Vilfredo Pareto who showed that the distribution of income was uneven, which focused attention on the vital few as opposed to the trivial many (Kume, 1985). His ideas were developed on by M.C. Lorenz in the US and ultimately by Juran who applied it as a means of classifying problems of quality.

The Pareto diagram is a bar chart with the bars arranged in descending order, what the diagram provides is not a problem solving technique but a technique for identifying problems to solve.

2.4.1.6 Ishikawa Diagrams

The Ishikawa diagram also known as Cause-and-Effect diagrams or Fishbone diagrams are widely used in industry as a structured problem solving technique. They provide a way for employees to deal with a large number of factors that are affecting their processes. It is used in conjunction with other tools, and requires the team to first identify the problem or effect that they want to study, and hopefully correct. Once the problem has been clearly defined then the team members list all of the factors that contribute to the problem, once completed then the information can be visualised on an Ishikawa diagram. The team members evaluate the causes and select the ones that they feel contribute the most to the observed effect, and work on removing that problem.

2.4.2 The Seven New Quality Tools

2.4.2.1 Affinity Diagram

Affinity diagrams are a type of brainstorming exercise and are part of the creative process. It is a useful way to generate ideas and categories that can be used in subsequent steps with more analytical tools. The technique collects large amounts of language data and groups them based on the relationships between them. Affinity diagrams are particularly useful in the following instances (Oakland, 1994):

- When the facts or ideas are in chaos, or when the issues involved are too large and or complex to be easily defined.
- When breakthrough ideas are needed, i.e. new concepts are needed to replace the traditional norms.

- When support for the initiative is essential for the success of the implementation.

2.4.2.2 Interrelationship Diagraph

This approach maps out the relationships between the various factors that impact on the central issue/problem. It develops on the affinity diagram by identifying the logical and sequential links between the ideas outlined, it also allows for the identification of unanticipated ideas and connections. It is a useful method to use:

- When dealing with a complex issue where the interrelationships between the factors is unclear.
- When the sequence of management tasks is critical.
- When there is a suspicion that the core issue is in fact just a symptom.

2.4.2.3 Tree Diagram

A tree diagram can be used to either map out the activities that are necessary to achieve the desired goal, or to identify all the factors contributing to the problem under consideration. One of the main benefits of the approach is that it forces the user to consider the logical and chronological links between the different tasks. This helps to reduce the human tendency to bypass the planning phase, where the implementers move from the clarification of the goal phase directly into the action phase.

2.4.2.4 Matrix Diagrams

The purpose of the matrix diagram is to display the interrelationships and correlations between the various tasks, functions or product characteristics and to show their relative importance. The matrix diagram is at the heart of the technique called the *'House of Quality'* which is discussed in more detail in a later section. The most basic of forms of the matrix diagram is the L-shaped matrix which shows the relationships between two groups of items, in a row - column format. Another common type is the T-shaped matrix diagram. Very simply it is a combination of two L-shaped matrix diagrams, which relates one group of items to two other groups of items.

2.4.2.5 Matrix Data Analysis

The origin of the data used in this analysis is from the matrix diagram. The technique results in a simple two dimensional graph that displays the strengths between the variables very clearly. The approach is used most frequently when conducting marketing and product development research.

2.4.2.6 Process Decision Programme Chart (PDPC)

A PDPC is a way to proactively address all the possible causes of failure for the particular project, and to define contingency plans in advance. The starting point for the construction of a PDPC is the tree diagram. For each of the main branches of the tree diagram the question 'What could go wrong at this stage?' is posed. All the possible problems are listed and a set of actions or counter measures that could be taken are identified.

2.4.2.7 Arrow Diagram

The arrow diagram is essentially the same as a Gantt chart and is used to plan or schedule a project. To construct an arrow diagram it is essential that both the sequence and duration of the sub-tasks are known. The technique is used extensively in the project management area as a way to schedule and control the series of tasks that need to be performed to complete the project. The technique is often referred to as the '*critical path method*'. For a detailed description of how to build the networks and find the critical path the author recommends the following texts Vonderembse and White (1996), Schroeder (1989), and Budnick, McLeavey and Mojena (1988).

2.4.3 Quality Function Deployment (QFD) - The House of Quality

This approach originated in Japan in 1972 at Mitsubishi's Kobe shipyard (Oakland, 1994). Since that time many different applications for the technique have been found. QFD provides a way to translate the voice of the customer into design characteristics for the product and process, through a series of matrices. These matrices are commonly referred to as the "house of quality", because of their shape, see Figure 2.4.

A QFD team must answer the following three questions:

1. WHO are the customers?
2. WHAT does the customer need?
3. HOW will the needs be satisfied?

The answers to these questions provide the input to the house of quality. The technique is repeated producing a sequence of house of quality diagrams, where the HOWs on the top level become the WHATs of the next step down the sequence and so on. The final house of quality defines the process requirements necessary to produce the product. In this way the customer requirements have been deployed throughout the entire organisation.

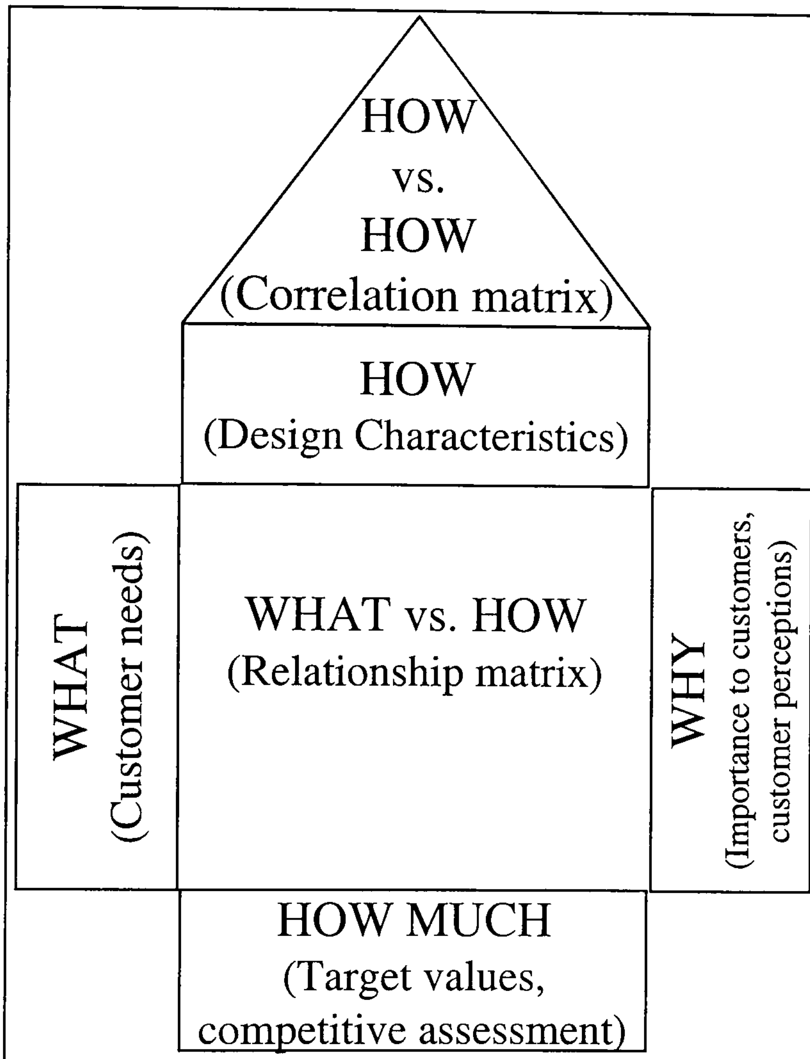


Figure 2.4. House of Quality, (Vonderembse & White, 1996).

2.4.4 Process Flowcharting

A flowchart is a pictorial summary of a process. It describes the flow of materials and information through the process, and identifies all the tasks that are integral to the process. The strength of this particular tool is that it provides a very clear overview of the process while being extremely simple to master and use. In all improvement projects one of the first things that should be done is to flowchart the process, as the job of flowcharting the process will improve the knowledge about the process and will highlight flaws in the process; unnecessary complications, and the movement of work and people that could be eliminated to simplify the process.

The different symbols used in flowcharts have been standardised and their use for process documentation allows for clear communication among process members (British Deming Association, A17, 1995).

2.5 Project Management

The project management area is a mature one with many techniques such as critical path method, and PERT analyses developed specifically for it. In spite of the advances in the area, project management suffers from many systemic problems, insufficient resources, lack of top management commitment/ understanding, and unclear/conflicting goals all of which contribute to the general observation that the majority of projects are not completed on-time, within budget or to specification. The problem is well documented in Information Systems (IS) organisations, where it has been reported that only 18% of all projects are completed within budget, with over half of the projects (51%) overrunning the original estimate by an average of 189% (Robert, 1997). Equally disturbing is the fact that very often the final product does not meet with customers expectations, because of the time pressure and a lack of knowledge about the overall project/product, corners are cut and specifications changed without much consideration given to the functionality of the end product.

The role of project manager is an unenviable one;

> "The title 'project manager' conveys the impression that its bearers have complete mastery over their destiny. Usually, the opposite is true. It is a generally accepted principle that the project manager has all of the responsibility for a project and none of the authority over it." (Robert, 1997).

At the same time many companies are adopting management by projects as their approach to general management in response to the pressures created by the increasing rate of change and complexity in both their technologies and markets. This change impacts on the management systems and procedures, and the people employed by these firms. Where the role of project leader assumes greater importance to the overall success of the organisation. At the International Institute for Management Development in Lausanne, the ability to manage projects is considered to be one of the key skills that graduates should learn while on campus. Clearly, a paradox exists between the current importance of the project manager and the predicted future importance of the project manager, which needs to be addressed.

In the last year Eli Goldratt has proposed a new approach to managing projects which applies his ideas on the theory of constraints (Goldratt and Cox, 1993) to the area. In his latest book *Critical Chain,* Goldratt (1997) applies the framework to the management of projects. The technique works well for individual projects and has been outlined in the book. Unfortunately the methodology is not well developed with respect to the management of a portfolio of projects. To the traditional approach of focusing on the critical path as the way to manage projects Goldratt (1997) adds a second critical constraint: scare resources needed by project tasks both on and off the critical path and also by other projects. The critical chain as defined by Goldratt includes both the critical path and also the scarce resources that need to be managed by the project manager. Another important feature of his approach is the use of time buffers, at the end of the each of the feeder chains and one at the end of the critical path.

Given that most company cultures do not applaud the project manager that kills projects early, and also the inherent reluctance of people to admit defeat, the result is the following:

> "The net effect is that most organisations have too many projects relative to their available capacity." (Elton and Roe, 1998)

This proved to be a huge problem in the company on which this study was based. With the limited resources in the development laboratories stretched beyond their optimum capacity, because of an over acceptance of projects that eventually were killed.

2.6 Conclusion

This chapter provided an overview of the some of the different approaches to quality as developed by Walter Shewhart, Dr. W. Edwards Deming, Dr. Joseph M. Juran, Dr. Kaoru Ishikawa, Armand V. Feigenbaum, and Philip B. Crosby. Having reviewed the fundamental teachings in the quality field, a synopsis of the current debate surrounding the disillusionment with TQM programmes is presented. The different perspectives discussed provide a review of the current thinking and attitudes towards the quality movement.

Given that certification is becoming practically a requirement to do business, the author briefly reviews the importance of quality certification and award programmes. This was followed by a section on some tools that are commonly used by practitioners, including both the seven old and new quality tools, the house of quality and process flowcharting. The chapter concludes with a discussion on the increasing importance of project management to a company's competitiveness. Additionally, some insights are provided on the problems in the field of project management.

Chapter 3 concentrates on the literature directly related to the use of and the barriers to the statistical process control charts.

Chapter 3.

Review of Statistical Process Control (SPC) Literature.

3.1 Introduction

Shewhart's techniques for data analysis have proved themselves in practice for over 60 years. They are an invaluable tool for unlocking the information that is hidden in many of the numbers and statistics with which we are inundated. The beauty of control charts is in their simplicity and ease of use which disguises the power of them as a filter of noise and provider of information.

> "Process control charts aid communication." (Wheeler, Summer 1996 seminar)

The traditional comparisons made by managers between weekly, monthly, yearly data can be at the very least limiting in their scope and at the worst contradictory. Shewhart's control charts define the voice of the process, that is they tell us how the process is performing and in the case of the control charts for individual values the limits indicate what a stable process is capable of (Neave, 1993).

> "Control charts can be used to bring the voice of the customer and the voice of the process into alignment." (Wheeler, Summer 1996 seminar)

3.2 The use and implementation of SPC techniques

While statistical process control (SPC) has played an important role in industry for some time now, the integration of the technique into management science has met with limited success.

The study reported on in this thesis was based on data collected from product development laboratories in a Flavour and Fragrance house. The information used was far-removed from the manufacturing floor of the company and, as such, it provided a good opportunity to observe and record some of the difficulties with the application of SPC methods in other areas.

In their article exploring the role that statistical thinking should play in management, Hare et. al. (1995) define four major issues that they feel need to be addressed before SPC can become an integral part of management:

- Managers must understand why they need to possess statistical knowledge.
- Current and future managers must develop this knowledge.
- Measures must be taken to ensure that the knowledge is effectively applied.
- The payoff from the knowledge and its application must be assessed.

They see the development of a statistical thinking mind-set as the key to the long term success of the organisation.

Wood (1994) outlines the basic assumptions underlying the philosophy of quality management, on which SPC depends, as follows:

- The important quality characteristics can be and should be measured.
- The aim should be the prevention of problems before they occur, rather than diagnosing them after they have occurred.
- Wherever possible the analysis should concentrate on the process rather than the output.
- The resources devoted to testing, monitoring and inspection should be as few as possible.

He argues that it is these principles and not the techniques themselves that are the real essence of SPC.

Numerous barriers to the use of SPC techniques by managers have been isolated by researchers, which vary in their seriousness. A spectrum of causes has been suggested to explain this phenomenon; the lack of top management commitment, inadequate training, cultural barriers, psychological biases, and resistance to change, (Oakland and Sohal, 1987, Bushe, 1988, Lascelles and Dale, 1988, Levi and Mainstone, 1987). Some of the practical problems of dealing with resistance from employees and trade unions when trying to implement SPC are highlighted by several researchers (Shaw and Dale, 1987, Preston, 1987). Some additional common concerns which they encountered during their work were, what should be measured and how often should samples be taken.

Wood and Preece (1992) observe that there is a lot of variation in the way that the different SPC techniques are used by practitioners in the field, they also question the validity and effectiveness of some of the results. They make several recommendations to help improve the current situation based on their interpretation of the key drivers behind the misuse:

- To specify clearly the objectives of the quality management system, before designing the measurement approach.
- Whatever the proposed measurement approach decided on it must be planned and evaluated as an entire system, incorporating all the skills and resources available to the team.

- When training employees in the use of the measurement approach, concentrate on the underlying concepts and their interpretation as opposed to just the technique.

A recent report based on a panel discussion on the subject of statistically based process monitoring and control, identified three independent groups of users (Palm, et. al. 1997):

- Group 1 with an interest mainly in the broad application of SPC across industries, and departments. This group is motivated by competitive issues and changing industry standards.
- Group 2 with an interest in the technical opportunities, makes use of the mass of on-line data available from industrial processes. This group is comprised of statisticians and engineers who are very knowledgeable about the subject area.
- Group 3 is interested in the development of theories and methods related to the area. This group consists of academics and researchers interested in developing variations of the control chart that provide some added value.

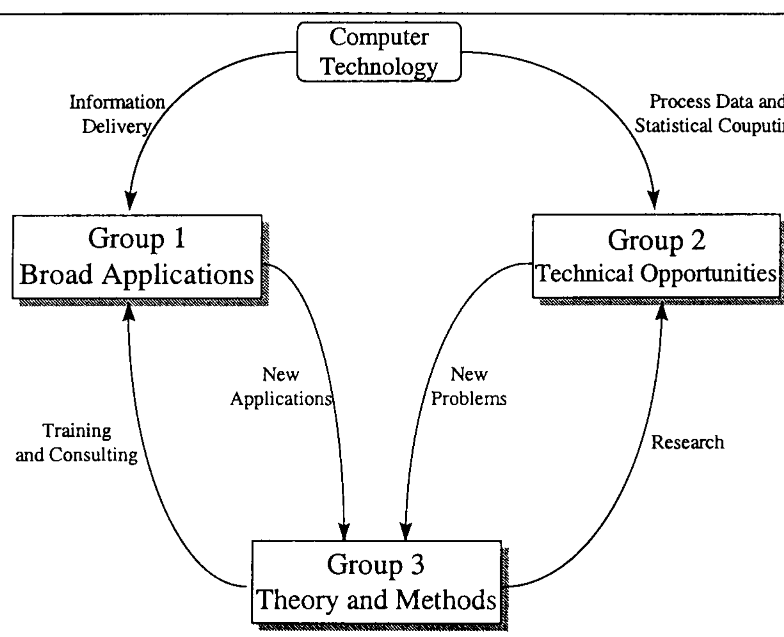


Figure 3.1. Interaction between SPC User Groups (Palm, et. al. 1997).

The three groups are linked and constantly challenge each other and benefit from each other's perspectives, see Figure 3.1.

The work reported on in this thesis consists of components that belong to each of the three groups. Firstly, the study involves the application of the techniques in a company belonging to the flavour and fragrance industry. While they belong to the larger group of the Chemical industry (SIC classification) they are an extremely specialised sector within the industry and have not been studied in any great depth. Additionally, the study conducted was not in the manufacturing division but instead used data from the product development laboratories. Secondly, the study made use of a large volume of data collected by the people in the laboratories and input into the project management database. Finally, given that the data collected was highly skewed and of the individual measurements type, the author was able to compare several different approaches to the construction of the individual measurements charts with the goal of developing a better understanding of the limitations, and add value to the field through the ability to recommend a particular approach for dealing with this type of data.

> "Traditionally, SPC has been used in manufacturing and most examples of its use are from the motor or chemical industries. Its potential in the service industry and in administrative areas generally is, however, enormous." (Morgan, 1998).

Indeed the use of SPC in manufacturing and the derived benefits in the way of less rework and scrap, reduced work in process inventories, and improved processes is well documented. Of more interest and relevance to this particular study were examples of its use in areas other than standard manufacturing environments. Some examples of the more pertinent case studies are presented below.

Kattan (1993) presents a case study of the use of SPC in ship production to reduce rework. The paper provides examples of how the tools can be used to solve problems in a 'make to order' industry. Another study involved the implementation of SPC in a low-volume environment (Al-Salti, Aspinwall, and Statham, 1992). The company studied was a manufacturer of aircraft components, where the batch sizes were generally less than one hundred. Al-Salti, et. al., suggest an alternative approach to using SPC because of several problems inherent to the production process under study. For example the small batch sizes created problems because of a lack of sufficient data to establish the control charts. They suggest monitoring the performance of the machining process as opposed to the components being machined.

Stankevich (1996) presents an interesting case showing the usefulness of SPC in the area of risk management in the health insurance industry. He demonstrates through the use of real data, the flawed decision making of the management in the particular company using traditional indicators, and builds his case for the use of SPC as a way to improve the management's decision making. Darragh-Jeromos (1996) through the use of very simple everyday examples illustrates the use of SPC. She develops on the idea of variation in all processes and how the tools can help prevent managers reacting to random variation, in so doing improve their decision making capabilities.

An interesting study involved using SPC to analyse crime rates in Houston Texas (Anderson and Diaz, 1996). Where the application involved monitoring the levels of different types of crimes in the area, checking for shifts in the numbers after some change was made to the system. For example, the rates of the different crimes were analysed after the Houston Police Department instituted an overtime programme. Zimmerman, Dardeau, Crozier, and Wagstaff (1996) discuss an interesting application of the tools to monitoring the quality of water. It is particularly relevant given the public and companies increasing awareness of the need to be environmentally responsible.

One observation that is slightly disturbing to the author was the large number of studies touting improved quality, increased productivity, improved ROI, and boosted Cpk, because of the implementation of SPC software packages (Aldred, 1998, Lingle, 1998, Chase, 1997, Litsikas, 1997 (a, b & c)). The emphasis seemed to be more on the software and ways to increasingly automate all aspects of the quality control process. While using technology is important, the author is concerned that input from the individuals working on the different products is being lost. Where that knowledge is vital for process improvement. The second concern is the need to manage the computer systems properly, as there is a risk of the workers and managers not accepting responsibility for the results produced.

Project management, in particular with respect to new product development, is an area where not much work in the application of SPC techniques has been done. It is traditionally an area to which companies devote a lot of resources, as it is key to their continued competitive success. However, it is also an area where companies waste huge quantities of resources, through bad project management, late projects, unclear specifications, lack of customer focus, and conflicting goals within the project team.

In particular the author was able to find some examples of the use of SPC in the construction industry. Arditi and Gunaydin (1997) argue that there is a huge potential for quality improvement in the construction industry. They highlight that the Japanese have been using the tools since the 1970s, despite the arguments that construction involves a creative, one of a kind product, and that the tools are only applicable to a mass production type of environment. In another study Baweja (1997) conducts a study to determine if SPC charts could be used for project controls on a construction project. The control charts were used to track and identify productivity trends. Interestingly Baweja highlights the need for a tool to identify problems with the aim of improving the process.

> "Though most construction organisations have sophisticated project cost and schedule-control systems, most do not use statistical analytical tools for effectively recognising poor productivity periods or trends on the project." (Baweja, 1997)

In another study (Giammalvo, Firman, and Dwiyani, 1996) data from the project scheduling process is used with different SPC tools as a means of improving the process. The example is also from the construction industry, specifically the construction of oil and process plant sites. They conclude that the tools improve the project teams ability to manage by fact and also gives the team a more global perspective of the whole project and how different steps can impact on the entire process.

The study on which this thesis is based used data from four different product development laboratories, and the author considers it to be a golden opportunity to test the appropriateness of using SPC tools in this area of project management. The study represents a novel application in an area of project management begging for improvement.

3.3 Background on control charts

The basic concept of control charts is that of a time-series graph which represents the data of interest, while maintaining their occurrence in time. Time is normally represented on the horizontal axis and the individual values on the vertical. To the time-series three lines are added: the mean line, and two control limits on either side of the mean, this technique was first proposed by Shewhart in the early part of this century. The traditional control limits are equidistant from the mean and are calculated from the data being plotted. The different lines serve different functions, the mean line allows us to detect trend shifts in the data, while the control limits represent the point within which the process is exhibiting controlled variation, and outside of which is an indicator of something special. These control limits have also been called "Natural Process Limits". Shewhart (1997) defined control as follows:

> "A phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that prediction within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within the given limits."

All processes exhibit variation. It is unavoidable but controllable, it is the result of either common or special causes. In fact, it would be more surprising if the processes showed no variation! Wheeler's definitions for controlled and uncontrolled variation are strongly influenced by Shewhart's work (Wheeler, 1995):

> *"Controlled variation* is characterised by a stable and consistent pattern of variation over time. Dr. Shewhart attributed such variation to *'chance'* causes."
>
> *"Uncontrolled variation* is characterised by a pattern of variation that changes over time in an unpredictable manner. Dr. Shewhart attributed these unpredictable changes in the pattern of variation to *'assignable'* causes."

In his book *"Out of the Crisis"* Deming (1992) clarifies that Shewhart used the term assignable cause, while Deming himself preferred to used the term special cause to mean the same thing. Deming (1992) defines special and common causes very simply as follows:

> "We shall speak of faults of the system as common causes of trouble, and faults from fleeting events as special causes."

Deming estimated that common variation is responsible for at least 94% of the problems with the system, the remaining 6% is attributable to special variation (Deming, 1992).

The actions required to isolate and remove a special cause are very different from those required to improve the process. It is management's responsibility to change the system if they are unhappy with the level of problems, due to common causes. While the detection and removal of special causes are the responsibility of people directly involved with the system. These special causes are not always undesirable, in which case once the cause has been pinpointed it may result in an improvement to the process.

Once the process is in statistical control and the voice of the process is being monitored at appropriate intervals, our actions must be in sync with what the process is saying to us. When there is a point which lies outside the process control limits and it is the result of a special cause. It must be investigated to try to determine what circumstances or actions produced it. The process of investigation is viewed as an opportunity. It is an opportunity to improve our process, either through getting to the root cause of the problem and ensuring that it can not happen again, or if it was desirable to ensure that it is incorporated into the process and becomes part of the normal activities. The more complex issues arise when the process is behaving in an orderly fashion, and is in statistical control exhibiting only common variation. To effect some change involves looking at the process in detail to seek areas for improvement. The standard control chart test as outlined by Shewhart, used the position of a point relative to the three sigma limits as the single criterion indicating the control or the lack of control in the process. The selection of this criterion was intended by Shewhart to strike an economic balance between the consequences of the two types of errors possible. Where the two types of errors are described as follows (Western Electric Co., 1956):

Type 1 error: "Looking for assignable (special) causes when no such causes exist; that is, having a point fall outside of the control limits when, in fact, there has been no change in the process."

Type 2 error: "Not looking for assignable (special) causes when such causes do exist; that is, having a point fall within the control limits when, in fact, there has been a change in the process."

To assist in the detection of a special cause, numerous run tests have been published by researchers. Western Electric Company (1956) engineers published a list of fifteen characteristic patterns they identified that they felt provided additional diagnostic power to their process control programme. These include tests to detect natural patterns in the data, shifts in the level (trends), and cycles. Wheeler (1995) is of the opinion that it is impractical to use all of the run tests published and recommends that the user start with just Shewhart's first detection rule -- a point outside of the 3-sigma control limits. As increasing sensitivity becomes necessary, and as people using the charts become more sophisticated then additional rules can be added. Care needs to be taken to avoid people over-adjusting or tampering with the system. The use of this simple criteria for indicating problems reduces the natural inclination of people to react to every mistake or defect as if it were the result of something special.

3.4 Overview of the different types of control charts

3.4.1 Different types of data

The two types of data of interest to this study are variable and attribute data. Variable data arise from measurements and can occur at any point along a continuous scale. Some examples of variable data are the weight of a tablet, the length of a metal rod, or the tensile strength of a wire. In principle the data are continuous but in practice they vary in jumps, because of the limitations of the measurement instruments used. On the other hand attribute data arise when numbers of particular types of occurrences or events are being counted. Some examples of attribute data are counts of defects, emergencies, or mistakes. Attribute data give rise to discrete data. (Neave, 1993, Wheeler, 1995, Oakland, 1986).

It is important to distinguish between the two types of data and to be clear on which type is being used, because the approaches to constructing the control charts are different depending on the type of data be it variable or attribute.

When dealing with measurement data there are several different types of control charts that can be plotted. Two of the most common types of charts used are outlined below.

3.4.2 The XmR chart

In the event that either it is not practical to collect subgroups of data or the data cannot be logically grouped together, then the XmR chart is the appropriate type of control chart to use to represent the data. The moving range between consecutive values is calculated, and used to represent the common cause variation in the data, which is used to calculate the control limits for the X-chart.

Two time-series are plotted the X-chart which is the chart of the individual values and the moving range chart, to which the centre lines and limits are added. The centre lines are the averages of the data points plotted in the time-series. In the moving range chart only an upper limit is plotted, the formulas used for the moving range chart are:

Upper control limit for the moving Range = $D_4 \times \overline{mR}$, and the

Centre line for the moving Range = $\overline{mR}$

For the X-chart both the upper and lower process limits are plotted, the formulas for the X-chart are as follows:

Upper process limit $X = \overline{X} + (E_2 \times \overline{mR})$,

The centre line for $X = \overline{X}$, and the

Lower process limit $X = \overline{X} - (E_2 \times \overline{mR})$

The two scaling factors used in the calculation are based on Shewhart's work and approximate three standard deviations from the mean. For the individual values chart these values are defined as (Wheeler, 1993); $D_4 = 3.27$ and $E_2 = 2.66$.

3.4.3 The $\overline{X}$-R control chart

When using grouped data the most common type of control chart is the average and range chart. In practice the size of the subgroups is generally less than seven. A key advantage of choosing to use sub-groups over individual measurements when feasible, is that, it provides a very good measure of the common cause variation present in the process, even when dealing with an unstable process. Given the short time span represented by data within a subgroup, as compared to between subgroups, it is very unlikely that any factors other than common causes would cause fluctuations within the subgroup.

The two time-series plotted are the $\overline{X}$ chart and the range chart. The formulas for the Range chart are as follows:

Upper control limit for $R = D_4 \overline{R}$,

The centre line for $R = \overline{R}$, and the

Lower control limit for $R = D_3\bar{R}$.

In the majority of cases where the size of the subgroups is no greater than six, the range chart has no lower limit as D_3 is undefined for subgroups with less than seven values.

The formulas used to calculate the limits for the $\bar{X}$ chart are as follows:

Upper control limit for $\bar{X} = \bar{\bar{X}} + A_2\bar{R}$,

The centre line for $\bar{X} = \bar{\bar{X}}$, and the

Lower control limit for $\bar{X} = \bar{\bar{X}} - A_2\bar{R}$

The values for the scaling factors used in the formulas vary depending on the size of the subgroup used. The author recommends Wheeler's book (1995) as a source of the complete table of values for the different factors for the different values of n (where n is the subgroup size).

When the data are of the attribute type then a slightly different approach is used to construct the control charts. Two types of charts for attribute data are described in the following subsections.

3.4.4 np-Charts

The *np*-chart is used whenever the data appear to be binomially distributed. Generally, for every sample drawn each item is classified as possessing or not possessing some particular characteristic. Additionally, the probability of any particular item possessing the particular attribute is unaffected by whether or not the preceding item possessed it, i.e. the counts are independent of each other. The conventional notation used in this case defines n as the sample size, and p as the probability that the item has the attribute being counted. In practice $\bar{p}$ is substituted for the parameter p, where, $\bar{p}$ is defined as the average proportion of non-conforming items over all the samples. The formulas used to calculate the limits for the np-chart are as follows:

Upper control limit for np-chart = $n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$,

The centre line for np-chart = $n\bar{p}$, and the

Lower control limit for np-chart = $n\bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})}$

If the sample sizes change then each count needs to be adjusted by the size of the sample to make comparison of the different counts valid, the result is a proportion. In this case the chart is called a p-chart.

3.4.5 c-Charts

Unlike the np-chart where the counts represent the numbers of items possessing or not possessing a particular attribute, the data used with this type of chart represent a count of the number of non-conformities that the item possesses, it is not possible to count the number of conformities. This type of count data are modelled by the Poisson distribution. The usual notation for the number of defectives is c. For the sake of comparison the average number of defectives per sample is used, this average is denoted by $\bar{c}$. The formulas used to calculate the limits for the c-chart are as follows:

Upper control limit for c-chart = $\bar{c} + 3\sqrt{\bar{c}}$,

The centre line for c-chart = $\bar{c}$, and the

Lower control limit for c-chart = $\bar{c} - 3\sqrt{\bar{c}}$

In the event that the area of opportunity changes from sample to sample the counts of defectives need to be changed into rates before they can be compared. The conventional notation used to represent the rates is u and the chart is called a u-chart.

3.4.6 Zones on the control charts

The control chart is often divided up into six bands between the control limits, to facilitate looking for the different out-of-control patterns (run rules). The bands are each one standard deviation wide and are drawn about the centreline. Figure 3.2 illustrates the position of the bands and their names.

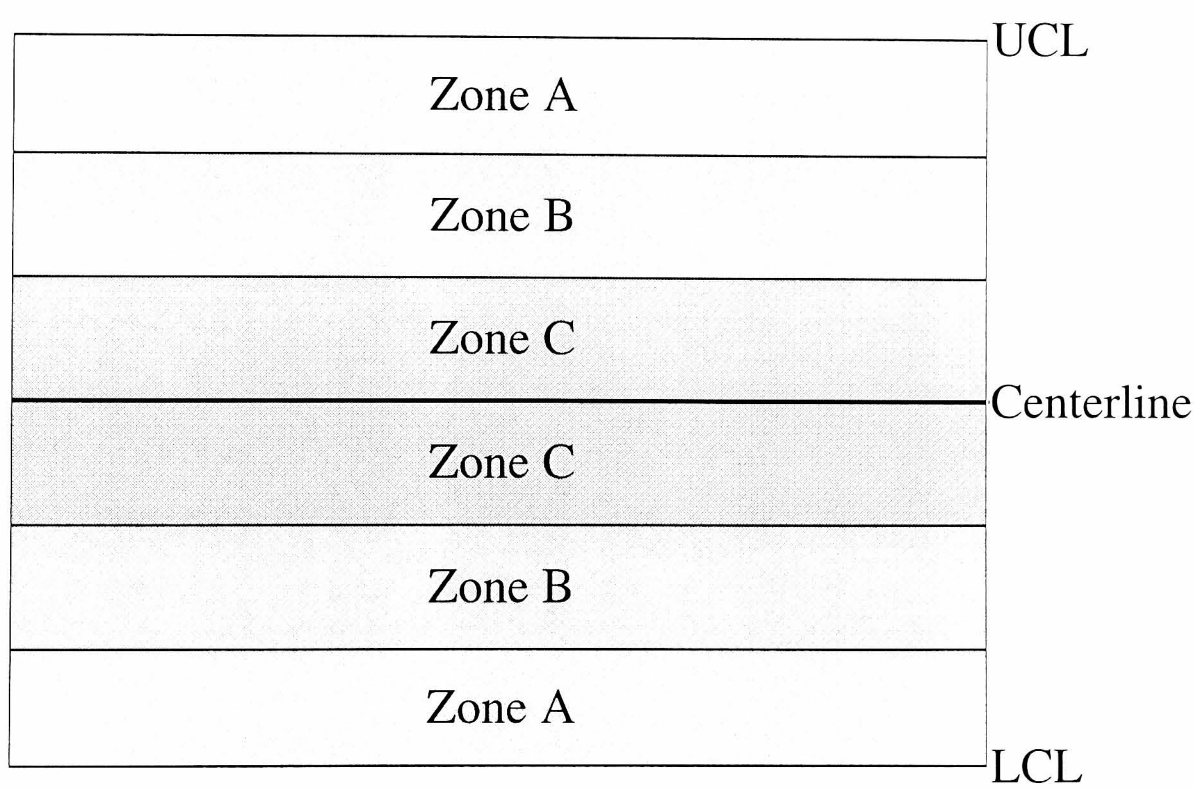


Figure 3.2. A, B, and C Zones for a control chart.

3.5 Discussion surrounding non-normal data

One debate which has aroused much ongoing controversy is the issue of the prerequisite of normality to plot the data on a variables control chart. Wheeler (1995) asserts that regardless of the distribution of the data being plotted the validity of the control chart is not in question. He demonstrates that while the central limit theorem is widely used and understood it is not required for the control charts to work. He considers this to be one of the biggest barriers to the effective use of control charts by managers.

> "Regardless of the distribution of the sample statistic, virtually all of the values will fall within three-sigma limits whenever the process displays statistical control". Wheeler (1995).

In another study based on a sample of 235 quality control applications Alwan and Roberts (1995) calculated that 86% of the applications studied displayed errors in the placement of the control limits. That the problem may be more widespread than is commonly believed, appears to be the case, given that, the 235 applications studied were considered to be expert applications, the data sources being quality control text-books and manuals, quality control software, vendors' advertisements and brochures, and a prominent quality control journal. The implication here was that, if the supposedly expert applications studied had such a high incidence of violations, then the broader population of users including the less sophisticated must have similar or worse levels of violations. The 235 examples studied were either X-bar charts, *p*-charts or *c*-charts.

Alwan and Roberts make the statement that:

> "The assumptions on which control charts are based are violated by real world data."

This is interesting in the light of the study reported on in this thesis involving the use of real world data, which proved to be anything but compliant with the prerequisites for the use of control charts.

Yourstone and Zimmer (1992) investigated the effect of non-normality as measured by skewness and kurtosis on the performance of control charts for averages. The assumption of normality implies that the control limits are symmetrical about the centre line. The validity of this approach is questioned by them, and they develop a technique for designing non-symmetrical charts, where the limits are not symmetrical about the centre line.

In fact, a lot of work has been carried out using the X-bar chart, looking at numerous ways of optimising their performance based on a variety of different factors (Yourstone and Zimmer, 1992, Alwan and Roberts, 1995, Zhang and Berardi, 1997, Wood, 1995). This abundance of research related to the X-bar chart is a natural outcome of the fact that, to date the majority of the applications in industry have been of this type.

Wood (1995) makes three suggestions for improving control charting procedures. The first is to avoid the terminology "in-control" and "out-of-control". The second and third methods are techniques for calculating the action and control limits. Of particular interest is the third method which involves the use of a 'bootstrapping' procedure. 'Bootstrapping' is a computer intensive statistical algorithm, that does not require that, the population be normal (Kennedy and Schumacher, 1993). In this instance, Wood used bootstrapping with replacement, that is random samples are drawn from the population replacing the value drawn before the next random sample is drawn. This technique has also been employed in the present study, to generate large datafiles based on the original project data. These datafiles of bootstrapped data were used to generate the control limits, for one of the approaches employed by the author.

3.6 Conclusion

This chapter starts by defining the value of SPC charts as representing the voice of the process, and their ability to act as filters of noise and as such aid communication. Having outlined their value as a management tool the discussion then moves to their use and implementation. In particular some of the problems with their transfer to management are discussed and different opinions on what needs to be in place are detailed. To establish the novelty of this study a review of other case studies using SPC is made, the review concentrates on applications that deviate from the standard manufacturing examples. The following section discusses the background on control charts. The different types of variation (controlled and uncontrolled) and the different types of errors possible are defined.

The next section gives the details on how to construct the charts and the different types of charts in common use depending on the type of data be it attribute or variable. The chapter concludes with a review of the current debate surrounding the handling of non-normal data on SPC charts. The next chapter will review in detail the methodologies used in this study.

Chapter 4.

Methodology

4.1 Introduction

The research reported on in this study is based on data collected from the European flavour division of a company in the Flavour and Fragrance industry. To comply with the request for anonymity the author will refer to the company as Caché Corporation, also individual's names have been changed.

4.2 Background on the Industry

The Flavour and Fragrance (F&F) industry as a whole is well known for its secrecy and as a result not much work has been done with companies belonging to the industry. Additionally, in the last three years the industry has been changing through a number of mergers and acquisitions, and finally, it is a growing market with predicted global growth in the flavours market of 6% in the next five years and about 3% in its sister industry, fragrances (Floreno, 1996).

While the mature markets of Europe and the US continue to be the most important to the industry, all eyes are turning towards the Asia Pacific rim as the key to future growth. Growth in the Asian market which is at an astounding rate, seems to be largely due to consumer trends. Studies have shown that consumption of flavoured products is related to the per-capita income (Floreno, 1996). As the middle class in the Asian countries grows, then demand for Western style food and beverages will also grow. The movement of Food & Beverage manufacturers into this region is the key driver fuelling the push by flavour companies into the region, in their role as supplier to the Food industry. The major players in the industry are scrambling for position, the latest being Givaudan-Roure with a plant in Fukuroi, Japan (Floreno, 1995). Givaudan is following behind other key players in the industry such as: International Flavors & Fragrances Inc., Bush Boake Allen and Firmenich Inc. who have already invested heavily in the region.

4.3 Background on Research Project

As stated earlier, the author worked specifically within the European flavour division of one of the top ten companies in the industry. The first contact was with the then Commercial Director of the division. The timing of the meeting was fortuitous as it coincided with a mandate from the European Director, to achieve a project turnaround time on all projects of five days. The current turnaround rate for the division was twenty eight days. As a result the agreement that was reached involved the author producing control charts for the Commercial Director, as a tool to help him understand and potentially improve the product development processes. In return the author would be able to use the data collected as the basis for this study.

4.4 Company Structure

The author received data from four different business units (BUs) within the European flavour division, these were; the Bakery BU, the Beverage BU, the Confectionery BU and the Dairy BU. As the names imply, the projects received from customers are categorised according to the type of product and market segment that they belong to. Once classified then the appropriate BU is responsible for all work related to the project.

The organisational structure within the division is depicted in Figure 4.1.

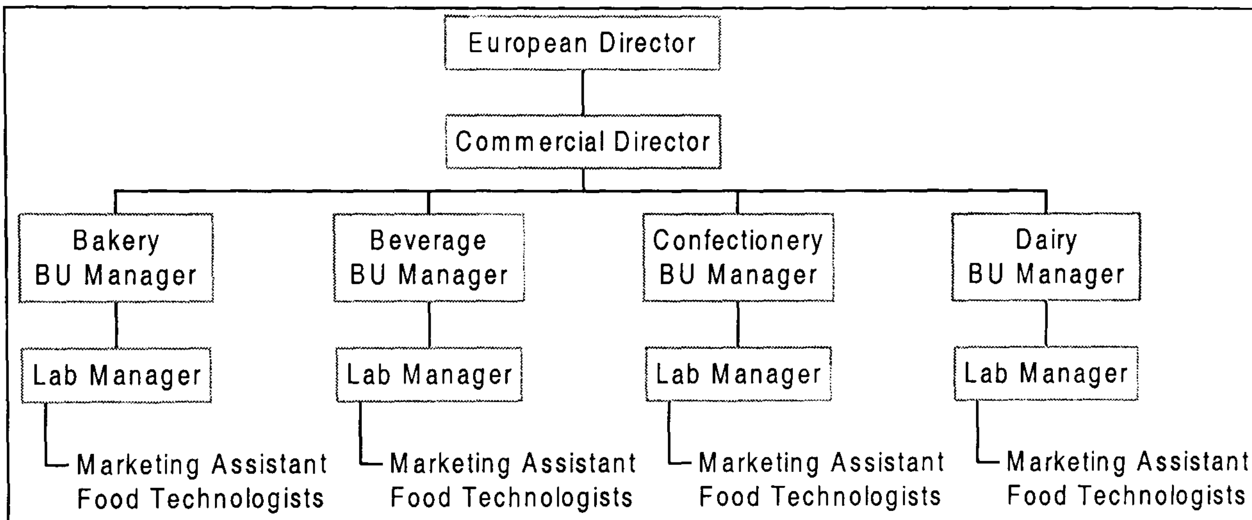


Figure 4.1. European Flavour Division Organisation.

4.5 Progress of research project

The first phase of the project was a meeting at which the author presented an overview of the project proposal, to the BU and the Laboratory Managers from the four BUs. In addition to getting the go ahead on the project, another outcome of this meeting was the decision that the authors interface with the BUs would be through the Marketing Assistants. This was considered to be the least disruptive approach for the BUs. In fact, it was the wish of the managers that the author interact as little as possible with the technologists working in the laboratories, as they were under constant pressure to meet deadlines.

Subsequently the author met individually with the marketing assistants to appraise them of the study, and their role as the authors first contact point. The then Marketing Assistant from the Confectionery BU, gave the author a detailed introduction to the project management database, including a description of the type of data that would be available to the author, and an overview of the company's product development process.

Within days of starting the project the author was faced with the first of many obstacles. In this instance the Database Manager was very reluctant to hand over any of the company data to an outsider. His opinion was that:

> "If there was any risk, no matter how small, of the data falling into their competitors hands then he would not take it!"

In fact, the author received the data not through any persuasive argument on her part, but courtesy of a direct order from the Commercial Director. As the author later learned, the Database Manager's attitudes were representative of many of the employees at Caché Corporation, in particular the ones who had been with the company for a long time, and were completely indoctrinated in the culture of secrecy. Fortunately, the majority of individuals that the author was in contact with in the development laboratories, were open to outsiders. The resistance that was encountered was completely different in nature, and had more to do with a lack of ownership and inertia towards the project.

The author developed XmR charts from the data, which she presented to the Commercial Director and the Marketing Assistants on a monthly basis. The agreement was that the author would receive the data exports, from the Database Manager at the end of every month. In practice the frequency was much less than monthly, due to various problems real or contrived of the Database Manager.

Within six months of starting the project it was announced that the Commercial Director was relocating to another country. The new Commercial

Director was introduced to the author by the departing manager and given an overview of the project, and some of the potential benefits that could be achieved outlined. At that time he agreed to let the project continue with his approval, however, in the following months it became more and more apparent that he had no real interest in the results of the project. Finally, the author and the new Commercial Director came to an understanding that the author could continue to collect and use the data for this study, but that the Commercial Director did not have any real interest in the results, and/or a practical application of the project through a process improvement initiative. The author had no choice but to accept this decision and while some potential richness of the data would be lost, it was felt that there was still sufficient data and detail to make the study worthwhile.

It would be an understatement to say that the company was experiencing some change, as in the time that the author has been associated with them, the number of structural changes and personnel movements throughout the corporation has been astounding. In fact, roughly seventy five percent of the people working in the four BU's that the author had access too, were not there six months prior. This is not to say that they were all new employees. The majority were transferred in from other filials towards the end of 1994. Where filials is the term used internally at Caché Corporation, to describe the company's branches in other countries. As can be expected after implementing such a large scale change, the teams were struggling under heavy workloads while simultaneously trying to acquire the necessary resources -- both hardware and people to achieve the levels of efficiency required.

4.6 Description of work

The basic work process carried out in the BU's is the same regardless of the different types of product. Essentially, a customer request outlines the product be it a new concept for a soft drink, sweet, or ice cream, etc.. The customer defines the specifics of the product that it is interested in, e.g. a 'citrus drink', 'juice based', 'only natural ingredients', etc.. The food technologist then prepares several different samples to meet the general specifications, incorporating a flavour system of any number of the company's flavours. There is no one right solution to the customer's request, and the technologist assigned to the project makes several different samples each with slightly different blends of flavours resulting in products that meet the overall specifications but with very different tonalities. The final product that the customer purchases is the flavour system (i.e. blend of flavours), as presented by the food technologists. The flavour system is broken down into its component flavours, which are mass produced and blended in the defined proportions to produce the specific flavour system.

Clearly, the work in the product development laboratories involves a mix of aspects from both mass customisation and craft work. Mass customisation, as every product produced (the flavour system used in the final product) is tailored to meet the specific customer's needs. At the same time craft comes into the picture as the actual development of the blend of flavours is very subjective, and represents the technologist's interpretation of the end taste, and mouth feel of the product. Additionally, the technologists have to understand how different flavours behave under certain conditions, and how performance can vary between, for example an ice cream, yoghurt or a beverage.

4.7 Product development process

The author developed a flowchart to represent the product development process, see Appendix 1. When a project is initiated it can be of the type solicited, proactive or defence. Where a solicited project has been requested by a customer, as opposed to a proactive project which is generated internally in response to expected market trends or expectations. The third classification - defence, is in response to a perceived threat from another flavour house, to a current account. Another classification that is added to every project is whether or not it is a collection, creation, or application type of project. Collection projects are the simplest and just entail using a flavour *'off the shelf'*, from the company's flavour collection. Application involves using flavours from the flavour collection, but also includes blending and applying the flavour system to the base substrate, to check its performance under normal use. Creation is the same as application but because of the forecast potential and the customer specifications, the assignment of a flavourist to develop a new flavour specifically for that project is justified. The flavourist works closely with the technologists to monitor the performance of the new flavour in the product.

Once the samples have been evaluated by both the internal taste panel and the customer, there are several possible outcomes. The customer agrees to buy the flavour system as is, rejects the proposal completely, or suggests some modification to the product. If modification is necessary then work continues on the project to incorporate the client's suggestions. Once the project is either accepted or rejected then the project file is closed and its status updated in the system.

4.8 Data description

The data used in this study was secondary in nature, it was input by the people in the BU's as part of the normal work practices related to project documentation. The database used for this study started in January 1995, through to the end of April 1997. The data fields, their names and a short description are presented in Table 4.1.

The original data received from the company was split into two files. These two reports were the only possibilities available to export the data into a spreadsheet format, from the company's database. Subsequently, the author was able to merge the data from the two files so as to create a single master database with all the information for each project. Given the difference between the four BU's with respect to the products that they work on, it was decided that they should not be grouped together, and the master database was split, by BU into four smaller databases. Another benefit derived from splitting the master database into the four smaller BU databases, was that they were more manageable and easier to manipulate than the single large database would have been.

One major problem with the export function was encountered. Towards the end of 1996 the program software was updated to a newer version, unfortunately the macros used to export the data were not updated and subsequently all exports lost data from several key data fields. Over a period of several months it was expected that the problem was to be corrected, however up until the time when the author stopped receiving data it had not been fixed. The author eventually had to individually fill in the missing fields for every project affected by the problem.

Variable Name	Description of Variable
Code	Unique identification number for every project.
Name	Descriptive name of project.
Client Code	Unique identification number for every client.
Client Name	Client's Name.
Application Code	Unique identification number for groups of products, e.g. Yoghurt.
Application Name	Descriptive name of product groups.
Segment	The name of the segment that the product belonged to, e.g. Dairy.
First Action Type	Classification into the categories of Collection, Creation or Application.
Type	Classification into the categories of Solicited or Proactive.
Action Report Entry Date	Date that the project was first entered into the system.
Client Call Date	Date of the client visit that initiated the request.
Client Deadline	Client deadline for delivery.
Potential (CHF)	Sales potential of project.
Action Report Status	Status of the projects, e.g. Completed, Active, Submitted.
Morning Meeting Date	Date that the project is first seen and discussed by the BU.
Submitted Date	Date of submission of samples.
Project Leader	Individual chosen as project leader for particular project.
Flavourist	Flavourist assigned to project when necessary.
Application person	Food technologist assigned to the project.
Termination Date	Date that project is terminated, i.e. the project file is closed.
Project Status	The status of the project e.g. Open or Closed.
Reason for termination	Classification of reasons for termination into the four groups, Won, Lost, Company abandon or Client abandon.

Table 4.1. Description of data fields.

The very messiness of working with real data, and the fact that it does not follow any neat predefined pattern is of enormous value when trying to develop solutions, that will work and be applicable in real situations. The author considers that, the difficulty of working with empirical data is outweighed by the potential practical benefits, and sees this as one of the key strengths of this study.

In addition to the numerical data, the author compiled a large quantity of anecdotal data throughout the duration of the project. This information provides additional richness and understanding of some of the problems, and is another advantage of using real world data as opposed to generating artificial data.

4.9 Sample Description

The sample sizes for each of the BUs and the five stratifications used are presented in Table 4.2. The sub-sample Collection of the Bakery BU, was too small to allow useful analysis and theory development and was omitted from further analyses. The first three sub-samples (Application, Collection and Creation), correspond to stratifying the data files by the variable 'first action type' as described previously, in Table 4.1. The last two sub-samples are a result of stratifying the data files by the variable 'type', which is also described

	Bakery	**Beverage**	**Confectionery**	**Dairy**
All BU	101	1312	399	379
Application	51	672	186	189
Collection	--	108	77	75
Creation	27	402	107	87
Proactive	32	279	85	113
Solicited	67	1022	310	262

Table 4.2. Sample size.

in Table 4.1. The sub-samples do not necessarily sum up to the total for the BU, as there are in reality some additional classifications for these two variables (e.g. defence), which are not displayed in Table 4.2. The numbers within in these additional groups were so small that the author chose to omit them.

4.10 Description of Statistical Package

For both the production of the control charts and any additional statistical tests performed, the statistical package used was StatView®. The decision to use this particular package was based on its availability to the author. The author had been using the package for more than a year on work-related projects and had found it to be very user friendly, and capable of performing the necessary analyses. The key algorithms used by the program for the analyses performed by the author, are presented in Appendix 2.

4.11 Description of analyses performed

Given the initial mandate to track the project turnaround times for each of the BUs, this was the first item tackled. To calculate the project turnaround time from the data available the author was faced with two choices for the start date:

1. To use the action report entry date, or
2. To use the morning meeting date.

There could be a difference of a few days between these two dates depending on both the time of day, and the particular day when the project was entered into the system. For example, a project entered into the system after 4:00pm on one day, would not appear on the new projects listing the next morning in the BUs, but would appear the day after. Given the minimum possible time lag of one day, and a maximum of three if the project was entered into the system on a Thursday afternoon, it was decided that the more accurate representation of the BUs actual turnaround times would be to use the morning meeting date. The end date used was the submission date which represented the day that work on the project was completed by the BU, and samples were submitted to the customer for evaluation. The project turnaround time was the difference in days between the submission date and the morning meeting date. If this calculation produced a negative value then it was an indication of a data entry error in one of the two dates. The author was able to resolve some of these errors by interrogating the project management database for the particular project, and reviewing the additional information there, that was not exported. If the author was unable to correct the error then the record was omitted from all further analyses.

One possible criticism with the calculation of the turnaround time was the structural bias built into its calculation. While the morning meeting date was the day that the project was accepted by the BU, and people assigned to work on it, it was not necessarily the day when work started on the project. Additionally, even if work started immediately it was rare for a single person to be working on a single project at any point in time. This problem was common across all the BUs and all the projects and random in nature. The decision to measure using a day as the smallest unit was taken by the management of Caché Corporation with this knowledge. The trade-offs between higher accuracy and more time spent tracking projects by technologists were not considered to be justified.

The author recognised that the duration time for the projects would be exaggerated. Given that the problem was common to all projects, in all BUs, and also given the randomness of the fluctuations it was assumed that the overall conclusions would not be affected by it.

One other variable which was originally derived but was subsequently dropped from further analysis was on-time delivery. Which represented the difference between the client deadline and the submission date. The rationale for this omission was the researcher's uneasiness about its accuracy. Over a period of time working with different people in the different BU's, it became clear that the customer deadline was negotiable. In point of fact it was very common for a BU, to request that the sales representative persuade the customer to agree to a new delivery date. The date in the system was then updated to reflect the new deadline. In so doing the original deadline was lost.

The author felt that this would produce an unacceptable bias into the data with a large percentage of the projects been delivered ontime. This was supported by some preliminary analyses performed, where the variable ontime delivery was very tightly distributed about zero. Where zero represents delivery on the day demanded by the client.

4.11.1 Tests for normality

The data for all the projects in each BU, and also for each of the subsets of projects corresponding to; Collection, Creation, Application, Solicited and Proactive from the BU were tested for normality. The tests performed were:

- The descriptive statistics for every data group were calculated, including the values for Skewness and Kurtosis, and
- A Kolmogorov-Smirnov test was performed

For both the skewness and kurtosis values a normal distribution would have values at zero, as calculated by the software. The author decided that values for either skewness or kurtosis more than ±1, would imply a non-normal distribution. Recognising the subjectivity inherent in this decision, and also that the software offered a more objective measure of normality the Kolmogorov-Smirnov test (K-S test), this test was also used to confirm the underlying distribution's normality or lack thereof. The K-S test involves generating a normal distribution with the same characteristics as the real data, and then comparing the two distributions. The null hypothesis tested is that the two distributions are the same, under the assumption that the observations from the two distributions are independent of each other. The results from the test include a p-value that indicates the likelihood of the null hypothesis being true. The author chose to use a p-value of 0.05, as the level of significance above which the other characteristics would need to be examined to determine the normality or non-normality of the distribution. Where a p-value of at most 0.05 implies that there is more than a 95% probability that the distribution is non-normal.

4.11.2 Calculation of control limits

The control charts produced were of the individual measurements type, i.e. '*XmR charts*'. This approach was chosen as not only are the projects independent of each other, but also every project is unique and consequently they could not be combined into rational subgroups.

In general the number of data points to be plotted were too numerous to fit on a single control chart. Seventy was chosen by the author as the optimal number that would be plotted on a single chart, simply because it produced control charts which were readable. In some cases where the data points were a few more than the seventy, but not enough to start a new chart this criterion was relaxed and all were plotted on one chart.

Seven different approaches were used to calculate the limits for the control charts. Because of the positively skewed distributions with the majority of points lying close to zero, the lower limits calculated for the project turnaround times were all negative. Given the earlier discussion regarding the invalidity of negative turnaround times, the lower limit of the control charts was set at the logical lower limit of zero.

It is impossible to trigger an outside out-of-control signal on the lower limit, because of the fact that it impossible to have a negative project turnaround time. This is true for both the actual calculated lower limit and the defined lower limit of zero. In essence, if the control charts were being used to monitor solely the outside out-of-control signals, then the approach mimics that of a one-sided control chart.

> "A one-sided chart should generally be installed whenever worsening of the quality of the process is associated with shifts from the in-control situation in only one direction…." Radaelli, 1998.

In this particular application that is certainly true. Where longer project turnaround times are undesirable, and the entire focus of the BUs is on ways to reduce the project turnaround times. Shortening the project turnaround times makes good business sense, as it reduces the time before the company can begin to receive payback for their development work. The underlying assumption being that the quality and functionality of the product are not compromised to achieve the shorter turnaround times.

One consideration in developing the control charts that could be debated, is whether or not the upper control limit should change, because the lower limit is unattainable. This assumption has its origins in conventional statistics. Where the area under the curve outside of the three sigma limits is defined as exactly 0.0027, for a two sided chart. This translates to a probability of 0.00135 in the two tails. Neave (1999) in a working paper, through the use of computer simulation is able to prove that in fact, using these probabilities as a measure of the false alarm rate is misleading. He asserts that the calculation and location of the control limits as defined by Shewhart, is valid and provides an operational definition that is not dependent on probabilities. According to Deming (1992):

> "It would nevertheless be wrong to attach any particular figure to the probability that a statistical signal for detection of a special cause could be wrong, or that the chart could fail to send a signal when a special cause exists. The reason is that no process, except in artificial demonstrations by use of random numbers, is steady, unwavering."

Additionally, given that several different run tests were used with the control charts to monitor the run out-of-control signals, the approach is no longer a purely one-sided one. Where the goal is overall improvement of the process, particularly in this example where special causes on the lower limit are impossible, then performing run tests is of even greater importance to try an isolate good practices that could be institutionalised.

The seven different approaches used to calculate the position of the limits on the control charts are outlined below.

1. The Default Method/Mean.

   This approach is the traditional method where the average moving range is used in conjunction with the data's mean, to calculate the limits for the *X*-chart. The mean of the data points plotted on the *X*-chart is the centre line about which the control limits are plotted.

2. Probability Limits.

   This method also uses the mean of the data points plotted on the X-chart as the centre line. However, the limits in this instance are the probability limits corresponding to a one in a thousand chance of a point falling outside of the limits.

3. The Median.

   This method involved calculating the median value for the data points plotted on every X-chart, and using that value as the centre line about which the control limits were placed. The limits were calculated using the average moving range of the data, in conjunction with the median value.

4. A 10% Trimmed Mean.

   This method entailed calculating the trimmed mean for the data points plotted on a control chart after discarding 10% of the observations furthest from the centre of the data. The value of the trimmed mean was used as the centre line about which the control limits were placed. The limits were calculated using the average moving range of the data in conjunction with the trimmed mean.

The next two methods involved the use of a bootstrapping algorithm. The data was resampled with replacement to produce larger samples than the original datasets available. For every BU and also for every subset of data corresponding to the categories; Collection, Creation, Application, Solicited and Proactive, the data was resampled two thousand times. This resampling of the data was performed in Excel® using a simple macro developed by the author. These new datasets were used in two ways with the actual data to produce limits for the control charts.

5. Resampled data's mean

   The resampled datasets were significantly larger and should therefore be more representative of the actual distributions underlying the real data. This technique involved first calculating the mean of the resampled data, which was used as the centre line on the control charts. The control limits were calculated automatically by the software using the average moving range of the actual data.

6. Resampled data, 1/1000 probability limits

   This approach utilised the significantly larger data sets of resampled data to determine the 1/1000 probability limits for the control charts. The resampled data was sorted by size, then the limits which corresponded to a one in a thousand chance of a point lying outside of them could be easily read off. Once the data had been sorted numerically, the two extremes of the data were inspected to identify the second smallest and the second largest values, in the array of numbers. Then a value between that value and the adjacent number was chosen as the limit for the control chart. An example for the solicited projects from the Beverage BU is presented in Figure 4.2. The lower control limit in this case was 0 and the upper control limit 285.

Number	1	0
	2	0
	3	0
	4	0
	5	0
	⋮	⋮
	1996	281
	1997	281
	1998	285
	1999	285
Number	2000	366

Figure 4.2. Resampled data limits

7. An Exponential Model.

The exponential distribution is frequently used to model the distribution of a random variable which is measured in time units (Pfaffenberger and Patterson, 1987). The data distributions of the project turnaround times were both positively skewed and consisted only of positive values. Given these features of the data and also that the exponential distribution is considered to be an appropriate model, for these types of distributions (Pfaffenberger and Patterson, 1987). The author chose to use an exponential model as the final approach to calculating the control limits.

The author was able to model the different distributions in Excel®, through the use of the EXPONDIST function in Excel®. The syntax for the function is reproduced below, a more complete description of the function taken from the application Help files, can be found in Appendix 3.

EXPONDIST(x, lambda, cumulative)

Where the x in this case is the turnaround time of a project, lambda was the reciprocal of the mean of the distribution and cumulative was set to TRUE.

When the cumulative variable is set to TRUE then the function returns the cumulative distribution function:

$F(x; \lambda) = 1 - e^{-\lambda x}$

To generate the distributions a spreadsheet was set up in Excel® with values of x ranging from 0.02 to 481 and means ranging from 11 to 70. Because of size restrictions for the spreadsheet, not all the values within these ranges are represented. Once the equation was applied to the spreadsheet it calculated for every mean the cumulative probability under the distribution for the entire range of x.

Mean time	40
Lambda (1/Mean time)	0.03
Limits for Turnround time	
0.02	0.0005
0.04	0.0010
0.06	0.0015
0.08	0.0020
0.10	0.0025
⋮	⋮
270	0.9988
274	0.9989
277	0.9990
284	0.9992
291	0.9993

Figure 4.3. Exponential control limits.

The end result being a look-up table which allowed the author to read the value for the control limits (x-value), knowing both the mean of a particular distribution and also the necessary probability of a point falling outside of the limits, see Appendix 4 for the complete lookup table. An example for a distribution with a mean time of 40 is provided in Figure 4.3.

For probability limits of one in a thousand, the lower control limit would be 0.04 and the upper control limit would be 277. Once the limits were read then they were used with the data on the control charts, the centre line was the mean of the actual data.

4.11.3 Comparison of results from the different charts.

StatView® can test for certain out-of-control signals. The author performed the following tests for special causes; any data points that fell outside of the control limits, and also six different run tests defined by StatView® as follows:

- Nine consecutive points above or below the defined centre line,
- Six consecutive increasing or decreasing points,
- Fourteen consecutive alternating points,
- Two of three consecutive in Zone A or beyond,
- Four of five consecutive points in Zone B or beyond,
- Eight consecutive points outside Zones C.

The zones A, B, and C are bands one standard deviation wide around the centre line, as defined previously in Chapter 3, Section 3.4.6.

One limitation of the StatView® program is that, it can only produce these results on the control charts where it calculates the limits, and where these limits are based on the standard deviation of the data. With respect to the seven methods used by the author, the program was able to run the tests for special causes on the following methods:

1. The Default Method/Mean,
2. The Median,
3. The 10% Trimmed Mean, and
4. The Resampled Mean.

In later analyses these methods are referred to as the *'Four Methods'*.

For the remaining three methods (Probability limits 1/1000, Resampled data probability limits 1/1000, Exponential limits), the author performed a manual count of the numbers of points lying outside of the control limits.

Summary tables for each BU and its stratifications were built, showing the numbers of special causes found for each division by the two groups – *'outside'* (special causes outside the control limits), and *'run'* (special causes based on the run rules). While a single point could in fact trigger more than one error message, it was only counted once. Histograms were used in conjunction with tables of the numeric differences, to provide some initial insights into the relative performance of the methods.

4.11.4 Contingency analyses

Contingency table analyses were subsequently run to determine whether or not relationships existed between several pairs of nominal variables; BU and out-of-control signals, and the *'four methods'* and out-of-control signals. In order to run contingency analyses a new database was developed, with the data fields defined as follows in Table 4.3.

Variable Name	Description of variable
BU	There were four possible categories for this variable - Bakery, Beverage, Confectionery or Dairy
Method	This was the particular method used to calculate the limits for the control chart.
Special Cause	This consisted of the two groups of special causes measured - Outside or Run

Table 4.3. Contingency analysis database described.

The null hypothesis tested in a contingency analysis is one of independence, where the likelihood of an observation falling into one group for one variable, is independent of the other group the observation falls into. StatView® tests this by calculating an expected value for the number of observations, for every combination of groups and then compares these values with the observed values. A chi-square test is run, a large chi-square value combined with a low probability, would result in a rejection of the null hypothesis of independence. In other words the test would indicate that a relationship between the variables exists.

4.11.5 Regression analysis

Also of interest to the author was the possibility of defining the relationship between the numbers of outside and run special causes. In her review of the relevant material the author was unable to find a study which defined this relationship. The author considers this to be important especially for practitioners in the field, as managers are working with limited resources and must chose carefully where to assigned those scarce resources. Monitoring and acting upon the signals produced by a control chart requires manpower, and training. It would be of value to the manager to be able to estimate the numbers of special causes that are being missed, before deciding to commit extra resources to their elimination. Additionally, the definition of the relationship between the different types of signals, would be useful to academics developing theories on missed signals and false alarms.

To this end, pairs of co-ordinates corresponding to the number of outside special causes, and the number of run special causes for every control chart were recorded in a new database. The description of the data fields in the new database are outlined in Table 4.4.

Variable Name	Description of variable
BU	There were four possible categories for this variable - Bakery, Beverage, Confectionery or Dairy
Method	This was the particular method used to calculate the limits for the control chart.
Outside	This was the number of outside signals counted for the particular method, for the particular BU.
Run	This was the number of run signals counted for the particular method, for the particular BU.

Table 4.4. Regression database description.

The last two data fields represent the pairs of co-ordinates which were used in the analysis. These co-ordinates were plotted and a regression analysis run to define the relationship.

4.11.6 Unpaired comparisons

A series of t-tests were run to compare several combinations of variables and their relative performance with respect to the project turnaround time. The first compared the relative performance of the four BUs to ascertain whether or not they belonged to the same population. The second test split the database by the *'first action type'* and tested to see whether or not application, collection and creation projects behaved in a similar way. The final test split the data by *'type'* of project be it proactive or solicited. The tests were performed on the master database and not the individual BU databases.

The t-test compares the different distributions to check whether or not they belong to the same population. For each comparison made, the t-test produces a *p-value* which indicates the likelihood that the two distributions are statistically similar.

4.11.7 Won / Lost analyses

The final set of analyses performed were the won/lost comparisons. For every project that is closed, a reason for the termination needs to be input into the project management database, there are four possible entries; won, lost, client abandoned or company abandoned. The relative percentages for every BU were produced and the BU's performance compared, using very simple techniques.

4.12 Conclusion

This chapter started by reviewing briefly the background on the industry in which the study is set, and the description of the company's structure and the specifics of the actual project. The author then proceeded to outline in detail the progress of the research project, and some of the difficulties that were experienced throughout the duration of the project.

The next two sections described the work processes in the BUs and explained the product development process at Caché Corporation. Having provided the reader with the appropriate contextual backdrop, the author proceeds to outline in some depth the data that was used, and the sample sizes for the different BUs and the stratifications therein.

The remainder of the chapter discusses in detail the different analyses that were performed. Of particular relevance to this study, is the description of how the project turnaround times are calculated and also the summary of the different methods used to calculate the control limits. The other analyses that were necessary to be able to evaluate the relative performance, of the different approaches to calculating the control limits are outlined. Additionally, the author presents other complementary analyses that were performed on the data, that are used to develop several secondary ideas to the main focus of the study.

Chapter 5 presents the results of these data analyses and some initial interpretations.

Chapter 5.

Results

5.1 Introduction

In this Chapter the results from the statistical analyses performed on the data are reviewed. The data are presented in several parts. Section 5.2 reviews the sample description, Section 5.3 summarises the descriptive statistics of the variables which provide the basis for the statement that the data is positively skewed. Section 5.4 reviews the standard control chart produced for each of the different methods. Section 5.5 presents the summary data of the percentages of out-of-control signals found for each BU for every method. This data is also presented graphically using histograms. Section 5.6 presents the results of the contingency analyses which investigates the similarities and differences between the four BUs and also the *'four methods'*. Section 5.7 presents the regression analysis between the out-of-control signals -- outside and run, to determine the relationship between the two. The independent variable is the number of outside signals and the dependent variable the number of run signals. Section 5.8 presents the results from three different t-tests which were run to compare the relative performance of the BUs and the different types of projects with respect to the project turnaround time. Section 5.9 presents the results of the won/lost analyses, which compare the four BUs performance with respect to the numbers of projects won and lost.

5.2 Sample description

Table 5.1 Gives the sample sizes for each of the four BUs and all the stratifications used. The data span a period of twenty-eight months and was secondary in nature. The author did not define the fields or participate in the

	Bakery	Beverage	Confectionery	Dairy
All BU	101	1312	399	379
Application	51	672	186	189
Collection	--	108	77	75
Creation	27	402	107	87
Proactive	32	279	85	113
Solicited	67	1022	310	262

Table 5.1. Sample sizes.

collection of the data. The data was part of the company's project management database, maintained and updated by the individuals involved with the projects.

The author received an exported spreadsheet file with the data from the project management database. Some data validation was performed by the author through interfacing directly with the project management database. Some data records were omitted from the final sample, when there was an obvious error with the data which could not be reconciled through interrogating the database.

5.3 Descriptive statistics

A summary of the descriptive statistics for the calculated variable project turnaround time for every BU and stratification therein, are presented below (Tables 5.2 - 5.5). A complete overview of the descriptive statistics including the results for the Kolmogorov-Smirnov (K-S) test, can be found in Appendix 5.

	All Projects	Application	Collection	Creation	Proactive	Solicited
Mean	27.450	27.863	---	22.308	28.094	27.470
Std. Dev.	35.820	31.635	---	24.870	31.443	38.346
Skewness	1.911	1.636	---	1.726	1.945	1.860
Kurtosis	3.013	1.785	---	3.019	3.391	2.611

Table 5.2. Descriptive statistics for Bakery BU.

	All Projects	Application	Collection	Creation	Proactive	Solicited
Mean	28.015	26.503	22.765	35.418	43.901	23.796
Std. Dev.	44.581	41.321	40.015	51.124	60.819	38.075
Skewness	3.256	3.367	4.219	2.801	2.157	3.785
Kurtosis	12.133	13.088	21.084	8.568	4.226	17.799

Table 5.3. Descriptive statistics for Beverage BU.

	All Projects	Application	Collection	Creation	Proactive	Solicited
Mean	29.196	27.688	28.803	32.299	33.447	28.029
Std. Dev.	44.913	39.743	53.299	42.163	49.801	43.759
Skewness	3.071	3.597	3.056	2.109	2.579	3.226
Kurtosis	10.560	15.290	9.205	4.651	7.019	11.785

Table 5.4. Descriptive statistics for Confectionery BU.

	All Projects	Application	Collection	Creation	Proactive	Solicited
Mean	17.979	17.571	12.600	22.218	26.372	14.523
Std. Dev.	28.606	23.774	18.555	33.117	33.643	25.565
Skewness	4.127	2.977	4.303	3.024	2.279	5.819
Kurtosis	23.459	10.485	21.342	10.883	5.411	46.003

Table 5.5. Descriptive statistics for Dairy BU.

The null hypothesis for the K-S test used assumes that the two distributions are the same, where in this case one distribution is a normal distribution with the same descriptive statistics as the real distribution. The test produces a p-value which indicates the probability that the two distributions are similar. Ten of the twenty-three groups produced p-values < 0.0001, ten produced p-values <0.01, while the remaining three groups belonging to the Bakery BU had p-values >0.10. These three remaining groups were the three smallest subsets which could be the cause of these low scores, nevertheless, despite their relatively high p-value scores, the values for both skewness and kurtosis indicate non-normal distributions. The interpretation of the p-values is that it is very unlikely that the two distributions are the same, for twenty of the distributions the probability of them being the same is less than one in a hundred. In simple English the distributions are non-normal.

5.4 Control chart review

One typical control chart from the Bakery BU is reproduced here for discussion, see Figure 5.1. The method used in this particular chart is the default (mean) approach which utilises the average moving range to calculate the control limits for the X-chart. The chart also includes some incidences of out-of-control signals tested for by the software, as denoted by the small numbers next to the offending data point. Counts of these out-of-control signals were used later on in subsequent analyses. Even if a single point produced more than one out-of-control signal it was only counted once.

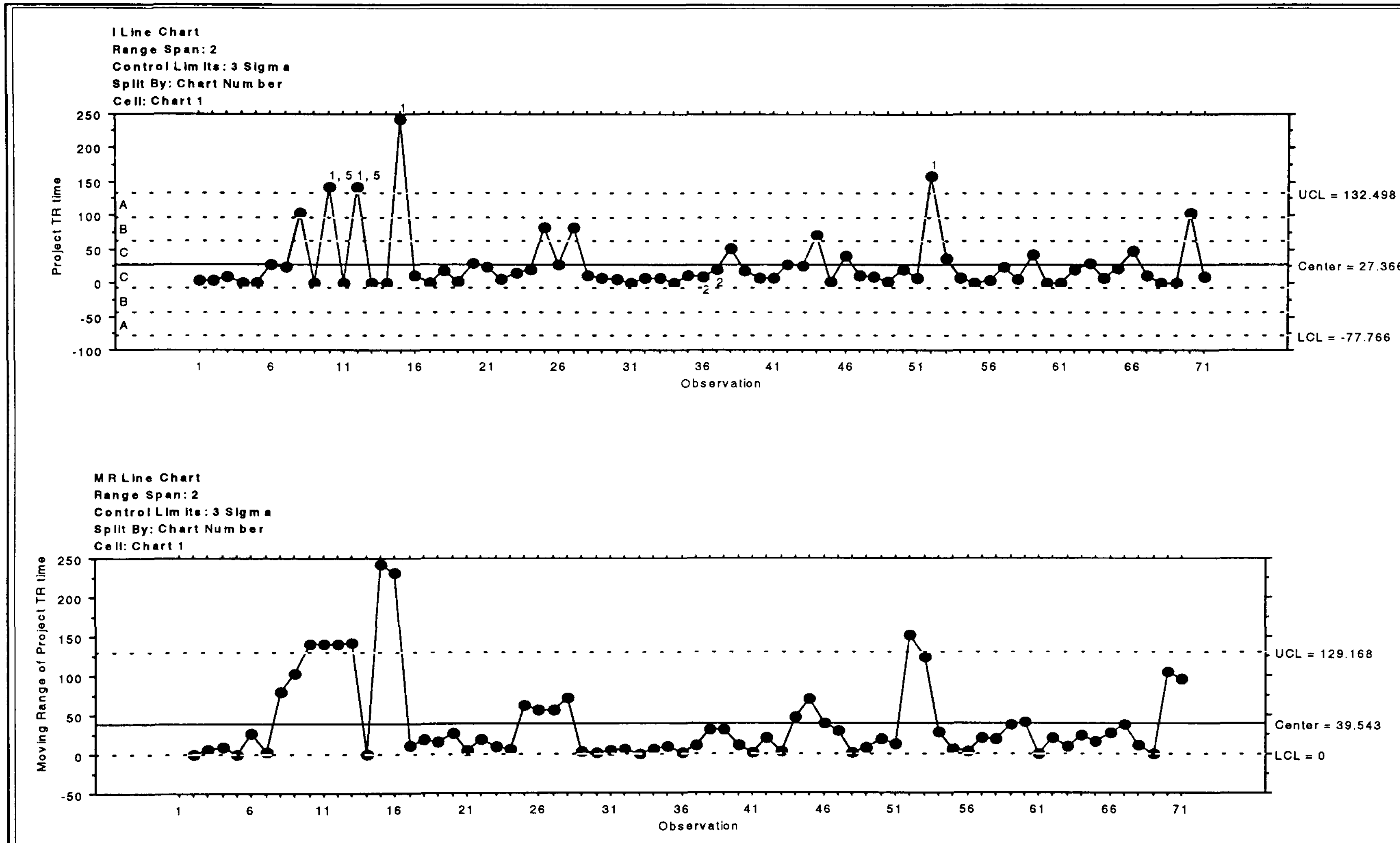


Figure 5.1. Typical control chart -- Bakery BU.

All the control charts plotted using the default method show both the moving range and individual measurement charts. However, this is not the case for all the methods. The number of charts produced was substantial and by omitting the moving range chart it was possible to fit two X-charts to a page. Additionally, the moving range chart did not change for the seven different methods and so no information was lost. A representative set of charts were compiled and can be found in Appendices 9 - 15 in Volume 2. For each of the seven methods used to calculate the control limits, a complete set of charts from one of the four BUs were chosen to display the approach. Every group of charts includes the top level of charts for the BU (i.e. all the projects together), and also the charts for each of the stratifications (i.e. Application, Collection, Creation, Proactive and Solicited). In addition, every BU is represented at least once. The selection made by the author is as follows in Table 5.6.

	Method	**Representative BU**
1	The Default/Mean.	Beverage
2	The Median.	Bakery
3	A 10% Trimmed Mean.	Confectionery
4	Resampled data's Mean.	Dairy
5	1/1000 Probability Limits.	Beverage
6	Exponential Limits.	Confectionery
7	Resampled data, 1/1000 Probability Limits.	Dairy

Table 5.6. BU assignment.

5.5 Summary of Out-of-control signals

Figures 5.2 – 5.5 graphically present the numbers of out-of-control signals as a percentage of the sample size for every BU, tables of the raw numbers of signals can be found in Appendix 6, and tables of the data as a percentage in Appendix 7. The figures represent the top level of the data, that is all the projects for every BU. The individual graphs for the different stratifications can be found in Appendix 8.

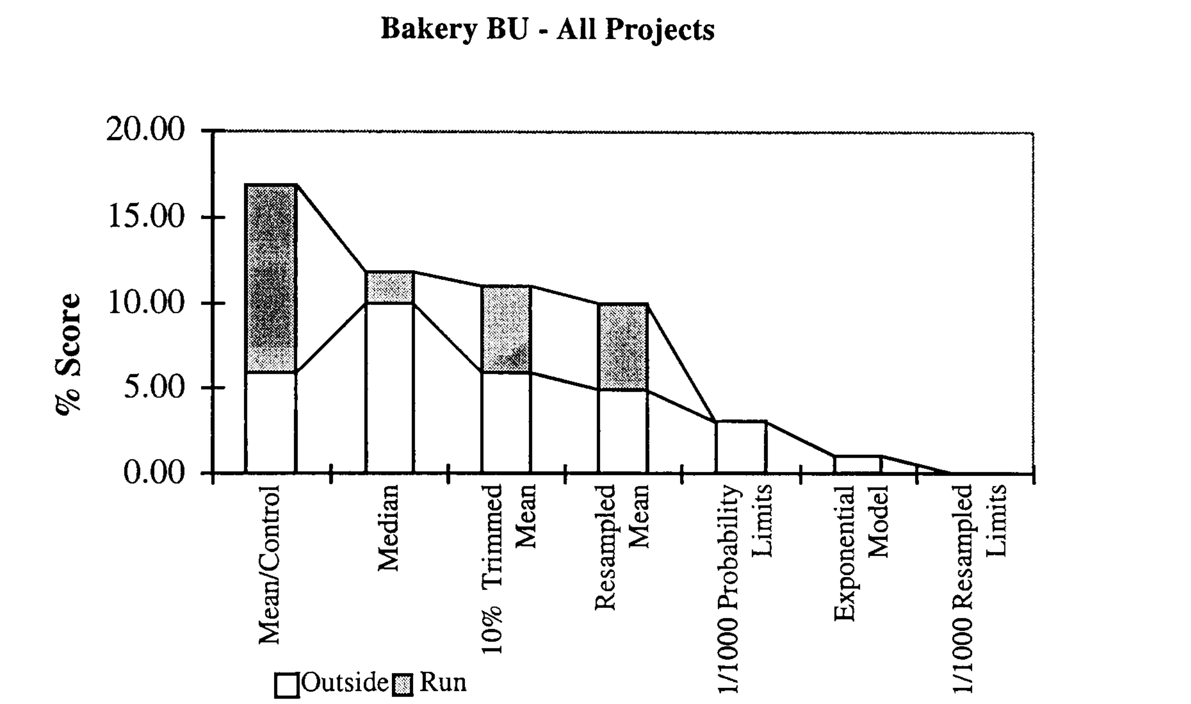


Figure 5.2. Bakery BU - Out-of-control Signals.

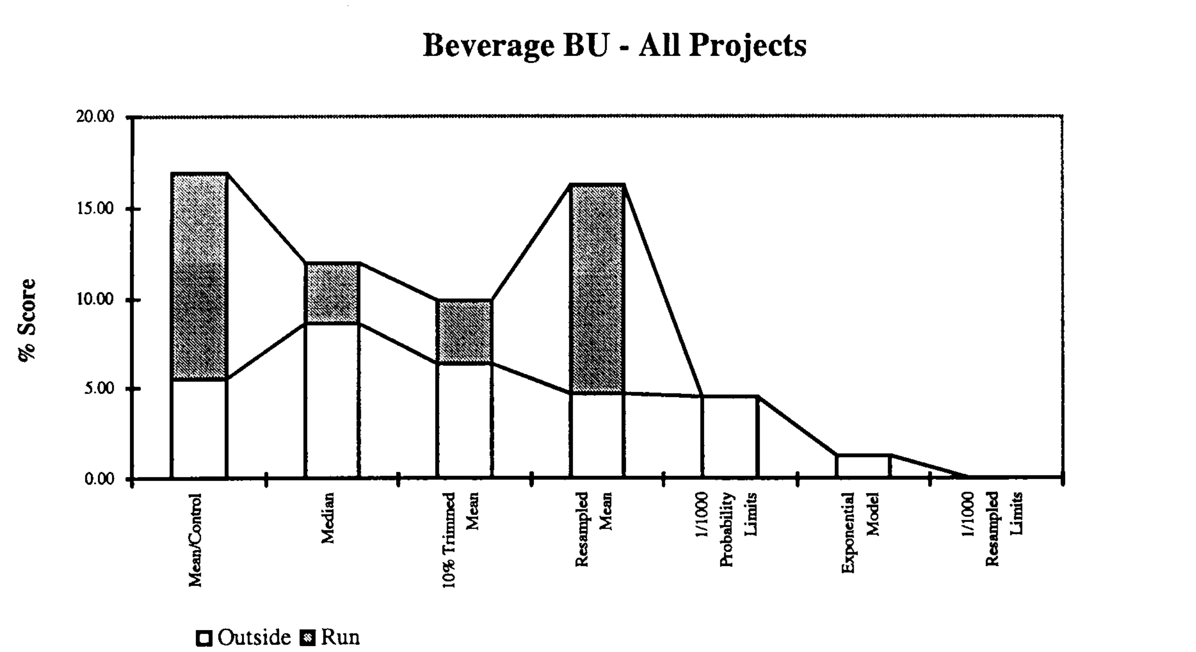


Figure 5.3. Beverage BU - Out-of-control Signals.

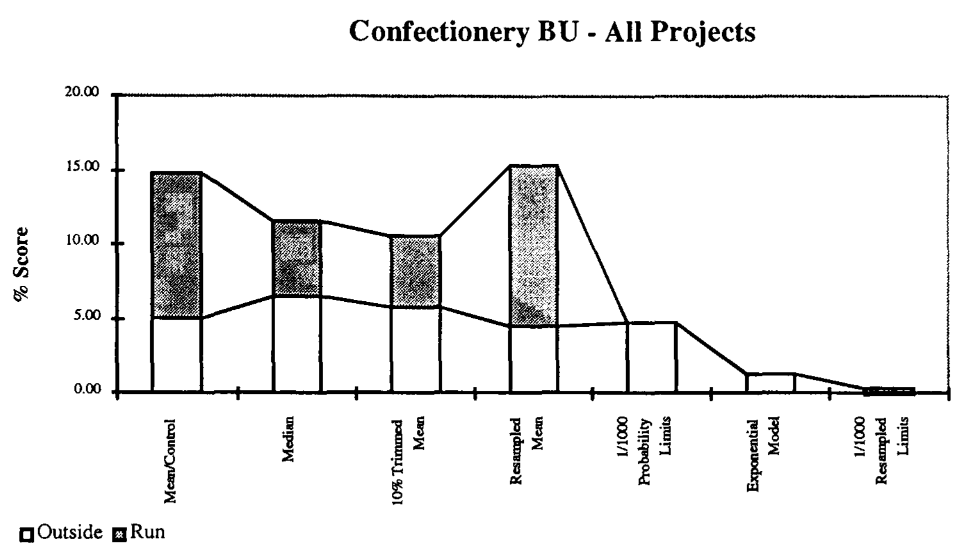


Figure 5.4. Confectionery BU - Out-of-control Signals.

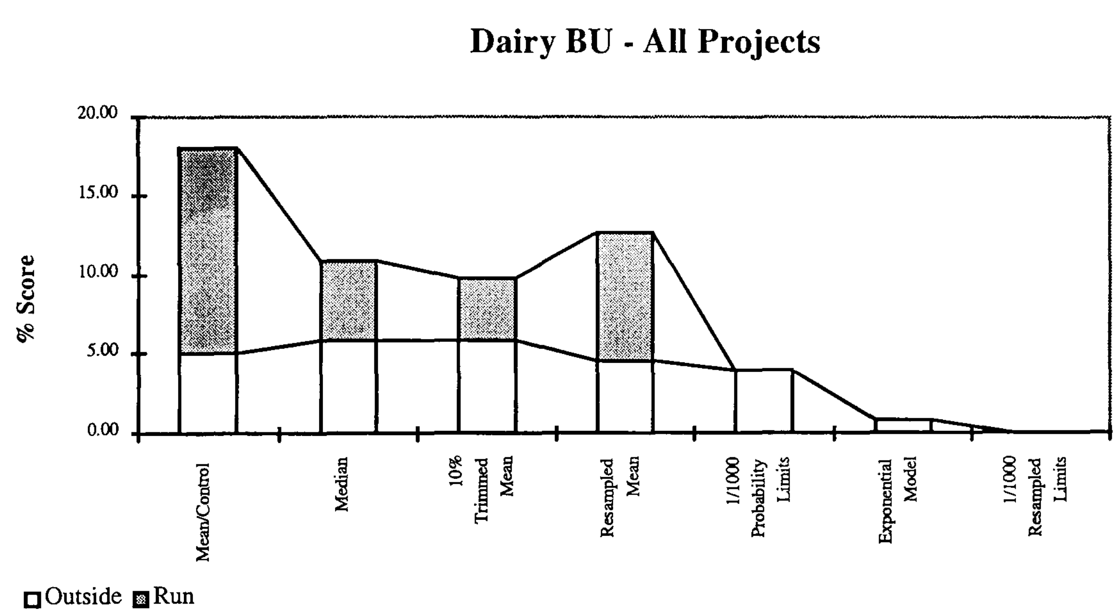


Figure 5.5. Dairy BU - Out-of-control Signals.

On reviewing the histograms a particular pattern emerges that is probably a result of the positively skewed distributions of the data. The last three methods; 1/1000 Probability limits, Exponential model and the 1/1000 Resampled limits, appear to be particularly affected by the outliers on the high side of the distribution. These outliers strongly influenced the location of the upper control limit, which was generally much larger than with the other methods, resulting in very few points outside. Of the four remaining methods;

Mean, Median, 10% Trimmed Mean and Resampled Mean, the general pattern for the outside signals matches the author's expectations given the positively skewed distributions. Both the Median and the 10 % Trimmed mean adjust for the large outliers, and would have a smaller numeric value than the actual mean for these distributions. The obvious outcome of shifting the centre line to the left of the mean, would be a comparative shift down in the upper control limits, the end result for the control charts being an increase in the number of points lying outside the process control limits. With respect to the differences in the number of run signals produced, there also appears to be a particular pattern to the numbers, the relationship between the run and outside signals is explored in more detail in the following sections.

5.6 Contingency table analyses

Two different contingency analyses were performed to investigate possible relationships between the out-of-control signals, the four BUs (Bakery, Beverage, Confectionery, and Dairy), and the *'four methods'* (Mean, Median, 10% Trimmed Mean, and Random/Resampled Mean). These analyses were performed only with the *'four methods'*. The remaining three methods (Probability limits, exponential limits, and resampled limits) were omitted from the contingency analyses as there was no value for the number of run special causes for these three methods. In addition, particularly for the exponential and resampled limits, the values for the number of outside special causes were too small for the software to perform the analyses.

Contingency analyses start with the null hypothesis that the variables are independent. The null hypothesis is rejected if the chi square value is relatively high in conjunction with a small p-value. To better understand the particulars of the relationship between the variables, it is necessary to review the *'Post hoc cell contributions'*. This table shows the weightings for each of the variables, relative to the characteristic being measured.

The first contingency analysis compared the *'four methods'* to ascertain whether or not they produce significantly different numbers of out-of-control signals, the results are presented in Table 5.7.

Summary Table for Special Cause, Method
Inclusion criteria: Four Methods from Limit Compare.svd

Num. Missing	0
DF	3
Chi Square	290.101
Chi Square P-Value	<.0001
G-Squared	292.431
G-Squared P-Value	<.0001
Contingency Coef.	.276
Cramer's V	.288

Observed Frequencies for Special Cause, Method
Inclusion criteria: Four Methods from Limit Compare.svd

	Default - Mean	Median	Trimmed Mean 10%	Random Mean	Totals
Outside	371	446	376	280	1473
Run	724	265	308	738	2035
Totals	1095	711	684	1018	3508

Post Hoc Cell Contributions for Special Cause, Method
Inclusion criteria: Four Methods from Limit Compare.svd

	Default - Mean	Median	Trimmed Mean 10%	Random Mean
Outside	-6.555	12.548	7.667	-11.115
Run	6.555	-12.548	-7.667	11.115

Table 5.7. Comparison of the *'four methods'*.

Based on both the chi square value and the equivalent p-value (see Table 5.7), the results indicate that there is a relationship between the method used to calculate the limits and the types of out-of-control signals produced, as was hinted at in the previous visual analysis of the histograms. Specifically, the results of the post hoc cell contributions statistically support the author's observation that both the Median and the 10% Trimmed Mean have higher numbers of outside signals as compared to the other two methods.

The second contingency analysis looked at the possible existence of a relationship between BU membership and the numbers of out-of-control signals produced, the results are presented in Table 5.8.

Summ ary Table for Special Cause, BU
Inclusion criteria: Four Methods from Limit Compare.svd

Num. Missing	0
DF	3
Chi Square	11.477
Chi Square P-Value	.0094
G-Squared	11.395
G-Squared P-Value	.0098
Contingency Coef.	.057
Cramer's V	.057

Observed Frequencies for Special Cause, BU
Inclusion criteria: Four Methods from Limit Compare.svd

	Bakery	Beverage	Confectionery	Dairy	Totals
Outside	70	924	276	203	1473
Run	72	1344	312	307	2035
Totals	142	2268	588	510	3508

Post Hoc Cell Contributions for Special Cause, BU
Inclusion criteria: Four Methods from Limit Compare.svd

	Bakery	Beverage	Confectionery	Dairy
Outside	1.801	-2.027	2.665	-1.082
Run	-1.801	2.027	-2.665	1.082

Table 5.8. Comparison of BUs.

The results from this contingency analysis are not as statistically significant as the first analysis. However, they still indicate some dependence between the BU and the two different types of out-of-control signals measured.

5.7 Regression analyses

Regression analyses were performed on the out-of-control signals, as a way of defining the relationship between the numbers of outside and run signals for each of the *'four methods'*. The scattergram of the points (see Figure 5.6) seems to support the author's observation that the *'four methods'* are clustered into two groups:

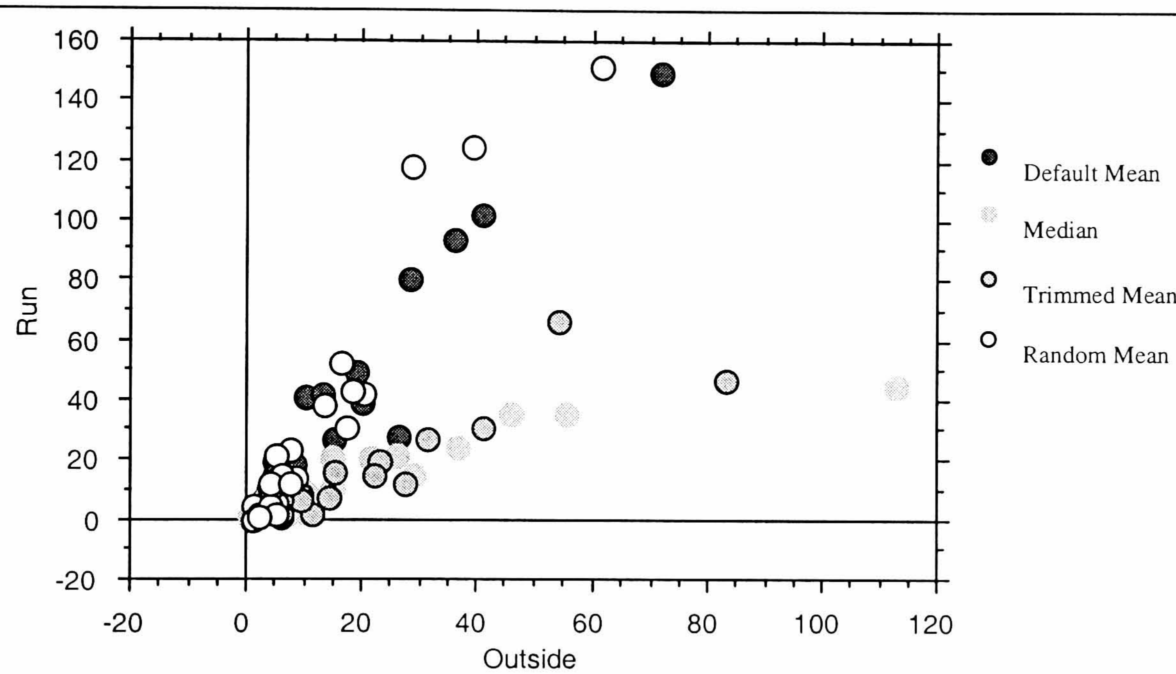


Figure 5.6. Scattergram split by method.

- Group 1. Default method/mean and Random/Resampled mean,
- Group 2. Median and Trimmed mean

Individual regression analyses were run for each of the methods so as to define the relationships for each of them. In addition, two separate regression analyses were performed for the two Groups defined above. A regression using all the points together was also performed but, as was expected, the model had a low explanatory power and the results are not presented here.

To determine the optimal model for each of the six regressions, the author compared the results using several different settings; simple linear models, polynomial models of different powers, and models with or without intercepts. In all six regressions, the models with the highest explanatory power were polynomial equations of order two with no forced intercept.

Regression Summary
Run vs. Outside
Split By: Method
Cell: Default - Mean

Count	23
Num. Missing	0
R	.981
R Squared	.962
Adjusted R Squared	.958
RMS Residual	10.305

ANOVA Table
Run vs. Outside
Split By: Method
Cell: Default - Mean

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	56024.020	28012.010	263.793	<.0001
Residual	21	2229.980	106.190		
Total	23	58254.000			

Regression Coefficients
Run vs. Outside
Split By: Method
Cell: Default - Mean

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Outside	2.493	.237	1.092	10.533	<.0001
Outside^2	-.005	.004	-.149	-1.183	.2499

Regression Plot
Split By: Method
Cell: Default - Mean

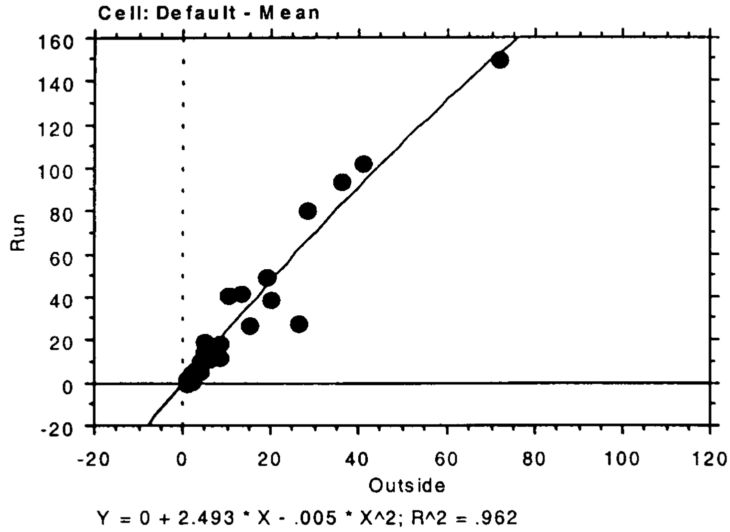


Figure 5.7. Regression analysis of Default Mean.

In all the regressions the independent variable was the number of outside signals, while the dependent variable was the number of run signals. The regression results including a regression plot are presented in Figures 5.7-5.12.

Regression Summary
Run vs. Outside
Split By: Method
Cell: Random Mean

Count	23
Num. Missing	0
R	.975
R Squared	.950
Adjusted R Squared	.945
RMS Residual	12.300

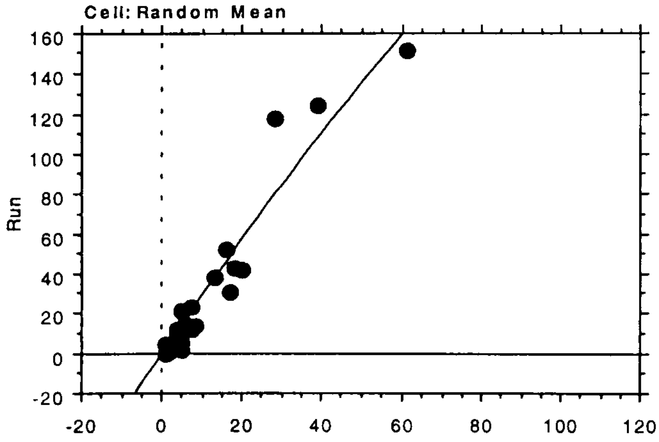
ANOVA Table
Run vs. Outside
Split By: Method
Cell: Random Mean

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	59963.103	29981.551	198.185	<.0001
Residual	21	3176.897	151.281		
Total	23	63140.000			

Regression Coefficients
Run vs. Outside
Split By: Method
Cell: Random Mean

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Outside	3.004	.340	1.007	8.830	<.0001
Outside^2	-.006	.007	-.108	-.778	.4452

Regression Plot
Split By: Method
Cell: Random Mean



Y = 0 + 3.004 * X - .006 * X^2; R^2 = .95

Figure 5.8. Regression analysis of Resampled/Random Mean.

Regression Summary
Run vs. Outside
Split By: Method
Cell: Median

Count	23
Num. Missing	0
R	.981
R Squared	.962
Adjusted R Squared	.958
RMS Residual	3.418

ANOVA Table
Run vs. Outside
Split By: Method
Cell: Median

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	6160.593	3080.297	263.588	<.0001
Residual	21	245.407	11.686		
Total	23	6406.000			

Regression Coefficients
Run vs. Outside
Split By: Method
Cell: Median

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Outside	.790	.054	1.600	14.568	<.0001
Outside^2	-.003	.001	-.757	-5.766	<.0001

Regression Plot
Split By: Method
Cell: Median

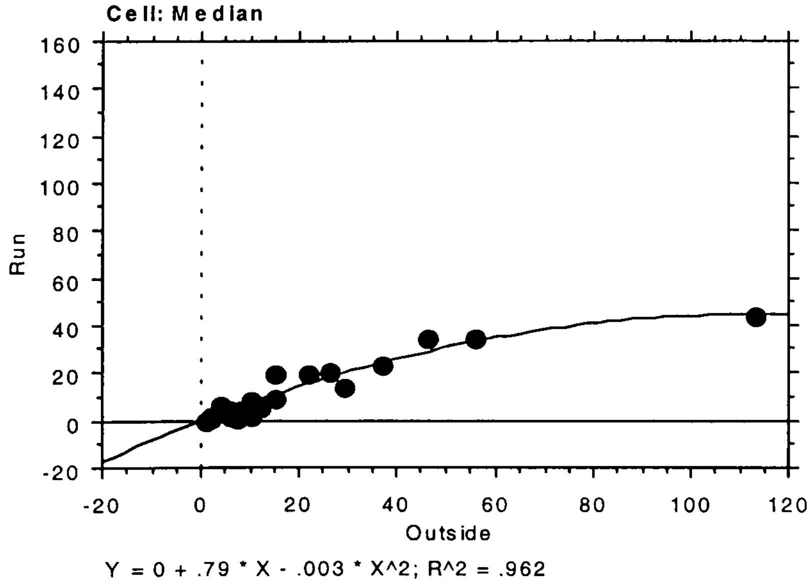


Figure 5.9. Regression analysis of Median.

Regression Summary
Run vs. Outside
Split By: Method
Cell: Trimmed Mean 10%

Count	23
Num. Missing	0
R	.946
R Squared	.895
Adjusted R Squared	.885
RMS Residual	6.952

ANOVA Table
Run vs. Outside
Split By: Method
Cell: Trimmed Mean 10%

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	8630.025	4315.013	89.278	<.0001
Residual	21	1014.975	48.332		
Total	23	9645.000			

Regression Coefficients
Run vs. Outside
Split By: Method
Cell: Trimmed Mean 10%

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Outside	.949	.142	1.156	6.680	<.0001
Outside^2	-.003	.002	-.319	-1.523	.1427

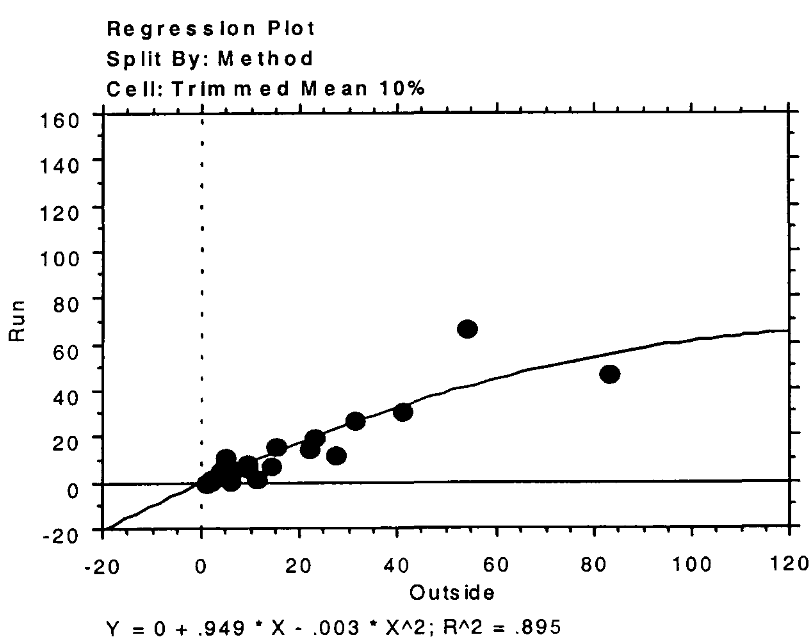


Figure 5.10. Regression analysis for 10% Trimmed Mean.

Regression Summary
Run vs. Outside
Inclusion criteria: Mean & Random Mean from Limit Coordinates.svd

Count	46
Num. Missing	0
R	.973
R Squared	.947
Adjusted R Squared	.944
RMS Residual	12.140

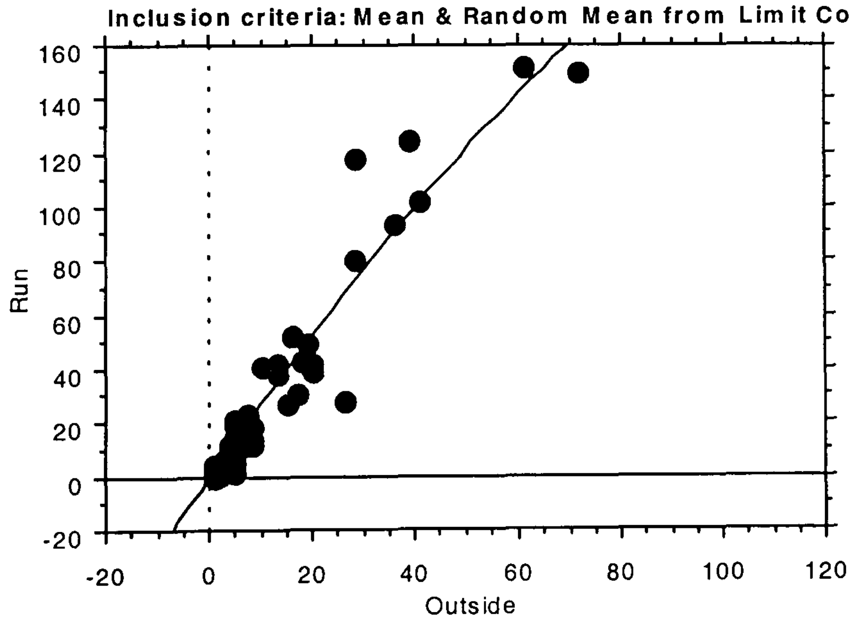
ANOVA Table
Run vs. Outside
Inclusion criteria: Mean & Random Mean from Limit Coordinates.svd

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	114909.084	57454.542	389.828	<.0001
Residual	44	6484.916	147.384		
Total	46	121394.000			

Regression Coefficients
Run vs. Outside
Inclusion criteria: Mean & Random Mean from Limit Coordinates.svd

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Outside	2.784	.212	1.076	13.141	<.0001
Outside^2	-.007	.004	-.170	-1.710	.0943

Regression Plot
Inclusion criteria: Mean & Random Mean from Limit Coordinates.svd



Y = 0 + 2.784 * X - .007 * X^2; R^2 = .947

Figure 5.11. Regression analysis of Group 1.

Regression Summary
Run vs. Outside
Inclusion criteria: Median & Trimmed from Limit Coordinates.svd

Count	46
Num. Missing	0
R	.953
R Squared	.908
Adjusted R Squared	.904
RMS Residual	5.797

ANOVA Table
Run vs. Outside
Inclusion criteria: Median & Trimmed from Limit Coordinates.svd

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	14572.174	7286.087	216.785	<.0001
Residual	44	1478.826	33.610		
Total	46	16051.000			

Regression Coefficients
Run vs. Outside
Inclusion criteria: Median & Trimmed from Limit Coordinates.svd

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Outside	.907	.068	1.420	13.306	<.0001
Outside^2	-.004	.001	-.637	-4.946	<.0001

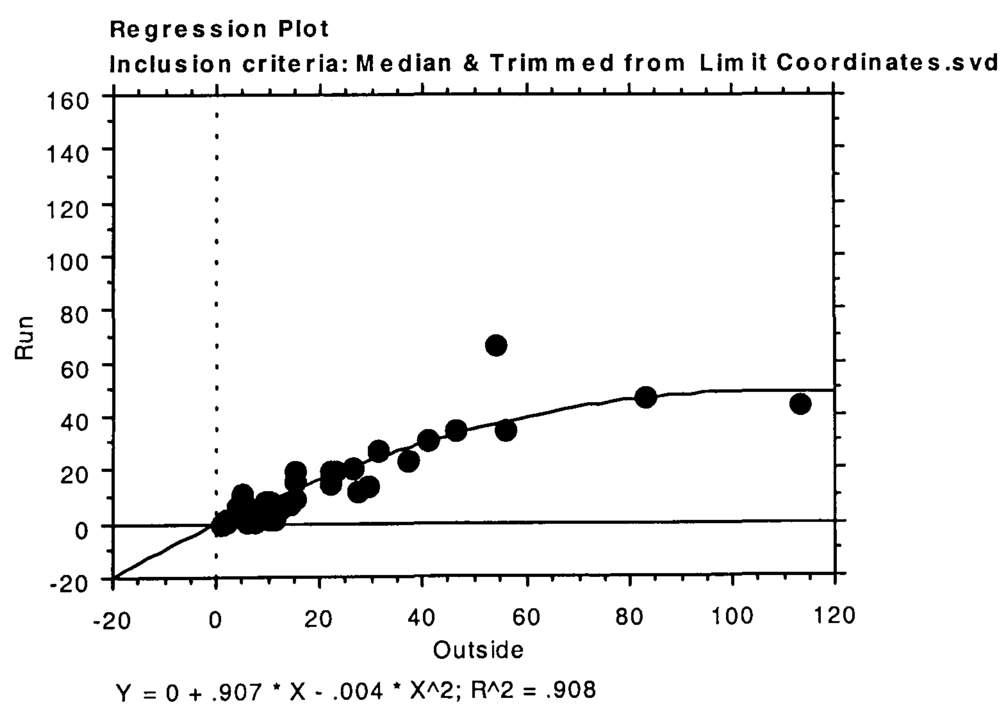


Figure 5.12. Regression analysis of Group 2.

The output from StatView® for a regression analysis consists of three different tables and the regression plot. The first table displays two important measures, the *'R Squared'* value and also the *'Adjusted R Squared',* value which represent the percentage of the variability in the dependent variable explained by the model. The *'P-Value'* in the second table is an indication of the reliability of the overall model, the smaller the *'P-Value'* the greater the confidence in the results. The third table provides the reader with the coefficients for every term in the regression equation, and also their individual *'P-Values',* which indicate their importance to the overall model. Finally the regression plot shows the points with an overlay of the regression equation, this allows for a visual check of the results.

5.8 T-tests

This section reports on the results of three different t-tests, comparing the performance of different groups of data as measured by the project turnaround time. The null hypothesis of the t-test states very simply that, the two groups being compared come from the same population. The distributions for each pair are compared and a *'P-Value'* calculated, the smaller this value then the less likely it is that the populations are the same, and therefore the null hypothesis is rejected.

The first t-test compared the four BUs; Bakery, Beverage, Confectionery and Dairy. The continuous variable which they were measured on was the project turnaround time, the results are presented in Table 5.9.

Unpaired t-test for Project TR time
Grouping Variable: Segment
Hypothesized Difference = 0
Inclusion criteria: 4 BUs from Phddata2.svd

	Mean Diff.	DF	t-Value	P-Value
BEVERAGES, DAIRY	11.259	1690	3.891	.0001
BEVERAGES, CONFECTIONERY	-4.042	1710	-1.048	.2946
BEVERAGES, BAKERY	.819	1411	.152	.8792
DAIRY, CONFECTIONERY	-15.301	778	-2.771	.0057
DAIRY, BAKERY	-10.440	479	-2.486	.0133
CONFECTIONERY, BAKERY	4.861	499	.470	.6382

Group Info for Project TR time
Grouping Variable: Segment
Inclusion criteria: 4 BUs from Phddata2.svd

	Count	Mean	Variance	Std. Dev.	Std. Err
BEVERAGES	1312	30.393	2797.035	52.887	1.460
DAIRY	380	19.134	1323.372	36.378	1.866
CONFECTIONERY	400	34.435	10332.522	101.649	5.082
BAKERY	101	29.574	1725.987	41.545	4.134

Table 5.9. T-test split by BU.

The second t-test splits the data by *'First Action Type'* and compares the project turnaround times for the different types of projects -- Application, Collection and Creation, see Table 5.10.

Unpaired t-test for Project TR time
Grouping Variable: First Action Type
Hypothesized Difference = 0
Inclusion criteria: 4 BUs & Appl., Creat. & Coll. projects from Phddata2.svd

	Mean Diff.	DF	t-Value	P-Value
CREATION, APPLICATION	6.045	1721	1.939	.0527
CREATION, COLLECTION	2.196	895	.533	.5944
APPLICATION, COLLECTION	-3.849	1370	-.834	.4042

Group Info for Project TR time
Grouping Variable: First Action Type
Inclusion criteria: 4 BUs & Appl., Creat. & Coll. projects from Phddata2.svd

	Count	Mean	Variance	Std. Dev.	Std. Err
CREATION	624	33.503	2544.292	50.441	2.019
APPLICATION	1099	27.459	4618.527	67.960	2.050
COLLECTION	273	31.308	4790.574	69.214	4.189

Table 5.10. T-test split by First Action Type.

The third and final t-test also compared project turnaround times of different types of projects, in this instance the variable that the data was split by was *'Type'*, which split the data into the two groups of Proactive and Solicited projects, see Table 5.11.

Unpaired t-test for Project TR time
Grouping Variable: Type
Hypothesized Difference = 0
Inclusion criteria: 4 BUs, Proactive & Solicited Projects from Phddata2.svd

	Mean Diff.	DF	t-Value	P-Value
PROACTIVE, SOLICITED	16.474	2170	5.232	<.0001

Group Info for Project TR time
Grouping Variable: Type
Inclusion criteria: 4 BUs, Proactive & Solicited Projects from Phddata2.svd

	Count	Mean	Variance	Std. Dev.	Std. Err
PROACTIVE	509	41.821	4309.080	65.644	2.910
SOLICITED	1663	25.348	3727.456	61.053	1.497

Table 5.11. T-test split by type

5.9 Won / Loss Analysis

In this final section the author delves into some of the differences between the BUs based on their reported performance with respect to the numbers of projects won, lost and abandoned. Where projects won are those that the company received orders for, in contrast to projects lost which are those where the company went the distance and lost the order to a competitor. Abandoned projects are of two types, those abandoned by the company, and those abandoned by the client. Both represent projects that were in the product development system, and for some reason interest in the project by the client, the company or both was lost, resulting in the project being closed and classified as abandoned.

This analysis is of interest as the issues surrounding project management and the efficient use of scarce resources is critical to competitive success. The scarce resources in this particular company are dedicating a large proportion of their time to projects going nowhere. There is a huge potential value to be gained, from a better use of the resources through the early identification of projects, destined to be abandoned. The results for the four BUs are presented in Figures 5.13 - 5.16.

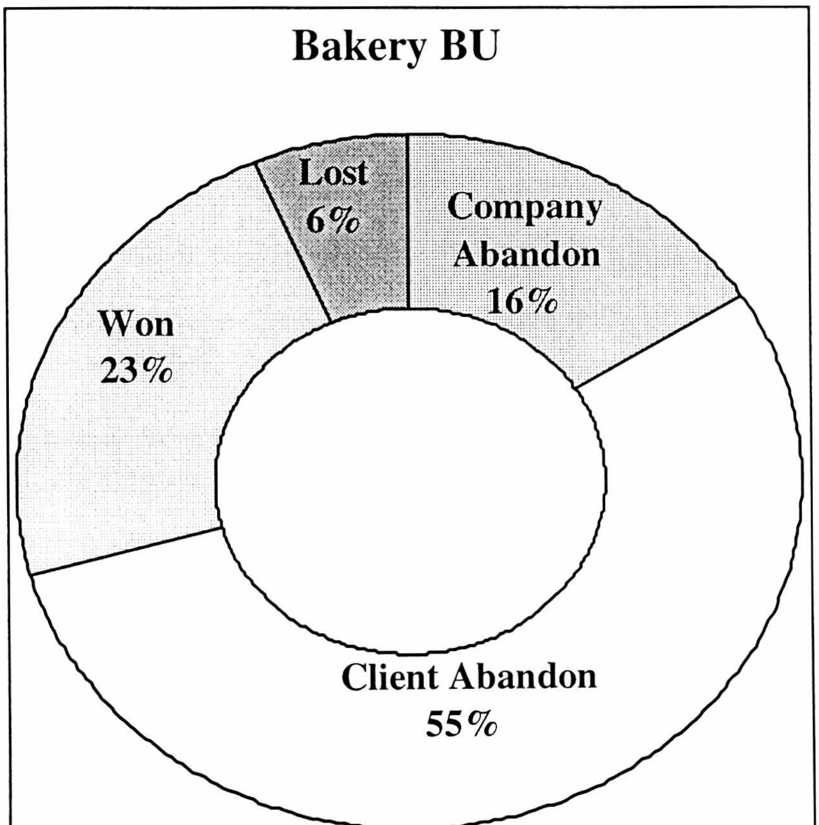


Figure 5.13. Bakery BU - Won Loss chart.

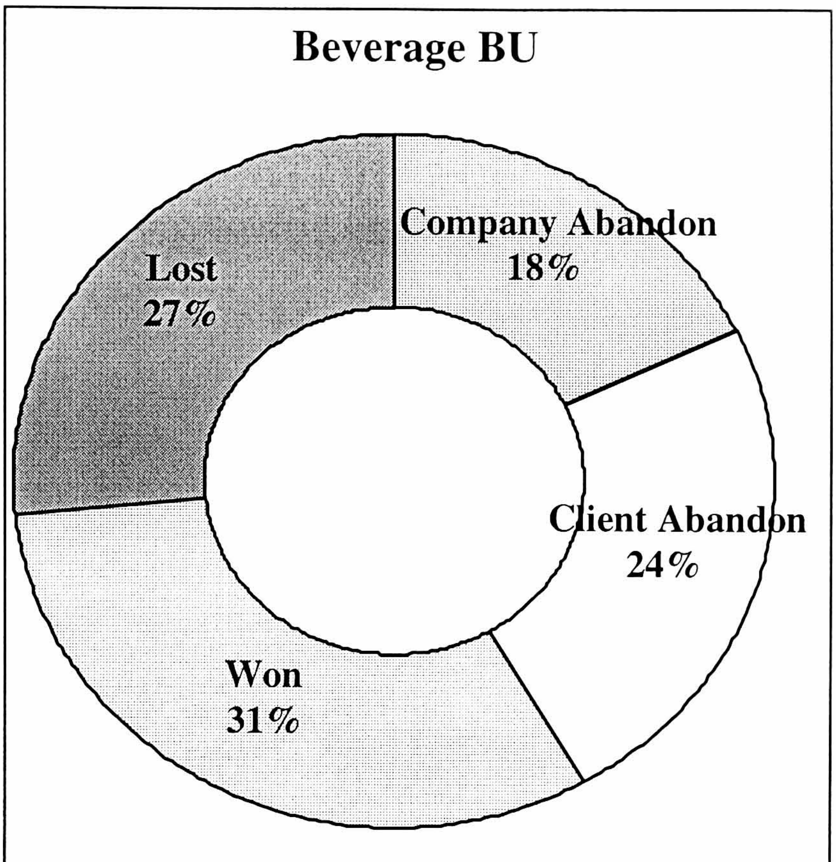


Figure 5.14. Beverage BU - Won Loss chart.

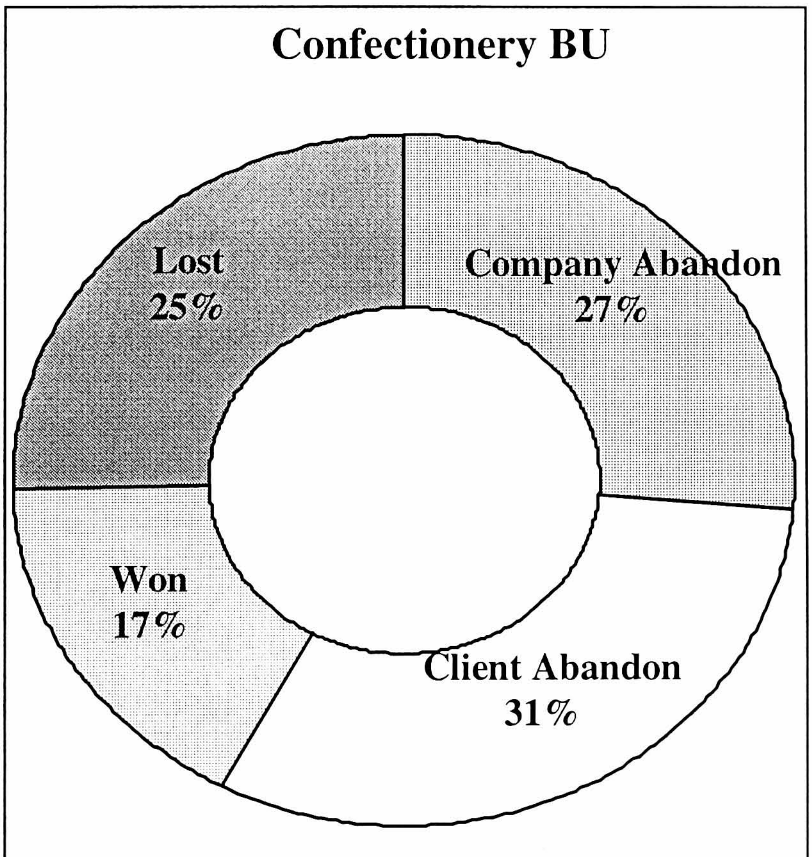


Figure 5.15. Confectionery BU - Won Loss chart.

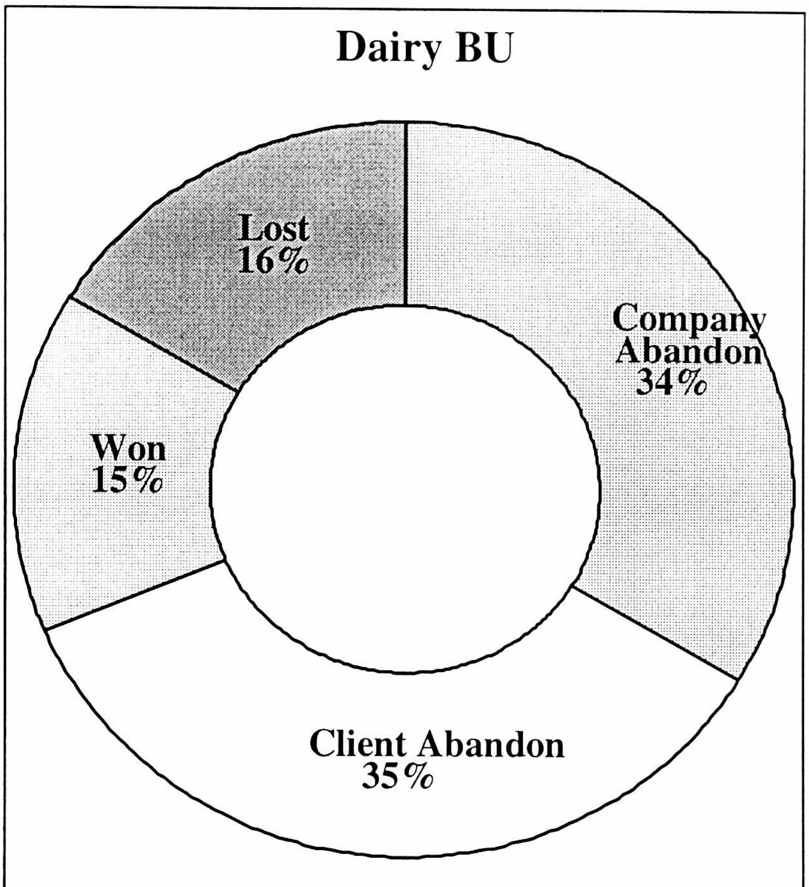


Figure 5.16. Dairy BU - Won Loss chart.

The results for the four BUs are summarised in Table 5.12, and presented graphically in Figure 5.17.

	Bakery BU	Beverage BU	Confectionery BU	Dairy BU
Company Abandon	16.13	17.78	26.51	33.72
Client Abandon	54.84	23.79	31.33	34.88
Won	22.58	31.64	16.87	15.12
Lost	6.45	26.79	25.30	16.28

Table 5.12. Comparison of BU's performance as a percentage.

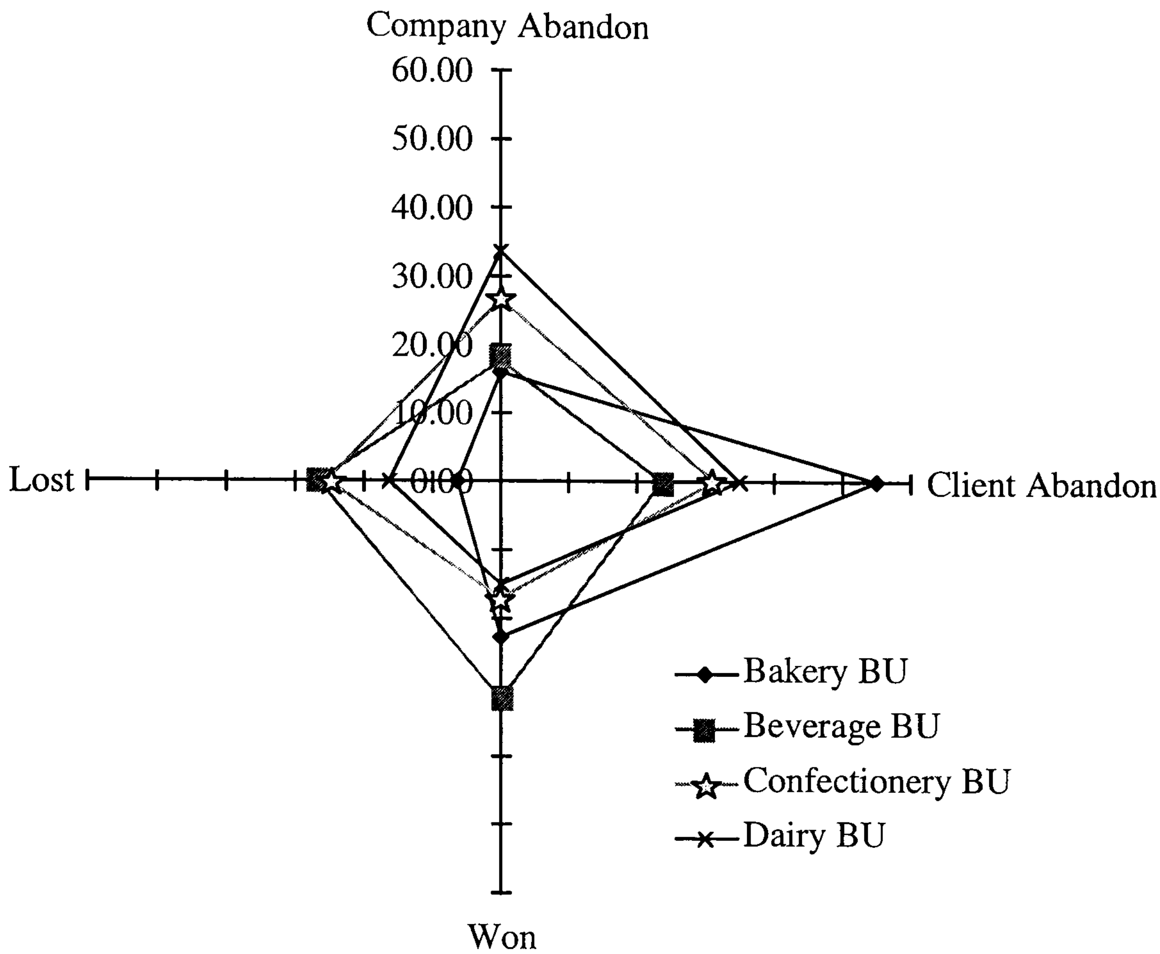


Figure 5.17. Comparison of BU's performance.

That the four BUs have very different levels of performance is clear from the various charts. However, the key question should be, whether or not there is a way for the BUs to learn from each other, through performing some internal benchmarking of best practices.

5.10 Conclusion

The chapter commences with the results of the skewness and kurtosis values for every BU and the stratifications therein. The results show that the data is not normal. This result was important as it supports the earlier observation that real data is generally not normal, and secondly, it was the reason that the author needed to develop and test several different approaches to calculating the control limits. The following section presented an actual control chart that was produced in the Bakery BU, the various aspects of this particular chart were explained to familiarise the reader with the charts' presentation. Because of the volume of charts produced the author selected a representative number of charts, from each BU and for each of the methods used to calculate the control limits. This designation was detailed at the end of this section.

The next section presented a summary of the out-of-control signals for the seven methods in a histogram format. For the *'four methods'* the data included two variables, the count of both the outside and run out-of-control signals. While for the remaining three methods the only variable was the count of the number of outside out-of-control signals. All the subsequent analyses were performed only on the data from the *'four methods'*. One reason being that in some cases the number of data points were too few and the software was unable to perform the analyses. Secondly, in some analyses it was necessary to have counts for both types of out-of-control signals.

The following section presented the results of the contingency analyses which determined the existence of a dependency between the types of out-of-control signals produced and both the four methods and the BU. The importance of this result is very simply that both the method used and the membership to a particular BU affect the numbers of signals produced. In addition, the analyses confirmed the earlier observation that the *'four methods'* appeared to be clustering into two groups.

The next analyses performed were the regression analyses. Prior to performing any regression analyses, the section plots a simple scattergram of the run out-of-control signals against the outside out-of-control signals. The scattergram displays visually the clustering of the methods. The regression analyses were able to define with a very high level of confidence, the relationships between the numbers of outside out-of-control signals and the numbers of run out-of-control signals. In total six different regressions were run, one for each of the *'four methods'* and one each for the two groups of methods.

The final two sections in the chapter tested some of the underlying assumptions in the company. Simple t-tests were performed which ascertained that the BUs were not as different as the managers believed. In fact, the Dairy BU was the only BU that is statistically different from the other three. The second t-test showed that despite the conceptual difference between the different types of projects, statistically they behave the same. The final section deviates away from the standard SPC application and performs a won/lost analysis. The results indicated a very high level of projects that are abandoned, which highlighted the need to improve the process and to manage the projects in the system better. Thereby reinforcing the importance of this study as a possible approach to managing the process better.

This Chapter has presented the results of the analyses performed along with some preliminary discussion and interpretation, Chapter 6 develops on these initial observations and discusses the results in more detail.

Chapter 6.

Discussion

6.1 Introduction

While Total Quality Management (TQM) is considered by some commentators to be yesterday's flavour of the month, quality of service and product is still crucial to maintaining market share. In fact quality leadership is still considered to be one of the top competitive issues by many executives (Malhotra, Steele & Grover, 1994). The value of Statistical Process Control (SPC) as a means of aiding understanding and ultimately process improvement is well established. That the transfer of the techniques from the manufacturing floor into management process is not a simple one, has been highlighted by many researchers (Sharman, 1992, Choi & Behling, 1997). Part of the problem has been with the data, where in many cases the management data does not lend itself to easy manipulation and use. Additionally, there is reluctance by many managers to use the techniques because of their lack of knowledge about statistical techniques and their unwillingness to appear ignorant in front of their colleagues.

This study has tested the usefulness of statistical process control techniques as a project management tool, in a new product development environment. In addition to the use of the techniques, the study was fraught with many of the problems that are faced by managers as they attempt to use the techniques, such as; negative attitudes towards statistics, insufficient commitment from top management, short-termism, and resistance to change.

This Chapter begins with a brief summary describing the study, followed by a discussion of the potential methodological and theoretical limitations of the study. The Chapter then focuses on presenting a summary of the results of the analyses carried out, and pulls them together in a coherent manner to aid in understanding the implications of the various analyses.

6.2 Research summary

The study was carried out in the European flavour division of a large Flavour and Fragrance company. The author worked within the product development laboratories of the company, where work is done to apply the company's products, in the form of flavours to develop food and beverage products for the market. The projects worked on are either in direct response to a customer brief, or are the result of an internal suggestion related to potential market demand or trends.

The author was unable to interact directly with the technicians because of management's reluctance to interfere with the running of the laboratories. The author did however meet to discuss the results and receive input from the Marketing Assistants, a Laboratory Manager, and an IT Manager. Both the Marketing Assistants and the Laboratory Manager provided a better understanding of the process and gave invaluable input to help explain the results. The IT Manager was mainly involved in organising the data exports to the spreadsheet program, and assisted in providing the author with access to the project management database for validation and completion of missing data fields.

The data and information received were fed into the authors software and used to produce the statistical process control charts that provided the basis of the research.

6.3 People issues

As mentioned previously the author encountered resistance from various individuals at Caché Corporation at different times throughout the project. In all fairness to the people at Caché Corporation, there were also many individuals who provided the author with a lot of assistance. In this section, a handful of the more memorable incidents as they relate to this study are described. While the focus of the study is on the harder issues surrounding the implementation of SPC, the author believes that the softer issues as related to the human side of the implementation and the insights that they provide, are one of the key advantages to using messy real world data.

6.3.1 Mistrust of statistics

Just prior to the start of the study the European Director had announced, that he wanted all the BUs to have a five day turnaround time for their projects. As with most targets of this type, no rationale was given for the decision, no indication of how to proceed, and more importantly no support financial or otherwise was provided. The BUs were expected to achieve this goal with no extra resources, while maintaining their current workloads. Another interesting factor that came into play, was that, the BUs had been set up in the previous six months and were still in the process of organising the facilities. In discussions with the Commercial Director, it was clear to the author that he was not concerned with the five day target, he considered it to be arbitrary and would not necessarily achieve customer satisfaction. For the Commercial Director his target was to ship the samples to the customer on the day that the customer wanted to evaluate them. Whether this translated to a one day or fifty day turnaround time was not important to him, his focus was on keeping the customer satisfied.

The Commercial Director considered the proposed study to be a good way of improving his understanding of the BUs performance, through the provision of factual data. He felt that the information that would be available to him from the control charts would enhance his decision making capabilities. Given the Commercial Director's outlook on the purpose of the study and complete disregard for the five day target, the reaction of the Marketing Assistants when presented with some of the early charts produced by the author, came as a bit of a surprise.

They were very disturbed by the fact that none of the BUs had average turnaround times anywhere close to the five day target! That the results threatened them and created a lot of anxiety were reflected by some of their comments during that meeting, such as:

> "Statistics are dangerous!" and "These charts are misleading.... They don't present the entire picture."

Additionally, they were very hesitant about showing the charts to their managers. They were of the opinion that management would not understand the reasons for their BU's poor performance, relative to the five day target. The author was unable to convince them of the positive aspects of the control charts, and that they could in fact be used to their advantage with management.

The meeting ended with the Marketing Assistants still very unsure about the value of constructing control charts to monitor their processes, while the author resigned herself to the fact that hopefully over a period of time she would be able to convince them of the value of the techniques.

Another important learning point was, the different attitudes displayed by people at different levels in the hierarchy, towards the five day target of the European Director. The people lower down in the organisation saw it as a very real goal against which their performance would be measured, and were unable to dismiss it as unimportant.

6.3.2 Too busy to manage effectively

The Beverage BU is the busiest of the four BUs studied. They work on the most projects, and they win the highest percentage of their projects and make the most money for the division. Despite this, at the time of the study they had roughly the same level of staffing as the other three BUs, and a lack of certain machinery that would greatly improve their efficiency. After several talks with the Beverage Laboratory Manager, the author produced an *'Ishikawa diagram'* for the Beverage BU (see Figure 6.1), as a way of focusing the Managers attention to specific problems that could be addressed by the team.

Based on feedback that the author received from the Laboratory Manager in early 1998, many of the problems that were highlighted by the Ishikawa diagram, have been addressed in the interim since the author first did the analysis. The Manager found the diagram useful as a way of condensing the key problems that needed to be addressed, to allow him to work more efficiently.

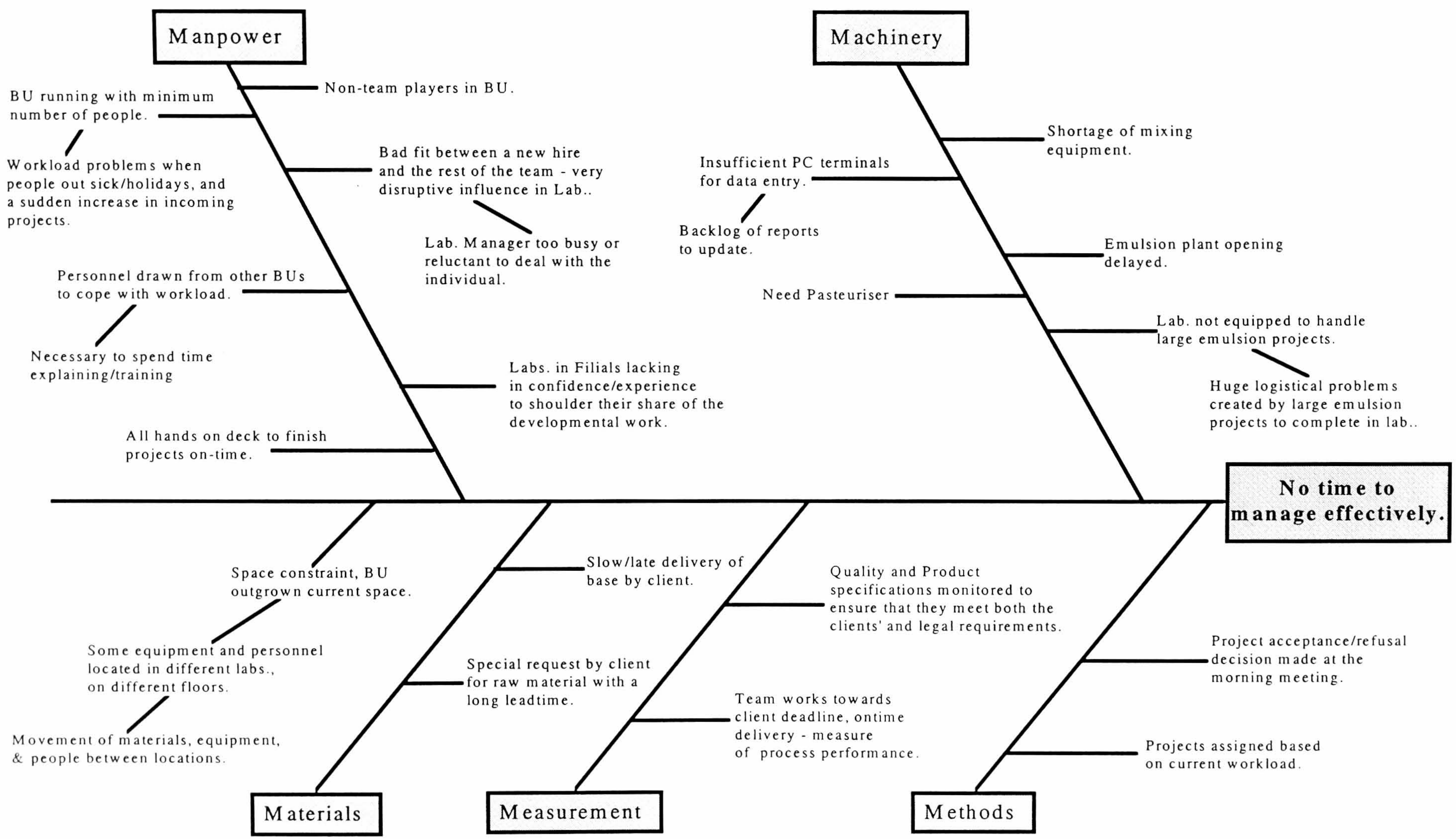


Figure 6.1. Ishikawa diagram for Beverage BU.

6.3.3 Lack of ownership

Within the first six months of the study, it was announced that the Commercial Director was leaving to work in a different filial. The author and the work that she was doing, were introduced to his replacement by the outgoing Commercial Director. The author was given the go ahead to continue with her work under the new Commercial Director. However, within a few months of the change over it became apparent to the author that the new Commercial Director was not enthusiastic about the study and the potential for improvement.

The author recalls one meeting where it became clear that the new Commercial Director was a very different manager, to the previous Commercial Director. At that particular meeting, in addition to presenting the BU's charts for their project turnaround times, the author also presented some of the early results of the won/lost analyses. His nonchalant reaction was very surprising as the author considered the volume of wasted resources, and potential for improvement as represented by the high percentage of projects abandoned, to be impossible to ignore. But as was reflected by some of his comments at that time, he was not prepared to go any further to investigate the drivers behind the observed results.

> "We expect to abandon projects. In fact, we accept projects for political reasons that we do not want to win, and do not put a lot of effort into them, so as to ensure that we don't win the order!"

The author was completely taken aback by this comment, as it reflected an approach to management that is completely at odds with what she considers to be good management. Apart from the obvious squandering of the resources in the BUs which were already being pushed to the limit, there was no consideration of the effect that this approach would have on the morale of the people.

While it is conceivable that there would be the occasional project that was accepted, because of the relative importance of the particular client making the request, it is the opinion of the author that they should represent a very small minority. The fact that across the entire division the average number of projects abandoned is running at about sixty percent, cannot be explained by these projects. In response to this the Commercial Director declared that they knew the reasons behind the lost and abandoned projects.

> "One of my assistants has polled our top ten clients to enquire about the quality of our service. Additionally, we get an explanation from the client when we lose an order."

Unfortunately, he was not knowledgeable of the results from this investigation, none of that information is entered into the project management database, or as far as the author was aware disseminated to the people in the BUs. In point of fact, it seemed to be yet another example of wasted effort, as nothing was done with the information to try and improve their processes.

Shortly after this meeting, an agreement was reached between the author and the Commercial Director, where the author could continue to receive the data and use it in her study, but that it was not necessary to produce any reports for him. While the author was very disappointed with his lack of interest, she was still grateful to be able to continue to collect and use the company's data for her study.

It is possible that the new Commercial Director lacked a sense of ownership with the study, as he had inherited it from his predecessor, or perhaps was not interested in the application of SPC techniques, or both. One thing that was clear to the author, was that he was not open to new ideas, or being challenged to find the reasons behind the observed performance, in fact he seemed content to maintain the status quo. In fact, he stayed in the position for one year, and in hindsight he was probably aware that it was just a temporary assignment, and was averse to taking any risks in that time that could backfire and reflect badly on him. Based on feedback received from many individuals in the BUs, his entire focus in that time was on cutting costs. His approach to cutting costs was through the refusal to approve any training, and to cut back on many inconsequential items. Clearly, his approach to management and cost reduction was very short term, and not in the best interest of either the employees or the company.

6.4 Study methodology

The author used the data to produce a series of control charts for each of the business units. Seven different approaches were used to calculate the limits placed on the charts, as follows:

1. The default method/mean
2. The median
3. A 10% trimmed mean
4. The resampled data's mean
5. Probability limits
6. The resampled data's 1/1000 probability limits

7. Exponential limits

The different methods were compared on the basis of the number of out-of-control signals produced. The statistical package could not perform the run tests for the last three methods listed above, as the tests are based on the standard deviation of the data which defines the zones in the control charts. Method 5 used the probability limits for the distribution, while in methods 6 and 7 the author defined the limits. For the first four methods listed above, the pairs of data points of outside signals against run signals were plotted and used in the regression analysis to determine the relationship between them. The author also used the data received to compare the performance of the BUs by the numbers of projects won, lost, or abandoned.

6.5 Potential limitations

One potential limitation is related to the fact that the study involved data from only one company. In actual fact the four BUs were effectively acting as separate companies, interacting with different segments of the market, but with a common data recording method and database. This is of tremendous value as the author was able to use the data either separately by BU or amalgamated, also comparisons between the BUs could be made given the commonalties between the data. Another positive was the quantity of data received as indicated by the sample sizes for the BUs, apart from the Bakery BU, the remaining three BUs had large sample sizes. Additionally, within the data there was a significant amount of diversity in the types of projects, products, and clients represented, which provided depth to the data.

In the following sections the results from the different analyses performed are discussed.

6.6 Comparison of the methods

This section is concerned with the possible congruence between the *'four methods'* and the definition of the relationship between outside and run signals for each of the methods. As was outlined earlier in Chapter 5, the other three methods dropped out of the more detailed analyses performed. The software was unable to perform the analyses for them, because of the low numbers of data points for the outside special causes and the lack of a value for the run special causes. As a consequence the author was unable to make any definite conclusions about their usefulness, that could be supported by statistical analysis. However, the author discusses them very briefly here and gives her opinion on their usefulness, based on her experience with the product development laboratories under study.

The 1/1000 probability limits produce outside signals slightly lower than the four methods but more or less on par. Unfortunately, the author was unable to perform the run tests for this method and as a result cannot make a definitive recommendation about its usefulness.

For the remaining two methods the exponential limits and the 1/1000 resampled limits, the numbers of outside special causes drop off significantly and produce very low counts of outside out-of-control signals. In many cases the numbers of signals are either zero or very close to zero. Based on the author's discussions with individuals in the BUs, there were many problems that were signalled by the other methods that would be classified as special causes and resulted in projects having long turnaround times. Neither of these two methods succeeded in signalling the presence of a problem, for the majority of these known special causes. These last two methods appear to be extremely susceptible to the presence of outliers, and the author would not recommend their use especially when dealing with highly skewed data, as the results produced are misleading.

The analysis was carried out on several different levels for the remaining four methods;

- Default method/Mean
- Median
- 10 % Trimmed mean
- Resampled data's mean

Firstly, by simply examining the data by eye, a pattern in their behaviour began to emerge. Secondly, armed with some suspicions a contingency analysis was performed, in an attempt to statistically confirm the similarities. Finally, a scattergram was plotted followed by regression analyses to define the relationships.

6.6.1 Visual check of the data

On looking at the histograms and the tables of data showing the numbers of out-of-control signals for each method and stratification a particular pattern emerges. With the overall data, both the median and the 10% trimmed mean have significantly less out-of-control signals than either the default method or the resampled mean, see Figure 6.2.

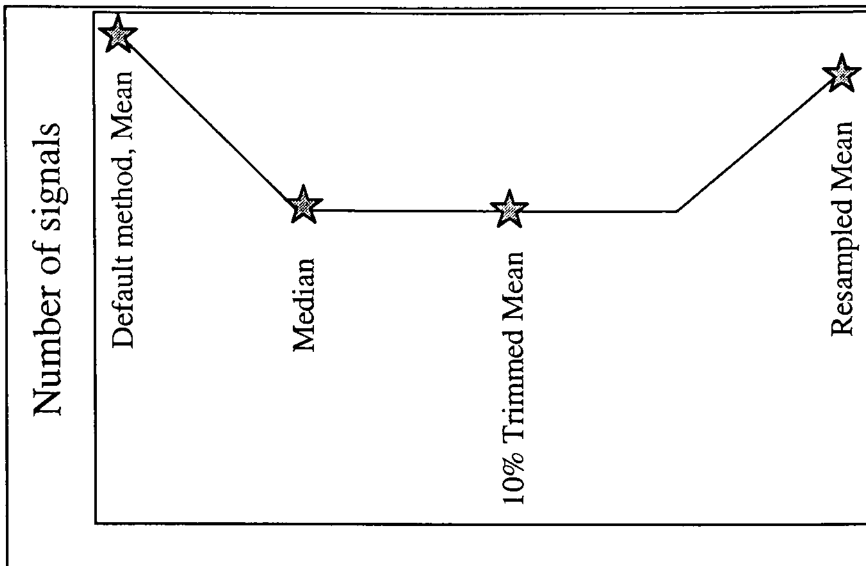


Figure 6.2. Pattern of out-of-control signals.

Breaking this down into the component parts that contribute to the overall pattern, it is observed that the number of outside signals vary much less than the run signals. The median and the trimmed mean tend to have slightly more outside signals than either the default method or the resampled mean, see Figure 6.3.

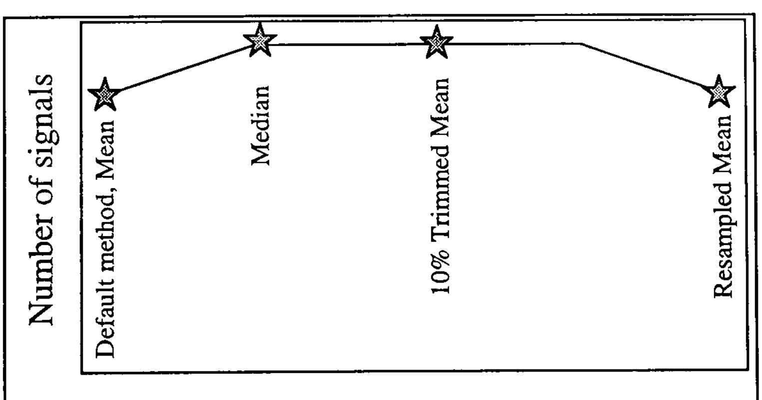


Figure 6.3. Outside signals pattern

This was to be expected as both the median and the trimmed mean adjust for the large outliers that are present in the skewed distributions. Given that the distributions are positively skewed both methods resulted in upper control limits that were smaller than with the other two methods, which would increase the number of points falling outside of the upper limit.

The overall pattern observed derives its shape mainly from the number of run signals produced by the different methods, see Figure 6.4.

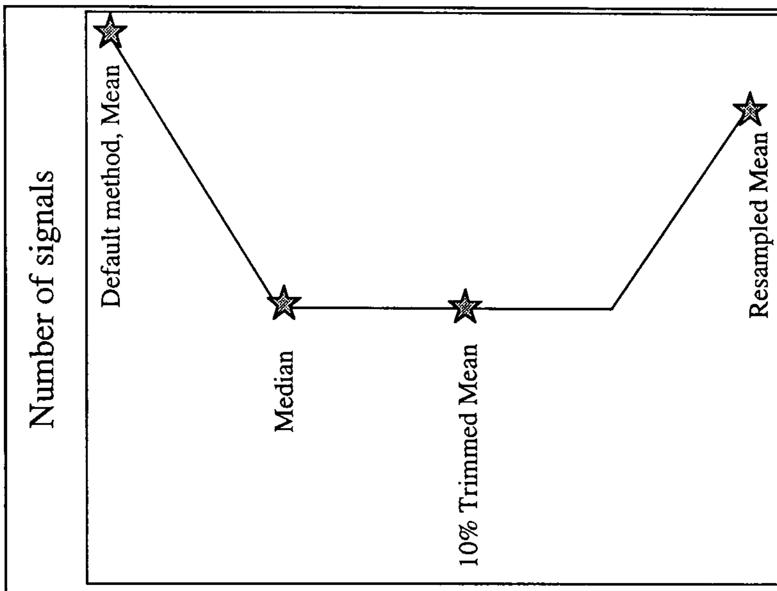


Figure 6.4. Run signals pattern.

The run tests that were performed are listed below:

- Nine consecutive points above or below the defined centre line,
- Six consecutive increasing or decreasing points,
- Fourteen consecutive alternating points,
- Two of three consecutive in Zone A or beyond,
- Four of five consecutive points in Zone B or beyond,
- Eight consecutive points outside Zones C.

Both the default method and the resampled mean produced significantly more run signals than either of the other two methods. On reviewing the charts the first run test; 'nine consecutive points above or below the defined centre line' was the main cause of the difference. In retrospect this should be expected when dealing with skewed distributions. In this study given that the distributions were positively skewed, the centre line for both the default method and the resampled data's mean, were larger than for either the median or the trimmed mean approach. The expectation would be that a large proportion of the points should lie below the centre line, particularly for the first two methods (default method and resampled mean). In actual fact, that was exactly what was observed and was the reason for the disproportionately large number of run signals produced by this test.

Based on the patterns described above the author felt that the four methods appeared to be split into two groups. Group 1 consisting of the default method and the resampled mean, and Group 2 consisting of the median and the trimmed mean. To investigate these suspicions more thoroughly a contingency analysis was performed.

6.6.2 Contingency analysis

The two variables used in this analysis were; the type of out-of-control signals and the method used to calculate the control limits. The results of the contingency test indicate that the null hypothesis of independence between the variables is rejected.. The very large chi square value (290.101) coupled with the very low probability value for the chi square p-value (<0.0001), provide the necessary support for rejecting the null hypothesis. In plain English this implies that there is some relationship between the method used and the types of out-of-control signals produced.

To better understand the differences, the post hoc cell contributions in the analysis's output were examined. The default method/mean and the resampled mean have a heavier weighting on the run out-of-control signals, 6.555 and 11.115 respectively while the median and trimmed mean have negative values.

The median and the trimmed mean have heavier weightings on the outside out-of-control signals, 12.548 and 7.667 respectively while the default method and the resampled mean have negative weightings. These results are in clear agreement and support the suggested relationships hinted at in the previous section.

As a visual check of the suggested groupings a scattergram was plotted.

6.6.3 Scattergram

The scattergram was plotted to visually demonstrate the clustering of the four methods into two distinct groups, see Figure 6.5.

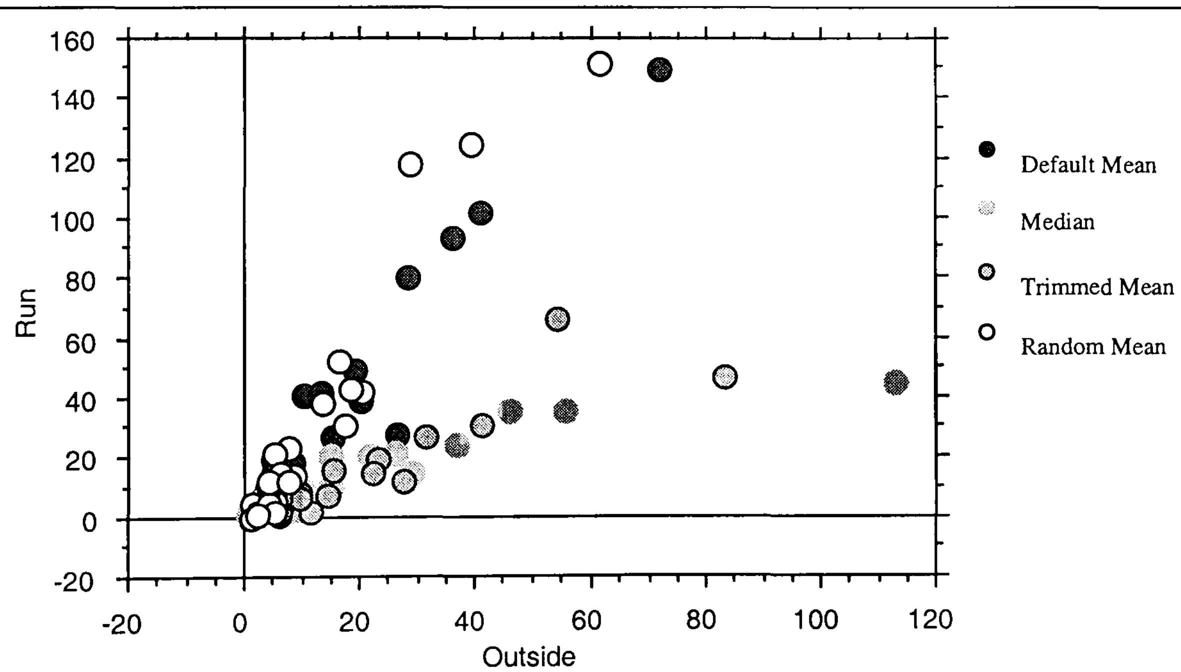


Figure 6.5. Scattergram split by method.

The scattergram displays the clustering and also the relative weightings of the four methods on the different types of out-of-control signals. The conclusion is that it is redundant to use two methods from the same group as they behave similarly.

Regression analyses were run to define the relationships between the types of out-of-control signals for each of the four different methods and also the two groups.

6.6.4 Regression analyses

The author considers that the unique opportunity to define the relationship between the different types of special causes to be of significant value to both practitioners in the field and also academic researchers. It should be recognised that managers need to spread their limited resources over a number of areas.

Typically when implementing SPC, managers initially just monitor the outside special causes and later on as they become more confident and sophisticated they include the run special causes. While the manager may concentrate on 'the low hanging fruit', as represented by the outside out-of -control signals in the early stages of the implementation. At the point where he/she is contemplating starting to monitor the run signals, it would be of value to the manager to have an accurate estimate of the numbers of special causes that are being missed, to allow the manager to make an informed choice on what the added value would be of increased detail.

The ability to define the relationship between the two types of out-of-control signals would also prove to be useful to researchers developing theories on missed signals and false alarms.

Going into the regression analysis it had been established that the methods clustered into two groups, and as such two separate regressions were run for the two groups of data. In addition, individual regressions were performed for each of the methods.

The results for Group 1 (default method/mean and the resampled mean) achieved an R-squared value of 0.947, which implies that 94.7% of the variability in the dependent variable (Run out-of-control signals) is explained by the independent variable (Outside out-of-control signals). Additionally, the overall p-value for the regression analysis was <0.0001, which allows for very high confidence in the explanatory power of the results, i.e. the regression model. That the squared term is useful to explaining the relationship between the two variables is demonstrated by its low p-value score of 0.0943.

The regression equation for Group 1 was defined as follows:

$$\mathbf{Y = 2.784 * X - 0.007 * X^2}$$

The results for Group 2 (median and trimmed mean) achieved an R-squared value of 0.908. This implies that 90.8 % of the variability in the dependent variable is explained by the independent variable. The p-value for the overall regression was <0.0001 which allows for high confidence in the result. Additionally, the coefficient for the squared term also had a p-value of <0.0001, which implies that it is important in explaining the relationship between the variables.

The regression equation for Group 2 was defined as follows:

$$\mathbf{Y = 0.907 * X - 0.004 * X^2}$$

The regression equations for each of the four methods are summarised below in Table 6.1. The overall p-value for all the regression models was <0.0001.

Method	Regression equation	R Squared value
Default mean	$Y = 2.493*X - 0.005*X^2$	**0.962**
Resampled mean	$Y = 3.004*X - 0.006*X^2$	**0.950**
Median	$Y = 0.790*X - 0.003*X^2$	**0.962**
Trimmed mean	$Y = 0.949*X - 0.003*X^2$	**0.895**

Table 6.1. Regression summary.

Having defined these models they can now be used to predict the number of run out-of-control signals to expect given the number of outside out-of-control signals, for any of the four individual methods or groups of methods.

All the regression equations reflect the earlier observation that both the default mean and resampled mean methods, have a structural bias built in towards producing very large numbers of run signals. While both the median and the trimmed mean produce fewer run signals than outside signals. These observations are based on the coefficients of the independent variable.

6.7 False alarm analysis

In this section the results from two of the methods (default method/mean and median), one each from Group1 and Group2 were compared in more detail. The comparison was based on the time-series of the first seven hundred data points from the Beverage BU, which corresponds to the first ten control charts. For this series of points, every outside out-of-control signal was considered and a reason special or otherwise, was assigned to it. This was accomplished after the fact in a couple of sessions with the Beverage Laboratory Manager.

Because of time constraints the Laboratory Manager was unable to meet on more occasions, and it was not possible to analyse all the charts for the BU.

Some examples of the type of reasons that the Laboratory Manager gave which were classified as special are outlined below.

The first example pertains to a particular client who is notorious for their treatment of their suppliers. The particular client is an extremely powerful company in the Beverage market, and uses their size to bully the suppliers. Additionally, the company is reluctant to trust any single flavour house to develop the complete flavour system for any of their products, and very often splits the project up into smaller components, that are tendered out to different flavour houses. The client then performs the final blending of the flavours in-house. This approach to product development produces many delays, because of the complex communication flows that need to be managed. Additionally, while this modular approach to product development/integration works well in other industries, its application to the blending of flavours is far from straight-forward. As a result many problems are experienced at the final blending stage, resulting in the individual flavour houses needing to rework their original submissions. All said and done, the final result is a tendency for all projects originating from this particular client to have long turnaround times.

Another example of a special cause attributable to a client, but very different to the previous problem has to do with the particular clients exuberance. The particular company is owned and run by a few very innovative individuals. Projects are started on for the client only to realise later that the client himself is unsure of many of the specifics of the final product, and changes his specifications many times throughout the duration of the project. As with any product in any industry the more changes made to the specifications throughout the development phase, the longer the turnaround time for that project.

One final example of a special cause, related to the type of product being worked on. Generally, when the product is a completely new product being introduced to the market the turnaround time is longer. The development phase for a new product normally involves several market taste tests, in the target market to determine the final specifications for the end product. These feedback loops and the modifications necessary to reach the final desired product, result in new product projects taking longer on average, than a project where a modification is being made to an existing product in the market.

A common example of a project that produces a special cause signal, but was not classified as special, is the proactive project. Recall that proactive projects are generated internally, and not in direct response to a customer demand. As a result they have a very low priority, and are the first to be put to the side when other projects with higher priority enter the BU. Another example of a false alarm signal was, a long term project that was testing the stability of the flavour system over a period of time. This type of project by default has a long turnaround time, and does not reflect the presence of a special cause affecting the process.

There were instances when the Laboratory Manager was unsure as to the cause of the long turnaround times for a project, in which case the reason was labelled *'unknown'*.

A summary of the numbers of special and non-special causes is presented in Table 6.2. The non-special causes section is subdivided into two groups;

proactive projects and others. The author has chosen to separate out the proactive projects as they represent the bulk of the false alarms, and while they result in a signal of a special cause, they are immediately identifiable as proactive projects (i.e. false alarms) and do not result in any action. One final reminder is that the table only represents, the outside out-of-control signals.

	Default method - Mean		**Median**		
	Raw number	% of total observations (700)	Raw number	% of total observations (700)	Difference
Total number of outside signals	47	6.71%	61	8.71%	2.00%
Special causes	23	3.29%	30	4.29%	1.00%
Non-special causes total	15	2.14%	21	3.00%	0.86%
Proactive projects	13	1.86%	19	2.71%	0.85%
Others	2	0.29%	2	0.29%	0%
Unknown	9	1.29%	10	1.43%	0.14%

Table 6.2. Special cause allocation.

The false alarm rate is often described by the probability of a Type I error, which in this instance is 0.0214 for the default method and 0.03 for the median. These false alarm rates translate to an average run length (ARL) of 47 for the default method and 33 for the median. However, the author considers these numbers to be exaggerated by the inclusion of the proactive projects, which would not initiate any action by the people in the BUs and do not represent a true false alarm. Consequently, the author considers the true false alarm rate to be represented by the *'others'* sub-category in the non-special causes section. Using these probabilities the false alarm rate for both methods is identical -- 0.0029 which translates to an ARL of 345.

It was not possible to determine the probability of a Type II error, i.e. missed signals. This would have entailed a much closer association between the author and the BU than was allowed, so as to be in a position to determine when a special cause had occurred that was not reflected in the data. One observation that can be made with respect to the probability of Type II errors, is that, the default method has a higher rate of missed signals than the median method. This is based simply on the fact that the Median approach, detects 1.00% more special causes than the default method.

The relative performance of the two methods based on their ability to detect special causes was compared to be able to make some recommendation. The default method detects fewer actual special causes than the median approach. If the total number of non-special causes are considered then the median produces more false alarms than the default method. If however, the proactive projects are omitted then the two methods produce the same number of false alarms.

Based on these results and the results presented in the previous section the author recommends the use of either the median or the trimmed mean as the preferred approach when dealing with positively skewed data. Either of these methods would detect more special causes with the same number of false alarms as the default or resampled mean methods. In addition, as was displayed in the preceding section, the default and resampled mean methods both overestimate the numbers of run signals, which would increase the false alarm rate for these methods.

6.8 Differences between the BUs

This section pertains to the similarities and differences between the four different business units. While there are obvious differences by the type of product worked on, the overall product development process is the same. One other difference that becomes quickly apparent is in the volume of work performed by the different BUs. The volume of projects worked on by the BUs, over the period of time represented in the data was; Bakery BU - 101 projects, Dairy BU - 379, Confectionery - 399, and Beverage - 1312.

These numbers translate to roughly 300% more projects handled by both the Dairy and Confectionery BUs, than the Bakery BU, and more than 1000% more projects handled by the Beverage BU. There was not a large difference in the staffing levels of the BUs at that time, with the Beverage BU consisting of four full-time people, as compared to three in the Dairy BU and three split between both the Bakery and Confectionery BUs. The impact of this difference in project throughput on the pace of work, and the stress levels can only be speculated at.

The second approach used to understand some of the differences between the BUs was through the use of a t-test.

6.8.1 T-test

The t-test compared the average project turnaround time for the four BUs to determine the likelihood that they came from the same population. The results show that with respect to the turnaround times the Dairy BU is significantly different from all the other BUs, and has a much lower turnaround time compared to the rest. Specifically, when compared to the Beverage BU the p-value = 0.0001, compared with the Confectionery BU the p-value = 0.0057, and finally with the Bakery BU the p-value = 0.0133.

The surprising result here was not that the Dairy BU was different, but that it had a lower turnaround time than the other three BUs. This is surprising simply because of the types of products worked on in the Dairy BU (e.g. yoghurts and ice creams), which very often need time for cultures to mature, or for the flavour's performance to be tested over a period of time under different physical conditions.

Perhaps the staffing levels holds the key to this behaviour, in that, the Beverage BU is clearly understaffed and as a result people are working on many different projects simultaneously, the end result being that all the projects take longer on average. Similarly the three people working for both the Bakery and Confectionery BUs, may also be doing a lot of multi-tasking between projects, again resulting in an overall increase in the project turnaround times.

A final interesting observation is that the average turnaround times range from a low of 19 days in the Dairy BU to a high of 34 days for the Confectionery BU. All of which are way more than the 5 day target set by the European Director.

The next analysis carried out was the contingency analysis.

6.8.2 Contingency analysis

This analysis compared the BUs by the number of out-of-control signals produced by each BU. The results of the contingency test reject the null hypothesis of independence between the variables of BU and the type of out-of-control signals. The high chi-square value of 11.477 and low chi-square p-value of 0.0094 provide the basis for rejecting the null hypothesis. Examining the post hoc cell contributions to understand the relative weightings of the four BUs, on the different types of out-of-control signals we observe the following: Both Beverage and Dairy weight positively on the 'run out-of-control signals', with 2.027 and 1.082 respectively. While Bakery and Confectionery weight positively on the 'outside out-of-control signals', with 1.801 and 2.665 respectively. Simply put both the Beverage and the Dairy BUs are inclined to have a higher percent to run signals, while the Bakery and Confectionery BUs have a higher ratio of outside signals. The author is unsure of the cause of this behaviour, but speculates that perhaps given that the Beverage and Dairy BUs are the most skewed distributions of the four, that the problem of an exaggeration of the numbers of run signals discussed earlier in this chapter, could possibly be driving this observation.

6.8.3 Won lost analysis

On reviewing the won lost analysis and comparing the four BUs several things emerge. The first observation is that the Beverage BU wins the largest percent (31.64%) of the projects worked on. The Beverage BU also loses the largest percent (26.79%) of projects worked on. Additionally, the Beverage BU abandons a much lower percent (41.57%) of the projects worked on as compared to the remaining three BUs, see Table 6.3.

	Bakery BU	Beverage BU	Confectionery BU	Dairy BU
Projects abandoned	70.97 %	41.57 %	57.84 %	68.6 %
Projects Won or Lost	29.03 %	58.43 %	42.16 %	31.4 %

Table 6.3. Won lost summary

On looking at the high percentage of projects lost by the Beverage BU the first impression formed is that this is a negative attribute, however, on thinking about the meanings behind the designations it may not be a negative and could in fact explain why they win the most projects as well.

When a project is abandoned either by the client or the customer it indicates that the interest in the project was not there from at least one side, if not both. Frequently, the project is abandoned after some period of time, during which time an extensive amount of development work will have been performed on the project, the end result being a waste of the already scarce resources. While a project that is not abandoned (i.e. either won or lost), goes on to the final phase and is potentially chosen by the client in their final evaluations before beginning production. Clearly, the more projects that reach to this final evaluation phase, the greater the probability of it being an order winner. This could explain why the Beverage BU has the highest percentage of won projects. One implication for the managers of the BUs would be to find ways to reduce the high numbers of abandoned projects, in so doing improving their probability of success.

The conclusion at the end of this section is that, the BUs do not seem to exhibit any consistent behaviour patterns between themselves, which would allow for them to be grouped. The four BUs studied appear to diverge in more areas than converge and should continue to be treated separately.

6.9 Company competitiveness

This section focuses on any results that could be industry specific. Continuing on from the above discussion related to the won lost analysis, the overall percentages are presented for the entire division, see Table 6.4.

	Overall %	Grouped scores	
Company Abandon	21.01 %		
Client Abandon	27.80 %	**48.82 %**	**Projects abandoned**
Won	27.01 %		
Lost	24.17 %	**51.18 %**	**Projects won or lost**

Table 6.4. Summary scores for division.

The final result being very close to a fifty-fifty split between projects abandoned and projects that reach the final round of customer evaluations. Whether or not this is acceptable is debatable. On presenting these numbers to the Commercial Director he did not appear to be overly concerned and considered it to be normal for their industry. If in fact this is normal for the industry, the opportunity for Caché Corporation to gain a strategic advantage over their competitors, through a decrease in the high numbers of projects abandoned is enormous. Additionally, this overall average is strongly influenced by the Beverage BU's better performance, and the potential for improvement in the other three BUs, combined with a reduction in the overall waste is necessary. There could be an opportunity to perform some internal benchmarking between the BUs, so as to ensure that the best practices across the four BUs are standardised.

While one could accept that in this type of dynamic environment where projects are very subjective, and the customer is very often feeling out a new market that there would be some considerable level of projects abandoned. The author felt that if the company spent some time looking into the characteristics of the projects that are abandoned, with the aim of isolating certain triggers which could feed into the decision making process, of whether or not to accept a project, then some competitive advantage could be gained. While some projects would always be accepted because of the importance of the client overall to the business, the end product should be less time wasted on projects going nowhere, and more time to spend on projects that have a higher potential of success.

6.10 Conclusion

This chapter described in detail some of the people issues that the author encountered during the study. The three areas reviewed were; the general mistrust of statistics by the people working in the laboratories, the beverage laboratory manager's problem, of being too busy to manage the running of the laboratory effectively, and finally, the lack of ownership displayed by the new Commercial Director towards this study.

In the following sections the author links the results from the visual inspection of the patterns of out-of-control signals, to the contingency analyses which support the observation that the *'four methods'* appear to be clustering into two groups. The regression analyses provided more support for the clustering of the methods into two groups. The regression equations show the similarity between the methods in each of the two groups. At this point however, the author was still unable to make a recommendation as to which method is more effective. The next section provided the necessary information to be able to select a preferred method to use when dealing with skewed data. This section compared two methods, one from either group in detail. The outside out-of-control signals were categorised into real special causes and false alarms with the help of one of the managers. The median method and by extension the trimmed mean approach are recommended by the author, as being more effective than either the default method or the random mean method based on the false alarm analysis.

The remainder of the chapter discussed the differences between the BUs and the overall competitiveness of the company. The author speculates about what could be the underlying reasons for some of the observed differences and discussed the relative performance of the different BUs as measured by project performance. The discussion concerning the company's competitiveness, reflects the author's strong belief that at the present level of abandoned projects, the company is wasting resources and has an opportunity to improve its competitive advantage.

The final chapter discusses both the theoretical and managerial implications of these results, and possible areas of future research coming out of this study.

Chapter 7.

Conclusion

7.1 Introduction

> "Obviously, a man's judgement cannot be better than the information on which he has based it." Arthur Hays Sulzberger.

Managers need timely information to aid their decision making. The modern manager cannot afford to make decisions in a vacuum, devoid of reliable information, and without a true understanding of the consequences of the particular decision on the entire organisation. More and more companies are moving away from a focus on the individual functions that comprise it, towards a process orientation. Managers are increasingly aware of the linkages between them and their departments, on the end customer, via the process that delivers the product or service. In the international companies of today a decision made locally in one area, can have global reach and effects.

For all these reasons it is important that decisions are based on good and accurate information. Many managers are reluctant to take actions and make decisions because of their mistrust of the information before them, the problems that this creates for companies that are dependent on decisive actions from their leaders, are numerous. The veritable *'superstore'* of managerial tools from which to choose, compounds the problem and increases the confusion of managers. Generally, the different tools and techniques have been developed for specific applications, and it is very unusual to see tools from one area cross over into other functional areas (Euske and Player, 1996).

This thesis has performed an in-depth study testing the usefulness of statistical process control tools as a way of managing projects. The study highlighted many of the potential pitfalls and technical issues related to their transfer into areas of the business other than on the manufacturing floor.

7.2 Value of SPC in a project environment

Based on this study the author is able to conclude that statistical process control charts are useful and provide valuable information to managers of projects. In particular in the environment described in this thesis, in which the traditional tools of project management were not suitable, the author found that SPC was able to fill the gap and succeeded in improving managers decision making.

Firstly, by providing a better understanding of their product development process, and their average project turnaround times. SPC provided the project managers with the ability to know what they were capable of, this knowledge allowed the managers to make better decisions with respect to acceptance of new projects and also to make realistic estimates of the time that they will take to complete. This knowledge based decision-making is a far cry from the previous situation.

Secondly, SPC can be used in a project environment to isolate problems with the process. Because of the volume of projects in the system and their relatively short turnaround times any changes/improvements to the process would rarely benefit the project that first signalled the existence of the problem. The root cause analysis performed after the occurrence of a special cause as flagged by the control charts is an effective way to make problems visible. Once the problems are well understood and a variety of solutions discussed then the managers can decide on the best course of action. In practice that may not always mean implementing the solution, for numerous reasons such as; lack of resources, and relative cost of the solution. However, even with no action the managers have improved their knowledge of their process and are aware of the particular shortcoming and may be able to develop contingency plans, for the next time that it occurs.

7.3 Recommended approaches for calculating the control limits

Given that SPC is a useful tool in project management, the next contribution that the author makes is a practical one. As was suspected at the outset of the study, most real data is not normal. In this particular case, the data was positively skewed. The author is able to recommend that users of SPC charts were the underlying distribution of the data is positively skewed, should use either the median or the trimmed mean approach to calculating the control limits. The author was able to show empirically that either of these two methods, were more effective than either the default mean or the resampled mean approaches. This is important to both practitioners in the field and academics as the placement of the centre line and the control limits is key to the overall value of the tool as a provider of accurate information. This recommendation is not limited to either the flavour and fragrance industry, or a project management environment. The author is able to recommend this approach whenever the underlying distribution is positively skewed, as the analyses were independent of both the industry and the application area.

7.4 How to apply SPC in practice

In any application of this type the author recommends that the process under study, be well understood and clearly defined before attempting to implement any changes. A good understanding of the process can be achieved through interviews, and meetings with various people working in different related areas. In the study reported on in this thesis the author found that the use of a process flowchart, to summarise the product development process proved to be extremely useful in clarifying the steps in the process.

The next step in the implementation would be to decide on the key success characteristics that need to be monitored, and the variables that would measure the process's performance in those areas. In this particular study the author chose to track the project turnaround times.

A historical sample of data points can be used to determine the distribution of the data, and subsequently the best approach for calculating the limits for the control charts.

Once all the preliminary work is completed then it should be the responsibility of the managers working in the system to monitor the process. To this end they would need to do the following at the agreed upon intervals:

- Collect the necessary data to calculate the variable(s) being plotted.
- Plot the new data point(s) on the appropriate charts.
- Interpret the results, based on their understanding of the process.
- Decide on an appropriate course of action.

One example drawn from this study was the problem with a very large customer in the beverage industry. Over a period of time monitoring the process, it became apparent that projects originating from this client had much longer turnaround times as compared to the other projects in the system. Because of the reluctance of the customer to trust their suppliers with the development of the entire flavour system, the customer was in the habit of splitting the project up into smaller modules. While the flavour houses were aware of the customer's practice, they were loathe to challenge the customer because of their fear of potentially losing the account. Ironically, while the customer considered this practice as a way to protect their business, the end result was longer development times for the end product, and possibly a loss of business opportunity and/or market share in the particular segment.

The managers in this case having identified and understood the root cause of the problem of longer than average turnaround times for the particular customer, can develop a proposal for the customer that addresses their concerns.

7.5 Value of regression models

Another contribution that the author makes is in the definition of the relationship between the outside out-of-control signals and the run out-of-control signals. The benefit of being able to estimate the number of run signals from the number of outside signals should not be underestimated. In practice, when implementing SPC charts the users typically start by monitoring only the outside out-of-control signals. As the users become more sophisticated there comes a point when, a decision needs to be made as to whether or not to start monitoring the run signals as well. This decision is not a trivial one, as it will require the use of additional resources. The model allows managers to have an idea of the number of signals that they are missing, in other words the number of missed opportunities for improving the process, before they make a decision.

The author also expects that the models would be of value to researchers developing theories about type I and type II error rates.

7.6 Additional learning points

Throughout the duration of the study the author used a variety of quality tools, and has been able to assess their usefulness to managers. Based on feedback from the managers in the BUs, the process flowchart developed to represent the product development process proved to be very useful, as a concise way to represent the big picture of how they worked. One advantage of the author preparing the flowchart was that, as an outsider she did not get bogged down in minute details that could unnecessarily complicate the chart. In fact, the process flowchart developed by the author has become the documented process description used by the BUs.

The Beverage BU managers found the Ishikawa diagram to be invaluable, as a way of focusing their efforts to address the root causes of their main problem of not being able to manage effectively. A good indication of its value to them, is in the fact that two years after presenting it to the Laboratory Manager, the bulk of the problems highlighted have been eliminated.

Another observation made by the author which is not a new one but bears repeating is that, when implementing a change programme it is essential to have the support of the top management, to ensure that the maximum possible benefit is gained from the implementation. Additionally, some continuity is necessary throughout the implementation, otherwise the programme could fall victim to some of the problems experienced in this study with respect to, the lack of ownership and the loss of the change agent driving the project.

With respect to the differences between the BUs, the managers in this case appear to be justified in their treatment of the BUs as separate entities. In fact, the BUs differ in numerous ways; they differ by the types of projects worked on, by the volume of projects handled, by the average project turnaround time, by the number of out-of-control signals that they produce, and finally, by their success rates with respect to winning business.

Another area which managers in this type of intense product development environment need to be aware of, is the need to maximise the productivity of the development laboratories. There is an inclination by managers in these types of research and development departments, to consider low productivity to be the norm. The opinion of the author is that, in the current tough business conditions world-wide, the situation in which the company in this study finds itself, where a large percent of the projects worked on end up being abandoned, is not good practice. The implication for managers is that if they can find a way to recognise inappropriate projects, before accepting the project then they could cut down significantly on wasted resources. Additionally, the introduction of a monitoring system once a project is accepted and work begun on it, to help managers to know when to kill a project that is going nowhere, would be extremely useful in reducing the level of wasted resources on the project. The extra capacity thus produced, can then be reassigned to other more appropriate projects, where the company has a better chance of winning the contract.

Finally, despite the industry's claim of uniqueness and self-propagated mystique, at least in the area of product development there are many similarities between them, and other product development departments from other industries. The implication being that they can learn from companies outside of their industry with better performance records, through some form of benchmarking programme.

7.7 Assumptions and limitations of the study

One key assumption underlying this study is that, the complicated process of product development can be represented simply using a graphical model. In order to use a graphical approach, the author needed to select the measure to be tracked. Where the selection of project turnaround time as a good indicator of the process performance, runs the risk of possibly oversimplifying the process. The underlying assumption in this choice being that, it was possible to compare different projects based on their project turnaround times.

Another consideration is whether there are measures other than project turnaround times that should also be tracked. It is possible that another measure may be found that is better at monitoring the project performance, which would replace the variable - 'project turnaround time'. However, without a closer relationship it was not possible for the author to experiment with such a variety of measures.

Finally, the author recognises that SPC makes no attempt to optimise the project schedules in the BUs. The author expects that there would be some gains in efficiency, through a better control of the project flow through the system and in the allocation of resources.

7.8 Scope of the application

The study reported on in this thesis was based on data from product development laboratories. The environment was a multi-project one with a large volume of projects in the system, additionally, the individual projects were independent of each other and had relatively short turnaround times. By extension the author would expect that in most research and development environments, that there would be many similarities with the product development process in this study and as such SPC would prove to be a useful tool for those managers.

Comparing the management of a single large project with this type of multi-project environment, the dynamics that need to be controlled would be different. However, despite the differences in both types of environments, the different types of projects are both subject to a multitude of factors that can impact on their success. SPC has been shown to be a useful approach to managing complex multi-project systems, affected by a kaleidoscope of special causes. The author's expectations are that SPC would also prove to be a useful tool, in the management of single large projects.

7.9 Critique of the study

One advantage of the case study approach is that you are unsure at the outset, of exactly what you may discover or encounter during the work. This can also be a disadvantage, as was experienced by the author in this study. The relocation of the Commercial Director during the study, to be replaced by someone less than enthusiastic about the study had serious implications on the scope of the study. As a result the author was unable to get the level of detail that she would have liked in certain areas, such as:

- some additional contact with the managers could have provided insights on the run signals, which could then have been included in the false alarm analysis, resulting in a better estimate of the type I error rate.
- The possibility to monitor missed signals would have been very instructive, and would have allowed the author to calculate the type II error rate for the process.

Both of these areas would have provided the author with a stronger argument, in her selection of a preferred approach to calculating the control limits.

Having identified the root causes of several of the special cause signals, the author would have liked to be involved in implementing some solutions to them, and to track the effects on the process by continuing to monitor it. The intent being to improve the actual product development process.

One disappointment was that the author was unable to produce the run signals for three of the methods developed to calculate the control limits. The lack of this data for these methods meant that the author was unable to perform all the analyses on them, and as a result was unable to make a thorough evaluation of their effectiveness.

Another area that the author would have liked to explore in more depth was the competitiveness of the BUs. It should be possible to develop a profile of the types of projects that get abandoned, and feed that information back to both the managers in the BU and the client managers. The goal being to move upstream of the actual product development process and improve also their project selection process, before the project ever gets into the system. It is vital that the client managers are also involved with this as they are the company's first contact with the customers. Their job responsibilities need to evolve to utilise this new knowledge, and as a result their relationship with the client would need to change. They should no longer accept a project that they know is going to result in wasted resources, instead they need to work with the client to try and develop their idea and the specifications, before deciding if they will submit a project proposal. The author does not expect that a change of this magnitude can be done in isolation. Among other things the company's incentive systems and performance evaluation criteria would need to support the initiative. The author considers this to be a more proactive approach to improving the overall efficiency of the BUs.

7.10 Future research

This study raised many questions and as such the possibilities for future research are numerous. The usefulness of SPC in other types of project management environments could be tested, to validate their value across other industries. Assuming that they make a positive contribution across several industries, they can then be considered as a generic tool that can be used in project management.

The study could be repeated with data from other companies within the same industry, to ascertain whether the results were unique to Caché Corporation, or if the effects observed were common across the industry. Several issues would be of interest, such as, whether or not the distributions from other product development laboratories in the industry were also positively skewed. If so, then the effectiveness of the different approaches could be tested, so as to determine whether or not the median (or trimmed mean) approach stands up and proves to be the better approach in general, when dealing with positively skewed data. It would also be enlightening to test the regression models derived in this study with other data, to establish the generalisability of these results. By the same token the results could also be compared to product development laboratories across other industries, to determine their overall usefulness. The discovery of differences between this study's results and others, could be instructive to gaining a better understanding of the different industries.

Additional research related to both the management of product development laboratories and project management, could help identify a way to combine the areas so as to improve the management of the project flow through the system. The author would be very interested to compare other company's performance, with respect to the management of development projects and the process behind the go/no go decision.

Finally, it would be interesting to perform a won/lost analysis both inter and intra industry, to ascertain if the problem of high numbers of abandoned projects is specific to the Flavour industry, or if indeed it is a problem that is endemic across multiple industries. The intent of the research being to find ways to improve the process and reduce the levels of waste.

7.11 Contribution to knowledge

This dissertation succeeded in establishing empirically the usefulness of *'Statistical Process Control'* as a project management tool. In addition, the author was able to identify the shortcomings of the traditional methods of statistical process control, when applied cross functionally in the area of project management.

Having identified that the traditional approach to determining the control parameters needed modification, the author was able to suggest an alternative approach supported by the empirical evidence, that was more effective at monitoring projects in a product development environment. Specifically, the approach produced control charts that were more effective as measured by their ability to detect special causes, where the underlying distribution was positively skewed.

Another important output from the study was the definition of the relationship between the number of outside out-of-control signals and the number of run out-of-control signals. The value to managers and academics will be in providing them a means to approximate the numbers of run signals that would be produced by a certain control chart, from the number of outside out-of-control signals.

7.12 Conclusion

Through the unique opportunity to work with one of the leading companies from an industry that remains even now, very closed to outsiders and secretive among themselves, the author has succeeded in increasing the overall understanding and knowledge about the industry.

On a personal level the author herself has benefited from the entire process. In conducting the company study she has learned an enormous amount about both the subject area, and also the practical considerations that need to be managed in this type of case study.

With respect to completing the PhD, the author has learned many a hard lesson with respect to self-discipline and the focusing of her energy. While at times the author has found the process to be restrictive and challenged the added value of some of the requirements, in the final analysis she has learned a hell of a lot from the overall experience.

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