CRANFIELD UNIVERSITY

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A STUDY OF THE STRATEGIC ENVIRONMENT OF AN R&D SECTION WITHIN A LARGER ORGANISATION.

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Supervisor: R Reeves

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for the degree of PhD.

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ABSTRACT

This work addresses the problem of how an R&D section should decide on a strategy to guide its work when there is no strategic direction supplied from above by the company. The work includes a participant observer case study carried out over five years in a single R&D section, an analysis of research papers on the subject of management of section level R&D, and a review of textbooks on strategy, management and organisational behaviour.

From the case study it was concluded that the company itself formed the strategic environment which the strategy of the R&D section had to address, and that the section's strategic environment was chaotic in the mathematical sense. From the review of management textbooks it was concluded that standard theories do not give usable guidelines for the manager in this situation. A theory was developed that R&D strategy can be thought about in four distinctly different ways. Publications concentrate on two of these, while the case study and surveys of practising managers revealed that the other two were more pertinent in practice.

The analysis of research papers was carried out using a newly developed technique, which showed that this body of literature is in a pre-paradigm state. The new technique was also used to show that the four different ways of thinking about R&D are present in the papers. The new literature analysis technique and the theory that R&D strategy can be thought about in four different way were tested by means of questionnaires filled in by authors of papers and by groups of R&D practitioners.

Dedication

I would like to express my gratitude to all those who helped and advised me during the time spent on this thesis. I would also like to thank my company for giving me the opportunity to undertake these studies and supporting me in the research.

In particular my thanks go to my colleagues and friends who supported me during the years of study. A task of this magnitude cannot be undertaken alone, particularly when the studies had to be undertaken on a part time basis in addition to a demanding full time job. The encouragement I received was absolutely vital to completing the studies. In addition I would also like to extend my gratitude to all those who completed my questionnaires and provided the raw data for my analysis, as well as those who piloted the studies and contributed valuable comments. Without them a large part of the research could not have been completed.

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Finally and most importantly I would also like to thank my family for putting up with the years of long evenings and weekends abandoned by me while I worked on my computer surrounded by textbooks and notes.

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Chapter 1 - Introduction

1.1 The problem of strategy formation at the level of the R&D section

The research described in this thesis concerns the problem of strategy for a small Research and Development (R&D) section within a large organisation. A major component of the work was a case study based on the author's own R&D section, which is the R&D unit of a small manufacturing unit called **VIL**[1]. **VIL** was a small part of one division of a large company. The research was carried out on a part-time basis over a period of eight years.

Because R&D is seen as a vital activity for many industrial companies it is considered normal for the activities of R&D to be directed as part of a company strategy (e.g. Friar & Horwitch (1986), Mitchell & Hamilton (1988), Roussel *et al* (1991), Reick & Dickson (1993)). It might therefore have been expected that the work of the R&D section in **VIL** would be guided by strategic directives given from higher levels in the company. In practice there were no such directives[2].

It fell to the R&D manager (i.e. the researcher) to set a technical strategy for the unit. The only practical constraint to the manager's freedom of action was the need to achieve approval for specific projects on a case by case basis through the annual budgeting process. In considering how to arrive at a strategy, the R&D manager felt that, with over ten years experience in the role,

[1] Specialised terms used within the thesis are shown in bold.

[2] "Strategic neglect" has recently been recognised in the literature and described as itself a form of strategy, (Inkpen & Choudhury (1995), Mintzberg *et al* (1998)).

he had a good knowledge not only of the technology supplied by his own company, but also that supplied by the competitors. He also had a good knowledge of all the companies' relative strengths and weaknesses, and their relative market positions. It had been the practice to set strategy for the R&D section by using this knowledge and applying native wit. What was sought from the present research was some way to improve on this approach and to adapt and apply the processes described in the literature, for example processes whereby competitors' positions are analysed and a strategy is set accordingly (Porter (1980)).

The key problem encountered in attempting to do this was that the processes in the literature are targeted at general business or corporate levels, rather than section level R&D. In fact the literature survey showed that there was no literature available specifically on strategy for R&D at the section level. Strategy for R&D was clearly seen as the preserve of the higher levels of management of the company (e.g. Burgelman & Maidique (1988), Chapman *et al* (1988), Roussel *et al* (1991)). Mintzberg even described an extreme but not uncommon view of this in what he referred to as the Design School, based on work by Christensen *et al* (1982). He states that[3]: "*Responsibility for the process must rest with the chief executive officer: that person is THE strategist*". Mintzberg (1994, p38).

At the outset of the research there was an unconscious assumption that the R&D section should undertake to develop a technical strategy on behalf of the company, and thus be able to direct its own work in the company's best interests. In the event it was found from the case study that this view of the problem was almost entirely irrelevant, and it became apparent that the R&D unit had to form strategy for its own survival as a part of its parent company,

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[3] Within the thesis direct quotations from other work are shown italicised in quotations, together with the reference.

and that the important environment to consider was not that created by the external competitors, but the corporate entity itself, which formed the real environment of the R&D section.

1.2 The importance of Research and Development

Technology is now seen as a principal area of competition between companies, and most companies look mainly to their R&D departments to supply their new technology.

R&D activity forms on average about 2.5 % of GDP in the principal industrialised countries, and this proportion has been rising for many years. Roussel *et al* (1991 p1) stated: "*The R&D imperative for industry has never been more compelling. Virtually all industry feels the impact of both increased competition – much of it technically based – and the accelerated pace of technological challenge and change*".

According to the UK Department of Trade and Industry[4], R&D is positively linked to company performance measures as shown below:

- **Sales growth**. 40% growth over four years is 75% more likely for high compared to low R&D intensity companies.

- **Productivity.** Generally in high R&D intensity sectors, sales per employee is at least doubled between the high and low spenders measured by R&D per employee.

[4] Source http://www.innovation.gov.uk/projects/rd_scoreboard/introfr.html downloaded at 19:30 20/4/2001.

- **Market value.** Over five years to July 1999, a portfolio of high R&D intensity companies showed twice the market value growth of the FTSE100 group of companies.

Industrial R&D is a major activity with over $600bn spent in 1999 around the world[5]. According to EIRMA[6] total spend on R&D in Europe in 1997 was over $73,520m.

A large proportion of R&D money is spent by large companies. Companies vary widely in how they allocate their R&D expenditure, but in many companies that have a wide range of products, R&D expenditure is allocated on some basis down to separate R&D units supporting particular products or product lines (Batty (1988)). **VIL** is assumed to be typical of one of these R&D units, and there are thousands of similar sections, many of which are likely to have similar strategic issues.

1.3 <u>The unit studied</u>

During the period of research the researcher was the manager of a section of approximately ten R&D engineers and scientists. The section was located as part of a manufacturing unit of about 30 people making medium voltage electrical switchgear. This manufacturing unit was structured as a wholly owned company and is referred to in the thesis as the **company**. It formed a very small part of GEC ALSTHOM, a company employing over 120,000 people world-wide, and itself a wholly owned subsidiary of GEC of England and Alcatel of France. GEC ALSTHOM is referred to within the thesis as the **group**. During the period of study, as well as in the years leading up to the

[5] *R&D Efficiency* Volume 10 Issue 4, February 2000.

[6] European Industrial Research Management Association. OECD, ANBERD database, March 2000

study, the **company** of which the R&D section is a part has had several names. For simplicity throughout the thesis it is referred to as **VIL** (Vacuum Interrupters Limited), its name prior to the case study.

VIL’s products are high technology devices called Vacuum Interrupters, which were developed constantly both before and during the period of study. The technology is explained in [Appendix A][7]. **VIL**'s continued success depended upon the efforts and success of its R&D section. **VIL** undertook development of vacuum interrupters, and supplied new designs to manufacturing divisions and subsidiaries of the **group**. It also manufactured specialist and prototype products on its own account, which were supplied to **group** companies, as components of their products.

In 1997 the parent group, GEC ALSTHOM[8] spent $512m on R&D, which was one seventh of the total spend in the EU in the Electrical Equipment Sector. To put this in perspective, during the same year the total manufacturing industry R&D investment in the whole of the Republic of Ireland was only $687m. **VIL**’s R&D turnover cannot be stated as it is confidential.

1.4 The case study

All events thought important to strategy, and observable at the R&D section level, were recorded over a five year period. In addition an appraisal of the strategic position was made by the researcher every three months, and these appraisals were also recorded.

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[7] Internal references within the thesis are in square brackets.

[8] GEC ALSTHOM is now known as Alstom. Data taken from the Published Accounts 1998.

It was originally planned that findings from the literature would be applied in the case and the results monitored. It was expected that a series of key points for the development of strategy at the R&D section level, on behalf of the company, would thus be found and tested.

However early in the research it became clear that this approach was inappropriate because little was found in the literature that was directly relevant to the problem being studied. Only two hypotheses concerning the topic arose from the literature, and some doubt about their validity arose early in the case.

A Deductive type of case study could have supported these hypotheses or not, but if the hypotheses were not supported the study, would have left no guidance for the R&D manager. As a result the case study was reformulated as having an Inductive purpose. The intention was then to generate new hypotheses for the strategic conduct of R&D at the section level. In the event, the two original hypotheses were not supported, while important new hypotheses did arise, so that this change of policy was justified.

The two hypotheses from the literature were that competitor action is important and that the policies of key individuals in the management hierarchy above the **R&D section** have an important effect on the section. No evidence to support these two hypotheses was observed during the case study. The most important of the new hypotheses developed was that the **group** is actually the environment of the **R&D section**, (so that the traditional analysis of outside competitors is not important to a section's strategy), and that the **R&D section** should stance its strategy internally, towards the **group**. Many instances supporting these two hypotheses were observed. Several other new hypotheses arose, which between them give a new view of the problem which would potentially be of value to any R&D section manager whose unit is in a similar position to that of the company studied.

The case methodology, data and analysis are presented in Chapters 6, 7 and 8. The case is presented in such a way as to allow comparison between this case and other situations, giving the possibility of researchers or managers in other R&D sections judging whether the results would apply to their cases. This follows established practise from the medical and legal professions (Kennedy (1976)). The value of inductive studies, and how they are applied to other cases is explained in Chapter 3, which deals with Methodology in general.

1.5 The case pre-history

At the outset of the research less formal methods were used to investigate the history of the company and of its technology over the 40 years leading up to the start of the case study. This pre-history does not only give useful background; it was also used as a second source of evidence for the hypotheses which arose from the case study. The pre-history extended into the first year of this research and the events of the first year of the case study were included in it. At this point the case study was reformulated as Inductive and then continued for a further five years. This pre-history is included in Appendix A, and a chronology of events in the pre-history is included as Appendix B.

1.6 The literature surveys

Two distinct bodies of literature were studied in this work: journal papers plus a few textbooks relevant to section level R&D, and textbooks plus a few journal papers relevant to Strategy, Management and Organisation Theory. In all, over one hundred textbooks and 700 papers were surveyed. These textbooks and papers are listed in Appendix H.

1.6.1 Section level R&D literature

There were no papers or textbooks found which were directly relevant to the problem of strategy for the R&D section. Rather than report no literature, the survey was widened to include research papers and books which were relevant to the topic of management of R&D at the section level. 655 papers were found which were relevant to this wider topic in some degree. These papers covered such topics as project management in R&D, project selection, personnel management, risk analysis, tactics for R&D, justifying R&D, and financial analysis.

The content of these papers was not considered to be sufficiently relevant to the strategic concerns of the R&D section as to warrant a review in this thesis. However, this body of literature was analysed as a whole, as explained in the next section.

1.6.2 Literature Analysis by the Context Analysis Method

Details of the large number of references studied were kept in a database. This proved to have unexpected benefits in facilitating analysis of the body of literature as a whole, and this was developed into a new method of literature analysis which was termed **context analysis.** It was found by this method that the research topic, which had arisen from practical need, did not exist as an academic body of knowledge, rather the papers which happened to have some relevance to section level R&D were drawn from other topic areas. **Context analysis** was used to study what types of research methods, authors and outputs were contained in the body of literature, and correlations among these factors yielded interesting findings. This new methodology tool is described in Chapter 4, and the results of the analysis are reported in Chapter 5.

It was felt that the whole body of literature did not provide much useful guidance to the practising R&D manager of an R&D section. The **context analysis** went some way to explaining why this could be so. The analysis supported the contention that this body of literature is in a pre-paradigm state. That is, most of its papers produce new theories rather than test or apply established theories.

1.6.3 Literature on Strategy, Management and Organisation Theory

Having not found anything relevant to section level R&D in the R&D management literature, it was decided to study a body of general management literature. It was hoped that concepts applicable to the problem of the research would be identified. Topics studied were Management, with a subtopic on R&D Management, Business Strategy, with subtopics on Technology Strategy and R&D Strategy, and Organisational Theory with a subtopic on R&D Organisation. The content of these bodies of literature is reviewed at some length in Chapter 2. It was found that this literature also did not give clear pointers to strategy for the R&D manager. The reasons why this might be so are discussed next.

1.7 Four ways of thinking about R&D strategy

The case study generated a number of observations about strategy for an R&D section. Three of these were:

1) What were termed **strategy destroying events** occurred sufficiently often and unpredictably in the case that the value of a long-term strategy was called into question.

2) The strategic importance of individual events was very often impossible to gauge immediately. Many, but not all, alarming events prove to be false alarms after a period of time. Also events occurred at all scales of apparent importance, but very small events proved occasionally to be strategically highly significant.

3) The data in the case was fractal in nature. In other words there is an almost infinite level of detail possible.

These three propositions taken together suggests that the R&D strategy problem in this case may have had a mathematically chaotic nature. [9]

This raised the question of how best to formulate R&D Strategy at the section level. Should it be formed by logical reasoning based on known facts at the beginning of a period, or should it be formed in the light of experience of how things generally happen? Should it be a response to chaotic events as they unfold, or should general policy should be adapted over time as the large-scale situation varies?

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[9] A problem well known to have this character is weather forecasting, where limits to predictability are now well understood in terms of Chaos theory, (Gleick (1988)).

It was realised that all four of these approaches were apparent in the different papers in the literature. The idea that there are these four possible approaches to R&D strategy was called the **four schools of thought** hypothesis.

Chapter 9 explains how **context analysis** was used to systematically analyse the body of papers relevant to section level R&D management for their **schools of thought**. It was found that all of the papers aligned well with one of these four approaches. Ball (1997) has reported that practitioners do not read much of the literature. In the light of the four schools hypothesis it could be conjectured that R&D practitioners do not read the literature because it is generally presented in the form of a different school of thought to that to which most of them subscribe. This conjecture was investigated, as explained in the next section.

1.8 Questionnaire surveys

Questionnaires were used to test the **context analysis** method and the **four schools of thought** hypothesis, as described in chapter 10.

Questionnaires filled in by the authors of papers on R&D management clearly showed that authors put their own papers in closely the same **context analysis** categories that the researcher had done, thus giving strong support to the results of the **context analysis**, and to the value of the technique. One of the categorisations was into **school of thought**, and here the agreement was exceptionally strong, indicating that this concept is a robust construct.

Questionnaires were also filled in by R&D managers on courses, and also by R&D managers within a group of companies. These showed that the **four schools** are strongly present in the views of the R&D management problem as perceived by practitioners. It was found that R&D managers subscribed most strongly to two particular schools of thought, whereas the literature subscribed most strongly to two different ones. The fact that managers do not read the literature might thus be explained by their usually finding that it does not describe an environment that they recognise.

Following this, the textbooks on general management topics, which had been reviewed in Chapter 2 were briefly re-examined, as discussed in Chapter 11. It could be seen that the various management theories could readily be classified into different schools. It was also realised that much supporting evidence for the **four schools** was latent within the existing theories and approaches. It could be further seen that one would not expect any of the theories ever to be proved right, rather the applicability of a theory to a situation depends on which school best describes the situation.

1.9 Outputs of the research

This work has produced the technique of **context analysis** and the **four schools** hypothesis together with a number of hypotheses about strategy for section level R&D. In chapter 12 the hypotheses which arose from the case study are reviewed, and it is concluded that when the environment of R&D is the company strategy should be stanced towards the company, with special regard to creating perceptions. It is concluded that producing a winning technology is a core component of strategy and this may be due to the input of a key individual technologist. It was found that in a chaotic environment the manager was not successful at predicting future events and it was important to persist with a policy even when the outlook appeared bleak. These findings support what many R&D managers probably do anyway, but this research has provided evidence that this a justifiable approach. It provides the additional advice that R&D managers should recognise the importance of creating a good perception of their section within their company.

1.10 Management of the research

This research was subject to annual reviews by a review panel in the School of Mechanical Engineering, whose members were initially Professor Hutchinson of that School and Professor Peter Allen of Ecotechnology.

Before embarking on the case study the validity of recording a manager's opinions as data was discussed by the panel and it was advised that this is a recognised procedure in management research. The policy of pursuing not only the case study but also the **context analysis** and the **schools of thought** hypothesis was also given careful consideration by the panel. It was felt that the case study was a safe form of research, whereas the other two lines were more ambitious. It was agree that both should be carried forward until the risks clarified. In the event all three yielded substantial results. The work was continued beyond the expected five years, up to the full eight years allowed, not because it was behind schedule but because extra work had been generated by moving forward on three related fronts, and it was felt worthwhile to carry all three lines of enquiry to a reasonable state of completeness.

In addition the advice of experts was sought at critical junctures. A world authority on applied psychology, Professor Helen Muir of Cranfield University was consulted when the **four schools** concept first clarified. She confirmed that this appeared to her to be a new and publishable concept, and work on it was continued.

In order to check on the novelty of the **context analysis technique** it was discussed at an early stage with Dr Grant Lewison of PRISM[10], a noted

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[10] PRISM stands for **P**olicy **R**esearch **I**n **S**cience and **M**edicine and includes the bibliometric section of the Wellcome Trust. It is now called simply the Policy Unit. Its' role is to help inform decisions on the most effective means of supporting biomedical scientific research. It is responsible for providing the information upon which Trust funding of £0.5 billion per year is based.

bibliometric expert, as well as with John Blagden, Librarian of Cranfield University. They both confirmed the novelty of the technique and recommended publication.

As a check on the novelty of the findings on strategy for an R&D section, a world authority on Strategy, Professor Gerry Johnson of Cranfield University, was consulted. Professor Johnson explained that attention is only just now turning to the strategic concerns of middle management in companies, and on his recommendation a copy of the only book yet available which tackles this topic (Floyd & Wooldridge (1996)) was obtained. Floyd *et al* see the role of the middle manager as one of facilitating strategy, and to some extent influencing company or corporate strategy but do not suggest the creation of a strategy for the section itself, as is done in this thesis.

Some of the methods used in different parts of this research are also used in the social sciences. Social science research methodology was not studied before carrying out the work, but it was studied afterwards. Full support for the validity of the methods used was found in the textbooks on methodology in social science, and this is discussed in chapter 3 of the thesis. Additional explanations of the research methods employed in the different parts of the work are given in the appropriate chapters.

1.11 Structure of the Thesis

The next chapter, Chapter 2, covers the textbook literature survey on general management topics, and Chapter 3 discusses the research methods to be used, from a social science perspective. The Chapters 4 and 5 cover the **context analysis** method and its application to the journal literature on section level R&D management. Chapters 6, 7 and 8 deal with the case study. Chapters 9 and 10 cover the **four schools of thought** and the questionnaire work. Chapter 11 discusses the findings and Chapter 12 gives conclusions.

Appendices contain the technical background and pre-history, a full list of the references cited in the text of the thesis, reproductions of the questionnaires, an explanation of the χ^2 test which is applied to some of the data, and an electronic copy of the database of the 655 papers relevant to section level R&D which were context analysed.

In each chapter references are given as an end-of-chapter list. A complete collated list, by subject, alphabetical by First Author, is given as Appendix C.

1.12 Publications and presentations arising from the Work

1.12.1 Papers published and in preparation;

"Context Analysis - A Technique For Analysing Research In A Field, Applied To Literature On The Management Of R&D At The Section Level" Falkingham L.T., Reeves R..(1997), *Cranfield School of Management Working Paper* SWP 11/97.

This was expanded into the paper published below.

"Context Analysis - A Technique For Analysing Research In A Field, Applied To Literature On The Management Of R&D At The Section Level" Falkingham L.T., Reeves R., (1998), *Scientometrics,* 42(21),. p97-120.

"The Four Schools of Thought in Research and Development Management and the Relationship of the Literature to Practitioners' Needs", Falkingham L.T., Reeves R., (1997). *Cranfield School of Management Working Paper* SWP 14/97.

This was expanded into the forthcoming paper below:

"The four schools of thought in R&D management and the relationship of the literature to practitioners' needs", Falkingham L.T., Reeves R., (2001), accepted by *Research Technology Management* for publication in June 2001.

1.12.2 Conferences;

R&D Society Meeting 26th April, 1992, Royal Society, London.
"Winners and Losers – Case Histories" A short case study showing the fractal nature of R&D work. Referred to in Chapter 8.

IEEE Engineering Management Society Conference, Vancouver, Canada, August 18-20, 1996.
Presented Paper, "The four schools of thought in R&D management". This was a preliminary paper which was expanded with more results into the paper below;

The R&D Management Conference, Manchester, England, July 14-16th 1997
Presented Paper, "The four schools of thought in R&D management and the relationship of the literature to practitioners' needs"

1.12.3 Courses;

R&D Strategy Course, Cranfield, 7-8 July, 1993
Presented research findings to the course delegates.

R&D Strategy Course, Cranfield, 6-7 July, 1994
Presented research findings to delegates, and issued practitioner questionnaire.

R&D Strategy Course, Cranfield, 11-12 July, 1995

Presented research findings to delegates, and issued practitioner questionnaire.

R&D Strategy Course, Cranfield, 9-10 July 1996

Presented research findings to delegates, and issued practitioner questionnaire.

R&D Strategy Course, Cranfield, 8-9 July 1997

Presented research findings to delegates, and issued practitioner questionnaire.

R&D Strategy Course, Cranfield, 22-23 Sept 1998

Presented research findings to delegates, and issued practitioner questionnaire.

Invited Lecture; Sevastopol, Ukraine, 18-22 November 2000.

Presented research findings as invited speaker to delegates at a meeting of Russian & Ukrainian engineering society (Tavrida).

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Chapter 2 - Literature Review

2.1. Introduction

A comprehensive review of literature relevant to "Strategy & Management of R&D at the Section Level" was carried out at the beginning of this project, and kept up to date throughout. This revealed no publications specifically on the topic of this thesis, "Understanding the Strategic Environment of the R&D Section", and it is therefore concluded that this has not been a recognised field of study up until now.

The wider bodies of literature that might be relevant to this specific topic are illustrated in Figure 2.1. Originally Business Strategy and Management were thought to be the most relevant topics, but Miles & Snow (1978) argue convincingly that business strategy and organisational structure are linked, and so literature concerning organisational structure was included as well. The term Organisation Theory is used in the thesis to denote concepts concerning "structures of organisations". These wider bodies of literature were studied in order to inform the research, and are reported on in some depth in this chapter in order to set a background which will be important when discussing the outcomes of the research, in Chapter 12. As explained below, this discussion of the wider body of literature is based mainly on a review of textbooks. The methodology of this Literature Review is included in Chapter 3.

The narrower body of literature, i.e. the innermost topic in figure 2.1, consisted mainly of 655 papers, and was analysed separately using a novel method in chapter 5. The method is explained in chapter 4. In all 704 papers and 157 textbooks were reviewed in the two analyses

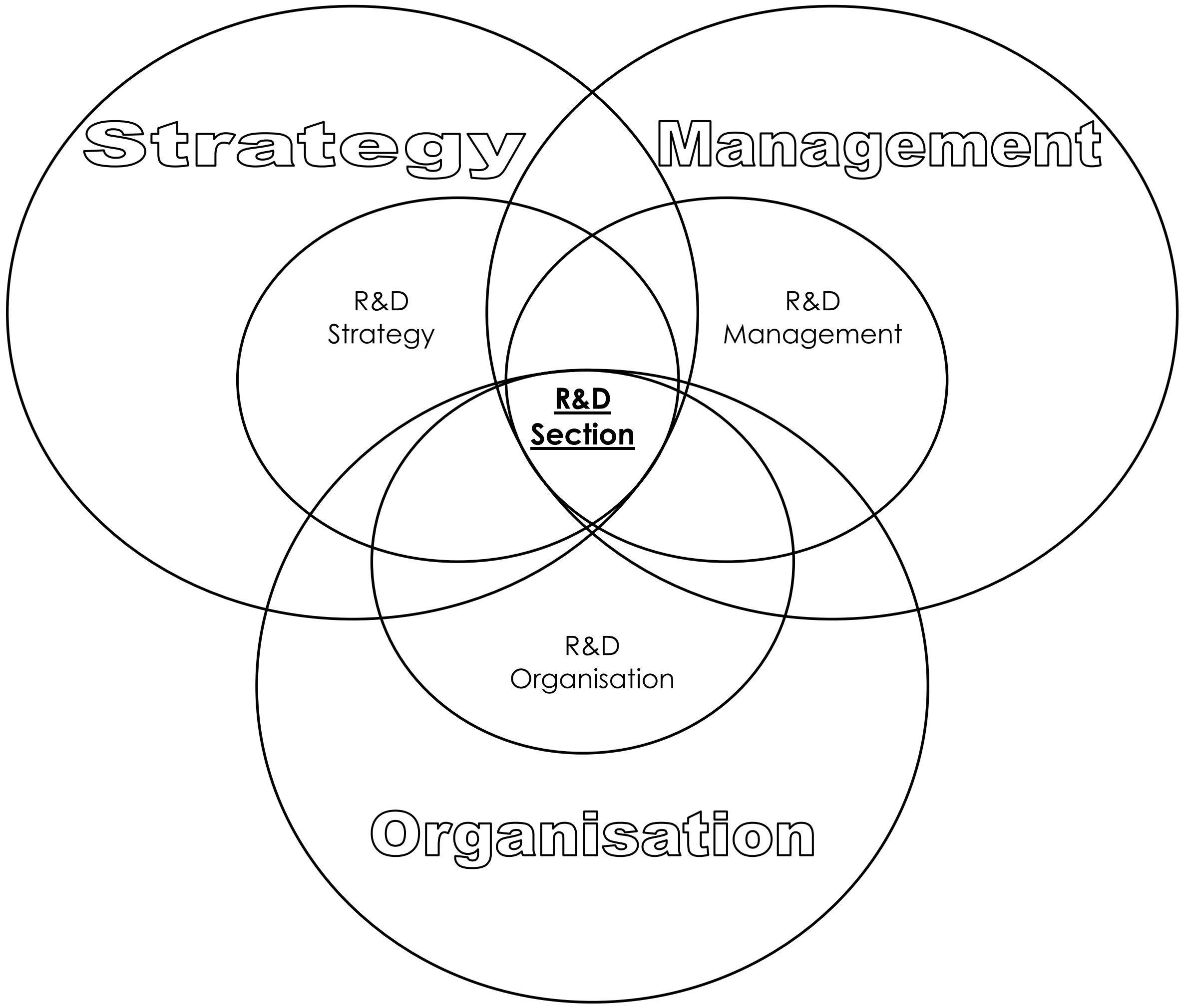

Figure 2.1 The Relationship of the Analysed Literature to the R&D Section.

In summary the bodies of literature studied in the present chapter were:

- The general literature on Business Strategy, with a subset on R&D Strategy
- The general literature on Management, with a subset on R&D Management
- The general literature on Organisation Theory, with a subset on R&D Organisation.

The use of textbook references

While not intended to be a definitive review of all of the literature in these large fields, the main ideas considered relevant to the research from each field are presented in this chapter. Key references are given to illustrate the main views and theories. These are normally textbook references. The papers generally reflected the theories expounded in the textbooks, but in a more compact and less complete form. Bowman (1990a) argues that textbooks are superior to journal articles, mainly based on the ability to expand arguments and data to a much greater level. It may be argued that journal articles are more immediate, but due to the long period of the study and the long period over which the ideas reported in the review have developed, this was considered to be not very important. Bowman actually argues that any important shift or creation of paradigm would be in book form as;

"A research book offers a forum for the iconoclast, whose ideas and position may not be well received by reviewers versed in the current state of the field." (Bowman 1990a, p22-23).

Journal articles have been referenced where they illustrate a specific point.

Approaches to presenting ideas in a field

Generally there are two main approaches to presenting the key ideas in a field. These are: chronologically, showing the development of the ideas (for example; Roussel *et al* (1991), Koch (1994)); and by "School" showing the adherents of each of the key theories or approaches (for example; Chapman *et al* (1988), Pugh & Hickson (1989), Mintzberg *et al* (2000)). In this chapter a combination approach is taken whereby the key theories are presented, but where possible in the chronological order of their conception. Each of the reviews of the three bodies of literature ends with a short summary of the findings. In addition examples from the history of R&D are used to illustrate the theories propounded.

2.2. Strategy Theory

Introduction to Strategy Theory

This section is split into three parts. In addition to Corporate Strategy which deals with general business strategy, and R&D Strategy which is specifically for the R&D function, there is an intermediate level of strategy which has developed more recently, termed Technology Strategy. Technology Strategy is corporate in nature, but is now seen as so important that it is developing its own distinctive literature separate from the normal Corporate Strategy, and has therefore been given its own section.

Corporate Strategy

There is a great deal of literature available on Business Strategy, and as a result there are a number of guides to Business Strategy available, (e.g. Bowman (1990b), Koch (1994) Mintzberg *et al* (1998), Dickson (2000)). Each approaches the subject in a different way. Koch (1994, p6-8) in his guide to strategy defines a total of six phases in the theory of the development of company strategy, and this structure has been used here to place the key concepts in context. Koch presents the different approaches as being sequential rather than alternate views, so that the later theories are improvements on the earlier ones. In fact all of the theories generated are still accepted by some groups and although popularities have changed over the years, each theory still has its adherents (Mintzberg 1998, 2000). Koch's six phases are better understood as the point of genesis of these theories, and do not imply that the start of one theory ends the previous ones. Mintzberg *et al* favour the categorisation of business strategy by school and have identified ten schools (table 2.1) which are fully described in Mintzberg *et al* (1998). A brief explanation is given here.

School	Definition	Adherents
1. **Design School;**	Strategy formation as a process of conception	Andrews (1971), Learned *et al* (1965)
2. **Planning School;**	Strategy formation as a formal process	Ansoff (1965) Chapman *et al* (1988)
3. **Positioning School;**	Strategy formation as an analytical process	Henderson (1970) Porter (1980)
4. **Entrepreneurial School;**	Strategy formation as a visionary process	Batty (1988), Morton (2000)
5. **Cognitive School;**	Strategy formation as a mental process	March & Simon(1958) Simon (1972),
6. **Learning School;**	Strategy formation as an emergent process	Hamel & Prahalad (1994) Prahalad(2000)
7. **Power School;**	Strategy formation as a process of negotiation	Astley & Fombrun (1983) Macmillan & Guth(1985)
8. **Cultural School;**	Strategy formation as a collective process	Rhenman (1973) Normann (1977)
9. **Environmental School;**	Strategy formation as a reactive process	Pugh *et al* (1968) Pugh & Hickson (1989)
10. **Configuration School;**	Strategy formation as a process of transformation	Chandler (1962), Mintzberg (1974, 1994,2000) Miles & Snow (1978).

Table 2.1 Mintzberg *et al*'s Ten Schools

Historically these schools were introduced in the phases defined by Koch as shown below;

First Phase: 1950's/1960's: This comprised classic strategic planning by the central organisation, with the key strategy concerning decentralisation by division, together with diversification by acquisition. Ansoff was a key proponent of this (Ansoff (1965) Mintzberg (1994, p145-151)). These are Mintzberg *et al*'s Design School, and Planning School, with the Design school being promoted particularly by the Harvard Business School (Learned *et al* (1965)).

Bailey & Johnson (1995) analysed the process of strategy development within organisations and agree that the early work in the 1960's and 1970's took the view that the formulation of strategy was a strictly logical methodical process. Bailey & Johnson argue however that the real strategy processes within organisations are not so simple or logical, and instead are influenced by a range of factors. They quote Allinson (1971) who argued that strategy making was based on a mix of political, organisational, and logical frameworks. Bailey and Johnson extend this by arguing that even if a strategy is determined, by the time it is implemented the environment is likely to have changed rendering the strategy ineffective or inappropriate in the worst case. This view is supported by others, (Mintzberg (1978, p934-948), Kay (2000))**.**

Second Phase: from 1965-75: According to Koch this was dominated by the Boston Consulting Group, (BCG) with the concept of Portfolio Management (Henderson (1970), Chapman *et al* (1988). This reinforced two contemporary trends, which were to have central planning performed by the head office, and to diversify the business. This is the start of Mintzberg's Positioning School.

Third Phase: mid to late 1970's: This was a period of disillusionment with corporate planning and strategy. Overall the benefits from large, expensive bureaucratic central planning and strategy departments were not forthcoming and their worth was seriously questioned (Mintzberg (1978, 1994)). Wilson summarised the problems in his "*Seven Deadly Sins of Strategic Planning*" (Wilson (1994, Title).

The Fourth Phase: from 1973 to 1980's: The concept was developed that firms did not actually derive strategies in a logical coherent manner, and the idea of an intuitive adaptive approach was developed. Mintzberg is a leading proponent of this and states;

"the strategy maker may formulate his strategy through a conscious process, or strategy may form gradually as he makes decisions one by one" (Mintzberg (1978)).

Bailey & Johnson go on to argue that;

"Strategy can be seen as the direction an organisation actually pursues over time, intended or not". (Bailey *et al* (1995, p2).

They see strategy as an evolving thing, which adapts to a changing environment as time progresses;

"Strategy development as characterised by this incremental dimension involves an adaptive response to the environment." (Bailey *et al* (1995, p2).

This phase includes Mintzberg's Configuration School and the Environmental school (Pugh (1989)).

Fifth Phase: from the 1980's: Porter (1980) introduced the concept of micro-economics to improve competitiveness. He says in the first line of chapter one in his book on the subject;

"*The essence of formulating competitive strategy is relating the company to its environment*". (Porter (1980, p1)).

His book effectively emphasises the importance of the role of the competitor and the knowledge of the competitive environment. Porter looks outside of the company for strategy. This a popular approach even today (Morton (2000)). This is Mintzberg's Positioning School, although according to Mintzberg *et al* this school started earlier, in the mid 1970's, with work basing business strategy on previous military strategy works, so that the work of Sun Tzu, Clauswicz, and even Machiavelli was included. (Buskirk (1974), Tzu (1983), Mintzberg *et al* (1998, p85-94)).

Sixth Phase: from the 1980's onwards: This saw the concentration on skills and competencies, with the head office concentrating on core competencies in the units rather than just resource allocation. (Meyer & Utterback (1993), Prahalad & Hamel (1994), Kay (2000). This is Mintzberg *et al*'s Learning School. In addition we see the development of the Entrepreneurial School (Batty (1988), and Morton (2000)).

Although the six phases of corporate strategy development give a wide range of approaches to strategy formulation, one element appears to be common to most of the approaches. This is the concept that the strategic environment is important to the formulation of strategy, (e.g. Porter (1980), Mintzberg (1990), Koch (1990), Brown & Eisenhardt (1998)).

"strategists are agreed that an understanding of the environment is essential to the development of corporate strategy". Lynch (2000, p104).

Lynch (2000, Chapter 3) covers this view very well, and goes on to recommend two measures of the strategic environment;

1. **Changeability:** the degree to which the environment is likely to change

2. **Predictability:** the degree with which such changes can be predicted.

According to Lynch, once these factors have been examined and understood it is then possible to identify those elements of the environment which are most important and determine the type of strategy appropriate to the situation.

Technology Strategy

According to Miles and Snow (1978, p256-259) Woodward (1965) was the first to introduce technology as an important variable and also later suggested that the organisation's structure and the form of control depended on this (Reeves & Woodward (1970)). Technology Strategy itself is a recent development (Reick and Dickson (1993, p397-412)) and was only mentioned in the literature since the mid 1980's, by for example Friar & Horwich (1989). Reick and Dickson go on to argue that there is currently a lack of a technology strategy paradigm. They base this on a study of the literature which they carried out, and which revealed that authors and researchers have not yet reached a consensus on the problem to be solved or a single methodology to approach this.

In Burgelman & Maidique's book (Burgelman *et al* (1988, p211-217)) Michael Porter himself discusses his Five Forces model of competition and argues that technological change is the single most important factor in significant changes in market share. Porter goes on to state that it is also probably the most frequent cause of demise of entrenched dominant firms, and as such can modify the competitive environment of the business unit by changing each of the five forces either in favour of the unit, or against the competition. This view is also supported by Johne & Snelson (1990). Thus technological strategy is not only a vital component of strategy for the organisation but can be clearly separated from general strategy.

Reick & Dickson define Technology Strategy formally as;

"*The process by which firms utilise their technological resources to achieve corporate objectives*" (Reick & Dickson (1993, p398)).

Reick & Dickson take a very wide view of technology strategy as a process covering the development of technology over a wide range in timescales shown in Table 2.3. Once again they assume that strategy is the prerogative of the corporation, and their assumption of the strategy formulation process is that it is quite deterministic. They argue that there are six components to be taken into account when formulating strategy and according to Reick & Dickson all of the six components must be present for a viable strategy.

Task	Timescale (Years)	Comment
Setting horizons	20+	Choice of industrial sector, technological implications of this.
Industry Forecasting	10-20	Future direction of industry, revolution or evolution.
Technology Positioning	5-10	Core technologies of firm, position relative to frontiers of technology.
Determining Technology Availability	2-5	Information sources on technology, technology acquisition internal and external.
Appropriating Technology	1-2	Effective use of technology, getting new technology into operation.
Managing Technology	0-1	Efficient use of technology, continuous improvement.

Table 2.2 Reick & Dickson - Six Tasks of Technology Strategy.

Burgelman & Maidique (1988, p233-235) believe that technology strategy is a "missing link" in corporate strategy. They state that the majority of firms in technological intensive industries do not include technology strategy explicitly as part of their corporate strategy, and that this is an important weakness. According to Burgelman & Maidique technology strategy is concerned with choices between alternative technologies, the manner in which they are implemented, and the utilisation of resources to allow successful implementation. To this extent they are in agreement with Reick & Dickson.

Burgelman and Maidique go on to propose that business strategy is built up from a set of functional strategies, one of which is technological strategy. Technological strategy as defined as including seven key areas;

- **Technology selection**
- **Embodiment**
- **Sources of technology**
- **Competitive timing**
- **Level of R&D investment**
- **Organisation & policy for R&D**
- **Competence levels**

These functional strategies are in turn defined by a set of interrelated decisions that define the business unit's posture towards the key areas of financial, manufacturing, technological and marketing issues.

Importantly for the present research, Burgelman & Maidique also introduce the possibility of devolving the strategy from the corporate level to the business unit. They argue that it is necessary to define a technological strategy for the business unit, and implicitly assume a level of freedom for the business unit to do this. They also argue that technological strategy parallels the more widely known marketing strategies, as shown in Table 2.3.

Marketing Strategy	Technology Strategy
- Distribution	- Technology
- Pricing	- Product design & development
- Product planning	- Sources of technology
- Promotion	- R&D Management & funding

Table 2.3 Comparison of Aspects of Marketing and Technology Strategy from Burgelman *et al* (1988, p13)

Note that Burgelman and Maidique do not discuss the concept of strategy being devolved to lower than the business unit.

According to Burgelman & Maidique strategy at a corporate level addresses different strategic issues to those of business units. They believe that it is valid to have strategy at different levels within the organisation, and that of necessity the strategy will be different at each level. They recommend that, when the corporate level deals with a number of business units, an innovation audit by corporate management will help to identify the crucial variables that influence the relationships between corporate level and business unit level in terms of innovative capabilities, and the formulation of overall corporate innovative strategy. The business unit in comparison performs an audit focussed on a distinct set of product markets, competitors, and resources. Burgelman and Maidique state that there are five important categories of variables, which influence the innovation strategies at a business unit level. These are;

- **Resources available for innovative activities.**
- **Capacity to understand competitor strategies and industry evolution with respect to innovation.**
- **Capacity to understand technological developments relevant to the business unit.**
- **Structural and cultural context of the business unit affecting entrepreneurial behaviour.**
- **Strategic management capacity to deal with entrepreneurial initiatives.**

The first three are important inputs for the formulation of business unit innovation strategies, and the last two are important characteristics, which determine the implementation of business unit innovation strategies.

Overall Burgelman & Maidique, describe a very structured approach to strategic planning, requiring the following of a precise set of steps. This approach is intended to provide sufficient information to create a logical strategy based on knowledge. The key element is what they have termed *Innovative Capabilities Audit Framework (ICAF)*. Which, following their belief in different strategies at different levels of the organisation, exists in two distinct forms as shown in Figure 2.2 and Figure 2.3.

Burgelman *et al* only build in the business and product marketing information at the last stage of the strategy creation process, which runs counter to the later view that marketing should be involved from the very beginning (Cooper (1993)). This may be due to their logic of creating the technological strategy separately from the business strategy, and then working to integrate it.

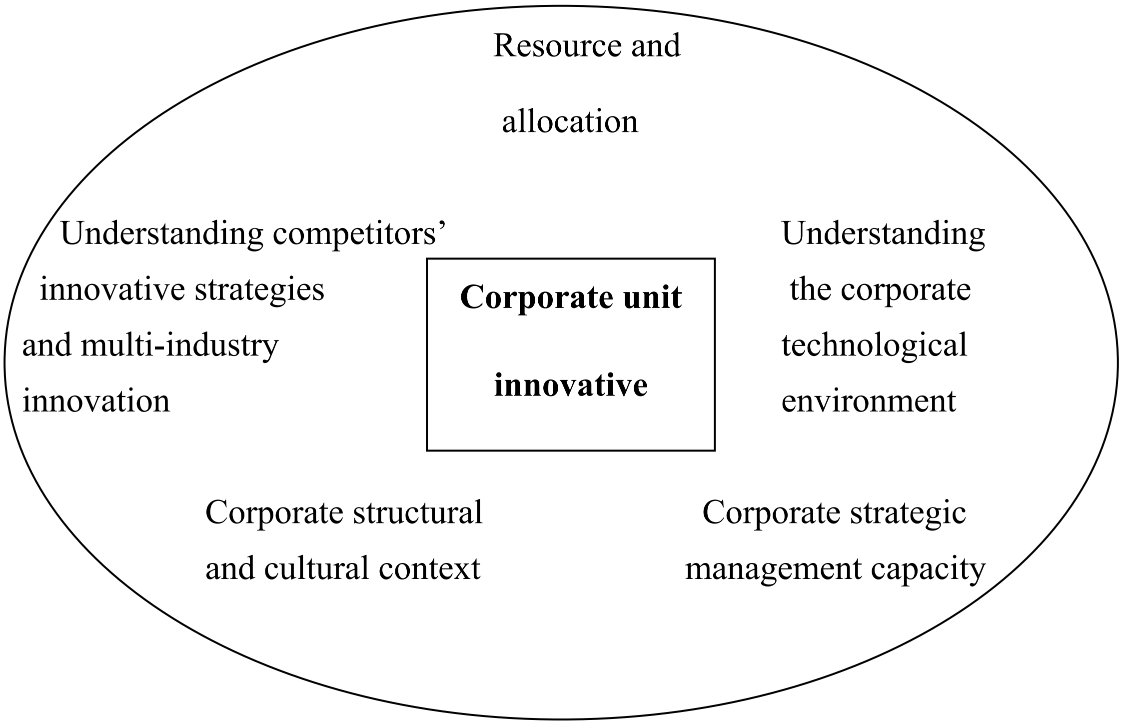

Figure 2.2 Innovative Capabilities Audit Framework – Corporate

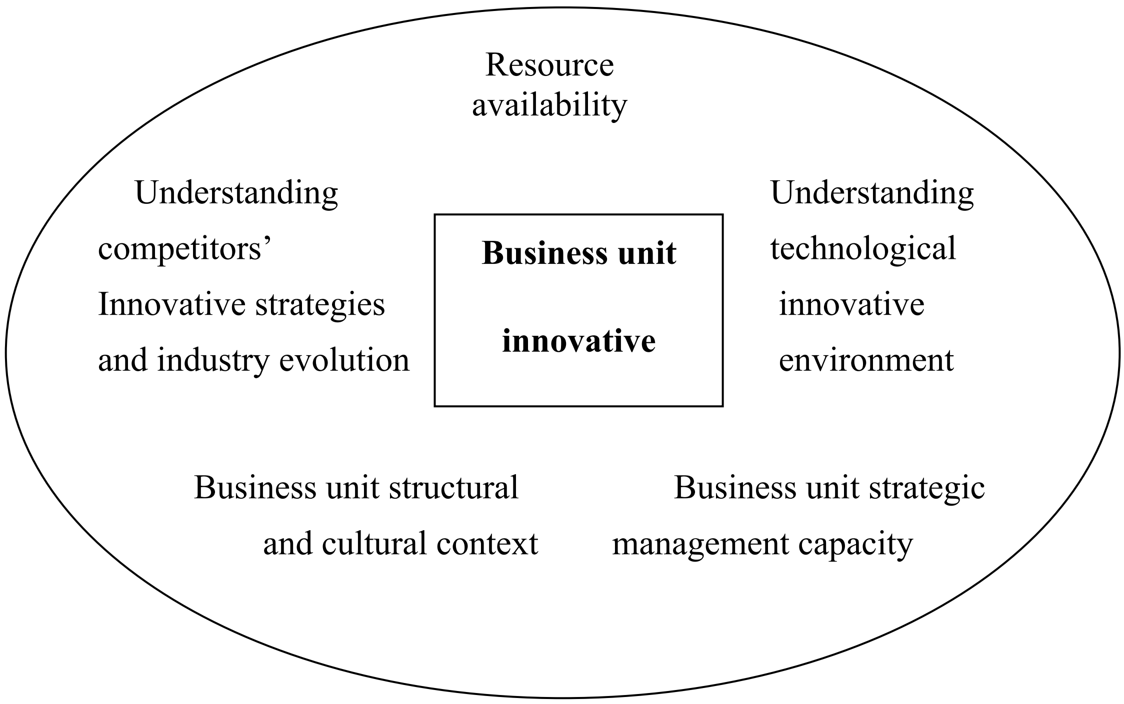

Figure 2.3 Innovative Capabilities Audit Framework – Business Unit

The table following is a distillation of the features and process described in their book which lists three stages in the process;

Stage 1 -	**Get the Information**
	Innovative Capabilities Audit Framework (ICAT)
	Technology Choice
	Technology Forecasting
Stage 2 -	**Make the Decisions**
	Design Choice
	Product Design
	Licensing and Marketing Technology
	R&D Resource Allocation
Stage 3 -	**Integrate Business and Technological Strategies**
	Business Information
	Product/Market Information

Others have also put forward recipes useful in formulating strategy, notably Peters & Waterman (1982), with the McKinsey 7S framework intended to facilitate an analysis of the organisation. This includes strategy defined as resource allocation but also includes other factors needed to develop strategy.

- **Strategy** The plan leading to the allocation of resources
- **Shared Values** The goals shared by organisational members
- **Style** The cultural style of the organisation
- **Structure** The characteristics of the organisation
- **Skills** The distinctive capabilities of key personnel
- **Staff** The type of functional specialists employed
- **Systems** The nature of the proceduralized control process

Johne & Snelson (1990) have adapted this into a series of questions to be applied by senior management when considering whether product development is being carried out by the R&D department in accordance with corporate strategy, as shown:

- **Strategy** Is there a product development strategy which defines the sort of old and new products to be developed and the resources to be released for this purpose?
- **Shared Values** Is there a shared belief in the need to pursue product development for the purpose of growing the business?
- **Style** Does top management provide active support for those involved in key product development tasks, or is a "divide and rule" management style practised in which individual functions are left to slog it out between themselves?
- **Structure** What types of formal organisation structures are used to implement old and new product development tasks?
- **Skills** What specialist knowledge and techniques are applied for executing old and new product development tasks?
- **Staff** What types of functional specialists are there for executing old and new product development tasks?
- **Systems** What type of control and co-ordination mechanisms are used for executing old and new product development tasks?

Although Johne & Snelson used this series of questions in their research to investigate product innovation activity within the organisation, they do not go as far as to recommend that the R&D section develops its own strategy. Rather they are monitoring the effectiveness of the company strategy within the R&D section.

R&D Strategy

The literature on Strategy for R&D is more limited than for Corporate Strategy, and Technology Strategy, and to some extent merges into the realm of R&D Tactics (Kaufman (1989)).

McLeod (1988, p50-59) indicates that although many strategies are possible in detail, there are four principle generic types of R&D strategy available;

- **First in the Field :-** Technically led, concentration on research at the expense of production and commercial.
- **Follow my Leader :-** Commercially led, some research, concentration on low cost production.
- **Application Engineering :-** Commercially led, some research, but emphasis on quick solutions not low cost.
- **Me Too :-** Production led, no research, concentration on cost and manufacturing.

Although it is possible to combine strategies, McLeod advises that the best approach is to pick one appropriate strategy and then stick to it.

Michael Porter in Burgelman & Maidique (1988) changes his famous five forces model to the one shown in figure 2.3. In this the original Substitutes is replaced by Technology, giving emphasis to the role of technology in driving change, and directly applying his five forces model to R&D Strategy.

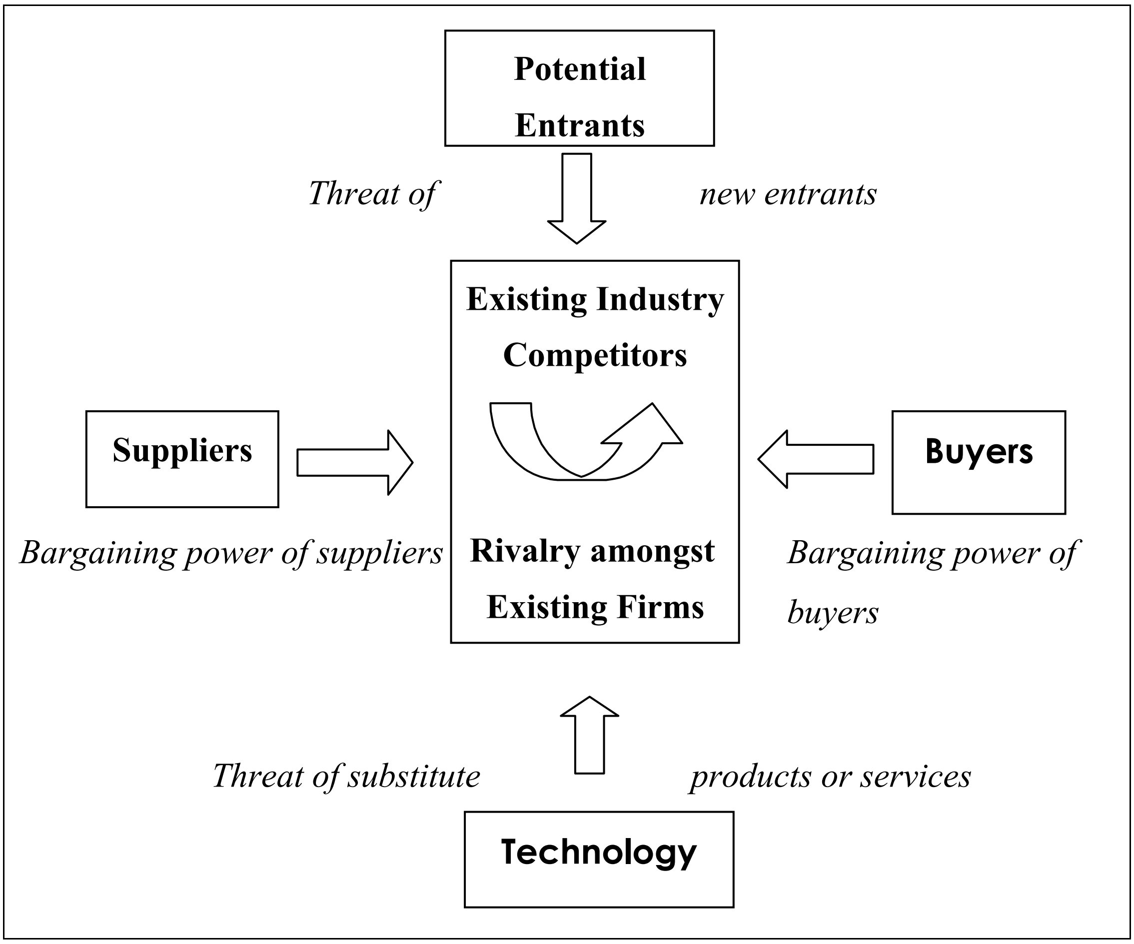

Figure 2.3 Porter's Five Forces Model of Industrial Competition.

The book Third Generation R&D – Managing the Link to Corporate Strategy (Roussel *et al* (1991)) gives a very good insight into recent thinking for R&D Strategy. Roussel *et al* argue that it is vital to link the R&D function into the corporate management function, and indeed the function of the book is to optimise the results of R&D from a corporate viewpoint. Although the book talks of a partnership between corporate, business, and R&D managers, the partnership refers to bridging the cultural gap between technical and general management functions.

Roussel *et al* defined R&D as having three strategic purposes within an organisation (Roussel *et al* (1991, p17-21));

- **To defend, support, and expand existing business**
- **To drive new business**
- **To broaden and deepen a company's technological capabilities.**

This is important as it defined what is expected of R&D in strategic terms and in a terminology that would appeal to corporate management. A process was described by Roussel *et al* which would lead to a consensus on which projects should be funded to discharge responsibilities in all three areas. However R&D strategy was clearly seen as a function of the company or corporate level, and as such ties in with the thinking on Business Strategy.

Summary on Strategy Theory

From the beginnings of recognisable Corporate Strategy in the 1960's there has been a large amount of study of this field without any real consensus or paradigm being developed. The views and models presented are useful in the presentation of the strategic issues and ways of dealing with them, but overall are to some extent confusing and inconsistent. Partly this is due to a split in the perspectives on strategy which on one side favours a rational approach, and the other which favours an incremental or adaptive process (Bailey (1999, p23)). This dichotomy is also seen in the other literature and will be returned to later in the thesis [Chapter 9].

Overall, there are a number of approaches to Technology Strategy which are mainly borrowed from Corporate Strategy, with a particular emphasis on a prescriptive systematic approach. This section of the literature seems to be a little way behind the Corporate Strategy in that the models being used are based on the early Planning and Design schools, using Mintzberg *et al*'s terminology. The later, more flexible, schools are absent.

R&D Strategy again tends to follow Corporate Strategy, with some emphasis on the Planning, and Design schools, and more recently with the introduction of portfolio systems includes aspects of the Positioning school. The concept that the strategic environment is important to the formulation of strategy does however appear to be generally agreed upon, and provides a firm basis for the research.

Overall it can be seen that there are a large number of concepts and views on strategy development and despite this research and study over the past forty years, no consensus has been reached. Indeed new schools are developing. We are left with what Mintzberg *et al* (1998, p1), describe as their "Strategic Management Beast", with many researchers grasping different parts of the beast, all of which may have validity, but failing to see or describe the whole thing.

2.3. Management Theory

Introduction to Management Theory

There is an immense amount of literature available on Management Theory, and so an overview presenting the key theories is given. This section is split into two parts. The first concerns the management of industrial organisations and looks at management generally. The second part concerns the management of R&D.

Business Management

The management of organisations has been studied widely this century, with Fayol (1949)[1] in 1916 giving possibly the first theoretical analysis of management, leading to a recognisable structure and explanation of what we now call modern management (Pugh *et al* (1989)). Fayol provided a structure for the workings of management and organisations by breaking down the activities into groups, and providing definitions and principles, which are recognisable today.

Fayol states:

"All activities to which industrial undertakings give rise can be divided into the following groups;

- ***Technical Activities** (production, manufacture adaptation).*
- ***Commercial Activities** (buying, selling, exchange).*
- ***Financial Activities** (search for and optimum use of capital).*
- ***Security Activities** (protection of property and persons).*
- ***Accounting Activities** (stocktaking, balance sheet, costs, statistics)*
- ***Managerial Activities** (planning, organisation, command, co-ordination, control).*

Be the undertaking simple or complex, big or small, these six groups of activities or essential functions are always present."
(Pugh *et al* (1989, p85-89)).

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[1] Fayol H., (1949), *General and Industrial Management,* translated into English by Storrs C., published by Pitman. Fayol originally published his work in the *Bulletin de la Société de l'Industrie Minerale* in 1916 as; Administration Industrielle et Générale – Prévoyance, Organisation, Commandement, Coordination, Contrôle.

Fayol then went further by defining management as comprising five main elements;

- **To forecast and plan**
- **To organise**
- **To command**
- **To co-ordinate**
- **To control**

In the 1950's, Peter Drucker (1954) reiterated these as his five management operations, **Planning, Organising, Leadership, Development, Controlling**. Drucker effectively included **Co-ordinate** within **Organise,** and added **Development,** which is defined as effectively developing the abilities of the workforce to continuously improve. This factor is Drucker's original contribution, but it is not universally accepted (Chapman *et al* (1988, p17-23)). Chapman *et al*. list only four elements but cover exactly the same ground as Fayol by defining organising as including the co-ordinating function. Generally Fayol's five elements are still today perceived as fundamentally defining the role of management (Scott *et al* (1988))[2].

In addition Fayol summarised his own experiences of management into fourteen General Principles of Management which have been modified and in some cases reduced by other authors (Chapman *et al* (1988 p17-21)), but are still recognisable in organisations and in organisational theory today. Fayol's ideas are important in defining management and providing lists of

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[2] In this book summarising contemporary thinking, Scott *et al*. erroneously attribute the creation of all of the five elements to Drucker, Chapter 10, p101-119.

requirements, but the organisation he put forward is rigid and hierarchical and forms only one of many possible organisational structures. Despite these limitations Fayol's model is probably the one most people would describe today as being typical in an industrial environment.

Fayol's General Principles of Management are:

- **Division of work**
- **Authority**
- **Discipline**
- **Unity of Command**
- **Unity of Direction**
- **Subordination of the individual interest to the general interest**
- **Remuneration**
- **Degree of Centralisation**
- **Scalar Chain (only one boss)**
- **Order**
- **Equity**
- **Stability of Tenure**
- **Initiative**
- **Esprit de Corps**

At the same time as Fayol was analysing management in France Frederick W. Taylor (1947)[3] was formulating his ideas of Scientific Management in the USA. Taylor's work was rational, based on the scientific study of work processes in order to increase productivity. According to Chapman *et al* (1988

[3] Taylor F.W., (1947), *Scientific Management*, Harper & Row. Originally partially published in 1903 as *Shop Management*, and in 1911 as *Principles of Scientific Management*.

p28-29), Taylor listed his Principles of Scientific Management as shown below;

- **Development of a science to replace rule of thumb working knowledge**
- **Scientific selection and development of individuals**
- **Combining the results of work study with selected and trained workmen**
- **Intimate, friendly co-operation between management and the workforce**

Taylor's approach assumed that once someone was clearly told what to do and given the required motivation, then they would perform their task more efficiently. In addition the implicit assumption was that there was an optimum way to perform any task, and that this could be determined by a logical scientific analysis. In other words the management of work is essentially deterministic in nature.

Today, based on and developed from this early work, management techniques are thought to fall into one of four categories as proposed by Rensis Likert (1961, 1967) in the 1960's;

- ***System 1***; is the **Exploitative Authoritative** type where the management uses fear and threats, decisions are made at the top, and communication is only used to inform the workforce. The management and workforce are psychologically separate.
- ***System 2***; is the **Benevolent Authoritative** type where management uses rewards rather than fear or threats, decisions are still made at the top, but some limited interpretation is allowed. Communication is mainly downward with extremely limited upward communication.

- ***System 3***; is the **Consultative** type where management uses a combination of rewards and punishment. Communication is two way but negative upward communication is still limited.

- ***System 4***; is **Participative Group Management** where management set performance goals but use full participation in the execution and organisation of the work. Communication is two way with no limits set. The management and workforce are psychologically close.

Later, in the 1970's, Lickert & Lickert (1976) developed this further with their System 4 Total Model Organisation, (System 4T). This is as System 4 but with additionally high levels of performance goals held by the leader and transmitted to subordinates, high levels of knowledge and skill of the leader, together with an optimum structure in terms of stable working group relationships.

Lickert believes that the best structure for dealing with conflict is by focussing on group needs rather than those of the individual, with higher levels only responding to inabilities to use group decision making techniques effectively, by providing training, not direction. Likert argued that the System 4 or System 4T is the optimum management system, but acknowledged that the other types can be made to work effectively under certain conditions. His main conclusion was that management is always a relative process, that there are no specific rules which will work well in all situations, but only general principles which must be interpreted to take account of the expectations, values, and skills of those with whom the manager interacts. Additionally he placed great importance on communication in both directions, a feature of management, which is now generally agreed to be the main problem area (Roussel *et al* (1991, p147-148), Crainer (1998), Smith & Reinertsen (1998,Chapter 8)). In connection with this, J.Birkinshaw of Stockholm School of Economics states that he has research results showing that top performing units are good at both receiving and transmitting knowledge, while poor units are good at neither (Crainer (1998)). In fact improvement in communication has been taken to be synonymous with improvement in efficiency and effectiveness for some time (Gee *et al* (1976)). Many writers in this field appear to believe that this is in fact a major, if not the prime, problem with modern management, and sell various solutions (e.g. Buck (1963), (Anon. (1978), (McLeod (1988 p9-10, 27-29, 35-39.)). Karger & Murdick (1980) go so far as to state that;

"The lifeline of the management process is the flow of information" Karger & Murdick (1980, p39-40)

Indeed the creation of what is effectively a new language specifically for R&D in order to improve communication within the organisation is promoted in the Roussel *et al* (1991) book.

Lickert went on from his four systems to argue that, in fact, hierarchy was not the most effective structure for an organisation, and instead promoted a co-operative structure in which all participants are equal. He called this System 5 in which the hierarchical system disappears completely, and consists of each member of the organisation working within their own sphere, interacting with the others as necessary, although how this could work in actuality is not clear.

All of this moves a long way from the "real world" approach of Fayol, and in an attempt to reconcile this apparent dichotomy, McGregor (1966,1967) examined the assumptions about human behaviour which underlie managerial actions. McGregor defined two different situations in which behaviour would be different depending upon the type of theory subscribed to. He labelled these Theory X and Theory Y.

Theory X clearly follows the theories of Fayol and states;

- The average human being has an inherent dislike of work and will avoid it if at all possible.
- Because of the human characteristic of dislike of work, most people must be coerced, controlled, directed, and threatened with punishment to get them to put forth adequate effort towards the achievement of organisational objectives.
- The average human being prefers to be directed, wishes to avoid responsibility, has relatively little ambition, and wants security above all.

McGregor argued that while Theory X does explain some behaviour within organisations it in no way provides a complete explanation. He proposed a second theory, Theory Y in which the assumptions are quite different, and much more in line with Lickert's System 4 or even System 5.

Theory Y States;

- The expenditure of physical and mental effort at work is as natural as at play or rest. The ordinary person does not dislike work, in fact according to the conditions it may be a source of either satisfaction or punishment.
- External control is not the only means of obtaining effort. People will exercise self control and self direction in the service of objectives to which they are committed.
- The most significant reward that can be offered in order to obtain commitment is to fulfil the individual's needs.
- The average human being learns, under proper conditions, not only to accept but also to seek responsibility.
- Many more people are able to contribute creatively to the solution of problems than actually do so.
- At present the potentialities of the average person are not being fully used.

McGregor argued that Theory Y would result in a more effective organisation with the members acting more efficiently, in effect supporting Lickert.

A popular management system currently based on Theory Y is Management By Objectives*,* as propounded by Drucker (1977, p345-346) in the 1970's. Its basic principles are clearly explained by Chapman *et al* (1988, p36-37) as are its limitations. System X however is still the system most widely utilised in most industrial organisations.

According to the Arthur Young organisation a major problem is that the theory of management does not stack up with the reality. They argue that although managers are taught to decide on objectives, then identify any problems and allocate adequate resources to overcome them, this assumes that the situation is deterministic. They argue that in fact the environment changes and that this approach is just not viable. They instead advocate a flexible approach

"*Detailed planning may be rendered obsolete when the environment changes. Better to know where you want to take your team and to develop a flair for seizing opportunities*". (Arthur Young (1986, p190)).

Recently, work by Busby and Payne (1988, p211-215) indicates that planning and management of normal engineering projects is not as precise as generally thought and they give a series of problems or myths which they believe to be inherent[4].

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[4] Busby & Payne are with the School of Industrial and Manufacturing Science, Cranfield University.

- **The Planning Fallacy** - A preference to decompose a project into low level tasks with great detail, which looks good, but is hopelessly inaccurate in situations where there are random influences, or large unknowns, as in R&D.

- **Anchoring and Adjustment Bias** - When planning people tend to start with a previous project, and adjust it to fit the new project. This adjustment is normally insufficient or inaccurate, giving an unreal bias at the start of the planning.

- **Hindsight Bias** - The overestimation of what could have reasonably been known at the time of planning. Normally results in a tendency to plan in more detail in the future in an erroneous belief that this would have helped.

- **Attribution Bias** - We generally wrongly identify and attribute the causes of unplanned events and deviations from plans. This results in a false correction in subsequent planning.

Interestingly Busby & Payne go on to give a system of training, based on the belief that good practise founded on 27 empirically derived success factors from an analysis of 40 engineers' experiences will train engineers to be better project planners. They report however that when they applied this training they met with some resistance to the part of their approach which effectively said that there is a correct answer to every problem encountered. Some of the experienced engineers did not agree. Busby & Payne attributed this resistance to preconceptions, presumably erroneous, on the part of the engineers.

None of these views gives a complete solution, and many organisations today are still clearly organised as either System X and System Y organisations.

For the past twenty years or so management theory has been dominated by American thinking, with work by Harvard Business School, and Arthur D. Little, as well as American Gurus such as Peter F. Drucker, being widely accepted. Crainer (1998) claims that this has changed recently, with faith in the US management model slipping. European management experts propounding a fundamentally different model are now appearing. According to Don Sull of the London Business School, the highly deterministic American model is of management as a social science to which a set of rules can be universally applied.

" *In the US business education has been construed more and more narrowly as applied science. Business school professors are engineers and managers are mechanics. Management education is about knowing the right thing to do and getting people to do it. The fundamental assumption is that there are universal laws, which can be extracted. I don't believe there are global business laws other than in finance. There are useful generalisations, but in management, context, timing, personality, and history are everything. The challenge lies in developing judgement, knowing which tool to use rather than reaching for the hammer every time*". (Crainer (1998, p30)

He goes on to say that there is a European school of theory developing which is much less prescriptive than the American model.

R&D Management

The management of R&D is a highly specialised subset of Management, as R&D itself has proven difficult to manage using normal general management techniques. This is now thought to be in the very nature of R&D, and as a result there are a number of books specifically on the management of the R&D function, (e.g. Twiss (1974), Glasser (1982), Bergen (1986) McLeod (1988)). But these all attempt to apply the general management techniques to the R&D function already described. Their main contribution is an attempt to view and integrate the innovation process within this. Many general works on management, or technical management, include a section on the management of the R&D function, either dealing with it as a variation of normal management (Chapman *et al* (1988)), or as a special case (Collinson (1964)). Typically Collinson attempts to apply general management principles to what he sees as a difficult subject, and neatly summarises the problem by contrasting the classical well defined management situation in Production with the flexible nature of the R&D situation. He opts out of the control of R&D generally, and instead concentrates on the personnel management side, which is seen to be manageable using classical techniques. Roussel *et al* (1991) include advice on the management of R&D within their context of linking to corporate strategy. They take the approach that tight control is necessary, and in particular that systems are necessary;

"…to ensure that original plans are monitored, modified, and made to happen in an optimum way". (Roussel *et al* (1991, p143)).

Reinertsen (1997) takes a different view in that he abandons the prescriptive approach and instead states that;

"*There are no best practices*" (Reinertsen (1997, p3-4)).

Instead he attempts to provide a set of tools which may be useful in certain situations. Effectively he promotes a flexible approach to R&D management.

Simon (1972, p55-61) looks at the theory of design management from the point of the literature and believes that there has been a change in view. He sees a distinction between older and newer professional schools. Older schools have a knowledge of design which is;

"*intellectually soft, intuitive, informal and cookbooky*," (Simon (1972, p57)).

whereas newer schools have become schools of natural science. Simon attempts to solve this problem by developing a science of design by emulating the optimisation methods, which have been developed in statistical decision theory.

A different approach is taken by Schon, who argues that;

" there is a widening rift between the universities and the professions, research and practise, thought and action". (Schon (1982,pviii)).

Schon builds his arguments upon challenging the "Model of Technical Rationality" derived originally from the nineteenth century philosophical doctrine of Positivism itself derived from Empiricism, and upon which much scientific and management theory is implicitly based. This doctrine saw laws of nature not as facts but as constructs created to explain observed phenomena. With this view science became a Hypothetico-Deductive system (Vesey & Foulkes (1990, p229)), implying that once a sufficient scientific understanding of cause and effect was built up, questions such as how to act in a given circumstance could be reduced to scientific ones. Finally the best means to act could then be selected according to a science-based technique. Craft and artistry had no part in this philosophy, and were to be suppressed.

Schon (1982)) builds his argument on a series of case studies and examples of failure of the Model of Technical Rationality arguing that the contemporary concept of Professionalism is flawed and that management can be effectively practised by means of skill and art as well as by logic and rationality.

"*An artful practise of the unique case appears anomalous when professional competence is modelled in terms of application of established techniques to recurrent events".* Schon (1982, p18)).

Schon claims support from Schein (1973, p43-44) who attempts to explain the failure of Technical Rationality as being due to the fact that basic and applied science is convergent i.e. deductive, whereas practise is divergent or inductive. Ackoff (1979) supports this view, saying;

"*managers are not confronted with problems that are independent of each other, but with dynamic situations that consist of complex systems of changing problems that interact with each other. I call such situations messes.*" Ackoff (1979, p90-104)

Schon argues[5] that Simon's approach is flawed in that;

"Although Simon proposes to fill the gap between natural science and design practise with a science of design, his science can only be applied to well-formed problems already extracted from situations of practise". Schon (1982, p47)

Schon's view is that it is futile to propose rational methods of overcoming the problems with the management of activities, particularly technical management. He advises to simply accept that practise in most cases inevitably involves situations which are not amenable to this approach, but which can be solved or dealt with, by practitioners using skill and experience in a non structured way.

Shenhar (1991, 1992) takes this further and adds a new perspective. He has examined the relationship between control and technological uncertainty, and suggests that tight control is acceptable for low-tech projects, but as technological uncertainty and therefore the requirement for innovation increases he recommends that control becomes more relaxed and flexible.

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[5] This argument is actually describing an empirical approach, slightly different to that expressed by Simon.

Summary on Management Theory

The first studies on management by Fayol and Taylor at the beginning of the 20th century introduced the "Command and Control" model of management, which has been widely applied ever since. However this model does not meet all requirements in management, and particularly in a field such as R&D where it is difficult to measure outputs, it is difficult to apply. The philosophy of management shows a dichotomy, encapsulated in McGregor's system X and System Y approaches. Both are reasonable, often found to exist, and completely opposed. As in the Strategy literature, new more holistic schools of thought are emerging, once again because the older schools only tell part of the story. The idea of systematically deciding on objectives, identifying problems, allocating resources, and then acting is very appealing, but in real life is often just not practical.

The R&D literature follows the same themes as general Management, with the added twist that R&D is almost universally seen as more difficult to manage than other functions within the organisation. Primarily this is because of the difficulty of measurement, and the ethereal nature of innovation. Some authors such as Collinson (1964) and Karger et al (1980), have retreated into a more structured approach, but paradoxically this is seen as counterproductive as there is a perceived inverse relationship between control and innovation. The tighter the control the poorer the flexibility and the level of innovation produced, (Shenhar (1991). Finally once again there is a dichotomy of thinking, particularly in R&D, leading to the empirical approach and the rational approach, which from the history are both seen to either work or fail depending on the circumstances.

2.4. Organisational Theory

Introduction to Organisational Theory

Organisations and how they work is a subject which has only been formally studied during the last hundred years or so, with interest really starting during the early part of the twentieth century, when large national, then multinational organisations came into being. This section deals with the theory of organisation particularly for industrial organisation. It is split into two parts, covering Business Organisation and R&D Organisation.

Business Organisation

Max Weber (1947) is credited with being the first researcher to categorise organisations by structure (Pugh & Hickson (1987)). One way of looking at organisations is to characterise them with regard to the authority relations within them. Weber did this and stated that there are two types of authority: *Power* in which people can be forced to obey instructions, and *Authority*, where people voluntarily obey instructions. The interaction of these types of authority in turn results in three pure types of organisation, which he labelled **Charismatic**, **Traditional**, **Rational-legal**.

- The **Charismatic** type is based on the personal qualities of the leader, and by definition is generally unstable. Normally found in smaller, more revolutionary organisations, some large organisations can be of this form, The Ford Motor Company (Henry Ford), being a good example. The key problem is succession. As a new charismatic leader is unlikely to be found the organisation normally devolves into one of the other two types.

- **Traditional** organisations are based on precedent, which is commonly expressed as custom and practise. These organisations have a rigid hierarchical structure in which power is inherited and is defined and limited by custom. When charisma is traditionalised by making its transmission hereditary continuing traditional ways of doing things becomes part of the leader's role.. In practise the organisation can take one of two forms. There is the *Patrimonial* form where officials are dependant on the leader personally for remuneration, and the *Feudal* form where officials have their own incomes and have much more authority and freedom of action. Both forms are characterised by a freezing of the relationships within the organisation and the justification of ways of doing things solely on the basis of things having always been done that way.

- **Rational-legal** is the third type of organisation, which was also called a *Bureaucratic* organisation by Weber. This is rational because the organisation is expressly designed to achieve certain well-defined goals, and legal because authority is exercised by means of a system of rules and procedures through the position which an individual occupies at a given time. Weber believed that this is the dominant form in all of modern society, particularly for companies. This was because it does not have the limitations of the other forms. Outmoded methods are discarded when necessary and the organisation does not rely on the personal whims of leaders or individuals. This type of organisation is fully rational[6] – in that it can calculate the consequences of its actions and personality and freedom of action are strictly limited by the written rules. Most importantly of all it is very stable, - the loss of an individual may cause some difficulty, but the organisation as a whole will continue.

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[6] Weber's definition was "*the methodical attainment of a definitely given and practical end by means of an increasingly precise calculation of means*" (Pugh & Hickson (1987, p8)).

Burns and Stalker (1961) investigated this problem of definition of organisations further and went on to propose a different model of two ideal organisational types, the **mechanistic** and the **organismic** or **organic** organisation.

- The **mechanistic** type of organisation is adapted to relatively stable conditions. In it the problems and tasks are broken down into specialisations within which each individual carries out an assigned, predefined, task. The system is clearly hierarchical with responsibility for direction and co-ordination resting solely at the top. Communication lines are vertical, with questions and information going up the hierarchy, and instructions and direction going down. This type follows Fayol's thinking, McGregor's **Theory X,** and approximates closely to Weber's **rational-legal** bureaucracy.

- The **organismic** or **organic** type is adapted to deal with unstable conditions when new or unfamiliar problems arise which cannot be dealt with by the existing systems and specialisations. This results in a system continually in flux with constant changes in individual tasks and responsibilities. Interaction and communication is no longer through a rigid hierarchy but instead may occur at any level as necessary. Communications lines are free in all directions, and decisions are made as necessary at all levels of the organisation. In this system organisational charts are of limited use as change occurs too quickly for a definition of structure except in the most general sense. This is in line with McGregor's **Theory Y**.

The key contribution of Burns and Stalker is that they take the idea of different organisational types much further by arguing that both organisational types actually exist. Secondly, and most importantly, they argue that it is not possible for one organisational type to change into the other, regardless of the need to do so. As proof of this they cite the example of the almost complete failure of traditional Scottish firms to absorb electronics R&D engineers into their organisations, a situation which they studied in depth. They argue that this failure is because individuals in a **mechanistic** structure are not totally committed to the organisation as a whole, but are also loyal to their local group or department, which can lead to conflict with the other parts of the organisation. This gives rise to what has been termed **pathological systems**.

Pathological systems are attempts by **mechanistic** organisations to cope with, unfamiliar problems concerning change, uncertainty, or innovation while attempting to retain a rigid bureaucratic structure. Burns and Stalker describe three of these systems seen in action in the cases which they studied. Some firms reacted as normal by passing information up through the normal channels, although because of the novelty of the problems they had invariably to be passed up to the top of the organisation for decisions. The large quantity of decisions soon swamped the ability of the individuals at the top to cope. It becomes clear to all levels of the organisation that decisions are only made at the top. At this point there develops an unofficial system, which Burns and Stalker termed an **ambiguous figure system** whereby links are effectively formed between the top of the organisation and individuals at many levels, with the normal system being bypassed. Some firms attempted to overcome this problem in true bureaucratic fashion by creating more specialist units to deal with each type of problem. This leads to what Burns and Stalker termed the **mechanistic jungle***,* where a new department or section is created and paradoxically its survival rests upon the continuation of the problem it was set up to solve! The third type of **pathological response** is the **super-personal** or **committee system**. The committee is a normal temporary bureaucratic response to specific problems which are seen to be transient. This was not used widely in the firms studied, mainly because it was seen as a very inefficient way of working, and again tended to be self-perpetuating. The

Burns and Stalker model has been extensively studied over the past decades, and although apparently simplistic gives rise to endless hypothesising and modification to fit specific situations. The main thrust of their work is that the management of an organisation depends primarily on the working of social systems within the organisation, and that attempts to change the organisation which work against the interests of part of the organisation will be resisted. Internal loyalties may be stronger than the subunit's loyalty to the organisation as a whole, giving rise to significant conflicts of interest. This is taken further by Silverman (1970), who compares the systems approach to organisations which looks predominantly outside the organisation with a more socially based internal view.

Chapman *et al* (1988 p19-20) approach organisations from a different angle, arguing that organisational culture can be categorised into four generic types, based on work by Handy (1981).

- **Power Culture** – Autocratic, results oriented.
- **Role Culture** – Organisation divided by function, hierarchy oriented.
- **Task Culture** – Project oriented, with the resources changing as required.
- **Person Culture** – Loose affiliation formed in mutual self-interest.

Chapman *et al* argue that all types exist, and are selected as to the most effective dependant on the activities of the particular organisation.

R&D Organisation

There are several clearly identifiable ways of organising R&D, and these have been approached by different researchers in different ways. Roussel *et al*

(1991) defined three generations of thinking in R&D and these are presented below;

Fist Generation R&D – The Intuitive Mode

• **Management and Strategic Content**	•No long term Strategic Framework •R&D is an overhead cost.
1. Philosophy	•R&D Decides future technologies. •Business decides current technology objectives.
2. Organisation	•Emphasis on cost/specialism centres •Avoid the matrix.
3. Technology/ R&D Strategy	•No explicit link to business strategy •Technology first, business implications later.
• **Operating Principles**	•Lacking business/R&D insight •Fatalistic
1. Funding	•Line item in annual budget •Fund what you can afford
2. Resource Allocation	•At the discretion of R&D •No upward visibility
3. Targeting	•Is anathema for fundamental R&D •Business and technological objectives sequential
4. Priority Setting	•No strategic priorities •Priorities vary with circumstances
5. Measuring Results	•Expected results not defined precisely •Measurements often misleading
6. Evaluating Progress	•Ritualistic and perfunctory •Periodic

First Generation is seen as the basic model, which came about in the 1930's. whereby corporate R&D centres were funded in a basically uncontrolled way to produce something useful.

Second Generation R&D – The Systematic Mode

• **Management and Strategic Content**	• Transition state • Partial strategic framework
1. Philosophy	• Judge-advocate management - R&D relationship • Customer-supplier business / R&D relationship.
2. Organisation	• Centralised and decentralised • Matrix management of projects
3. Technology/ R&D Strategy	• Strategic framework by project • No integration - business or corporate
• **Operating Principles**	• Distinguish between types of R&D • Combined business/R&D insights at project level
1. Funding	• Funds based on need / risk sharing • Different parameters by R&D type
2. Resource R&D Allocation	• Allocation to fundamental R&D by central management • Allocation to other R&D jointly by customers & suppliers
3. Targeting	• Consistent business and R&D objectives by project for incremental and radical R&D
4. Priority Setting	• Priority for fundamental R&D by central R&D management • Priority for other R&D jointly by customers and suppliers
5. Measuring Results	• Quantitative for incremental R&D •“Market intelligence gap” for radical R&D
6. Evaluating Progress	• Formalised peer reviews • Good communication with business for incremental and radical project

Second generation represents the introduction of more controlled R&D, where attempts were made in the 1950’s and 1960’s to harness R&D to the planning and command and control management systems then in fashion. The idea of funding what you can afford was no longer acceptable. Companies wanted R&D results on demand. This had worked in the 1940's with the development of the atom bomb and was seen as a more efficient way of working.

Third Generation R&D – The Strategic and Purposeful Mode

• **Management and Strategic Content**	• Holistic strategic framework
1. Philosophy	• Partnership
2. Organisation	• Breaks into the isolation of R&D
3. Technology/ R&D Strategy	• Technology/R&D and business strategy integrated corporate wide
• **Operating Principles**	• Varies with technology maturity and competitive impact
4. Funding	• Based on balancing of priorities and risk/reward
5. Resource Allocation	• All R&D has defined, consistent business and technological objectives • Allocation to other R&D jointly by customers & suppliers
6. Targeting	• Consistent business and R&D objectives by project for incremental and radical R&D
7. Priority Setting	• Priority for fundamental R&D by central R&D management • Priority for other R&D jointly by customers and suppliers
8. Measuring Results	• Against business objectives and technological expectations
9. Evaluating Progress	• Regularly and when external events and internal developments warrant

Third Generation R&D was proposed by Roussel *et al* as the next stage in the evolution of R&D. Breaking away from the rigid command and control systems it links R&D to the market and business strategy.

Von Braun (1997, p239-241) added a fourth "Zero Generation R&D" by pointing out that a form of R&D was carried out before this century based on craft and practise. Without the formal structures we recognise today, this was completely empirical. Most importantly he also points out that this form still exists in innumerable companies and organisations around the world, quietly improving products by use of skill and experience, frequently by those who have had not received any formal technical training.

Kohler and Tebbe (1987, p43-50) however took the approach of analysing organisational structure with a regard for product design and state that there are three different stages to the innovation process, and that different organisational structures may be needed for each stage. Originally based on work published by Thompson (1966), the three stages are as shown below;

1). Idea Generation;

- Utilisation of information
- Use of creative techniques
- Proposal of ideas

2). Idea Adoption;

- Evaluation of proposal
- Preparation of alternative plans
- Final selection of a product idea

3). Idea Implementation;

Production activities to introduce new product to market.

Following the general philosophy of Third Generation R&D and Kohler *et al*, Robert Cooper (1993) has developed a series of research based methodologies aimed at the New Product Development (NPD) role of R&D. This is summarised as his Stage-Gate project control system. Cooper is unusual in that he is a Professor of Marketing and Technology Management. His strong involvement in R&D is based on the idea that NPD is as much a marketing function as a technical one. Cooper states that;

"New Products account for a staggering 40% of company sales" Cooper (1993 p4)

Cooper (1993, Chapter3) believes that both the process and the team used in implementing product development are vital. Because of this he concentrates heavily on producing a system of NPD aimed at the project level. Although he also discusses strategy at the company level, he reserves this for the last part of his book as being less important

Cooper's Stage-Gate system of New Product Development is very popular and is summarised in the flow chart shown below (Cooper (1993, p108);

Cooper's work is founded on the "Success Factor[7]" approach whereby a number of projects were studied and common factors were seen in the successful ones and a series of rules derived for success.

[7] The most famous Success Factor project was Project SAPPHO carried out in the UK in the 1960's which attempted to identify success factors in industrial R&D projects by simply analysing a large number of projects and identifying common features. Published as; Science Policy Research Unit. (1972), *Success and failure in industrial innovation*. University of Sussex, Report on Project SAPPHO.

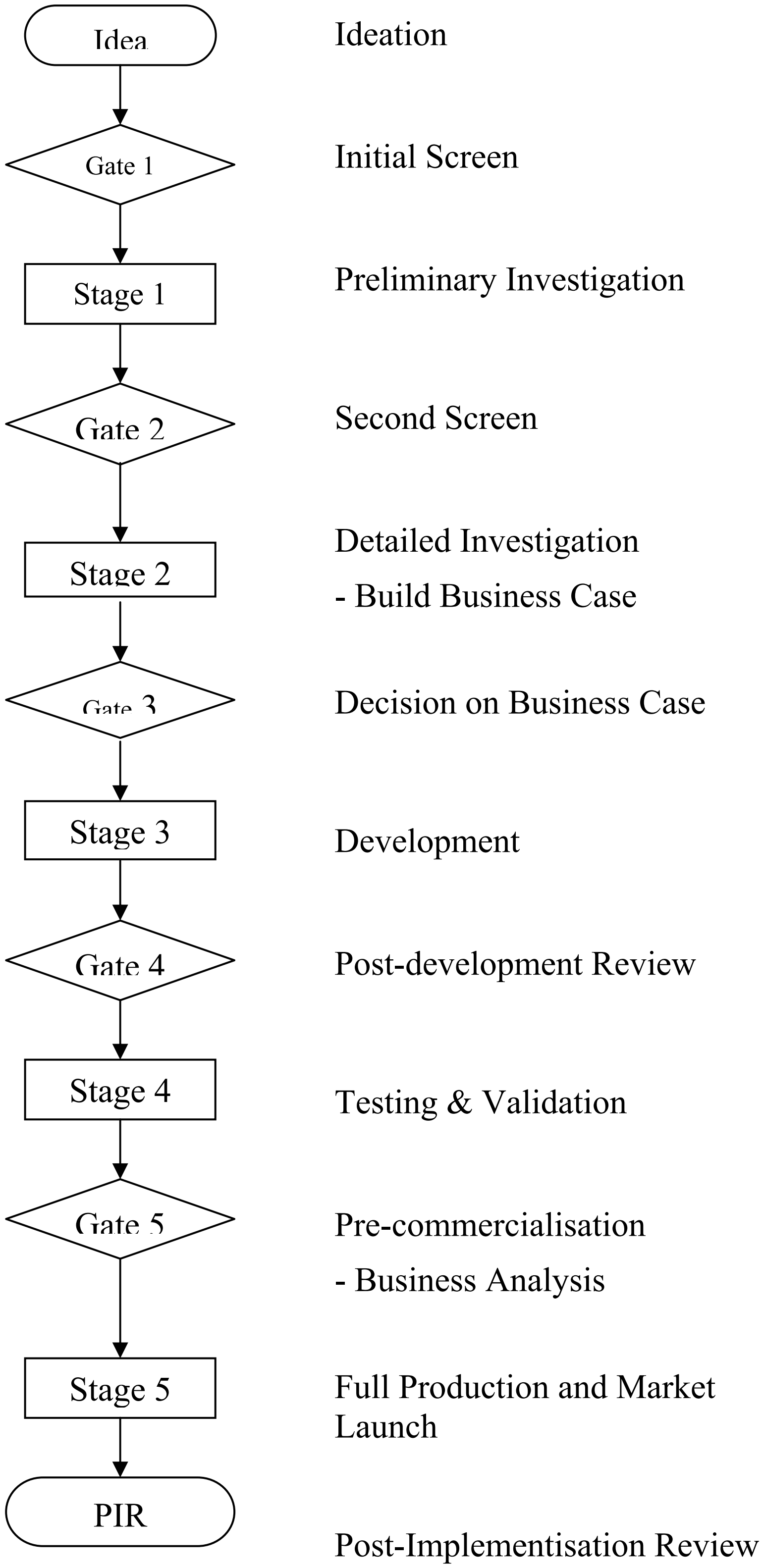

Figure 2.4 Cooper's Generic Stage Gate New Product Process.

Summary on Organisational Theory

The study of organisations and how they work has been a major interest for the past century, however, as with Strategy and Management theories, there is no real consensus. Instead authors have mainly produced descriptive models of organisations such as Weber's three organisational types, which are to some extent recognisable in different organisations. However tying together this approach with Handy's Culture models produces a matrix of twelve possible types, and by including other approaches, soon develops into a large number of possible sub types. Burns & Stalker's organisational types link in with the work by McGregor and Fayol and others on Management, and may even reflect some of the schools Mintzberg *et al* identified in Strategy.

The four generations of R&D thinking mirror quite well the work on Strategy and Management. Once again there is a movement from little or no control, through a period of tight control and then to a more holistic approach, although the third generation R&D still emphasises control.

However the work by Burns and Stalker (1961) which identified the difficulty of changing an organisation from one type to another is highly significant. If this translates into the R&D environment this would imply that it is extremely difficult to change from one of Roussel et al's Generations of thinking in R&D Organisation, and may explain why all of the four generations of R&D still exist.

2.5. R&D Examples from History

In order to illustrate the special problems of R&D it is interesting to look at the examples of R&D management this century, stating with the most famous of all R&D managers, based on Von Braun (1997), Israel (1998).

When Thomas Alva Edison founded the first commercially oriented research laboratory in Menlo Park in 1876 his stated intention was;

"To create an inventions factory that would produce a minor innovation on the market every ten days and a big trick every six months"(Von Braun (1997, p1-4)).

Inventions were only to be produced on demand, i.e. at customer request. In the century following, a great deal of R&D has occurred, much of it very successful. But the current view is that the goal of commercially viable inventions on demand has not been achieved by a long way, as exemplified by the large amount of literature already discussed on trying to achieve this. Was it ever achieved, even by Edison? According to Drucker (1991, p12-13), Thomas Edison was a very poor manager, and he believes that much of high tech business today is being mismanaged the Edison way!

Although the laboratory at Menlo Park, and later at West Orange, was immensely successful, it also had its problems. At firstly Edison decried the academic world, and originally just employed twenty mechanics and led all of the projects himself. The laboratory was at the start just a machine to turn Edison's personal inventiveness into reality. When later he employed scientists, most notably Nicola Tesla, it can be argued that the overall effectiveness of the laboratory dropped. Secondly, although the number of inventions was prodigious, with up to 400 patents applied for per year, the idea of market demand always resulting in success was never present. While

Edison established quite clearly that to invent something with no demand was pointless (his very first invention came into this category), he also established that no matter how high the demand, some problems were insoluble. He did this convincingly by spending over $4,000,000 fruitlessly in attempting to develop a method of extracting low grade iron ore magnetically. This was a huge amount when you realise his whole laboratory had only cost $40,000 to set up. This loss completely offset the profits from the invention of the light bulb, which was probably the greatest commercial success of his laboratory, and emphasises the true difference between R&D and all other activities of a company. No matter how good you are technically and managerially and how much you spend, you cannot guarantee success in R&D.

To further illustrate this point, it is important to note that there are two easily identifiable views of the operation of R&D, the empirical and the analytical. These are summed up by Whyte (1975,1978), in two books on the subject which describe these two approaches. These books generally describe case histories drawn from the Proceedings of the Institution of Mechanical Engineers, (I.Mech.E.).

To quote Robert Stevenson who was previously president of the I. Mech. E. and apparently favoured the empirical approach.

"…nothing was so instructive to the younger Members of the Profession, as records of accidents in large works, and of the means employed in repairing the damage. A faithful account of those accidents, and of the means by which consequences were met, was really more valuable than a description of the most successful works. "(Whyte 1975,v).

The two books give examples of both the empirical approach and the analytical approach. However they clearly show that the analytical approach was not too successful, indeed one section is on what the author call*s "A Law* *of Overspend*"(Whyte 1978, p4-7) which is an analytical way of dealing with the failings and limitations of the empirical approach.

Whyte (1975, p1-3) describes two different approaches taken to the development of gas turbines. One was by Rolls Royce, a company with a background in luxury cars and military aero engines, markets in which cost was a minor consideration compared to performance. Metropolitan Vickers (Metrovick) on the other hand was a company which manufactured steam turbines in a highly competitive market dominated by cost and reliability considerations. The difference in approach between these companies was quite extreme. Metrovick had never in its history made a prototype steam turbine. This contrasted strongly with Rolls Royce practise which was to build six prototypes to run to destruction in order to generate knowledge from which the final design was evolved.

Development of new engines at Rolls Royce was carried out by two departments, the Design Department who generated a specific design and then handed this over to the development department who were responsible for developing the design into a working product[8]. Because the design was first to be tested as a prototype the Design Department was encouraged to take risks to gain the maximum advantage out of an engine.

In contrast the Metrovick approach was to have one department, the Design Department, which handled both the design and the development work necessary to produce a finished product. Any problems arising with the design

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[8] Interestingly McLeod (1988, p14-20) reverses this generally accepted sequence, saying that Development comes after Research but before Design. He sees the R&D process as extremely deterministic, with Development producing *" ...a complete statement of facts and figures from which a design team will be able to produce the schedules and drawings from which a saleable product can be manufactured"*. The Design team *"..must be subjected to a firmness of discipline.."* .

had to be sorted out on site at the customers' premises and was seen as a mistake by the design team. This considerably discouraged risk taking and led to a pattern of small incremental improvements in design with each model.

Both approaches met with success for a long period, establishing their respective companies as world players. However both approaches eventually ran into serious difficulties for their respective companies due to changes in the size and complexity of their products.

The Rolls Royce approach which was spectacularly successful on the Dart engine resulted in the bankruptcy of the company when applied later on to the RB211 engine. The key difference was that the Dart cost £5,000 each, which enabled the company to modify the designs easily and quickly without too much difficulty. The RB211 however cost upwards of £250,000 each and was so large and complex that changes to components were prohibitive in both time and money. Rolls Royce's approach was simply inappropriate under these circumstances.

Metrovick, on the other hand, successfully developed new steam turbines for many years until their customer the Central Electricity Generating Board (CEGB) decided that, on the basis of theoretical efficiency calculations, much larger steam turbines were needed. This forced Metrovick into much more radical development than previously and their approach of minimal testing and correction on site led to immense problems. This was exacerbated by the CEGB who showed a remarkable lemming-like tendency to order ever larger turbines before the previous generations had been commissioned, and therefore before the limitations and problems of the designs were known. For example the CEGB ordered 47 off 500MW sets in 1961 at a time when the largest sets commissioned were only 100MW! After the disasters of the time this approach was later referred to as *"Buying in the Dark"* (Whyte 1978, p2-3).

These two approaches to industrial R&D are also widely promoted by many authors, although seen from different perspectives. Karger *et al* (1980, p349-369) recognise both approaches to R&D but dismiss what they see as the normal empirical approach as "muddling through" and promote a rigid highly structured deterministic approach instead.

2.6. Discussion on the Literature

Business Strategy is a complex subject and although much has been written it is clear that there is no consensus in general and almost no mention of the section level. It would appear that Frederickson (1990, p4) is correct in stating that there is no paradigm for Business Strategy yet available. Taking Mintzberg's view it is unlikely that one will be forthcoming. The situation is the same with Organisational Theory, Technology Strategy and R&D Strategy literature: we see a lack of consensus. On Management there is also a lack of consensus, with Fayol's Command and Control philosophy vying with the more flexible holistic approaches.

The lack of consensus seems to stem from the same basic problem in each field. The clash between a rational approach, and an incremental or adaptive process. This dichotomy is seen in each of the bodies of literature, as the split between the early Planning and Design schools and the later Holistic schools in Strategy, Between McGregor's Type X and Type Y organisation in Business, and between Burns & Stalker's mechanistic and organismic Organisational types. This is reflected even more clearly in the R&D

management cases where the rational and adaptive approaches are clearly identified.

As far as the R&D literature in each field is concerned it is clear that the R&D literature is behind that of the mainstream thinking, tending to reflect the earlier more deterministic planning thinking. After all this debate and research there is no clear guidance for R&D managers. Overall there is little for the R&D section. Because in each field reviewed the work is oriented towards the business or corporation it is difficult to apply to the section. In the R&D Management literature for example, the advice of Burgelman & Maidique and also Reick & Dickson is difficult to apply at the section level as the control of resources and investment, seen as vital, is not within the full sphere of influence of the section. During the period of research reference to the role of the section level or “middle manager” has appeared for the first time in the strategy literature, but the role is still seen as enabling or interpreting strategy from above, not creating strategy in the absence of direction (Floyd & Wooldridge (1996)).

As a result of this review of the literature it is clear that the subject area of the research is new. The literature reviews have also shown that the area of research is not a recognised one, in that it straddles several known areas. That the literature divides into the Empirical and Rational approaches is an important finding and plays a key role in the research, as will be explained in Chapter 9.

In chapter 11, the findings from the research are discussed in relation to the body of literature just reviewed. Chapter 3, which follows, discusses the methodologies used in the research, including this review chapter.

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Chapter 3 - Research Design & Methodology

3.1 Introduction

This chapter explains the choice of methodologies used during the research, explores the reasons for selecting these as opposed to other possible methodologies, and examines their strengths and weaknesses. In addition the application of the methodologies used in this research is discussed. More detail on the application of the methods used in the different parts of the research is given in the relevant chapters where appropriate.

This chapter discusses the methods used in the case history, the survey of the literature on strategy, management and organisation theory, and questionnaire surveys. There were several questionnaires, termed the Author survey, the Practitioner survey and the Delegate survey, as explained in chapters 9 and 10. The method used to survey the literature on section level R&D is explained in chapter 4.

3.2 Research Strategy

The research to be carried out was in the domain of R&D management. The researcher was employed by a major international group in the role of unit R&D manager during the period of research. As a part time student working full time in R&D the use of a case study as part of the research was an obvious choice, particularly as acceptance on the course required that the research be directly applicable to and form part of the normal work of the student. This predisposition to a particular research strategy is not only acceptable but is quite common, and may be based on circumstances as well as the training and background of the researcher, (e.g. Yin (1994), Mason (1996), Silverman (2000)).

As the research developed, the work was expanded to include a series of questionnaires, which were necessary to explore developing aspects of the research, and to include a greatly expanded review of the literature. Once again, the evolution of research in a new direction together with the flexibility to deal with this is an accepted aspect of research strategy (Yin 1994, p 57-58).

3.3 Quality of Research Design

There are four commonly used tests to establish the quality of empirical social research (Kidder & Judd 1986, p26-29), and in particular, case studies (Yin 1994, p33-38). These tests were considered to be relevant to the research undertaken, and are termed Internal Validity, External Validity, Construct Validity and Reliability.

Internal Validity

According to Yin (1994. p35) Internal validity is a major concern particularly for causal or explanatory case studies when the researcher is trying to determine whether event x led to event y. Kidder & Judd (1984 p75-76) concur and list the following five threats to internal validity;

1. Maturation; Changes with time, fatigue, boredom, etc.

For the Case Study maturation concerns were dealt with by designing what was effectively a self-administered questionnaire or structured interview in the form of a series of questions to be answered at fixed intervals. Although changes with time could occur on the part of the subject, the contemporaneous nature of the research prevented any hindsight error, and the structured method of recording the case allowed comparisons to be made over a considerable time period. For the questionnaires Maturation was eliminated by ensuring that after the pilot studies, the questionnaires were not changed during the research, and they were kept as short as possible.

2. History; Any external event coincident with the study which could affect the result, either via the subject or the experimenter.

History in the case study research was not seen to be a problem, as monitoring the external environment was part of the research, and all events were judged as to their possible effect on the case. The questionnaire surveys were thought not to be prone to this effect, and the Delegate series of questionnaires confirmed this, with no deviation against expected results over a large number of surveys and a long time period.

3. Instrumentation; Any change in the measurement procedures.

Instrumentation error was taken very seriously and was dealt with by consciously resisting any attempt to make any changes to the questionnaires or changes to the strict structured approach to the case study. In order to ensure that no changes would be needed, very thorough pilot studies were undertaken prior to collecting the main data.

4. Mortality; The loss or dropout of subjects in the study.

Mortality as a problem did not affect the case study, as changes of this type were in fact part of the study. Also this was not an issue for the questionnaires as there was no dropout in the Practitioner survey, and the few unanswered questions in the Delegate survey were checked for this type of bias and this was not found to be a problem. In the Author survey the respondents and non-respondents were checked for any such bias. None was found.

5. Selection; The non-random selection of subjects.

Selection was also carefully considered as a possible source of error and is dealt with in detail in section 3.5.

These five possible threats to Internal Validity may lead to alternative possible explanations of the results measured. Yin (1994) argues that Internal Validity may also be generally addressed by considering the alternative explanations and eliminating them, but specifically excludes exploratory cases. As the research in this case was considered to be exploratory it was felt that it was not necessary to follow this approach. Even so, some discussion of possible causality is made in the chapter discussing the case study. In addition, according to Kidder & Judd (1984, p 98-100) there is a trade-off between Internal and External Validity. It is possible to maximise Internal Validity at the expense of External Validity, and they state that this is common in laboratory experiments. Kidder *et al* argue that it is necessary to have a representative sample of respondents for Internal Validity. Taken in combination, the respondents of the Author survey, the Practitioner survey and the Delegate survey are considered to comprise a representative sample and so contribute to Internal Validity.

External Validity

Are the results of a case study generalisable to other situations? It is difficult to generalise from one case to another particularly for a single case study, and to prove that a particular case is representative is very difficult Yin (1994, p 10-11). Instead Yin recommends that the researcher should generalise to a theory in the same way that an experimenter generalises from experimental results to theory rather than attempting to create a representative experiment.

Kennedy (1979) however, takes a quite different approach. She proposes utilising the methodologies used by clinicians and by the legal profession whereby they perform reasonable generalisations from single cases to larger populations. In this approach the most important points are 1). That the generalisation is performed by the user of the data, and not the original researcher. 2). That the user decides on relevance or applicability on a case by case basis, and that 3). In order to do this it is necessary for the original researcher to provide sufficient information as to the case and its attributes to allow a reasoned judgement by the user as to its applicability. In this research this advice was followed and the detailed technical and historical backgrounds to the case study which are included as appendices to this thesis should allow other researchers to decide on the relevance of the case and its findings to their particular situations.

Construct Validity

This requires that the researcher select the types of change to be studied, and then demonstrate that the selected measures do indeed reflect the types of change selected. Kidder & Judd (1984) advise that construct validity be maximised by multiple ways of measuring. This approach was generally followed in the research and is dealt with in detail below in section 3.7.

Reliability

Would another researcher have come to the same results? The Author, Delegate, and Practitioner surveys each included data from samples collected over a long period and the results proved to be consistent and repeatable. Specifically in the case of the Delegate questionnaire the survey was, in fact, repeated several times on different courses with little variation in results. This amounted to Replication of the results and as such gave enhanced weight to the results. This is considered vital for enhancing credibility (Miles & Huberman 1994, p273-274)

A case study such as the one carried out cannot however be precisely repeated, as exactly the same situation will not present itself again. In order to overcome this difficulty Yin (1994) proposes that the case study should be treated much as a laboratory experiment in which the researcher must give sufficient information to allow another researcher to repeat the experiment as far as possible at another time or in another case. For the questionnaires and the case study a conscious effort was made to ensure that sufficient information was provided to allow this. The questionnaire surveys would be simple to repeat, and in the Case Study the creation of a rigid structure of questions to be answered at fixed intervals together with a real time chronology was designed to facilitate repeatability in another case at a later date. More details are given in chapter 6.

3.4 Literature Survey

The literature survey carried out at the commencement of the research was intended to establish the current state of knowledge as well as to determine those questions most relevant to the chosen topic. Thus the survey's primary objective was to allow more insightful questions to be posed, which would in turn allow an appropriate Research Strategy to be developed, as recommended by Yin (1994, Chapter 2). In the event the Literature Survey did not provide a good conceptual framework specifically relevant to the chosen topic. Instead a large quantity of information of only peripheral or partial relevance was found. Therefore it was thought appropriate to formulate the research as an exploratory study.

The references were found by the usual methods of keyword computer searching of databases of journals and text books, manual scanning of identified key journals for relevant papers, and initially some citation searching. It was thought that searching of journal articles was particularly important in order to obtain the latest thinking. Databases searched were ABI/Inform, BIDS, Compendex, INSPEC, NTIS, and PsycLit. In addition the Cranfield Library, Cranfield School of Management Library, the Library of the Institution of Mechanical Engineers, and the Library of the Institution of Electrical Engineers were visited and their catalogues searched.

Bibliographic methods

Citation searching was initially thought to be a potentially valuable technique but unfortunately proved not to be particularly useful. It gives the number of citations of a particular paper, but cannot tell which is the most cited paper on a particular topic, which would be far more valuable. Once a number of papers have been identified, it is possible to decide which is the most cited, but this is a clumsy approach and will not work unless the most cited paper happens to be already found. An additional problem was that it was felt that citation searching could introduce a possible self-citation bias, or a restriction to a network of citations, which could over emphasise the importance of a particular view. As a result of these difficulties this approach was abandoned.

According to Osareh (1996a, 1996b) the literature review phase of research has fewer established methodology tools than most parts of the research process. As the research proceeded a novel method of bibliographic analysis of literature was developed and applied to the literature found. This approach of " inventing your way out of a problem" during the research is accepted and even advised by Miles & Huberman (1994 p14). This new tool is termed **context analysis.** This is a generally useable technique for analysing research in a field and is described in Chapter 4. The work on **context analysis** has been published (Falkingham & Reeves, 1998).

Analysis of the papers found

In order to facilitate analysis the bibliographic data was placed in a computer database designed and set up by the researcher, as recommended by Yin (1994, p90-100) and Miles & Huberman (1994, Chapter 3). The categorisation of individual papers by the researcher proved straightforward, but the possibility of bias or error on the part of a single rater was considered unacceptable. The technique of inter-rater sampling as recommended by Kidder & Judd (1986) was considered as a technique to check for rater bias, and was actually used to test a small sample. However it quickly became clear that for a large sample this would prove to be an impossible task, as over 655 papers were involved in total and it would be necessary to read each paper in order to evaluate and categorise it. It would be unrealistic to expect a second rater to undertake this amount of work, or even rate the number of papers necessary to statistically validate the researcher's ratings. Instead, a novel approach was developed in which the primary author of each paper was asked to rate their own paper by means of a postal questionnaire. Primary authors were, of course, already familiar with their own papers and so for them the effort involved in answering the questionnaire was minimal. The choice of a postal questionnaire is discussed in section 3.5.

The Author questionnaire was structured so as to allow data about the papers to be entered into the database in the same format as the categorisation of the papers by the researcher. This provided effective confirmation of the ratings given by the researcher. Kidder & Judd argue that it is reasonable to assume that self-rating is fairly accurate, and that:

"self-ratings have been shown to be equal or superior to other types of assessments in predicting a wide range of criteria". (Kidder & Judd (1986, p199-200)).

They do however cite the concern that multiple raters may suffer from variable results as a result of different frames of reference. In order to minimise this possibility the piloting of the questionnaires included correspondence with the pilot raters on their perceptions concerning the primary questions. This showed that frames of reference appeared to coincide.

Another primary concern was that after a large number of questions raters may tire and give different results. So called "rater fatigue" was avoided in this survey as each author, practitioner, or delegate only rated a limited number of questionnaires, normally one, and the questionnaire was developed to be very short. A survey of pilot respondents indicated a time to fill in the questionnaire of only seven minutes. Rater fatigue by the researcher was avoided by rating a few papers at a time over a long period.

It was felt that if a sufficiently good correlation was found to exist between the author ratings and researcher's ratings then the researcher's categorisation of all of the papers would be validated. In the event this was found to be the case, and is discussed in detail in chapter 5.

3.5 Choice of Survey Method

Once the need for an Author survey had been established three possible survey methods were considered;

1). Structured or Semi-structured Interview. This would have given the advantages of being able to clarify or probe answers, as well as control of context and question order. However it also has the possibility of introducing interviewer bias, as well as incurring high costs (Kidder & Judd 1986, Chapter 10). This approach was discarded as being impractical as most of the authors lived overseas and to conduct such interviews would have constituted an immense task, which was beyond the resources of the researcher. In addition, for the purposes of this research, this technique had no advantage over a postal survey.

2). Telephone Questionnaire. This would have had the advantages of the Structured or Semi-structured Interview, with lower cost, together with the advantage of speed of response, although speed in this case was not important. It does have the disadvantage, however, of requiring interviewer supervision if more than one interviewer is used, otherwise the possibility of interviewer bias is high (Kidder & Judd 1986, p 230-231). It was also practical to the extent that once telephone numbers had been obtained it would have been within the resources of the researcher to conduct. However this approach gave no advantage over the postal questionnaire approach and had the significant difficulty of obtaining telephone numbers for the first authors. These are rarely included in the author information of papers and obtaining them would have posed a significant problem in conducting the research.

3). A postal questionnaire. This approach was favoured, as it would allow the collection of the required data, with an acceptable amount of effort. According to Kidder & Judd (1986, Chapter 5) a postal questionnaire has the advantages of low cost and no interviewer bias. Although they generally recommend telephone surveys as a method of choice they do recommend postal surveys when the targets are homogenous groups, as are the authors in this case. This approach was facilitated by the fact that the papers normally had first author affiliation included together with an address. An E-mail questionnaire approach was also considered, but this was seen to be effectively a variant of the postal questionnaire, and was not pursued as it was not accessible by all authors, and would have introduced an unnecessary variable into the research.

For these reasons the Postal Questionnaire approach was chosen as the one most suited to the Author survey. Once the survey method had been established for the Author survey, this dictated the method to be used for the later Delegate and Practitioner surveys. This was because the results of the three surveys were to be correlated, and therefore it was important to eliminate unnecessary variations or differences in the surveys to prevent any biasing of the results. As a result of this it was decided to use the questionnaire approach on all three surveys, with the questionnaires being intentionally made as similar as possible.

3.6 Questionnaires

Three different questionnaires were used in the research. Although these were targeted at different respondents, all of the questionnaires were intended, at least in part, to test the **four schools** hypothesis which is dealt with in detail in a later chapter. The three questionnaires were;

1. The **Author** questionnaire sent to authors of papers relevant to the research. This questionnaire also tested categorisation of papers.

2. The **Delegate** questionnaire given to delegates on R&D management courses.

3. The **Practitioner** questionnaire sent to practising R&D managers within a multinational group.

There is a great deal of literature available on questionnaire design. This is an established research method and the questionnaires were designed in accordance with best practise according to Kidder & Judd (1986), Oppenheim (1992), Hague (1993), Wilson & McLean (1994), Yin (1994), and particularly Sudman & Bradburn (1984) who defined "Rules for Developing a Good Questionnaire" as listed below;

1. Restrain the impulse to write specific questions until you have thought through your research questions,

2. Write down your research questions and keep them handy when you are working on the questionnaire.

3. Every time you write a question ask yourself "why do I want to know this?"

In a questionnaire survey the quality of the response is vital, and is normally termed Validity. Validity is defined by Sudman & Bradburn as;

"The degree to which the question elicits the information the researcher desires". (Sudman & Bradburn (1984, p13)).

This may seem obvious, but they go on to list three possible sources of problem;

Bias; Defined as an estimate which is more or less than a true value. A subset of Bias is Halo Bias (Kidder & Judd 1986, p200-201) whereby the respondent confuses two or more characteristics, and while overtly rating one factor is in fact rating another different factor which is related in their mind.

Variability; This is the susceptibility of measurements to differences in question wording.

Error; The respondent may contribute one of four specific types of error;

- **Memory** – Event or information is forgotten or wrongly remembered.
- **Motivation** – Respondents may not tell the truth because of external factors.
- **Communication** – Respondents may not understand the question.
- **Knowledge** – Respondents may not know the answer.

In order to minimise these potential problems the questionnaire must be carefully designed. Typically Sudman & Bradburn (1984, p283) advise that you use the following procedures to ensure a good questionnaire design;

1. Pilot the study.

In fact this is seen to be so important that they go on to say;

"If you do not have the resources to pilot-test your questionnaire, don't do the study!" (Sudman & Bradburn (1984, p283)).

The Author questionnaire was piloted twice on UK authors. The Delegate questionnaire was also piloted twice on delegates to courses. The Practitioner questionnaire was piloted three times, initially on a senior member of the organisation with specific responsibility for R&D within the Group, and then on a small sample of Practitioners. In each case the pre-test respondents were asked for general comments and specifically what they understood the questions to mean, after which their understanding was tested by further questions. The feedback gained was then used to firstly develop and then refine the questionnaire design.

Early on, the questionnaire returns from the main Author survey showed that a few authors did not quite understand what was meant by the term "cookbook" used in one of the ***four schools*** questions. This was investigated by speaking to some of these authors. These authors were predominantly American and interpreted "Cookbook" differently to the UK authors used in the pilot study. After discussion with the authors it was decided to adopt the term "Empirical" instead, which was felt to describe this school more accurately. This was then re-tested on a number of UK and US authors successfully. In the version of the Author questionnaire shown in this thesis the category "Cookbook" has been replaced by "Empirical" and the word "Cookbook" has been moved into the definition, which is otherwise unchanged.

2. Answer your own questionnaire & comment.
The questionnaires were answered by the researcher, both as an author, and independently. This proved surprisingly valuable. Answering as a real author immediately revealed problems which had not been apparent when the questionnaire was first written.

3. Get co-workers to answer questionnaire & comment.
My Supervisor, Dr R. Reeves and a fellow student, Dr Ali Jawad, whose research included the use of questionnaire methodology, both kindly answered the questionnaires and provided valuable comment and advice.

4. Avoid Forced Choice questions – Have "other" categories.
All Questions included an "Other" or "Comment" category to allow respondents the freedom to express additional views. This was particularly important during the pilot stage of the questionnaires, when respondents were encouraged to comment on each question. The extra category was retained in the final questionnaires to allow freedom to all respondents but generally was not used by them. This gave the interesting result for the **four schools** question that no additional schools were suggested, indicating that four categories are sufficient to cover all options.

In addition to following the above four points of advice, additional techniques were used to improve Validity by avoiding other known problems mentioned in the literature including;

Order Effect. It is possible that the question order may have an effect on the responses, particularly if the questionnaire is lengthy. Sudman & Bradburn (1984) recommend that the questionnaire is kept short and that the "Split Ballot" technique is used whereby questionnaires are used which are identical except that there is a change in the order of questions. The Split-ballot technique is particularly recommended by Kidder & Judd (1986, p258) as a method for eliminating wording or order effects on survey results. This advice was thought to be very important particularly for the **four schools** question. As a result this technique was used in the questionnaire in the form of changes in the sequence of the options on this question, as explained in Chapter 5. An analysis of the Split Ballot results indicated no discernible bias in the responses.

Non Threatening Questions. Is there perceived to be a right and a wrong answer? The questionnaire was designed to eliminate this by phrasing the questions in such a way as to eliminate threats. In addition the important questions were mixed in with those less important. According to Sudman & Bradburn (1984 p56-60) this helps to reduce over reporting of desirable attributes. This was a possible concern, particularly with the Practitioner survey and so anonymity was promised to the respondents. Also the questions did not relate to known company policies, which could have introduced false responses. After completing the Practitioner questionnaire a sample of the respondents were questioned on the relation between company policy and the **four schools** concept. No perceived connection was found.

Ethical Issues. The conduct of any social research can potentially raise a question of ethics. It is possible that there may be a conflict between the need to carry out the research and the obligation to protect the welfare of the subjects of the research. This arises due to the use of so-called “questionable practices” intended to give benefits to the research. These may include misleading or deceiving the participants, coercion to participate, invasion of privacy, or general mistreatment of the participants. This issue is dealt with in some detail by Judd *et al* (1991, Chapter 20).

In the conduct of this research no "questionable practices" were used, and the participants in the research were treated fairly and were shown consideration and respect both during the period of the research, and during the preparation and presentation of the results. The Case Study and the Questionnaire surveys were by their nature not anonymous, but once the raw data was collected anonymity was preserved as far as possible for all participants. The Practitioner survey potentially could come under the coercion category, and certainly the fact that the participants were employees of the organisation contributed to the exceptional response rate. However it was made clear to the respondents that participation in the survey was optional, and in the reminders given to those who did not respond immediately this was reiterated. In the final analysis Oppenheim (1992, p83-84) recommends that *"no harm should come to the respondents as a result of their participation in the research"*. It is believed, by the researcher, that all respondents were well able to look after their own interests, and that no harm was likely to come to them as a result of participation in this research.

Intensity of Attitude.

"The inclusion of a middle category diminishes extreme responses but does not change their ratio". Sudman & Bradburn (1984, p141).

As a result Sudman & Bradburn advise to include a middle category unless there is a good reason for not doing so. The size of the middle response gives an indication of strength of view held, and when combined with an "Intensity Scale" allows a measurement to be made of the intensity of attitude. This advice was followed where appropriate with all intensity scales in the questionnaires being set from 1 (strongly negative) to 5 (strongly positive), 3 being neutral. The possibility of using rating scales such as those developed by Thurstone (1929), Lickert (1932), and Guttman (1944), was considered, but as the questionnaire was originally created to confirm the researcher ratings of characteristics of papers, these techniques were felt inappropriate and were abandoned in favour of simplicity and a short questionnaire.

Response Rate & Bias. One problem with a postal questionnaire is non-response. This is a particular problem as, in the case of a postal questionnaire survey such as the Author survey undertaken, it is possible to overcome a low numeric response merely by sending out more questionnaires. This may superficially solve the problem but in fact the main concern on a survey of this kind is not the number of non-responses but the possibility that non-response may introduce Bias. That is there may be a pattern in the non-responses which would influence the result of the survey, (Oppenheim (1992, p106-107)). Because of this concern the non-responses of the Author questionnaire were analysed both for a pattern, e.g. by author type, and also by checking where possible for the reason for non-response. This analysis indicated no measurable bias.

In addition, the response was improved by techniques such as those following;

- Any author who did not respond within two months received a reminder except in those cases where a reason for non-response was known, such as the questionnaire being returned marked “Not-known” or “Deceased”. The response “Retired” was not accepted as an end, and a second attempt in these cases with a specific letter noting the Author’s retirement asking “please forward” met with a response of 25% success and aided bias prevention.

- In addition the Author questionnaire was sent out on green paper to give a distinctive look, and a self-addressed envelope was included. These points were discussed with the pilot groups at the commencement of the research. Importantly, this included members of the non-response category of the surveys. In each case the pilot groups preferred the green paper over plain white paper, and it was suggested that a self addressed envelope would improve response, although the inclusion of a stamp was not felt to make a difference. The advice was taken, and used in the research. These points were opinion only as they were not scientifically studied by means of a sub-survey splitting the questionnaires by paper colour or inclusion of envelope or not to assess effectiveness. The approach of assessing the detailed design of the questionnaires in this way was considered but then abandoned because it was felt that although the results might be interesting, they would only contribute quantitatively to the research by increasing the response rate. The extra effort and delays which would be incurred were not thought to contribute sufficiently to the primary objective of obtaining sufficient reliable qualitative data to justify the diversion of effort.

These measures gave an overall response rate on the Author survey of 38%, which is extremely high for a postal questionnaire.

The Practitioner questionnaire had the backing of senior management of the group, which resulted in a very high first response. A simple reminder by telephone or E-mail was sufficient to finally obtain a 100% response rate.

The Delegate questionnaire used captive audiences and so non-response was not a problem. A few respondents however failed to fill in some questions and this was again checked for possible bias. None was found.

Sampling Philosophy

Kidder and Judd (1986) identify three types of sampling which could be used in this type of research;

> **Accidental Sampling.** The analysis of the literature undertaken was an example of Accidental Sampling. The sample was effectively random or accidental in that no attempt was made to select or define the grouping other than by subject matter. A danger of this type of sampling is the possibility of introducing bias, and unfortunately there is no known way of assessing the level or direction of any bias (Kidder & Judd 1986, p150). However an attempt was made to reduce bias by using as wide a number of sources as possible, and also to avoid the use of techniques such as citation search and key author search because of their obvious possible biasing of results. Multiple occurrences of the same author were allowed as it was felt that some authors were more prolific than others and because of this had a greater effect on the literature as a whole.

> **Quota Sampling.** The Author questionnaire followed the Quota sampling method whereby provision is made to include different groups in the survey. In this case an effort was made to ensure that representatives of all author types were included in the responses. This

was done both by selecting authors by the type assigned to them and then also cross-checking their response to ensure significant representation of each category.

Purposive Sampling. This is where judgement is used to select "typical" cases which are representative of the whole. This technique has serious difficulties particularly where an objective basis for judgement is difficult, and also suffers from the possibility that what may be typical today may not be typical tomorrow (Kidder & Judd 1986, p154). Because of these difficulties purposive sampling was not used.

3.7 Case Study

According to Yin a case study may be defined as follows;

"A case study is an empirical inquiry that; 1). Investigates a contemporary phenomenon within its real-life context, especially when 2). The boundaries between phenomenon and context are not clearly evident." Yin (1994, p.13).

The case study was set up to provide Qualitative Data relevant to the Research Question. According to Miles & Huberman (1994, p10) Qualitative Data has the advantage that when data is collected over a sustained period it is possible to assess causality as it happens in a given situation. They also claim that it is the best strategy for developing hypotheses, and is also particularly useful to validate or explain Quantitative Data from the same setting.

Data Collection

Monitoring of the case study was set up using a series of techniques intended to give structure to the research. These techniques are listed in Miles &

Huberman (1994), and consisted of; 1). A chronology. This is a form of time series analysis and is a commonly used technique (Yin 1994 p113-118). It allows the researcher to investigate causal events over an extended time period, and to compare the trends seen with various hypotheses or explanatory theories. 2). A series of structured reports at fixed time intervals. This technique is known as "Repeated Observations" (Yin 1994 p120-121) and allows a cross-section of the case to be made. In the research it also was configured to allow the research to be repeated in another case, following the principles outline by Kennedy (1976).

Single or Multiple Case study?

An initial choice to be made was whether to study a single case or multiple cases. One justification for a single case according to Yin (1994) is that the case is Critical – it has all the attributes for testing a theory or hypothesis. Or it may be Unique – it is so rare that any study is worthwhile. Or, as in this case, that it is Revelatory. A Revelatory case is where a researcher has an opportunity to observe a phenomenon previously inaccessible to investigation. It was felt that this case was Revelatory in that it revealed the workings of an R&D unit of a larger organisation in great detail over a very long period. The fact that the observer was also the R&D Manager and therefore a Participant-observer was felt to give a unique insight into this situation.

Participant-observer cases

Participant-observation is an available research methodology which was particularly appropriate for the present research. According to Yin (1994, p87-90) it allows possibly unique opportunities to collect data from within an organisation which could not be collected in any other way. Yin goes on to state that;

"another distinctive opportunity is the ability to perceive reality from the viewpoint of someone "inside" the case study rather than external to it". Yin (1994, p88).

In addition a unique strength of the case study approach when coupled to Participant-observation is the ability for a Participant-observer to informally manipulate the situation. As the situation facing the researcher was almost perfect for a Participant-observer case study it was felt that this would be the best research approach consistent with developing hypotheses and exploring the Research Question. Yin (1994, p88-90) however refers to possible pitfalls of using this technique and notes these as being related to the introduction of bias. These pitfalls concern the involvement of the researcher, who may become deeply involved in the case to the detriment of the role of observer. Also there is a known phenomenon whereby the researcher becomes a supporter of the organisation being studied. Finally the participant role may overwhelm the researcher to the detriment of good data collection. While these are real concerns, a conscious effort was made to minimise their effect from the outset of the research and although difficult to eliminate, their effect was reduced by means of a structured approach to the recording of the case, a disciplined approach to time spent on the study, and the requirement to complete specific forms of data collection within fixed time periods. Becoming a supporter of the organisation was not seen as detrimental and was accepted because an important part of the research was the perception of the Participant-observer of the organisation and its environment as seen by the R&D manager.

However it was recognised that apart from the specific difficulties of Participant-observation, case studies are not an easy option, and that this approach posed a series of potential additional problems which needed to be addressed;

Choice of Case Study as a Research Strategy;

It is sometimes proposed that a hierarchy of research strategies exists and that case studies are to some extent a method of last resort (Platt 1992, Kidder & Judd 1986, Chapter 5). Yin however refutes this and states that it is incorrect to consider that a hierarchy of Research Strategies exists (Yin 1994, Chapter 1). Instead a strategy must be selected which is appropriate to the research situation and the research question (Yin 1994, Oppenheim 1992 p12-13). The sections above explain why the techniques chosen were appropriate to the different parts of the research.

Rigor;

The greatest concern in case study research is a lack of rigor. This may be a result of poor or sloppy research, or even deliberate manipulation of results to make a point (Yin 1994, p9-10). A criticism of lack of rigor is difficult to refute directly, but Yin argues that this problem is not restricted to case studies, and that other research strategies such as conduct of experiments and questionnaires are open to being distorted in a similar way. The fact that bias potentially can occur is not a reason for not using a case study. Instead it is necessary to take steps to minimise this. The steps taken are discussed throughout this chapter, and are referred to in the chapters on each aspect of the research.

Generalisation;

A common criticism of case studies concerns the possibility of generalisation of the results. In order to overcome these criticisms Yin recommends that three Principles of Data Collection are used (1994. pp. 90-100);

1). Use multiple sources of Evidence. This is also known as Triangulation, and is a technique which requires that multiple sources of evidence be used which converge to a fact. Although case studies can be based upon one source of evidence it is preferable to use multiple sources, which Yin considers to be a major strength of the case study in that it allows the investigator to develop converging lines of inquiry. This in turn makes any findings and the case study itself much more convincing (Yin et al 1983, p 92). This view is not universally held, however. Silverman ((2000), p98-100) warns that the use of multiple sources of data does not necessarily improve the reliability of a single method, and can in fact lead to a cursory analysis of the data with more effort spent on relating the different sources than on the data itself. He argues that it may be better to analyse data from one source in detail rather than treat data from several sources in less depth.

Patton (1987) lists four possible types of Triangulation.

- **Data Triangulation**
- **Investigator Triangulation**
- **Theory Triangulation**
- **Methodological Triangulation.**

Bearing in mind Silverman's warning, Methodological Triangulation was used in four stages of the work. 1). The Participant-observer case study gave rise to hypotheses about management of R&D at the section level. One hypothesis, the **four schools** hypothesis, also arose out of the literature study. 2). This was then tested in the literature database, and verified by the Author questionnaire. 3). Further questionnaires were used to test the **four schools** theory in the practice of R&D as perceived by R&D managers. 4). The method of analysing the literature was tested by the researcher and the Author questionnaire just mentioned was also used to verify its effectiveness and accuracy.

2). Create a Case Study Database. A full database of information arising from the case study was designed and used from the beginning of the research and was extensively used to search and collate the data in the analysis phase.

3). Maintain a Chain of Evidence. As the case study was exploratory, the evidential link from data to hypotheses was short. The hypotheses were the output of the case.

Negative case analysis

In order to test and evolve hypotheses in Inductive research with qualitative data it is usual to apply a technique known as Negative Case Analysis (Kidder & Judd, (1986), p178-186). This technique relies on the researcher looking for data within the case which would disprove the hypothesis. As the case progresses, so the hypotheses are modified or discarded in line with the developing evidence. This technique is a powerful way of dealing with inductive research, and according to Kidder & Judd, Negative Case Analysis in effect replaces statistical analysis for inductive research (Kidder & Judd, (1986), p181). This technique was used in the research and is discussed in Chapter 6, Chapter 8 and Chapter 11.

3.8 Summary

This chapter has reviewed methodologies available and explained why a participant-observer case study was chosen as the primary research method. It has explained why questionnaires were applied as the research developed. The chapter has also explained the steps that were taken in order to ensure that the research was carried out in a way which maximised aspects such as Validity and Rigor. In particular the research was set up using the principles suggested by Kennedy (1976) in order to allow application in other cases. Details of some of the specific methods used are given in the appropriate chapters.

3.9 References;

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Chapter 4 - The Context Analysis Method

4.1. Introduction

The literature review phase of research has fewer established methodology tools than most parts of the research process (Osareh 1996a, 1996b). As part of the research a new tool was developed to assist in the investigation of the literature. This tool was termed **context analysis**. **Context analysis** is a technique for analysing research in a field. In this chapter and the following chapter it is explained how the method was developed and then applied to literature on the management of R&D at the section level.

4.2. Bibliometric Analysis

Context analysis extends the already known methods of bibliometric analysis. In bibliometric analysis features of papers in a body of literature, such as numbers of references or author nationalities, are studied (White (1982), Osarah (1996a), Osarah (1996b). These features are completely external to the subject matter of the papers and could be assigned by an observer without specific knowledge of the field in question. To carry out a **context analysis** it is necessary to understand the subject matter of the papers and be familiar with the field of research.

The method arose from compiling a database of papers read during a conventional literature survey, and finding unexpected benefits from having information about the papers in database form. A paper describing the technique was published in Scientometrics magazine (Falkingham & Reeves, (1998)).

4.3. Defining Context Analysis

The Context of a paper is defined as an assembly of factors concerning the paper which are external to its research content, such as the nationality of the author, the topic the paper discusses, or the type of output of the paper. Some such factors could accurately be described as attributes, others as features and others perhaps as characteristics, but for the purposes of this technique they are grouped together as Context Factors. By contrast, the internal content of a paper might be certain data measured, or a certain theory proposed or proved. These are defined as Internal Factors, and do not concern this technique.

Thus "The output of the paper is a theory" is a context statement, which is of interest, while "The output of the paper is the theory that R&D managers should be over 35" is a content statement, and is not of concern here.

Note; that in the example given in section 4.3 Author Type could be considered to be a bibliometric factor, assignable quickly by a librarian for example, whereas Output Type is a **context analysis** variable. To assign this it is necessary to read and understand the papers and to have the insight of a researcher. Four levels of factor have been defined together with the level of knowledge necessary;

1. **Elementary:** (e.g. number of references): can be assigned by a clerk
2. **Bibliometric:** (e.g. author type) might be assigned by a librarian
3. **General Context:** (e.g. quality of writing) could probably be assigned by any researcher who has read the papers
4. **Specific Context:** (e.g. school of thought), can only be assigned by a researcher familiar with the particular field who understands this new term.

4.4. An Example - Author Type and Output Type

It was noticed during reading of the literature that the type of author appeared to influence the type of output of the paper. To investigate this quantitatively first authors were placed into the following categories of Author Type:

Academics:	Authors who have a university address Shenhar (1993)
Journalists:	Authors who appear to be full time journal employees Wolff (1992)
Consultants:	Individuals or employees of consultant organisations Gilmore (1995)
Practitioners:	Authors who practise or directly supervise R&D Ransley (1994)
Corporate Management:	Managers above practitioner level Zurn (1991)

Table 4.1 - Definition of Author Types. The references are of papers which exemplify author type.

One paper is given as a reference to exemplify each category. New columns were added to the database for recording the Author Type and Output Type of each paper. The Output Types defined by the researcher are shown below [Table 4.2].

Recipe	Rules, normally empirical, claimed to be generally applicable. E.g. Top management support promotes new product success (Brenner (1994))
Strategy	An argument leading to things to do in general situations to place the whole organisation in a good position. (Fusfeld (1995))
Tactics	An argument leading to things to do in particular situations to place a project or department in a good position. (Fairtlough (1992))
Model of R&D	A statement of how the whole R&D management process is thought to work. (Cooper (1985))
Theory of an aspect	An explanation of how an aspect of R&D management is thought to work. (Barpal (1990))
Comment only	A statement with no apparent support within the paper, or a comment giving rise to no recommendation. (Friedman (1993))
Data	The simple presentation of data with no interpretation. (Keller (1994))
Measurement method	A technique for measuring the effectiveness of R&D. (Bohn (1997))

Table 4.2 Definitions of output types. The references are papers which exemplify each author type.

Clearly other possible outputs could be thought of, but the definitions above were derived from reading the papers and all of the papers clearly fell within one of them. One might for example expect papers which present data plus reasoning following from the data, but none were found. In the category Measurement Method, all papers were on measuring the efficiency of R&D, and none were on how to measure other aspects of R&D, such as effectiveness.

Author Type was gleaned from the authors' biographical notes or addresses, and was deducible in all but one of the papers.

Output Type was assigned by the reviewer, and this proved practicable for 100% of papers. Table 4.3 presents a cross-tabulation of this data, which was easy to output from the database once the data had been compiled.

Output Type	Journalist	Academic	Consultant	Corporate	Practitioner	TOTAL
Rules	3	82	23	26	6	140
Strategy	18	68	13	69	11	179
Tactics	22	61	25	21	29	158
Model	0	63	4	12	5	84
Theory of an aspect	0	19	2	6	2	29
Comment only	9	0	8	7	3	27
Data	0	18	0	3	0	21
Measurement method	0	11	2	4	0	17
TOTALS	52	322	77	148	56	655

Table 4.3 Author type against output type of papers on management concerns of the R&D section.

It can be seen that the idea that Author Type to some extent determines Output Type is supported by this data. Corporate and Practitioner authors concentrated on strategy and tactics respectively, which was not thought surprising. Academics concentrated somewhat on rules. The dominance by academics in number of papers published is not surprising, however the significant contribution made by journalists was not expected. The classification of Journalist is based upon the authors' affiliation, and it is clear that some Journalists were previously Practitioners or Academics. However real Journalists can still make a significant contribution to research for example by carrying out case studies (Yin (1994, p15-16)).

It is surprising how few of the papers presented data or theory, since it would be expected that these would be the main outputs of research.

χ^2 tests[1] showed that the different pattern of output type for each type of author is statistically significant at better than 99% in each case. It was felt that the above results were important, and so it was decided to conduct further work along the same lines to investigate and develop this method of analysing literature.

4.5. Advice on Using the Context Analysis Method

Selecting Context Factors

The Context Factors used would not all have arisen from the literature review alone. For this technique it is important to firstly do some work to define the matters of concern in the research field. This work can include findings from outside the literature as well as reading a sample of the papers. The Schools of Thought factor to be described in chapter 6 arose from the research whereas Output Types arose from the literature itself.

The initial list of Context Factors created seemed logical, but several factors proved not to work, in that papers could not be assigned to them. As an example, in Table 4.3 a rating for Quality of Research would have been desirable. This did not prove possible for two reasons. 1). Quality of writing overlay the desired factor: usually poor writing obscured any underlying research that may have been done. 2). Papers simply did not report research in the expected way, i.e. to enable the reader to understand what was done, what results appeared, and the chain of reasoning or analysis that was applied to

[1] χ^2 tests are discussed in Appendix G.

reach stated conclusions. This problem of lack of detail is already known in the literature (Bowman (1990, p22-23)).

In the initial stages, as the work progressed patterns were noticed in what was appearing in the literature which gave rise to further questions necessitating creation of new factors. This meant re-reading a large number of papers in order to categorise them according to the new factors. It would be logical to identify all of the factors needed at the outset, to pilot the factor list on a sample of the papers, and to check that intended cross-tabulations do in fact work out. However it is believed that this is just not possible as the research itself generates categories and so an iterative approach is necessary.

Definitions of Context Factors

Carrying out **context analysis** involves some techniques that are familiar to researchers in the field of social science (e.g., Grosfot (1985), Easterby-Smith (1991)). In social science research a concept such as the output type Recipe, shown in Table 4.2, would be called a construct. The need to develop a name and definition for a construct is well known, as well as the need to test whether it is a robust construct, which means that it would be interpreted in the same way by all researchers.

In order to achieve this each Context Factor was given a name, which was as accurately descriptive as possible, and also a definition, as exemplified in Table 4.2. It is important to have written definitions of factors for three reasons. One is that the definition list gives the researcher a reference for deciding how to allocate each paper. The second is that the definitions will be required when reporting the work. The third is that in the research a special meaning is often assigned to a common word or phrase, and this needs to be notified. For example, in Table 4.2 and Table 4.3 the factor Theory of an Aspect can be seen from the definition to be used in the somewhat derogatory sense of “that’s just a theory, it’s not proved”.

The definitions adopted described not so much what was looked for in the literature as what was found, and definitions had to be adapted in the light of findings until it was found that all papers fitted into factor categories. It can be seen that during the initial stages definitions were an output of the examination of the literature, not an input.

Finding the Papers

It was found to be very difficult to use the standard literature databases to find the relevant papers. Many unwanted papers were found, and many wanted papers were not found. There was no search criterion provided which exactly matched the chosen topic and so it was necessary to use several apparently relevant criteria that were available, together with key words. This yielded over 4000 articles, which were manually sifted down to 655. Half of these proved to be of low relevance on full examination. The main problems were inaccurate titling, misleading abstracts and too many keywords. Some keywords had only slight applicability to a paper. It was necessary to read some papers right through in order to know what was in them. Once the key journals had been identified it was necessary to go through the actual journals manually. Almost half the papers found this way had not appeared in the database searches. Even this does not guarantee complete coverage because the research shows that key journals do not contain all significant papers [Chapter 5].

Presentation Format for Results

Although it was easy to extract tables once query writing had been mastered, it was difficult to cast the results in the form required for presentation. Table 4.3

was originally output from the database in the form shown in Table 4.5, called here the Database Format. Only the start of the table is shown.

It was thought preferable to present this information in the more compact style of Table 4.3. Here called the Matrix Format, because one factor is spread out horizontally and the other vertically. Unfortunately all of the entries had to be transferred more or less by hand from the old framework to the new framework. MS Access has facilities to present data in a number of forms of pie chart or graph, but cannot easily convert output into the matrix format. Overall this entailed considerable extra work.

Author	Output	Count Of Output
Academic	Tactics	61
Academic	Strategy	68
Academic	Model	63
Academic	Rules	82
Academic	Theory	19
Academic	Data	18
Academic	Measurement	11
Academic	Comment	5
Consultant	Tactics	25
Consultant	Strategy	13
Consultant	Rules	23
Consultant	Recipe	7
Consultant	Comment	8
Consultant	Model	4
Consultant	Theory	2
Consultant	Measurement	2

Table 4.5 Original output in database format (partial)

4.6. Discussion

The database can be interrogated remarkably rapidly to ask new questions within its scope, such as “How many journals feature” or “Which journals do Canadians publish in?” As an example Table 5.4 [Chapter 5], includes a column for **how well written** which was added in order to be able to enter an average writing rating for each journal. It was then trivial on the computer to rank the journals by quality of writing and to produce a league table for this (not shown here). It was almost trivial to go on to produce a table of average quality of writing against Author Type, (also not shown). The number of relationships examinable with a database of this type is very large. If n factor columns are entered, then $n(n-1)/2$ pairs of matrices will be possible. Thus it is just not practicable to report all cross-tabulations in a publication such as this. Because of this reporting difficulty a full active copy of the database is included in the thesis as Appendix H to allow further relationships to be investigated.

In fact a single output table can be too large to publish. As 124 journals feature in the database, then obviously Table 5.4 was originally 124 rows deep, but it was possible to include only a sample of this table here. It is easy to browse such a table when it is in a computer, but it is just not practical to publish it on paper. It is thus necessary when using **context analysis** to be selective about which results are presented.

Context analysis is a new methodology which arose out of a need to analyse the literature studied in new ways. The technique was made possible by the use of a computer database, and proved useful in the research carried out. In the next chapter **context analysis** is applied to the body of literature relevant to section level R&D, and in chapter 9 it is applied to the same body of literature to provide evidence in support of the **four schools hypothesis**

4.7. References

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Chapter 5 - Context Analysis of the Literature

5.1 Introduction

The previous chapter explained the principles of context analysis[1]. In this chapter the application of this technique to the analysis of the literature studied in connection with the research topic is explained, specifically the 655 papers relevant to R&D at the section level. These papers are listed in the database which is included as [Appendix H].

5.2 Construction of a Database of Papers

Selection of Context Factors

The database was expanded to record the following context factors for each paper in addition to title and first author. In order to make the data manageable all factors concerning the author refer to the first listed author only. This list of context factors was partly thought up by the researcher and supervisor, partly arose from reading of the papers, and partly arose out of the case study. The factors were as follows;

- Author type (as in Table 5.3)
- Output type (as in Table 4.5 [Chapter 4])
- Reference, broken up into journal, issue and year
- The degree of relevance to management concerns of the R&D section

[1] This work has been published in Falkingham & Reeves (1998).

- A grading of the reviewer's opinion of how well written the paper was
- A grading of the reviewer's opinion of the importance of the paper in its own field
- Nationality of author
- Affiliation of author
- How formal the work was, from formal study to expression of views [Table 5.2]
- The primary research methodology used[2]
- The School of Thought underlying the work [Chapter 9]
- The relationship of the paper to theory: whether it describes or tests a theory

The publications included 655 papers on the subject of "Strategy & Management concerns of R&D at the Section Level", published since 1975. Most were refereed journal papers, the most important exception being that papers in *Research Technology Management* are reviewed by the Board of Editors. The papers were found by the usual methods of keyword computer searching of databases, manual scanning of identified key journals for relevant papers, and some citation searching [Chapter 3]. Databases searched were ABI/Inform, BIDS, Compendex, INSPEC, NTIS, and PsycLit.

The list of papers is thought to be more or less comprehensive for the restricted field in question. It was estimated by the researcher that these papers relevant to management concerns of the R&D section comprise roughly 20% of papers on all R&D Management topics. The conscious decision was made not to do searches for key authors as this would perhaps bias the database towards those who feature a number of times, and lead to the neglect of rarer authors.

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[2] Up to four research methods were identified in each paper and recorded in the database. But for simplicity only the primary one is shown here.

Categorising the Papers

All papers included were read by the researcher, and were categorised accordingly. The list of possible categories for each factor was modified and extended slightly in the light of experience with the papers. The development of the categories was performed early on in the study, and after this was done there was no particular difficulty in categorising all of the papers.

5.3 Results from the Database

Distribution of Papers by Journal

It was found that publications relevant to the field in question are highly dispersed. The 655 publications on the topic were distributed among 114 journals and were distributed as shown in Table 5.1.

It can be seen that the top journal yielded one third of the papers, the first six journals yielded just over half the papers, and nearly half the papers were distributed among 108 other journals. The comment may be made that management concerns of the R&D section is a clear enough concern to the section level R&D manager, but this analysis shows that it has not been a recognised field of study, with its own journals or sections in journals. Therefore it is not surprising that papers having some relevance have to be searched for widely. The question arises as to whether a new topic subdivision could be created for this subject within the existing known categories, or whether some topics of practical interest will necessarily be found cutting across subdivisions made by journals.

Publication	Papers
Research Technology Management	140
IEEE Engineering Management Rev.	61
R&D Management	56
Research Management	53
IEEE Trans. Engineering Management	40
Journal of Product Innovation Management	21
Management Science	20
Technology Management	20
Engineering Management Journal	19
Management Today	17
Project Management Journal	12
Harvard Business Review	11
Professional Engineering	7
Engineering Management	7
Sloan Management Review	6
Long Range Planning	5
Annual Reliability & Maintainability Symposium	5
California Management Review	5
Journal of Marketing	5
Proceedings of the I.Mech.E.	5
Industrial Marketing Management	4
World Class Design to Manufacture	4
Technology Analysis and Science	4
Interfaces	4
IEEE Spectrum	4
Organisational Dynamics	4
Technovation	3
International Journal Technology Management	3
Technology Analysis & Strategic Management	3
Research Policy	3
Business Horizons	3
European Journal of Marketing	3
12 journals	2
70 journals	1
TOTAL	655

Table 5.1 League table of publications studied. This clearly shows that the papers are widely distributed throughout the literature.

Type of Author Against Formality of Research

Four categories of research formality in descending order were defined as shown in Table 5.2. The references given are for typical papers of each type.

1. **Formal study,** which is the reporting of a research project with methodology, data and reasoning explained (e.g. Pelled (1994)
2. **Reasoned Argument,** which represents a proposition or analysis based on a self contained chain of reasoning. (e.g. Udayagiri (1991))
3. **Declaration**, which is a presentation of beliefs with justification by selected evidence from supporting research. (e.g. Bart (1993))
4. **Views,** which are statements which are unsubstantiated in the paper. (e.g. Coppendale (1995))

Table 5.2 Hierarchy of Formality of Research

The relationship between author type and research formality is shown in Table 5.3. It is interesting to note how little of the work was categorised as formal study. What was termed reasoned argument was usually a discourse based on premises considered by the author to be self evident, and did not appear to represent an extension of previous work.

Formality of Research	Journalist	Academic	Consultant	Corporate	Practitioner	TOTAL
Formal study.	2	65	1	15	6	89
Reasoned Argument.	6	92	20	38	9	165
Declaration	7	85	17	43	11	163
Views.	37	80	39	52	30	238
TOTALS	52	322	77	148	56	655

Table 5.3 Author type and formality of research

Quality, Relevance and Significance of the Papers

One paper judged to be very useful was found as a one-off, on its own in *Irish Marketing Review* (Kohler (1984)). This raised the question of whether some journals publish the best papers, or whether one needs to read all the journals to capture all the good papers. To explore this, new columns were created in the database to record our ratings of how well written each paper was, its relevance to our topic, and it's importance as a paper in its own right. Each of these was rated on a scale of 1 to 5, with 5 as high[3].

Table 5.5 shows the results for these three factors for the journals at the top and bottom of Table 5.4. A **Relevance** rating of 1 means that the paper has some relevance to but is not aimed primarily at our special topic. It could be a good paper on R&D management at the corporate level or on general management at the section level. A rating of 5 means that the prime concern of the paper is indeed relevant to the R&D section.

Importance is the researcher's view of the significance of the paper in its own intended field. It might for example be a very important paper on business strategy, which has a relevance rating of only 1 or 2 to our special topic.

How well written was the researcher's judgement of the writing quality, based simply on an opinion of whether the paper was easy to read and easy to understand.

From the information in Table 5.4 it can be concluded that the recognised top journals are high on quantity of papers, but average on quality, with quality ranging from very high to very low. *Research Technology Management* has ratings from 1 to 5 for writing, and 2 to 5 for significance. Its averages are

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[3] The use of this scale is discussed in Chapter 3 section 3.6.

similar to those of journals at the bottom of the league table. Since there are so many journals with one or two papers in our field, it is clear that looking at only the top few journals would lead to missing a lot of highly rated papers.

Note that Table 5.3 could be considered to be an example of purely bibliometric analysis at level 2 in Table 5.2. Whereas Table 5.4 required informed judgements to be made about context factors and knowledge of the field of study, and so is an example of **context analysis**, at levels 3 and 4 in Table 5.2.

Journal	**Papers**	**Relevance**			**Quality**			**Significance**		
		Av.	**Max**	**Min**	**Av.**	**Max**	**Min**	**Av.**	**Max**	**Min**
Top of table										
Research Technology Management	140	3.2	5	1	2.7	5	1	3.3	5	2
IEEE Engineering Management Review	61	3.3	5	2	2.7	5	2	3.2	4	2
R&D Management	56	3.0	5	1	2.7	5	1	3.2	5	1
Research Management	53	3.5	5	2	2.8	5	2	3.4	5	2
IEEE Transactions on Engineering Management	41	3.2	5	2	2.4	4	2	3.2	5	2
Journal of Product Innovation Management	21	3.3	4	1	2.7	5	2	3.5	5	2
Bottom of Table										
Irish Marketing Review	1	4	4	4	2	2	2	4	4	4
Operations Research	1	4	4	4	2	2	2	3	3	3
Electronic Business	1	3	3	3	4	4	4	3	3	3
Strategic Planning Society	1	3	3	3	3	3	3	4	4	4

Table 5.4 Rating of papers in a selection of journals for relevance to the research topic. Writing quality and significance in their own fields. 1 is low, 5 is high.

Distribution by Country in which the Work was Performed

The national origins of the papers is shown Table 5.5 The database concerns solely papers written in English, which may to some extent explain the predominance of the USA and the UK. As a matter of definition, a Japanese researcher working in France and publishing in the USA would be classified as French.

One author has significantly distorted the results, by elevating Canada to third position almost by himself. Professor R J Cooper of McMaster University and his co-authors have written over 30 papers within the field of study, which comprise the bulk of the Canadian papers.

Country	Papers
USA	438
UK	114
Canada	45
Japan	14
Germany	8
Switzerland	6
Holland	5
France	4
Korea	4
Israel	4
India	2
14 countries	1
TOTAL	655

Table 5.5 National origins of the papers

Centres of Activity in the Field

A total of 208 organisations contributed papers selected as relevant to the research topic. With some significant exceptions authors are thinly spread among a very large number of organisations, and even the largest centre provides less than 4% of the total papers [Table 5.6]. The second centre, IRI, is the publisher of *Research Technology Management*, and its articles are mostly commissioned reviews.

There was sometimes difficulty identifying research centres. For example, Manchester has three university institutions doing management research, and it is difficult for an outsider to know which belong together, and which are distinct. Is the University of Pittsburgh the same as Pittsburgh University? For that matter, is Cranfield Institute of Technology different from Cranfield University? In practice these problems turned out not to greatly affect the outcome, i.e. that research is very widely dispersed among a large number of centres in this field and that the largest single centre is clearly at McMaster University in Canada. This information is of considerable strategic importance for a researcher in the field.

Affiliation	**Papers**
McMaster University, Canada	26
Industrial Research Institute (IRI)	10
US Government	8
Carleton University	7
Rensellaer Polytechnic Institute (RPI)	7
Management Today	7

Table 5.6 The top six contributing research centres, out of 208.

Primary Research Methodology Used

It was thought interesting to analyse what methods of research were employed, and therefore the papers were classified as shown in Table 5.7. It should be noted that many papers used more than one methodology and these were classified in the database as primary, secondary, etc. For simplicity only the primary methodology is shown here.

Primary Methodology	Journalist	Academic	Consultant	Corporate	Practitioner	TOTAL
Case Studies	10	61	16	59	17	163
Theoretical analysis	12	119	38	65	4	238
Questionnaire	0	36	2	5	2	45
Interview	22	31	4	7	1	65
Literature Review	2	33	14	10	2	61
Empirical data	0	17	3	2	0	22
Data Analysis	0	10	0	0	1	11
Experience	6	13	0	0	30	49
Delphi	0	0	0	1	0	1
TOTALS	52	320	77	149	57	655

Table 5.7 Primary Methodologies employed in the papers

In Table 5.7 terms are used which normally stand for well recognised techniques of management research, but in this case these terms must be considered to be modifiable by the formality factor of Table 5.3. Thus an author may claim to base a paper on case studies, and be so classified in Table 5.7. However if they did not show that the case study was conducted with recognised case study methodology, the work would be rated in Table 5.3 as Views (e.g. Kelsey (1995)), Declaration (e.g. Dancy (1977)) or even Reasoned Argument (e.g. Lyles (1981)), as opposed to Formal Study (e.g. Elmes (1992)). Formal techniques taught to management researchers, such as Questionnaires (e.g. Roberts (1995)), Interviews (e.g. Macdonald (1994)), and Data Analysis (e.g. Saleh (1991)) were clearly only used in the minority of papers, and the Delphi method, which is one of the major recognised techniques, was only used once (Khorramshahgol (1986)).

It appears from the results that the popularity of a research method was inversely proportional to the amount of work it entails. Indeed Table 5.4 and Table 5.7 suggest that this body of literature provides more of a forum for debate than a medium for reporting research results. This in turn suggests that this body of research is in the pre-paradigm state described by Kuhn (1970), where many competing theoretical bases are being offered. It is proposed that this body of literature is in the same state as chemical research was before the atomic theory was developed, and it lacks widely accepted explanatory and predictive powers.

Snow (1994) suggested that in the post-paradigm phase most publications concern firstly the testing and acceptance of a theoretical concept. For the purposes of the research this was reformulated as the hypothesis;

“The literature studied is in the pre-paradigm state”.

To test this hypothesis, a new context factor Contribution to Theory was created and the papers were re-analysed, and assigned to one of two categories. 17% of papers were found to be concerned with testing different theories, whereas 83% were concerned with building theories. Of the theory-building papers, 70% were concerned with describing a theory, 25% were concerned with explaining a theory, and only 5% were concerned with making predictions from a theory. This agrees with the hypothesis and provides quantitative support.

It would be interesting to apply **context analysis** to determine the breakdown of methodologies for other fields of publication, to see how different fields compare.

Confirmation of Analysis Allocations by Authors' Own Opinions

Much of the previous work relies on the opinion of the reviewer in classifying the papers. At this stage it was necessary to perform further work to eliminate bias and introduce more validity to the results as discussed in Chapter 3. This was undertaken by asking the authors of the papers to categorise their papers themselves. This together with the detailed methodology is discussed further in Chapter 3.

A questionnaire was developed and piloted on eight UK authors followed by a further twelve. After minor modification it was then posted to the first authors of a further 274 authors plus those in the pilots. This asked for much of the same information as is contained in the database. The questionnaire is reproduced in Appendix D. In total 121 responses were received, a response rate of 41%. This response is very high, especially as some papers were over 10 years old, and many questionnaires were returned 'gone away', 'not known' or even 'deceased'. Many authors expressed interest in this exercise, and some offered other papers. A few were even alert enough to photocopy the questionnaire, and fill it in for additional papers.

When an author gave exactly the same answer as the reviewer did, this was called a primary hit, and for all questions the rate of primary hits was in excess of 75%. For Researcher Type it was 83%, for Primary Research Method it was

76%, and for Contribution to Theory it was 87%. For School of Thought (see below) the agreement was 79%. From this it can be concluded that these results sufficiently justify the original allocations, and indicate that the **context analysis** technique can give similar results whether author opinions or researcher opinions are used[4].

5.4 Discussion

By using **context analysis** on publications on "Strategy & Management concerns of R&D at the Section Level" it was possible to gain a most useful overview of the whole field. It was found that this body of literature is widely dispersed by author, research centre and publication, and that relatively informal research methods predominate. It was also possible to provide some quantitative support, for the weakly held hypothesis that the literature is in the pre-paradigm phase.

It will be shown in Chapter 9 how **context analysis** was used to show that the **four schools** concept represents a real phenomenon in R&D management and in research upon it. The **four schools** concept arose out of the case study which is the subject of the next three chapters.

[4] The statistical significance of this was verified using χ^2 Test, [Appendix C].

5.5 References;

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Chapter 6 - Design & Methodology of the Case Study

6.1. Introduction

This chapter describes and explains the detailed methodology used for recording data in the case study. The organisation studied was the R&D section of GEC ALSTHOM Vacuum Equipment Limited (***VIL***) in Rugby, England. The reasons for using a single case study, and the selection of a Participant-observer approach were explained in Chapter 3. The data recorded in the case is presented in Chapter 7, and the analysis of the data is explained in Chapter 8, together with the findings.

6.2. Inductive versus Deductive Case Studies.

Research can be classified either as Inductive or Deductive. Exploratory research intended to generate a hypothesis is classed as Inductive, whereas research to demonstrate or develop a hypothesis is Deductive (Judd *et al* (1991). Experimental research is generally Deductive, with the pattern of work flowing from a hypothesis generated from a theoretical background. The hypothesis is then tested by gathering data to support or refute the predictions of the hypothesis[1].

In Inductive research however, the researcher starts with data collection and then generates hypotheses to fit the data.

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[1] According to Kidder & Judd (1987) when carrying out Inductive research "It is important to realise that at best research can only be consistent with or demonstrate a hypothesis. It can never *prove* the hypothesis" (author's *italics*, p25).

This case study was primarily Inductive. It ran for five years from the beginning of the second year of the research. In the first year of the research the case study had not yet been reformulated to be Inductive, and results from this were used in the pre-history, reported in Appendix A.

Conducting a case study in an inductive investigation such as this means that the case itself generates the hypotheses. Hypotheses which are generated by research may emerge entirely from inspection of the data or may be initially based *on "previously held hunches and crude hypotheses"* (Kidder & Judd, (1986), p179). The hypotheses then evolve with time as the theoretical structure of the research emerges. This phenomenon is well known, as exemplified by Kidder & Judd, (1986, Chapter 8) and McCleary (1978). The case described by Cressey (1953) is a particularly good example of the process of developing and testing hypotheses during a Participant-observer inductive case study. In it Cressey describes the detail problems of a case study on embezzlement and in particular the evolution of ideas and hypotheses as the case progressed. The work generally consists of Cressey proposing weak hypotheses, which are then continuously tested and modified as the case develops. He also investigates the environment of the violator to try to determine common factors leading to the violation of trust being studied. These basic research principles are used in this research, although modified to fit the different requirements.

6.3. The Chronology of Events

The Chronology of Events consisted of notes made each month of all events thought to impact on the R&D department. Kidder & Judd (1987, p173-176) insist that in an inductive case study the maximum possible level of detail should be recorded, as it is not possible to know what is important in advance.

In addition they go on to claim that recording of data like this will result in improved memory of the events, even those not fully recorded, which will be useful as an memory aid during the writing up stage of the research. This was found to be true and this effect assisted greatly in placing events in their true context when writing the overview of the case.

The set of data recorded in this way was termed the Chronology as it represented a series of events set in chronological order. This technique of using a chronology is particularly appropriate for case studies and is advocated by several sources, (e.g., Miles & Huberman (1994), Yin (1994)). However attempting to record everything means the accumulation of a vast amount of data of initially unknown value. The fact that there is normally simply too much data to record is well known (e.g., Miles & Huberman (1994), Yin (1994)), and necessitates some level of editing on the part of the observer.

The Chronology was initially recorded in real time in order to eliminate any unintentional editing due to hindsight. In practise this approach was quickly found to be impractical, as the number of potentially significant events occurring was just too large. It was quickly decided to limit the log to those events thought to be significant after a short delay, and so the Chronology was completed at monthly intervals. This was always done two weeks after the end of the monthly period, so there was 2 to 6 weeks distance from all events.

Evaluation of events as to whether they were significant was of necessity personal, but as the Participant-observer (R&D Manager) had operational control of the section, those events thought significant by him were those to which he responded. The views of key players within a case are important in their own right particularly where they are held by decision makers who can, and do, act upon them (Molina (1997)) [2]. Also according to Miles & Snow (1987, Chapter 11) managers may have a perception of their environment which is not necessarily true from an objective viewpoint, but nevertheless is one to which they will respond. The perceptions of the Participant-observer as R&D Manager were therefore an important feature of the case.

This aspect of the research could in theory lead to bias (discussed in Chapter 3), and this possibility must be considered. However self rating is an accepted technique and;

"In fact, self ratings have been shown to be equal or superior to other types of assessments in predicting a wide range of criteria," (Kidder & Judd (1987), p199-202).

This is with the limitation that it is difficult to cross-reference the results between multiple observers due to differing frames of reference. This does mean that an absolute scale of response is in practise not possible, however a background of the events is given which is thought sufficient to allow some interpretation of events. In order to reduce the problem of differentiation of scales, the results were limited to recording the occurrence of events, together with a simple scale recording positive, neutral or negative events.

A major limitation of this technique, noted by Kidder & Judd, is in obtaining the subject's co-operation and motivation to give accurate ratings. In order to overcome these limitations this research relies on the observations of one Participant-observer only - the researcher, but with sufficient information given to allow a judgement to be made of the scale of response by others. In this case co-operation and motivation were not a problem.

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[2] Molina's paper gives a good example of the importance of the perceptions of key

When the project was reviewed after about 18 months seven hypotheses emerged all at the same time. The chronology was then re-examined and events were classified according whether they illustrated one of the hypotheses. After 18 months, the classifications of events were assigned at the same time that the notes were recorded.

6.4. The Quarterly Situation Appraisals

The second type of case notes, the Quarterly Situation Appraisals, took the form of a review of the strategic situation of both the R&D section and the company, made by the observer at three monthly intervals. It should be noted that what was being recorded here was the opinion of the R&D manager at each review point as to the position of the department. These Appraisals were made in a structured way in order to be able to evaluate later how these views had changed over an extended period. This technique of Appraisals reflects aspects of Stiegelbauer et al (1982) who created their "Critical Incident Chart" and class this type of technique as a Structured Observational Method, a technique also reported by Miles & Huberman (1994, p113-115). In this research aspects of Checklists, and Specimen Records were also included (Kidder & Judd (1987, p292-297)). The variant of the Structured Observational Method used was designed by the researcher to allow, in this specific case, some numeric analysis of what is subjective data.

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players within an R&D environment.

Each Quarterly Situation Appraisal included the following items:

- **Status;**
- **Key Events;**
- **Strategic Position of VIL;**
- **Tactical Options for R&D;**
- **Company Options;**
- **Short Term Prediction for R&D;**
- **Long Term Prediction for R&D;**

At the end of the five year period this record of the changing views of the R&D section manager was analysed by assigning numerical values to the views stated and then presenting the results graphically (Chapter 8).

The Quarterly Situation Appraisals are in the form of a self-administered structured interview (see section below). They include two types of data, graded and ungraded. For graded questions the position of the **R&D section** is given a rating termed the Level. This is expressed both as a word and a number defined as follows:

Excellent (5),	No foreseen problems
Good (4),	Situation good, no serious problems
Neutral (3),	Some serious problems, believed to be controllable
Poor (2),	Serious problems, possible solutions foreseen
Bad (1),	Very serious problems, no direct solutions foreseen

The number was included as an aid to data management. In the data, each

Level is followed by a paragraph reviewing the position and the reasons for the rating. Ungraded data consists of a descriptive paragraph such as Tactical Options. As discussed in Chapter 3, a middle value was included to allow a measurement to be made of the intensity of attitude, (Sudman & Bradburn (1984, p141)). The data recorded is presented in the next chapter.

The Template for Self Administered Structured Interview used in compiling the Quarterly Situation Appraisals

Quarterly Situation Appraisal *Number;* **VIL as at** *Date* **-** *Date completed*

Status; *Level, Number*

Present position of the company, i.e. VIL, as seen by the R&D manager.

Key Events;

Events thought to be important to be reviewed in order to give background and to tie in with the Chronology.

Strategic Position of VIL; *Level, Number*

This was the overview of the strategic outlook, long term, as seen by the R&D manager.

Tactical Options for R&D;

The options thought to be available to the R&D section, and the thinking behind them.

Company Options;

The options thought to be available to the company VIL, and the thinking behind them.

Short Term Prediction for R&D ; *Level, Number*

A prediction of the future of the R&D section at six months from the date. This is in the form of a single grading plus a paragraph of explanation.

Long Term Prediction for R&D; *Level, Number*

A prediction of the future of the R&D section at one to two years from the date. This is in the form of a single grading plus a paragraph of explanation.

6.5. References;

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Chapter 7 - Data from the case study

Apart from the first section, this chapter contains the semi-raw case study data, which is not expected to be read as text.. The following Chapter, Chapter 8, deals with the analysis of the data.

7.1 Introduction

This chapter is in two sections: the first contains the 60 data entries for the monthly chronology of events and the second contains the 20 quarterly situation appraisals. The methodology and format of these were explained in the previous section. For compactness in presenting this large amount of data, a single line spacing is used in the rest of this chapter. In order to meet the requirements of ethics discussed in Chapter 3, the names of the key participants have been changed to codes, M1 – M14, in order to prevent their being easily recognisable.

7.2 Key to chronology of events

The chronology is annotated with symbols in the left-hand margin. Events marked in **bold** were thought to be particularly important at the time. The symbols signify as follows;

+	=	Positive event
-	=	Negative event
Comp	=	Competitor action
SDE	=	Strategy Destroying Event
SCE	=	Strategy Confirming Event
1	=	Hypothesis 3

2	=	Hypothesis 4
3	=	Hypothesis 5
4	=	Hypothesis 6
5	=	Hypothesis 7
6	=	Hypothesis 8

The meanings of all of these terms are explained in the next chapter, [section 8.4], together with a summary of the events. In order to understand the background, the roles of the companies mentioned and the acronyms used, it is necessary to study the sections on the technology and the pre-case history which are presented in appendices A and B.

7.3 Chronology of events

January 1992

+	M3 returns to VEL as Technical Director.
-	Major compulsory redundancy programme announced at DSL.
- SDE	Damaging six week strike starts at DSL.
Comp.	Return visit by Siemens to UK postponed at GEC ALSTHOM request.
+ SCE	GEC South Africa ask VEL to design a new interrupter for a 24 kV Recloser requirement in South Africa.
-	Group announces that the VEL accounts are to be split, with Vacuum Interrupters and Vacuum Switches becoming Vacuum Switches Rugby (VSR) and the balance of the company becoming Vacuum Equipment Rugby (VER). Joint accounts remaining as VEL.

February 1992

-	Extended redundancy programme announced at DSL.
+	Proposal for South African 24 kV development made.

+	M3 invited to rewrite a technical paper on Vacuum Interrupter Design, previously published at a conference in the USA for inclusion in the Proceedings of the IEEE.

March 1992

- SDE	Meeting held between M2, Divisional M.D. for the division covering GEC ALSTHOM India and GEC ALSTHOM South Africa, and M1, Divisional M.D. for the division covering VEL. It is stated that VEL are to continue in "Traditional UK Dominated Markets". EVI and VEL are to exist in parallel until the most effective company is determined.
+	R&D at VEL is to be expanded and the team strengthened. Recruitment to start immediately.
- SDE 1	Proposal for 24 kV South African Development is refused.
-	South Africa decide to go it alone.
+	M3 invited as a guest speaker on Vacuum Interrupter Technology to a major international conference to be held in Darmstadt, Germany, in September 1992.

April 1992

- SDE 1	All VEL Applications for Development Expenditure (ADE) for 1992-93 are refused authorisation by Group. VEL R&D is now to be "Market Led".
-	Recruitment of new/replacement Engineers at VEL is suspended by Group.
+	M3 visits India to assess changes since the last visit, and to help in the start of manufacture of the V500 range of Vacuum Interrupters. M9, Distribution Group Technical Director is appointed, based in France, but with apparently no involvement with VEL.

May 1992

Internal GEC ALSTHOM Group document refers to

	VSR and VER as separate companies.
-	Presentation of an Enhanced R&D Programme cut short by Group.

June 1992

+	VEL Three Year Strategic Plan developed, (Created initially over a two week period). This is to be market led, but market information is not yet available.
-	Permission refused for M3 to attend or speak at the Darmstadt conference by Group. Reason not given.
-Comp	Return visit by Siemens to VEL again postponed.
-	Permission also refused by Group for the republication of a previously published technical paper on Vacuum Interrupters in the Proceedings of the IEEE.
-	VEL announces that the order position is poor for the immediate future, mainly in Excitation Control Systems, and HV Motor Starter product ranges.
- SDE	M10 Chief Engineer Vacuum R&D collapses and is taken to hospital. Off sick for four weeks.

July 1992

-	M11, General Manager and Director of VEL for previous five years **resigns**.
-	M12, Chief Engineer DSL **resigns,** becomes Technical Director for Whipp & Bourne (Competitor).

August 1992

+	M6 appointed Acting General Manager of VEL, was previously Works Manager.
-	A corrosion problem with old interrupters in the field (10-15 years old) appears, but is dealt with.

September 1992

-	Group meeting arranged With the M2 Divisional Managing Director responsible for non European units

	including India and Africa to discuss support to licensees. Support was considered by to be inadequate at all levels. Concern was also expressed that the promised recruitment to enhance the technical capabilities of the vacuum side of VEL had not taken place.
+	It was agreed with Group that recruitment would proceed immediately, with possible secondment from India.
	Visit of M12 new MD for GEC India T&D Group including the Interrupter plant.
-	Applications for Development Expenditure
	represented to Group for half year 1992-93. Still no approvals.

October 1992

	VEL Three Year Plan represented to Group.
-	Further problems are experienced with interrupters manufactured in 1991 subsequent to the move to Rugby.
-	M13, Chief Engineer Vacuum Engineering, goes to hospital for a hip operation. Off work until the end of January 1993.
- SDE 1	Announcement of the closure of GEC ALSTHOM Ceramics Ltd in Stafford. This is a key supplier of Glass ceramic and Alumina ceramic insulators to VEL.
	M14 Group Financial Director **resigns.**

November 1992

+	Joint development programme decided upon between VISA and GEC India. VEL (M3) to be responsible for developments and design of 24 kV interrupter for VISA and 12kV interrupter for India.
8	Visit of M15 of GEC India to VEL.
-	Joint Development Programme suspended pending market information to be supplied by

	licensees.
- SDE	Problems are being continually experienced with interrupter manufacture, both current and since production started in Rugby. These are due mainly to the move from Finchley to Rugby and the inadequate engineering effort available to deal with them.
+	Visit of Siemens to VEL. Overall the Germans appeared to be very impressed with the plant and in particular with the extremely limited manpower and resources required to produce the interrupters and switches.
	Siemens are contacted by Sprecher Energie to supply 24 kV &36 kV interrupters. Surprising as these are supposed to be supplied by EVI.

December 1992

- SDE 1	DSL are instructed by Group to certify their 36 kV circuit breakers with a Westinghouse design. Again surprising as they are already certified with a VEL design, and have just spent the last year redesigning and recertifying their circuit breakers to take the EVI interrupter.
-	Due to a stock error the V8 conversion to Alumina insulators is accelerated. GEC ALSTHOM Ceramics to stop making old Glass ceramics immediately. V8 rushed into production to meet DSL demand.
-	Investigation into history of broken Glass ceramic insulators. This is a problem of increasing proportions for the last four years.
Comp.	**Westinghouse announce that due to unrelated losses by their Real Estate business they are to sell off their Distribution and Control business, which includes the Interrupter operations.**

January 1993

-	Problems encountered with V307 development, tests not successful & test equipment not yet commissioned.
-	Due to a lack of available manpower, several

	development projects are suspended. Investigations into problems are slow due to lack of resources.
+ Comp.	New Siemens low voltage interrupter found to have "Shieldless" insulator design - partial copy of V200 design.
-	Joint Development Programme submitted for approval, rejected for insufficient market information, and then resubmitted for approval.
-	M3 instructed to try to personally recruit engineers to fill vacancies.
February 1993	
-	Major problem discovered with manufacture of V5 & V8 interrupters made in Rugby. Due to manufacturing error restraining bands not correctly fitted.
-	Major investigation and rectification programme underway. Resources insufficient for investigation. Possible problem with bellows manufacture also investigated.
	Broken V8 Alumina returned from DSL for investigation.
March 1993	
	M1, T&D Group MD retires early. (He was scheduled to retire in July 1993). His replacement is M5, from EGT.
-	V307 fails certification in SBV4 circuit breaker at KEMA. Design very close, proposal to repeat with slight design change. Verified by internal testing.
- SDE	Reported failure of V807 on traction breaker fitted to TGV. GEC ALSTHOM told that the V807 would not be available in 18 months to two years time.
-	Attempts at recruitment very low level and totally unsuccessful.
April 1993	
+ 3	Start of new financial year. New project for small

	interrupter commences. Titled TSR1.
	Traction failure investigated and found to be a cracked insulator. Believed to be a "one off" incident.
- 1	Surprise instruction by Group to use HWX circuit breaker for V307 tests at KEMA. Then countermanded when GEC ALSTHOM South Africa offer to pay for the tests.

May 1993

-	V307 project continues. In the space of two weeks the project is first top priority, then to be cancelled as GEC ALSTHOM South Africa no longer require it. Then it is again top priority, then it is a low priority as GEC ALSTHOM South Africa are in production with an earlier type for 25 kA.
+	TSR1 built and tested, Short circuit performance good, impulse performance poor. Design TSR2.
+	Permission given to widen field for engineers to non specialist companies.
+	Engineer to be seconded from India for two years.
-	M16, VEL financial controller **resigns**.
-	EVI now believed to have commenced stable production of 12 kV devices.

June 1993

- SDE 1	Major change in company structure announced by Group. HV and ECS are to be moved to other GEC ALSTHOM companies, manufacture of 12 kV interrupters is to cease with VEL retaining Vacuum Switches, Vacuum Contactors, and Vacuum Interrupters for 36 kV and special applications such as Traction use. 170 redundancies announced leaving approximately 74 people. However 39 will be associated with HV and will be effectively part of DSL in Manchester. VEL will effectively consist of 35 people.
+	Engineer arrived from India for training. Seconded for

	one to two years.
- 2	V307 project cancelled despite internal test success.

July 1993

-	M13, **Chief Engineer Vacuum retires**, under the present circumstances he will not be replaced.
- SDE	The new budget has zero spend on R&D for vacuum products. M3 is instructed that the new departmental priorities are to support production, and to support the licensees.
- SDE	Joint Development Programme abandoned by Group.
+	Permission was given to continue limited R&D projects provided no external cost was incurred.
-	Although the company has announced 170 redundancies, it has not stated which people are to be made redundant. This has caused a difficult situation with morale very low. Unofficially M3 is told that the Vacuum Engineering department will be unaffected by the redundancies, and indeed Group stated that they intend to retain the technical capability of VEL in this field for the time being.
+6	TSR 2 Prototypes built and appear successful at 12 kV 20 kA rating. Believed to be the smallest interrupter at this rating in the world. Project proceeding without formal permission. Group informed of results.
- SDE	GEC ALSTHOM India and GEC ALSTHOM South Africa are proceeding with their own developments of 12 kV and 24 kV interrupters respectively.

August 1993

-	Permission refused for M3 to give details of the TSR1 & TSR2 projects to India and South Africa.
	EVI have apparently been asked to provide information on the MTTF and reliability of Toshiba interrupters in the field. VEL instructed to provide similar data for comparison.

September 1993

-	Redundancies commence. This will reduce VEL to a skeleton operation. Control of production and quality will be a problem.
+	M3 Requested to give lecture at Indo-British Partnership Initiative in Bombay. Organised by M17, MD of GEC ALSTHOM (UK).

October 1993

-	EVI overcome their start up problems and commence full production.
	M3 visits GEC ALTHOM Calcutta to audit start-up of V506 manufacture.
-	M3 requests permission to attend ISDEIV conference in Russia. Permission denied.
+	M3 requests permission to give paper at IEE Conference on "Developments in Switching Technology Conference" in November 1994. Permission granted subject to approval of actual paper.

November 1993

	M3 gives paper on behalf of GEC ALSTHOM at IBPI Conference in Bombay.
-	**M4 (UK Group MD) resigns,** M18 appointed as temporary replacement.

December 1993

-	Orders for interrupters from DSL reduce as EVI come on line.

January 1994

+ SCE 3	Meeting in Vendargues. **VEL to be centre of R&D for vacuum switching in GEC ALSTHOM Group.** Appropriate programme to be set up.

February 1994

- SDE	Major quality problem for VEL interrupters made over last 12 months. Interrupters recalled for inspection.

	Paradoxically orders for interrupters increase as replacements made.

March 1994

-	Meeting at VEL R&D programme discussed. R&D to concentrate on new Contactor and Switch Range. No Power interrupters to be developed for the moment.
+ SCE	However, 27 kV Recloser interrupter to be developed for new OXR Recloser based on TSR work.

April 1994

+	M3 receives permission to attend ISDEIV conference in Russia, but not allowed to give paper.
-	VEL redundancies complete, level now down to 37 people. Production of power interrupters drops to very low level, portions of plant mothballed.
+	Group to perform recruitment of two engineers on behalf of VEL to supplement R&D capability in Rugby.

May 1994

+ SCE 3	Recloser interrupter to have 12 kV; 13.1 kA variant. This would overlap with a large part of the EVI market. Final use not discussed but would meet requirements of GEC ALSTHOM India and GEC ALSTHOM South Africa, and eliminate the need for their independent programmes.
-2	South Africa write to say that they have decided not to proceed with the re-certification of the new V304 interrupter. VEL not allowed to proceed and project is now closed as a failure. Despite test results indicating success.

June 1994

-	Paper for IEE conference heavily edited before approval given. Virtually all new work removed, together with references to latest (post 1986) VEL designs.
-1	During planning of VSL Three Year Plan, GDE in

	Vendargues state no power interrupters are to be included in the plan for the time being.
-	Potential problem with Vacuum switch production over last 12 months. Recall narrowly avoided.
- Comp.	GEC ALSTHOM OXR Recloser launched at 15.5 kV with Westinghouse interrupter.

July 1994

-	Cost reduction of existing Contactor commences. Large savings may be made. But these are to be available only for GEC ALSTHOM customers.

August 1994

	OXR considered to be expensive for 15.5 kV rating. 27 kV rating more lucrative, DSL talk to Westinghouse about possible interrupter.
-	No progress on recruitment by Group.
+	South Africa report large orders for V204 and V207 interrupters, plant running at capacity. India also report high level of business.

September 1994

+	Costing of new VEL interrupter indicates very low cost product (c. 50% of VEL existing).
+ SCE	Westinghouse do not have 27 kV rated device small enough to fit OXR circuit breaker!
-1	Possible customers in USA for interrupters are to be quoted by EVI only.

October 1994

+3	Divisional R&D meeting in Paris. M3 asked to give unscheduled presentation on new miniature interrupter, VI 100. German delegates very interested.
+	Development of optimised miniature interrupter continues. High priority for DSL for use in OXR Recloser project.
-	Manufacturing problems in VEL continue due to

lack of care and trained personnel at Rugby. Diverts effort from R&D programme.

+	Orders continue to be received from DSL for old style interrupters due to inability of EVI products to meet certain ratings.

November 1994

+	Presentation by M3 at IEE conference, London,. New low cost interrupter shown and receives positive response from delegates.
+ SCE 3	DSL insist that new interrupter is taken to KEMA for certification at earliest opportunity, despite the fact that the cost has not yet been optimised. Also DSL marketing have identified higher rating outside original specification.
+3	German subsidiary asked to receive more information on new interrupter. Instructed to deal through Division only.
-	India progressing with development of 12 kV; 13.1 kA interrupter.
	South Africa struggling with their development of 27 kV Recloser interrupter due to high workload for production.

December 1994

+ SCE 1,6	**New miniature interrupter VI 100 certified** at KEMA in Holland, ahead of schedule, in OXR Circuit Breaker, at 27 kV. Rated at 12.5 kA, which is in excess of 10 kA requirement. Congratulations from UK and Division.
+ SCE 3	**VEL told that Rugby is the sole centre of excellence for the research and development of vacuum switching technology for GEC ALSTHOM.**
+ SCE 3	Action to discourage India and South Africa from performing own development to be taken. Threat of closure of VEL lifted, (in fact denied that it ever existed).

+	**M19 appointed** as Managing Director for UK sub group, and DSL in Manchester, Replacing M18 who was acting Managing Director.
	EVI rumoured to be not performing due to low orders and high prices. Also rumour that Toshiba in Japan are having financial difficulties and have cut back on R&D effort!

January 1995

+ SCE	Capital expenditure which has been held since April is released. New car arrives for the General Manager, also new expensive notebook computers arrive for both the General Manager and the Financial Controller.
- 1	Test programme intended for VI 100 at KEMA in February changed at instruction of Group. Intention was to test 16/20 kA variant, but this was considered to be embarrassing to EVI at this time. Proposal dropped.
	M18 resigns, goes to competitor.
+	**M6 replaces M18** as Director and General Manager of Long & Crawford in Manchester. Maintains responsibility for VEL, with only one day per week in Rugby.
+	VEL instructed to recruit the technical man from India (M19). Solves recruitment problem while reducing Indian R&D effort.

February 1995

+	Technical Director receives newer car (Old General Managers car), first capital item for engineering department for several years.
+	M19 from India interviewed. Job offer to be prepared. Group to recruit German metallurgist.
+ SCE	KEMA testing goes very well, with good results at 12kV and also at 36kV. Group very pleased.
-	DSL express interest in use of VI 100 in their HWX (12kV) Circuit breaker. Blocked by Group.

March 1995.

-	Increasing involvement in R&D department's activities by Group. Plans for new facility in other building incorporating Laboratories and offices.
- 1 SDE	Group wishes to become involved in the R&D strategy, planning and departmental organisation.
-	No progress on metallurgist front.

April 1995

+	Three patent applications registered.
+	ADE approved.

May 1995

+	**M19 joins VSL from India**. This adds resource to VSL while reducing the capability of MVI to perform R&D on vacuum interrupters.
-	Pressure problems with switch manufacture, under investigation.
-	Draughtsman has heart attack. Sick for eight weeks.
-	Seconded Engineer returns to India.

June 1995

+	VI 100 tested at KEMA in OXR results good.

July 1995

	Temporary draughtswoman recruited.
-	Engineer resigns.
+	Preparations for introduction of VI 100 into production made.

August 1995

+ SCE 3	Relocation of Engineering department into a new building commences. This was unexpected as the normal policy was to have R&D pushed into a corner with old facilities. The relocation included new desks, computers, and infrastructure for the department

and was intended to give an image of a world class R&D department.

September 1995

\+ Switch pressure problems resolved

\+ Testing of VI 100 pre-production going well. Costing indicates lower than predicted costs.

October 1995

\- Reliability problems with production magnetrons, old 15-20 year equipment (Life normally 10 years).

Corrosion tests on VI 100 gave strange results - to be investigated.

November 1995

\+ Patent registered with UK patent office.

Interviews held for metallurgist position.

Relocation of Engineering Department continues.

\+ Three pre-production batches of VI 100 made, (3x66) without problem.

December 1995

Technical audit performed on Indian vacuum interrupter plant.

Draughtsman restarts work.

\+ New engineering laboratories commissioned.

\+ Laboratory magnetron rebuilt and used by production.

January 1996

\- Problems with Traction interrupters made in India investigated.

\+ New Technician (replacement for Engineer) recruited.

\+ New Mechanical Engineer for contactor

	work recruited.
+ SCE	Research to be carried out on new AMF contact geometries.
+ SCE	First production order for VI 100 received (1,992 devices).

February 1996

+	Two patent applications are made.
-	Agreement with a supplier to develop new contact materials still held up by group. This has now been in negotiation for almost eighteen months.
+	Work commenced on new interrupter project.
+	Permission received from Group to commence collaboration with RPI (New York) on electromagnetic field simulation.

March 1996

+	Group failed to find German metallurgist. Instead metallurgist appointed (from UK).
	AMF project has progressed to prototype build stage.

April 1996

+	Sample VI 100 interrupters supplied to other group companies.
-	AMF work to be reviewed by division before proceeding further.

May 1996

-	India announce that they have developed a new low performance interrupter based on the existing licensed designs. To be tested shortly.
+	Collaboration with RPI has now commenced.

June 1996

+	Four patent applications are in progress.
+	AMF work approved and recommenced.

July 1996

-	New contactor engineer leaves – not suitable.
+1	Group evaluating VI 100 for general use in MV circuit breakers.
+3	Indian interrupter fails test. India to rely on VSL for future developments.
+	M3 attends ISDEIV conference in USA – Gives paper.

August 1996

+	New mechanical life test facility commissioned.
+ SCE	Design study for next generation of vacuum interrupters commenced.

September 1996

-	Problem with Indian manufacture interrupters investigated.
-	Three interrupters returned for investigation.
+	Development programme for new contact geometries to be accelerated.

October 1996

+ SCE	VSL to assist India in uprating an existing interrupter to 250kV bil.
-	Target ratings for new interrupter study changed by group. Group involvement increasing
	Relocation completed.
+	Materials collaboration finally allowed to go ahead.

November 1996

+	Request for uprated (150kV bil) version of VI

	100 requested –tests look good.
-	Group becoming more involved in detail decisions of new interrupter designs – slowing down process.
+ SCE 3	New contact materials laboratory approved - £200,000 investment.
+ SCE 6	M3 to receive Nelson Gold Medal from GEC for outstanding technical innovation.

December 1996

+ SCE 3	VSL appointed sole R&D centre for vacuum interrupter R&D within GEC ALSTHOM group world-wide.
- SDE 4	GEC ALSTHOM buys the power engineering part of AEG from Daimler-Benz, this includes their vacuum interrupter plant in ULM Germany.

7.4 Quarterly situation appraisals

The format of these appraisals was explained in chapter 6. Acronyms are explained by footnotes in the first appraisal.

Quarterly situation appraisal 1; VIL as at March 1992[1] - 30/3/92

Status; Poor 2

The company has seen a change in direction by Group management. A meeting was held between M1, MD of the division controlling VIL, and M2, MD of the division controlling VIL's licensees. At this meeting it is reported that the future of VIL was not in doubt, but that interrupter manufacture would be restricted to 12kV only. This does not tie in with the development programme at DSL aimed at recertifying their equipment with EVI[2] interrupters. However it was also said that VIL would immediately begin recruitment to expand the R&D team, and would produce an expanded R&D programme.

The company has a worry though, in that DSL[3] accounts for 60% of the interrupter sales, and the recent six week strike at DSL has been very damaging to the company.

Key Events;

a). The strike at DSL

b). The meeting between M1 and M2

c). The approval for new recruitment.

d). The move of M3 back to VIL

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[1] For the previous history refer to Appendix A

[2] EVI is European Vacuum Interrupters Limited, A joint venture company between GEC ALSTHOM and Toshiba using Japanese Vacuum Interrupter technology, and as such, effectively a rival to VIL.

[3] DSL is GEC ALSTHOM Distribution Switchgear Limited in Manchester. A sister company, and the main customer for VIL and possibly EVI.

Strategic Position of VIL; Neutral 3

The company is now in an improving position. The meeting between the two group MD's has to some extent cleared the air, with direction being given, if a little vague, and in some cases contradictory. The approval for recruitment is very significant, and will give the company an opportunity to both stabilise its manufacture, and to accelerate the R&D programme.

Tactical Options for R&D;

To pursue the new developments as fast as possible. Although the recruitment and training of new engineers will take time, it will give an opportunity to provide evidence of the technical capabilities of the company. The new manpower will also allow increased assistance to the Production department to give full stability to production in the UK, Africa, and India.

Company Options;

The best approach seems to be to continue to pursue a policy of technical excellence, in designing products for intra company niche markets. This may, as in the past, give a breathing space to the company in order to see how things pan out with EVI/DSL. Providing increased support for the Licensees will also provide benefits, not only in promoting the VIL technology, but also, as has just been seen, in gaining powerful allies.

Short Term Prediction for R&D; Neutral 4

The new product developments will continue, and an expanded R&D team will allow good product support for Production at VIL and the Licensees. We will also be able to take advantage of the combining of the switch and interrupter operations. However the restriction to 12kV only means that the company products are severely limited, and the problems at DSL will result in a poor level of sales for the next year.

Long Term Prediction for R&D; Poor 2

The current problems at DSL will cause major difficulties for VIL as DSL accounts for almost 60% of the interrupter orders. This coupled with the fact that DSL are certifying EVI interrupters for 12kV applications will cause real problems in the future. The proposed expansion in the R&D team will give stability to the company and its licensees, but unless clear direction is given over the company's role in the group and its direction, the prognosis is still not good.

The current prediction is that VSR and VER will be split into two companies. VER will continue in operation in Rugby as a much smaller company, producing HV Starters and Vacuum Contactors, possibly using Toshiba/EVI Switches. VSR will continue in Rugby for a year or so until EVI is fully operational, and then will be closed, with possibly the switch operation remaining to support the starter manufacture.

Quarterly situation appraisal 2; VIL as at June 1992 - 30/6/92

Status; Bad 1

The company is currently undergoing a very difficult time. A lack of orders for both H.V. Starters and Excitation Control Systems has resulted in a serious lack of work for the factory. Vacuum Products orders are currently at a high level, but this is not expected to last. As a result the company has announced 33 redundancies (c 10% of workforce), and a Short Time Working regime. This is expected to last for at least three months, as there is no possibility of extra HV or ECS work in this period.

By order of Group Management the R&D programme is not to be affected by Short Time Working, and recruitment is to proceed. However we are still in the position of having no Applications for Development Expenditure approved for the year. Also the expanded development programme is still held awaiting market information, as is recruitment.

An old historic problem connected with the corrosion resistance of the Vacuum Interrupters manufactured in Finchley has resurfaced with some failures being reported. The devices in question are ten to fifteen years old, but as the service life is twenty years this is perceived as a potentially major problem.

As an added complication the Chief Engineer Vacuum R&D was taken seriously ill, and it is thought that it will be some weeks before he is fit for work.

Key Events;

a). The announcement of 10% redundancies, and Short Time Working.

b). The failure of three old interrupters in the field due to corrosion.

c). The possible new market in Low Voltage Interrupters.

d). The renewed interest in a Recloser Switch for DSL.

e). The new interest in a Ring Main Switch for Long & Crawford.

f). The lack of progress on approval of ADE/ expanded ADE programme.

g). The lack of progress on recruitment.

h). The lack of progress on release of previously completed developments.

Strategic Position of VIL; Bad 1

The company is now in an extremely poor position. The previous financial strength has been eroded, paradoxically by the non-vacuum part of the business. With EVI scheduled to commence manufacture in July, DSL in difficulties with the recession and the aftermath of their strike and large-scale redundancies, and a historic Interrupter problem looming, the company must be approaching an all-time low. The company image with Group is being severely eroded, and unless these problems can be satisfactorily resolved, the outlook is extremely bad. The only good news is a renewed interest in developing new products for other group companies, in niche markets where EVI do not have products. Vigorously pursuing this seems to give the main chance of survival.

Tactical Options for R&D;

To pursue the LV Switch and Ring Main/Recloser developments as fast as possible. If the client GEC ALSTHOM companies can be involved quickly and progress demonstrated then approval of the projects is more likely. As authorisations are slow to come, and may never appear, then a co-operative approach enmeshing the other Group companies into the developments is the approach most likely to succeed. If the projects are eventually approved then the survival of the company is not assured but is more likely for the short term.

Company Options;

The best approach seems to be to continue to pursue a policy of technical excellence, in designing products for intra company niche markets. This may, as in the past, give a breathing space to the company in order to see how things pan out with EVI/DSL. The company must in the short term recover its order situation however otherwise closure is a distinct possibility.

Short Term Prediction for R&D; Poor 2

The new product developments will proceed under local management approval, but fairly quickly they must come to the attention of Group Management. The most likely option is that no decision will be made. Allowing limited progress, but with extremely limited resources.

Long Term Prediction for R&D; Bad 1

The current financial problem due to lack of orders removes the company's major strength. As a result, although interest in new vacuum products from within the group is reviving, the prognosis is bad. This coupled with the lack of progress on approval of developments, the lack of orders from DSL, and the potential major corrosion problem results in a terminal outlook.

The current prediction is that VSR and VER will no longer be split into two companies, but that the complete company will now be closed down within eighteen months. Aspects of the company being disposed of as follows; ECS going to the GEC ALSTHOM operation in Belfort, France, HV Starters going to DSL, Manchester, perhaps with some of the related Contactor business, and aspects of the Vacuum Products going to EVI Montpellier, France, with the balance being closed.

Quarterly situation appraisal 3; VIL as at Sept.1992 - 30/9/92

Status; Bad 1

The company is still undergoing a very difficult time. The lack of orders for both H.V. Starters and Excitation Control Systems has continued in a serious lack of work for the factory. Vacuum Products orders are however maintaining a high level. The 33 redundancies (c 10% of workforce) have now taken place, and the Short Time Working regime has now been working for some time. This is expected to last at least until December, as there is no possibility of extra HV or ECS work in this period.

At the end of July the General Manager & Director left the company suddenly. He had been with the company for over five years. It was rumoured that he had a violent disagreement with the divisional management over policy. M4 was appointed as Acting General Manager, with the M6 the UK Group MD acting as company MD.

By order of Group Management the R&D programme is not to be affected by Short Time Working, and recruitment is to proceed. The unit has been instructed to proceed with a new five year plan for strategic development of the company, marketing led. This is to form the basis of our new expanded development plan. The plan was formulated during the period, and presented to the group MD at the end of September. No representative of R&D was present at the meeting, only finance and commercial. The plan is definitely viable for all sections except Vacuum Interrupters, where meeting the target prices is not possible without major development, and the projected sales volumes are just too small to support the product.

In September a meeting was held with M2 in order to discuss the licensees. At the meeting it was confirmed that VIL suffered from a lack of engineering resource, which affected the development programme and ability to support the licensees. Again it was stated that we would recruit immediately to increase our capabilities and expand our development programme.

Despite this, still no Applications for Development Expenditure have been authorised. A new set for the half year have now been submitted. Personnel are to commence recruitment.

As an added complication the Chief Engineer Vacuum R&D who was taken seriously ill in July is now back at work, but the other Chief Engineer Vacuum Engineering has now gone to hospital for a hip replacement operation, and is not expected back until January.

A further problem is that the new V307 interrupter which was released for manufacture in June, after long delays due to lack of resources, had to be withdrawn almost immediately, as on test it appears to be marginal in performance. It is intended to divert resources to re-engineer this product.

Key Events;

a). The enactment of 33 redundancies, and Short Time Working.

b). The partial failure of the V307 and its withdrawal.

c). The possible new market in Low Voltage Interrupters for GALVI

d). The renewed interest in a Recloser Switch for DSL.

e). The loss of interest in a Ring Main Switch for Long & Crawford.

f). The lack of progress on approval of ADE/ expanded ADE programme.

g). The lack of progress on recruitment

h). The commencement of the TSR1 small interrupter development.

Strategic Position of VIL; Bad 1

The company is now in an extremely poor position. The previous financial strength has continued to be eroded, paradoxically by the non-vacuum part of the business. The perceived instability increased due to the unexpected sudden loss of the General Manager. However EVI's scheduled start of manufacture in July appears to have hit problems with first deliveries being delayed by three months. DSL is still in difficulties with the recession and the aftermath of their strike and large-scale redundancies although they do appear to be staging a recovery. The company position for VIL has not changed substantially since July. Although some of this is good news, it is clouded by the failure of the V307 launch, which strikes at the technical credibility of the company. This was a result of the run down of technical resource in the company, coupled with an unforeseeable problem with our method of testing.

The company image with Group is being severely eroded, and unless these problems can be satisfactorily resolved, the outlook is extremely bad. The good news is a continued interest in developing new products for other group companies, coupled with the apparent problems of EVI. It is rumoured that their problems are both technical and cost based. Vigorously pursuing the new developments and correcting the problems with the V307 seems to give the main chance of survival.

The highly bureaucratic approvals system of GEC ALSTHOM is actually working in the favour of VIL, as no projects have yet been approved for 1992-93 the instruction is to continue against Budget. This effectively gives a relatively free hand to the Technical Director.

Tactical Options for R&D;

To continue to pursue the LV Switch and Recloser developments as fast as possible. If the client GEC ALSTHOM companies can be involved quickly and progress demonstrated then approval of the projects is more likely. Unfortunately the LV Switch does not appear to be commercially viable, and this must be resolved quickly with GALVI or this will be stopped. As authorisations are slow to come, and may never appear, then a co-operative approach enmeshing the other Group companies into the developments is considered the approach most likely to succeed. If the projects are eventually approved then the survival of the company is not assured but is more likely for the short term. Currently the apparent paralysis by Group in approving the ADE is working to the company's advantage in that the apparent tight control is completely ineffectual. Work is proceeding against the general budget proposals in the absence of formal approval of the ADE.

The Key tactic is to develop the new Low cost Small interrupter quickly. This will re-establish the company’s credentials as a technical world leader, and is probably the most important long-term survival action.

Company Options;

The approach of pursuing a policy of technical excellence, has received a blow with the V307 problems, but is recoverable. The other strategy of designing products for intra company niche markets is proceeding, but must result in financial viability to be pursued long term. This may, as in the past, give a breathing space to the company in order to see how things pan out with EVI/DSL. The company must in the short term recover its order situation however, otherwise closure remains a distinct possibility.

Short Term Prediction for R&D; Bad 1

The new product developments will continue to proceed under local management approval, but they must soon come to the attention of Group Management. Having said that, we have already completed half of the year! The most likely option is that no decision will be made on the current development programme, despite the promises made. The three year plan offers the most hope, but again the Vacuum Interrupter developments are proving to be irreconcilable without Group direction on policy.

Recruitment is expected to be slow or non-existent, while resources are continuing to reduce. This is leading to a serious shortage of manpower which is exacerbated by the lack of expertise in the Production and Production Engineering functions. In the last six months this has now become critical, with insufficient resources being available to cope with the development programme and the support to manufacturing. Unless recruitment is forthcoming problems will escalate, both with developments and production.

Long Term Prediction for R&D; Bad 1

The current financial problem due to lack of orders removes the company's major strength. As a result, although interest in new vacuum products from within the group is reviving, the prognosis is bad. This coupled with the lack of approval of developments, the lack of orders from DSL, results in a terminal outlook.

The current prediction continues to be that VSR and VER will no longer be split into two companies, but that the complete company will now be closed down within eighteen months. Aspects of the company being disposed of as follows; ECS going to the GEC ALSTHOM operation in Belfort, France, HV Starters going to DSL, Manchester, perhaps with some of the related Contactor business, and aspects of the Vacuum Products going to EVI Montpellier, France, with the balance being closed.

Quarterly situation appraisal 4; VIL as at Dec.1992 - 2/1/93

Status; Poor 2

The company is now beginning to see an improvement. The lack of orders for both H.V. Starters and Excitation Control Systems has now worked its way through the system. Vacuum Products orders are continuing at a high level. The 33 redundancies (c 10% of workforce) have now taken place, and the Short Time Working regime has now stopped. The company is now working' normally from 4/1/93.

The M5 as the Acting General Manager has not yet had his appointment confirmed. The company is in effect being run directly by M4 who is taking a keen interest in day to day activities.

By order of Group Management the R&D programme was not affected by Short Time Working, and recruitment is still to proceed, although the Personnel department have not yet taken steps to advertise the positions. It is now planned to advertise for UK engineers in January, subject to Group approval. Meanwhile we are planning the secondment of an engineer from India to the UK for two years to assist with the development programme. We have not heard any more of the new five year plan for strategic development of the company, marketing led. This was to form the basis of our new expanded development plan. Although the company budget must have been agreed by the Divisional and Corporate management, we have not yet been informed of its content. This is very unusual.

The V307 interrupter problem is continuing. Lack of resources is hindering the development. The entire VIL development team left when VIL moved from Finchley, and this is also causing problems. This has now been given top priority, although this is somewhat academic as the key projects on Switch development and conversion of V5 and V8 interrupters to Alumina ceramic insulators have now been successfully completed.

M2 has proposed, in view of the needs of India and Africa for new products, and the lack of resource at Rugby, that a Joint Development Programme be set up between the companies, with the design and control being performed by VIL (M3), and the prototype build and test being performed by the Licensees. It was proposed that this commence immediately, but this was stopped by M4, who is insisting on a marketing justification and costing for the project, even though this is to be paid for by our partners and the risk is entirely theirs! This will cause some delay.

Key Events;

a). The ending of Short Time Working.

b). The redevelopment of the V307.

c). The successful completion of the Contactor switch developments.

d). The stopping of the Recloser Switch/TSR1 project by D.R.M4.

e). The stopping of other projects due to lack of resources.

f). The lack of progress on approval of ADE/ expanded ADE programme.

g). The lack of progress on recruitment.

h). The successful completion of the V5 & V8 Alumina development.

I). The proposed Joint development with India and South Africa.

Strategic Position of VIL; Poor 2

The company is now in an interesting position. The previous financial strength is starting to return. The switch factory is running flat out. However the lack of resources is hurting the interrupter and switch business. EVI's scheduled start of manufacture in July appears to have hit serious problems with first deliveries still not appearing! DSL is coming out of its difficulties with the recession and the aftermath of their strike and large-scale redundancies. DSL is changing as an organisation with most of the long service people leaving. The company position for VIL has improved financially, although technically the lack of resources is beginning to have its effect. Although some of this is good news, it is still clouded by the failure of the V307 launch, which strikes at the technical credibility of the company. This was a result of the run down of technical resource in the company, and recovering the situation is hindered by the same lack of resource.

The company image with Group continues to be severely eroded, and unless these problems can be satisfactorily resolved, the outlook remains extremely bad. The good news is a continued interest in developing new products for other group companies, coupled with the apparent problems of EVI. It is rumoured that their problems are both technical and cost based. Vigorously pursuing the new developments and correcting the problems with the V307 seems to give the main chance of survival, however the new interrupter development has been stopped by direct intervention of M4. The proposal for a joint development between India, South Africa, and VIL is now a key project, but is being hindered by Group intervention.

Tactical Options for R&D;

To continue to pursue the Joint Development Programme as fast as possible. If the client GEC ALSTHOM companies can be involved quickly and progress demonstrated then approval of the projects is more likely. If the projects are eventually approved then the survival of the company is not assured but is more likely for the short term. Currently the apparent paralysis by Group in approving the ADE is working to the company's advantage in that the apparent tight control is completely ineffectual. Work is proceeding against the general budget proposals in the absence of formal approval of the ADE. We are now in the ludicrous position of no projects being worked on having received approval, but one, the Recloser/TSR1 project being stopped, effectively because it has not received approval!

The Key tactic to develop the new Low cost Small interrupter quickly remains, as the TSR1 project has been stopped, the features of this device have been incorporated into the proposals for the Joint Development Proposal. This will re-establish the company's credentials as a technical world leader, and is probably the most important long term survival action.

Company Options;

The approach of pursuing a policy of technical excellence, has received a blow with the V307 problems, but is still recoverable. The other strategy of designing products for intra company niche markets has received a blow, but must result in financial viability if pursued long term. This may, as in the past, give a breathing space to the company in order to see how things pan out with EVI/DSL.

Short Term Prediction for R&D; Bad 1

The remaining new product developments will continue to proceed under local management approval. The three year plan offers the most hope, but again the Vacuum Interrupter developments are proving to be irreconcilable without Group direction on policy, and we have not had the increase in resources scheduled in the plan for September 1992. This means that already the plan is out of date.

Recruitment is expected to be slow or non-existent, while resources are continuing to reduce. This is leading to a serious shortage of manpower, which is exacerbated by the lack of expertise in the Production and Production Engineering functions. In the last nine months this has now become critical, with insufficient resources being available to cope with the development programme and the support to manufacturing. Unless recruitment is forthcoming problems will escalate, both with developments and production.

Long Term Prediction for R&D; Bad 1

The current prediction continues to be that VSR and VER will no longer be split into two companies, but that the complete company will now be closed down within twelve months. Aspects of the company being disposed of as follows; ECS going to the GEC ALSTHOM operation in Belfort, France, HV Starters going to DSL, Manchester, perhaps with some of the related Contactor business, and aspects of the Vacuum Products going to EVI Montpellier, France, with the balance being closed.

Quarterly situation appraisal 5; VIL as at March 1993 - 16/4/93

Status; Fair 3

The company is continuing to see an improvement. Orders for both H.V. Starters and Excitation Control Systems have increased. Vacuum Products orders are continuing at a high level. The company is still being run directly by M4 who is UK MD.

We have not heard any more of the new five year plan for strategic development of the company, marketing led. This was to form the basis of our new expanded development plan. The V307 interrupter problem is continuing but there is now confusion as to whether to proceed or not.

Key Events;

b). The banning of the 24kV project by M4

c). The lack of progress on approval of ADE/ expanded ADE programme.

d). The lack of progress on recruitment.

e). The information from GEC ALSTHOM Traction

f). The apparent failure of a V807 in a Traction breaker.

g). The proposed Joint development with India and South Africa.

Strategic Position of VIL; Poor 2

The company is now in an interesting position. The previous financial strength has now returned. The switch factory is running flat out. However the lack of resources is hurting the interrupter and switch business. EVI's scheduled start of manufacture in July 1992 appears to have hit serious problems with first deliveries still not appearing! DSL was coming out of its difficulties with the recession and the aftermath of their strike and previous large-scale redundancies. Now, however, 70 more redundancies have just been announced! The company position for VIL has improved financially, although technically the lack of resources is beginning to have a bad effect. Although some of this is good news, it is still clouded by the failure of the V307, which strikes at the technical credibility of the company. This was a result of the run down of technical resource in the company, and recovering the situation is hindered by the same lack of resource.

The company image with Group continues to be severely eroded, and unless these problems can be satisfactorily resolved, the outlook remains terminal. The good news is a continued interest in developing new products for other group companies, coupled with the apparent continuing problems of EVI. It is rumoured that their problems are both technical and cost based, although certainly the technical problems at least will be solved in time. Vigorously pursuing the new developments and correcting the problems with the V307 seems to give the main chance of survival. However the new interrupter development has been stopped by direct intervention of M4. This proposal for a joint development between India, South Africa, and VIL is now a key project, but is being hindered by Group intervention. Also the revelation by GEC ALSTHOM Traction that M5 told them in January that we would not be manufacturing their interrupters within 18 months. This goes completely against the statements made within the company and appears to indicate that a decision to close the company, or at least the Vacuum Interrupter business, has already been made. Low sales volume, manufacturing problems and a policy to load the interrupter costs is making manufacture increasingly uneconomic.

Tactical Options for R&D;

To continue to pursue the Joint Development Programme as fast as possible. If the client GEC ALSTHOM companies can be involved quickly and progress demonstrated, then approval of the projects is more likely. Currently the apparent paralysis by Group in approving the ADE is working to the company's advantage in that the apparent tight control is completely ineffectual. Work is proceeding against the general budget proposals in the absence of formal approval of the ADE. We are now in the ludicrous position of no projects receiving approval during the 1992-93 year, although the development programme actually continued against budget.

The Key tactic to develop the new Low cost Small interrupter quickly remains a priority. When the TSR1 project was stopped, the features of this device were incorporated into the proposals for the Joint Development Proposal. As this will probably not receive approval, the features of the project have been transferred to a general technology project for 1993-94 aimed at developing the technology of the next generation of vacuum interrupters. As this is suitably vague it is hoped that we will have a device soon to demonstrate the concept. This will re-establish the company's credentials as a technical world leader, and is probably the most important long-term survival action.

Company Options;

The approach of pursuing a policy of technical excellence, has received a blow with the V307 problems, but is still recoverable. The other strategy of designing products for inter company niche markets has received a blow, but must result in financial viability if pursued long term. This may, as in the past, give a breathing space to the company in order to see how things pan out with EVI/DSL. This is particularly important in view of the appointment of M5.

Short Term Prediction for R&D; Poor 2

The new product developments for 1993-94 will continue to proceed under local management approval. The three year plan offers the most hope, but again the Vacuum Interrupter developments are proving to be irreconcilable without Group direction on policy, and we have not had the increase in resources scheduled in the plan for September 1992. This means that already the plan is out of date.

Recruitment is expected to be slow or non-existent, while resources are continuing to reduce. This is leading to a serious shortage of manpower which is exacerbated by the lack of expertise in the Production and Production Engineering functions. In the last twelve months this has become critical, with insufficient resources being available to cope with the development programme and the support to manufacturing. Unless recruitment is forthcoming problems will continue to escalate, both with developments and production.

Long Term Prediction for R&D; Bad 1

The current prediction is now that VSR and VER may be split into two companies, but that the VSR company will now be closed down within twelve months. This may however change with the appointment of M5. Local Divisional management still appears to be following the old plan, however.

Quarterly situation appraisal 6; VIL as at June 1993 - 22/6/93

Status; Bad 1

A major restructuring of the company was announced. Two thirds of the workforce are to be made redundant. The HV motor starter product is to be moved to DSL in Manchester, with the commercial function remaining for the time being in Rugby. The ECS function is to be transferred to the GEC ALSTHOM Machines company in Rugby. The manufacture of 12kV interrupters is to cease with demand being met by EVI in France. VIL will continue to manufacture 36kV interrupters and also those for special applications such as Traction. Despite the previous indications the change came as a surprise to the workforce, particularly as the company is continuing to see an improvement. Orders for both HV. Starters and Excitation Control Systems have increased. Vacuum Products orders are continuing at a high level.

The reason why the M5, the Acting General Manager has not yet had his appointment confirmed is now clear. The company is in effect still being run directly by M4 who is taking a keen interest in day to day activities. As it is likely that the entire Personnel department will be made redundant Personnel officers from DSL have been seconded to VIL to handle the redundancy programme.

Meanwhile we have arranged the secondment of an engineer from India to the UK for two years to assist with the development programme. The reason why we were not informed of the Budget proposals is now clear. Interestingly the Budget does not reflect the current situation, as an analysis of the figures clearly show that the company (VIL) was to completely close by March 1994. As the Budget was submitted in November 1992, this decision must have since been modified, probably in the light of technical problems at EVI which delayed the start up of interrupter manufacture by almost 12 months, the fact that GEC ALSTHOM Traction convinced the divisional management that the EVI interrupters were significantly inferior to VIL for Traction applications and were totally unsuitable, and also due to the change of management of T&D division with the early retirement of M1 and his replacement by M5. M5 is reported to be unhappy with the situation on interrupter technology, specifically that he sees that at EVI the key technology is and remains Toshiba. EVI will not provide a route for GEC ALSTHOM to develop its own technology. As a result he appears to be following two paths. Firstly he has commenced an effort to develop knowledge of the technology at the research laboratories in France. Secondly he has said that we must not lose our in house ability to design and develop vacuum interrupter technology which currently is only at VIL in Rugby. In connection with this M4 has made some effort to convince M3 to stay with the Group, and that there is a role for an expert in this field within GEC ALSTHOM.

The V307 situation is still confused. GEC ALSTHOM South Africa are now to test the interrupter for 31.5kA in their circuit breaker at their next test access, which is not scheduled until next year. Meanwhile it appears that they have been manufacturing V307 interrupters and selling them for the lower rating of 25kA for some time. This was without VIL's knowledge

Key Events;

a). The restructuring of VIL.

b). The continuation of support for licensees

c). The intention to retain Vacuum Interrupter knowledge.

d). The lack of progress on recruitment.

e). The abandonment of the R&D programme.

f). The secondment of the engineer from India.

g). The starting of development programmes be India and South Africa

Strategic Position of VIL; Bad 1

The company's position has now completely changed. Despite the fact that the previous financial strength has now returned, and the switch factory is running flat out, the restructuring of the company will result in two thirds of the employees being made redundant.

Tactical Options for R&D;

To continue to pursue the Joint Development Programme as fast as possible. If the client GEC ALSTHOM companies can be involved quickly and progress demonstrated, then approval of the projects is more likely. Currently the apparent paralysis by Group in approving the ADE is working to the company's advantage in that the apparent tight control is completely ineffectual. Work is proceeding against the general budget proposals in the absence of formal approval of the ADE. We are now in the ludicrous position of no projects receiving approval during the 1992-93 year, although the development programme actually continued against budget.

The Key tactic to develop the new Low Cost Small interrupter quickly remains. When the TSR1 project was stopped, the features of this device were incorporated into the proposals for the Joint Development Proposal. As this will probably not receive approval, the features of the project have been transferred to a general technology project for 1993-94 aimed at developing the technology of the next generation of vacuum interrupters. As this is suitably vague it is hoped that we will have a device soon to demonstrate the concept. This will re-establish the company's credentials as a technical world leader, and is probably the most important long-term survival action.

Company Options;

The approach of pursuing a policy of technical excellence, has received a major blow, but may still be recoverable. In fact its success can be seen by the fact that for the time being the interrupter and switch business is to survive. This was not the original plan, and has been forced by the technical superiority of some of the products, particularly for traction applications. However the situation is still particularly dangerous, and can only be a temporary reprieve. In order to give long term survival something more is needed, and the key is in the TSR project. If this can result in a new low cost technology for 12kV this should give credibility and more value to the survival of VIL. Although there may be resistance to 12kV in view of its direct confrontation with EVI the fact that VIL is to produce interrupters for special applications may give an opportunity. There is a need for a very low cost interrupter for Recloser applications for DSL. Toshiba do not have a suitable product, and currently they are buying from Westinghouse. If VIL can supply a suitable product which is also suitable for 12kV this may give an opening.

Short Term Prediction for R&D; Bad 1

The new product developments for 1993-94 have now been stopped. It is planned that no R&D will be carried out during the current financial year. Indeed the actual budget shows no spend on R&D. However in discussions with Group management it has been vaguely agreed that some R&D can be carried out if resources permit. I am intending to continue with the TSR1 & TSR2 projects for the time being. It is likely, however that the full resources of the department will be absorbed in the restructuring of the company. Morale is very low, and most employees believe that the remnants of the company will close within a year.

Long Term Prediction for R&D; Bad 1

The current prediction is now that VIL continues for the time being, but cannot be economic. The HV section remaining in Rugby will stay for six months then be transferred to Manchester or closed down. The vacuum business will continue to operate at a loss until GEC ALSTHOM in France believe that they have sufficient expertise to design and develop a new range of interrupters, after which the VIL company will be closed down within twelve months.

Quarterly situation appraisal 7; VIL as at Sept. 1993 - 22/10/93

Status; Bad 1

The major restructuring commences with major redundancies. In total two thirds of the workforce are to be made redundant by next April. The manufacture of 12kV interrupters is to cease with demand being met by EVI in France. VIL will continue to manufacture some 36kV interrupters and also those for special applications such as Traction, although a major effort is to be made to convert DSL circuit breakers to EVI products where possible. Despite this the company is continuing to see an improvement orders for HV. Starters, Switches and Vacuum Interrupters and Excitation Control Systems.

The seconded engineer from India has arrived to assist with the development programme. This is particularly bad timing with regard to the redundancy programme. Interestingly the Budget issued in April transpires to have been a dummy just to fool VIL employees. The real budget is now revealed and an analysis of the figures clearly show that the company (VIL) was to completely close by March 1994. M5 is reported to be still unhappy with the situation on interrupter technology and he still appears to be following two paths. Firstly he has commenced an effort to develop knowledge of the technology at the research laboratories in France. Secondly he has said that we must not lose our in house ability to design and develop vacuum interrupter technology which currently is only at VIL in Rugby.

The V307 situation is still confused. VIL have now been instructed to proceed no further with the V307 project which is officially a failure. VISA continue to manufacture V307 interrupters without permission.

Key Events;

a). The restructuring of VIL.

b). The continuation of support for licensees

c). The intention to retain Vacuum Interrupter knowledge.

d). The lack of progress on recruitment.

e). The abandonment of the R&D programme.

f). The secondment of the engineer from India.

g). The starting of development programmes be India and South Africa

Strategic Position of VIL; Bad 1

The company's position has deteriorated. Mass redundancies will seriously change the company.

Tactical Options for R&D;

To continue to pursue the Joint Development Programme as fast as possible. If the client GEC ALSTHOM companies can be involved quickly and progress demonstrated, then approval of the projects is more likely. The R&D programme has now been stopped. Although permission has been received to continue a low level of development with minimal expenditure to keep the team busy.

The Key tactic to develop the new Low Cost Small interrupter quickly remains, but is now more difficult, the features of the project have now been transferred to a general technology project for 1993-94 aimed at developing the technology of the next generation of vacuum interrupters. As this is suitably vague it is hoped that we will be allowed to proceed.

Company Options;

The approach of pursuing a policy of technical excellence, has received a major blow, but may even now be recoverable. In order to give long-term survival our technical reputation is needed, and the key is in the TSR project. If this can result in a new low cost technology for 12kV this should give credibility and more value to the survival of VIL. Although there may be resistance to 12kV in view of its direct confrontation with EVI the fact that VIL is to produce interrupters for special applications may give an opportunity. There is a need for a very low cost interrupter for Recloser applications for DSL. Toshiba do not have a suitable product, and currently they are buying from Westinghouse. If VIL can supply a suitable product which is also suitable for 12kV this may give an opening.

Short Term Prediction for R&D; Bad 1

The new product developments for 1993-94 have now been stopped. It is planned that no R&D will be carried out during the current financial year. Indeed the actual budget shows no spend on R&D. However in discussions with Group management it has been vaguely agreed that some R&D can be carried out if resources permit. I am intending to continue with the TSR1 & TSR2 projects for the time being. It is likely, however that the full resources of the department will be absorbed in the restructuring of the company. Morale is very low, and most employees believe that the remnants of the company will close within a year.

Long Term Prediction for R&D; Bad 1

The current prediction is now that VIL continues for the time being, but cannot be economic. The HV section remaining in Rugby will stay for six months then be transferred to Manchester or closed down. The vacuum business will continue to operate at a loss until GEC ALSTHOM in France believe that they have sufficient expertise to design and develop a new range of interrupters, after which the VIL company will be closed down within twelve months.

Quarterly situation appraisal 8; VIL as at Dec. 1993 - 12/1/94

Status; Poor 2

The major restructuring continues with major redundancies before Christmas. Half of the workforce have now gone, with most of the rest to be made redundant by next April. The manufacture of 12kV interrupters is to cease by next April . VIL will continue to manufacture some 36kV interrupters and also those for special applications such as Traction. Orders for interrupters increases greatly as customers are informed that this is a final possibility of buying spares.

The small interrupter development is continuing at a low level. Morale is very low. Concern is expressed over the support of technology for Licensees. EVI overcome their problems and start production. M3 asked to give paper on vacuum technology in India. This is a request by the UK MD of GEC ALSTHOM and cannot be refused. M4 resigns, joins a competitor.

Key Events;

a). The restructuring of VIL.

b). The continuation of support for licensees

c). The intention to retain Vacuum Interrupter knowledge.

d). The lack of progress on recruitment.

e). The abandonment of the R&D programme.

f). The secondment of the engineer from India.

g). The starting of development programmes be India and South Africa

h). The resignation of M4.

Strategic Position of VIL; Bad 1

The company's position has deteriorated, with the mass redundancies reducing the company's ability to perform. Quality of the products in doubt due to morale.

Tactical Options for R&D;

To pursue the Joint Development Programme as fast as possible. Also to try to reduce damage to manufacturing during redundancy period. Maintain quality as far as possible.

The Key tactic to develop the new Low Cost Small interrupter quickly remains, but is now more difficult, although allowed to proceed effort is being diverted into maintaining output and quality.

Company Options;

The approach of pursuing a policy of technical excellence, has received a further blow. In order to give long term survival our technical reputation is needed, and the key is in the TSR project. However more and more effort is being absorbed in just keeping the company afloat. Also during this period the Chief Engineer Vacuum Interrupters retired and will not be replaced, further reducing resources.

Short Term Prediction for R&D; Bad 1

The new product developments for 1993-94 have now been stopped. It is planned that no R&D will be carried out during the current financial year. The section is still intending to continue with the TSR1 & TSR2 projects, but effort is limited as production problems are building as the workforce is made redundant. Morale is very low, and most employees believe that the remnants of the company will close within a year.

Long Term Prediction for R&D; Bad 1

The current prediction is now that VIL continues for the time being, but cannot be economic. The HV section remaining in Rugby will stay for six months then be transferred to Manchester or closed down. The vacuum business will continue to operate at a loss until GEC ALSTHOM in France believe that they have sufficient expertise to design and develop a new range of interrupters, after which the VIL company will be closed down within twelve months.

Quarterly situation appraisal 9; VIL as at March 1994 - 21/4/94

Status; Bad 1

The major restructuring is now effectively complete. Over 90% redundancies in the last eighteen months!

Possible quality problems have been noted in the field with some interrupters. A decision is made to replace production since last September. This requires a major expenditure and high level of manufacture for the next six months. Company credibility badly damaged. VIL will continue to manufacture some 36kV interrupters and also those for special applications such as Traction.

The small interrupter development is continuing at a low level. Morale is very low. EVI are now in full production. VIL told that VIL are to remain as an R&D centre for Contactors and switches only. No power vacuum interrupters to be developed. However as neither Westinghouse nor EVI have a suitable interrupter for 27kV Recloser requirement VIL allowed to proceed with a low level development.

Key Events;

a). The restructuring of VIL.

b). The restriction of the R&D programme.

f). The Quality problems in the Field

g). The starting of development programmes be India and South Africa

h). The decision to allow Recloser interrupter development.

Strategic Position of VIL; Bad 1

The company's position has deteriorated, with the mass redundancies reducing the company's ability to perform. Quality of the products now seriously in doubt, major problems seen in the field.

Tactical Options for R&D;

The Key tactic to develop the new Low Cost Small interrupter quickly remains, but is now channelled into the Recloser requirements. If possible this may be the vehicle to show our abilities in this technology.

Company Options;

The approach of pursuing a policy of technical excellence, has received a further blow with the field problems, although this has been attributed, correctly to the disruption caused by the reorganisation and redundancy programme. In order to give long-term survival our technical reputation is needed, and the key is in the Recloser project. This may be the opportunity to shine.

Short Term Prediction for R&D; Bad 1

The new product developments for 1994-95 have now been severely limited. The policy is still to continue with the TSR1 & TSR2 projects, under the guise of the Recloser interrupter. It may be possible to illustrate our capabilities with this, but the technical requirement is very great, and it may not be possible to do other than meet the bare specification . Morale is extremely low, and most employees believe that the remnants of the company will still close within a year.

Long Term Prediction for R&D; Poor 2

The current prediction is now that VIL continues for the time being, but cannot be economic. The HV section remaining in Rugby will stay for six months then be transferred to Manchester or closed down. The vacuum business will continue to operate at a loss until GEC ALSTHOM in France believe that they have sufficient expertise to design and develop a new range of interrupters, after which the VIL company will be closed down within twelve months, unless the TSR work can be turned to advantage in the Recloser project.

Quarterly situation appraisal 10; VIL as at June 1994 - 17/7/94

Status; Poor 2

The major restructuring is now complete. Programme for contactor and switch development commenced, but little interest from Division. Major exercise in progress to replace products in the field, although not strictly necessary. This has resulted in a continuation of manufacture of the 12kV interrupter range. Surprisingly large orders for the other interrupters are also received. It is believed that the EVI range do not meet all of the requirements for the more difficult ratings. Official policy still to close 12kV production as soon as possible. Other quality problems surfaced on Vacuum Switches and Contactors in the field.

The small interrupter development is continuing at a low level. However using the technology developed in the TSR projects it may be possible to develop a very low cost general purpose interrupter for 12kV applications as well as 27kV requirement. Morale is still very low. M3 made a large effort to attend major conference on Vacuum Arcs. Morale very low company now just 37 people. (One year ago almost 375).

Key Events;

a). The restructuring of VIL.

b). The restriction of the R&D programme.

f). The Quality problems in the Field

g). The decision to allow Recloser interrupter development.

h). The decision to allow M3 to attend conference.

Strategic Position of VIL; Bad 1

The company's position has deteriorated, with the mass redundancies reducing the company's ability to perform. Quality of the products now seriously in doubt, major problems in the field are being dealt with. A large proportion of effort is still being absorbed in fire fighting.

Tactical Options for R&D;

The Key tactic to develop the new Low Cost Small interrupter quickly remains, but is now channelled into the Recloser requirements. Indications are that we may be able to produce a very good product.

Company Options;

The approach of pursuing a policy of technical excellence, has received a further blow with the field problems. However the Recloser project has great possibilities, which are not realised by the group management. It is intended to produce a general purpose interrupter with specific abilities at 12kV. Although this goes against instructions, once it is available it is believed that this will produce pressure within the organisation to be used, and incidentally may make allies of our customer companies within the group

Short Term Prediction for R&D; Bad 1

Despite the new product developments for 1994-95 being severely limited. The Recloser project has great strategic possibilities and if successful will be a powerful weapon in convincing our division of our worth. Longer term the usage at 12kV will also bring us back to large scale production, although this will also bring us head on against EVI. Morale is extremely low, and most employees still believe that the remnants of the company will still close within a year.

Long Term Prediction for R&D; Poor 2

The current prediction is now that VIL continues for the time being, but still cannot be economic. The HV section remaining in Rugby will stay for six months then be transferred to Manchester or closed down. The vacuum business will continue to operate at a loss until GEC ALSTHOM in France believe that they have sufficient expertise to design and develop a new range of interrupters, after which the VIL company will be closed down within twelve months. An alternative is if the Recloser project is very successful and the project to build a facility in France hits problems.

Quarterly situation appraisal 11; VIL as at Sept. 1994 – 18/10/94

Status; Poor 2

Large orders for interrupters continue to be received particularly for the niche ratings. Official policy is still to close 12kV production as soon as possible. Quality problems on Vacuum Switches and Contactors are dealt with.

The small interrupter development is continuing at a low level. Testing carried out for 12kV applications as well as 27kV with good results. Morale is still very low. Company now consists of just 35 people.

Key Events;

a). The restructuring of VIL.

b). The restriction of the R&D programme.

f). The Quality problems in the Field

g). The decision to allow Recloser interrupter development.

Strategic Position of VIL; Poor 2

The company's position continues to deteriorate. Quality problems in the field are being dealt with. A large proportion of effort is still being absorbed in fire fighting.

Tactical Options for R&D;

The Key tactic to develop the new Low Cost Small interrupter quickly remains, but is now channelled into the Recloser requirements. Test results confirm that that we may be able to produce a very good product for 12kV as well as the original 27kV requirement.

Company Options;

Continue to build reputation within group of technical excellence and prowess. Build on Low Cost Interrupter project to give indication of possibilities at 12 kV. Vital to maintain cost reductions in other areas such as uprating vacuum switches to 6 kA, and perform major cost reductions on existing contactor products for short term survival.

Short Term Prediction for R&D; Poor 2

The Low Cost Interrupter project has great strategic possibilities and if successful will be a powerful weapon in convincing our division of our worth. Longer term the usage at 12kV is a two edged sword, on one hand it could bring us back to large scale production, on the other hand it will bring conflict with EVI. Overall morale is still extremely low, and most employees still believe that the remnants of the company will still close within a year.

Long Term Prediction for R&D; Poor 2

The current prediction is now that VIL continues for the time being, but still cannot be economic. The HV section is being transferred to Manchester. The vacuum business will continue to operate at a loss until GEC ALSTHOM decided to close Rugby. VIL to be closed down within twelve months.

Quarterly situation appraisal 12; VIL as at Dec. 1994 - 25/1/95

Status; Good 4

The company position has changed somewhat in the last three months. The successful certification of the Low Cost Interrupter (VI 100) in the OXR has re-established the company's technical credibility with the group. This image has been further enhanced by the cost reduction work carried out on vacuum switches and Contactors in parallel. Because of this the continued existence of the R&D function appears no longer in doubt. In fact the apparent weakness and problems of EVI coupled with this have further enhanced VIL's position. However DSL the company's main customer does appear to have problems, and the closing of the DSL support in Rugby for the motor starter business will not help sales of switches for VIL. The ongoing redundancies also affect the atmosphere of the company. We have been in a continuing redundancy situation now for over two years!

Although the R&D department now appears to be in a good position, it is still threatened by poor control of the manufacturing function, with resultant quality problems in the field, and disruption of the R&D programme due to the high level of support required.

The manufacturing level at VIL is still too low to be really viable. The policy of only supplying GEC ALSTHOM customers may be logical, but this internal market is currently too small and growth is to a great extent out of VIL's control. The overseas licensees do not have this market restriction, and are currently reported to be making large quantities of interrupters. The Licensees are also pursuing their own R&D programmes, with some success, and this can only threaten VIL's position in the long term.

Key Events;

a). The certification of the VI 100 in the OXR, ahead of schedule, and at a rating higher than specified.

b). The continuation of support for licensees

c). The release of some capital expenditure in the year.

d). The lack of progress on recruitment.

e). The appointment of M19 as UK Group MD

f). The appointment of M6 as Director & General Manager of Long and

Crawford in Manchester.

g). The perceived problems with EVI and also Toshiba.

Strategic Position of VIL; Good 4

Once again the company's position has completely changed! Due to the actual success in obtaining certification for the VI 100 in the OXR, both at the original rating, and also at an enhanced rating. Taken in conjunction with the perceived technical prowess of the company, VIL now appears to have a secure future as the technical centre of excellence for vacuum switching technology. In addition problems with the actual performance of EVI together with the perceived problems, means that VIL appears now to be not just a bargaining counter to Toshiba, but an asset in its own right. Also there appears to be a loosening of the restrictions on capital expenditure.

Tactical Options for R&D;

The key tactic to develop the new Low Cost Small Interrupter appears to have been successful. This has re-established the company's credentials as a technical world leader. It is now vital to build upon this and to prevent any other problems, such as production quality from tarnishing the image. The high perceived cost of the EVI product together with its high minimum rating is a weakness which may be carefully exploited. A very low cost interrupter based on the VI 100 rated at, say, 12 kV; 16 kA would be very popular, and would meet the major UK requirement. However this would also eat into a major part of the EVI market. Although this would not be allowed, the comparison of technology would be very favourable to VIL, and long term would apply pressure to change. The development of a small range of miniature interrupters would also fulfil the real needs of the Licensees and if made available to them would remove the need for any further local development. Unfortunately the transfer of technology in this way appears to be against the T&D policy! The availability of such devices may however provide sufficient pressure that the group allows this.

Company Options;

Continue to build reputation within group of technical excellence and prowess. Build on VI 100 project to give indication of possibilities at 12 kV. Also maintain cost reductions in other areas such as uprating vacuum switches to 6kA, and performing major cost reductions on existing contactor products. This will give a good basis for the growth of manufacturing within one to two years.

Short Term Prediction for R&D; Fair 3

Survival of VIL as an R&D unit. Continued loss of non group customers. Success in R&D programme, but a reluctance to exploit this as products competing with EVI. A loosening of restrictions on company, and progress with recruitment. Further enhancement of reputation. This may have a negative effect, possibly causing delays in programme due to embarrassment. India and South Africa will continue their development programmes independently.

Long Term Prediction for R&D; Good 4

Survival of VIL as an R&D unit, but with a revival of manufacturing volumes within three years. Also more co-operation with licensees and spreading of technology for manufacture within the group. Centralisation of R&D at Rugby. Possible absorption of EVI within GEC ALSTHOM?

Quarterly situation appraisal 13; VIL as at March 1995 - 24/4/95

Status; Good 4

The company position has solidified in the last three months. The performance of the VI 100 continues to re-establish the company's technical credibility with the group, despite some sniping on the part of other units. In particular DSL tried to use minor problems and events on test to muddy the VI 100's image and to cover up problems with the circuit breaker. This effort has had only limited success, with the VI 100 still perceived as a world beater. The continued existence of the R&D function is now no longer in doubt. Further problems at EVI coupled with the rising Yen have further enhanced VIL's position. The last of the redundancies have just taken place, and hopefully the situation will now improve. We have been in a continuing redundancy situation now for over two and a half years!

The R&D department now appears to be in a good position, and control of the manufacturing function has been improved, although at the cost of some disruption of the R&D programme due to the high level of support required. This was seen as a necessary investment in order to safeguard the company's image with the group. The manufacturing level at VIL continues to be too low to be really viable, although the low cost and high level of performance of the VI 100 appears to be giving substantially increased possible sales of the OXR unit, as well as possibilities for use in normal 12kV circuit breakers.

The overseas licensees are currently reported to be making large quantities of interrupters. The Licensees are also pursuing their own R&D programmes, with limited success, South Africa have now formally requested to buy VI 100 interrupters for their Recloser programme, this has been refused for the moment.

A strange effect of the success of the VI 100 was the release of capital expenditure in the year. This was used for the purchase of two portable computers for the General Manager and the Chief Accountant, after a period a third unit was purchased for the Technical Director, which was only the second piece of equipment bought for the R&D department in five years! One other effect of the success was negative, a renewed and increasing interference in the running of the R&D by both UK management and French Divisional management. They are attracted to the apparent success. There is also a rumour that the department may be moved into different, improved accommodation.

Key Events;

a). Further certification of the VI 100 in the OXR, and testing in the BLV circuit breaker.

b). The continuation of support for licensees

c). The release of some capital expenditure in the year.

d). The lack of progress on recruitment.

e). The appointment of M6 as Director & General Manager of Long and Crawford in Manchester.

f). The perceived problems with EVI and also Toshiba.

g). The further successes of the VI 100 during test.

h). The new interest and interference in the R&D function.

Strategic Position of VIL; Excellent 5

Due to further success in obtaining certification for the VI 100 in the OXR, and testing well outside the rating the perceived technical prowess of the company, is strong enough to withstand knocking from DSL in problems with the test which can be laid at the door of their OXR unit. In addition further problems with the actual performance of EVI together with the increasing value of the Yen, means that VIL are being increasingly rated as the important option for the company.

Tactical Options for R&D;

The key tactic to develop the new Low Cost Small Interrupter appears to have been more successful than imagined. There now appears to be no doubt the VIL are the technical centre of excellence and may indeed be a world force in this technology. The tactic of building upon this by making a conscious effort to improve production quality has maintained the image, even against some criticism and indeed some small setbacks. The high and increasing perceived cost of the EVI product together with its high minimum rating is a weakness, which has now been noted. The VI 100 has now been proven at 12 kV;16 kA. However for the moment this is not an option for VIL as this would also eat into a major part of the EVI market. The development of a small range of miniature interrupters has also been noted by the Licensees and although not yet available to them, pressure is increasing to allow them to buy or make, which would in time remove the need for any further local development. Issue discussion paper on R&D

programme, manpower and resources. Take control of the future.

Company Options;

Continue to build on the reputation within group of technical excellence and prowess. Attempt to widen credibility by success in other areas such as uprating vacuum switches to 6 kA, and performing major cost reductions on existing contactor products. This will also give a good basis for the growth of manufacturing within one to two years. Apply pressure to use VI 100 in 12kV switchgear. In addition use current reputation to improve resources. Such as equipment, working conditions and manpower.

Short Term Prediction for R&D; Good 4

Survival of VIL as an R&D unit. Continued loss of non group customers. Success in R&D programme. A loosening of restrictions on company, and progress with recruitment. Further enhancement of reputation. This may have a negative effect, as increased interference is being felt in the running of the R&D programme. India and South Africa will continue their development programmes independently.

Long Term Prediction for R&D; Excellent 5

Survival of VIL as an R&D unit, but with a revival of manufacturing volumes within two years. Limited co-operation with licensees and spreading of technology for manufacture within the group. Centralisation of R&D at Rugby. Improvement of resources at Rugby, but increased interference by others in R&D.

Quarterly situation appraisal 14; VIL as at June 1995 - 20/6/95

Status; Excellent 5

The company position has continued to solidify. The VI 100 continues to re-establish the company's technical credibility with the group. The continued existence of the R&D function is now no longer in doubt.

The R&D department now appears to be in a very good position, and the company's image with the group is being restored. In fact so much so that plans are made to move the department into new building together with new equipment and desks! It is said that the department needs to look like a work class unit! In addition recruitment of new staff commences in earnest.

The manufacturing level at VIL still continues to be too low to be really viable, although the VI 100 is attracting interest, which may lead to orders. The Licensees are continuing to pursue their own R&D programmes, with limited success.

The UK management and French Divisional management continue to become more active in the R&D programme.

Key Events;

a). The planning of a relocation of R&D.

b). The continuation of support for licensees

c). The release of some capital expenditure in the year.

d). Recruitment commences.

e). The appointment of M6 as Director & General Manager of Long and Crawford in Manchester.

g). The further successes of the VI 100 during test.

h). The new interest and interference in the R&D function.

Strategic Position of VIL; Excellent 5

VIL are being increasingly rated as the important option for the company exemplified by the planned move to new improved premises.

Tactical Options for R&D;

The key tactic to develop the new Low Cost Small Interrupter appears to have been far more successful than imagined. VIL are now seen as the technical centre of excellence and as a result it is planned to move into premises in keeping with this image. The VI 100 continues to be proven at 12 kV; 16 kA. The discussion paper on R&D programme, manpower and resources was issued and a response is awaited.

Company Options;

Continue to build on the reputation within group of technical excellence and prowess. Continue the attempt to widen credibility by success in other areas such as uprating vacuum switches to 6 kA, and performing major cost reductions on existing contactor products. In addition build on the reputation to improve resources including equipment, working conditions and manpower.

Short Term Prediction for R&D; Excellent 5

Continued survival of VIL as an R&D unit. Success in R&D programme with continued progress with recruitment. Further enhancement of reputation with the new premises and equipment. This may have a negative effect, as increased interference is being felt in the running of the R&D programme. India and South Africa will continue their development programmes independently.

Long Term Prediction for R&D; Excellent 5

Survival of VIL as an R&D unit. A revival of manufacturing volumes within two years. Limited co-operation with licensees and spreading of technology for manufacture within the group. Centralisation of R&D at Rugby with a significant improvement of resources at rugby. Increasing interference by others in R&D.

Quarterly situation appraisal 15; VIL as at Sept.1995 - 20/10/95

Status; Excellent 5

The continuing redundancy situation is now completely over. New recruitment is in progress and the move to new facilities is taking place.

The R&D department now appears to be in a good position with new high quality offices, computer facilities and laboratories. The overseas licensees are making large quantities of interrupters but their own R&D programmes are not making progress.

Key Events;

a). The move to new facilities and accommodation

b). The continuation of support for licensees

c). The continued release of some capital expenditure in the year.

d). Progress made on recruitment.

g). The further successes of the VI 100 during test.

h). The new interest and involvement in the R&D function.

Strategic Position of VIL; Excellent 5

The new facilities confirm the view by Group that VIL are the preferred option for interrupter technology. This is seen as a commitment to the future.

Tactical Options for R&D;

The key tactic to develop the new Low Cost Small Interrupter has clearly been successful. There is no doubt the VIL are now the technical centre of excellence for the Group and are seen as a world force in this technology. The discussion paper with proposals on R&D programme manpower and resources is still under consideration.

Company Options;

Continue to build on the reputation within group of technical excellence and prowess. Continue to widen credibility by success in uprating vacuum switches to 6 kA, and performing major cost reductions on existing contactor products. Write technical papers if possible to enhance technical reputation.

Short Term Prediction for R&D; Good 4

Survival of VIL as an R&D unit. Continued loss of non group customers. Success in R&D programme. A loosening of restrictions on company, and progress with recruitment. Further enhancement of reputation. Increasing interference by Group in the running of the R&D programme. India and South Africa will continue their R&D programmes.

Long Term Prediction for R&D; Good 4

Survival of VIL, as both an R&D unit, and as a manufacturing unit for the foreseeable future. Continuing limited co-operation with licensees and spreading of technology for manufacture within the group. Centralisation of R&D at Rugby. Improvement of resources at rugby with increased interference by Group in R&D.

Quarterly situation appraisal 16; VIL as at Dec. 1995 -

Status; Excellent 5

The company position has again improved over the last three months. The continued existence of the R&D function is now no longer in doubt with three new recruits starting in January. The R&D department is now at full strength. Some disruption of the R&D programme continues due to the high level of support required to production, particularly to determine the cause of pressure problems with vacuum switches.

A surprising change was the exchange of roles between M8 and M7 at group level. M8 becomes Group Industrial Director, which was M7's previous role, and M7 becomes Group Managing Director. Presumably this will affect company policy at the unit level.

The manufacturing level at VIL continues to be low, although an order for 1,992 of the VI 100 interrupters has been received for delivery over the next twelve months.

The overseas licensees are still reported to be making large quantities of interrupters. With India still awaiting approval for its increase in capacity. Interference in the running of the R&D is increasing in direct proportion to the perceived success of the unit, by both UK management and French Divisional management. In addition the new Group R&D Director is attempting to invoke a new tight control over all R&D activities in the group.

Key Events;

a). VI 100 interrupters supplied to Sprecher Energie Switzerland for incorporation in their12kV and 24kV circuit breakers.

b). The continuation of support for licensees, mainly India

c). The change of M8 and M7's roles.

d). The completion of the recruitment programme.

e). The continued perceived problems with EVI and also Toshiba.

f). The receipt of the first production order for VI 100 interrupters

g). The new interest and interference in the R&D function.

Strategic Position of VIL; Excellent 5

The increasing value of the Franc and the Yen, is seriously affecting the viability of the EVI interrupters, and means that VIL are being increasingly rated as the important long term option for the company.

Tactical Options for R&D;

To build up the technical expertise and reputation of the unit. As we have now received the resources asked for, progress must be seen to be made. It is important to set up the R&D programme to drip feed successes, albeit small ones, for the divisional management. Also to improve visibility within the company.

Company Options;

Continue to build on the reputation within group of technical excellence and prowess. Attempt to widen credibility by success in other areas such as uprating vacuum switches to 6 kA, and performing major cost reductions on existing contactor products. This will also give a good basis for the growth of manufacturing within one to two years. Continue to apply pressure to use VI 100 in 12kV switchgear.

Short Term Prediction for R&D; Good 4

Survival of VIL as an R&D unit. Continued loss of non-group customers. Success in the R&D programme. Increased interference in the running of the R&D programme. India and South Africa will continue their development programmes independently.

Long Term Prediction for R&D; Good 4

Survival of VIL mainly as an R&D unit, but with a revival of manufacturing volumes within a year. Limited co-operation with licensees and spreading of technology for manufacture within the group. Centralisation of R&D at Rugby. Improvement of resources at Rugby but increased interference by others in R&D.

Quarterly situation appraisal 17; VIL as at March 1996 - 14/4/96

Status; Excellent 5

The company position has been mixed over the last three months. With the approval for new product research on AMF contacts an opportunity has been given to shine. However the refusal to approve the collaboration with RPI limits opportunities, and the announcement by India that they have now developed a new interrupter is threat to the position of VSL. The manufacturing level at VEL continues to be low, although work is commencing on the order for 1,992 VI 100.

The overseas licensees are still reported to be making large quantities of interrupters. With India still awaiting approval for its increase in capacity. Interference in the running of the R&D is increasing in direct proportion to the perceived success of the unit, by both UK management and French Divisional management. In addition the new Group R&D Director is attempting to invoke a new tight control over all R&D activities in the group.

Key Events;

a). New Axial Magnetic Field arc control geometry to be developed

b). India reported to have developed a new interrupter

d). The completion of the recruitment programme.

f). The receipt of the first production order for VI 100 interrupters

g). Possible alliance with RPI on magnetic field simulation held up by group.

Strategic Position of VIL; Excellent 5

The decision to develop a new arc control geometry is an acknowledgement of the ability of VSL to perform this work. This is an opportunity to shine.

Tactical Options for R&D;

To build up the technical expertise and reputation of the unit. To pursue the collaboration with RPI as a means to enhance reputation and forge links with academia.

Company Options;

Continue to build the reputation within group of technical excellence and prowess. Attempt to widen credibility by performing major cost reductions on existing contactor products. If successful this will also give a good basis for the growth of manufacturing within one to two years. Continue to apply pressure to use VI 100 in12kV switchgear.

Short Term Prediction for R&D; Good 4

Survival of VEL as an R&D unit. Continued loss of non group customers. Success in the R&D programme. Increasing interference in the running of the R&D programme. India and South Africa will continue their development programmes independently.

Long Term Prediction for R&D; Good 4

Survival of VEL both as an R&D unit, and with a revival of manufacturing volumes within a year. Licensees continuing to become more independent. Improvement of resources and facilities at Rugby, but increased interference by others in R&D.

Quarterly situation appraisal 18; VIL as at June 1996 - 20/7/96

Status; Excellent 5

The company position has solidified in the last three months. The performance of the VI 100 continues to re-establish the company's technical credibility with the group, despite some sniping on the part of other units. In particular DSL tried to use minor problems and events on test to muddy the VI 100's image and to cover up problems with their circuit breaker. This effort has had only limited success, with the VI 100 still perceived as a world beater. The continued existence of the R&D function is now no longer in doubt. Further problems at EVI coupled with the rising Yen have further enhanced VEL's position. The last of the redundancies have just taken place, and hopefully the situation will now improve. We have been in a continuing redundancy situation now for over two and a half years!

The R&D department now appears to be in a good position, and control of the manufacturing function has been improved, although at the cost of some disruption of the R&D programme due to the high level of support required. This was seen as a necessary investment in order to safeguard the company's image with the group. The manufacturing level at VEL continues to be too low to be really viable, although the low cost and high level of performance of the VI 100 appears to be giving substantially increased possible sales of the OXR unit. As well as possibilities for use in normal 12kV circuit breakers.

The overseas licensees are currently reported to be making large quantities of interrupters. The Licensees are also pursuing their own R&D programmes, with limited success, South Africa have now formally requested to buy VI 100 interrupters for their Recloser programme, this has been refused for the moment.

A strange effect of the success of the VI 100 was the release of capital expenditure in the year, used for the purchase of two portable computers for the General Manager and the Chief Accountant, after a period a third unit was purchased for the Technical Director, which was only the second piece of equipment bought for the department in five years! In addition the Technical Director's car was replaced by the General Manager's old one. One other effect of the success has been negative, a renewed increasing interference in the running of the R&D by both UK management and French Divisional management. They are attracted to our apparent success. There is also a rumour that the department may be moved into different, improved accommodation.

Key Events;

a). Further certification of the VI 100 in the OXR, and testing in the BLV circuit breaker.

b). The continuation of support for licensees

c). The release of some capital expenditure in the year.

d). The lack of progress on recruitment.

e). The appointment of M6 as Director & General Manager of Long and Crawford in Manchester.

f). The perceived problems with EVI and also Toshiba.

g). The further successes of the VI 100 during test.

h). The new interest and interference in the R&D function.

Strategic Position of VIL; Excellent 5

Due to further success in obtaining certification for the VI 100 in the OXR, and testing well outside the rating the perceived technical prowess of the company, is strong enough to withstand knocking from DSL in problems with the test which can be laid at the door of their OXR unit. In addition further problems with the actual performance of EVI together with the increasing value of the Yen, means that VEL are being increasingly rated as the important option for the company.

Tactical Options for R&D;

The key tactic to develop the new Low Cost Small Interrupter appears to have been more successful than imagined. There now appears to be no doubt the VEL are the technical centre of excellence and may indeed be a world force in this technology. The tactic of building upon this by making a conscious effort to improve production quality has maintained the image, even against some criticism and indeed some small setbacks. The high and increasing perceived cost of the EVI product together with its high minimum rating is a weakness which has now been noted. The VI 100 has now been proven at 12 kV; 16 kA. However for the moment this is not an option for us as this would also eat into a major part of the EVI market. Marketing the possibilities in this way has not been missed, and although not an option for the short term, is definitely being considered for the future, in the full knowledge that this would be a serious setback for EVI. The development of a small range of miniature interrupters has also been noted by the licensees and although not yet available to them, pressure is increasing to allow them to buy or make, which would in time remove the need for any further local development. Issue discussion paper on R&D programme, manpower and resources. Take control of the future.

Company Options;

Continue to build on the reputation within group of technical excellence and prowess. Attempt to widen credibility by success in other areas such as uprating vacuum switches to 6 kA, and performing major cost reductions on existing contactor products. This will also give a good basis for the growth of manufacturing within one to two years. Apply pressure to use VI 100 in12kV switchgear. In addition use current reputation to improve resources. Such as equipment, working conditions and manpower.

Short Term Prediction for R&D; Good 4

Survival of VEL as an R&D unit. Continued loss of non group customers. Success in R&D programme. A loosening of restrictions on company, and progress with recruitment. Further enhancement of reputation. This may have a negative effect, as increased interference is being felt in the running of the R&D programme. India and South Africa will continue their development programmes independently.

Long Term Prediction for R&D; Excellent 5

Survival of VEL as an R&D unit, but with a revival of manufacturing volumes within two years. Limited co-operation with licensees and spreading of technology for manufacture within the group. Centralisation of R&D at Rugby. Improvement of resources at Rugby, but increased interference by others in R&D.

Quarterly situation appraisal 19; VIL as at Sept. 1996 – 22/10/96

Status; Excellent 5

The company position has again improved over the last three months. The new interrupter developed independently by India failed its tests, and the group has decided to abandon development in India and South Africa and to concentrate development in Rugby. In addition approval of the collaboration with RPI means that university liaison can commence together with an enhancement of the technical resources of VSL.

The manufacturing level at VEL is improving slightly. The overseas licensees are still reported to be making large quantities of interrupters. The control of R&D by Group is steadily increasing with a more bureaucratic approach to project approval.

Key Events;

a). VI 100 interrupters supplied to more group companies for testing.

b). The failure of the Indian development, and the decision to concentrate development in Rugby.

c). The commencement of work with RPI

g). The increasingly bureaucratic control of R&D.

Strategic Position of VIL; Excellent 5

The position of VSL has improved due to the failure of the Indian development, which has also emphasised to group that mastery of the technology is not easy.

Tactical Options for R&D;

To continue to build up the technical expertise and reputation of the unit, and in particular to support the Licensees with the technology necessary to remove the need for them to again attempt to develop their own devices.

Company Options;

Continue to build up the reputation within group of technical excellence and prowess. Continue to perform the major cost reductions on existing contactor products. Continue to apply pressure to use VI 100 in12kV switchgear.

Short Term Prediction for R&D; Good 4

Survival of VEL as an R&D unit. Continued loss of non group customers. Success in the R&D programme. Increased interference in the running of the R&D programme. India and South Africa will abandon their development programmes completely.

Long Term Prediction for R&D; Good 4

Survival of VEL both as an R&D unit and as a manufacturing unit. Increased co-operation with licensees and spreading of technology for manufacture within the group. Centralisation of R&D at Rugby. Increased bureaucracy and control of R&D by others.

Quarterly situation appraisal 20; VIL as at Dec. 1996 - 22/1/97

Status; Excellent 5

The company position has again changed radically over the last three months. After building an apparently unassailable position and fighting off the threat from EVI, another strategy destroying event has occurred. Immediately after being confirmed as the sole R&D centre world wide for vacuum technology within the group, the continued existence of the R&D function is now threatened by the announcement of the acquisition of the Vacuum Interrupter functions of AEG! The uncertainty and the need to re-prove worthiness has returned. The manufacturing level at VEL has increased and overall orders are good.

The overseas licensees are still reported to be making large quantities of interrupters, India has received approval for its increase in capacity, and VISA has also apparently increased its capacity. Interference in the running of the R&D is still at a high level, but there are hopes that the acquisition of AEG will divert this attention for some time.

Key Events;

a). The decision to make VSL the R&D world centre for vacuum technology.

b). The continuation of support for licensees, mainly India

c). The approval of £200,000 investment in R&D facilities in Rugby

d). The acquisition of AEG including the Vacuum Interrupter plant.

e). M3 to receive a Nelson Gold Medal for outstanding technical innovation.

Strategic Position of VIL; Fair 3

Receipt of the Nelson Gold Medal is a recognition by GEC of the importance of the technology and the world class nature of the research. This together with the decision to make VEL the world centre of R&D for vacuum technology means that the main strategic objective has been achieved. However the completely unexpected acquisition of AEG negates this success and introduces an internal competitor once again.

Tactical Options for R&D;

Once again it is necessary to prove that VSL is a worthy choice for the group versus the new rival. This should be easier than last time, as there is an established track record of success, but the outcome is uncertain.

Company Options;

Continue to build on the reputation within group of technical excellence and prowess. This will also give a good basis for the expected comparison with AEG.

Short Term Prediction for R&D; Good 4

Survival of VEL as an R&D unit. Success in the R&D programme. A difficult comparison with AEG technology.

Long Term Prediction for R&D; Fair 3

Survival of VEL mainly as the R&D unit for the group, but a possible amalgamation of resources with AEG, location to be decided!

Chapter 8 - Analysis of the Case Study Data

8.1. Introduction

The case study was formulated to test two weakly held hypotheses from the beginning of the research and to generate new hypotheses. Seven new hypotheses were generated, which are referred to below. The events during the case study are summarised in the next section, to set the background to the analysis. This is followed by the method of analysis and that is followed by the results of the analysis.

8.2. An overview of events during the Case Study.

This section sets out the story of the case as it unfolded, and is included for orientation purposes and to place the data in context.

The GEC Strategy

Before the start of the case in 1990, GEC's strategy was to move VIL, the vacuum interrupter manufacturing and development unit of one hundred people, from its own site in Finchley where it had been for twenty years, to join a much larger unit, GEC Industrial Controls, which employed over one thousand people manufacturing a variety of electrical products at a site in Rugby.

Significant cost reduction was expected from the move, by eliminating the overheads at Finchley. Also there would be synergy with a small section of

GEC Industrial Controls manufacturing a similar product, low voltage (1kV up to 7.2kV) vacuum switches and some switchgear.

The ALSTHOM Strategy

Two French companies, ALSTHOM and Group Schneider[1], had developed medium voltage interrupters based on a gas, SF_6, instead of vacuum. ALSTHOM did not like being reliant on this one technology for their supply of switchgear to French-influence markets, as the rest of the world was predominantly committed to vacuum technology, they decided to take a license from Toshiba in Japan to manufacture medium voltage vacuum interrupters in France using Toshiba technology. This action built upon a previous relationship in which ALSTHOM had licensed their high voltage SF_6 technology to Toshiba, and was a logical strategy based upon the good relationship with Toshiba.

Formation of GEC ALSTHOM

In 1990 a merger was announced. The new company consisted of the electrical equipment parts of GEC and ALSTHOM, and was to supply the combined UK and French national influence markets. There had been no prior notice to the operating units in either company. The two merging companies naturally had a great deal of overlapping capability, but they also had two completely different policies with regard to interrupters. The new company was called GEC ALSTHOM.

During 1991/92 despite the merger, the move of VIL from Finchley to Rugby carried on, because it was in train.

The case study commenced in January 1992.

During 1992 the post-merger situation was reviewed and the merged company decided to continue with the building of the joint venture factory in France presumably because Toshiba's technology and support seemed a much better bet than the GEC technology from Finchley. At this time the eventual closure of the vacuum section in Rugby was seen as inevitable. However rationalisation as a consequence of the merger continued, and from 1992 to 1997 GEC ALSTHOM Vacuum Equipment Limited was reduced in size by a series of rationalisation programmes until by 1997 there were only 40 people left. The only product to remain was the vacuum related manufacturing and R&D section.

GEC ALSTHOM Strategy

The GEC ALSTHOM strategy was thought to be to keep VIL running until the new factory and technology in France was established and then to close VIL. This was foreseen to take one to two years. However, management effort was absorbed by the needs of the merger, and by the time management had been integrated in the two companies and attention was again paid to strategy, things had changed. The Rugby unit had been stripped down to purely vacuum-related production and research, and the staff at the Rugby site was reduced to just 40, including the people from Finchley, (out of over 100 people employed in the plant in Finchley, only five transferred). The residual unit consisted of an R&D staff of 10 and a small production unit. This was then structured as a wholly owned subsidiary company called GEC ALSTHOM T&D Vacuum Equipment Limited (VIL). The R&D unit mostly developed interrupters and switchgear to meet customer requirements. The associated factory unit made specialist units, prototypes, and early production units.

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[1] The relevant part of Group Schneider is called Merlin-Gerin.

The Strategy of the VIL R&D Section

The R&D section of what had been VIL had come to realise that it needed a strategy for its own survival within the company. The core of the strategy was to convince the Group that the R&D unit had a value to the Group. The question was how to accomplish this. VIL had always felt that it had the technical know-how to make the world's smallest interrupter, but had never done so because there was not a customer requirement calling for such a specification, and the Group required R&D effort to be closely linked to market needs. Rugby now set out to make a very small interrupter, which had no customer in prospect. This project went ahead unofficially at first. The Group knew that some R&D activity was still going on, but this was seen as a good thing as it kept the people occupied while the run-down took place, and so the project was tolerated. The new device was duly produced and certified at KEMA[2] which is an international test station in Holland. It was named the VI100. Purely fortuitously a market need appeared within GEC ALSTHOM for which the VI100 was the only solution. Next it proved to be a useful cost-saving substitute for other existing products. Then it began to create its own markets, based on its considerable advantages of price and specification, plus an adaptability that resulted from its smallness. Another fortuitous occurrence was that the Toshiba technology which ALSTHOM had been committed to, failed to fully live up to its requirements, and did not supply all of the ratings required. It was extremely fortunate for the merged Group that the VIL technology was available to it. In 1996 as a direct result of the technical success of the VI100, GEC ALSTHOM designated Rugby as its World Technology

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[2] It is a requirement for switchgear to be certified to international and national standards. For IEC Standards this is performed by ASTA (Association of Short-circuit Testing Agencies) accredited test stations around the world. These are independent of the manufacturers to guarantee credibility of the certification. KEMA is a widely respected test station in Holland.

Centre for Vacuum Switching. All vacuum R&D would be performed there. The staffing was increased and significant investment made in the laboratories.

Three years later the VI100 was still the smallest interrupter in the world at its rating.

8.3. Methods of Analysis

The case study generated data based on the Participant-observer's perceptions of the situation concerning the R&D section. These were generated both from the Chronology of events and the Quarterly Situation Reviews. The principal method of analysis for the Chronology was to examine events and to assign a simple value; positive, negative, or neutral, according to their perceived effect on the well being of the R&D Section. In addition events were examined as to their relevance to the nine hypotheses (two initial and 7 emergent) and the record was annotated accordingly. This allowed the amount of support for each hypothesis to be estimated (Miles & Huberman (1994, p9). The hypotheses were also tested using the Negative Case Analysis technique (Judd et al (1991), in which the data from the Case Study was searched for information which would disprove the hypotheses. As a result of this testing the two original hypotheses had to be discarded, and during the research, other emerging hypotheses had to be modified in line with the changing data.

For the Quarterly Situation Reviews, in order to allow some analysis of what is qualitative data, Levels had been assigned to the views of each category as explained in Chapter 7. These were predictions of the state of the company at six months and one to two years from the date of prediction together with a statement as to the current status of the company.

In addition, in pursuit of Internal and External Validity a form of data triangulation was used to validate the data: for each hypothesis similar examples were searched for in the case, in the pre-history, and in the literature, as appropriate (Yin (1994), Silverman (2000)).

Formation of hypotheses

In total nine hypotheses were tested, two from before the case commenced, two derived from the study of the pre-case history, and five which were derived from the case when progress was reviewed after 18 months. Following this review all hypotheses were tested firstly against the existing data, and then against subsequent data generated by the case.

The two initial hypotheses were:

- "The actions of competitors are an important factor in the strategic environment of the R&D section".
- "Changes in key players within the organisation are important and will change the strategic environment of the R&D section".

The two hypotheses generated from the history were:

- "For a unit within a group, the major part of the strategic environment is provided by the group. The group can act to frustrate the unit's strategy".
- "Companies can throw away technology they have developed, at the brink of exploitation, due to lack of faith or understanding, and they may even allow competitors to take up the technology".

The five hypotheses generated by inspection of the case study after 18 months were:

- "Stancing strategy with regard to the group can be a matter of creating perceptions, which are as important as facts".
- "Success can be achieved by a sense of mission, pursuing an objective despite an appearance of great odds".
- "Success can be due to an individual's innovative break through".

- "Strategy-Destroying-Events occur quite frequently, rendering specific strategies void".
- "Strategic decision-making can involve a range of factors of great complexity and fractal-type detail. Small events can have great strategic significance".

8.4. Findings from the Chronology

Table 8.1. shows the rate at which significant events occurred during the five year period. Each of the event types is explained and discussed below. Hypothesis 9 is not shown in the table as it is not demonstrated by specific events but follows from consideration of the whole of the data.

Event	Number of Events Recorded	Average Months Between Events
Hypothesis 1 (Competitor Action)	4	15.0
Hypothesis 2 (Change of Key Personnel)	12	6.0
Hypothesis 3 (The Group as Environment)	11	5.5
Hypothesis 4 (Throwing Away Technology)	2	30.0
Hypothesis 5 (Creating Perceptions)	11	5.5
Hypothesis 6 (Strategy Destroying Events)	16	3.8
Hypothesis 7 (Sense of mission)	2	30.0
Hypothesis 8 (Innovative Breakthrough)	3	20.0
Total number of events recorded		
Positive events	82	0.7
Negative events	85	0.7
Neutral events	31	1.9

Table 8.1 Event count from the Case Study. Evidence for each hypothesis is discussed in detail later in this chapter.

By inspection the events supporting (or refuting) each hypothesis were identified, and the number noted, as in Table 8.1. The evidence concerning each hypothesis is described and reported on in the following sections. In each section the number recorded in the case study is given together with one example of the type of event. A form of data triangulation as discussed in Chapter 3 was used to validate the data: for each hypothesis, and for each type of event one example is included from the case, plus one from the history, plus one from the literature where relevant.

Hypothesis 1: Competitor Action

"The actions of competitors are an important factor in the strategic environment of the R&D section".

At the start of the case study, and following the principles outlined by Porter (1980), the actions of competitors were thought to be important. As a result competitor actions were assigned a category and monitored. In the event only four competitor actions were thought significant from the point of view of the R&D section during the five-year case period. Of these only one, the change of direction by Westinghouse [8.3.3], was considered as potentially serious, and even this in the end had no effect. The hypothesis clearly failed the Negative Case Analysis test. In fact these results indicate that competitor action was quite irrelevant in this case.

An Example from the Case Study

Westinghouse had a small R&D team working on vacuum interrupters but their assumption was that the technology is mature, and this team concentrated on minor production improvements and variant models. Westinghouse then sold its switchgear division to Cutler – Hammer who imposed a change of policy[3]. It was now assumed that the technology is still developing, and the R&D team was expanded, to do more fundamental work, which might lead to radical product improvements. This only constitutes a theoretical threat to VIL - so far no harm has materialised, and no strategy response by VIL has resulted[4].

An Example from the History

The action by GE to sell its technology to Mitsubishi was beneficial to Mitsubishi, whose role was the passive one of accepting a gift. No clear example was found of a competitor action which was significantly damaging to the company as seen from the R&D section.

An Example from the Literature

The literature quite clearly assigns a critical role to competitors and their actions in the formulation of strategy. Porter (1980)[5] in particular emphasises this. Competitor actions do occur constantly but in this case competitor actions were not important from the perspective of the R&D section.

Hypothesis 2: Key Players

"Changes of Key personnel are an important factor in the Strategic Environment of the R&D section".

At the commencement of the case study it was thought that changes in key personnel, in particular managers with direct responsibility for the unit R&D,

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[3] This view was confirmed in discussions with the Westinghouse interrupter team.
[4] Note that as far as the Westinghouse vacuum interrupter R&D section are concerned, from their viewpoint this action by their parent company would come under Hypothesis 3, described in the next section.
[5] In fact Porter wrote a book on this subject, with a full title of "Competitive Strategy – Techniques for Analysing Industries and Competitors". Porter M.E. (1980).

would result have a major effect on the environment of he R&D section.. All of the managers mentioned in the case (M1-M14) were signatories on the R&D project authorisation paperwork for the R&D section of VIL with one exception. The manager designated M2 was the MD of another division of Alstom and influenced the R&D by means of his control of the overseas subsidiaries, and was in effect a customer for the technology developed. In fact the changes of key personnel had no measurable effect on the environment of the R&D section and so the Hypothesis was abandoned.

An Example from the Case Study

Although there were 12 changes of key managers during the period studied, in fact these changes had no effect on the R&D section. No changes of policy were noted when changes occurred, and no response was needed by the R&D section.

An Example from the History

During the history there were many changes of personnel, but the records are insufficiently detailed to say whether the changes directly affected the R&D or not. However in one area where the Participant-observer had personal knowledge despite four changes of personnel in the Technical Manager role at VIL over ten years, the company retained its reputation for technical innovation throughout the period.

An Example from the Literature

The management literature clearly indicates the importance of key personnel (Crainer (1997), as does the R&D literature (Kaufman (1989)), and in fact Arthur Young (1986, p32-33) uses the change in a key manager to explain the rise and fall in fortunes of a department as a worked example.

Hypothesis 3: The Group as Environment

"For a unit within a group, the major part of the strategic environment is provided by the group. The group can act to frustrate the unit's strategy".

This is clearly demonstrated during the case study. On eleven occasions during the five year period the group acted in a way which frustrated the strategy of the unit. This ranged from detail decisions such as a decision not to perform product tests to fundamental decisions such as the closure of units and the acquisition of rival technology. No evidence was found within the case to refute the hypothesis.

An Example from the Case Study

The unexpected Group decision to terminate the budget for all R&D projects at Rugby, preventing all but minimal R&D effort at a critical time. This forced a review and change in strategy at the R&D section level.

An Example from the History

During the history of the technology GE and GEC repeatedly made decisions which frustrated their respective vacuum interrupter units, these ranged from the decision to license the technology to competitors, to decisions on mergers and disposals which significantly affected the units although this was incidental.

The decision by GE to sell the first vacuum interrupters for HV, which was an inappropriate application and eventually led indirectly to their loss of market share switchgear is a specific example.

An Example from the Literature

This concept is not common in the literature but does occur occasionally when a case study is being reported. A good clear example exists from Blake (1978), concerning the development of the Sidewinder Air-Air Missile (AAM) where the higher levels of the Group were clearly against the project.

Hypothesis 4: Throwing Away Technology

Hypothesis; "Companies can throw away technology they have developed, at the brink of exploitation, due to lack of faith or understanding, and they may even allow competitors to take up the technology".

On two occasions during the case study the company threw away technology. This is not apparently as unusual as might be thought as similar cases are also seen during the history, although the literature only weakly supports this.

An Example from the Case Study

For example in June 1993 VIL was instructed by the Group not to manufacture an interrupter which had been successfully developed. Although on this occasion the competition was not allowed to have the technology it meant that in effect there were no direct benefits of the development (although in fact the technology developed was, as is often the case, recycled in other projects).

An Example from the History

In the 1970's due to a lack of faith in the technology GE gave up their technical advantage by licensing the competition and in so doing eventually lost the market, VIL did the same later in the 1970's due to a drive for short term profitability.

An Example from the Literature

This is only obliquely mentioned in the literature. Von Braun (1997) mentions that companies sometimes license technology very soon after development before full exploitation, although he attempts to give plausible explanations for this action.

Hypothesis 5: Creating Perceptions

Hypothesis; "Stancing strategy with regard to the group can be a matter of creating perceptions, which are as important as facts".

During the case study this occurred eleven times during the five year period. The principal action to create a positive perception was the development of the VI100, but other actions also took place. The idea of creating perceptions is an accepted one in the literature and is clearly referred to, for example, as part of the art of negotiation by de Bono (1991).

An Example from the Case Study

The creation of the world's smallest practical interrupter was a deliberate attempt to influence the perception of the Group by the R&D section. At the time this development had no apparent practical use, but resulted in the perception of the R&D section by the Group being radically changed, and an unexpected by product was the relocation of Engineering Department into a new building. The relocation included significant investment in infrastructure for the department and was intended to give an image of a world class R&D department. The Group had accepted the new role of the section before it had achieved any benefit for the Group and had then changed the image of the department to fit the new role.

It is very interesting that in actual fact the VI100 did not bring the company a net return in terms of sales or market share. Indeed it has now been superseded by the next generation of interrupter. Despite this, the R&D section now has a very high reputation within the Group, and its designs are being put into large scale manufacture around the world, as the main basis of future business. The sole measurable benefit of the VI100 has been this change of perception.

An Example from the History

During the history of the technology GE suffered because the perception of vacuum technology was poor within their group. This was what caused the group management to abandon their advantage and license to the competition. The fact that the GE technical people had finally solved the problems with the new technology was irrelevant as the group management had by then lost faith in it.

An Example from the Literature

This point is not clearly brought out in the R&D literature. However Roussel et al (1991, p 3) do refer to "good technical judgements and insights" as being acceptable in the absence of hard data.

Hypothesis 6: Strategy Destroying Events

Hypothesis; "Strategy-Destroying-Events occur quite frequently, rendering specific strategies void".

Initially during the period studied it was very difficult to apply any coherent strategy as events completely outside the control of the R&D section kept rendering the existing strategy irrelevant or impossible to follow. Over the five-year period of the case there were sixteen occasions when unexpected events rendered current strategy irrelevant or necessitating a response.

An Example from the Case Study

The closure of GEC ALSTHOM Ceramics in October 1992 was a major blow as they were the sole supplier of a key component in the current interrupter manufacture. This resulted in a crash programme to redesign the old interrupters to take a new type of ceramic which effectively starved the other projects of resources, and necessitated a change of direction.

An Example from the History

The history has many examples of what must have been strategy destroying events at the time. A major example was the merger of GEC's power division with ALSTHOM which completely destroyed the strategies in place for both groups.

An Example from the Literature

The concept of the Strategy Destroying Event is not a generally recognised one in the R&D management literature. Where examples arise in cases they are normally expressed as being one-off events or being due to bad planning or incompetence. A typical example of this is given by Busby & Payne (1988) who obliquely refer to these problems as part of what they call "Planning Myths". However Roussel et al (1991, p143) do state that "pitfalls will turn up and mid course corrections will be necessary" in the course of R&D projects, and that "Research and Development by its nature is filled with unknowns".

The closest approach to this is in the strategy literature by Ansoff (1984) who talks of "environmental turbulence" and gives five levels of turbulence up to "surpriseful".

Hypothesis 7: Sense of Mission

Hypothesis; "Success can be achieved by a sense of mission, pursuing an objective despite an appearance of great odds".

On two occasions during the case study, work was carried out despite a hopeless outlook for the R&D section, in order to create a slim chance of survival. Although rare, this type of action proved to very important, and one example was probably the most significant single item in the case study, as it enabled the strategy which ultimately proved successful.

An Example from the Case Study

In July 1993 the position for the R&D section looked hopeless and the Group was moving quickly to close down the capabilities of the unit. Mass redundancies had been announced of over 80% of the unit, and the previous strategy, that of providing technical support to the licensees had been abandoned. In the midst of this the project to try to develop the world's smallest interrupter without official backing had just commenced and was pursued despite little apparent chance of success.

An Example from the History

This occurred in the 1980's when VIL was in a "Catch 22" situation of needing to increase output in order to generate money for capital equipment in order to increase output. The VIL team managed to extract themselves from an apparently impossible situation by redesigning their technology to allow for a large increase in production with almost no capital investment, a feat previously thought impossible.

An Example from the Literature

There are many examples of lone inventors or small teams working with little resources on apparently impossible problems, a classic example is the development of the Jet Engine by Whittle, where many years of apparently fruitless effort was needed before the final breakthrough (Whyte (1975)).

Hypothesis 8: Innovative Breakthrough

Hypothesis; "Success can be due to an individual's truly innovative break through".

This is the classic perception of the inventor, which is at the core of R&D. During the case study this occurred three times, and in the end successful R&D strategy requires innovation which can normally be traced to a single inventor. Without this there is little for the other, optimising, processes to work on.

An Example from the Case Study

The VI 100 concept was based on the development of an innovative asymmetric approach to interrupter design. Partly as a result of the work carried out, an award was made of GEC's Nelson Gold Medal for Outstanding Technical Innovation to M3, the inventor.

An Example from the History

The invention of a special contact geometry by M3 in 1984 gave GEC a significant advantage because it allowed a much smaller interrupter to be made. This was a case where individuals in competing companies were competing head-on in inventiveness. The several companies able to develop effective interrupters each ended up with their own patented versions of the key technologies, but some were fundamentally better than others .

An Example from the Literature

Individual cases abound throughout the literature. About Thomas Edison we read of "Edison's self confidence in his ability to beat out other inventors" (Israel (1998)).

Hypothesis 9: Fractal-like Detail

Hypothesis "Strategic decision-making can involve a range of factors of great complexity and fractal-type detail. Small events can have great strategic significance".

This principle occurred throughout the case study and also in other aspects of the work. The fact that there is normally simply too much data to record is well known (Miles & Huberman (1994), Yin (1994)), and necessitates some level of editing on the part of the observer. The collection of data during the case study is an example of this. It became obvious that possibly significant events at the section level are too frequent to record, or to react to on a daily or weekly basis. It was necessary to provide some sort of filtration in order to have handleable quantities of data. The filter used was to review what was thought to be significant each month. This gave rise to an interesting effect because with the exception of immense events such as closure of units, it proved impossible to predict which events would be considered significant after one month. One area which was originally thought to be significant was the changing of key players within the organisation. As a result this was logged during the case study but the final analysis showed these changes as being completely irrelevant to the situation.

The Quarterly Situation Appraisals taken every quarter provided further filtration, and at the end of the case the overview again filtered more data. Overall the data appears to be Fractal like in nature, with more and more detail being available as the investigation goes deeper. However, in true mathematical Chaos style the increase in data does not help with understanding the problem or providing a solution[6].

[6] Chaos theory and fractal natures are dealt with by Hall (1992), Gleick (1993).

As this principle came from an overview of the whole data rather than being evidenced by specific events a fuller explanation is appropriate and is given below.

An Example from the Case Study

An example of fractal events and timescales was the purchase of movie film for one of the R&D section's laboratories. This example was edited out of the actual case due to the monthly filtration but it illustrates the point well. The film in question is special and is used in a high speed (10,000 fps) camera for filming high energy vacuum arcs. This filming activity was crucial to a particular development project. One week a problem occurred in that due to unexpected test results, the rate of consumption of film was increased significantly and immediately absorbed the small company stock. The events shown in Table 8.3 then occurred.

Day	Situation	Consequence
Monday;	No problem - adequate film supply,	no project delay
Wednesday;	Change of priority, order new film,	1 week delay
	Supplier out of stock.	Indefinite delay
Thursday;	Order film from Kodak,	4 week delay.
Friday;	Kodak UK no longer supply the item,	Indefinite delay
	Discover it is available from USA	12 week delay
Monday;	Look for alternative - Contact Fujifilm	
	- suitable film available from Japan,	6 week delay
Tuesday;	Contact Fuji stockholders - same day delivery,	0 week delay

Table 8.2 Detail of Film Supply Problem

As can be seen, viewed on a daily basis a prospective project delay arose which varied up to a very significant 12 weeks, (ignoring the possibly indefinite delays). Viewed on a weekly basis the delay was 6 weeks, and on a monthly basis it was not worth reporting, with zero delay. Even within one day at times the view changed dramatically. This event has now been lost and forgotten in the mists of time, but for a short period it was seen as very important, with potentially disastrous consequences[7].

An Example from the History

Unfortunately it is not possible to examine cases from the history as due to the lapse of time the data has been filtered so that only those events seen as significant remain.

An Example from the Literature

An example of the overwhelming detail possible is the view of Ackoff (1979) who describes typical management situations as "Messes". Most such events fade away of their own accord or are dealt with by a short term action but occasionally one such small event may survive to have a critical impact.

8.5. Other analyses from the Chronology

This sections deals with other observations that arose from study of the case data, in addition to the work on hypotheses.

Positive & Negative Events

All of the recorded events in the Chronology were rated at the time of recording as positive, negative or neutral, from the perspective of the R&D

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[7] This case was presented as a lecture at the R&D Society Meeting held on 26th April, 1992, at the Royal Society, London. During discussions afterward there was some indication that other members had seen a similar effect.

Section. Out of a total of 198 recorded events, 82 were thought to be positive, 85 negative, and 31 neutral[8].

The neutral events, although thought to be significant and worth recording at the time were not seen as either positive or negative. Since they first occurred none of these events has resulted in a significant effect on the R&D section it appears from this that the initial categorisation of events was accurate, and that in fact it might be considered unnecessary to list events seen as neutral.

Figure 8.1 shows that throughout the case both positive and negative events occurred, but that negative events were in the majority up to month 33, and then there was a rapid change to a much more positive environment. It is believed that this change was a result of the new strategy of the R&D section to develop the VI 100 and so impress the Group.

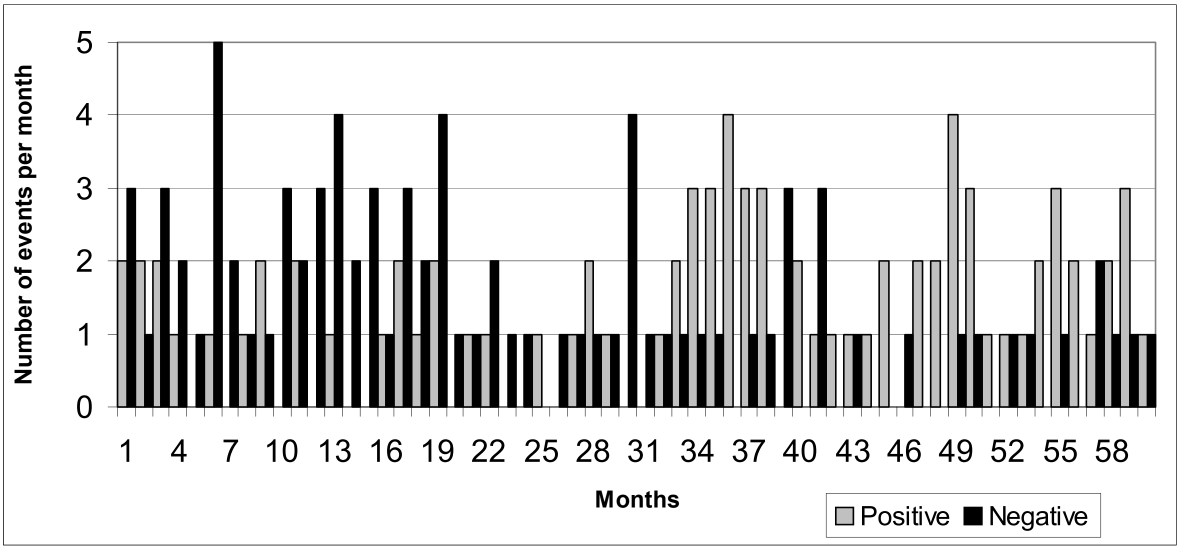

Figure 8.1 Timeline of events seen to be positive and negative from the perspective of the R&D Section shown monthly. The neutral events were ignored. An improving trend over the period studied can be discerned.

[8] Note that all events were graded at the time as Positive, Negative, or Neutral. All neutral events were later discarded. The other classifications, SDE, Competitor, etc, are included in the Positive and Negative numbers.

The strategy was first conceived in month 12, and the first tangible results, the VI 100 testing, occurred in month 24. However there appears to be a delay until month 33 before the observed situation changes significantly. This is discussed further in Chapter 11.

Strategy Confirming Events.

The Strategy Destroying Events were discussed previously as Hypothesis 6, however at a fairly late stage in the case study, it was noticed that not only were SDE being found but that there was another type of event, which was the reverse of an SDE, and was termed an Strategy Confirming Event (SCE). SCE are defined as those events which are again outside the control of the strategy forming section but provide support to the strategy. One again they are unpredicted by the R&D section.

Event types	Number of Events Recorded	Average Months Between Events
SDE	16	3.8
SCE	19	3.0

Table 8.3 Frequency of SDE and SCE events.

One point to note here concerns the concept of "unpredictable". In this study the coming of the event was not known at the time to the R&D section and it had no reason at the time to believe that it would happen. The event might have been predictable, but in fact it was not predicted. Reviewing the situation afterwards often leads to the false belief that the event should have been known to the R&D manager. This is known as the "Planning Myth" and is described by Busby & Payne (1998).

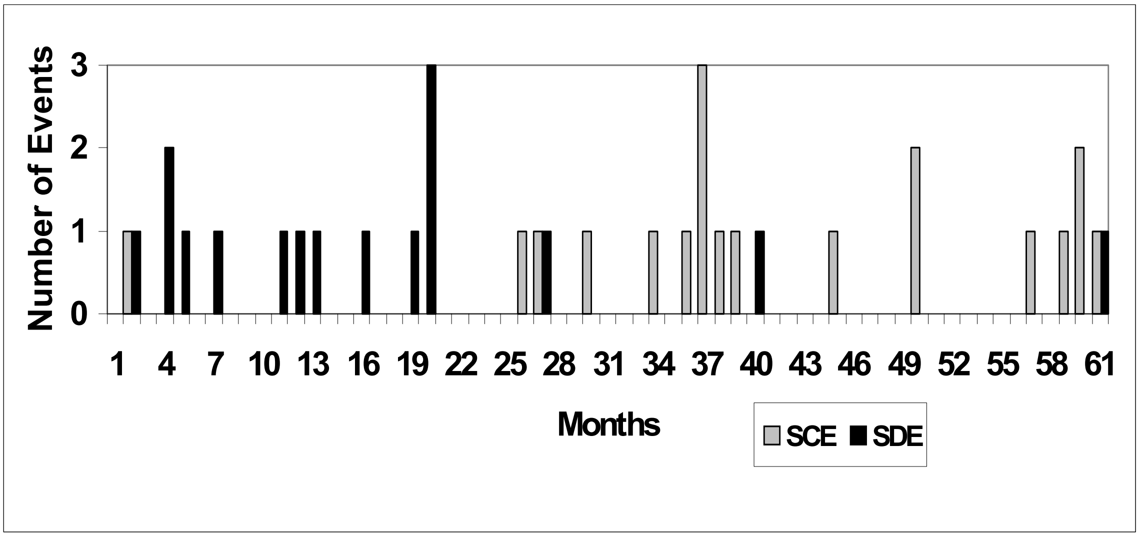

Figure 8.2 Chart of SDE and SCE During the Case Study.

Figure 8.2 shows the significant events as SDE and SCE. During the case study 16 SDE and 19 SCE were recorded. However the average rate of occurrence of the events is not uniform through the case. As can be clearly seen a change in the frequency of SDE (Strategy Destroying Events) occurs together with a rise in SCE (Strategy Confirming Events) in the later part.

Figure 8.2 indicates that something occurred around month 24 to change the trend from more SDE than SCE to more SCE than SDE. This coincides with the establishment of the new R&D Section strategy, but is considerably earlier than the change in proportion of positive and negative events shown in [Figure 8.1]. Figure 8.2 also indicates that even with a successful strategy in place SDE still can and do occur.

Interestingly the delay in change of fortune after the implementation of change in strategy was very short, indicating that the method of logging positive and negative events as well as SDEs and SCE's could perhaps be used in real time to see if a strategy is being effective or not. This is discussed further in Chapter 11.

An Example from the Case Study

A typical example of an unexpected SCE was the relocation of the Engineering Department into a new building. This was unexpected as the previous practice was to have R&D pushed into a corner with old facilities, (the average age of the desks was over 40 years!). The relocation included new furniture, computers, and full infrastructure for the department and was intended to give an image of a world class R&D department. Interestingly this occurred after the key work had been done.

An Example from the History

It is difficult to distinguish SCE after a long period as events seem to take on a level of inevitability or obviousness with hindsight, however the buying out of the other shareholders in VIL by GEC was at the time an unexpected beneficial result of the development of the new "Shieldless" interrupter range[9].

An Example from the Literature

Again this concept is not directly recognised in the literature. Examples of unforeseen benefit are normally attributed to luck, foreseen benefits are simply confirmation of the strategy. However an example is given by Kidder (1982); During the computer battles of the 1960's when Data General first started, their strategy was to pursue design of the best "small computer" in the world. However they were very small compared to DEC who had over 85% of the small computer market in the USA. This strategy of being the best technically had the unforeseen effect of frightening DEC into warning their customers

[9] Confirmed by discussions with ex-GEC managers involved at the time.

away from Data General, thereby paradoxically drawing attention to Data General's existence, and contributing greatly to their success.

Overall the Strategy Confirming Events were regarded as an extension to the Strategy Destroying Events hypothesis, rather than as representing something new. As a result the hypothesis was modified to read;

Hypothesis; "Strategy-Destroying-Events occur quite frequently, rendering specific strategies void. In addition Strategy-Confirming Events may also occur giving rise to unexpected benefits of the strategy".

8.6. Findings from The Quarterly Situation Reviews

The Quarterly Situation Reviews were intended to monitor the position of the company, VIL and also the ability of the R&D Manager to predict the future outcomes of his actions during the case. Originally it was thought that the status of the **group** was the target outcome of any strategy by the R&D section. Later it was seen that there may be times when a conflict of interest could occur between the R&D section and the **group**. However on analysing the data it was found that the status of the company R&D section was closely tied to the fortunes of the company (i.e. the small company of which the R&D section was a major component, as distinct from the **group**), and so it was decided that the Status reports from the case study could apply equally well to the R&D section as to the Company. As a result in this section the Status has been used to compare the effectiveness of the predictions of the future position of the R&D section. This is all discussed further in Chapter 11.

Situation Predictions

Figure 8.3 & Figure 8.5 show the changing views of the R&D manager at three month intervals on the present status and predictions of short and long term prospects, taken from the Quarterly Situation Reviews. The opinions of the R&D manager were not independently verifiable, but these opinions were what was required. The manager's opinions were what he based decisions on, and a second opinion would have been irrelevant to this research. It can be seen that the predictions were highly correlated to the perceived current status of the company. The manager did not predict the improvement in company fortunes which occurred.

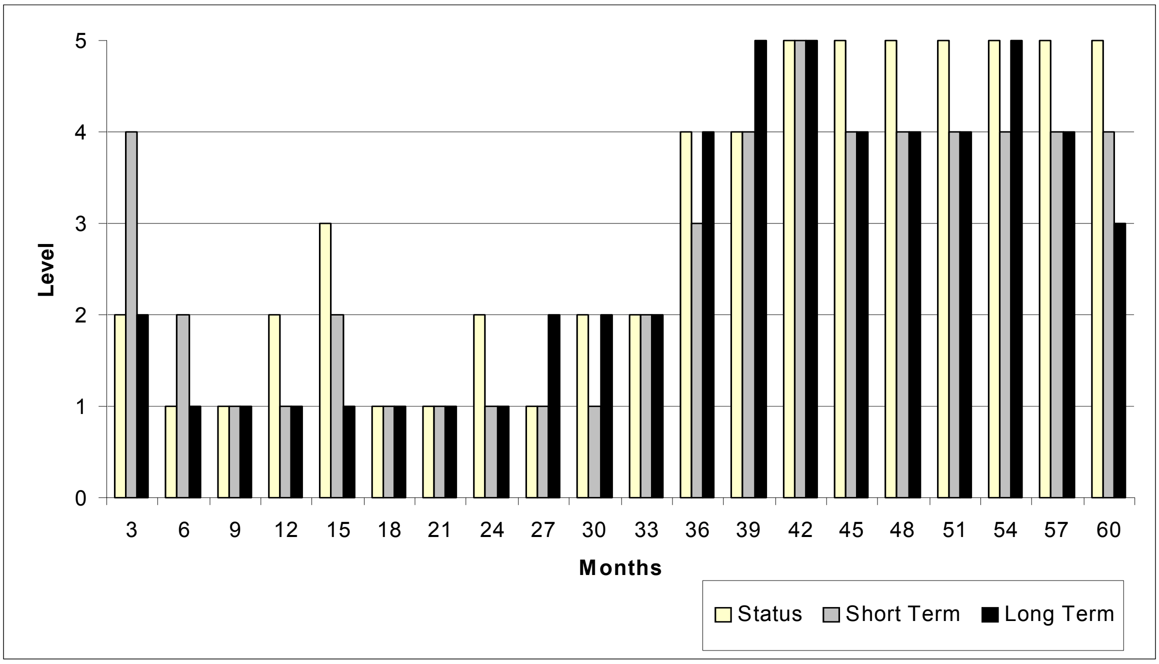

Figure 8.3 The Changing Views of the R&D Section Manager at Three Monthly Intervals, Current Status v Short Term and Long Term predictions. This shows the manager's opinions as recorded

It can be seen that the views shown in figure 8.3 followed closely the occurrence of SDEs and SCEs as in Figure 8.2.

In Figure 8.4 the data from the Short Term prediction is offset by six months, and the data from the Long Term prediction is offset by one year[10]. This time shifting enables the actual Status at a time to be compared with the predictions made previously. It is clear that the predictions were not accurate.

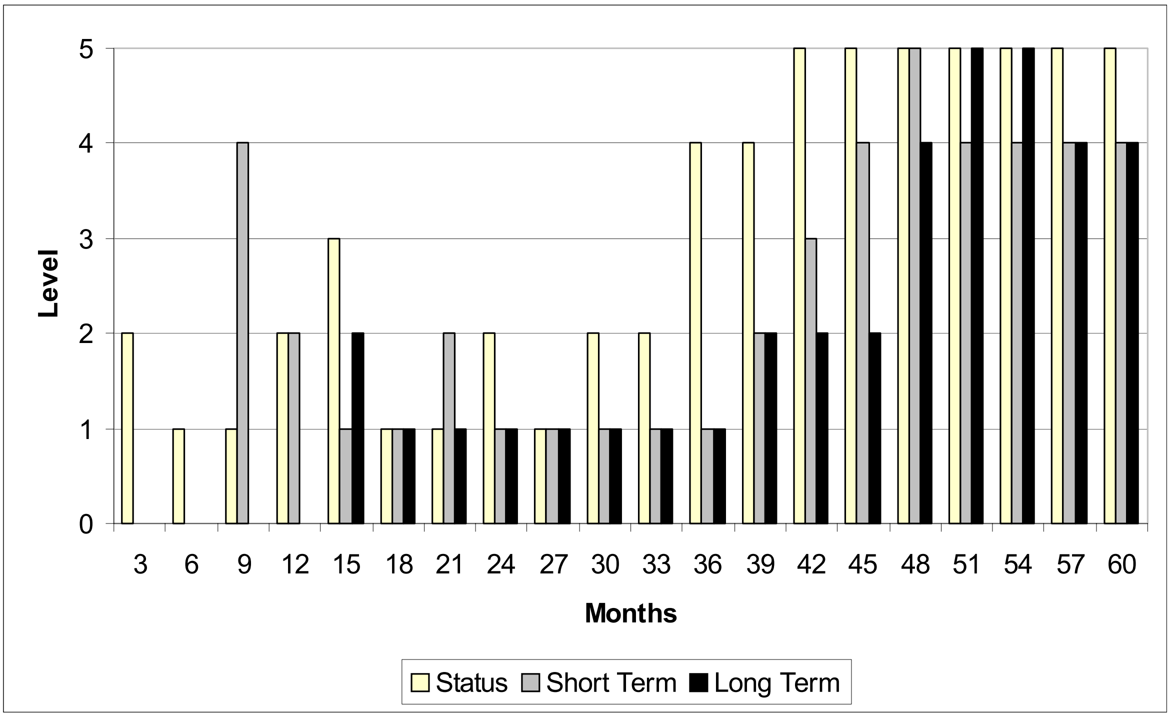

Figure 8.4 The Changing Views of the R&D Section Manager at Three Monthly Intervals, Status v Short Term and Long Term prediction. This shows the data offset by six months for the short term and offset by one year for the long term

[10] The actual long term prediction was for the status in one to two years time, however it is clear that at both one and two years (and indeed in between) there is no correlation with the Status. The graph [Figure 8.4] shows the data offset by one year only for clarity, and only goes up to month 60, as after that point no Status data was recorded.

Status and Strategic Position

Figure 8.5 shows that the Current Status and Current Strategic Position noted by the R&D manager over the case period changed around month 33, and coincides well with Figure 8.3. The correlation between the Status and the Strategic view is very clear. The view of strategic position is clearly influenced by the current status of the unit.

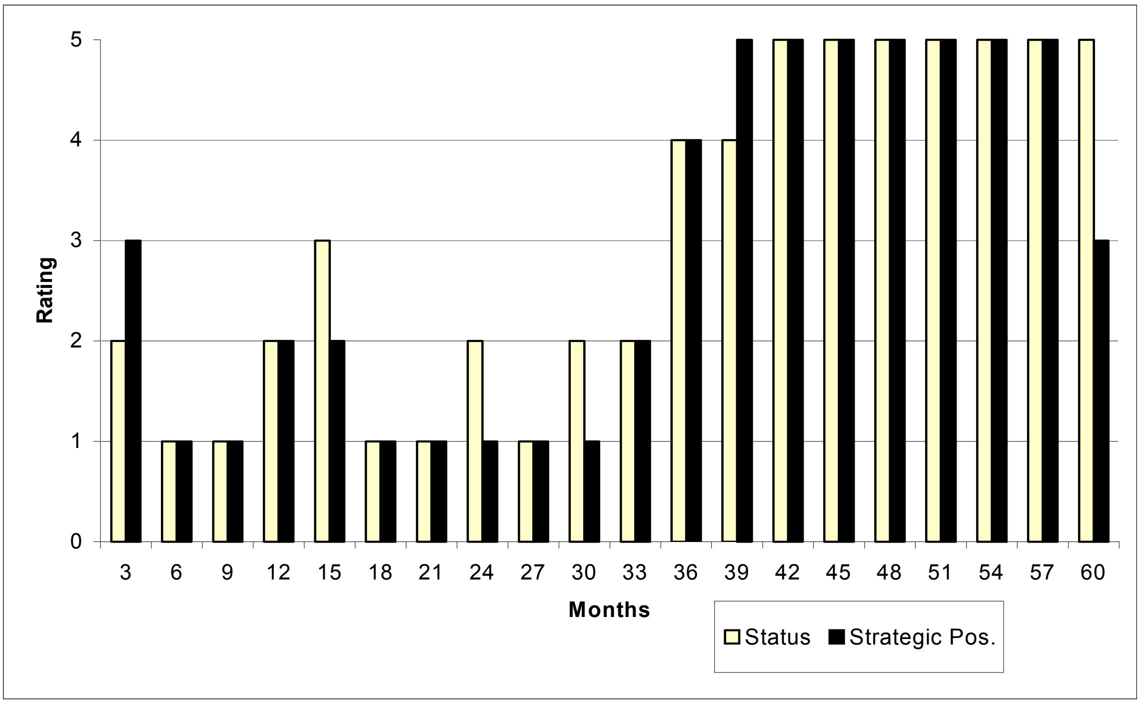

Figure 8.5 The Changing Views of the R&D Section Manager on the company's Status & Strategic position at Three Monthly Intervals.

Overall it is clear that that the attempts to predict the future by the R&D manager (Participant-observer) using the long term and short term views were not successful. All of the data was influenced by the current status of the R&D section. This means that the value of the predictions was very low. With this inability to predict outcomes, the value of any strategy that might be put in place is called into question.

The findings from this section are summarised and discussed in Chapter 11.

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Chapter 9 - The Four Schools of Thought

9.1 Introduction

In this chapter it is proposed that there are four types of reasoning that can apply to the management of R&D. Evidence is also presented that research on the topic of R&D management tends to assume that one specific type of reasoning is applicable to this activity, whereas practitioners of R&D management tend to believe that a different type of reasoning is applicable. These types of reasoning are termed the Four Schools of Thought[1] and are referred to within the thesis as **four schools**.

During the five-year period of the case study, it appeared to the Participant-observer that both small and large decisions within the company often did not appear logical based on the information available. Small decisions concerned project approvals and terminations. A typical large decision was to purchase a technology from outside when it already existed within the company or to sell technology at the point of exploitation. These decisions differ from the **SDE** mentioned earlier as in these cases the R&D section was directly involved, and should have been able to influence the decisions made. However in many cases the decision made did not accord with the views or logic of the R&D section.

The **four schools** hypothesis explains how this kind of situation can arise.

As discussed in Chapter 2 it is generally accepted that at least two different approaches to most situations are possible, the Empirical and the Deterministic,

[1] The use of the term Schools of Thought occurs in Mintzberg "Strategy Formulation: Schools of Thought" in Frederickson (1990).

(e.g., Burns and Stalker (1961), Whyte (1975,1978), Karger *et al* (1980),). It is, however, also known within the literature that different people can have many different models of their environment and how things work depending on the circumstances, (Holsti (1962), Allinson (1971). Mintzberg (1994, p 263) stated *"Managers describe their worlds in terms of conceptual models that they develop in their heads"*). Markides (1997) in particular implies that there are a large if not infinite number of possible models for strategic innovation.

However, during this research these ideas were given a more specific form and following hypothesis was developed and tested;

Hypothesis; "There are four schools of thought about the environment of R&D".

Evidence for the four schools from context analysis of the literature

The presence of four schools of thought underlying the approaches to research on the topic of R&D management was first developed as a hypothesis while reading the 655 papers in the literature review. The following definitions were developed in the light of this reading:

> **Deterministic** - in order to manage it is necessary to measure what is happening and apply logic. This approach concentrates on methods of measuring R&D outputs, for example by counting patent productivity or calculating return on R&D expenditure. This approach derives from the traditional production management approach
>
> **Empirical** - a series of rules or guidelines is derived by empirical analysis of a large number of previous R&D projects. This "cookbook" approach assumes that universally applicable success factors can be derived from past experience without needing any theoretical justification for their

importance. Project SAPPHO is a well known example of the popular success factor approach (SPRU (1972)).

Biological - the situation will change over time and what is needed is a management approach which can evolve. The building of an organisation capable of adapting is more important than the tactics for a particular project. The main concern is how to provide an organisation which is robust and adaptable enough to cope with events and changes as they occur.

Chaotic - this word is used in the mathematical sense of referring to situations which are acknowledged to be ultimately susceptible to logic, but which are too unstable or complex for logic in practice to be useful. The pattern of the chaos can be described, but a given case cannot meaningfully be worked out. You do not plan in detail, because things will change. Each case is individual, and it is a waste to put a lot of effort into trying to manage it.

Once the first fifty papers had been read, the definitions had stabilised. A check was made in which a pilot group of authors were contacted and asked for additional schools (these were respondents to the author questionnaire described below). No additional schools were suggested and no further definitions were added. Subsequent classification of six hundred more papers did not give rise to the need for any further categories. It was therefore concluded that these four forms of reasoning exist in our field, and that there are no others.

To analyse the papers quantitatively it was decided to open a new column in the context analysis database (Chapters 4 and 5) and to enter for each paper which school of thought the reviewer thought its content belonged to. It was found quite easy to assign the papers to schools. Very few contained more than one school, and none suggested a new school. It was noticed at the same time that the school of a paper appeared to be related to the background of the author:

whether academic or industrial, for example. It was therefore decided to develop definitions of author types and create another new column in the database for these to be entered.

Author backgrounds were Academic, Consultant, Corporate, Practitioner and Journalist. Corporate means a hands-off corporate level manager. Practitioner was defined as someone with hands-on involvement in R&D or its management. It was then found that different researcher types did indeed favour different schools of thought, as shown in Table 9.1. Note that the category None indicates that due to a lack of information it was not possible to assign the paper to a particular school of thought.

School of Thought	Journalist	Academic	Consultant	Corporate	Practitioner	TOTALS
Deterministic	9	89	11	93	12	214
Empirical	30	189	55	46	11	331
Biological	5	10	3	7	21	46
Chaotic	7	26	8	2	13	56
None	1	6	0	1	0	8
TOTALS	52	320	77	149	57	655

Table 9.1 School of thought and researcher type.

It can be seen that academics strongly favour the empirical school, Corporate managers favour the deterministic school and practitioners are more evenly divided, but do clearly favour the biological school. The chaotic school finds little favour except with practitioners.

χ^2 tests showed that the variation of distribution of school of thought for each type of author is significant at better than 99% except in the case of journalists, who are significant at better than 80% (see Appendix G).

A Practical Example of Two of the Schools of Thought in action

In order to fully appreciate the concept of the **four schools** hypothesis in action, it is appropriate to examine an example taken from the case study.

This typical example observed during the research concerned the divided reactions of a group of R&D managers to a simple technical problem. It shows how the causes of an unresolved disagreement can be understood in terms of two of the **four schools**.

Medium voltage switchgear is certified according to the International Electro-technical Commission (IEC). One regulation (IEC60056) defines the temperature rise allowable for a bolted connection in electrical conductors. The allowable rise is higher for a connection with silver between the conductors than for bare copper. This is because bare copper will oxidise at temperature giving a higher resistance with time and possible a thermal runaway effect. However the regulation does not say whether both surfaces need to be silver plated or only one. During discussion it became apparent that some companies within the group plate both surfaces, and some only one. The objective was to standardise procedures for the group, but it was immediately clear that agreement would be difficult. One group, Group A, argued from a logical/theoretical point of view, stating that it is necessary to plate both surfaces in order to prevent oxidisation of the copper and too high a temperature being generated, which was the intention of the regulation. The other group, Group B, stated that they had been plating one surface only for many years and that there had been no problem in the field, and temperatures had not exceeded those allowable, therefore this clearly worked.

Neither group accepted the other view, and interestingly both proposed different ways of resolving this. Group A wanted to consult metallurgical experts to discuss oxidisation of the surfaces in order to prove that plating both surfaces was necessary. Group B wanted an analysis of field experience to show that under all conditions there was not a problem. However neither group accepted that the further work suggested by the other group would give a definitive answer!

We can see that Group A were basically **determinist**, and Group B were **empiricist**. After a year of debate both groups are no nearer a common solution.

Furthermore a proposal that an experiment be performed to resolve the difference between single and double plating was not considered definitive by either group. The **determinists** argued that if the results showed no difference then they would not accept that the experiment was valid unless backed by a theoretical justification. The **empiricists** stated that they would not accept a result requiring plating on both surfaces as it did not agree with their long-term experience.

Neither group could really understand the position of the other to what they saw as a very simple technical problem with a clear solution. Even more interestingly this debate is obviously wider than just this company, as the IEC regulations have now been changed to state specifically that only one surface needs to be coated with silver. The immediate response of the **determinists** was that merely complying with the regulations was not enough and that plating one surface only introduced unacceptable risk.

Confirmation by author questionnaire of the Four Schools Classifications of the Publications

At this stage the **four schools** hypothesis relied on the opinion of one person, the researcher, reading all of the 655 papers. In order to validate this the authors of the papers were asked to classify their own papers into schools of thought.

The reasoning was that if they gave the same allocations as the researcher, then the concept of schools of thought would be shown to have a wider validity. A question on schools of thought was inserted in the questionnaire that was used to test the **context analysis** method, as described in section 5.4. The development of the questionnaire and the measures taken to maximise validity were discussed in Chapter 3, the questionnaire is reproduced in Appendix D.

In the questionnaire the definitions above were reduced to one line and authors were asked simply to tick which school of thought most closely described the conceptual framework in which their paper was set.

The simplified definitions were:

1. **Deterministic** - R&D can be managed by logic and reason
2. **Empirical** - Cookbook rules can be found that apply to R&D most of the time
3. **Biological** - R&D management must adapt continuously to change.
4. **Chaotic -** R&D is complex and variable, and there are limits to manageability

The authors were also asked to give their background, and there was strong agreement with the researchers' categorisations. No new categories were proposed.

The questionnaire was sent to 296 of the most recent authors. 121 responses were received. 112 answered this question.

		Researcher Classifications			
		Biological	Chaotic	Deterministic	Empirical
	Deterministic	0	1	35	5
Author	Empirical	0	0	3	30
Classifications	Biological	22	0	0	5
	Chaotic	0	8	1	2

Table 9.2 Comparison of Authors' Allocation of Their Papers to a School of Thought with the Researcher's Allocation of Their Papers.

Table 9.2 shows that there was very strong agreement indeed between the Researcher's classifications and the authors' classifications. This strength of correlation is strong evidence that the **four schools** construct has validity.

The questionnaire allowed for authors to make a comment after answering this question. There were no significant comments, and no one offered a new category.

9.2 Discussion

The **empirical** approach requires collation of research information drawn from experience, and it is therefore understandable that this will be favoured by academics and consultants, who need to base their contributions on some substantial work. The **deterministic** approach requires no substantial amount of work, since only reasoning ability is required. Corporate managers presumably see it as their function to apply reasoning, and therefore favour this approach. It is less clear why journalists might favour the **empirical** approach, since presumably they do not undertake the substantial amounts of work that academics and consultants put in. However investigative journalism is well recognised and can lead to good case studies (Yin (1994, p16)). The **chaotic** school appears to leave little to be researched or acted upon, so perhaps that is why it is not favoured by any group. However, the ***chaotic*** school is given reasonable weight by the practitioners.

The most notable finding from Table 9.1 is that practitioners subscribe much more uniformly to all **four schools** than other types, but are strongest on the biological, which is least favoured by the other author types. Only 9 per cent of authors were practitioners but they wrote nearly half the biological papers. This raises a question about the match between the mindsets of those who supply research papers and those who presumably would be expected to benefit from them.

It is now proposed that

1. There are only four distinct types of reasoning applicable to R&D management.
2. All four forms of reasoning may be valid in different circumstances.
3. Different people have unconscious biases towards different schools and this dominates the way individuals think and act.
4. People’s adherence to a particular school in a case is not changed by arguments.

However the firm data upon which the **four schools** hypothesis is based at this point is limited to the study of research papers and books, and the single case study. In order to validate the **four schools** hypothesis further, more research was needed. This is the subject of Chapter 10.

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Chapter 10 – The Delegate and Practitioner Surveys

10.1 Introduction

As part of the research a number of surveys of non-publishing R&D professionals was undertaken. These were designed to compliment the survey of authors of papers in connection with the **four schools** hypothesis described in Chapter 9. This additional work was carried out in order to provide data triangulation by sampling two other populations with an interest in R&D. This was part of the work carried out in pursuit of Rigor and Generalisation as discussed in Chapter 3.

A number of other hypotheses concerning practitioners, training and the management literature were also tested using the same questionnaires, and these are reported.

Authors and Practitioners

The most important finding from Table 9.1 [Chapter 9] is that practitioners subscribe much more uniformly to all of the **four schools** than other types, but are clearly strongest on the **biological**, which is least favoured by the other author types. Only 9 per cent of authors were practitioners but they wrote nearly half the **biological** papers. This raised a question about the match between the mindsets of those who supplied the research papers and those who presumably would be expected to benefit from them. Taking this finding alone it appeared that the literature reflects a view which is not in keeping with the views of the publishing practitioners.

This led on to a further question. The large majority of practitioners must be non-publishers. What schools do non-publishing practitioners belong to? Is there a difference between publishing and non-publishing practitioners? These are important questions, as the results so far could be explained by one of the following alternative hypotheses:

Hypothesis A; "Publishing practitioners are representative of all practitioners which means that practitioners subscribe to a different school of thought to that favoured by the literature".

However it is possible that publishing practitioners may be a special group who are, for example, unhappy with the views expressed in the literature, and feel the need to express a different view. Conversely the non-publishing practitioners may be perfectly happy with the views expressed in the literature and do not feel a need to contribute to the huge amount of work already available. This leads to an alternative hypothesis;

Hypothesis B; "Publishing practitioners are a special group who are not representative of the majority of practitioners who do not publish".

To investigate these hypotheses surveys were developed and applied to find what school of thought non-publishing practitioners belong to.

10.2 R&D Course Attendee Survey

The full survey of the literature described in Chapter 9 indicated that the preferred School for papers on the subject of R&D management was **empirical**, whereas the preferred school for practitioners was **biological**. If this represents a true difference in thinking then non-publishing Practitioners should also reflect this view. In order to test this a questionnaire was given out to delegates on the "R&D Strategy Course" held annually at Cranfield University. This was intended for practitioners in R&D, and according to the questionnaire returns from delegates, a significant number were practitioners. This questionnaire asked for people's backgrounds and the school of thought which they believed most closely described the process of managing R&D. The questionnaire is shown in full in Appendix E. The sample was of seventy three delegates over four years, and the response rate was 100% of those present. The few publishing practitioners were excluded.

	Academic	Journalist	Consultant	Corporate	Practitioner	Other	TOTAL
Biological	1	0	2	15	8	7	**33**
Chaotic	4	0	2	11	5	3	**25**
Deterministic	4	0	1	3	2	2	**12**
Empirical	0	0	0	1	2	0	**3**
TOTAL	**9**	**0**	**5**	**30**	**17**	**12**	**73**

Table 10.1 Results of Course Attendee Survey. Schools of thought assigned to the R&D management process by non-publishing event attendees of different backgrounds.

The results clearly show a preference for the **biological** school, closely agreeing with the results of the Author Questionnaire, and supporting hypothesis A. However, the results of the corporate people do not concur with the results of the literature analysis. Indeed they align much more closely with the expected Practitioner results, and it would be interesting to investigate the reasons for this result further. χ^2 tests were carried out on these results and gave a high level of significance [Appendix G].

10.3 Practitioner Survey

In order to triangulate this result further the same questions were asked in a survey of a number of practitioners within a single company (GEC-Alsthom). This was because the course attending practitioners could again possibly be seen as a special group, which could be non-representative of most practitioners. From the previous results the prediction was made that again the practitioners would show a strong preference for the **biological** school.

As an additional point, from the experience of the researcher and discussions with colleagues, there was a view that the majority of practitioners did not attend courses on R&D. The questionnaire included additional questions intended to confirm or deny this view. The questionnaire is reproduced in full in Appendix F. Full results of the survey are shown at the end of this section in Table 10.6.

	Number	**Percentage**
Biological	16	59%
Chaotic	3	11%
Deterministic	6	22%
Empirical	2	7%
TOTAL	**27**	**100%**

Table 10.2 Results of in-house Practitioner Survey – Schools of Thought

Table 10.2 shows that the single-company non-publishing practitioners clearly favour the **biological** school, which is consistent with the results of the surveys carried out on course attendees, and the original sample of publishing practitioners.

The full results in table 10.6 show that these are all non-publishing practitioners, the majority of whom have over 10 years experience in R&D management. These Practitioners also have had very little formal training in the management of R&D, and in addition they generally read very little on R&D management. Table 10.3 shows that for most cases, with experience of over ten years in R&D management, very few respondents had read more than five articles or books on the subject during that period. Considering that these are a wide cross-section of practising R&D managers in a large multinational organisation this indicates that the literature is having very little effect on the practise of R&D management, certainly within this company. It is also clear from the survey that the R&D managers had very little, if any, formal training in R&D management. It is proposed that this indicates that exposure to the theory by means of formal training is also very low.

Number of Replies	Books/Articles Last Year	Number of Replies	Books/Articles Previously
13	0	8	0
5	1	3	1
5	2-5	8	2-5
4	5+	8	5+

Table 10.3 Results of Practitioner Survey – Exposure to the Literature.

10.4 Discussion

The result of the three practitioner surveys is summarised in Table 10.4. This clearly indicates that the practitioners in each group consistently favour the **biological** school. The combination of the results from publishing practitioners, course attending practitioners, and non-publishing non-course attending practitioners clearly answers "yes" to the question “Does the literature favour a School of Thought which is different from that of the majority of R&D practitioners?”

	Author	Course Attendee	Practitioner	TOTAL
Biological	21	8	15	**44**
Chaotic	13	5	3	**21**
Deterministic	11	2	5	**18**
Empirical	12	2	2	**16**
TOTAL	**57**	**17**	**25**	**99**

Table 10.4 Results of the three surveys. Schools of thought assigned to the R&D management process by Practitioner Authors, Practitioner Course Attendees, and Practitioners

The results indicate that all three groups of practitioners clearly favour the **biological** school of thought, as opposed to the majority of the literature, which favours the **empirical** school of thought.

The position with regard to the school most favoured in the literature and the school most favoured by practitioners is summarised in Table 10.5. The very clear distinction between the two groups is apparent. There appears to be a trend towards the biological school as we go from publishing practitioners through course attenders to practitioners in a company.

	Empirical school	Biological school
All non practitioner authors	**54%**	**4%**
Publishing practitioners	21%	37%
Course attending practitioners	12%	47%
Practitioners in company	8%	60%
All practitioners	**16%**	**44%**

Table 10.5 Summarised results of the three practitioner surveys compared to the results of all non practitioner authors. Only the two schools most favoured by two groups are included.

A good indicator of a successful theory is that it can make predictions. Prior to starting the in-company survey it was predicted that these practitioners would show a strong preference for the biological school. The results came out strongly as expected.

Referring to **Hypothesis A**;

"Publishing practitioners are representative of all practitioners which means that practitioners subscribe to a different school of thought to that favoured by the literature".

We can see that the hypothesis is largely supported, except that the publishing practitioners are a little less strongly biological than the non-publishers.

The low interest of practitioners in the literature, which is revealed by the survey, may be due to the fact that the R&D environment described in the literature is alien to that experienced by the practitioners so that they find little of interest in the literature. However this hypothesis needs to be tested further.

The company used for the in-company survey is multinational, and respondents were of several nationalities. It was not possible to make a meaningful analysis of school of thought against nationality as the sample size was too small; however with a larger sample it would be interesting to see if there are any differences in national views. This could be undertaken as future work. Also the sample size was too small to allow for other relationships to be investigated, for example if exposure to theory via the literature or training affected which schools of thought individual practitioners favoured. This would provide another opportunity for further investigation.

Position	Nationality	R&D Role	Experience	Edu. Back-ground	R&D Training	Books/ Articles Read		View of R&D Environment
(Current)	(Birth/ Education)	A= high	Years	(Subject)	Days	Last Year	Prev. Years	School
Manager	British	A	10+	Eng.	0	5+	5+	Biological
Manager	British	A	10+	Eng.	0	2-5	2-5	Biological
Manager	British	A	10+	Science	6-20	0	0	Biological
MD	British	D	4-9	Eng.	0	1	2-5	Biological
Manager	British	A	10+	Science	6-20	5+	5+	Biological
Chief Engineer	British	C	10+	Eng.	1-5	0	2-5	Biological
Technical Director	German	A	10+	Eng.	1-5	5+	5+	Deterministic
Project Manager	German	C	1-3	Eng.	1-5	1	1	Biological
Engineering Director	British	A	10+	Eng.	20+	0	5+	Deterministic
Technical Coordinator	French	B	10+	Eng.	1-5	2-5	5+	Empirical
Technical Director	French	A	10+	Eng.	1-5	0	0	Deterministic
Technical Director	French	A	4-9	Eng.	1-5	0	0	Biological
Technical Director	Italian	B	10+	Eng.	1-5	0	2-5	Chaotic
Manager of R&D	German	A	4-9	Science	1-5	2-5	2-5	Deterministic
Technical Director	Belgian	A	10+	Eng.	1-5	2-5	0	Biological
Engineering Director	British	B	10+	Eng.	6-20	1	2-5	Biological
Chief Engineer	British	B	10+	Eng.	1-5	0	0	Biological
Director of Engineering	British	A	10+	Eng.	6-20	1	1	Deterministic
Head of Aerodynam.	British	B	10+	Eng.	0	0	2-5	Biological
Engineer	French	B	1-3	Eng.	0	0	0	Chaotic
Senior Vice president	French	C	4-9	Eng.	1-5	0	0	Biological
Technical Manager	French	B	<1	Eng.	1-5	5+	5+	Chaotic
Director of Engineering	French	A	<1	Eng.	0	0	1	Empirical
MD	British	A	10+	Eng.	20+	2-5	5+	Biological
MD	British	C	10+	Eng.	1-5	0	0	Biological

Table 10.6 Results of Practitioner Survey.

Chapter 11 - Discussion

11.1. Introduction

The research described in this thesis concerns the strategy needs of a small Research and Development (R&D) section within a large organisation. In the formulation of strategy understanding the strategic environment is considered vital (Lynch (2000, p104)), and this research has examined the environment of the R&D section as well as the possibilities and problems of developing a strategy for R&D from within the organisation at the section level. The results of the research were obtained from a number of sources; the literature review, the case study, and the questionnaire surveys.

11.2. The Literature Review.

As explained in Chapter 2, nothing was found in the literature specifically concerning the strategic concerns and environment of an R&D section within a larger organisation. There are large bodies of literature on business strategy, management, and organisational theory, which might have been expected to shed some light on this area. However these literatures were not found to be particularly helpful from the point of view of the R&D section manager, and indeed the research carried out [Chapter 10] indicated that the literature was largely ignored by practitioners. We need to ask: Why does the literature not help?

Lack of consensus in the literature

The literature contains conflicting theories, with no overall theory or paradigm being pre-eminent (e.g., Lickert (1961, 1967) Frederickson (1990, p6), Mintzberg *et al* (1998)). This was found for each of the three bodies of literature studied.

In the strategy field there is no consensus on approach. For example, Mintzberg *et al* identify no less than ten different schools (Mintzberg *et al* (1998)). Partly this fragmentation is due to a split in perspectives on strategy which on one side favours a rational approach, and on the other favours an incremental or adaptive process (Bailey (1999, p23)). The management field is in a similar position to strategy, with several different approaches to general management. These range from Fayol's command and control system (e.g. Fayol (1947), Chapman *et al* (1988), Pugh *et al* (1989)), to Lickert's four management techniques (Lickert (1967)), and McGregor's System X and System Y (McGregor (1966,1967)). The main additional contribution that the specialist R&D management literature makes is the concept that R&D is difficult to manage (e.g. Collinson (1964)). The management literature is fragmented, with conflicting theories and approaches, and has been for some time (Collinson (1964)). Organisational theory is in a similarly fragmented state, with researchers mainly producing descriptive models of organisations such as Weber's three organisational types (Weber, 1947), Handy's culture models (Handy (1981)), and Burns & Stalker's organisational types (Burns and Stalker (1961)). Burns and Stalker's work is particularly important in that it not only recognises that different forms exist, but it implies that organisations cannot change their organisational form at will.

Pre-paradigm state of the literature

Frederickson (1990) stated that there is no overall paradigm for business strategy. Reick & Dickson (1993) held that the R&D strategy literature lacks an overall paradigm. When a field of study is in this state, there is not yet an agreed set of tools to apply to problems. In Chapter 5 **context analysis** of the literature relevant to section level R&D showed clearly that the bulk of the literature did not concern testing and acceptance of theoretical concepts thereby supporting the view that this body of literature too is in a pre-paradigm state.

It is suggested that all the bodies of literature studied are in a pre-paradigm state.

The *four schools* hypothesis and the literature.

The **four schools** hypothesis provides a possible explanation of this problem of a fragmented, inconsistent view of strategy, management and organisation theory, in which different authors appear to be describing different models of reality. Just as it was easy to classify the 655 papers relevant to section level R&D according to which **school of thought** they adhered to, so it is easy to see the **four schools** at work in the larger bodies of literature that were reviewed in chapter 2.

By taking out the references to R&D, the definitions of the **four schools** can be expressed in a more general form:

> **Deterministic** - in order to manage it is necessary to measure what is happening and apply logic.
>
> **Empirical** - a series of rules or guidelines is derived by empirical analysis of previous experience. This "cookbook" approach assumes that

universally applicable success factors can be derived from past experience without needing any theoretical justification for their importance.

Biological - the situation will change over time and what is needed is a management approach which can evolve. The main concern is how to provide an organisation which is robust and adaptable enough to cope with events and changes as they occur.

Chaotic - this word is used in the mathematical sense of referring to situations which are acknowledged to be ultimately susceptible to logic, but which are too unstable or complex for logic in practice to be useful.

Taking these definitions it is possible to identify the theoretical backgrounds of each of the theories described in chapter 2. For example, Taylor's Principles of Scientific Management approach assumed that there was an optimum way to perform any task, and that this could be determined by a logical scientific analysis. i.e. work is **deterministic** in nature (Taylor (1947), Chapman *et al* (1988)). Other examples of **deterministic** theories are Fayol (1947) in Management, Burgelman & Maidique (1988) in Strategy, and Burns and Stalker's (1961) Mechanistic organisation in Organisational Theory.

On the other hand Schon (1982), has the view is that it is futile to propose rational (**deterministic**) methods of overcoming the problems particularly with technical management. Instead he advocates simply accepting that situations regularly occur which are simply not amenable to this approach, but which can be solved, or at least dealt with, by practitioners using skill and experience in a non-structured way. This can be seen to be an example of the **chaotic** school. Ackoff agrees, saying;

" *Managers do not solve problems; they manage messes*" (Ackoff (1979)).

In contrast the Arthur Young organisation takes the view that;

" *Detailed planning may be rendered obsolete when the environment changes. Better to know where you want to take your team and to develop a flair for seizing opportunities*" (Arthur Young (1986, p190)).

This is **biological** thinking. Busby & Payne (1988) on the other hand promote a management system using **empirically** derived factors.

There is little difficulty in classifying all of the literature reviewed in chapter 2 in this way.

It seems reasonable to suppose that different situations occur that are amenable to understanding in terms of the four different schools of thought. **Deterministic** authors find plenty of **deterministic** examples, plus problems which can be solved by their methods. **Empirical** authors do so too, but these are different sets of problems and situations. The same goes for the **biological** and **chaotic** approaches. From a practical point of view, a given situation a manager has to deal with may be best tackled using the most appropriate one of the four schools. It is necessary to characterise the situation according to its school before seeking help from the literature. One would not expect any of the four approaches ever to be proved "right". Rather the applicability of a theory to a situation depends on which school best describes the situation.

It can be speculated that each person may have a predisposition to a particular school of thought in their mental processes. Readers are likely to be attracted to the work of authors whose school of thought coincides with their own. This would explain why all four schools can coexist in the literature.

Previous recognition of different forms of reasoning in the literature

Researchers have previously found that managers deal with the world in terms of a preconceived model, which they have developed over time. (Holsti (1962), Allinson (1971), Mintzberg (1994, p263)).

There has always been a dichotomy between two approaches which are generally termed the **empirical** approach and the **rational** approach, (Vesey & Foulkes (1990)). It is generally agreed that both empiricism and rationalism exist in the approaches of scientists, managers and engineers and that they fundamentally affect their ways of reasoning and understanding of the world about them and how to deal with it.

Both the **empirical** and the **rational** approaches have been proven in the past to be both useful and valid (Whyte (1975,1978)). Thus the literature gives validity to the idea of at least two incompatible but equally valid views of the nature of scientific investigation.

However there is a perception that two approaches are insufficient, and the need for multiple approaches has been identified in Strategy (e.g. Hart (1991, p120), Mintzberg (1990)), in Management (e.g. Lickert (1961, 1967)), and in Organisational Theory (e.g. Astley & Van de Ven (1983)).

It is shown in this thesis that the **four schools hypothesis** is very successful in enabling the form of reasoning in a publication to be classified. It is further suggested that different types of problem are amenable to the four forms of reasoning. It is also suggested that individual managers favour particular schools, and an example of this in action was given in chapter 9.

R&D Practitioners and the literature

Business strategy is dominated by writing concerning corporate or company views, with senior management reserving the role of strategy maker for themselves (Mintzberg (1994)). There is nothing specifically for the R&D section manager, and very little for the middle manager. Floyd *et al* (1996) propose a role for middle management but only to influence company strategy.

Ball (1997) published survey evidence that most practising section level R&D managers do not read the literature on R&D management, and are often not even aware of its existence. The experience of the participant-observer confirmed that practitioners generally are not exposed to the literature on R&D management: during the five year case study no courses on R&D management were attended by any of the participants (with the exception of the participant-observer). The surveys reported in chapter 10 further confirmed this picture.

School of thought	Journal publications	Course attending practitioners	Non-course attending practitioners in a company
Deterministic	36.8%	12.5%	*22%*
Empirical	53.5%	4.7%	*7%*
Biological	4.2%	50.0%	59%
Chaotic	7.2%	32.8%	*11%*

Table 11.1 Collated results on the four schools. The numbers in italic are not statistically significant because of small numbers of respondents.

Strong evidence has been presented that the publications are dominated by the **empirical** and **deterministic** schools, while practitioners perceive R&D as having a **biological** or **chaotic** nature. In table 11.1 data from tables are converted to percentages and collected together. Data from table 9.1 has been modified to exclude practitioner authors from the tables. Data from table 10.1 has been modified to exclude academic course attendees.

It can therefore be proposed that R&D practitioners do not read the literature because it is generally presented in the form of a different **school of thought** to that to which most of them subscribe. That this is the reason would need to be tested more thoroughly, and a causal link demonstrated, before it could be considered to be validated.

11.3. Strategy for the R&D section

The nature of the strategic environment of the R&D section

"strategists are agreed that an understanding of the environment is essential to the development of corporate strategy" Lynch (2000, p104).

The key to business or R&D strategy lies in the environment of the entity formulating the strategy (e.g. Porter (1980), Mintzberg (1990), Koch (1990), Brown & Eisenhardt (1998)). Lynch (2000, Chapter 3) goes on to recommend two measures of the strategic environment;

1. **Changeability:** the degree to which the environment is likely to change

2. **Predictability:** the degree with which such changes can be predicted.

According to Lynch, once these factors have been examined and understood it is then possible to identify those elements of the environment which are most important and determine the type of strategy appropriate to the situation.

The case study was designed to record the strategic environment of the R&D section, and changeability of the environment was measured by means of the Chronology. The environment was seen to be very turbulent during the case study. This could have been a uniquely turbulent period just seen in this case, and this would impact on the external validity of the research. Investigations into the company pre-history [Appendix B], and the industry in general [Appendix A] show that this turbulence was in fact quite typical. Examination of the literature also indicated that this level of turbulence was not confined to this company and its environment, (e.g. Whyte (1975, 1978), Israel (1998). The case study by Jones & Marriott (1970) is particularly appropriate in that it describes the turbulence in the electrical equipment industry in the UK in the 1960's, referring directly to the precursor companies of **VIL**. It is not suggested that the R&D environment is always turbulent, rather it is proposed that it is quite often turbulent, and therefore that the case study findings will be applicable to at least some other R&D sections. How widespread a turbulent environment is, would be a topic for further research.

The case study also addressed Predictability by means of the Quarterly Periodic Reviews, where an attempt was made to make predictions for the future. As described in Chapter 8, these reviews failed to give any meaningful level of accuracy of prediction and were of no use in formulating strategy. The environment of the R&D section was effectively unpredictable to the R&D manager.

It was noted during the case study that frequently events outside the possibility of prediction by the R&D manager would occur which would significantly affect the strategy in place or the strategic environment. These Strategy Destroying Events (**SDE**) occurred so often that they were felt to be a normal part of the environment**.** As has been explained, analysing the strategic environment using Lynch's (2000) Changeability and Predictability criteria rates the strategic environment of the R&D section as turbulent, possibly up to Ansoff *et al's* (1984) level five – surpriseful. The literature does not introduce the concept of the **SDE**, but occurrence of the **SDE** is not surprising in a turbulent environment. What was unexpected was the presence in the case of what have been termed Strategy Confirming Events (**SCE**). These were unpredicted events which were beneficial to the R&D section but were not expected. With hindsight some were clearly seen to be connected to the strategy in place, but as Busby & Payne (1988) point out in their Planning Myths, this may be obvious in hindsight, but was not obvious at the time. Although unexpected, their frequency led to the belief that they formed part of the normal environment of the R&D section, and as such had to be included when considering strategy.

Considering the turbulence experienced and the presence of **SDEs** and **SCEs**, the environment experienced was seen to be largely **chaotic**. The case study was therefore valuable in defining the environment of the R&D section. This gives another reason why applying the literature to the situation, as originally intended, proved very difficult: the literature has very little to say about **chaotic** situations.

The group as the environment of the R&D section

One hypothesis held before the case study was that competitor actions were an important factor in strategy formulation. This was clearly mentioned in the literature (e.g. Chapman *et al* (1988), Roussel *et al* (1991)), and particularly promoted by Porter (1980). The case showed that as far as the R&D section was concerned this was just not true. The actions of competitors proved to be irrelevant to the decision making of the R&D section. On analysing the environment of the R&D section from the case study data it was clear that the section's environment was dominated by internal considerations within the group. This resulted in the realisation that the group provided the strategic environment for the R&D section, and its direct competitors were other R&D units that were acquired by the group from time to time as a consequence of take-overs and mergers.

That the **group** is the environment of the R&D section is an extremely important idea. From the case study it is clear that the **group** dominated the thinking of the R&D manager. It can be seen that the majority of the recorded events of the Chronology and the Quarterly Situation Reviews concerned the relationship between the **group** and the R&D section.

Interfaces of the R&D Section

It is possible to define different levels inside an organisation by means of relationships of the parts with other parts of the organisation and the environment outside of the company. It is proposed that three levels of management within a company can usefully be defined in this way. Depending on the size of the organisation these three levels may be merged as far as the company organigram is concerned, but it is believed that the three levels are logical and generally applicable [Figure 11.1].

- **Level 1**, the highest level, termed Corporate. This level interfaces with the business environment, shareholders etc, but has no direct interface with the market.

- **Level 2**, the intermediate level, termed Business Unit. This interfaces with the market as well as with both level 1 and level 3.

- **Level 3**, the lowest level, termed Section. This interfaces with other sections or departments within the company at a peer level as well as with Level 2. Level 3 is where the R&D Department or Section is located.

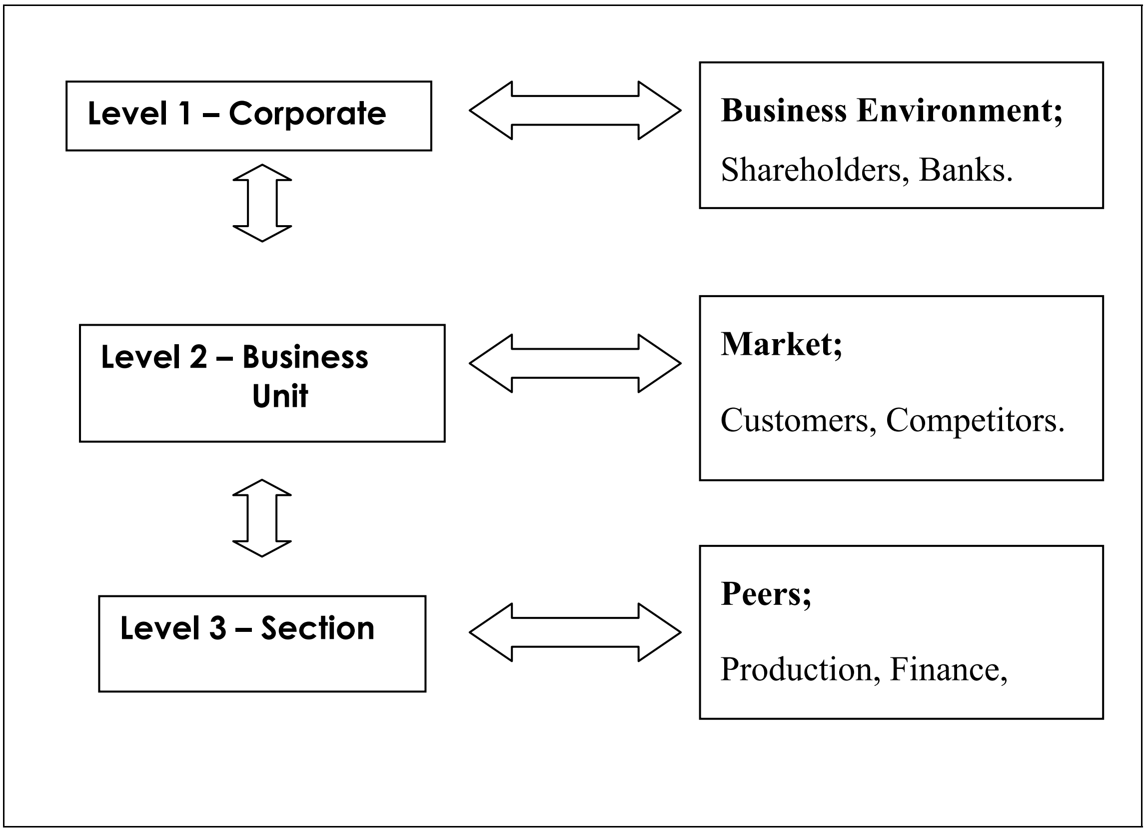

Figure 11.1 The Environments of the Three Levels of Management

Both the Corporate level and the Business level interface with the outside world, and this is reflected in the views reflected in the literature (e.g. Porter (1980)). However the Section level does not interface directly with the outside world, and so it is not surprising that considerations of the outside world are of much less importance to it. The most important interfaces are with the peers within the organisation, and the business unit, and through the business unit the corporate level. This may go some way to explain the problem with utilising the advice from the literature at the section level, and also the preoccupation of the R&D section with the corporate level.

An important question is: If the group is the major part of the environment of the R&D section, what are the consequences of this? One possibility is that the company may act against the best interests of the R&D section. This was seen twice during the case, and an examination of the pre-history of the company revealed that there were cases where this had happened before. The literature was also found to support this, although only weakly (Von Braun (1997)).

Hierarchy of Strategic Loyalties

Maslow (1943) argued that individuals are primarily motivated by the lowest level need which remains unfulfilled. Although not entirely accepted (e.g. Chapman et al (1988, p25-26)) this is a widely known theory and is useful for analysing potential conflicts of interest and improving the motivation of employees. Applying this idea of a hierarchy of needs to strategy gives the table shown below;

(6) My Industry

(5) My Corporation

(4) My Business Unit

(3) My own R&D Section

(2) My Specialist Technology

(1) Myself and my career as an individual

Technology is shown as a very high priority for technologists, who for example quite often change company, or even industry, while retaining their specialism. As with Maslow's hierarchy, the table requires that ideally all levels should be in harmony, but if this is not possible due to a conflict of interest then the hierarchy shown will apply with the lowest level loyalties dominating in any conflict. Internal conflict within the organisation is known (e.g. Burns & Stalker (1961), Bailey and Johnson (1995)) but this hierarchy provides a framework, for example to explain the response of the R&D section to some of the actions of the **group** which were perceived to be against the interest of the R&D section, and to help the R&D section to formulate a response.

As discussed previously, classical strategy theory deals with the corporation and to some extent the unit, but does not appear to give useful guidance for the section, or the individual. Armed with the above hierarchy it is possible to test alternate strategies against the hierarchy to see how well they fit the needs of the R&D section

Strategy in Action

In the light of these new principles, and particularly having decided that the company is the environment, strategy actions were developed in the case which addressed these problems, and actually proved effective in ensuring the survival of the R&D section, and, to a lesser extent, the factory. The first question was how to deal with the **group** as environment. It was thought that the R&D section should strive to increase its perceived value to the **group**, thereby influencing **group** decisions concerning the section. This was partly based on a study of the company prehistory and the early part of the case study.

The strategy developed was to show technical competence within the organisation, initially by means of a sample development. The target was not chosen from a sales point of view, but merely as an example of technological prowess, with the clear intention of impressing the **group** with the technical capabilities of the unit. This task had to be accomplished with minimal resources, during a time when the company was being dramatically reduced in size, and the survival of the unit was in question. In the event the strategy appeared to work, based on the actions of the **group**. Interestingly the sample development, although technically advanced and with some sales potential, never achieved any substantial sales, and its only measurable effect was the change in perception of the R&D section by the **group**. Considering the occurrence of **SDE** and **SCE** shown in Chapter 8 it appears that the ratio of **SDE** to **SCE** changed once the new strategy was in place. Although this effect was not predicted by the strategy it can be explained by it. Another noticeable change was the change in Positive against Negative events. Although causality has not been proven, it is a reasonable to hypothesise that this change was a result of the new strategy. It is also clear from the case study data that changes in perception take a significant time to have an effect. The delay between the strategy being decided upon and a change in the Positive against Negative events was over six months.

The strategy was pursued during a period of continuous redundancies and rumours of closure. During this time the manpower of the company dropped by 80%. It was obviously difficult to continue under these circumstances, but possible. In R&D as exemplified by the history (e.g. Whyte (1975, 1978), Israel (1998)) this perseverance is not unusual.

It is also necessary to be technically successful**.** All of the technical breakthroughs seen during the case study can be traced to individuals. It is believed that for long term success in R&D it is necessary to innovate, and in the end this relies on the individual. All of the other factors in the strategy are enhancing factors working on this point. This thinking implies that individuals in R&D really can make a difference. The many changes in the managerial personnel above the R&D section level did not have any measurable effect on the strategy, its implementation, or its effects. It appears from this that the effect of an individual is seen mainly at the R&D section level, although this is not proven and needs to be researched further.

One problem throughout the case study was the level of detail possible. It was found that an almost infinite level of detail on the case was available. However it was also found that in many cases having more data did not improve understanding of the environment of the R&D section or its situation. This was to some extent counter-intuitive but was clearly present. This is an important point in that firstly it is necessary to decide on an appropriate level of detail to monitor, and secondly that it is not possible to identify many of the critical events or data when they first appear amongst the other data. A consequence of this was that the attempts discussed in Chapter 8 to predict the future state of the R&D section during the case study failed totally.

11.4. Conclusion

Recognising that the company is the environment for the R&D section, strategy should be stanced towards the company, and in particular towards creating a positive perception of R&D by the company. Having thus gained support and resources R&D can proceed with its task of producing good technology for the company.

Producing a winning technology relies in the end on simply being good at R&D, and being seen to be good. It must be accepted that while carrying out these tasks, strategy-destroying events (**SDE**) can and will occur. In addition, at any one time the significance of recent events will be hard to judge because of their fractal nature. Thus it will be necessary at times to proceed on faith alone when things look black or the outlook is uncertain.

This advice is very similar to the policy previously being pursued by the R&D section, the main difference being that previously, efforts were not consciously made to impress the company. This research indicates that this policy was appropriate to the circumstances. A better policy was not found. The research has drawn attention to the limited powers of the R&D section in that it can presents the company with a superior technology but success is then dependent on the company successfully exploiting this advantage.

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Chapter 12 - Summarised Results, Contribution and Further Work

12.1 Introduction

This chapter summarises the results of the research and discusses its contribution. The results of the research were obtained from a number of sources; the literature review, the case study, and the questionnaire surveys. These results were combined during the study and used to test a number of hypotheses which were developed during the research. In this chapter the hypotheses are presented in a systematic order which is different from the order in which they arose during the work. Hypotheses that had numbers in previous chapters have had their numbers preserved here, so the hypothesis numbers are not sequential in this chapter.

12.2 Hypotheses

Fifteen hypotheses were developed and tested and these are listed below.

Hypothesis:

“The literature studied is in a pre-paradigm state.”

This was based on work by Snow (1994) who suggested that in the post-paradigm phase most publications concern firstly the testing and acceptance of a theoretical concept. Context analysis showed that the literature relevant to section level R&D did not do this, and so the hypothesis was supported.

Hypothesis:

"There are four schools of thought about the environment of R&D".

The **four schools** hypothesis was developed initially from the study of the research papers: when **context analysis** was used to analyse papers for their schools, all papers aligned with one of these four approaches. Testing for the hypothesis by means of questionnaires filled in by authors, course delegates, and practitioners strongly validated the hypothesis, which was also seen to be present in the case study.

Hypothesis:

"Authors with different backgrounds involved in research on R&D tend to subscribe to different schools of thought".

This hypothesis referred to authors backgrounds as academics, managers etc. was developed as a continuation of the previous hypothesis. Context analysis of the literature clearly supported this hypothesis.

Hypothesis:

"Practitioners generally subscribe to a different school of thought to that favoured by most of the literature".

It was shown by surveys and context analysis that the favoured school for practitioners is **biological**, whereas the favoured school for the literature is **empirical**.

Hypothesis:

“Practitioners are not well exposed to the theory of R&D management.”

This was originally a weakly held idea. Although the sample was small, the questionnaire research on practitioners supported this hypothesis.

Hypothesis:

“One reason that R&D practitioners do not read the literature is that generally it is presented in the form of a different school of thought to that to which most practitioners subscribe.”

This was a development of the previous hypotheses, and the research results give strong support for this. However the causal link is considered weak, and further work is needed to fully verify this.

Hypothesis 1:

“The actions of competitors are an important factor in the strategic environment of the R&D section”.

At the start of the case study, the actions of competitors were thought to be important. However events recorded in the case study did not support this hypothesis. Indeed the results indicate that for the R&D section the actions of competitors may be irrelevant, but this would require further research to verify. A reason why competitors may be irrelevant was proposed, in terms of the interactions to which an R&D section is exposed.

Hypothesis 3:

"For a unit within a group, the major part of the strategic environment is provided by the group".

This was clearly demonstrated in the case study and no evidence was found within the case to refute this hypothesis. On eleven occasions during the period studied the group acted in a way which frustrated the strategy of the unit. This included the acquisition of rival technology, which seriously threatened the survival of the R&D section. This is possibly the most important of the hypotheses from the point of view of strategy for the R&D section, indicating that the section should stance its strategy internally, towards the group.

Hypothesis 4:

"Companies can throw away technology they have developed, at the brink of exploitation, due to lack of faith or understanding, and they may even allow competitors to take up the technology".

On two occasions during the case study the company threw away technology, and similar cases were also seen during the history. Thus hypothesis 4 certainly reveals a realistic danger, but it is not as strongly apparent as some of the other hypotheses.

Hypothesis 6:

"Strategy-Destroying-Events occur quite frequently, rendering specific strategies void. In addition Strategy-Confirming Events may also occur giving rise to unexpected benefits of the strategy".

SDE and **SCE** occurred sufficiently often and unpredictably in the case that the hypothesis can be considered strongly supported.

Hypothesis 5:

"Stancing strategy with regard to the group can be a matter of creating perceptions, which are as important as facts".

During the case study this occurred eleven times during the five-year period. The idea of creating perceptions is an accepted one in the literature and is clearly referred to, for example, as part of the art of negotiation by de Bono (1991).

Hypothesis 7:

"Success can be achieved by a sense of mission, pursuing an objective despite an appearance of great odds".

On two occasions during the case study, work was carried out despite a hopeless outlook for the R&D section, in order to create a slim chance of survival. Although rare, one example was probably the most significant single item in the case study, as it enabled the strategy which ultimately enabled the section to survive.

Hypothesis 8:

"Success can be due to an individual's truly innovative break through".

Successful R&D strategy in this case required successfully applied inventiveness, which could be traced to a single inventor. During the case study this occurred three times, and again the occurrences were critically important for the section.

Hypothesis 2:

"Changes of Key personnel are an important factor in the Strategic Environment of the R&D section".

In fact the changes of key personnel had no measurable effect on the environment of the R&D section. The results did not support this hypothesis and so it was abandoned.

Hypothesis 9:

"Strategic decision-making can involve a range of factors of great complexity and fractal-type detail. Small events can have great strategic significance".

This occurred throughout the case study and also in other aspects of the work. The data in the case was clearly fractal in nature: there is an almost infinite level of detail possible. This means that obtaining more detail does not necessarily help improve the understanding or decision making process of the R&D manager.

12.3 Contribution of the research

This research has investigated the strategic environment of the R&D section within a larger organisation. In doing so it has provided insight into the decision making process and the problems and limitations experienced.

The research has confirmed the previously reported low influence of the literature on practitioner R&D managers (Ball (1997)), and has provided insights into why this is so. In addition advice is also provided on how this problem can be addressed.

During the research a new bibliometric tool was developed which provides a useful tool for researchers in many fields and whose utility has been demonstrated in Chapter 5.

A number of hypotheses were developed and tested during the research and these provide information on the situation facing the R&D section manager together with advice on how to deal with some situations.

Four of the hypotheses are thought to be particularly important.

- **The four schools of thought.**
- **The company as environment for the section**
- **The presence of Strategy Destroying Events in the environment of the section.**
- **The fractal nature of information at the section level.**

Finally the research has provided a longitudinal study into the history of one R&D section over an extended period. This provided valuable insights into the workings of an R&D section within a larger organisation, and also answers the call by Bowman (1990 p24) for more studies on strategy that are “peopled”. That is studies about people who are doing real things for real reasons, and which allow you to think about why things are happening the way they are. It is believed that this participant observer case study performed from inside an R&D unit and extended over 5 years has given a unique opportunity to record a strategic R&D environment unclouded by hindsight or filtered by observation at the distance of an outside observer.

12.4 Implications of the research

The research carried out has implications both for the Academic world and for the R&D manager or Practitioner.

Academic relevance

The research presented here provides a new insight into the environment of the R&D section, and considers the applicability of known theories of Business strategy, Management, and Organisations to this previously unexplored area. The work carried out confirming the lack of effect of the literature on practitioners is important. The **four schools** hypothesis gives a framework within which some of the problems of the R&D section and in particular its relationship to the literature can be explained. This framework is also useful for understanding the management literature from the viewpoint of the R&D practitioner. The use of the **four schools** hypothesis as a possible explanation of the lack of exposure to the literature by practitioners is a practical example of its academic relevance.

In addition the development of **context analysis** should prove a useful tool in academic research in other fields.

Managerial relevance

In addition to the academic value of the research, the intention of this work was to provide help to managers of small R&D sections within larger organisations. Particularly by means of the case study the environment of the R&D section has been illuminated. The reason for the apparent lack of relevance of the literature to the practitioner has been illuminated by the **four schools** hypothesis, which explains why much of the literature appears to describe an environment unrecognised by the practitioner. This should also lead to an understanding by authors as to how to orient their work to be understandable and relevant to their target audience, be they academics, or practitioners, or any other group. That the **group** can be the true environment of the R&D section is an important factor, which should be considered by the R&D manger in establishing strategy. The manager should also consider whether the environment has a **chaotic** nature, as evidenced by the presence of **SDEs**, and by the information available having a fractal nature. The **four schools** concept will he helpful in characterising situations before deciding on the best approach to them, and also sometimes in understanding differences of opinion over specific issues. Finally the manager of an R&D section should recognise the hierarchy of strategic loyalties and work out what persons or organisations a strategy is for.

12.5 Limitations

Overall the research undertaken improves understanding of the environment and formulation of strategy at the R&D section level, but does not provide a full theoretical context.

As a result of carrying out this research it is now possible to see that alternative research questions, hypotheses, and research methods could have been used. This is a normal consequence of the learning process, and is seen as a demonstration of learning (Bailey (1999, p199). However despite its acknowledged limitations the research carried out contributes significantly to knowledge in the field selected.

According to Hickson (1987), also quoted by Bailey (1999, p199)

"All research is bad research, inasmuch as it could always be done better and there is always more to do", (Hickson (1987, p187)).

This research was Inductive, i.e. exploratory in nature, and as a result there are many areas which should be researched more deeply. Inductive research generally creates many more questions than were answered and so is normally a fertile ground for further research. Chapter 3 discussed the limitations of the methodology in some detail.

Of necessity the literature analyses undertaken were of papers and textbooks written in the English language. It is possible that the results found apply more to an Anglo-American culture. The sample of non-native English speaking authors was too small to allow any meaningful analysis of this. The other research carried out by questionnaire did include a significant proportion of non-native English speaking respondents, but the sample was too small to identify any national or cultural pattern. As a result it is possible that the outcomes of this, particularly the **four schools** theory, can only be said to have been shown to apply to the Anglo-American world. Further work would be needed to see if this is universally applicable.

As explained in Chapter 3 the use of questionnaires incorporates several limitations to the research and some weaknesses. The questionnaire is not a precise tool for research and was chosen as the best compromise between the quest for good information and practicability. However as outlined in the relevant chapters steps were taken to reduce the limitations of the questionnaire technique, and it is believed that these were successful.

The context analysis technique was developed during the research, and as such is an unproven research tool. However the results obtained here were clear and useful, the operation of the tool is straightforward .

The use of a single case study leads to questions concerning the external validity or applicability of the research to other organisations, or in other circumstances. Steps were taken to address this problem, in particular following the advice of Kennedy (1976), and it is believed that these go some way to addressing this. However it remains a perceived weakness, and the next clear step would be to repeat the case study research in other organisations to show wider applicability.

12.6 Further Research

Parts of the research could usefully be repeated with larger sample sizes. In addition the outcomes of the research undertaken lead to a number of new research questions;

1. How common a **chaotic** environment is in R&D should be studied by developing tests and examining R&D in a number of companies.

2. How widespread **SDEs** are in companies should be studied by surveys of more companies.

3. The hypothesis concerning the exposure of practitioners to the theory needs to be further researched with a larger sample of practitioners from a number of companies to verify the general validity of this.

4. Some of the surveys of chapter 10 could usefully be repeated with larger sample sizes, and sampling of complete groups of practitioners in a range of companies.

5. The applicability of the **four schools** hypothesis to other management situations than that of the R&D section could be investigated.

6. The applicability of the **four schools** hypothesis to other cultures than Anglo-American should be tested.

7. The conjecture that individuals have a bias towards a particular school could be investigated.

8. The hypothesis that practitioners do not read the literature because of a difference in school of thought between publications and the perceived R&D environment, needs to be tested to prove a causal link. This would require a dedicated research programme. If validated this would prove extremely valuable in determining the relationship between the theoretical background of the literature and that of the target audience. This is a potentially wide area of research as it can apply not only to the R&D management and strategy literature, but also perhaps to any body of literature.

9. **Context analysis** could be further applied in other bodies of literature because of the rich harvest of knowledge about a research field as a whole, which it yields.

10. The use of all of the hypotheses concerning formulation of strategy for the R&D section level should be studied more, preferably in a number of different organisations to show the efficacy of this approach and the applicability of each of the hypotheses.

11. More studies concerning the strategic environment for R&D within the organisation should be carried out on different organisations. This will overcome the weakness of a single case study, and as more information is gathered so more light will be shed on this fascinating but little explored area of strategy formulation.

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