CRANFIELD INSTITUTE OF TECHNOLOGY

SCHOOL OF MANAGEMENT

Ph.D. Thesis

Academic Year 1992-3

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Planning Product Support for Medical Products

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October 1992

ABSTRACT

Product support is a key aspect in the marketing of high-technology products, since it strongly influences customer satisfaction and can also be an important source of revenue. Typical forms of support include operator training, equipment maintenance and, if necessary, repair - all of these are normally provided by manufacturers' support organizations. Good support is particularly important in some markets; an example is medical equipment where good operator training and quick repairs are essential because products are used in critical situations. Despite its importance, support has not been extensively researched. This study describes a management investigation of two aspects.

Several authors have identified that product support is dependent on product design. Consequently, the same authors emphasize that support should be thoroughly evaluated during product design. This study identifies the range of factors that may be evaluated and shows that most of the companies surveyed do not fully evaluate support during the design stage. These results are not covered by previously published material and have implications for management.

As support influences customer satisfaction, it is important to know how customers perceive support. The study investigated the customer attributes of good support, using interviews with medical equipment customers. The results show that a common set of attributes are associated with support, some relating to the product itself and some to the support organization. The characteristics of products which are easier to support were also identified from the interviews.

The contribution of the research is that it made an exploratory investigation of the concept product support. It not only gave the first survey data on how companies plan support but also investigated customers' perceptions of product support. Consequently the study provides a foundation from which there is real scope for further management research, into what is becoming recognized as a vital element of high-technology marketing.

ACKNOWLEDGEMENTS

Completing a Ph.D. parallel to full-time employment abroad was something that I found rewarding but seldom easy. It would have been impossible without the direct and moral support of many people, all of whom I want to sincerely thank here.

Firstly, my thanks to Colin New and Graham Clark for being excellent supervisors who, through suggestions, ideas, constructive criticism and encouragement taught me how to conduct research into management. They brought me a long way from my initial (and naive) ideas of how a piece of research should be done. Particularly beneficial was their ability to work together as a team and give complementary advice on different aspects of the research process. In addition, their recommendation that thesis-writing should be a continuous process, best conducted parallel to the research, stood me in good stead.

It was stimulating to work at Cranfield Institute of Technology's School of Management and meet many of the staff. In addition to my direct supervisors, several lecturers gave advice at various stages of the project including the research reviews; my thanks to Simon Knox, Frank Fishwick, Joe Nellis and particularly Colin Armistead.

The topic of product support chosen for the research arose from my full-time employment with Hewlett-Packard's Boeblingen Medical Division (BMD) in Germany. In addition, Hewlett-Packard were forward-looking enough to realise that supporting the research would not only provide motivation to the researcher but would also lead him to study issues of direct relevance to the company. Particular thanks to Steve Emery, BMD Marketing Manager, for his encouragement and interest in the project. Many colleagues also showed interest over the four years of research, particularly some of the engineers who were interviewed as part of the survey work.

Arranging regular meetings to discuss the progress of the research was not easy due to the full (and often conflicting) programmes of my two research supervisors and myself. Sheila West, Colin New's secretary, did an excellent job of "making it happen" several times per year. In addition, Sheila was very helpful with the logistics of the postal survey stage of the research. (It is not easy to organize a survey from abroad and it would not have been possible without Sheila's help.)

During the course of the project over four hundred articles and books were consulted, thanks to the assistance of the staff of the management library. I am very grateful to Doreen Dunbar who helped in quickly tracing references and obtaining inter-library loans for me.

The postal survey of the UK members of the Association for Services

Management International (AFSM International) was a key step in the research. AFSM International gave both advice on the questionnaire and financially supported this part of the research. Thanks to Mick Floyd for his useful suggestions on the questionnaire. Particular thanks to John Bache, who not only really helped with the organization of the survey but also became interested in the wider research project - his interest and encouragement were appreciated.

One of the problems of part-time research is that one has little contact with other research students and therefore limited opportunities to exchange ideas. Only during my last year of research was I was fortunate enough to meet Amin Khan, who is investigating another area of customer service. Discussions with Amin were really useful and, in addition, his help in running some data analysis for me on the Cranfield computer was really appreciated. (Good luck to Amin, who I am sure will successfully finish his research in 1993.)

Writing a thesis takes considerable time and effort, despite the availability of word processors. The assistance of several people in reading, correcting and suggesting improvements to drafts was essential. Thanks to Peter Whitby, David Russell and Eva-Maria Braun. Special thanks to Helen Muehling for her extremely accurate proof-reading. I also want to thank Kjell Nordstroem, of Stockholm School of Economics, for giving me a copy of his 1990 thesis, from which I gained some ideas about structuring my own report.

Moral support is essential for the part-time researcher - there are times when you wish you had never started but have already invested too much time to be able to give up! My family really encouraged me. My gratitude to my father Gerald Goffin and *danke* to my parents-in-law, Ella and Kurt Koerner. Friends who offered regular motivation include Hilde and Georg Schubert, Martin Perraudin and Daniel Nordstroem. Juergen Draeger, a colleague who is studying medicine part-time, understood the problems part-time study can bring and offered tips on coping with it. (Good luck to Juergen with his continuing studies.) My regular rock-climbing partners, Cecil Coffin and Ruben Mookerjee, showed interest and were understanding enough not to distract me too often (or too seldom!) by asking me to go climbing.

At my *viva* the examiners commented that the project had been completed part-time very quickly and said, *"you must have an extraordinarily understanding wife"*. This is true, as without Sonja's patience and inspiration I would never have found the energy to complete this research.

This thesis is dedicated to my late mother Joyce, who offered me much encouragement in the initial stages and who so much wanted to see the research completed successfully.

Esslingen, Germany, October 1992.

PLANNING PRODUCT SUPPORT FOR MEDICAL PRODUCTS

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CHAPTER ONE

Introduction

1.0 INTRODUCTION

This thesis describes research into the field of *product support*. Product support is increasingly being recognized as a key aspect in the marketing of high-technology products. However, it is an area in which there has only been limited management research. Consequently, the research described in this thesis is exploratory in nature.

Product support is the generic name given to the various forms of assistance that companies provide to customers to help them obtain maximum value from high-technology products. Typical forms of support include training on a product, advice on its use, repair services (generally termed *service*), availability of spare parts and warranty schemes. Product support plays a key role in the marketing of high-technology products; it is an essential factor for ensuring customer satisfaction and can be a major source of revenue. In spite of this, management research into support is limited and it is a topic which is almost totally ignored in marketing textbooks[1]. Consequently, there is considerable scope for research but only sparse understanding of the concepts involved. The subject of this thesis is the investigation of two aspects of product support: how companies evaluate support at the design stage of new products and the customer attributes of good support. Both of these investigations break new ground.

This chapter explains how the topic of research was chosen, outlines the research design, its intended contribution and the structure of the thesis. Subsequent chapters describe in detail, with supporting references, all of the points covered here.

1.1 BACKGROUND

Why was product support chosen as an area for research? The main reason for the choice was influenced by the responsibilities of the researcher, in his full-time employment with the Hewlett-Packard Company. As a manager involved with the support of medical equipment, it was clear to him that the understanding of product support was, at least in his industry, not very well

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[1] "Standard" marketing texts such as Kotler, *Marketing Management* (5th Edition, 1984) make no reference to the planning of product support. This is because most marketing texts concentrate on consumer products, and for these support is not important.

developed. This, together with the recognition that support is a key factor in the medical electronics market, led to an initial review of the literature.

The initial review of the literature identified many anecdotal articles on support but showed that very little has been written on how support should be evaluated for new products. Although several authors[1] point to the importance of evaluating support requirements at the design stage, few give any guidance on how this can be done or even what support consists of. Similarly, in the literature on product management, very little could be found on the importance of support for high-technology products or if product design considerations should include support requirements. From his practical experience the researcher saw that product design can have a strong influence on the quality of support that can be provided by a manufacturer. In addition, it was seen that customer expectations of support were changing in the medical equipment and other high-technology industries.

Good product support has traditionally been very important in the medical equipment market. Product reliability plus, when necessary, quick repair is essential for obvious reasons; often the equipment is used in critical care situations. This causes hospitals purchasing equipment to carefully consider both the reliability of equipment and the repair services offered by manufacturers. Traditionally, some manufacturers obtained competitive advantage by being able to design more reliable equipment. With the introduction of new technologies (e.g. microprocessors), the reliability of equipment from all manufacturers has increased tremendously. Since highly reliable equipment is now available from most manufacturers, this is leading to a change in customers' expectations of product support.

Product support, which is also called *post-sales support*, covers wider issues than just reliability, maintenance and repair. It is to these wider issues that customers' attentions are now changing. Two examples of this are the focus of hospitals on the training provided by manufacturers and on equipment cost of ownership. Hospitals are interested in staff training costs, equipment running costs (for supplies, maintenance, repair etc) plus the costs of keeping the equipment updated (i.e. upgraded to the latest functionality) over the lifetime of the product.

The operators of medical equipment (mainly nurses) are not normally experienced in using complex computer-like equipment. Most medical electronics equipment is used in specialized units (such as intensive care units) and nurses moving to these units require equipment-specific training. As there is often a very high turnover of hospital staff, this increases the need for training. This means that manufacturers need to produce easy-to-use products, good documentation and offer cost-effective training - all aspects of good product support.

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[1] Details are given in the review of the literature on product support: Chapter Two.

The medical equipment market is becoming increasingly cost-conscious. This leads hospitals to critically assess all purchases of new equipment and part of this assessment often includes an evaluation of cost of ownership. For most medical equipment the running-costs (electricity and accessories) are comparatively low but the costs of maintenance, repair, staff training and equipment updating can be high. Therefore, hospitals are likely to become increasingly interested in the way companies give support and how improvements can lead to reduced cost of ownership.

How can good product support be given, for medical or other high-technology equipment? A sufficiently large, well-trained field organization can enable a manufacturer to offer his customers good support. However, the quality of support that can be given is also dependent on the characteristics of the product or products being supported. For instance a product which is difficult to repair or which is not easy to operate will be more difficult to support. Anecdotal evidence found in the literature suggests that products designed with support requirements in mind would be easier to support.

Will products designed with support requirements in mind really be easier to support? The advantage of assessing product support at the design stage is probably analogous to a problem that existed in manufacturing management some years ago. For many years products were designed with little consideration of how they would be produced. Then the Design for Manufacture (DFM) methodology was introduced and this has been very successful. DFM is the full consideration, at the design stage, of how a product can be efficiently manufactured. The most important element of the DFM approach is that, during product design, the ease by which the design can be manufactured is quantitatively estimated. The product design finally chosen is one which meets the required design goals, including those from the manufacturing viewpoint. DFM methods are now widely applied in manufacturing industry and they have allowed big advances to be made in efficient product manufacture. Several authors writing on support suggest that evaluation at the design stage, similar to DFM, would improve support.

Do companies today evaluate support at the design stage? And what are the attributes of good product support? Essentially, it was these two questions that led to the research.

1.2 AN OUTLINE OF THE RESEARCH

The background knowledge of the researcher and the review of the literature led to the two main research questions given above. These led to a number of possible hypotheses, from which three actual research hypotheses were chosen.

Two research hypotheses are connected with how support is evaluated by high-technology companies at the design stage of new products. The supposition was that the evaluation of support often takes place late in the design cycle and is not comprehensive. The third research hypothesis was linked to the meaning, from the customer's viewpoint, of good support. The supposition in this case was that a set of common customer attributes of good support can be identified. All three hypotheses are closely linked.

1.2.1 The Research Objectives

Derived from the hypotheses were the following main research objectives:-

1) To identify the amount and type of support planning made by high-technology companies at the product design stage.

2) To explore the customer's perception of good product support[1].

1.2.2 The Methodology

As already stated, product support is an area where there has been negligible management research. Therefore the research was exploratory in nature and there are no established concepts on which to build. This led to careful considerations as to the most suitable methodology. In the event, the survey style was chosen and the reasons for this choice are described in the chapter on methodology.

Two different survey methods were used in the research. Firstly, a postal survey was conducted to identify the types of support planning in use today by high-technology companies. The choice of a postal survey was influenced by a number of factors, the most important of which was the need for anonymity. The second step in the research was the study of the attributes of good support using in-depth interviewing. For this Kelly's Repertory Grid Test was chosen, due to its proven success in market research into ideal product attributes. Its particular advantage is that it stimulates respondents to identify ideal product attributes, which they are often unable to do, following direct questioning. The method was applied in the form of structured interviews with customers from the medical electronics market.

1.3 THE INTENDED CONTRIBUTION OF THE RESEARCH

The intention of this study was to contribute to management knowledge on product support. The lack of previous management research meant that the literature on this area consists largely of anecdotal reports on how product

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[1] The term *good product support* itself needs to be better understood - although it is used in the literature there is no accepted definition of product support. There have been no previous investigations of exactly what *good* product support means.

support is managed by particular companies. The research aimed to change this, at least partially, in three ways.

Firstly, it was intended that the study would start to bring structure into the subject, by bringing an understanding of the concept of *good product support*. This would be done by comparing the definitions of support in the literature with actual results of research into customer attributes of good support. Secondly, the intention was to contribute to the knowledge by surveying the current practices of high-technology companies in planning product support. Finally, from a pragmatic standpoint, the researcher's company hoped that it would identify some steps which could be implemented to improve product support for their medical products.

1.4 THE STRUCTURE OF THE THESIS

This thesis is divided into nine chapters. It has already been mentioned that there is a significant literature on the subject of product support but that there are gaps in the knowledge. Chapter Two gives a comprehensive review of the literature on product support and identifies some of the areas where research is necessary. It finds, in particular, that there is a lack of information in the extant literature on how companies typically plan product support and on the meaning of good support.

Implicit in much of the writing on support planning is the assumption that planning automatically leads to more effective business management. Several authors state that improved planning will increase the quality of product support. However, this is jumping too far; *does planning improve the quality of product support?* Chapter Three examines the background to this question by covering the literature on management planning and whether there is a causal link between planning and more effective management. After starting by reviewing the history of planning, Chapter Three concentrates on new product planning, from both the marketing and manufacturing standpoints. Planning methods from marketing and manufacturing are discussed, together with the evidence for a causal link between these methods and better quality products. This leads in turn to a discussion of the field of Design for Quality (DFQ), the generic name for all management planning methods which aim to produce quality products (where *quality* in this sense means suitability for its intended purpose).

Chapter Four explains how the research was designed. It takes a chronological view, describing the initial hypotheses and why these needed modification, to make them researchable. The concepts of interest are explained, as are the variables chosen to make the concepts measurable. In particular the concept product support, as it is central to the research, is discussed in detail. The specific research objectives, derived from the hypotheses, are listed. For these suitable methodologies are presented, with their advantages and disadvantages. The approach chosen is introduced; the postal survey and structured interview technique. Finally the choice of the two samples used in the research is presented.

Chapter Five explains the specific market used as the case study during the research - the medical electronics market. The types of equipment and their use are explained, together with the key market characteristics. These include the variety of different users of the equipment, the international controls on the market plus the importance of product support. The relevant details of the Hewlett-Packard Company, from which one of the samples was drawn, are presented.

Chapter Six takes the specific research objectives and identifies suitable methodologies. The literature on these methodologies is reviewed, including the advantages and disadvantages of postal surveys and Kelly's repertory test. From the information in the literature, the pilot tests for the survey and interviews were designed and it is explained how these were developed until reaching their final form.

In order to determine the type of product support planning undertaken in industry a postal survey was used. The results of this questionnaire are presented in Chapter Seven in detail. The full results are given and then compared to the research hypothesis, so that conclusions can be drawn.

Structured interviewing was chosen as the best method for identifying the attributes of an ideal product from the support standpoint. Over sixty interviews were made, with customers in the medical electronics market. Chapter Eight gives the results of these interviews, which includes not only the identification of ideal product attributes but also the scoring of current products as to their "supportability". The results are compared to the hypotheses and conclusions drawn.

Chapter Nine takes the combined results of the survey and interviews and compares them to the hypotheses in order to reach the conclusions of the research. It reviews in detail the research questions asked, the results found, the conclusions that can be made and the areas to which they are applicable. Particular limitations of the research are acknowledged, suggestions for rectifying these are made and extensive recommendations for further research are given. The general conclusions on the research are given.

1.5 SUMMARY

Good product support is essential for high-technology products because it has a strong influence on customer satisfaction. The research described in this thesis aimed to identify the attributes of good support and the degree to which support is evaluated by companies at the product design stage. The survey style of research was used: applied as a postal questionnaire to investigate companies' planning of support and in-depth interviewing to identify customer attributes of good support. The nine chapters of this thesis describe the literature, how the research was designed, the methodology, the results and the research conclusions. The conclusions include an analysis of the degree to which the results can be generalized, their limitations and ideas for further research.

CHAPTER TWO

The Literature on Product Support

2.0 INTRODUCTION

Product support is the term applied to the range of items, methods and organizations that a company employs to help customers obtain maximum value from their products. Typically, support includes such components as technical advice, training on a product, repair services (generally termed *service*), availability of spare parts and warranty schemes. An emphasis on the importance of product support for industrial products has emerged during the last few years. This chapter will discuss in detail the literature on support[1], which was found to contain information on five main topics:-

- Background information on the growing importance of product support for industrial products.
- Definitions of product support, with identification of its various components.
- Organizing a field service organization for the optimum delivery of support to customers.
- Identification of strategies for improving the quality of support plus, in some cases, analysis of specific strategies.
- Designing products with support in mind.

2.1 THE IMPORTANCE OF PRODUCT SUPPORT

The increase in management interest in product support is due to the recognition of five factors:-

1) Support can be run as a highly profitable business and may be a major source of revenue for industrial companies.

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[1] Refer to the appendix for details on the literature search.

2) Good product support is essential if customer satisfaction is to be achieved and is a key to influencing existing customers to buy again.

3) Good product support can give a company competitive advantage.

4) It is becoming easier to offer good support, due to both advances in technology plus new approaches that have been developed for the delivery of support. Some of these new methods have the added advantage that they increase the feedback from the customer, thus giving companies a key source of information on customers' acceptance of their products. (This information can be invaluable when new products are being designed.)

5) There is a changing attitude towards support. It is now seen as an essential part of the business for industrial products, which requires a professional approach.

2.1.1 Support as a Source of Corporate Revenue

Large companies seldom give very detailed information in their annual reports on the amount of revenue and profit that they earn from their support organizations. However, a number of articles and one survey have been published over the last few years, which give an indication on how support can be a key source of corporate revenue, at high profit margins and with significant growth potential.

Repair services for electronic products are estimated to cost more than $60 billion annually in the US alone, including $20 billion from the computer industry (Potts, 1988[b]). The European market is also significant; it was estimated in 1986 as being about 60% of the size of the US market (Lambert, 1988). These markets offer the opportunity for companies to earn significant amounts from service; for example the computer companies Digital Equipment Corporation and Data General Corporation obtained 33% and 28% respectively of their 1983 revenues from this source alone. The high level of revenue which can be generated from service is confirmed by a number of other authors. Pittiglio and Hoole (1987) found manufacturers to earn 15% to 33% of their revenue from service and Anderson (1988), in a large survey, found the average level to be 26%. Berg and Loeb (1990) quote a range of 25% to 35%, whereas the highest figure can be found in Stewart (1990) who says that "*as a percentage of total revenues ... for many companies now represents 35% or more*". Certainly the amount which can be earned from service is high enough to gain management attention.

In addition to being an important source of revenue, support has generally been reported to be a highly profitable and growing area. Gross profit margins achieved in the electronic products service industry were found to be at an average level of 33%, with some companies reaching 40% (Anderson, 1988). In this same study some companies were found to earn up to 50% of their profit from service. The area of electronic service has also been found to be growing particularly fast. Anderson (1988) estimated the average growth rate between 1980-1985 to be 11%, whereas Mathe (1988) quotes figures for computer service revenue growth of between 29% and 47%, for four well-known companies.

Although support can be a highly profitable area, it is one in which competition is increasing. In the past, high-technology vendors had a "captive market" with the support of their products but this is no longer the case. The emergence of "third-party maintenance" (TPM) organizations has removed this monopoly. These organizations, which specialize in the repair and maintenance of the products of other companies, often sell support at significantly lower prices than those of the manufacturer. This has enabled TPMs to capture a large slice of the US service market - Zemke and Schaaf (1989) estimate TPMs' revenue was $1.5 billion in 1987. Equipment manufacturers have started (and will no doubt continue) to meet this challenge in three main ways:-

1) By attempting to differentiate the quality of their services from the competition.

2) By attempting to limit the efficiency of third parties using technological means. An example of this is manufacturers who limit the availability of certain diagnostic tools to their own service organization (Kastiel, 1987).

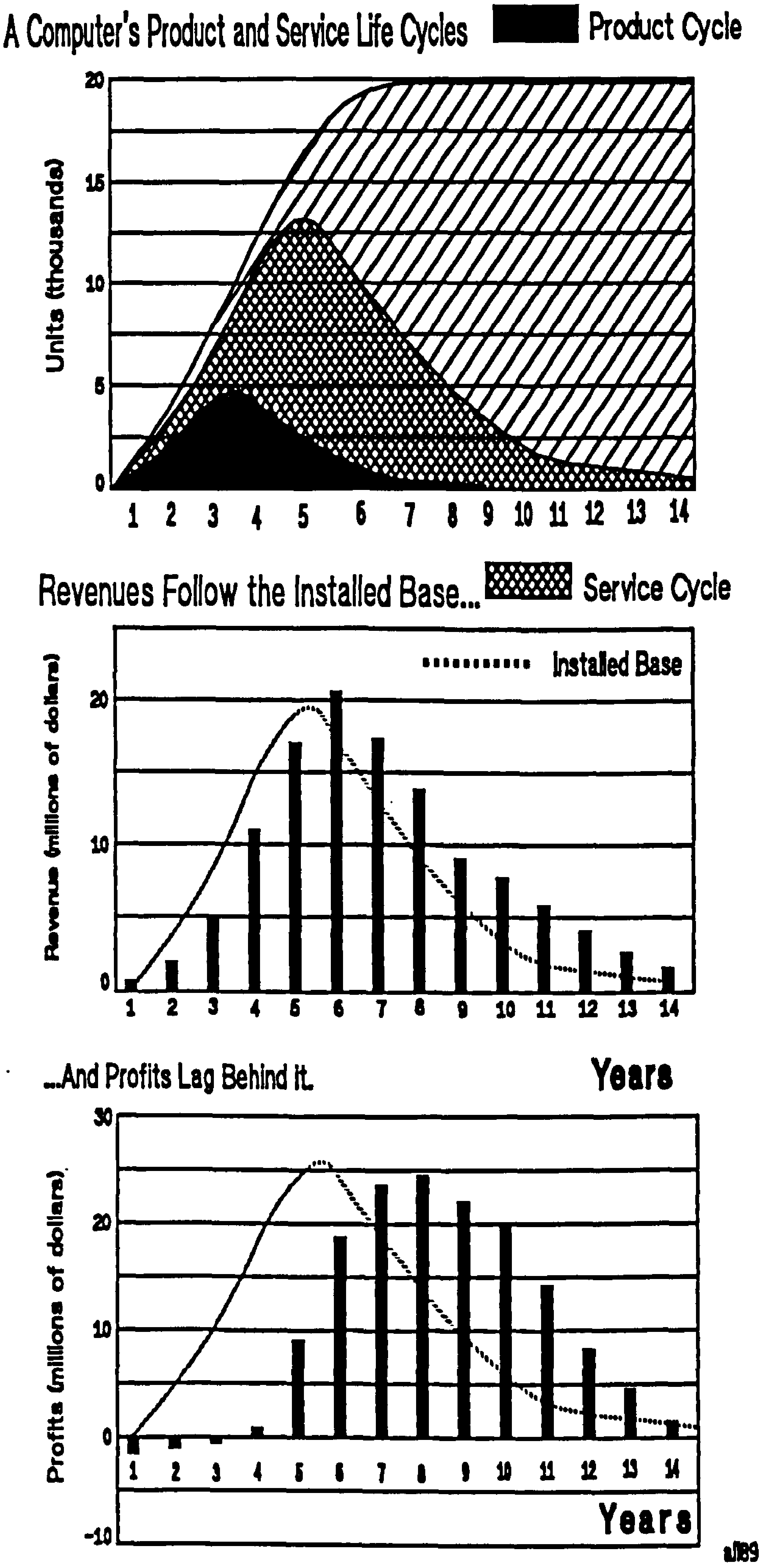
3) By entering the third party market themselves and repairing equipment from other manufacturers (and therefore widening their own potential for business).

The presence of third party service companies will very likely, by introducing competition, have a big influence on support in the next few years.

Two factors determine the amount of revenue and its profit level that can be earned from service. These are the range of products serviced and the position of each product in its service life cycle.

The range of products serviced effects revenue because characteristics of each product determine the level of service required. On a simplistic level, reliable products require little or no service and therefore generate less revenue. This was noted by Djurdjenic (1987), in his review of International Business Machines' (IBM) business. He found that although 26% of the 1986 sales revenues came from computer processor sales only 8% of service revenues came from maintaining these products. Computer peripheral products, although less important from the sales revenue point of view, generated 65% of the service revenue.

Figure 2.1: The Service Life Cycle (from Potts, 1988[b]).



The second factor influencing service revenue and profit is the service life cycle. According to Potts (1988[b]) the most important phase of a product's life, from the service revenue standpoint, is in the period following the peak in instrument shipments. As shown in Figure 2.1, the service revenues reach their maximum at about the time the installed base peaks (this is significantly later than the peak in product shipments). From the investigations of Potts, at Data General Corporation, the most important period for service profits is well into the product lifetime, with the time directly after product introduction showing losses. Potts makes a good point that it may be easier to generate profits from "mature" products, since experience allows much better support planning to be made. However, it can by no means be taken as the rule that service losses will be incurred following product introductions. Most service organizations are run as profit-centres (Anderson [1988] found the figure to be 87% in the high-technology sector) which may make lower profits on newer products but not normally losses. The service life cycle is an important concept though, which needs to be incorporated into the planning of product support and which has significant effect on service revenues.

Up until now, figures have only been quoted on the size of the markets for equipment maintenance and repair: *service*. However, many other areas of support offer potential for highly profitable business. Anderson (1988) investigated what was termed *alternative services*, such as software support, consulting and systems integration. It was found that these types of support are, for most companies, still only a small source of revenue. However, the potential is there and the current situation is that the "*alternative service lines* [are] *poised for takeoff*" in most markets. In the mini-computer market this change was found by Anderson (1988) to have already started. Training and software support were found to be already highly-profitable and significant businesses (with some companies reporting that 25% of their support revenue comes from these sources). This trend was also identified by Kemp (1983), who found that software maintenance was an area growing nearly twice as fast as traditional hardware service.

With the high revenues involved and their growth and profit potential it is likely that even more management attention will be focused on support in the coming years. In addition the wider issues of support, such as customer training etc., are becoming important revenue generators.

2.1.2 Support and Customer Satisfaction

Good product support is essential to achieving customer satisfaction and is a key to influencing customers to buy again. However, support is by no means the only factor influencing customer satisfaction. Therefore, firstly it is important to see support in context with the other factors which influence customer satisfaction. Subsequently, it is easier to understand the role of support in bringing customer satisfaction.

Anderson (1988) found that most high-technology service organizations see their work as crucial to customer satisfaction and actually use *customer satisfaction* as a measure of their performance. This approach, however, is too simplistic since satisfaction is not only determined by the field service organization. For example, a customer will not be satisfied, no matter how good the service organization is, if he has an unreliable product; the product itself is also a key in influencing satisfaction.

Exactly *what* are the factors which determine whether a customer will be satisfied? Grenier (1985) states that there are two ways whereby customer satisfaction can be achieved:-

1) Product quality - uninterrupted user satisfaction throughout the life of the product.

2) Quality of after-sales programmes: keeping customers satisfied with quality of service, timely availability of spare parts, and an administration network that handles after-sales problems quickly.

Lele and Sheth (1988) go further and state that there are four fundamentals of customer satisfaction:-

1) The Product.

2) The Sales Activity.

3) The After-Sales.

4) The Company Culture.

Lele and Sheth's analysis does not, unfortunately, attempt to identify quantitatively the relative importance of each of these factors. Therefore all that can be said is that support is one of a number of factors which influence customer satisfaction. The relative important of support can be somewhat gauged by reviewing some of the anecdotal evidence available on its influence on customer satisfaction.

Exactly *how* does good product support lead to customer satisfaction? By helping a customer obtain maximum value from their purchase. Support is the range of items, methods and organizations that a company employs to this end. Support helps customers in the process of meeting the expectations they have of their product. The examples showing the importance of good support for customer satisfaction tend to be "negative" ones - i.e. examples where lack of support led to customer complaints. A number of these can be found in the literature.

Take, for example, the microcomputer market (hardware and software) which is characterized by relatively complicated machines being sold to office users who are not computer specialists. Support, in the form of good customer training, is fundamental to user satisfaction since without it the equipment cannot be used to its full potential nor will it fulfil the customer's expectations. Beaver (1986) found that because good customer training was not available that it was actually being demanded by the customers, as a condition of purchase. In this market single customers typically buy in such volume that they have the necessary bargaining power to influence manufacturers. Joy (1987) details similar findings on the importance of support in the microcomputer market. He found that a high number of users were not satisfied with their equipment and were only utilizing 20%-30% of their software's potential capabilities. He states that this is because there is not enough training offered for these products and discusses how this could be rectified, by retailers using consultants to give training. However, this recommendation is in direct contradiction to a figure quoted in his article: 39% of the cause of user dissatisfaction with microcomputers is due to "Too much training required" . If customers cannot use the equipment well but do not want more training then what could be a suitable solution? One answer is to offer telephone support[1], whereby customers can call companies and talk to product specialists for advice. Joyce (1989) discusses the success of telephone support for software and emphasizes the investment companies are making in this area: 10% and 33% respectively of their total staff are allocated to give telephone support by the well-known companies Microsoft and WordPerfect.

The data which Joy (1987) presents, includes a figure that 29% of dissatisfied customers complain that the software is too complicated, it is clear that support is not the only factor leading to satisfaction. The product design and, in this case particularly ease-of-use, is also of prime importance and very often the effectiveness of support is very heavily determined by the product design.

Turning to the personnel computer market it is found that support is essential if customer satisfaction is to be achieved. This market is characterized by most sales being made through retailers, who seldom have the expertise to offer very good software consultancy to their customers. Brewster (1984) identified how this was leading to dissatisfaction with products and stressed support as being more important than the product itself, by saying *"Firstly, users want a relationship* [i.e. good support from the supplier]. *Secondly, users want a quality product"*.

A final example of the level of customer dissatisfaction which can arise when adequate support is not given can be found in McWilliams (1987). This article covers the case of a number of users of Digital Equipment Corporation (DEC) computers who became very dissatisfied with the support given by DEC on computer software problems. The lack of support was so bad that one user contacted other DEC customers, found they had similar problems, formed a "pressure group" and contacted the computer press to

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[1] See the later section on "Methods for Offering Good Support" for more details on telephone support.

publicize their problems.

The role of support in leading to customer satisfaction has been discussed and it has been seen that it is very important, even though the evidence quoted is anecdotal in character.

2.1.3 Support as a Competitive Advantage

Any factors which offer companies an opportunity for competitive advantage are obviously of interest to management. In high-technology businesses support has often been used to gain competitive advantage, especially in the last two decades.

Customers consider a range of elements before coming to their decision on the purchase of new equipment. Customer service, including product support, is one of these factors. La Londe and Zinszer (1976) found that customer service was very important in influencing customers' buying decisions, throughout a wide variety of industries. This study, made by surveying top management in Canada, showed that the respondents allocated an average of 20 points out of a possible 100, to the importance of customer service. Table 2.1 shows the allocation of points to the factors of the marketing mix; both for the average across several industries plus, as an example, one single industry: the electronics industry.

Table 2.1: Importance of Customer Service (adapted from La Londe and Zinszer, 1976).

Element	Average allocated value over six industries	Allocated value for the electronics industry
Product	38	48
Price	24	14
Customer Service	20	22
Advertising/ Sales Effort	18	16

Similar results to those discussed above were found by Clark (1988), who surveyed product support in British industry and found that it is an important factor in the buying process. Bessant (1982), also in a survey conducted in the U.K., found that companies buying new manufacturing equipment rate the following four factors as the most important in their choice of supplier:-

1) Quality of after-sales service.

2) Availability of technical advice.

3) Previous reputation of the supplier.

4) Opportunity for small-scale trials.

In addition to the surveys quoted, several authors identify the importance attached by customers to support in their buying decision. Pittiglio and Hoole (1987) stress the importance of good product support in differentiating from the competition in the electronics industry. Powers (1988) states "*In many ways these non-product related elements* [support] *are of primary importance and deserve greater attention*". In this type of competitive climate, support takes on a particularly important role.

In high-technology markets competitive advantage used to be gained just by having technologically superior products. However now, with the wider availability of technology, leading companies can no longer rely on technological prowess alone; they must consider other issues. This point is covered in detail by Quinn *et al* (1990), who say "*facilities - including a seemingly superior product - seldom provide a sustainable competitive edge*".

From the above examples it can be seen that support plays an important role in influencing the buyer's decision. Recognizing this fact, some companies promote support both internally and in their advertising, and really try to obtain an advantage over their competitors. An example of this is the Caterpillar Company's worldwide 24 hour parts delivery strategy. This recognizes that heavy earth-moving equipment is often used in inaccessible corners of the world and when it fails the owner may be faced with a severe loss of earnings, until the fault is repaired. By offering their customers a security against this happening (by speedy parts delivery, anywhere) Caterpillar responded to a real customer need. They were then able to capitalize on this advantage over their competitors and promoted it strongly in advertising (Lele, 1986).

Particularly in the high-technology sector, much importance is attached to gaining a competitive advantage through offering good support. Initially in this sector the key factor for gaining an advantage was the technology itself. However, with the wide diffusion of technology, companies have now turned their attention to other items, and increasingly support is one of them.

2.1.4 Methods for Offering Good Support

There are now more methods available to companies to make sure that they give their customers good support. Over the last ten years the advances in technology have enabled companies to build products which are far more reliable. These products are moving towards the ideal product, from the service standpoint, since "*if you eliminate the need for service, you are giving good service*" (Davidow, 1986). This change, together with ways of making support more accessible to customers (through "Response Centres"), means that it has become easier to give good support. Several examples of how it has become easier to give good support will be discussed: "Redundancy" in product design, "Response Centres", "Remote Support" and better communication methods.

Companies have not only used the advances in electronic component technology to build more reliable and compact equipment. They have also started to go one step further and build "redundancy" into products, whereby if one component or sub-system fails a back-up takes over. This idea is particularly effective for improving the supportability of equipment where the duration of the failure is associated with high costs (lost earnings) or inconvenience to the customer. An example of this approach to support is the Tandem Corporation's "never fails" strategy with mainframe computers, which was very successful against the more conventional ideas of IBM (Lele, 1986). Tandem's approach was based on their recognition that in certain applications of computing (e.g. banking) failures lead to major inconvenience and high associated costs. Reducing the risk of this happening is something that the computer purchasers want and they are therefore strongly attracted by the security against downtime[1] that redundancy offers. IBM, although able to give rapid, high-quality support in the case of equipment failure, had missed a key customer need.

Customers across a wide range of industries attach importance to the availability of advice on the products that they have purchased. The type of advice sought by customers may be technical in nature or guidance on how to use the product correctly. Making this type of advice easily available to customers has become a goal of a large number of companies. The usual approach in the high-technology industries is the "Support" or "Response Centre", which usually consists of a number of support experts who are based in one location and are equipped with a large selection of the company's products. They can then give advice to customers over the telephone using, if necessary, some of the centre's equipment so that the expert has the same product in front of him as the customer telephoning him. It has been found that support experts can, in fact, substantially help customers over the telephone; examples are Sperry's U.K. Support Centre (Lawrence, 1984) and GTE's Technical Assistance Center (Thorborg, 1983). The costs of response centre support are typically $75 an hour, which is significantly lower than an on-site visit by an engineer (Fodor, 1989). Customers really value the service of being able to obtain quick and effective advice on problems and are willing to pay for it; most response centres in the mainframe computer sector are funded by customers buying special contracts, which allow them to make use of these centres. In other sectors which are more price sensitive, such as the

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[1] Downtime: that portion of calendar time during which an item or equipment is not in condition to fully perform its intended function (Patton 1980[a]).

personal computer software market, the picture is different. Joyce (1989) presents a comparison of the telephone support available from five major software companies. He found that telephone support is in most cases free-of-charge for the first three months and it is then offered at a premium rate after that time.

The advantage of response centres is by no means limited to the high-technology area only. The consumer goods producer Proctor and Gamble prints a toll-free number on all its product labels. In the first year of this scheme they received 250,000 calls, providing customer feedback. This feedback gave Proctor and Gamble a very efficient means of collecting market data and allowed them to design new products, which were nearer to customers' needs (Lele and Sheth, 1988).

"Remote Support" is another innovation in support that has been made possible by changes in technology. Basically, it consists of extensive diagnostic routines in equipment which can be accessed, or even loaded, via telephone lines (with the equipment being interfaced to the telephone lines by a so-called modem). The method originated in the networks sector and has the advantage that equipment function can be checked, failures predicted, faults analysed and sometimes even fixed remotely. This, of course, drastically improves response time to failures. With higher costs of field service personnel and the problems of providing cover over large areas, remote support is likely to be used much more in the future. Remote support is normally implemented to achieve two goals: the reduction of downtime for customers and the reduction of on-site time for engineers (Levine, 1986). *"The odds are better that the right service person with the right test equipment and the right replacement boards and components is going to be on the customer's site when proper remote diagnostics or customer accessible self-diagnostics has been built into your products"* (Mendelson, 1983). Today remote support is normally delivered via a central department of the manufacturer's field organization, normally a response centre. However, with the falling price of technology, it is likely in the future that the individual service engineer will also become equipped with some equipment to perform remote support.

Fodor (1989) makes two key observations in his article on remote support. Firstly the investment required per installation to allow equipment to be remotely accessed is typically $1000, for a modem. This not only enables easy diagnosis of hardware or software problems but *"promises to transform user training. Because the support contact can now see on his or her screen precisely what the new user is viewing"* (*ibid*). Fodor's first point is too simplistic; the costs of enabling remote support are not just dependent on the current price of a modem. Significant investments may be necessary to develop the software required to run remote diagnostics etc.

Response centres and remote support can make a field service organization more efficient. This is through having problems analysed before an on-site visit by an engineer and, in many cases, by eliminating the need for a visit. The latter point has led to concern in some companies that the amount of face-to-face contact with the customer is dropping and that this is negative. One way to allow contact to be kept-up with customers, when visits are reduced, is to have the local engineer telephone his customer as a follow-up immediately after remote fixes. This is now possible by the better communications tools available to the field service engineer, in particular the cellular telephone and portable computer (Anonymous [Computing-UK], 1990).

No doubt more innovative approaches to support will be developed. As long as these are cheap and relatively easy to apply then they will be quickly adopted by companies. These will, long-term, raise customers' support expectations further, since; "*your service delivery capabilities increase at a pace of n, while the customer's expectations increase at a rate of n+1*" (Munn, 1985).

2.1.5 The Changing Attitude to Support

What was the attitude in industry to service in the past and what is it today? Why has there been a change? This section will discuss service and support from a historical perspective and answer these questions.

Figure 2.2: From Service to Support (from Clark, 1988[b]).

1950	**Spares and Repairs**
1960	**Field Service**
1970	**After Sales Service**
1980	**Product Support**
1990	**Customer Support**

The attitude to service in industry has not always been positive. Several authors have, since the mid-eighties, begun to recognize this. Lawrence (1984), concentrating on the computer industry, says, "*As computer maintenance is a post-sales service, it has not always received as much attention ... as customers would like*". Lele (1986), commenting on the situation across the whole of industry, goes further and speaks of how service had a, "*historical image as a backwater meriting little attention from top management.*" Pittiglio and Hoole (1987) make an almost identical point; "*service is a corporate backwater for many U.S. electronics firms.*" However, each of the three authors quoted all point to a change in the attitude to service. Blumberg (1987) states succinctly, "*service has been considered a necessary, but unprofitable, duty owed to the customer. Increasingly, however, attention is being given to the strategic importance and value of service within* *the corporation, and it is being recognized as a rapidly emerging and highly profitable line of business"*. Clark (1988[b]), however, takes a wider historical perspective and points to the evolution reflected in the names used for the service department from 1950 to 1990, illustrated in Figure 2.2. This evolution is, according to Clark, simply due to changing customer requirements, which have focussed more attention on post-sales support, *"The change in name (and status) of service activities is a reflection of this change in* [customer] *requirements"*.

Clark (1988[b]) sees the greater interest in customer support as the result of changing customer expectations alone. However, looking further than the high-technology sphere to the services industries, it can be seen that there is another reason - service has become a significant part of the US economy. Levitt (1972), in Harvard Business Review, pointed to the need for companies to stop *"thinking of service as servitude"* because *"once service ... receives the same attention as products ... a lot of new opportunities become possible"*. Levitt's article is often quoted by other authors and has been influential in changing the management attitude to service and has produced a wave of writing on customer service[1]. This, in turn, has led to more emphasis on customer service within manufacturing industries. With service now a major part[2] of the economy in the US, it is certain it will continue to receive the management attention it deserves

2.2 THE COMPONENTS OF PRODUCT SUPPORT

Support and its importance has been discussed up until now in general terms, without a full definition of its elements being given. This section will review some of the definitions of product support (often referred to as service, customer service, post-sales service or customer support in the literature).

2.2.1 Definitions in the Literature

The term "service" has two meanings within the context of industrial marketing, which must be differentiated. These are: *"1) When service is central to the transaction and it is a service rather than a product which is being sold (i.e. a transport service or an industrial cleaning service). (2) When the product is central to the transaction but service is supplied in conjunction with it (i.e. a guarantee that the product will be replaced if it fails or the speed of response to provide a repair service)."* (Cunningham and Roberts, 1974). Obviously it is the latter meaning that is of interest in this thesis and so only

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[1] There have been several books and articles published in the last few years concentrating on service. they include:- ALBRECHT, K. and ZEMKE, R. "Service America" (1985),ZEMKE, R. and SCHAAF, D. "The Service Edge" (1989),ZEMKE, R. and BELL, C.R. "Service Wisdom" (1989),DAVIDOW, W.H. and UTTAL, B. "Total Customer Service" (1989) and PHILLIPS *et al* "King Customer" (1990).

[2] Heskitt (1987) states that 70% of US income comes from service industries.

those definitions which are relevant will be given. Some confusion can arise from the dual meaning of service: "*Field service is one of the major service functions in manufacturing industry... It is effectively a service organisation within manufacturing industry. Because of this its role is frequently misunderstood*" (Voss, 1987).

A number of definitions of product support can be found in the literature. La Londe and Zinszer (1976) defined, somewhat loosely, product support as consisting of four elements (see Table 2.2).

Table 2.2: From La Londe and Zinszer (1976).

	Post Sale Product Support
1	Repair Parts/Service
2	Warranty
3	Technical Advice
4	Other

Clark (1988), in a survey gathering the opinions of U.K. service managers, used the definition shown in Table 2.3, which includes five elements. (Note that this definition was not developed from the results of the survey but was the definition used in one of the questions.)

Table 2.3: From Clark (1988).

	Elements of After-Sales Service
1	Service Engineer Response Time
2	Spares Availability
3	Technical Advice (Support)
4	Ease-of-contact
5	Installation

Cooke (1987) goes further in his definition, which is given in Table 2.4 and gives a total of ten elements which he considers are part of support.

Table 2.4: From Cooke (1987).

	Post Shipment Services
1	Installation
2	Start-up
3	Warranty
4	Field Service
5	Renewed parts, spare parts or repair parts
6	Maintenance
7	Technical assistance
8	Rebuilding or modernization
9	Customer education (as to operation, maintenance, repair and/or safety)
10	Information (including drawings, instructions, advice, etc.)

The authors Lele and Karmarkar, who have been active in investigating support, say that it encompasses everything that is "*Designed to ensure that customers obtain the most value from use of a product after the sale*" (Lele and Karmarkar, 1983) and define the eight elements given in Table 2.5.

Table 2.5: From Lele and Karmarkar (1983).

	Elements of Product Support
1	Parts and parts delivery
2	Service
3	Warranty
4	Operator Training
5	Maintenance
6	Reliability engineering
7	Serviceability engineering
8	Product Design

Finally Rautmann (1988) gives a definition which names five elements, shown in Table 2.6.

Table 2.6: From Rautmann (1988).

	Product Support
	Any interaction with the customer after the product has been shipped including:-
1	Product repair
2	Documentation
3	Training of customers
4	Internal training
5	Parts and parts locations

Comparing the five definitions, it can be seen that the one from Cooke (1987) is the most comprehensive and therefore this one will be used as the basis for discussion in Chapter Four.

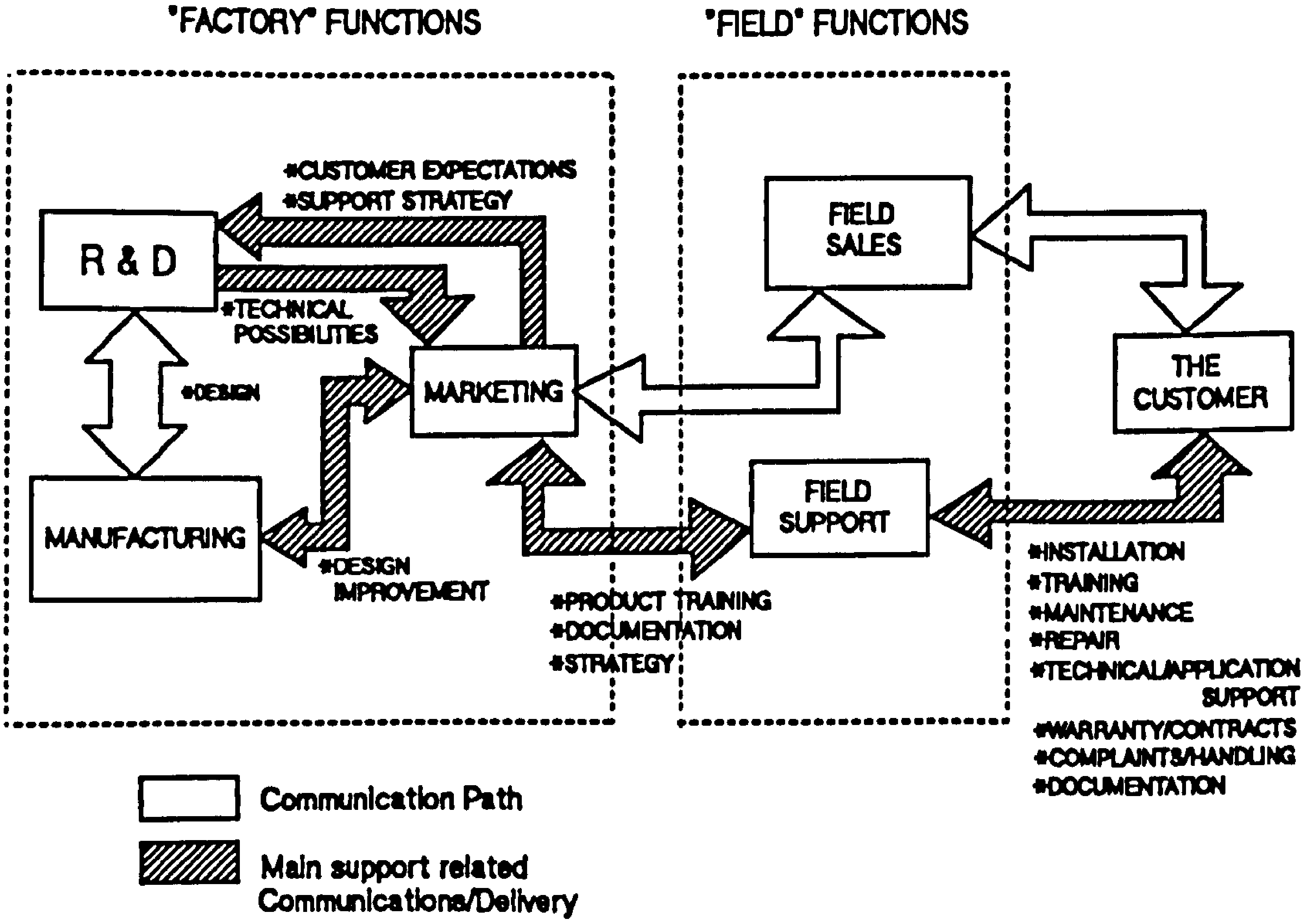
2.3 THE DELIVERY OF SUPPORT

How support is delivered to the customer is an important aspect which has not yet been considered. Which parts of companies' organizations are responsible for implementing product support? The answer to this question is important when planning how strategies for good support are to be executed. Surprisingly, the way in which support is defined and delivered has not been fully described in the literature; most authors have concentrated on only one particular aspect - the field service organization. Therefore this section will attempt to describe how support is delivered by a typical industrial company.

Typically new industrial products are the result of a project in a research and development department, guided by the inputs from a marketing department, on market requirements. These inputs should include both the support requirements of the customer and of the field organization (an "internal" customer). Once the design is ready then the product is produced, in a manufacturing department, and sold to the customer via a field sales force. Once the customer has placed his order then the post-sales phase is entered during which the field support (service) organization will install the product, train the customer in its use and then maintain or repair the product as necessary. This is illustrated in Figure 2.3.

Figure 2.3 is fairly simple and does not cover the many variations that may exist, for example, in the case of companies distributing through dealers, or small companies where the salesman may also service equipment! However, the diagram can be of assistance in explaining some of the aspects of support delivery. A key point to note from the diagram is that a number of departments are involved in the chain of support implementation. Each of these departments have differing objectives which may, at times, come into conflict. Any strategy for product support must therefore take this into account by identifying the effect on each element of a company's organization and where compromises on individual department goals will need to be made. This point is raised by Lele and Karmarkar (1983), who see it as one of the reasons that good product support is seldom planned into product at the design stage. Similarly, Berg and Loeb (1990) see that too few inputs from the field organization reach the factory and influence product design. Therefore they argue for the field organizations to take a central role in feeding support requirements to engineering, manufacturing and marketing directly.

Figure 2.3: Typical Organization/ Communication Channels for the Delivery of Support on Industrial Products. (Drawn by the researcher.)



PATH

From Figure 2.3 it is clear that the field organization plays an important role in the delivery of support. The size, availability and skills of this organization are, for a given product, a key in ensuring customer satisfaction. The recognition of this fact has led several authors to publish articles on the management of field service organizations. Surprisingly, although there is wide recognition of the transition from *service* to *support*, all of the articles on field organizations still refer to the *field service organization.*

There are three main topics of field service management which are covered in the literature, which will be discussed. These are:-

- Managing a field service organization to provide sufficient cover for a given installed base.
- Managing the logistics of spare parts supply and the repair of failed components.
- Managing service personnel to ensure good customer relations and hence customer satisfaction.

2.3.1 The Size of the Field Organization

The goal of a field service organization is to "*maximise availability of parts and engineer utilisation whilst minimising costs*" (Little *et al*, 1988). The size of the organization required is influenced by a number of factors. Nixon (1971) stated that "*the size and the technical strength of the* [service] *department will depend upon the technical complexity of the product, its reliability, the consequences of failure, and the extent to which the users are dispersed over the world*". Nixon does not, however, go into further detail of the influence of these factors on the size of the organization. Two authors go further than Nixon (1971), giving a comprehensive view of the management decisions that have to be made when setting the size of a field service organization.

Blumberg (1989), in a very detailed article on field service management, lists the nine major factors affecting service engineer requirements shown in Table 2.7. Although Blumberg (1989) explains in detail and gives models of how each of his major factors influence the size of a field service organization there is a significant gap in his argumentation. He concentrates entirely on how service issues affect a field organization and omits to consider the emerging wider support responsibilities for these organizations. A key area is therefore missed; the failure rate characteristics of equipment are becoming relatively unimportant (as technology brings increases in reliability) and other factors, such as the amount of help a customer requires to obtain maximum use of his product, are increasing in importance. This fact is recognized by Wellemin (1984), in his handbook on service management.

Table 2.7: Major Factors Affecting Service Engineer Requirements (from Blumberg, 1989).

Factor	Impact
Territory Size	■ Travel Time
Number of Sites	■ Service Demand
Equipment Density per site	■ Travel Time ■ Service Demand
Failure Rate Characteristics of Equipment	■ Service Demand
Service Engineer Trunk Stock	■ Travel Time ■ Repair Time
Courier / Delivery System	■ Travel Time ■ Repair Time
Skill Levels	■ Repair Time
Technical Assistance and Call Avoidance	■ On-site Service Demand ■ Repair Time
Dispatch and Assignment Procedure	■ Travel Time ■ Customer Repair and Closure Time

Wellemin (1984) covers the background factors which determine the manpower required, by dividing them into what he calls "technical" and "market" parameters. The technical parameters that he identifies are the equipment failure rate, preventive maintenance required, "work time" (amount of time required for typical repairs and installations) plus a factor he calls mean time between service calls (MTBSC). MTBSC is the average time between customer reported failures and includes both actual equipment failures plus operator misunderstandings. In this way Wellemin accounts for broader responsibilities of a modern field support organization omitted by Blumberg (1989). The market parameters identified by Wellemin are the number of products installed, response time required by the customer and the travel time to the customer site. Using his technical and market factors Wellemin develops a quantitative model for calculating the required size of the field service organization. No examples of how successfully this model has been applied are, however, given and so the validity of the model is questionable.

2.3.2 Parts Supply Management

Spare parts logistics management is an area which has attracted significant interest from researchers into field service management. Several papers have been published and, in addition, this is a topic covered by the textbooks on field service management.

Patton (1980) points to the weakness of many support organizations' parts activities and suggests improvements. He found that, although much had been published on the management of parts in manufacturing inventories, that little was available on managing field inventories. Therefore, he analysed the factors that are important in determining inventory levels, producing the list shown in Table 2.8. Each factor is explained by Patton, in order to produce a model of the best approach to a parts inventory problem and this is covered in exhaustive detail in his book on parts management (Patton, 1984).

Although Patton has produced comprehensive information on the management of field inventory there are a number of other authors whose work is important. Little *et al* (1988) and Blumberg (1989) cover the management of multiple locations for parts storage, concentrating on the decisions which need to be made on how many echelons are necessary. This work is closely related to the ideas of the previous section; the number of parts locations chosen is inter-related to the size of the field organization required. Otto (1988) presents arguments for the repair of sub-assemblies by the field organization, as this can significantly reduce the inventory levels required. However, Otto's approach is somewhat simplistic as he does not explain the costs involved (for repair and test equipment plus qualified personnel) in setting-up field repair centres. These costs often make such centres financially non-viable, since modern technology is often highly reliable and the volume of repairs to be done in field repair centres is consequently low. A new approach to field inventory management is the Just-in-Time (JIT) method, which originates from manufacturing. This method concentrates on keeping the amount of stock held to the minimum required to cover requirements. This is done by minimizing the delivery times from a central location to the engineers and removing unnecessary echelons and reserves of stocks. This philosophy, which has been successfully applied in manufacturing, is likely to become the most common approach to parts management (Downton, 1990).

Table 2.8: Service Parts Inventory Factors (adapted from Patton, 1980).

Service Parts Inventory Factor	Explanation
1)Product life phases	The age of products affects parts requirements. Parts requirements for established products can be set by reviewing historical data. New product requirements must be estimated using laboratory predictions of reliability.
2)Future demand variability	Future demand can be predicted using computer models but, in addition, manual corrections are required to account for design changes etc.
3)Causes of replacement	Obviously this includes equipment failure but allowance must be made for wrong replacement of boards due to poor diagnostics or mistakes.
4)Multiple locations	The distribution of the inventory, with centralization being one extreme, and large inventories per engineer being the other, play a key role.
5)People influence	The quality of the engineers in the organization.
6)Risk	Every part which may fail cannot be stocked - otherwise the field inventory would be too high. Acceptable risk factors must be built -in (e.g. 95% availability of parts).
7)Systems approach	The life-cycle of all products must be considered, in a systems approach.
8)Essentiality	All parts should be ranked for their "essentiality" in the inventory. Large stocks of low-ranked parts should be avoided.
9)Flexibility	A flexible approach to problems can be used e.g. higher level assemblies may be stocked.
10)Gain or loss	The cost of stocking a part can be calculated and weighted against the probable chance of selling it for a certain cost.

2.3.3 Management of Field Personnel

The final topic of field service (or support) management which is to be found in the literature is the management of field personnel. It concerns the choice of personnel, their required skills and how to motivate them. It is an area of the literature where the style of the articles that have been written is almost exclusively anecdotal. However, in order to give a full picture of the literature these will be discussed.

In his 1984 "Handbook of Professional Service Management" Wellemin discusses the type of engineers required for field service. He advises that field organizations need to consider education, experience and "human" requirements when recruiting. The latter factor includes how well a candidate would fit into an existing team and if he is likely to be self-motivated. Mitchell (1990) sees ten factors as essential skills for service engineers in a modern field organization. These include skills related to equipment maintenance (technical competence, experience and practical ability) plus a number of skills related to the engineer's personality. These include a requirement for confidence but the need to recognize when additional help should be sought and the ability to build up good working relationships with customers (through being able to understand their needs but remaining realistic as to which of these are possible). Mitchell (1990) places emphasis on the importance of hiring engineers with the right personalities and his view is echoed by others. Wallower (1979) points out that *"good servicing requires more than technical skills"*. He particularly sees the importance of engineers building up good relationships with their customers so that intermittent problems, when they occur, can be better approached, with the customer then being willing to provide more information to the engineer on the fault. Wagner (1990) also sees it as essential that field engineers have the right skills to build-up a *"partnership"* with the customer and states that he sees maintaining this partnership as one of the most important aspects of regular preventive maintenance visits by field engineers. Finally, Roussel and Miller (1990) highlight, from a strategic standpoint, the need for field organizations to manage *"the transition from fixing the broken box to managing the customer* - [since] *the skill mix of service organizations will have to change."*

On the topic of motivation of field engineers, work from only three authors was identified. Ellis (1988), in an article titled "Motivating the Service Engineer", concentrates entirely on two issues; training and technology. Ellis sees that just by training engineers' technical and interpersonal skills plus providing them with the latest technology (e.g. response centre back-up and diagnostic tools) they will be highly motivated[1]. Mitchell (1990) also mentions the two factors from Ellis but he goes much further and discusses the need for field engineers to receive appropriate salaries, a similar standing in the company to salesmen and consideration and recognition of the difficulties encountered in their work. The most comprehensive advice on motivation of field engineers is to be found in Wellemin (1984), who lists "hygiene" factors (*"their absence or inadequacy are detrimental to the job but their existence does not positively motivate an individual"*) and factors that positively motivate engineers. The factors identified by Wellemin in both of his categories are shown in Table 2.9.

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[1] Despite the title of this paper, it is almost entirely concerned with the advantages of response centres. It is almost as an afterthought that the subject of engineers' motivation is discussed.

Table 2.9: Factors Which Influence the Motivation of Service Engineers (adapted from Wellemin, 1984, pp 106-112).

Category	Factor	Explanation
"Hygiene" Factors	Appropriate pay	
	Local organization	Structure required to enable an engineer to be able to work efficiently.
	Opportunities to meet with peers	Engineers work alone but need to meet colleagues to build up a feeling of belonging to a team.
Positive Motivators	Recognition	Achievements should be identified and rewarded.
	Expansion of job content	Giving engineers extra responsibilities (e.g. the training of junior colleagues).
	Provide reasonable support	Adequate technical and administrative support plus essentials such as spare parts, documentation etc.
	Good communication	As engineers are often travelling it is particularly important that they are kept informed of company plans (e.g. new products).
	Good opportunities	Chances for promotion within the company.
	Contribution to the decision making process	Management should allow engineers to give their ideas on planned decisions.
	Disciplined operation	It is important that engineers are supervised to an appropriate level.
	Frequent counselling	Frequent informal counselling is more effective than formal review sessions alone.

2.4 STRATEGIES FOR PRODUCT SUPPORT

Planning is essential if good product support is to be achieved. A suitable support strategy needs to be chosen, that not only meets customers' expectations but also fits with the company's own goals. Once the strategy has been chosen then it is important that it is well communicated since, as seen in the last section, the implementation of support plans often involves cooperation between several departments. This section will review the strategies for product support in the literature.

2.4.1 General Strategies in the Literature

There are very few articles which take a generic approach when discussing product support strategy for industrial products. Two independent literature searches[1] identified approximately two hundred articles on product support but most of these were from trade journals and discussing specific examples. Only eight pieces of work discuss general support strategy as such, as applied to technological equipment. These are Lele and Karmarkar (1983), Blumberg (1987), Voss (1987), Rautmann (1988), Davidow and Uttal (1989[a], 1989[b] and 1990) and Armistead and Clark (1990). In addition, a number concentrate in detail on specific strategies and how these can be made optimum. Both the work on generic and specific support strategies will be described.

2.4.1a Lele and Karmarkar (1983)

Lele and Karmarkar (1983) identified seven factors of product support strategy and analysed their costs and benefits (Table 2.10). In order to choose the most suitable alternative, or combination of alternatives, these authors recommend a three-step method for developing an effective strategy:-

1) Defining customer expectations.

2) Determine the trade-offs implied in each of the support strategies listed in Table 2.10.

3) Identify the strategies that best fit management's objectives.

If the contents of Table 2.10 are reviewed it can be seen that the strategies listed can be grouped into three categories: design-related, risk reduction and service support-related strategies. These were identified by Ives and Vitale (1988) in their review of the previous authors' work (Table 2.11). The design-related factors listed concentrate mainly on improving reliability and minimizing downtime. This means that Lele and Karmarkar have restricted their analysis to only part of product support - major issues such as customer

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[1] Refer to the appendix for details.

training are not mentioned. However, their three-step method for choosing a strategy is useful and will be discussed.

Table 2.10: Support Strategies: Costs and Benefits (from Lele and Karmarkar, 1983).

Support strategy	Suppliers' costs	Customers' benefits
1 Improve product reliability	Design, engineering & manufacturing	Lower rate of failure
2 Use modular designs, component exchange	Design, engineering & inventory holding	Less downtime per failure, greater availability
3 Locate service facilities near markets	Site and facility; transportation & inventory	Faster access, less downtime, greater parts availability
4 Provide diagnostic equipment	Design, manufacturing and service	Faster diagnosis, less downtime, greater parts availability
5 Provide equipment on loan / standbys	Holding equipment for loan	Less downtime
6 Offer longer warranty periods and wider coverage	Warranty reserves and repair	Less uncertainty
7 Use mobile repair units	Transportation, inventory and personnel	Faster response, improved service availability

The first step is determination of the customer's expectations. What part does determining the customer's expectations play in selection of a strategy? Lele and Karmarkar describe how a customer's requirements are influenced by the environment in which the product is used. As an example of this they discuss the contrast between an office with only one word processor and another with many machines. The former office is, in the event of a failure, in a critical situation. Therefore, this type of customer expects a low failure rate and a minimum downtime and the repair cost is of secondary importance. In the multi-machine office, on the other hand, important work can still be done; therefore downtime is probably not so critical. Provided that the failure rate and downtime are reasonable then, in the multi-machine office, low maintenance costs are likely to be high on the customer's list of expectations.

Table 2.11: Generic Service Support Approaches (from Ives and Vitale, 1988).

Design-Related	Risk Reduction	Service Support-Related
1 Increase product reliability 2 Modular construction 3 Building in redundancy	1 Warranties 2 Service contracts	1 Improving service responsiveness 2 Reducing equipment repair time

An additional point which affects customers' expectations of support are the costs that are incurred in the event of a failure. Lele and Karmarkar (1983) and Lele (1983) discuss in detail what they term *fixed costs* (independent of the length of the downtime) and *variable costs* (dependent upon the length of the downtime and the major component of which is the value of the service lost). They give examples, such as that of plant-hire industrial tractors, where a failure causes loss of income for the owner. Such high variable costs as this drive the owner (customer) to expect very low downtimes (the Caterpillar Company actually meets this need by offering delivery of parts within 24 hours anywhere in the world). The issue of costs discussed by Lele and Karmarkar could, in fact, be broadened out to what could be termed "inconvenience factors". Short downtimes can also be important to customers in some markets, even though there are no associated variable costs. An example of this is the medical electronics market, where equipment failure can affect patient care and therefore low downtime is essential.

Once the customer expectations have been adequately analysed (Step 1) then, according to Lele and Karmarkar, the choice of strategy can be made. (Step 2: using Table 2.10). The choice is complicated since the limitations and costs of the individual strategies and their interactions need to be determined. A typical limitation are the diminishing returns of investing solely in improving reliability - once a certain reliability has been achieved the customer may not be interested in further advances. Interactions may occur between strategies. An example is good diagnostic equipment - this is more effective when used together with modular designs. The final step, Step 3, in Lele and Karmarkar's method is the management review of the choice, to see if it fits with the company's objectives. This is a review of the results of the analysis of Steps 1 and 2, followed by a comparison against the general marketing plans of the company. For example, this review could show that, although from the analysis a loaner strategy appears the most cost-effective choice, this may be too easy for competitors to copy. A more expensive approach, such as major design changes, could therefore be the final choice.

In their three-step method Lele and Karmarkar discuss how a customer's expectations need to be determined but they discuss this in terms of product reliability and downtime per failure only. This is over-simplified. They have ignored the broader issues of customer expectations on other elements of product support. It can be said that Lele and Karmarkar have limited themselves to the service issues only and have not covered support completely. With new technologies enabling more and more reliable equipment at low cost, the angle taken by Lele and Karmarkar is becoming quickly out-of-date. It is worth noting that some of the factors listed have already been researched in detail and will be discussed in the section on specific product support strategies.

2.4.1b Blumberg (1987)

Blumberg (1987), from his experience gathered whilst acting as a consultant on service to various companies, believes that there are three critical issues which affect the choice of support strategy. These are the company's service objectives, the relationship between product and service sales and the sensitivity of the customer to the price of service. Blumberg considers how these factors can be evaluated, so that a service strategy can be chosen.

The choice of objectives for a service organization is fundamentally important. Is service to be a profit centre? Will the service organization's aim be "*simply supporting product sales*"? Or will it be "*managing the full set of values associated with* [good] *service*"? The answers to these questions, according to Blumberg, determine much of the service strategy. In addition, the relationship between service and product sales has "*considerable importance in the design of the service strategy and business plan*". However, Blumberg does not explain this statement. In addition, the explanation of the sensitivity of customers to the price of service is too simplistic; Blumberg only says that it can limit the revenue and profit that can be made from service.

Blumberg's article stops short of giving concrete steps for service strategies and unfortunately mainly limits itself to giving a catalogue of questions which should be asked when choosing a strategy. Only in one area, segmentation, is more detail given and a stress put upon the importance of considering the environment in which the equipment is used. In the past many manufacturers believed that "*equipment service is the same regardless of the environment*". This is not the case and Blumberg identifies four segments (office, manufacturing, distribution and "special markets" environments), in which the customers' expectations are very different. These different expectations must be considered by manufacturers, in their choice of service strategy. Relevant strategies for each segment are, unfortunately, not identified by Blumberg.

2.4.1c Voss (1987)

This conference paper (Voss, 1987) is one of the few pieces of academic research into product support that have been conducted. Voss' approach was to carry out case study research into seven different companies and to categorize the field service that they offer into two dimensions. Although the results cannot be generalized (a limitation of case study research) they are of interest.

In developing a strategy for field service management companies have two dimensions that they can vary. These, according to Voss' empirical results, are "*offensive or defensive strategies, and ... service maximising or cost minimising strategies*" (*ibid*). Offensive strategies are those which heavily promote support[1] to obtain competitive advantage (whereas some companies simply use support to defend against potential market entrants). Service maximizing strategies rely on excellent service as a differentiator, whereas "*cost minimising*" strategies simply compete on price.

The limitation of Voss' study is that the results cannot be generalized since, as stated, they may be dependent on a particular environment. In addition, the paper does not make clear exactly how the two dimensions were identified from the empirical results. On the other hand, the results do demonstrate some very different approaches to support amongst the seven companies studied.

2.4.1d Rautmann (1988)

Useful points on the development of a support strategy are raised by Rautmann (1988). He says, "*The strategy for supporting a product goes beyond just fixing the product if it fails. It is also documentation, training of customers and your people, parts and parts locations, technical and applications support, etc. In fact, it defines any interaction the customer has with your company after the product has been shipped*". Rautmann discusses a number of factors that affect the choice of support strategy, starting from the type of customer and his expectations. He identifies the following factors which affect choice of strategy:-

1) The market (type of customer).

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[1] Voss (1987) uses the term *service* but in his discussion considers issues such as user training.

2) The location of the customers.

3) The problems caused by instrument downtime (which he terms *inconvenience factor*).

4) How long should the product be supported?

5) How will the customer pay the support costs and will reasonable profit levels be possible?

6) What are the technical and applications support requirements?

7) What are the long-term industry trends?

8) Does the present support organization fit the customer's needs?

Rautmann then takes these factors and discusses a single example of developing a support strategy, for a piece of manufacturing test equipment. The customers used the test equipment for supporting shift work, on typically five or more days per week and, because failure affected production, had a requirement for a downtime of not more than two hours. The locations where the product would be sold were scattered and this, together with the low downtime requirement, would have required a very large field service organization. This was not practical for the company. Therefore a strategy of modular design with "self-fix", by the customer repairing by swopping the offending module, was chosen. To back this, both special documentation and technical/application support were made available. Service profit levels were considered by planning to make profit on the repair of the returned failed modules.

Rautmann's article is very useful in that it makes a wider analysis of the selection of a product support strategy, compared to that of Lele and Karmarkar. However, unfortunately Rautmann does not attempt to list the possible alternative strategies for all of the areas of support he identifies. In addition, he gives no indication other than the manufacturing equipment example of how he reached his conclusions on the best way for developing a support strategy.

2.4.1e Davidow and Uttal (1989 and 1990)

These authors have published two articles on choosing a service strategy (1989[b], 1990), both of which are based on their 1989 book. They recommend that a service strategy is developed by:-

1) Segmenting the customers.

2) Recognizing customer expectations.

3) Influencing customer expectations.

These points will be explained.

"The essence of any customer service strategy is to segment the customers to be served" (Davidow and Uttal, 1989[a]). Different types of customer, within the same market, may have very different service needs. A company may not have the expertise or resources to give good service to all customers. Therefore it is essential to choose the segments where the company can be successful, or to provide differing levels of service for different segments. For example, *"Veteran users of home appliances may prefer getting repair instructions over the telephone, while novices expect a repair person to show up"* (Davidow and Uttal, 1990). A company must consciously choose the segments that it intends to serve.

The expectations of the customer (and not necessarily his needs) determine the extent of the service which will be offered. In the above example the novice user *expects* a repairman to call, although his actual *need* is for a repair. Market research is necessary to determine customer expectations, for each of the segments in question. Unfortunately, as *"most companies see customer service as a necessary evil, it's no wonder that they don't research customers' service expectations"* (Davidow and Uttal, 1990).

The third stage of Davidow and Uttal's method for developing a service strategy is to find ways of influencing customers' expectations. This is essential, since it may not be economical or a company may not have the resources to offer perfect service. If the customer's expectations are higher than the actual service which he receives then he will be dissatisfied. Influencing expectations can be particularly difficult in markets where the expectations are climbing with the general improvements in customer service (see Section 2.1.4).

Davidow and Uttal's method for choosing a service strategy is similar to that of Rautmann (1988), except that it is accompanied by many examples of successful and unsuccessful service strategies. Unfortunately, these examples, which span a wide range of industries, are simply presented as anecdotal evidence. General recommendations for a service strategy are drawn from this evidence, without any consideration of the validity of the conclusions.

2.4.1f Armistead and Clark (1990)

These authors develop a framework for developing or reviewing after-sales support strategy by drawing heavily on analogous research into manufacturing strategy. Their central points are that it is essential *"for a company to make strong linkages between* [their] *manufacturing, design and after sales service strategies"* and that the support strategy is determined by:-

1) Whether a company wants to gain a competitive advantage from support and

2) The choice of the delivery system for support.

Essentially, companies need to decide the role of service or support in gaining a competitive advantage. Armistead and Clark identify the dimensions *expertise* and *personalisation* as being important for support. For example, manufacturers of capital equipment may decide to offer support which is differentiated on both of these points; by having a support organization that act as *consultants* to the customer. This approach is unlikely for consumer goods manufacturers as, for these type of goods, expertise is not necessary. However a differentiation through personalized service can lead to a competitive advantage. Some companies may choose to ignore after-sales support and therefore not attempt to differentiate themselves on either of the above dimensions.

The decisions on the differentiation of support are one factor which affects the choice of the delivery system. The delivery system for support ranges, as identified by Armistead and Clark, from highly-trained company specialists, through engineers to service agents and third party maintenance companies. The choice of which type of support organization to use is mainly determined by the amount of in-house control a manufacturing company requires over customer support. The amount of control obviously decreases from company specialists to agents or TPMs. In-house control may, however, be necessary for complex equipment or equipment where there are safety issues. Additional factors which influence the amount of control required are the product installed base and the position of the product in the product life cycle. Companies may wish to support new products themselves directly, in order to ensure a quality service and to obtain customer feedback. Older products with large installed bases, where the customer requirements for support are better understood, may be passed to more economical delivery systems, such as agents[1].

The work of Armistead and Clark is, in contrast to the other work on support strategy discussed, based on survey and case study research and not purely anecdotal evidence. This means that the validity of the results is much clearer and the type of companies to which they are applicable are not ambiguous. The support strategy framework is tested against a number of case studies, in industries ranging from white goods to computer manufacturing and support.

2.4.2 Specific Strategies in the Literature

Several of the factors listed by Lele and Karmarkar (1983) in Table 2.10 are

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[1] Armistead and Clark omit any discussion of revenue and profit from support in their discussions. Companies may well choose to keep in-house control of mature products as these may be good sources of profit. This point was made by Potts(1988[b] - see Figure 2.1.

covered by articles on specific support strategies. These will be reviewed.

The service/support related strategies listed by Lele and Karmarkar (1983) are determined by the field service organization of a company. The best ways to manage service/ support organizations were covered in a previous section.

Other areas where work has been published are points 2 and 5 in Table 2.10; *modular designs and loaner equipment.* Karmarkar and Kubat (1987) systematically analyse the advantages of modular designs (lower downtime) versus the higher costs (per repair and also for the inventory holding) plus develop a cost model for this. Karmarkar *et al* (1983) present a study of the optimum level of loaner equipment for a field service organization.

Blumberg (1984) considers the strategy behind offering the customer risk reduction, in the form of maintenance contracts. He identifies three approaches to the pricing of these contracts and considers the advantages and disadvantages according to the type of customers being served.

The design-related strategies of product support are of particular relevance to this thesis and are presented in the next section.

2.5 DESIGN FOR SUPPORT

The hypotheses investigated were all related to designing products with product support in mind. Therefore, it was crucial to identify what has previously been published on this topic plus to point out where gaps in the knowledge exist. The aim of this section is to cover these two issues.

The review of the literature showed several categories of information on the subject of designing products so that service or support is easy. The terms "Design for Service" or "Design for Serviceability" are used, as will be seen, by a number of authors in articles on how service requirements should be considered during product design. The consideration at the design stage of support requirements, which are broader than service requirements, is fairly new. However, the term "Design for Support" (DFS) is starting to be used and is a suitable title for this section. The categories of information on design for support in the literature are:-

- Information on why product support requirements should be built into product designs.
- Information on how product design affects product support.
- Specific approaches to design for support.

2.5.1 The Importance of Design for Support

Several authors recognize the need to fully evaluate service requirements at the design stage. In addition, a few go further and state that all the requirements of support (the term having a broader meaning than service) need consideration.

Heckman (1982) uses the term "Design for Serviceability", in an article concentrating on disc drives. He says, "*since some percentage of a manufacturer's equipment is going to fail ... it becomes important to design the product so that it can be serviced in an efficient and economical method. For this to occur, serviceability must be designed into the product*". Floyd (1988) also stresses the importance of considering service needs since, if these are built into a design, they can enable a service organization to work more efficiently: "*the ability to monitor, predict and isolate failures provides the service organization with the ability to operate in a more proactive way and ... run more efficiently*". Both Heckman and Floyd focus entirely on service requirements related to equipment failure and a similar view is taken by Breiling (1990). He identifies the setting of design goals for service requirements as essential. These goals must be set "*before the start of development and from the point of view of customer service*"[1]. The areas that should be covered by these goals are: the amount of service required on a product, the type of organization that is required to deliver the service, the type of documentation and the service costs per year. Heckman (1982), Floyd (1988) and Breiling (1990) all concentrate on service requirements and fail to recognize the need for a broader approach. However others do go further.

Davidow (1986) discusses the importance of designing products for serviceability, in that they must be reliable and easy to repair. However, he says, "*serviceability must be designed into products in other ways ... For example, computer companies offer a very important service. They sell updates to their software products ... But if the software is not properly designed ... it becomes almost impossible to maintain it*". Unfortunately Davidow only gives the example of designing for easy software upgrades and does not specify any of the "*other ways*" he says are important.

Livingston (1988) uses the term "Design for Service" but sees the need to have a broad view of this: "*as more and more companies are attempting to service customer requirements rather than pieces of hardware*". Livingston (*ibid*) details that companies should be "*not only designing for service productivity, but ... designing for customer satisfaction*". The customer's requirements, which the design should meet, are listed in Table 2.12. This list can be seen to contain both *service* issues (such as time to fix, installation etc) and wider issues of support (such as ease-of-use). Livingston's article is therefore a key one, in its recognition of the wider issues that need to be considered at the design stage. Furthermore, Livingston gives details of ways to approach the evaluation of support needs

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[1] Translated from the original conference paper which is in German.

during design - this is discussed in a later section.

Table 2.12: Customer requirements for service performance (from Livingston, 1988).

	Customer Requirements
1	Enhance customers own business / performance
2	Total cost of ownership
3	Fault free installation
4	Customised offerings
5	Scheduled maintenance
6	Ease of use
7	Time to fix / availability
8	Customer diagnostics
9	Supplies

One industry where maintenance has always been considered at the design stage is the aerospace industry. This stems from the obvious fact that catastrophic faults in aircraft must be prevented; maintenance programmes must replace parts before failures can occur. The amount of maintenance required is typically high and so it is normally evaluated at the design stage. Patton (1980) gives a checklist of issues to be considered, including access to parts, adjustments and how the need for maintenance can be minimized. Although the maintenance requirements of aircraft are much higher than those of many other high-technology spheres, such as computing, the evaluation of maintenance at the design stage is relevant. The estimation of maintenance requirements for different designs related to their in-service performance (man-hours of maintenance per flying-hour for aircraft) could also be useful with other products (Patton, 1980).

Three authors point to the success of Design for Manufacture (DFM) methods, which quantitatively evaluate manufacturing requirements at the design stage, and suggest that support should be treated similarly. Berg and Loeb (1990) comment that field service requirements received *"little attention"* in the past but that their evaluation, in a similar way to DFM, is becoming essential due to market pressures in the high-technology sector. Juran (1988) also sees an advantage in approaching support planning in a similar way to DFM and says *"those who do quality planning for service* *activities can learn much from the experience of formalized quality planning in design and manufacturing*". Thirdly Goffin (1990[b]) contrasts the quantitative approach of the DFM methodology with the informal, often late, planning of support. He proposes that formal, quantitative planning of support during the design stage (in what he terms a "Design for Support" approach) would improve the quality of product support.

All of the authors quoted above recommend that service requirements are evaluated at the design stage. However, is this the case in industry? Only two articles give an estimation of the typical degree to which support requirements are considered in industry. Lele and Karmarkar (1983) say "*support needs are considered late in the design cycle*", but give no data to support this view. Clark (1988), in a survey of UK manufacturing companies, found that 40% of these companies "fully" considered service requirements at the design stage with 50% "partially" considering them (10% did not consider them at all). The limitation of this result from Clark (1988) is that different respondents may have had very different understandings of what "fully" means, in this context. No attempt was made in this survey to identify exactly how companies evaluate and plan service needs, or if those who claimed to "fully" evaluate these were more thorough in their approach than those who answered "partially".

The need to plan service requirements at the design stage is well recognized in the literature. Additionally, the need to plan for the broader support requirements is also clear from some of the later articles. However, very little information is available as to when, how and with what success it is normally done by manufacturing companies. This is a real gap in the current level of knowledge on product support.

2.5.2 How Product Design Affects Product Support

Product design obviously can have a big influence on the quality of product support that can be offered. Two articles concentrate on this topic.

Lele (1986) discusses how service needs influences product strategy at the design stage. Table 2.13 shows Lele's analysis of the strategic implications of product design. It can be seen that four categories are shown: "Disposables" up to "Never Fail" products. Each category has implications on the service required. For instance, the "Rapid Response" products are repaired on-site but, since operational availability is a key customer concern, loaner equipment may also be made available.

Although Lele (1986) discusses how important it is to consider service at the design stage, he concentrates on the issue of reliability. He omits any discussion of other service issues , such as installation and maintenance, and certainly makes no mention of support aspects, such as customer training.

Karmarkar and Kubat (1987) concentrate on one aspect - the

Table 2.13: Strategic Implications of Service Strategies (from Lele, 1986).

Strategic Implications					
Segment	Key Customer Concerns	Product Strategy	Support Strategy	Keys for Success	Examples
"Disposables"	High reliability Low replacement costs Repairability not important	Very high reliability Low manufacturing costs	1-2 year warranty	Very high reliability Low product cost Credibility, reliability, warranty	Timex
"Repairables"	High reliability Moderate / Low expected repair costs Low skill requirements / easily available service	High design reliability Repairability important in design	Conventional: i.e. on-site Wide availability e.g., do-it-yourself kits, third-party service etc.	High reliability Design simplicity Low repair costs	Maytag Sears/ Whirlpool

Strategic Implications (continued)

Segment	Key Customer Concerns	Product Strategy	Support Strategy	Keys for Success	Examples
"Rapid Response"	Downtime / Failure Operational availability Service support costs	Balance: -reliability -ease of repair Standardize parts to lower logistic costs	Mix: -loaners -on-site maintenance Maintain high fill rates in logistic system	Ability to choose most cost effective mixture of design and support	Caterpillar Deere
"Never Fail"	Protection against *any* and all failures / interruptions Affordability	"Fault-Tolerant" design Built-in or add-on redundancy Delivery to Acceptable Cost	Back-up maintenance Inspection / Replacement	Very high component reliability Cost-effective design Credibility	Tandem

influence of modular product design on product support. They develop a model which analyses the different repair and inventory costs associated with modular or non-modular designs and find that "*while modulization is often studied from the point of view of standardization and manufacturing costs reduction, it seems likely that ... support aspects are paramount*" (*ibid*).

2.5.3 Methods of Design for Support

The two articles in the previous section showed how specific aspects of product design influence the product support. However, they did not give a generic technique for evaluating support needs at the design stage. Designing products to meet support requirements is still a new area, with little published literature. The two papers which focus specifically on this area will be discussed.

2.5.3a Livingston (1988)

Livingston (1988) is a key article since, as already stated, it points out the need not only to consider service requirements but also the broader customer needs. The four driving elements of the design are shown in Table 2.14. The customer requirements, which are shown in Table 2.12, are comprehensive and cover many aspects of support, from installation to cost of ownership, to the actual enhancement that the product gives to the customer's own business or performance.

Table 2.14: Key Elements of Service Design (from Livingston, 1988).

Driven
▪ By customer requirements ▪ By functional requirements ▪ By product technology ▪ By service productivity

The functional requirements for a good design are, according to Livingston (1988), those design features which directly affect the extent of the field organization required. That is, for example, the parts supply required for a product or the administration for the supplies required for the product. Product technology drives the service design in that new technologies are making serviceability easier - for instance remote support or documentation within the equipment itself. Service productivity drives the design by giving prerequisites for an easy to service product; these are listed in Table 2.15

Table 2.15: Service Productivity (from Livingston, 1988).

Service Productivity
■ Software / hardware definition
■ Self-adjustment
■ Reliability
■ Preventive maintenance / Predictability
■ Documentation
■ Directive diagnostics
■ Customers' own maintenance Customer diagnostics
■ Installability
■ Tool requirements
■ Service billing
■ Logistics
■ Self-cleaning
■ Refurbish ability
■ Time to fix "wear-out" components

The analysis of the customer and service productivity requirements are very important, according to Livingston *ibid,* in the management of service design. They form part of a seven-step method for managing service requirements (Table 2.16). The necessity for a clear management process for service requirements comes from the fact that many different departments in a company may be involved. This may lead to a clash of objectives which must be resolved. Livingston gives an example of this. One aim of manufacturing is to drive assembly costs as low as possible. This can lead to a design that can efficiently be built (manufactured) but which is hard to disassemble and re-assemble in the field. For photocopiers (Livingston's article reports on the work of Rank-Xerox), with their high failure rates, each product may be disassembled / re-assembled in the field eight times over its working lifetime. Therefore, it is important that the manufacturing requirements do not overrule the service requirement for a design in which it is easy to exchange failed components. The way that this is achieved at the design stage is by setting clear objectives (Step 5 in Table 2.16) and establishing a measurement (Step 7).

Table 2.16: Managing Service Requirements (from Livingston, 1988).

1. Identify your customers
2. Understand customers' business
3. Establish scope and customer requirements
4. Define market and competition
5. Define your objectives
6. Establish an organization and management team
7. Establish a management process
    - Reports
    - Events (inputs / outputs)

To make sure that the exchange of failed components is easy, clear objectives for this have to be set. This takes the form of an analysis at the design stage of the access time for components, versus their predicted failure rate. This is shown in Figure 2.4, which helps to identify problem designs. [Curve (1) shows that the less reliable components are hard to access, (2) shows equal access time for all components, (3) shows easier access to the components which are most often exchanged[1] and (4) easy access to all parts[2]].

To summarize, Livingston's approach to design for service is comprehensive and fully covers customer and internal company requirements. It consists of a seven-step management process in which the key elements are the identification of all requirements, the setting of specific objectives and having the management reporting systems necessary to check these are implemented. Only one example is given of the type of analysis behind the setting of the specific objectives. This is a limitation of this paper but it is only a slight criticism of an important presentation of product support planning.

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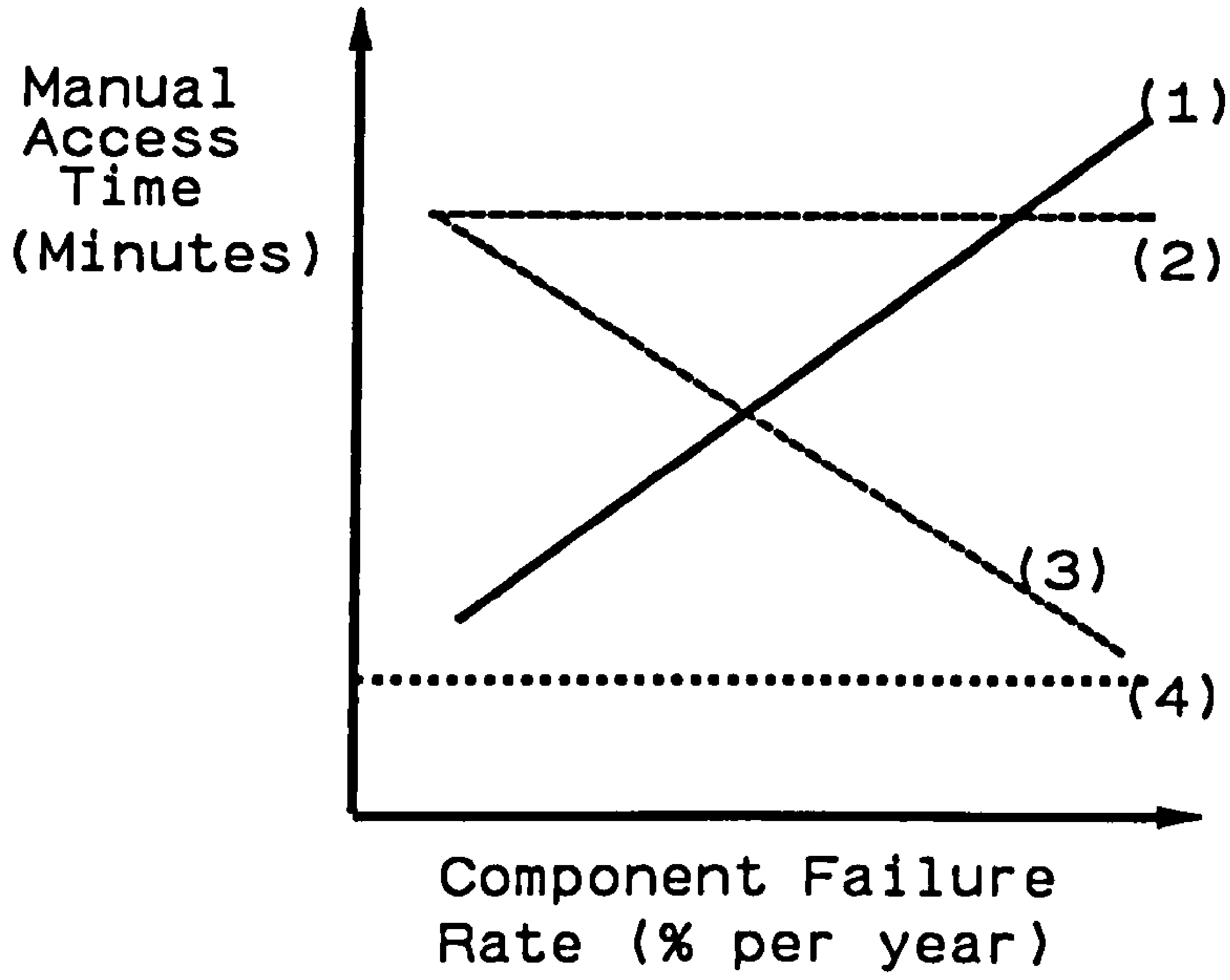
[1] These are termed the "wear-out" components by Livingston, *ibid.*

[2] Use of this analysis led Rank Xerox to adopt a rule that the access time to any module in any new product should not be more than 9 minutes (This was reported, but not documented in his paper, by Du Bois in his 1990 presentation, *Quality Management in the Service Function,* 1990).

Figure 2.4: Access versus Failure Rate (drawn from the ideas of Livingston, 1988).



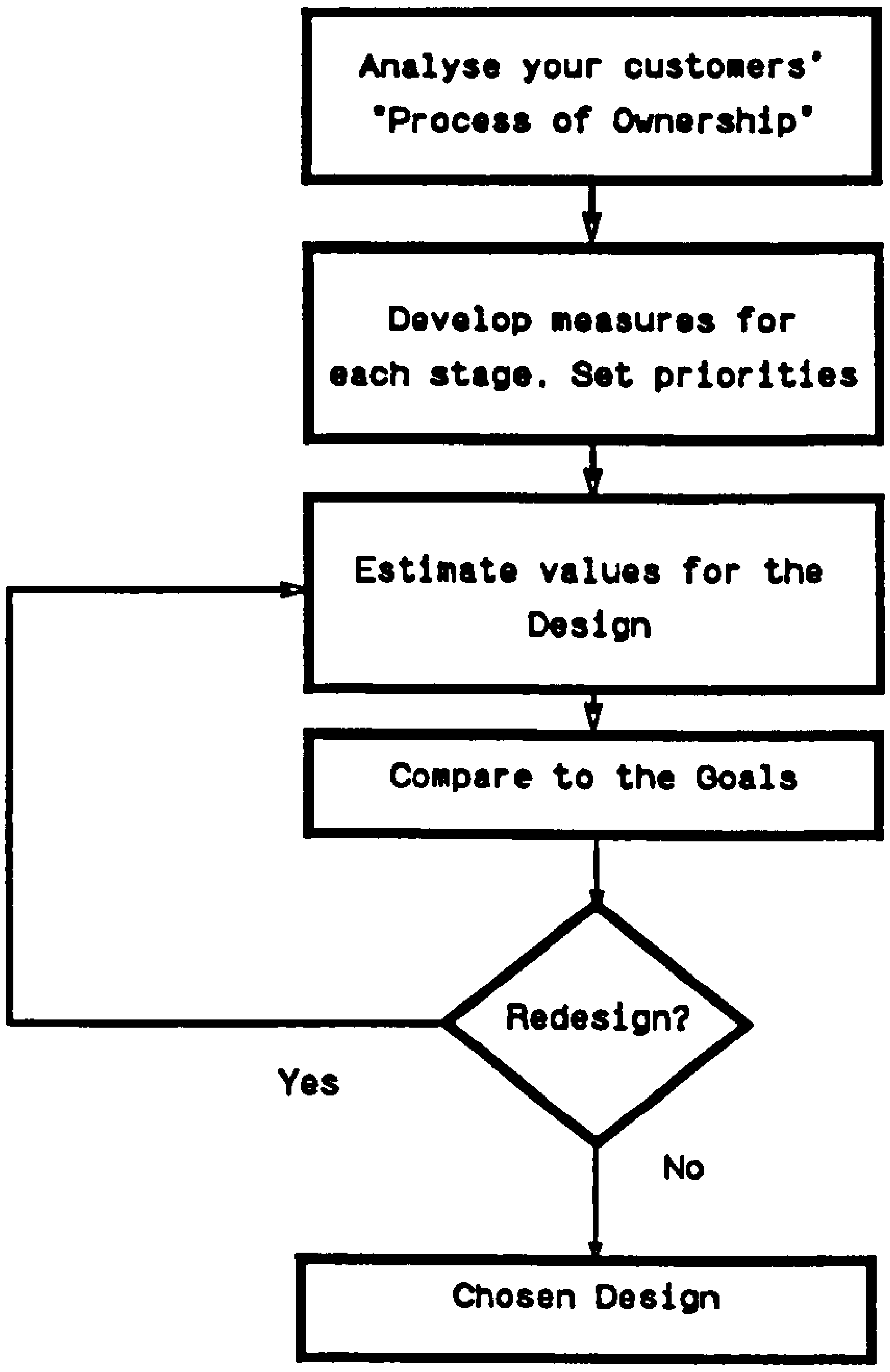
2.5.3b Goffin (1990)

This conference paper presents a "Design for Support" process which concentrates on the setting of quantitative objectives for support requirements at the design stage.

Figure 2.5 shows the flow diagram for design for support. Firstly, what is termed the "Process of Ownership" is analysed to identify the post-sales interactions between the customer, his product and the support organization. this includes the installation and learning phase, maintenance, repair upgrading etc. This is illustrated in Figure 2.6. It should be used to identify the priorities in the support, for instance if the equipment is more often upgraded than it is repaired then the priorities should be set accordingly.

Goffin *ibid* continues that it is essential to develop measures and set goals for each stage in the process of ownership. A design can then be evaluated against these measures and improvements made, if necessary. Similarly to Livingston (1988), Goffin does not give a comprehensive set of measurements for all of the elements of product support. Instead he only quotes measures for installation and indicates some of the questions that should be asked to determine others (e.g. "*What training does the customer require to understand the product? What skill level must the trainer have and how long will the training typically take?*").

Figure 2.5: Design for Support Process (from Goffin 1990[b]).



In summary, Goffin (1990[b]) stresses the need for quantitative goals for support requirements to be set at the design stage, to ensure that the product has high "supportability"[1]. The argumentation used for this approach is that since DFM, which uses a similar technique, is successful then it could also be applied to support. However, this is a big assumption. In addition, too little information is given on the measures which should be adopted for each of the aspects of product support.

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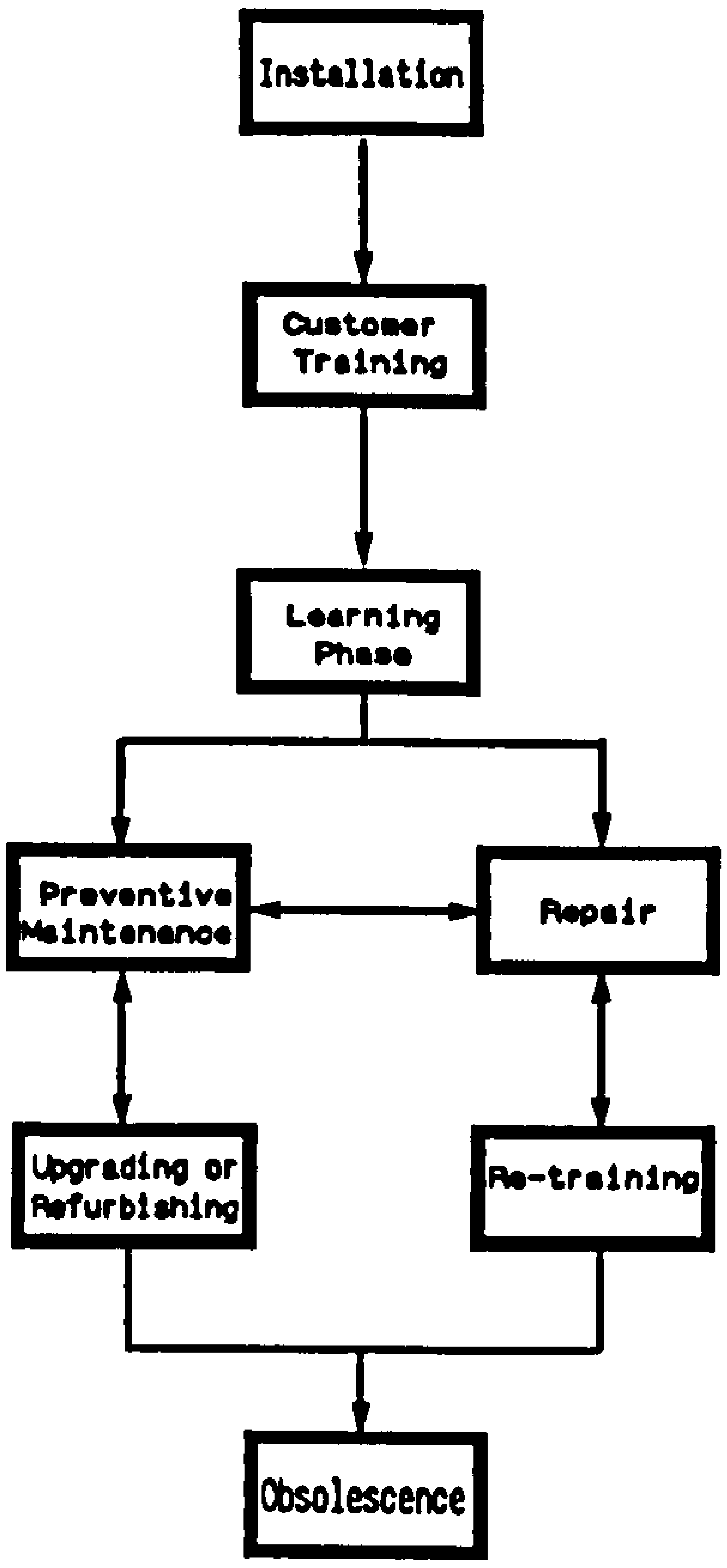
[1] Supportability: a product with high supportability is one that is easy to install, maintain, repair, for the user to learn etc. Refer to the Glossary.

Figure 2.6: The Process of Ownership for a Typical Computer Product (from Goffin 1990[b]).



2.5.4 Limitations of Design for Support

The articles reviewed on evaluating the support requirements at the design stage do not identify any limitations to this approach. This is not surprising, since design for support as such is new, as shown by the paucity of information on this subject. Only one set of authors have, indirectly, identified a limitation of designing for support but their point is important.

In the section on support strategies the work of Armistead and Clark (1990) was reviewed, including their recognition of the need for "*strong linkages between manufacturing, design and after sales service strategies*". This is necessary because the support received by the customer is dependent on the interplay of these three elements. Design for support in isolation will not necessarily improve the quality of support, it needs to be planned in conjunction with the manufacturing and support strategy. For example, "*The delivery of the service is clearly affected by product design, for example by the ease of problem diagnosis or component replacement, and by manufacturing in the cost and availability of spares or capacity for in-house repairs*" (*ibid*). The increasing need to design both products and services in unison is also identified by Vandermerwe (1990), who also points out that it is essential to understand from the customer's perspective what are the key attributes of the required product and services.

2.6 SUMMARY

The literature on product support has been reviewed in detail. It was found to contain material on the following areas:-

- The importance of product support.
- The definition of product support.
- The management of support organizations.
- Product support strategies.
- Designing products to meet support requirements.

However, there are some gaps in the literature. These include the lack of recognition that support strategies and design for support are not only dependent on service issues. The change in the scope of support is not yet reflected in the literature on choosing strategies and only partially reflected in the articles on design for support.

On the specific topic of design for support three gaps were identified. The first of these is the lack of quantitative data on when and how companies evaluate product support for new products. The second is, despite the recommendation of several authors that a similar method to DFM should be used for support, the lack of concrete information on how this should be implemented. The third area where new research is necessary is in the identification of the attributes of good support, from the customer's viewpoint.

If support were planned at the design stage of new products, then this would *surely* lead to products which are easier to support. Behind this statement, however, lies the assumption that planning is always effective and this cannot be taken as a fact. Before the value of planning product support can be understood, the role of planning itself needs to be discussed and so this is the subject of Chapter Three.

CHAPTER THREE

The Literature on Planning

3.0 INTRODUCTION

This thesis is concerned with the way in which product support is planned for new products and how this planning can be improved. Implicit in the research project is therefore the assumption that planning, as a management activity, is necessary and effective; obviously this assumption needs to be given foundation. Consequently, this chapter discusses the meaning and development of planning. It starts with an account of the history of planning and then gives an explanation of the process of planning for business applications. Further discussion covers the advantages and disadvantages attributed to planning and a specific example of a planning method used in new product development is explained. This method is the Design for Quality (DFQ) concept and the related Design for Manufacture (DFM) planning methods. Case studies on DFM have shown that it has led to big improvements in the manufacturing area of the companies where it has been implemented.

3.1 THE HISTORY OF PLANNING

Many management textbooks discuss the value of planning without even considering if it is really necessary or effective. In fact, some texts do not really differentiate between management and planning as processes since, as stated by Taylor (1977), *"most managers would probably claim that managing and planning are virtually synonymous"*. This also probably explains why there are relatively few references which discuss the history of business planning.

Two authors who reviewed the history of management planning, Walters (1973) and McDonald (1982), focus on the period after the Second World War. However, management planning (and general planning as a human activity) is so old that it is hard to say when it evolved. Albrecht (1978), discusses this and says planning is like *"the concept of professional management; its origins are lost in history"*. To illustrate this, Albrecht points to the achievements of the ancient Egyptians, around 4000 BC, and how their pyramids would have been impossible to build without detailed planning. Shores (1988) also points to the civilizations of the Egyptians and Sumerians. He particularly stresses that the Great Pyramid, built around 2560 BC, could only have been possible with excellent planning, since it was the result of a project involving 100,000 workers who, over a twenty year period, produced a perfectly proportioned monument. The Great Pyramid is, according to Shores, the earliest example of the use of the goal-oriented planning method called Management by Objectives (MBO or MbO). Other examples from ancient history include the development by the Chinese in 1100 BC of a planning and control system (Shores, 1988). Throughout the rest of history numerous examples of the use of planning can be identified, from military campaigns to the building of cathedrals and monuments. In fact, planning has been a part of everyday life for centuries because "*planning is, simply, thought before action*" (Amara and Lipinski, 1983). The focus on planning as a business activity first came, however, this century.

In an early reference to business planning, Holden *et al* (1941), considered the need for planning, and answered the question "*why plan?*" with "*There is nothing more important about an organisation than its future*". Gilmore (1986), in an article on planning and business strategy, points to the 1950s as the turning point in management planning. Before the fifties, the planning used was largely "*size-up*" (*ibid*), in nature. That is, business problems were approached as they arose (i.e. reactively), were quickly analysed, significant findings noted and then combined to produce the overall diagnosis. The newer approach, developed in the fifties, was more of constant surveillance, identification of opportunities and comparing progress to the objectives (i.e. pro-active). This has continued, up to the present time, with a particular emphasis on formal planning from the mid-seventies (Gilmore, 1986). The pattern of this formal planning has been "*largely inspired by the "Planning, Programming and Budgeting System", or P.P.B.S., originally used by Robert McNamara in the United States Defense Department*" (Taylor, 1977).

An important date in the evolution of management planning was 1954, as this was when a method which originated from managerial practice was refined by researchers and named MBO (Carroll and Toshi, 1973). MBO is a method where the focus of planning is the selection of the desired objectives and the translation of these into concrete, where possible quantitative, goals. MBO was originally used for the management of employees' work but was later used for project management and has been credited with many benefits. Humble (1970), for example, says "*There are many case histories throughout the world which demonstrate that this system produces significant results*". MBO is one of many variations on the planning process that have been developed in the field of management.

The major part of the literature on business planning is concerned with long-range or strategic planning. The interest in strategic planning started in the mid-1960s and resulted in the growth of both the consulting industry and of in-company planning departments (Javidan, 1985). The investments by large companies in strategic planning were particularly high during the 1970s and 1980s. In the late-1980s, however, the effectiveness of strategic planning compared to the level of investment required became increasingly questioned and this led some companies to cut their investments significantly (Cross, 1987). The popularity of strategic planning is changeable, as can be seen by the recent revival of management interest (Fisher, 1990).

One limitation of the literature on planning is that, as stated, much of it concentrates on strategic planning. Due to this focus, for many authors the term *planning* has become almost synonymous with strategic planning. Consequently, investigations of the effectiveness of planning tend to investigate whether "high-level" (strategic) plans are effective and largely ignore the role of planning in "lower-level" (project) management. Similarly, most articles on the process of planning take the strategic perspective. However, the next section will present a number of processes, from across the spectrum of high to low-level business planning.

3.2 THE PROCESS OF PLANNING

The form of the planning process is situational; many different recommended methods can be found in the literature which, however, all have common features. Hammermesh (1986), writing on portfolio planning in particular, stated this succinctly; "[you must] *tailor planning to the situation. There is no single right way to plan*". Some of the different processes from the literature, from areas ranging from marketing to corporate strategy, will be presented. These will be used to illustrate not only the variety of approaches to planning but also that there are some common elements to these.

3.2.1 Examples of Planning Processes

In total, six planning processes will be presented, as they illustrate the differences found across the literature.

The number of stages to planning varies widely, according to various authors. Bayliss (1985), writing on marketing planning, states that there are three stages:

1) Defining what should be achieved (objectives).
2) Deciding how they can be achieved (strategies).
3) Implementation.

Six steps are defined for product planning by Kotler (1984), who says "*A product plan describes objectives, strategies, and tactics for a particular product*". The six stages are:

1) Analyse the situation.
2) Set objectives.
3) Choose strategies.
4) Set action plans (who is responsible for what at which time).
5) Consider finances.
6) Set controls.

Also discussing product planning, Patton (1980) describes in detail ten steps to planning. Much of Patton's emphasis is on the goals being documented, understandable, measurable, challenging and achievable. Steps 5) to 10) can be seen to be related to the implementation of the product plan and the monitoring of its progress.

1) Setting objectives.
2) Detail goals including cost, schedule and quality factors.
3) Specify operational and support requirements.
4) Develop strategies, policies, procedures and plans as necessary for the specific product.
5) Acquire necessary hardware and software.
6) Test the system to demonstrate success.
7) Direct acquisition and implementation.
8) Assure testing and measurement.
9) Analyse information.
10) Oversee tradeoffs and revisions as necessary.

Two authors writing on corporate (strategic) planning present processes. Lorrange (1980) defines five stages:

1) Setting objectives.
2) Choosing strategies.
3) Setting the budget(s).
4) Monitoring the progress.
5) Providing suitable incentives.

Taylor (1977) gives six steps that are necessary for corporate planning. These are:

1) Set company objectives.
2) Appraise company resources.
3) Analyse trends.
4) Assess alternatives.
5) Develop strategies (to reach objectives).
6) Track performance.

Finally Shores (1988), in a discussion of approaches to planning quality gives the following five steps to "Total Quality Control" (TQC) planning:

1) Set goals.
2) Choose strategies.
3) Define responsibilities.
4) Document.
5) Review and update.

Shores emphasizes the importance of the first stage, saying *"Goals / Measures are the most significant part of the planning process"*. Certainly the setting of the objectives[1] and goals[2] is a key part of planning and one which features in all of the examples above.

3.2.2 The Common Elements of the Planning Process

The six planning processes given in section 3.2.1 illustrates the variety found in the literature. Although the order and number of steps recommended varies (planning is situational, so this is to be expected) there are some common elements. These are:

- A pro-active analysis (i.e. anticipating problems before they occur).
- The setting of objectives and goals.
- The choice of how to reach them (review of current situation, strategies, resource analysis etc).
- The review of progress (control and updates to the plan).

The use of the four steps above, however, does not mean that success is guaranteed. In addition, considerable effort is required in "*making planning work*" (Hammermesh, 1986), which could be seen as a disadvantage of planning. This required effort is implicit in the last step ("review of progress"), which is the means by which the progress of the plan is controlled. The means of control is usually that of checkpoints - progress at key phases is compared to the set objectives. For complicated plans a whole series of checkpoints may need to be set, for each of the constituent parts of the plan. Various methods (often called "tools") are available to help visualize plans. The most common is the Gantt Chart (Randolph and Posner, 1988), which is a horizontal bar chart with the length of bars representing the length of time required for each activity. Commonly, each separate bar on the Gantt Chart is labelled with a short description of the activity and the person or department responsible for it. Use of Gantt Charts, or similar methods, is particularly important for the management of complicated projects, where the success of the project depends on the aggregation of work from many departments (*ibid*).

3.2.3 The Role of Objectives and Goals

Shores (1988) sees the development of the goals from the objectives as the salient part of planning. His view is repeated by a number of authors, who

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[1] objective: in the planning literature this is normally taken to mean a target expressed in general terms (Lorange, 1980) e.g. "improve market share".

[2] goal: this is normally taken to mean a target expressed in specific, measurable terms (Lorange, 1980) e.g. "increase market share by 7% before January 7th".

also see the importance of the stage: "*This is an extremely critical phase of the planning process ... that is characteristic of good planning*" (Lorange, 1980). The emphasis on goals is central to MBO technique.

Management by objectives places the accent in the planning process on the identification of the objectives to be achieved and the translation of these into measurable goals. Albrecht (1978) defines MBO as consisting of the four stages (which are very similar to the common elements of planning given in the previous section):

1) Analysis.

2) Goal setting.

3) Action.

4) Monitoring.

Albrecht stresses that the goals must be "*specific, concrete, unambiguous and verifiable*". MacInnes and Heslop (1990) attach similar importance saying; "*Develop specific, quantifiable, realistic measurable objectives*".

The preoccupation of MBO techniques with only measurable goals has, however, drawn some criticism. This is because not all objectives can be quantified. Therefore focusing only on quantifiable goals means that some important objectives may be ignored plus creativity in planning may be lost (Kerr, 1989). Some authors writing on MBO consider this and point to other types of objectives. Humble (1970) says that three types of goals are acceptable, these ranging from "*general*" ("*of necessity vague*") to "*specific*" to "*quantitative*".

The importance of objectives and goals in planning can be seen to be central. They form a key element of planning, provided that they do not blinker good-sense in the planning process, by excluding proper situational analysis. This was nicely analysed by Hayes (1985), in an article explaining the advantages of a "*means-ways-ends*" sequence to the planning process, as opposed to the more normal "*ends-ways-means*". Hayes *ibid* introduces these two terms to illustrate that when management becomes focussed on ends alone, then the available resources may not be adequately analysed. This will lead to limited success in the implementation of the plan. Full consideration of the resources, how they can be used and what steps forward this will bring is an alternative approach which Hayes concludes is more effective.

3.3 THE ADVANTAGES OF PLANNING

Planning is widely believed to be valuable and effective. This assumption is often found in management literature, with the effect that it is seldom questioned or substantiated. Some of the assumed advantages of planning will be presented plus some management research into the effectiveness of planning.

Two examples of the belief shown in the literature in planning can be found in Humble (1970) and Kotler (1984). In his well-known text on marketing management, Kotler (1984) lists six advantages of planning, including "*encourages systematic thinking*" and "*leads to the development of performance standards of control*" but he gives no arguments to support these claims. Humble (1970) also makes strong claims for planning because "*There are many case histories throughout the world which demonstrate that this system* [MBO] *produces significant benefits*". However, what Humble (1970) does not mention is that many of these case studies, from management practice, do not prove there is a causal link between planning and business effectiveness.

In management practice, new methods including planning are very often tried-out in an "experimental" ("try something different") fashion; one in which no attempt is made to control extraneous variables. Consequently, these "experiments" have, from a research viewpoint, limited internal and external validity. To explain this in more detail, consider the case of a company which introduces marketing planning. The effectiveness of this planning may be measured by an increase in the company's sales and profits following introduction of planning methods. However, the increase in sales and profits may simply be due to a changed market situation and not due to the results of the planning (McDonald, 1982). In addition, some scepticism must be attached to the proof offered by case studies on the business successes resulting from planning. This is because normally only case studies of planning successes are published (Kerr, 1989).

McDonald (1982), in his thesis on the effectiveness of marketing planning, attempted to avoid the problems of case study research by combining it with survey and quasi-experimental techniques. His results firstly show the belief in planning found in management circles; "*Eighty-two percent of ...* [his sample] *either strongly agreed that, or agreed that planning is necessary. Only fifteen per cent disagreed*". Further interesting results, from a group of companies using detailed planning, were found, although "*it is dangerous to generalise from such a small sample*". Three main conclusions were reached about marketing planning. These were: that marketing planning is particularly necessary in a hostile competitive environment; that going through a formal planning cycle enormously helps management to become familiar with the details of their business and; that planning does, in fact, lead to business success (McDonald, 1982, p350). The results which led to these conclusions can, however, be questioned for their internal validity, due to the use of a quasi-experimental and not a true experimental design. The improvements quoted as due to planning could well have been due to other effects such as maturity.

Greenley (1988), in a review of the literature on marketing planning, found that it could be divided into two categories, which he termed "*prescriptive*" and "*empirical*". The former category of countless articles gives guidelines on what organizations ought to do when making their marketing plans (without questioning whether planning is appropriate). The latter category - investigations of how companies actually plan marketing and how effective this planning is - consisted (in 1977) of only seven papers! Greenley's investigation illustrates well, in the field of marketing, that the general believe in planning means that little real investigation of the value of planning has been made.

Another academic investigation of the effectiveness of planning is that of Rhyne (1987). He noted that most previous studies of planning simply contrasted planners with non-planners. He postulated that this view was too simple and that the characteristics of the planning system have a strong influence on its effectiveness. Rhyne's research, conducted with *Fortune 1000* companies, showed that distinct patterns existed in the characteristics of planning used by companies performing at different levels financially. More successful companies, for instance, "*appeared to achieve a balanced approach in their planning effort*" (Rhyne, 1987) i.e. they managed to consider equally well both external factors (e.g. a changing market situation) and internal ones (e.g. coordinating different areas of an organization). Rhyne acknowledges that his research has a limitation - that he concentrated solely on financial performance as a measure of planning effectiveness. However, no attempt is made to substantiate this assumption and the assumed causal link of planning to financial performance is tenuous. In addition, the correlation of the type of planning to the level of financial performance could be a spurious one. This is because the sample of companies came from a wide range of industries, each of which are likely to have different market financial climates. This contextual possibility is not discussed and so, from this angle, Rhyne's results on planning effectiveness are equivocal. King (1984) makes a similar criticism of various evaluations of planning effectiveness. He argues that a detailed framework is required to assess planning effectiveness, in terms of the actual goals set and not simply by assuming there is a "*black box*" relationship between planning and business performance.

Taylor (1977) stresses the value of formal planning techniques. He says, "*There are many benefits to be reaped from a more formal approach to planning. It forces a manager to think forward and anticipate problems before they occur. It provides a detailed forecast and plan that makes it easier to discover why the action taken did not produce the expected results*". As evidence of this they quote the results of studies in the U.S.A., showing that companies using corporate planning outperformed those who did not. (The measures of performance being the earnings per share, earnings on common equity and earnings on total capital employed.) Since the better performance could also have been the result of extraneous factors, the study went further and used an experimental angle of investigation. This produced results which showed that the performance climbs after the introduction of corporate planning. "*The evidence therefore strongly suggests that corporate planning can lead to significant improvements in performance*" (Taylor, 1977).

The evidence from the literature is that planning is useful and that it probably does lead to better business performance. However, proving that planning leads to better performance is difficult and little research has concentrated on designing the necessary experiments to prove this link. Most of the studies to-date have tried to contrast the planning systems of successful companies with less successful ones. This approach can be questioned, both for its internal validity and to the degree to which the results can be generalized. In addition, planning has some disadvantages.

3.4 THE DISADVANTAGES OF PLANNING

As was seen in the previous section, many of the claimed advantages in the literature are unsubstantiated. Similarly the limitations and disadvantages identified by authors are ones mainly without research proof. The main limitations found in the literature are:-

- Planning requires significant time and resources.
- Planning can become very bureaucratic.
- It can lead to a loss of flexibility (particularly if the focus on the objectives becomes narrow-minded).
- The use of planning does not guarantee success.

These will be reviewed and their significance discussed.

Planning requires time and resources, which not every organization may have. Gilmore (1986) points to the staff and company processes required to develop business strategy and says these are unrealistic for small companies. Gilmore (1986) did, however, support the idea of planning, as long as the process was simple and practical enough for small companies. The time required for formal product planning is seen by Stalk (1988) as a major drawback and can lead to loss of competitive advantage and says that consequently *"Japanese companies today are ... shortening the planning loop in the product development cycle"*. On a different line, from an investigation of high-technology companies, MacInnes and Heslop (1990) found that *"Management did not perceive that they had the "luxury" of time for planning, even though the value of planning was recognized"*.

One charge that is often found in the literature is that planning is, or can become too bureaucratic. Lovett (1988) warns against planning becoming oriented towards the production of long planning documents, which are never read (Lovett recommends that planning documents should be a maximum of four pages long). Exactly this point is also raised by Hayes (1985), who cynically warns against the production of *"plans ... with increasingly sophisticated graphics and fancy covers"*. A more general warning on the dangers of planning becoming too bureaucratic is given by Mills (1985), *"When planning gives the wrong directions or becomes too bureaucratic, of course it deserves to be condemned"*. A piece of research which gives more substantial proof to the limitations caused by bureaucratic planning is the survey work of Ames (1968), who found that the failure of planning at fifty "Fortune 500" companies was in part due to *"Overemphasis on the system"*. Related to the charge that planning can become too bureaucratic is the criticism that it becomes detached from reality, if performed by staff planners. Baldwin and McConnell (1988) therefore see that *"successful implementation of the planning process and implementation of the plan go hand in hand"* and that staff planners should only have an advisory role.

The loss of flexibility and creativity caused by formal planning processes is mentioned by several authors. Shank *et al* (1986) see that there will always be conflict between the pragmatic and creative styles in planning and that *"planning ... must achieve a workable compromise between creativity and practicality - twin goals which are often in conflict"*. A similar point is made by Kerr (1989), in his analysis of MBO saying *that "numerous examples can be cited where performance suffered because non-quantifiable objectives were ignored altogether or because some simple-minded ... measure of creativity was substituted for them"*[1]. Cross (1987) argues the need for planners to be flexible and not to rely on data analysis too heavily because *"most successful strategies do not rise logically from the data. Instead they are informed 'gut feels' "*.

It was stated earlier that effort is required to ensure that planning works. The effort required is continuous from the setting of the goals until they are reached (or the goals are altered) and, without it, planning will not be successful. Lovett (1988) points this out and warns against managers only *"going through the planning process"* without real commitment. Similarly Mills (1985) sees that the implementation and monitoring of progress demands effort because *"when planning stops with objectives and short of implementation, the business advantages it provides are likely to be lost"*. Whether success follows planning can therefore be seen to be dependent on the quality of planning and particularly its implementation.

3.5 GENERAL CONCLUSIONS ON PLANNING

Planning, as a technique, has developed over the centuries and has been extensively used in business. The review of the literature has shown that the planning process depends on the situation but includes three main components. These are the analysis of the situation, the choice of objectives and setting of goals plus the monitoring (control) of progress. The application of planning to business problems has been credited with many successes, although the evidence in many cases is not substantial. The lack of substantial evidence for the effectiveness of planning is partly due to the focus of the literature on strategic planning (proving the effectiveness of

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[1] Kerr's investigation was mainly in the area of human resource management. Hayes (1985), on business planning, also concluded that a strong focus on quantitative goals may sometimes drive out creativity.

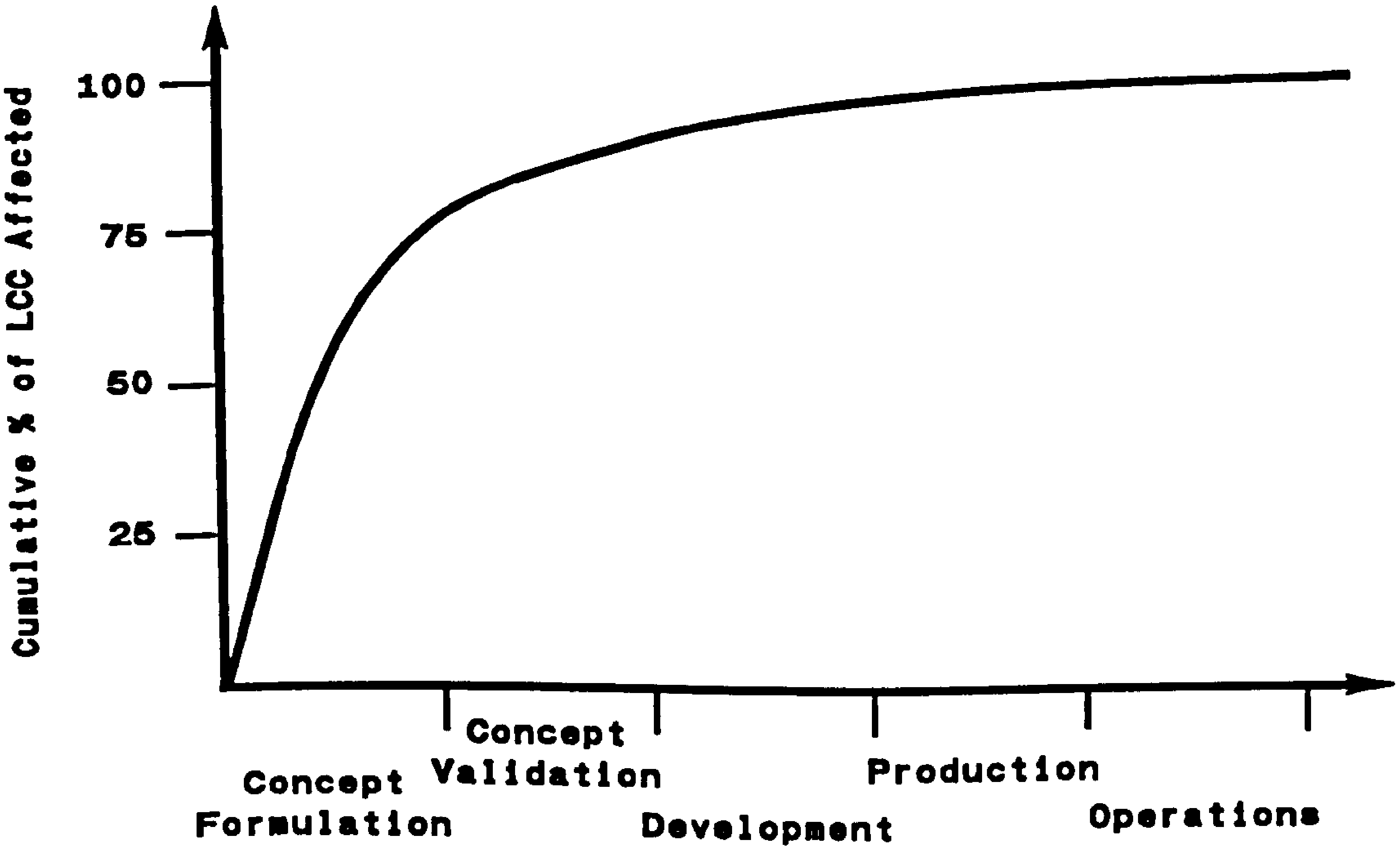
strategic planning is particularly difficult). However, the consensus is that planning is valuable and that *"There is no level within the business organisation that can consider itself as having no need for planning"* (Walters, 1973). The limitations of planning should, however, be recognized since they can be significant.

So far, this chapter has concentrated on the general literature on planning and not specifically on the planning of new products, which is relevant to product support planning. However, detailed management methods have been developed for the planning of new products, to ensure that these products achieve quality and meet customer expectations. These methods, known under the heading of Design for Quality (DFQ), are relevant because they demonstrate the success of planning applied to new product development.

3.6 DESIGN FOR QUALITY

There is a strong trend within manufacturing industry towards detailed planning of products at the design stage, to ensure that they not only meet market requirements but also can be efficiently manufactured. The methods by which this is achieved are generally termed Design for Quality (DFQ) and they aim to coordinate the skills of an organization so that a product is designed, manufactured and marketed which meets the customer's needs.

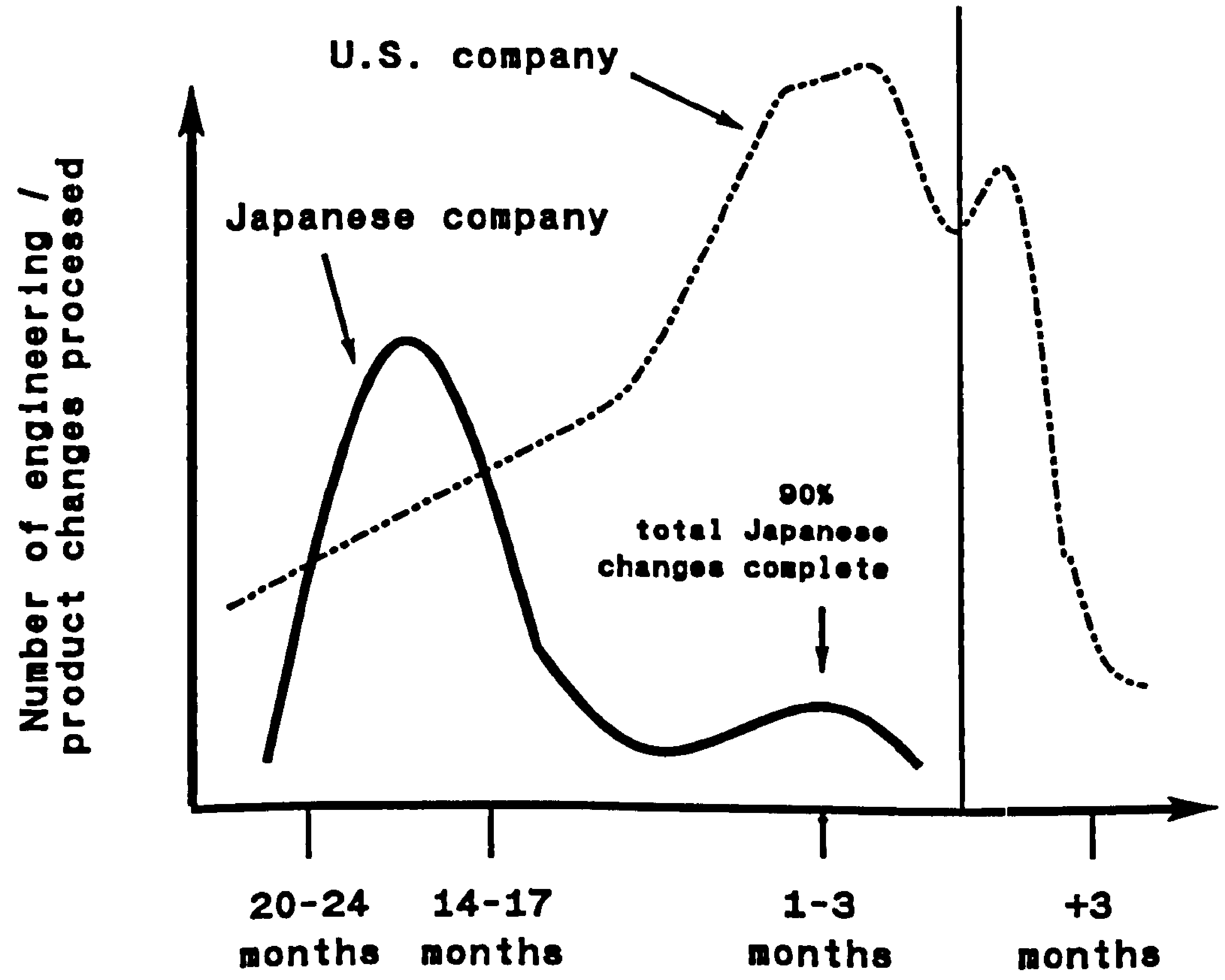
Figure 3.1: Actions Affecting Life Cycle Costs - The Results From an Empirical Study (from Patton, 1980, p31).



The philosophy behind DFQ is that the design phase is critical, since it determines to a major degree product characteristics and costs. (A study at Rolls-Royce, for instance, showed that 80% of the final production costs of 2,000 components was determined by the design - Whitney, 1988.) The affect of the design on life cycle costs (LCC) is enormous, as illustrated by Figure 3.1. Consequently, much of the literature on manufacturing places very strong emphasis on the design stage because *"design is an activity which must include the whole life costs of the product"* (Spickernell, 1983).

DFQ, which originated in Japan, is still a fairly new concept which is not yet widely applied in the West. Spickernell (1983) defines Design for Quality as consisting of a process by which all the design alternatives are investigated and reviewed for their performance, safety, reliability, maintainability, availability, durability, size, shape and weight. Often, according to Garvin (1988), it is not desirable to try to build products which excel in all of the dimensions of quality; priorities need to be set. "Quality Function Deployment" (QFD) is a management technique which looks at the priorities. The basis of QFD is *"the belief that products should be designed to reflect customers' desires and tastes - so marketing people, design engineers, and marketing staff must work closely from the time a product is first conceived"* (Hauser and Clausing, 1988).

Figure 3.2: Japanese / U.S. Engineering Change Comparison (from Sullivan, 1986, p39).



QFD consists of a set of planning and communication techniques. Case studies have shown, since the development of QFD in Japan in 1972, that it leads to products which closely meet customers' expectations. These products therefore require fewer modifications or improvements once they are on the market. Many well-known companies such as AT & T, Ford, Digital Equipment and ITT are already using QFD or are now planning to implement it (Hauser and Clausing, 1988). Sullivan (1986) found that QFD had enabled Japanese companies to become more efficient in the process of product design and therefore to require less engineering changes once products reached production (this is illustrated by the results shown in Figure 3.2). Coupled to this Sullivan (1986) also noted that start-up costs for new products were lower when QFD was used.

The central item in the QFD planning process is the "Planning Matrix", which allows customer requirements to be entered along one axis and compared against key design information on the other axis. The matrix is then used as a management tool, for deciding how a range of customer requirements can best be met, as this will always require a certain number of compromises to be made.

A subset of Design for Quality is Design for Manufacture (DFM) - the full consideration, during the design stage, of how a product can be efficiently manufactured. DFM stresses the importance of planning the manufacturing process early and uses quantitative methods to estimate the manufacturability of designs (i.e. how efficiently they can be produced). These quantitative measures have been found to be very useful and are now widely used in large US companies (Boothroyd [1987] and Kumpe and Bolwijn [1988]).

3.6.1 Design for Manufacture

Design for Manufacture is the full consideration, during the design stage, of how a product can be efficiently produced. "*DFM stresses that seemingly insignificant decisions made during the initial design phase will affect manufacturing throughout the product's life cycle. Most products can be designed for easy manufacture and assembly if manufacturing is considered early in the design process*" (Stoll and Cole, 1985). There are several stages to DFM and these will be described, together with their advantages.

Stoll (1988) defines the objectives of DFM as "*to identify product concepts that are inherently easy to manufacture, to focus on component design for ease of manufacture and assembly, and to integrate manufacturing process design and product design to ensure the best matching of needs and requirements*". The process has three tiers: "Component DFM", which is also known as Design for Assembly (DFA), "Product DFM" (assembly of the product from its constituent major assemblies) and "Robust Design" (the design of the production line for efficient production). According to Boothroyd (1987), " *DFA is the key to Design for Manufacture*" and therefore this will be discussed.

Design for Assembly is a methodology developed primarily to check product designs to ensure that they are easy to assemble. This process does, however, bring with it one very significant advantage - it enables product simplification and consequently brings lower production costs. Three main DFA methods are in use today: the Hitachi Method, the Boothroyd Method and the Combined Method (Boothroyd and Dewhurst, 1988). Each of these methods is applicable right at the beginning of the development cycle and can even be applied to evaluate conceptual drawings. This allows several alternative designs to be compared, or a single design to be optimized. The key to the methods is that they are quantitative, thus allowing meaningful comparisons to be made between designs. The difficulty with and time required for product assembly can be evaluated and therefore the production costs can be projected, even before a prototype is available. An effect of using DFA is that designs are simplified - only those parts that are really necessary remain in the finished design as a separate part. This has significant implications for production costs; the lower number of parts can cut material costs, an important factor even for products with short assembly times (Boothroyd, 1987). The strong role that DFA has played in manufacturing is well described in the article by Kumpe and Bolwijn (1988) and it is from this article that the examples of reduced parts counts (Figure 3.3) are taken. To make the workings of DFA processes clearer, the Hitachi Method will be described.

Figure 3.3: The Reduction in Parts possible with Design for Assembly - The Average Results from an Empirical Study of 29 Products (adapted from Kumpe and Bolwijn, 1988, p79).

Category	Before DFA	After DFA
Number of parts	100 %	75 %
Number of sub-assemblies	100 %	65 %
Number of operations	100 %	70 %
Assembly time (manual assembly)	100 %	75 %
Costs of feeding mechanisms and assembly heads	100 %	60 %
Parts which can be assembled automatically	30 %	90 %

"We have studied 29 products including compact disc players, video cameras, telephones, and portable irons, from 1984 to 1986. In all, there have been striking reductions in the number of components and assembly operations, and corresponding reductions in costs."

The Hitachi Assembly Evaluation Method (AEM) develops two measures of product design; the Assembly evaluation score "E" and the estimated assembly cost ratio "K" (Miyakawa and Ohashi, 1986). Design improvement is achieved by reviewing the quantitative evaluation scores E and K from both the original and a proposed improved design. E is a number between 0 and 100, as indicated in Figure 3.4, with a higher E score indicating a better design. A score of 80 or more is desirable, for efficient manufacturing.

Figure 3.4: The Evaluation Score E (adapted from Miyakawa and Ohashi, 1986,).

0	30	80	100
Infinite time to assemble	Great deal of work to assemble	Highly-efficient design	Ideal design

$$E = \frac{\text{The number of parts} \times 100}{\text{Assembly time (AT)}}$$

The AEM technique uses a model to estimate the assembly time. Each part is assessed (and scored) as to how easy it can be assembled with the other parts. Parts which are known, from previous experience, to be particularly awkward (e.g. screws with left-handed threads) are given penalty points. The scores from each part are added up and this leads, via a normalization process (which equates the scoring to actual assembly times, based on previous experience), to the assembly time (AT). The exact values of the scores for different types of parts and the related assembly times have been defined empirically by Hitachi and are proprietary information. (Hitachi offer courses on AEM and license its use by other companies.) A similar scoring model, based on the actual costs of assembling parts in the past, is used to obtain the cost factor K. Use of the E and K assessments makes clear which are good and which are poor designs, from a manufacturing standpoint.

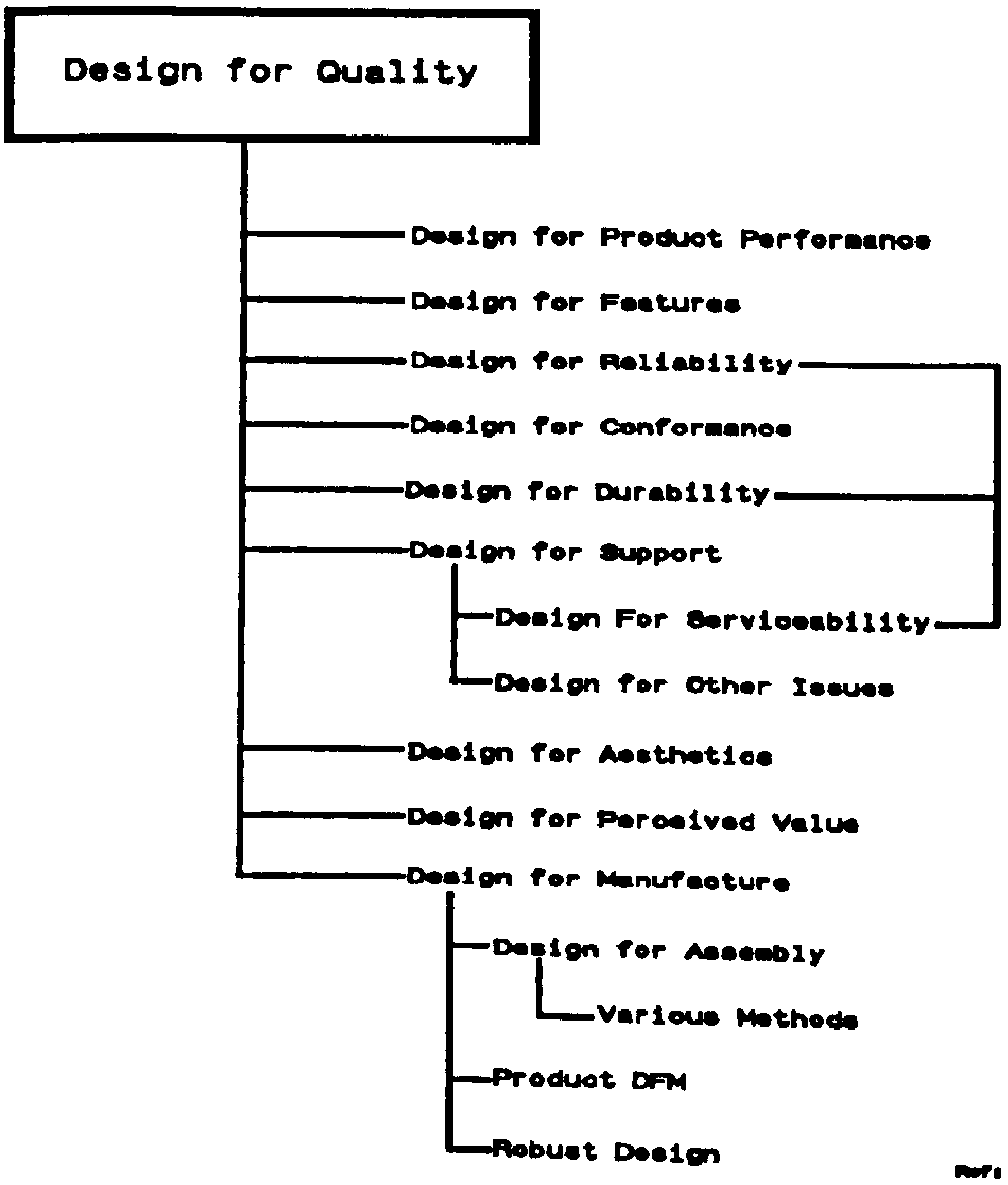
3.6.2 DFQ as a Planning Process

How does the DFQ technique compare to the common elements of the planning process (see Section 3.2.2) ? In fact, it compares very closely to the common elements, as can be explained by considering three points. Firstly, DFQ is a very pro-active process, in that potential production problems are assessed long before they arise (i.e. at the design stage). Secondly, the objective of good manufacturability is converted into specific, quantitative goals such as the Hitachi E Score. Thirdly, the chosen design is implemented (action stage) and finally the design is monitored once it actually goes into production. The successes credited to DFQ are empirical case studies but are, nonetheless, impressive. Consequently, it is not surprising that a number of authors writing on support have pointed to the success of DFM and suggested that something similar is required for support.

3.6.3 Support and Design for Quality

How are support and DFQ related? Design for Quality in its broadest definition includes DFM and design for maintainability (Spickernell, 1983). However, there is some confusion in the literature about the scope of DFM and whether this includes support. This section will try to show the relationship between support and DFQ.

Figure 3.5: The Relationship between Design for Quality and Support (drawn from the definitions given by Garvin [1988], Juran and Gryna [1988] and Spickernell [1983]).



Joshi (1985) defines DFM as including "*design for ... customer service ... installability and repairability*" whereas other writers see design for customer service as outside of the scope of DFM but nonetheless part of DFQ (Garvin, 1988). Garvin *ibid* defines *"eight dimensions or categories of quality"* from performance to perceived quality and including serviceability, which need to be evaluated during the DFQ process. Spickernell (1983) and Juran and Gryna (1988) include DFM in their definition of Design for Quality and so, combining the definitions of these two authors with that from Garvin, a broad definition is obtained. This is illustrated by Figure 3.5, which shows that DFQ is a broad concept, covering all the dimensions of quality which should be covered at the design stage. DFM, DFA and design for support are sub-categories, which are inter-related to some of the other dimensions. For instance, a key link is between reliability and serviceability; reliability has a key influence on serviceability.

3.7 SUMMARY

This chapter reviewed the literature on planning and found that the planning process, although situational, has four consistent elements:

- Pro-active (early) analysis of the situation.
- Setting of objectives and goals.
- Action to meet the goals.
- Monitoring of progress versus the goals.

It is widely assumed that planning leads to business success, although the research evidence is not extensive and, where available, often equivocal. The success is certainly dependent on the quality of the planning and its implementation. One "success story" is the product planning technique Design for Quality. The various forms of this technique have been credited with bringing big improvements in manufacturing management. The definition of DFQ does, in fact, cover evaluation of support at the design stage. However, although the need has been recognized by several authors, no detailed planning process for support as part of DFQ has been developed and quantitative goals for support have not been identified, as was seen in Chapter Two. Any research to identify a method for planning product support must, however, recognize that the effectiveness of planning cannot be assumed. Consequently the research design must be carefully chosen - this is the subject of Chapter Four.

CHAPTER FOUR

The Research Design

4.0 INTRODUCTION

This chapter explains how the research design was developed. It starts with an explanation of the background ideas which led to the research project, continues on how the topic was narrowed-down and carries all the way through to explaining the research objectives and samples. The six main topics covered in this chapter are:-

- The background on why research into product support was chosen.
- The initial hypotheses which arose from a review of the literature and anecdotal evidence.
- Discussion of the concepts involved, especially product support, and selection of suitable variables for these concepts.
- The development of researchable hypotheses from the initial ideas.
- The choice of the style of research.
- The choice of the samples used in the research.

4.1 THE BACKGROUND TO THE RESEARCH

The choice of the area of research was prompted by the researcher's own experience of product support in the medical electronics industry. From his personal experience and discussions with others in high-technology industries[1], the researcher noted that product support was not often evaluated systematically at the product design stage. Many managers working in support were heard to complain about products which were "not designed for supportability" and were consequently difficult to support. Newer products, although designed with new technologies, were often criticized by managers as not necessarily being better, from the support point

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[1] At conferences on support, such as:-
1st International Conference on After-Sales Success, 29th-30th November, 1988, London
Association for Services Management International, UK Branch Meetings, 1990
Using Customer Care as a Competitive Weapon, 4th-5th July, 1990, London.

of view. A typical comment to this effect was *"The use of SMT has not enhanced the cost or ease of support, merely the cost and ease of production"*[1]. This anecdotal evidence led the researcher to investigate the literature on product support, which was found to echo the comments of managers; namely that support should be evaluated and planned at the product design stage.

The initial hypotheses, as will be seen, required substantial modification to make them researchable. They were derived from the evidence (both anecdotal and in the literature) on four points:

- Systematic evaluation of all of the elements of support at the design stage would lead to improved product supportability.
- The attributes of high-technology product support are changing and this means that new elements need to be considered. Some of these are not yet being evaluated by companies at the product design stage.
- The evaluation of product support that currently takes place at the product design stage is largely focused on product reliability and ease-of-repair (serviceability).
- The designs of newer products are not necessarily better in all aspects of support (i.e. their supportability is not necessarily better).

4.2 THE DEVELOPMENT OF THE HYPOTHESES

4.2.1 The Initial Hypotheses

The direction first contemplated for the research was the identification and application of a method of planning product support at the design stage. This would "obviously" improve the supportability of products, as shown in the diagram below. (This corresponds to the hypothesis that if support was planned with a method like Design for Manufacture (DFM) then support would be improved.) This pragmatic but somewhat naive approach came as a result of the practical need for such a method, seen by the researcher in his daily work, plus the focus on formal planning in the researcher's company. From a more disciplined, academic standpoint this approach was seen to be unacceptable; the proposed research included a significant assumption (i.e. that planning is always valuable and effective). Although this assumption

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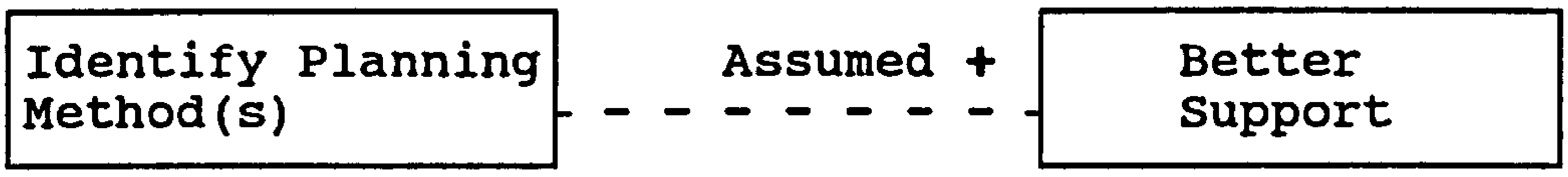
[1] SMT - Surface Mount Technology. The quote is from a reply (Case 15) to the survey on support described in Chapter Seven.

proliferates in management circles[1] it could not, for the purposes of research, be simply taken as a fact that planning is always effective.



A review of the literature (Chapter Three) showed that it is very difficult to prove that planning is effective. The realization that no assumptions should be made about the effectiveness of planning led to the recognition that the initial hypothesis could not, realistically, be investigated within the scope of the research project. However, the initial hypothesis forms the background to the actual hypotheses chosen and it is so closely related to them that it will be discussed as the "*Background (structural) Hypothesis*". (The reason why this term was chosen will become apparent in the sections which follow, discussing the relationships between the hypotheses and objectives.)

Three hypotheses were chosen. The choice was based on the relation of these hypotheses to the Background Hypothesis, the anecdotal evidence already discussed and the pragmatic need to produce results relevant to the company supporting the research. The four hypotheses which will, therefore, be discussed are:-

Background Hypothesis:

> *Systematic evaluation of all of the elements of product support at the product design stage leads to improved supportability of products.*

Research hypotheses:

> *1) Most high-technology companies do not systematically evaluate support at the product design stage.*
>
> *2) Product reliability and ease-of-repair are the factors of product support which are most often quantitatively evaluated at the product design stage.*
>
> *3) Customers perceive differences in the supportability of different products. Newer products are not necessarily better than similar older products on all of the attributes of good support.*

These hypotheses are illustrated below[2], to show where (possible) causal

---

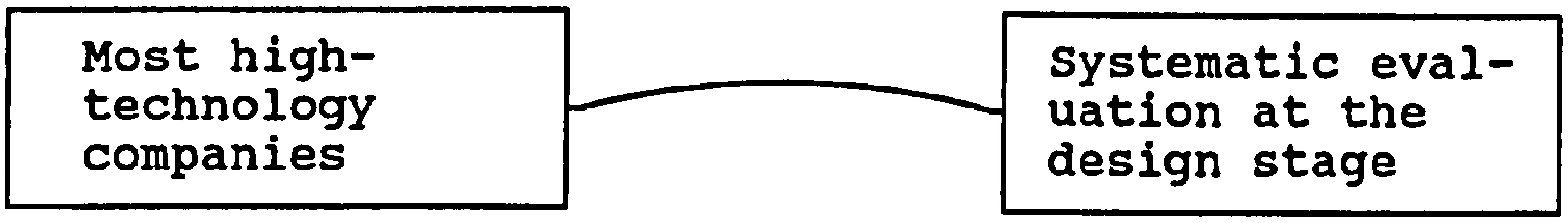
[1] For examples of the widespread belief in the effectiveness of planning refer to Chapter Three.

[2] The diagrams use the notation of curved lines to represent relationships and straight lines to represent (believed) causal links.

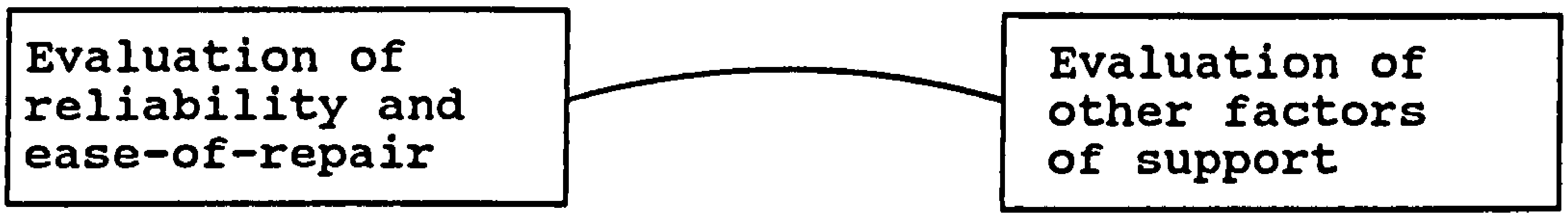
links or correlations exist:-

Background (structural) Hypothesis: Conceptual

Hypothesis 1: Conceptual



Hypothesis 2: Conceptual



Hypothesis 3: Conceptual

Once the hypotheses were formulated, it became obvious that the concept of product support needed defining. In Chapter Two the meaning of the term was explained and the various definitions given in the literature quoted. However, these definitions warrant further discussion, in order to develop a better understanding of the scope of product support.

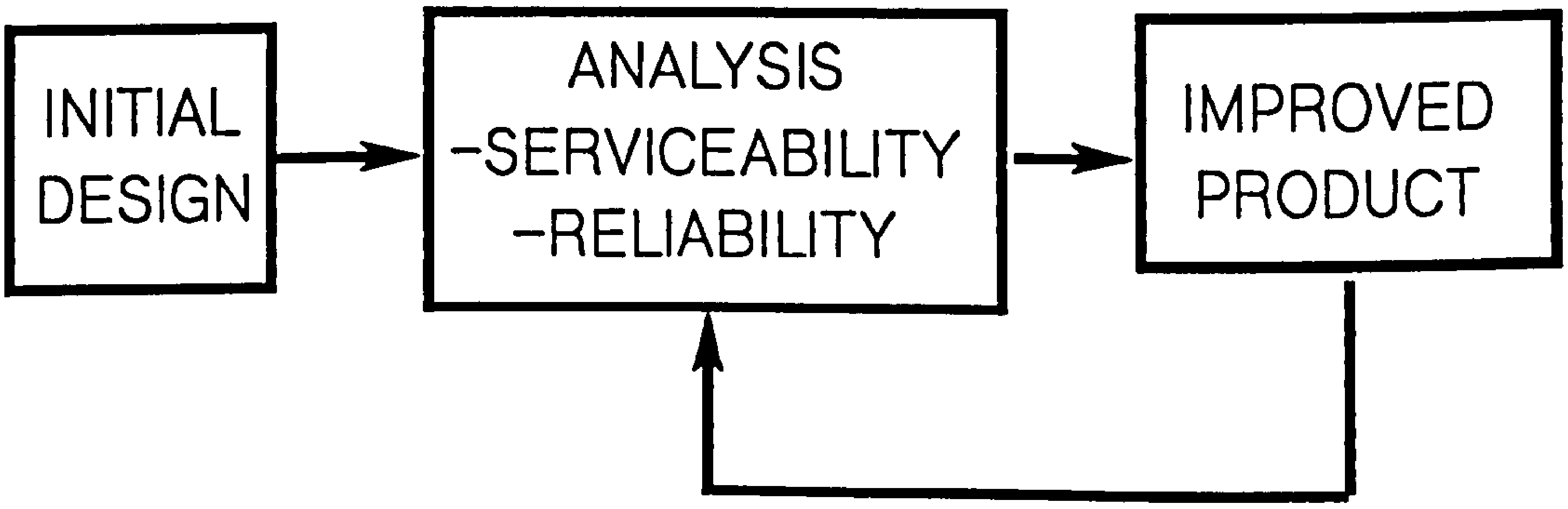
4.2.2 The Concept of Product Support

This section will discuss the definitions from the literature and come-up with a proposed definition that will be used in the research. Comparing the five definitions presented in Chapter Two (Section 2.2.1), it can be seen that the one from Cooke (1987) is the most comprehensive and therefore this one will be used as the basis for discussion.

Cooke's list (Table 2.6) includes two elements that are not found in the other authors' definitions. These are: *start-up* and *information.* Information is certainly a key part of good product support as it can help a customer gain the most from his product but a better term is documentation - this covering the various forms of product information (e.g. technical and operating guides, video tapes on operation etc). But what about start-up? Unfortunately, Cooke does not define what he means by this term. However, it is probable that he means how well the initial phase, including installation and training, is managed by the supplier. This means how quickly the customer is able to use his equipment to a high-degree of efficiency, through a good understanding and a usable product (which is run-in). In this case *start-up* is redundant in the definition, as the terms customer education and installation are also listed. Therefore, start-up will be omitted.

Cooke's list does not include some terms listed by other authors; these are *service engineer response time* and *ease-of-contact* (Clark, 1988[a]) plus *reliability engineering, serviceability engineering* and *product design* (Lele and Karmarkar, 1983). Are these elements which merit inclusion in a full definition of product support, or are they already implicit in the list of Cooke?

Figure 4.1: Reliability and Serviceability Engineering Cycle.



The two terms from Clark are, in fact, dependent upon the size and responsiveness of a field service organization - therefore they are already covered by Cooke's element *field service.* Lele and Karmarkar's points need closer analysis. The product design determines, to a very large extent, how easily the product can be supported. If the initial product is monitored for its reliability and serviceability then, once engineering resources are invested, improvements can be made. This is illustrated by Figure 4.1, which is a graphical representation of Lele and Karmarkar's points *reliability engineering, serviceability engineering and product design.* The importance of continuing to change the design of a product, in order to improve its supportability, should not be underestimated. Improvements can, over the life cycle of the product, generate significant extra revenue as discussed by in detail Potts (1988[b]). Product enhancements which not only offer improved reliability but also new features are important as they offer a customer the chance to *upgrade* his equipment to the latest level. On large installations this is termed *rebuilding* or *modernization,* as listed by Cooke (1987). Therefore, it can be seen that Cooke's definition is, in fact, very comprehensive and includes just about everything mentioned by the other authors, including the concept of *design improvements.*

An additional point that needs to be included in the discussion of product support is *service contracts* (where the customer pays a fixed charge which covers his product's maintenance and repair). These are an important service which is offered to customers by many companies; the strategies behind them and their pricing are discussed by Blumberg (1984). Logically, service contracts can be grouped together with warranty, since they offer a similar security to the customer. However, it should be noted that warranty and service contracts are very different from the field service organization's standpoint: warranty repairs seldom bring profit whereas service contracts may bring significant profits.

An area which is not mentioned by any of the above authors in their definitions of product support is that of *complaints handling,* also called *escalation management.* Complaints handling refers to the formalized process by which a dissatisfied customer can have his complaint analysed and answered by a company. If, for instance, a customer complaint cannot be solved by the local field service organization then a complaints handling process allows the problem to be "escalated" to a level where the expertise exists to find a solution (usually in the manufacturer's marketing or research departments). Especially in the high-technology sector this type of process is important, since the local field service organization may not always have enough expertise or resources to solve difficult (e.g. software) problems encountered by customers. By implementing and publishing complaints handling procedure, a company gives the customer the security of knowing that his problems will be professionally managed. The importance of complaints handling can be seen by the fact that the British Standards Institution (BSI) set rules and standards for escalation procedures, in their assessment schedule BS5750 for service organizations (BSI, 1987). The guidelines of BS5750 are also being introduced worldwide by the International Standards Organization (ISO 9000).

If the points discussed above are incorporated into Cooke's definition of the elements of product support then we arrive at the new listing of Table 4.1, which includes ten elements. In order to avoid any confusion of what is meant by each of the elements they are defined individually in the Glossary. The definition of product support developed will be used as the basis of discussion, particularly with respect to support strategies and product design for support.

Table 4.1: Elements of Product Support (Extended Definition).

	Elements of Product Support
No.	Element
1	Installation
2	Warranty/service contracts
3	Field support organization
4	Parts
5	Maintenance
6	Customer education
7	Technical advice
8	Complaints Handling
9	Documentation
10	Design improvement

4.2.3 A Model of Product Support

The previous section discussed the elements of product support and came up with a list of ten items. Can these be grouped in a way as to form a model of product support? Yes, they can be grouped into categories. Exactly how will be explained in order to develop an understanding of support from the customer's viewpoint.

Lele and Karmarkar (1983) said that good support is "*designed to ensure that customers obtain the most value from use of the product after the sale*". Effective support is therefore achieved when each element of product support is delivered to the customer in such a way that he obtains maximum value from his product. This is shown in Figure 4.2, in which the elements of support have been grouped into three categories. These are:-

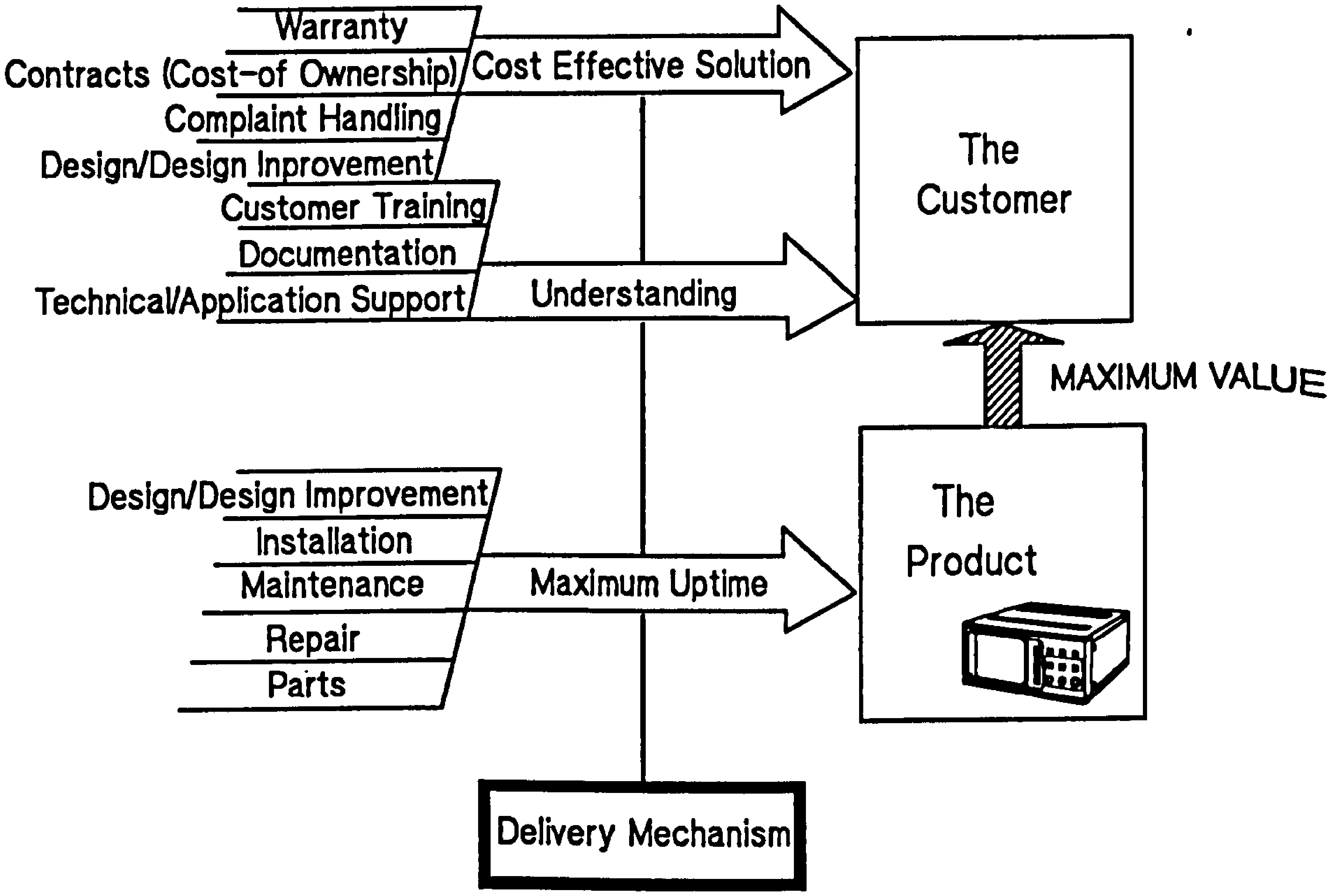
1) Assurance of a Solution: This covering the factors which offer a customer security that his purchase will give him a cost-effective answer to his expectations (This includes *design / design improvement, warranty, service contracts and complaints handling*).

2) Product Knowledge: This covers *customer training, documentation and technical / application support.*

3) Maximum Product Availability: This covers *design / design improvement, installation maintenance, repair and parts.*

The figure illustrates that the first two categories are aimed directly at the customer whereas the third category is more product-oriented. The way that the three categories are delivered to the customer depends on the field organization of the company - this was also identified as an element of support. Therefore, Figure 4.2 covers all of the elements of support and it will be used as the basis for discussions in later chapters.

Figure 4.2: A Model of Product Support (proposed by the researcher).



4.2.4 From Concepts to Variables and Objectives

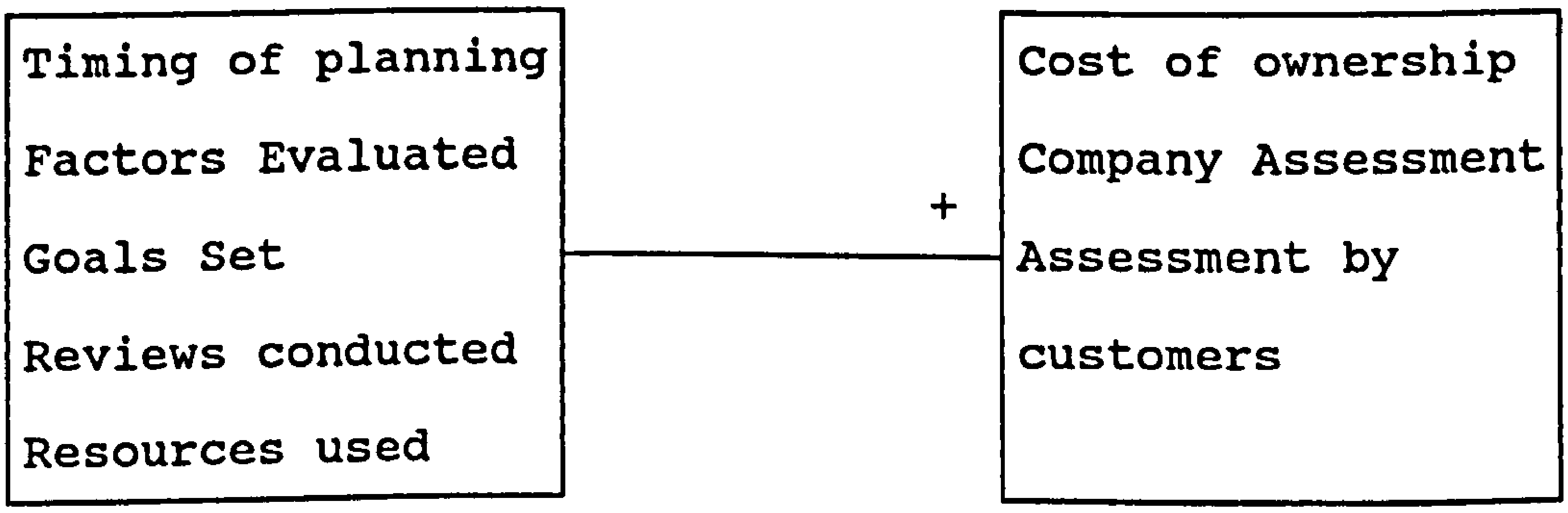
After developing a model for the concept of product support, the next stage in the development of the hypotheses was the choice of individual variables. For some of the hypotheses given in Section 4.2.1, this proved difficult because the concepts involved are not simple. For instance, the background hypothesis is vague. What do the concepts *systematic evaluation* and *better supportability* mean and how can they be operationalized? And once these concepts have been operationalized, can a causal link between planning and better support be established? These two questions illustrate the key problem of the exploratory nature of the research; previous research into the concept of support and its planning has not been made. Therefore, consideration was given to possible variables that would allow each of the concepts to be operationalized.

4.2.4a Background Hypothesis

Systematic evaluation of all of the elements of product support at the product design stage leads to improved supportability of products.

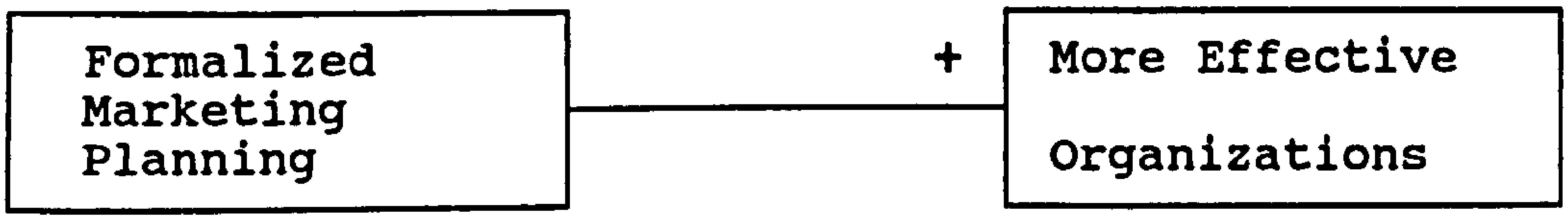
The choice of variables for this hypothesis was complicated. For the (supposedly) independent concept, *systematic evaluation*, a number of variables were considered. These included the time at which companies start their planning, if the plans are reviewed by management, the number of factors that are evaluated and what goals are set. For the dependent concept, variables such as companies' assessments of the quality of their support, the cost of ownership or the customer's perception of support quality were possibilities. This led to the empirical level hypothesis shown below.

Background Hypothesis: Empirical Level



The two problems with the above empirical level hypothesis are the validity of the variables chosen for the concepts and establishing that a causal link exists between them. It was clear, since very little formal research has been done into product support, that the concepts are not well-understood. Therefore using the variables shown above would be hazardous.

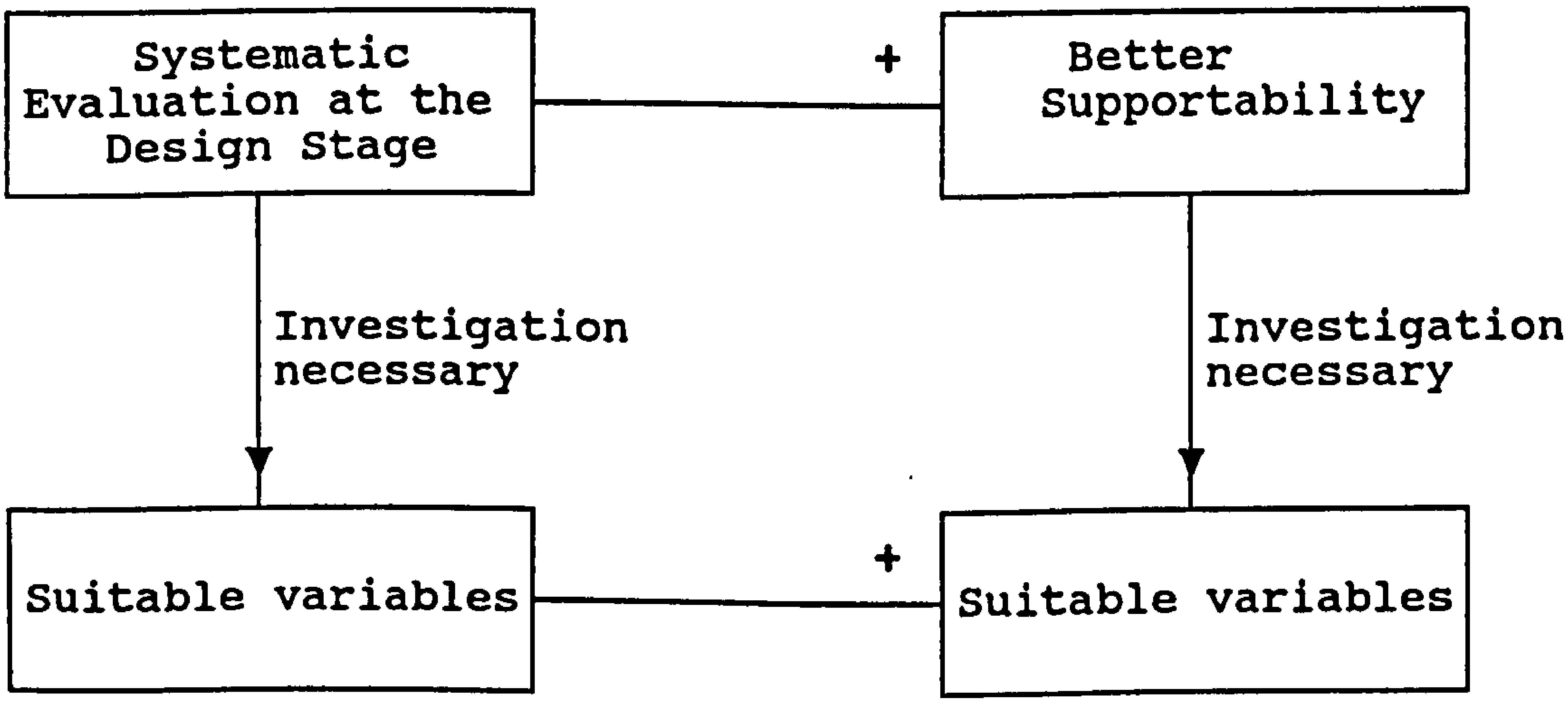
An example of this is the use of cost of ownership for measuring the quality of product supportability. It may not be a valid measure of the quality of product support from the customer's viewpoint. For instance, repairs may be cheap but they may take a long time and therefore cause inconvenience. In addition, the cost of ownership is influenced not only by support planning but also many other factors that change over time (e.g. the current hourly rate for a field engineer's time). This means that it would be very difficult to causally link low cost of ownership to the adequacy of the planning process. (It may be easy to show correlation but this, of course, does not mean there is causation.) A similar conclusion on the risk of choosing variables was reached by McDonald (1982), in his investigation of the marketing planning process and its influence on company efficiency. The conceptual hypothesis investigated by McDonald is shown below.



In attempting to operationalize this hypothesis McDonald considered a suitable variable for *effective organizations* and rejected the intuitively obvious one - financial performance - saying that financial health is "*the one criterion of success that matters most. However, the financial performance of a company at a particular point in time is not necessarily a true reflection of the adequacy or otherwise of its planning procedures*".

There is clearly a problem of validity which must be closely considered when the research variables are chosen, or as stated by Nixon *et al* (1987), "*This is the problem of validity. When we move from the abstract to the concrete we encounter problems. It is not obvious. Not everyone will agree with our selection of variables*". This is illustrated, for the Background Hypothesis, below.

Background Hypothesis: From Conceptual to Empirical



The problems with the variables for the Background Hypothesis were only one side of the challenge of choosing a research design for this hypothesis. The other side was, of course, the predicament of attempting to prove a *causal* link between planning and better supportability. From Chapter Three, which reviewed the literature on planning, it was seen that in all management areas there is a problem in proving that there is a causal link between planning and business effectiveness. Therefore, it was deemed that the Background Hypothesis was, within the limitations of the research project, too ambitious. The main reasons for this conclusion were:-

- The difficulties found by researchers working on similar investigations of planning (see Chapter Three).

- The only way to prove a causal link is to apply the experimental style of research. The difficulty would be in designing an experiment to test the Background and in finding a company or companies willing to cooperate on the experiment (which would require significant resources).

- The limitations on time and resources available for the project.

Consequently, the research was narrowed-down and the Background Hypothesis, as such, was dropped. In its place, exploratory research objectives were adopted which were chosen so that they would form a platform, such that future further research could investigate the causal link between planning and better product supportability (i.e. investigate the Background Hypothesis itself). Support for this approach can be found on texts on research design: "*The design of exploratory research is characterized by a great amount of flexibility and ad hoc versatility ... No clear hypotheses can be developed about the problem*" (Green *et al*, 1988). The research objectives chosen to investigate the concepts were:-

1) To identify the range of different support factors which are evaluated by companies at the product design stage.

2) To collate the different support factors which can be evaluated, in order to derive a systematic evaluation of product support at the design stage. To base this on the model of product support derived from the review of the literature.

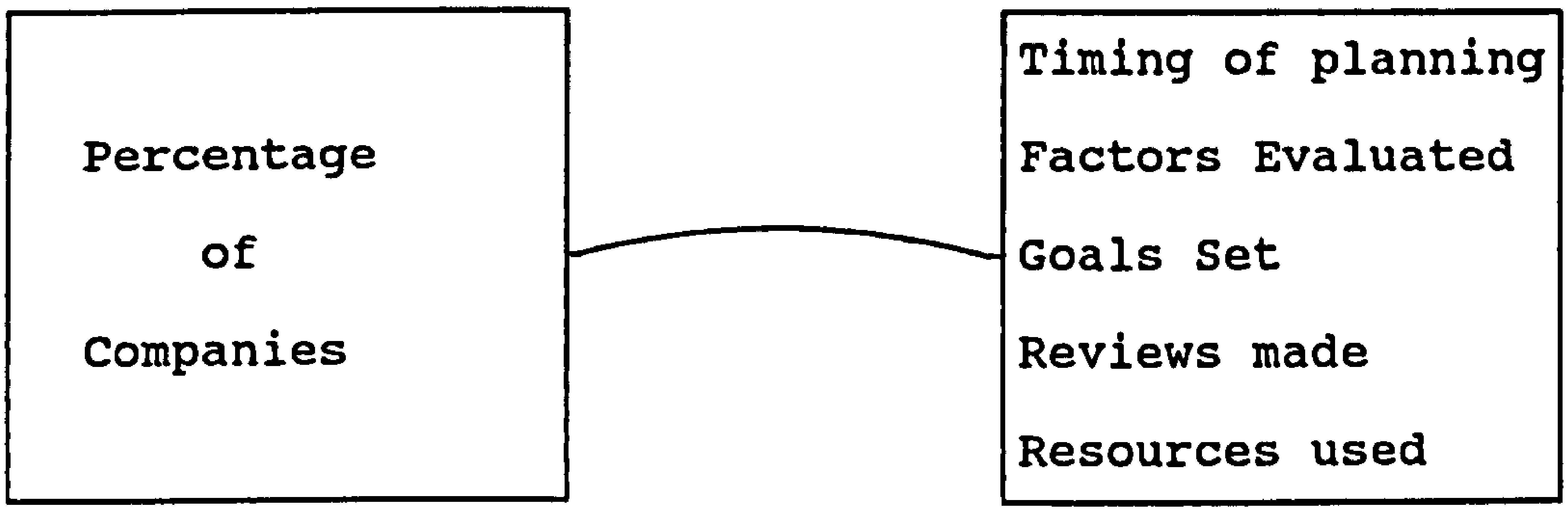
3) To then determine what approach would be necessary to investigate the causal link between planning and supportability (using similar methodology to that used in management research on other types of planning).

4.2.4b Hypothesis 1

Most high-technology companies do not systematically evaluate product support at the product design stage.

The variables for this hypothesis were easier to identify. The main variable for whether support is evaluated at the design stage is the timing of the planning, in relation to the product development cycle. However using only this one variable does not account for the quality of planning done. For instance, although two companies begin planning at the same time it does not mean that their planning is necessarily comparable in quality. Chapter Three showed that the four main elements of planning are the early analysis of the situation, setting of goals (and documenting them), implementation and monitoring of progress. The second variable is the percentage of companies, from a suitable sample, that evaluate support during design.

Hypothesis 1: Empirical



The related research objectives therefore became:-

1) To determine the time at which product support planning starts, during new product development cycles, at high-technology companies.

2) To determine the level of planning undertaken by companies.

3) To compare the results against the hypothesis and draw conclusions.

4.2.4c Hypothesis 2

Product reliability and ease-of-repair are the factors of product support which are most often quantitatively evaluated at the product design stage.

Suitable variables for the concepts can be found; in the literature the factors used to assess *reliability* are AFR and MTBF[1]. Similarly, in the literature, the factor used to measure ease-of-repair is MTTR[2]. The

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[1] AFR - Annual failure rate; MTBF - Mean-time-between-failures.

[2] MTTR - Mean-time-to-repair.

literature on planning stresses the importance of quantitative goal setting and therefore the variables chosen for *evaluation of reliability* and *ease-of-repair* was whether goals are set at the product design stage for MTBF/AFR and MTTR. The degree of the use of these particular goals can be contrasted to the use of goals for other support factors; this is shown below.

Hypothesis 2: Empirical

The research objectives arising from Hypothesis 2 were:-

1) To identify all of the support factors which are quantitatively planned by companies at the design stage.

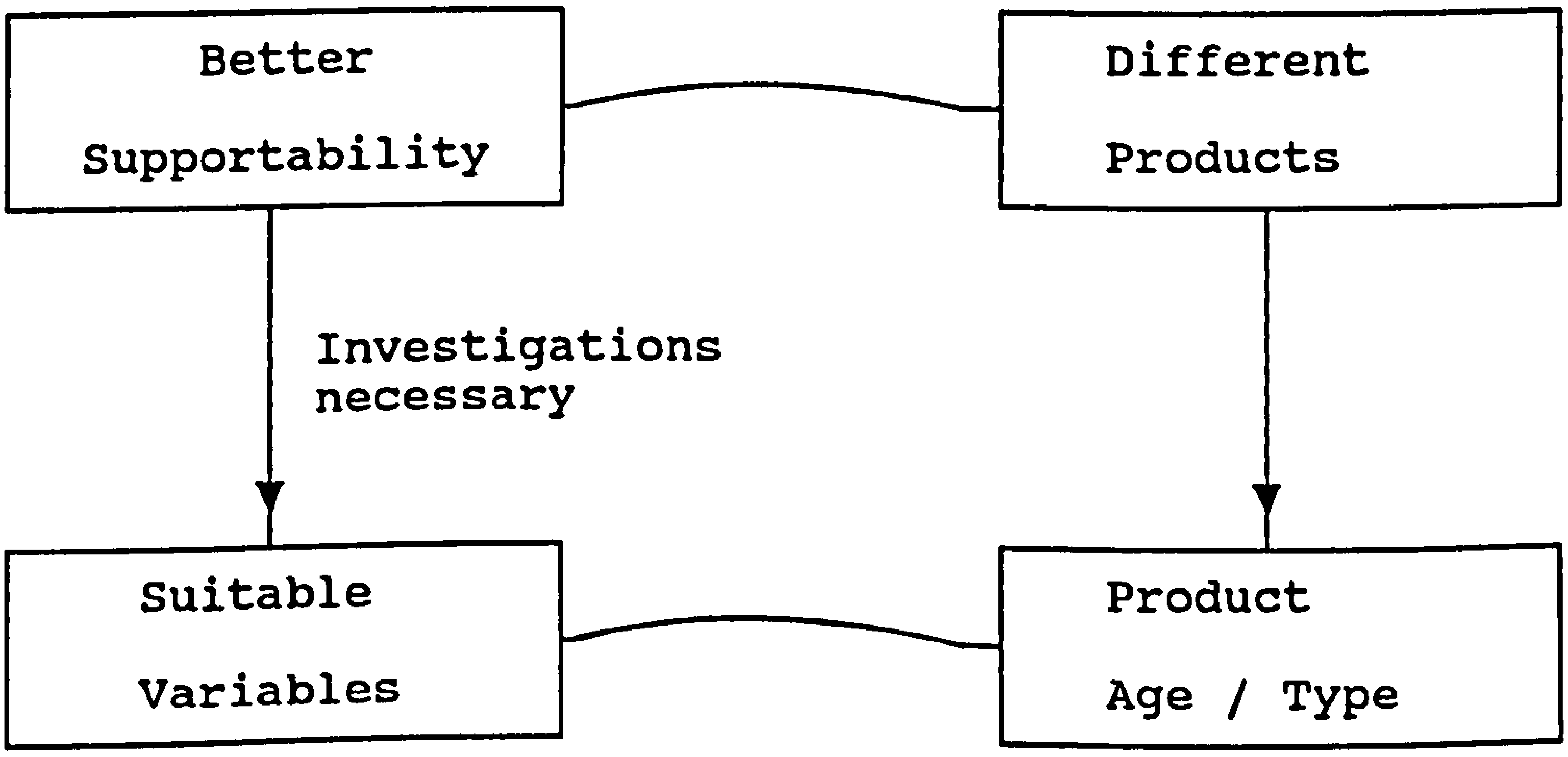
2) To determine the degree of use of the different goals across companies.

3) To compare the results against the hypothesis.

4.2.4d Hypothesis 3

Customers perceive differences in the supportability of different products. Newer products are not necessarily better than similar older products on all of the attributes of good support.

Hypothesis 3: From Conceptual to Empirical

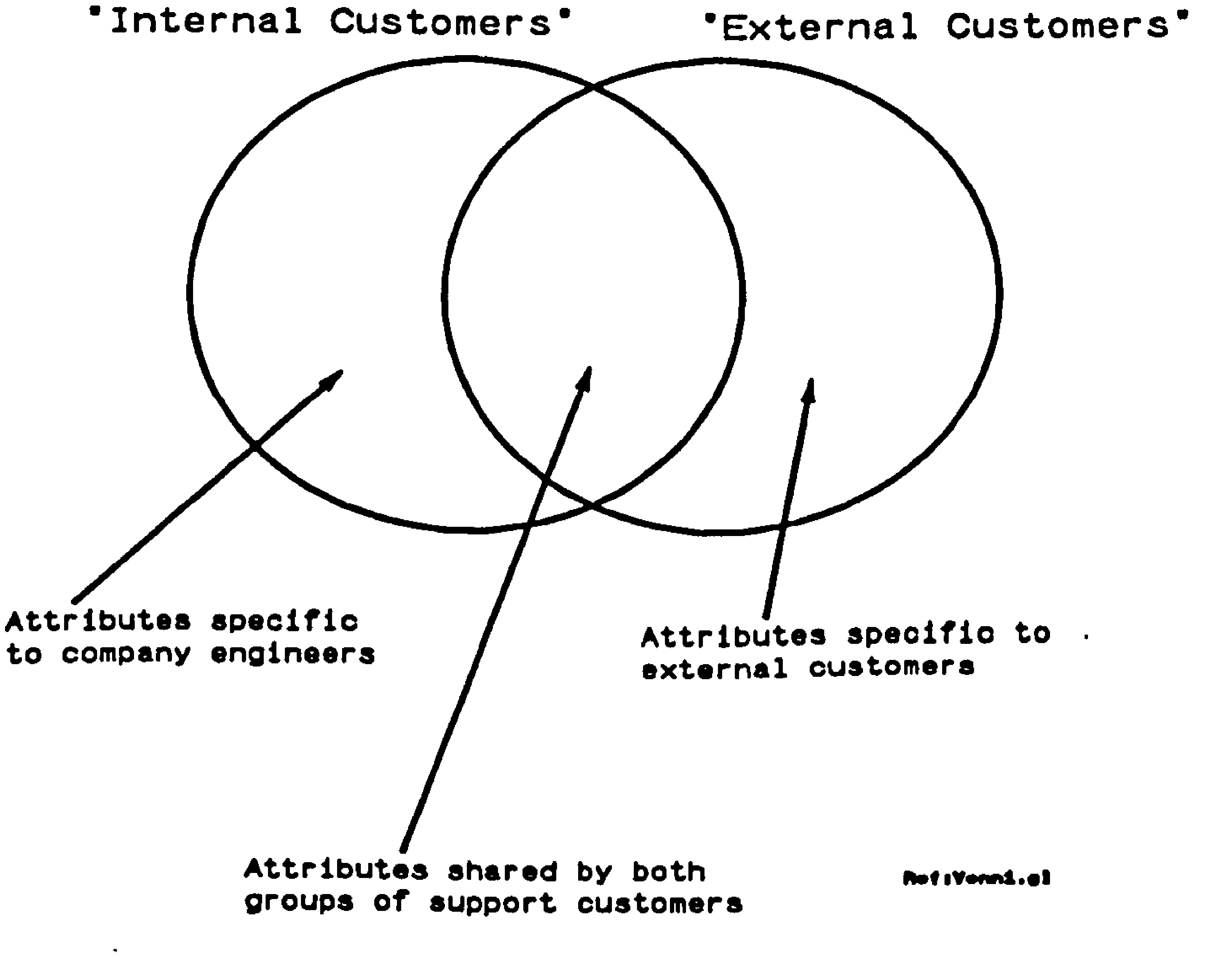


For this last hypothesis the choice of variables was difficult. Although the concept *different products* can be operationalized to product type and the date of the product's market introduction, choosing a variable for *supportability* is not trivial. This is illustrated in the diagram above.

The investigation of the variables which can represent *better supportability* became a major part of the total research project. Since no research had been done into this area before, the process chosen was to determine the customer attributes of good supportability. For the medical equipment market, which was chosen for the research, there are different types of "customer" involved with product support - both company-internal (e.g. company service engineers) and external users [see the discussion on the sample and Chapter Five on the medical market]. This led to three sub-hypotheses:-

> H_{sub}*3a: Newer products are not necessarily better than similar older products on all of the attributes of good support.*
>
> H_{sub}*3b: The common attributes differ between the internal and external customers. Internal customers perceive supportability as related to products themselves whereas external customers perceive supportability as also related to the manufacturer's field organization.* (see Figure 4.3).
>
> H_{sub}*3c: The factors reliability and MTTR (which are frequently evaluated at the design stage) are perceived as the most important ones by all customers.*

Figure 4.3: Expected Overlap of the Attributes of Good Support from the Two Categories of Customer.



The research objectives for Hypothesis 3 and its sub-hypotheses were:-

1) To identify the customer attributes of good product support.

2) To contrast the attributes for the two categories of customer.

3) To rate different products against each of the customer attributes of support.

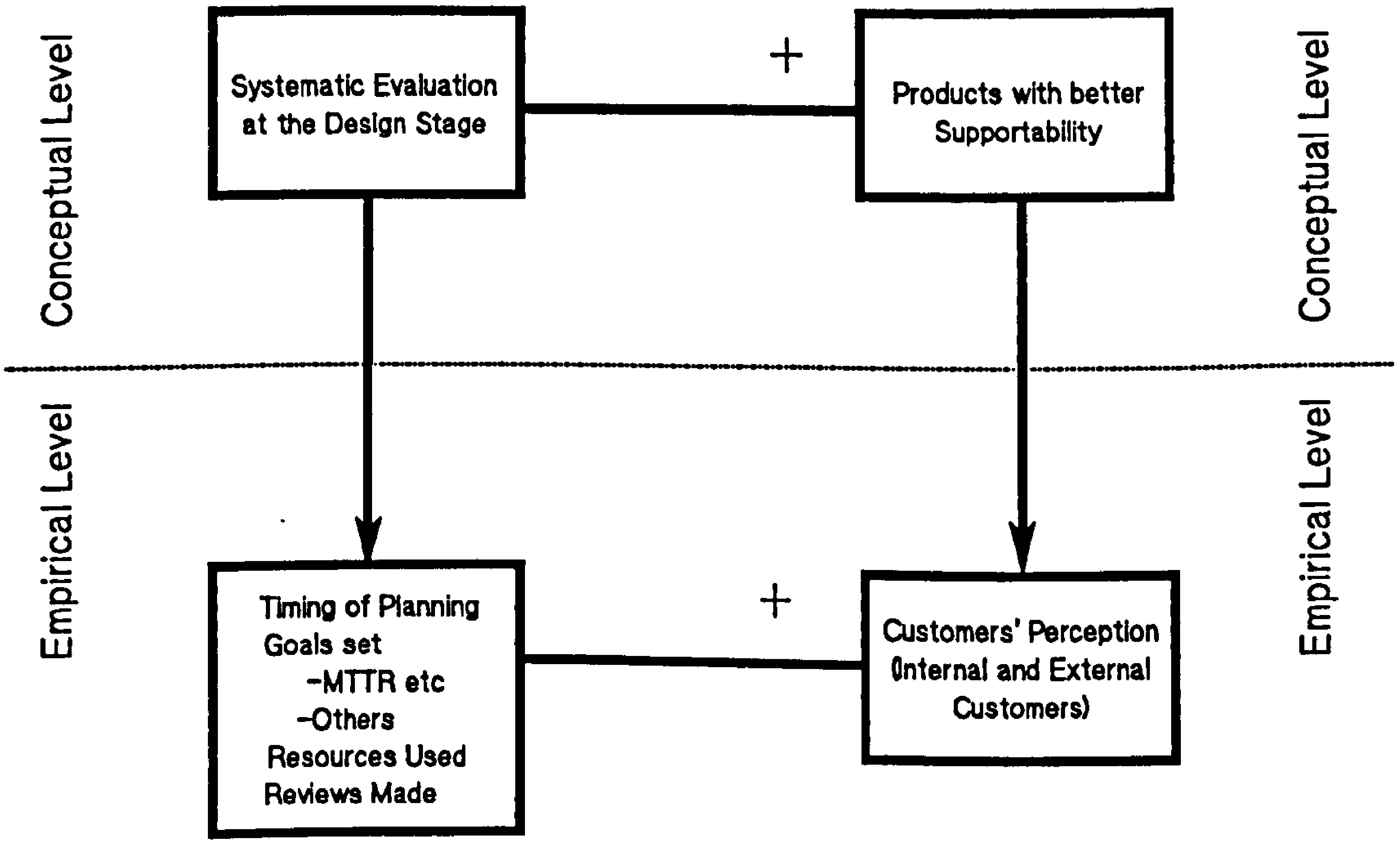
4) To compare the ratings of old and new products, to see if newer products are better in all aspects of support.

5) To compare the results against Hypothesis 3 and draw conclusions.

4.2.5 The Research Hypotheses and Objectives

All of the hypotheses and objectives which have been discussed are closely related. It is these inter-relationships which are particularly important when considering the context of the current research to the proposed future research into product support. Therefore they will be discussed in detail and it will be attempted to show graphically the inter-relationships.

Figure 4.4: The Background (Structural) Hypothesis.



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The Background Hypothesis, which prompted the research into product support, is shown in Figure 4.4. Both the conceptual and empirical levels are shown. As explained earlier, a set of research objectives investigating the relevant concepts were adopted in place of this hypothesis. However, the Background Hypothesis is a very interesting one from a practical management standpoint. If it could be proven that planning at the design stage led to products with better supportability, then this would have significant implications for high-technology companies. The objectives-driven research into the concepts is the first step towards researching the Background Hypothesis (i.e. the investigations probed the meaning of the concepts but did not attempt to check for a causal link). The other hypotheses link into the Background (Structural) Hypothesis; hence the use of the term *structural hypothesis.* The first linkage is shown in Figure 4.5.

On the left-hand side of Figure 4.5 Hypotheses 1 and 2 are shown. Hypothesis 1 - *Most high-technology companies do not systematically evaluate product support at the design stage* - is shown as a relationship (curved line) between companies and the concept of evaluation. The empirical level is indicated by the shaded area in Figure 4.5. Hypothesis 2 - *Product reliability and ease-of-repair are the factors of product support which are most often evaluated at the product design stage* - is shown in the bottom left-hand corner of Figure 4.5. Hypothesis 3 links into the right-hand side of Figure 4.5, as shown in Figure 4.6.

Hypothesis 3 - *Customers perceive differences in the supportability of different products. Newer products are not necessarily better than similar older products on all of the attributes of good support* - involves the concept of supportability. The empirical level (the shaded area of Figure 4.6) requires the investigation of customers' perceptions of the supportability of various products. The diagram indicates that internal and external customers need consideration. Combining all of the research objectives with the diagram of the inter-relationships between the hypotheses gives Figure 4.7. This shows how the investigation of Hypotheses 1,2 and 3 gives information on suitable variables for future into the Background Hypothesis. Figure 4.7 will be used in later chapters, when discussing the results compared to the hypotheses.

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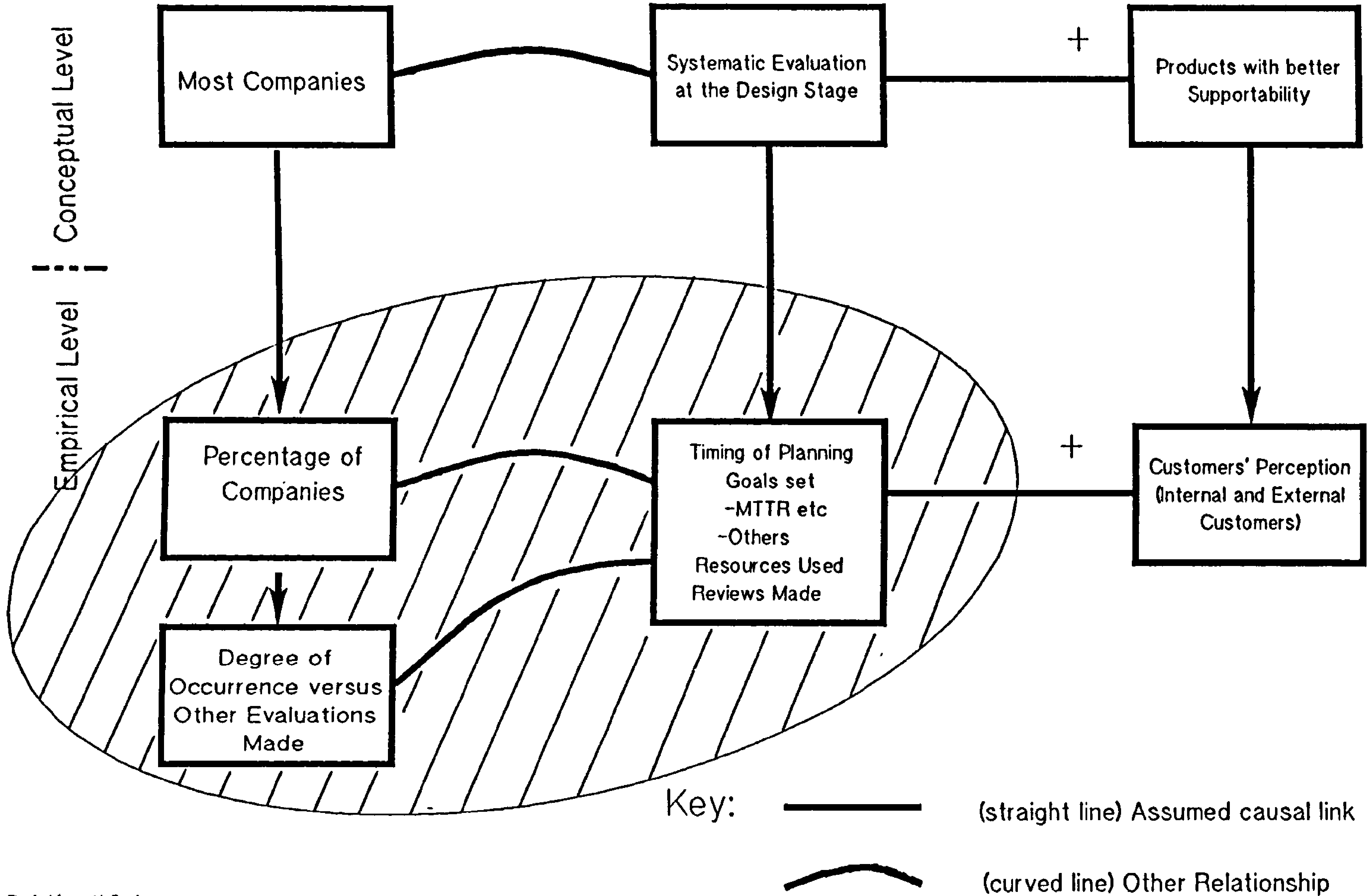

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Figure 4.5: The Relationships between the Background Hypothesis & Hypotheses 1 & 2

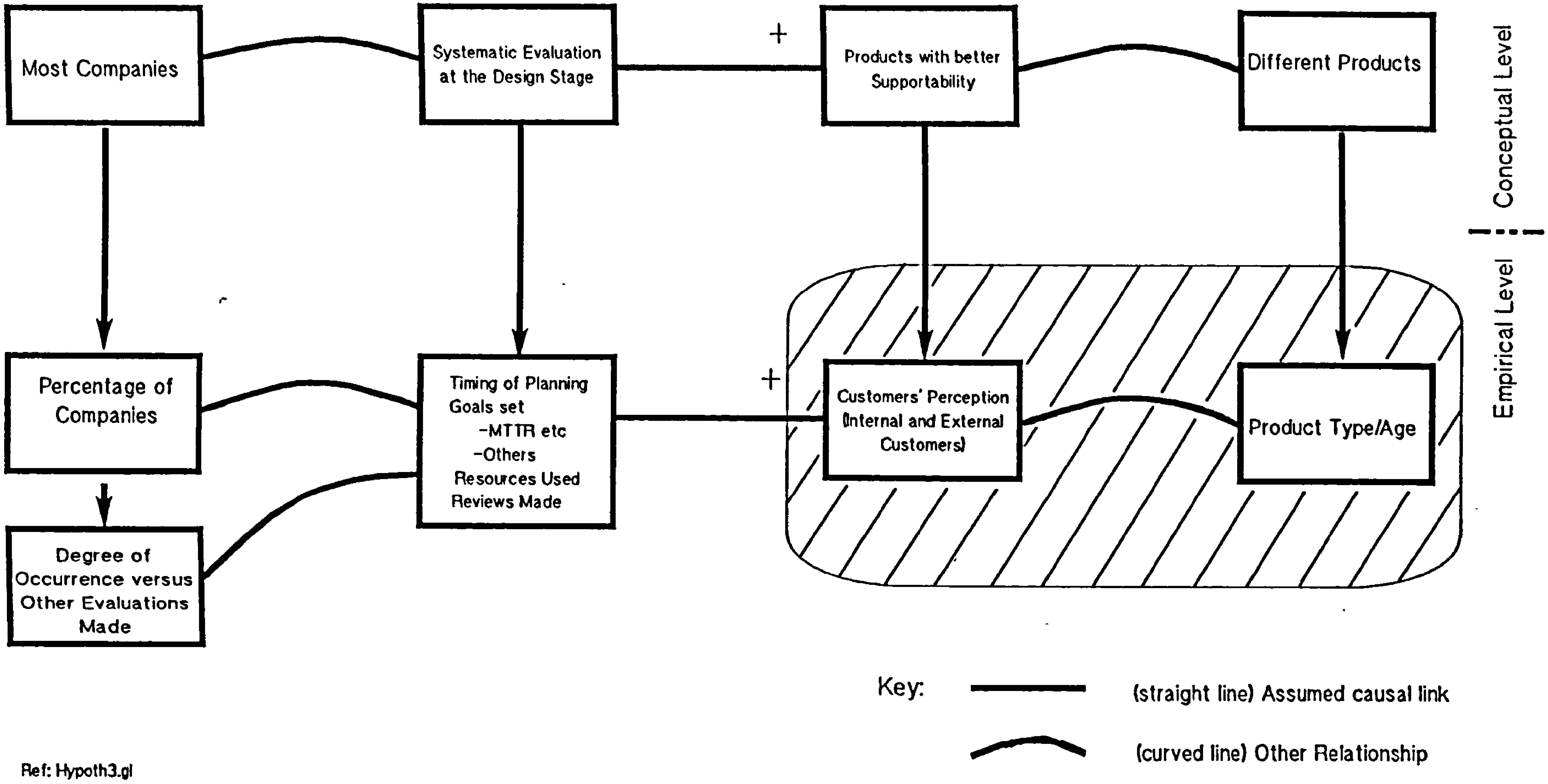
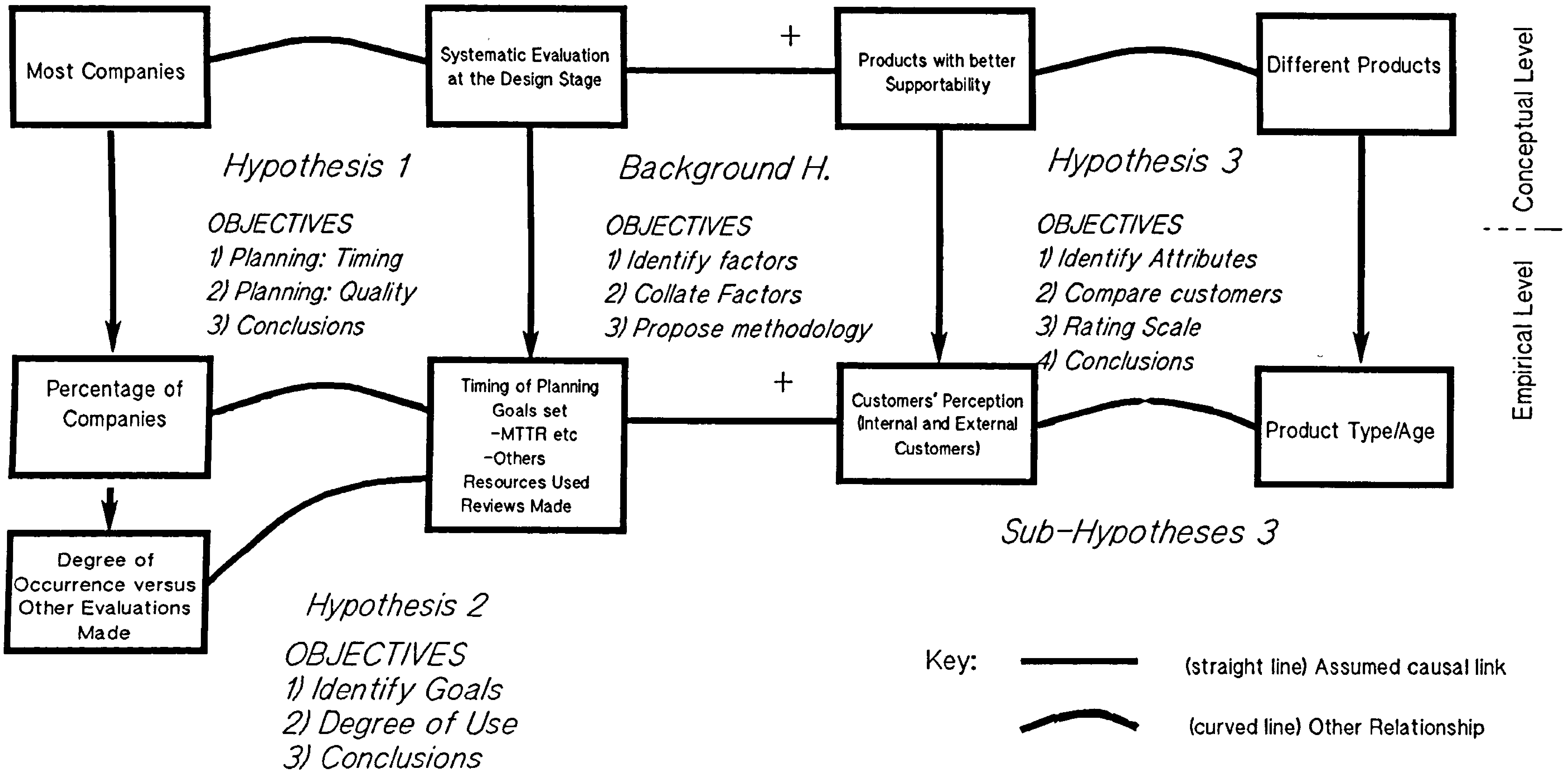


Figure 4.6: The Inter-relationships of Hypothesis 3 to the other Hypotheses



Ref: Hypotht.gl

Figure 4.7: The Inter-relationships between all of the Hypotheses and Objectives

4.3 FROM RESEARCH OBJECTIVES TO METHODS

Once the research objectives had been determined, the next stage was the choice of methodology. The initial choice to be made was the most suitable style of research (i.e. ethnographic, survey or experimental) for achieving the main research objectives which were:

- Identification of the timing of product support planning at companies.
- Identification of the objectives and goals used by companies in support planning.
- Identification of the key customer attributes of supportability and of how different products rate against these.

The initial decisions on the style of research are explained here whereas details of the individual methods used are covered in Chapter Six.

The ethnographic style would, using observation of how different companies evaluate support, bring much qualitative data on this process. Weighed against this though would be several factors. Firstly the confidential nature of the process under investigation and the possibility that many companies would be unwilling to admit a researcher to their meetings on product planning (especially considering the researcher's affiliation to a company, in his full-time employment). Secondly, the pure practical problems of trying to observe the product planning process at several different companies would be enormous.

The survey style offers several advantages; it can easily be applied anonymously and can cover a larger sample than the ethnographic approach. Weighed against this are the disadvantages, such as a possibly low reply rate, the question of whether the sample is representative and constructing data collection tools that are easily understood by the respondents.

The experimental style offers an advantage, since it is the only way in which a causal link (in this case between the planning of and the quality of support) can be established. The disadvantage would be the difficulty of designing an experiment to test the hypothesis and finding a company or companies willing to cooperate with the experiment. (The true experimental style would, for instance, require parallel control groups working on projects. This amount of extra investment would be accepted by almost no companies.) Since the Background Hypothesis was rejected as a research hypothesis, this meant that none of the research objectives were related to proving a causal link. Consequently the experimental style was not a must for any of the hypotheses and it was rejected.

The survey style of research was chosen. The initial problem was to choose a survey method by which detailed information on companies' support planning methods could be gathered. Since planning methods are usually treated as company confidential it was obvious that the survey would have to be confidential. An additional point to consider was that the researcher was in full-time employment with a company and this would obviously influence the openness of respondents in an interview. Therefore the survey method chosen was a postal questionnaire, where the respondents were assured that the survey was anonymous[1].

The second stage in the research was identification of the attributes of good product support. It was seen as essential to identify the customer's perception of good product support, as opposed to the view of company managers, for example. Therefore, a method was required for measuring the customer attributes of good support. Since support is a somewhat abstract concept, it was seen that a postal survey of customers would not be effective. Consequently, a number of interview techniques were considered including direct questioning. From these Kelly's Repertory Grid Test was chosen, due to its proven success in market research into ideal product attributes. Its particular advantage is that it stimulates respondents to identify ideal product attributes, which they are often unable to do, following direct questioning (especially on abstract concepts like support). The method was applied in the form of structured interviews with customers from the medical equipment market. The use of only one market in the study of the attributes of good product support was deliberate - different markets have very different characteristics and it is essential to focus on a sample where results can be duplicated and therefore verified.

In summary, the research consisted of two stages:-

1) A postal survey to investigate how companies plan product support.

2) Interviews with customers, to determine the attributes of good product support.

4.3.1 Rejected Methodologies

Several possible methodologies were rejected and it is important to understand why. Although this was indirectly explained above, this short section will re-emphasize the reasons for not choosing various methods.

Once the survey style had been chosen as the most suitable one for investigating support planning, three main methods were possible. These were interviewing, a telephone survey or a mail survey. Interviewing offered several advantages, including the fact that complex themes can be handled, the format is flexible and the response rate is high (Dane, 1990). However, the acceptance of an interviewer from another company (sometimes presumably from a direct competitor to the interviewee's company) would be

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[1] Refer to the appendix for notes on ethical considerations.

severely limited and so this method was rejected. A telephone survey also was rejected because of acceptance from the interviewees. A telephone survey could however, for a non-affiliated researcher, offer an efficient way of obtaining data on support planning than interviewing (although it must be considered that telephone surveys are less suitable for complex issues).

For the investigation of customer attributes of good product support the repertory grid method of interviewing was chosen. The methods rejected included direct questioning and motivational research. Direct questioning was dropped for two reasons. Firstly, support is abstract and so many customers cannot answer the sort of question "What aspects of product support are important to you?" easily and comprehensively. Secondly, in preliminary testing of direct questioning, it was found that interviews always asked for an explanation of support - in providing this significant interviewer bias could be introduced. Motivational research, where the respondent is required to complete unfinished statements, was also seen as susceptible to bias. Therefore, the method for obtaining attributes which would be least susceptible to bias was chosen - the repertory grid.

4.4 THE SAMPLES USED IN THE RESEARCH

For each stage of the research a suitable sample had to be chosen. How was this choice made? This section will answer this question at length, since sample choice obviously has a major influence on the extent to which findings can be generalized.

4.4.1 The Sample for the Postal Survey

The postal survey was used for investigating Hypotheses 1 and 2, both of which are connected with the extent to which *most high-technology companies* plan product support. The goal was to obtain access to managers from a sample of high-technology companies who were:-

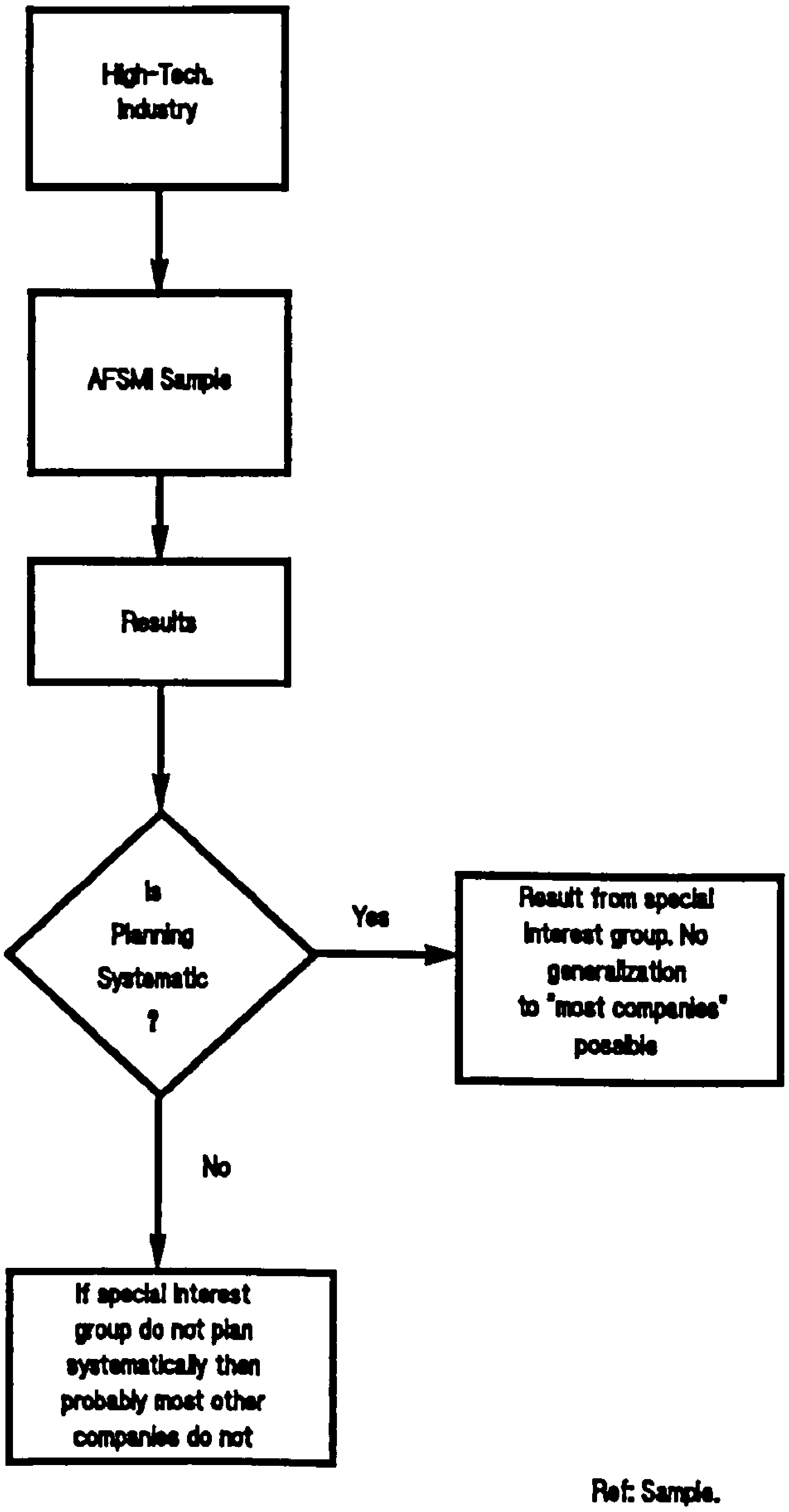
a) Closely involved with product support and therefore knowledgeable enough to answer relatively complicated questions on support.

b) Likely to be interested enough in such a survey so as to give a high response rate.

c) Representative of high-technology companies in general.

In addition, the exploratory nature of the research had to be considered. One of the research objectives derived from the Background Hypothesis was: *To identify the range of different support factors which are evaluated by companies at the product design stage.* In addition, a research objective connected to Hypothesis 2 was: *To determine all of the support factors which* *are quantitatively planned by companies at the design stage.* These two research objectives work somewhat in opposition to the goal of having a representative sample. It requires a sample of companies who make the most detailed (presumed "best") evaluation of support. A sample of typical companies may not allow all of the factors of support that are being evaluated to be identified. These opposing requirements led to a compromise in the choice of sample which will be explained.

Figure 4.8: The Affect of the Results on the Ability to Generalize from the Sample.



Ref: Sample.

One alternative considered was to send the postal questionnaire to a selection of companies, addressed to "The Service Manager". However two major problems were anticipated with this approach; firstly that the reply rate would not be very high and secondly that the quality of the answers would not be good. Both these anticipated problems stem from the fact that little motivation could be given to respondents to answer the questionnaire, other than promising them a copy of the results of the survey. Consequently the idea of mailing to "The Service Manager" at companies was rejected.

The approach chosen was to approach a professional association, of managers involved with product support - The Association for Services Management International [AFSM International], U.K. Branch. They were asked if they were interested in cooperating on a survey concerned with product support. This Association was very interested in the survey and in collaborating with the Cranfield School of Management. They therefore readily agreed to a questionnaire being sent to their members.

The AFSM International (U.K. Branch) has over 600 members, drawn mainly from the electronics and computing industries, who are professionally involved with product support. These members attend local meetings and regularly receive newsletters and a professional journal. Through their inherent interest in support and the fact that their association actively promotes the exchange of ideas it was felt that AFSM International members would be an ideal group to survey on design for support. Additionally some extra motivation could be offered to answer the questionnaire by stating that the results were to be published in the Association's journal. The proposed survey was discussed with the governing committee of the association. They thought that their members would be interested enough in the survey so as to give a good response rate. To impress on their members that the survey was important, AFSM International suggested that the covering letter should carry both the Association's and Cranfield School of Management's logos and be signed by the AFSM International's U.K. president, in addition to the researcher (a copy of the covering letter is included in the Appendix).

Normally in survey work, it is very important to check that the sample is representative. With this exploratory questionnaire the approach was different because of the somewhat opposing goals and objectives and, it must be said, somewhat opportunistic. However, *"exploratory projects may not require a probability sample"* (Dane, 1990). A sample which was almost certainly not representative of high-technology industry as a whole was chosen - AFSM International members are a "special interest" group, which means that the sample is almost certainly biased (and not industries are represented). This leads to a problem with trying to generalize the results from AFSM International to *most high-technology companies*. Consider Hypothesis 1- *Most high-technology companies do not systematically evaluate product support at the product design stage.* Using AFSM International as the sample (and recognizing that only a limited reply rate would be achieved) how could the results be interpreted? The results would presumably show that either: a) most AFSM International companies do plan support systematically or b) most AFSM International companies do not plan support systematically [an additional possibility is that those AFSM International members who would reply would be a biased sample]. An attempt to generalize the results is limited to (a) because, if anything, it is likely that a "special interest" group like AFSM International companies do indeed plan support systematically. This is illustrated in Figure 4.8, which will be compared against the results of the survey (Chapter Seven), in a detailed discussion of sample bias.

4.4.2 The Samples for the Structured Interviews

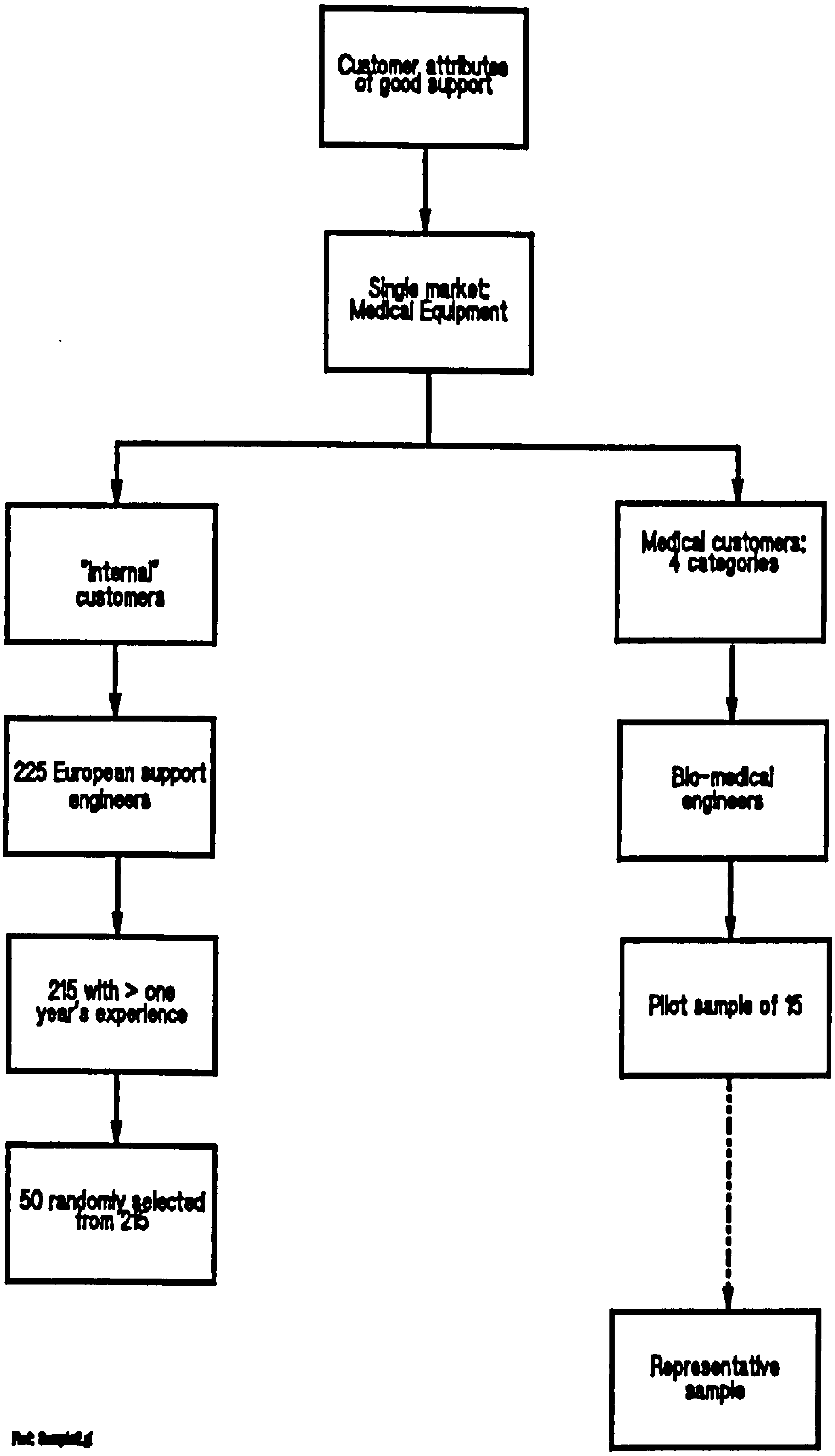
The second stage of the research used structured interviews to identify the customer attributes of good product support. The customers chosen were both company "internal" and "external" customers, all from one particular market. The process by which the samples for the structured interviews were chosen is illustrated by Figure 4.9 and this will be explained.

Different markets have very specific characteristics. Almost certainly, these different characteristics mean that product support is viewed differently between markets. Trying to determine the common attributes of good support by surveying a cross section of markets would be a wrong approach. Therefore, a single market - medical equipment - was chosen for the study of support attributes. This market was chosen due to the researcher's experience in this area and the pragmatic requirement to produce results relevant to the company supporting the research. The medical equipment market is described in detail in the next chapter. In the medical equipment market two types of "customer" perceive the quality of products, from a support standpoint. These are company customer support engineers (termed "internal" customers in Figure 4.9) who maintain customers' equipment, plus the bio-engineers working in hospitals ("external" customers).

The internal customers surveyed were 50 Hewlett-Packard support engineers, from the total of 225 working in Europe. The fifty interviewed were chosen in two stages. Firstly only those engineers with one or more years' experience were selected. This was because those with less than one year's experience would not have enough knowledge of the products to be discussed in the interviews. This left a total of 215 engineers and from these fifty were selected by choosing them randomly from company employee lists. (The engineers were numbered from 1 to 215 and then subjects were chosen by using a table of random numbers.)

The external customers for medical equipment fall into four main groups; doctors, nurses, administrators and bio-medical engineers. Each of these groups are discussed in detail in Chapter Five and the conclusion was reached that the biomedical engineers are the group most involved with equipment support and consequently the most suitable group to interview during exploratory research into support attributes. (The investigation of the attributes from the other categories of customer could be a suitable topic for further research.)

Figure 4.9: The Decision Process for the Choice of Samples for the Structured Interviews.



A representative survey of biomedical engineers would involve surveying a large sample across many countries and is beyond the scope of this research project. This research project investigated the differences between the attributes of good support, from the viewpoint of "internal" and "external" customers and, as such, took a limited sample of biomedical engineers. Fifteen biomedical engineers were chosen in different sized hospitals in southern Germany (8) and the London area (7) - i.e. A sample was chosen for the purposes of the investigation[1] (the only criteria used in the selection were that the biomedical engineering departments had contact with Hewlett-Packard [were accessible to the researcher] and that representative selection of hospital sizes were covered). However, the interviews with the fifteen engineers serves as a first step, in that it identified a suitable interviewing procedure which could be applied to a representative sample. This is shown by the dotted line in Figure 4.9 (this market research will be conducted by Hewlett-Packard in the future).

4.5 SUMMARY

The idea behind the research into product support was that systematic planning at the design stage of new products would improve the quality of support. This led to a background hypothesis which, although of great interest from a practical business point-of-view, was too wide in its scope to be investigated in this research project. Three hypotheses were chosen which, it was shown, were researchable and which would deliver information on the concept of support - which is not yet well understood as there has been limited research into this area.

The concepts involved in the three research hypotheses and suitable variables for them were identified, in order to make the hypotheses researchable. The style of research - the survey style - was identified for the hypotheses and suitable samples were chosen. The choice of the survey style was the first step towards finding suitable research methods. The methods chosen were:-

- A postal survey of managers from a professional association, to investigate their planning of support.
- Structured interviews with customers, to identify the attributes of good supportability.

These two methods required detailed preparation and pilot studies before they could be used; this is the subject of Chapter Six. Firstly, however, Chapter Five gives information on the medical equipment market, chosen as the sample market for the investigation of the concept of supportability and explains the choice of the category of customer chosen for the survey sample.

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[1] The term *purposive sampling* is used by Dixon *et al* (1987); it is dependent on the researcher selecting a representative group to be studied. Since it is impossible to know whether the sample is typical, "*only tentatively suggested generalizations* may be made" (*ibid*, 1987).

CHAPTER FIVE

The Medical Equipment Market

5.0 INTRODUCTION

The market chosen for the research into product support was medical equipment. The worldwide market for medical equipment and supplies is huge; the US market alone is estimated to be $25.7 billion (Medistat, 1990[a]). There are some important characteristics of the medical market, including the importance of product support, which will be discussed in this chapter since they are relevant to the research.

Specifically, this chapter will explain the investments made in health care in developed countries, the proportion spent on equipment, the types of equipment and specific characteristics of the medical market. The role of the Hewlett-Packard Company in the medical electronics industry will also be discussed, as some of the research into product support was conducted with field personnel and customers of this company.

5.1 HEALTH CARE

Health care is now one of the major areas of expenditure in the developed world. The percentage of gross national product (GNP) spent on health care is, in many countries, high and now being scrutinized: in the UK and Spain it is just under 6% but higher in Germany (8%), France (9%) and the US (11%) [Sullivan, 1988]. In the US, the current level of 11% is double that of the 1960s and the government is now taking measures to strictly control these costs. The portion of these costs which result from the purchase of technological equipment is probably about 6%. Technology "*is a component of health care that saves lives and inflicts less trauma, and sometimes costs less, than alternative forms of diagnosis and treatment. But there is a dilemma: the high capital investment needed ...* [Consequently] *More and more, medical researchers are evaluating various high-technology procedures' costs and benefits*" (Fitzgerald, 1989). This critical investigation of the benefits of technology in health care will almost certainly have a strong influence on the quantity and type of medical equipment used in the future.

5.2 TYPES OF MEDICAL EQUIPMENT

There are four main types of technological equipment in use in hospitals today. These are:-

- Diagnostic devices.
- Monitoring devices for checking patient status and warning of lapses.
- Therapeutic devices.
- Hospital computer systems, for storing patient clinical and administrative data.

There have been major advances in the last twenty years in the range and quality of medical equipment available. This is true, to varying degrees, for each of the above categories. Driven by the desire to offer the best care possible, hospitals have adopted equipment replacement cycles which reflect the technological advances for that category of equipment. For instance, in the US, diagnostic devices such as ultrasound imaging systems may be replaced (or upgraded) after only three years use, whereas monitoring equipment is typically used for five to six years and possibly up to ten years (Borenstein-Levy, 1990).

5.2.1 Diagnostic Equipment

There is a very wide range of diagnostic equipment in use in hospitals today. This ranges from the cheap and simple stethoscope up to the multi-million dollar magnetic resonance imaging (MRI) systems. Advanced diagnostic equipment falls into two main categories; imaging systems and devices which measure physiological signals. Some of the most important devices will be described.

One of the most common pieces of diagnostic equipment is the electrocardiograph, which records the electrical signals from the heart - the electrocardiogram (ECG or EKG[1]). Interpretation of the morphology of the ECG, which is typically recorded for ten seconds using electrodes attached to the patient's skin, allows certain types of heart disease to be diagnosed. During the recording the patient may be allowed to rest or may be required to physically exert himself, which can identify heart problems not seen whilst resting (so-called "stress testing"). The electrocardiograph has been used as a diagnostic tool for many years (the first ECG recording was made in 1887). Consequently the technology is fairly mature; this leading to few innovations and a working lifetime of these machines of typically fifteen to twenty years (Borenstein-Levy, 1990). The availability of microprocessor

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[1] From Elektrokardiogram (German). EKG is the abbreviation commonly used in the USA.

technology has, however, influenced the design of cardiographs. Many now have built-in interpretation capabilities, which saves some of the time cardiologists normally require to interpret ECGs. Cardiographs, depending upon their complexity, cost typically in the region of $400 to $8000. In addition to cardiographs, which are normally only used to make short recordings of ECG function, compact recording equipment may be carried by a patient to analyse his ECG over twenty-four hours. These devices - called Holter monitors after Norman Holter, the inventor of the first portable ECG amplifiers - enable a cardiologist to spot if heart problems occur at particular times during the patient's day.

Ultrasound scanners use transducers which transmit sound waves and analyse the reflected signals in order to produce an image of the tissues scanned by the transducer. They were first introduced in the early 1970s but since that time have developed rapidly into a key piece of diagnostic equipment. Modern machines use ultrasound of various frequencies, to penetrate deep into tissue and can produce high resolution images of organs or blood flow. The main clinical areas where ultrasound is routinely used are cardiology (for diagnosis of heart disease), radiology (mainly abdominal imaging), obstetrics and ophthalmology. The quality of the images that can be produced by ultrasound are so high that, for instance, the sex of an unborn child can normally be identified, or a heart valve which does not close correctly can be seen. The worldwide market for ultrasound equipment is estimated to be growing rapidly (MIR, 1988).

X-ray devices have been used for diagnostic imaging purposes since the beginning of this century and are now in use in most hospitals. Typical modern X-ray devices contain a large amount of control electronics. The market for X-ray imaging systems is estimated to be $2 billion in the US (Medistat, 1990[a]). Simple X-ray machines produce a two-dimensional image on photographic film, whereas newer computerized tomography (CT) technology introduced in the 1970s allows a three-dimensional image to be constructed. There are estimated to be about 4000 CT scanners in use in the US today (Fitzgerald, 1989).

One of the early uses of the CT scanner was in the diagnosis of brain disease and head injuries. For this purpose, however, it has now been superseded by magnetic resonance imaging (MRI). MRI detects the magnetic spin on the electrons in hydrogen atoms; therefore, it images tissues containing water but "sees" right through bone. For this reason it is especially useful for producing images of the brain and the spinal cord. Its drawbacks are its cost (typically $2.5 million for the machine plus $2 million for suitable site installation) plus the thirty-minute examination time. Currently, it is estimated that 1300 MRI machines are installed in the US (Fitzgerald, 1989).

The use of radioisotopes in diagnostic medicine began in the 1960s and they are now used extensively for the diagnosis of various types of cancer. Cancerous cells have the property that they have a higher uptake of radioactive substances that normal cells. For example, in the diagnosis of thyroid cancer the patient is administered a safe amount of iodine-131 isotope. The thyroid of the patient is then scanned, using electronic photomultiplier (PM) tubes, to determine the uptake of iodine-131 and whether aberrant tissue is present (Aird, 1975). Diagnostic scanning equipment has progressed rapidly in the last thirty years, especially with the availability of fast, cheap computers for the construction of images from the data received from the photomultiplier tubes.

One research area which shows promise for diagnostic purposes is biomagnetism, where the tiny magnetic fields emulating from the heart or brain are measured. Biomagnetism shows particular potential for diagnosing heart disease and brain disorders. For the diagnosis of brain disorders, biomagnetism has a key advantage over the traditional technique of measuring the electroencephalogram (EEG - the electrical signals from the brain). This is the spatial accuracy with which brain activity can be detected with biomagnetism. The first biomagnetic diagnostic devices are now entering the market (Walker, 1990).

5.2.2 Monitoring Equipment

Monitoring equipment measures various patient signals, such as heart beats (via the ECG) or blood pressure, and gives warnings if the patient status, as indicated by these signals, changes. These so-called *patient monitoring* devices are used in two main areas of the hospital; the operating room (O.R.) and intensive care units (I.C.U.s)[1]. Additionally, less sophisticated monitoring equipment may be found in many other hospital departments. The worldwide market for this type of monitoring equipment is expected to reach $1.2 billion by 1996 (Medistat, 1991[b]). Another type of monitoring device which warrants discussion is the *foetal monitor*, used to check at various stages during pregnancy that the foetus is healthy.

The monitoring equipment in the O.R. is operated by the anaesthetist. He is responsible for administering anaesthesia, ensuring that the patient's status (neurological, respiratory, cardiovascular status etc.) is maintained throughout the operation and then bringing the patient round from the anaesthetic. Modern monitoring equipment takes a number of signals from the patient (e.g. ECG, temperature and oxygen saturation value) or the gases he is breathing (e.g. CO_2 value, O_2 value) and displays them as waveforms and values on a display. The monitor not only displays the patient information on a screen but also includes alarm functions - for instance an alarm is sounded if the heart rate exceeds a pre-selected value. Each of the gas or patient signals monitored - termed the monitored *parameters* - has its own advantages for warning the anaesthetist of problems. Complex equipment includes more parameters and, when correctly used, gives more assurance that the patient's condition is stable. Recommendations on the parameters which should be monitored during anaesthesia now exist in

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[1] Also called Intensive Therapy Units (ITUs) in some countries.

many countries, such as those described in Whitcher, *et al* (1988) for the US.

Similar monitoring equipment, with displays and alarm functions, are used in the I.C.U. However, different parameters may be monitored depending on the type or age of the patient. For example, parameters commonly used for the monitoring of neonates (babies) include transcutaneous gases (i.e. gases emitted through the skin), which cannot be measured on adults due to their thicker skin. Typically each patient in an I.C.U. is monitored by one device connected to him - the so-called *bedside monitor*. Each of the bedside monitors (typically eight on an I.C.U.) is normally connected to a *central station* - a unit which displays the signals from all of the patients. The central station may also perform more complex functions, such as *arrhythmia monitoring*; this is detailed analysis of the ECG waveform to detect abnormal heart beats. Arrhythmia monitoring is very common in Coronary Care Units (C.C.U.s), which are intensive care units for patients with heart disease.

Although patient monitoring helps to ensure patient safety, by warning of changes in condition, it is not without some drawbacks. One of these is that some of the measurements are invasive (e.g. arterial pressure is measured via a needle inserted in an artery). Invasive measurements carry a risk of infection and so the trend is, where possible, to use non-invasive monitoring such as non-invasive blood pressure devices and oximeters (for measuring the amount of oxygen in the blood). Consequently these non-invasive devices now account for 25% of monitoring sales (Medistat, 1990[b]).

Foetal monitors[1] are based on the simple phenomenon that maternal contractions stress the foetus and produce foetal heart rate reactions. These may be either accelerations or decelerations and are indicative of the health of the foetus. The maternal contractions are measured by a pressure transducer applied to the abdomen and the foetal heart rate is detected by an ultrasound transducer, also positioned on the mother's abdomen. The two signals are simultaneously recorded and the correlation between them can be interpreted by experienced doctors. Foetal monitors are used several times during pregnancy to verify foetal status and are also used in the last hours before birth to warn of complications. Modern foetal monitors contain complex software for the accurate determination of the foetal heart rate; this is necessary because this value must be calculated even in the presence of significant signal noise (due to maternal movement, the maternal heart beat etc).

5.2.3 Therapeutic Equipment

The main types of high-technology therapeutic equipment are radiotherapy machines, lasers, pacemakers, internal and external defibrillators, lithotripters, ventilators, anaesthesia machines and infusion pumps.

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[1] Also known as cardiotocographs (CTGs).

Radiation has been used for medical therapeutic purposes since 1910. In its simplest form, radiotherapy consists of implanting needles containing isotopes into cancerous growths. These needles are obviously invasive and have limited use compared to machines for external therapy (Aird, 1975). Machines for external therapy either contain strong radioactive sources or linear accelerators producing high-energy X-rays. Both types have progressed significantly in the last twenty-years and use electronics and computers for the control of the therapy. (Ensuring that the required dose of radiation reaches the organ under treatment, whilst minimizing the dose to the surrounding healthy tissue, is a complex process.) Modern radiotherapy machines may cost up to $1.5 million (Fitzgerald, 1989).

Lasers are now commonly used for surgical purposes. They are used for precision incisions, for instance during eye surgery, or now can also be used for welding body tissues together. This latter use has potentially wide applications as it avoids the need to use surgical staples. Surgical lasers typically cost between $40,000 and $70,000 (Fitzgerald, 1989).

Pacemakers and internal defibrillators are similar implantable electronic devices for correcting heart disorders. The pacemaker, which is battery powered, is used to deliver a small electrical signal to heart tissue which is not correctly triggering heart beats. This ensures that the heart beats at the necessary speed. Internal defibrillators are used for patients with different types of heart problems than those requiring pacemakers. The internal defibrillator delivers a strong shock to the heart, if it beats too quickly or if it starts fibrillating (beating chaotically in a manner that pumps no blood and which is therefore fatal). One big difference between the two implantable devices used for heart patients is their cost; pacemakers cost $2,000 - $7500 whereas internal defibrillators cost around $18,000 (Fitzgerald, 1989). External defibrillators are used to treat unexpected fibrillation by applying a large shock directly across the chest of a patient. These devices, which are usually combined with monitoring equipment are strategically placed around hospital wards to deal with emergencies. They are also carried in ambulances in many countries.

Lithotripters are used to treat kidney stones, by accurately directing electromechanical shock waves at them, which cause the stones to disintegrate. The advantage of lithotripters is that they avoid the need for painful surgery and this led to their quick adoption following their introduction in 1984. (Within one year 150 lithotripters, each costing $2 million, were in use in the US.) Now, however, their use is not universally accepted as questions have arisen on the side-effects and effectiveness of lithotripters (Fitzgerald, 1989).

Ventilators and anaesthetic machines are two types of equipment which are mainly mechanical in their design. The ventilator is used to help patients with severe breathing difficulties and modern machines consist of mechanical systems with extensive electronic control circuits. Similarly modern anaesthetic machines, for gas administration, include extensive technology in their designs, mainly for monitoring that the levels of gases are safe. Both ventilators and anaesthetic machines are starting to be interfaced to patient monitors, so that key information from these devices can be displayed on the monitor's screen.

One of the most common technological devices in hospital use is the infusion pump. These are used to continuously administer medications to patients. The devices are fairly simple, consisting of precision pumps with control electronics but, obviously, they must be manufactured to a very high quality and include circuits which warn of malfunction. The control circuits allow hospital staff to easily set the fixed amount of drug to be given per hour. The latest development for infusion devices is the US Government's approval of a "closed-loop" control device, for the control of blood pressure (Walker, 1990). This device consists of a pressure monitoring system combined with an infusion pump which automatically administers (i.e. closed-loop control) nitroprusside to patients with high blood pressure. A dose of nitroprusside reduces blood pressure by an amount which is dependent on each patient i.e. the drop in blood pressure is subjective and it is this value which is used to control subsequent doses of the drug. The combination of monitoring and therapeutic devices will, most probably, become common in the future.

5.2.4 Computer Equipment in Hospitals

Computer equipment has been increasingly used in hospitals over the last twenty years. It is utilized for two main purposes; the management of administrative data, such as patient admissions (and in certain countries patient billing) plus the storage of patient medical data. The storage of medical data from certain procedures, such as the delivery of babies, can have significant legal implications. Some countries (US, Australia) require these records to be kept for up to twenty-five years. One area of clinical record keeping which will change significantly over the next few years is the storage of X-ray films. In the past, film storage has taken up much space but the development of computerized radiography (where images are registered and stored by computer) will bring cost savings (ECRI, 1989).

The computer systems on offer to hospitals are rapidly improving in their performance. This means that university institutions may consider replacing software and systems on a rapid cycle (Borenstein-Levy, 1990). "*The 1990s will see rapid clinical fruition of many of the research developments of the last decade, and the computerized workstation and microprocessor will be taken for granted as a routine part of the medical care delivery team*" (Fitzgerald, 1989). It is in hospitals' administration departments that computers are making the biggest in-roads. They are not only making these departments more productive but are also producing information which allows hospitals to calculate exactly the costs of treating individual patients (Froitzheim, 1990).

The two types of computer system - clinical and administrative - need to be interfaced in order to exchange data. The need for the future will be for powerful computer systems which can link all hospital departments, both clinical and administrative, so that paperwork can be reduced. This should result in better patient care and more efficient hospitals (ECRI, 1989).

5.3 MARKET CHARACTERISTICS

The medical equipment market is a significant one with some important characteristics. These are:-

- A substantial size worldwide.
- Wide variations in the type and size of hospitals where equipment is used.
- Strong regulatory controls exercised in most countries by government agencies.
- A range of different types of customers, within the hospital.
- Particular requirements on product designs, to ensure that they can be used effectively in the hospital environment.
- A purchasing process which is made complex by the various groups involved.
- A strong influence of cost control mechanisms.
- A particular importance of product support.

5.3.1 The Market Size

As already mentioned, the size of the market for medical equipment is significant. In the researcher's experience the figures given for market size by market research companies are often inaccurate. However, a number of commercial market research reports were reviewed, in order to collate information on the size of the markets for the categories of medical equipment introduced in Section 5.2.

In Section 5.2 four categories of hospital equipment were introduced and the main types of devices within these categories described. These categories and devices are shown in Table 5.1, together the average price for devices and estimates of the corresponding market sizes. It can be seen that the approximate size for the worldwide medical equipment market in 1990 was $16,500M. The largest markets at the present time are diagnostic and therapeutic devices. Monitoring is a market of about $1,300M whereas the computer market is still small but growing rapidly. The largest geographical market for medical equipment is the US, which accounts for about 50% of sales of all categories of equipment. Europe accounts for about 30% and the remaining 20% are sold in the rest of the world.

Table 5.1: The Worldwide Medical Equipment Market - Estimated Size per Category of Equipment.

Type of Equipment	Unit Price	Market Size
1) Diagnostic		
ECG Machines	2K$	900M$
X-ray Devices	750K$	4,000M$
CT Scanners	1000K$	
MRI	2.5M$	
Ultrasound Scanners	50K$	3,400M$
Radioisotope Scanning		
Biomagnetic Devices		
TOTAL		10,000M$
2) Monitoring		
Patient Monitors	10K$	910M$
Central Stations	40K$	325M$
Foetal Monitors	4K$	65M$
TOTAL		1,300M$
3) Therapeutic		
Radiation Therapy Machines		
Surgical Lasers	55K$	
Pacemakers	4K$	
Internal Defibrillators	18K$	
Defibrillators (external)		
Lithotriptors	2M$	
Ventilators		
Anaesthetic Machines		
Infusion Pumps		
TOTAL		5,000M$
4) Computers		
For Administrative Data		
For Clinical Data		
TOTAL		200M$
TOTAL MARKET (APPROX)		16,500M$

Note. The approximate market figures and equipment prices were compiled from the following publications: Wieger (1990), Brown (1987), MIR (1988), BBI (1985), Fitzgerald (1989), Simpkins (1989), Patient (1989), ECRI (1989) and Medistat (1990[a],[b], 1991[a],[b] and [c]).

5.3.2 Types and Sizes of Hospitals

Most high-technology medical equipment is used in hospitals and not in primary healthcare (care provided by general practitioners, district nurses etc). The types of hospitals where medical equipment is most often used are those which perform diagnosis, surgery and intensive care (it is in these types of care that technology has made the most in-roads). Psychiatric and geriatric hospitals, for instance, use comparatively little high-technology equipment.

The three main types of hospitals using medical equipment are general hospitals, specialized and teaching hospitals. General hospitals typically have departments for all types of care including obstetrics (labour and delivery), surgery, cardiology and respiratory care. Specialized hospitals offer only particular types of care and are increasingly common in the US, where concentrating on only particular types of patients allows hospitals - *Patient-Specific Technology Centers* - to be run more economically (ECRI, 1989). Teaching hospitals are normally some of the largest hospitals in a particular country and may have up to several thousand beds, offering some very specialized treatment. Teaching and other large hospitals are more likely to buy new types of equipment as they have the staff and training programmes to cope with such technologies - *"Large hospitals with training programs seem more likely to adopt new technology more quickly"* (Eisenberg *et al*, 1989).

Table 5.2 shows the number of hospitals for a selection of countries and the associated number of beds. The size of a hospital is usually referred to by the number of beds. This may vary from very small institutions with well under one-hundred beds to university teaching hospitals, which may have several thousand beds (as already mentioned). From Table 5.2 it can be seen that, in the developed world, the number of hospital beds per thousand population ranges typically between 5.3 and 14.6. For a developing country, such as Egypt chosen as an example, it is much lower at 1.9. It appears strange, at first glance, that the USA has a comparatively low number of beds per thousand population but, as discussed earlier, has a very high expenditure on healthcare. The explanation behind this is that much of the US healthcare system is geared to out-patient treatment, with patients returning home after treatment which in many other countries would traditionally only be available to in-patients.

The number of privately-run hospitals varies widely between the example countries, from only 2% in Sweden to 80% in Holland. These private hospitals may be run for profit or may be non-profit organizations. In either case the medical equipment purchases are closely scrutinized, as part of the cost-consciousness that is prevalent throughout hospital management. The major difference between private and state hospitals from the medical equipment market viewpoint is that private hospitals usually consider the amount of revenue a device will bring, in their pre-purchase considerations. In the US a number of very large *hospital chains* exist, who in some cases own over a hundred hospitals. These chains centralize their equipment purchasing and consequently are able to obtain large discounts on volume purchases.

The term *acute beds* is used to refer to the hospital beds that are occupied by patients undergoing short to medium term therapy for physical illness. It therefore excludes the hospital beds used for geriatric and psychiatric patients. The number of acute beds in the countries can be seen to vary from 47% in the UK to 81% in Holland. *Critical beds* is the term used for the hospital beds in intensive care areas - ICUs, CCUs etc. The number of acute and critical beds in a country is a key factor in determining the size of the medical equipment market, as it is these beds which have a large amount of associated equipment.

Table 5.2: Comparison of Basic Hospital Statistics for selected countries - which were chosen to illustrate differences between Europe, USA and the developing world (from Patient, 1989 with additional information from Simpkins, 1989).

Country	Number of Hospitals (% privately-run)		Number of Beds (% acute beds)		Beds per 1000 population
UK	2,686	8%	410,683	47%	7.3
Germany (West)	3,130	63%	707,110	61%	11.5
Sweden	273	2%	122,700		14.6
Holland	774	80%	92,200	73%	6.3
Italy	1,813	37%	470,570	81%	8.2
France	4,486	30%	722,378	52%	12.9
USA	6,986	65%	1,308,500		5.3
Egypt	268	0%	96,700		1.9

Table 5.3 shows the distribution of the size of hospitals, measured by the number of beds, for the UK and Germany. Note that the number of beds is often used as a criterion for comparing healthcare between different countries. This has a limitation though, as the number of beds is dependent on the type of hospitals listed in national statistics. Some national statistics will include nursing homes under "hospitals" whereas others may not. This can lead to apparently very big differences in healthcare between different countries. It is the probable explanation for the big discrepancy in the reported number of beds in the UK, between Simpkins (1989) and Patient (1989).

Table 5.3: Distribution of Sizes of Hospitals in the Germany (1986) and the UK (1985) [from Simpkins, 1989].

No. of Beds	No. of Hospitals Germany	(%)	No. of Hospitals United Kingdom	(%)
<50	571	19%	723	39%
50-249	1,612	52%	709	38%
250-499	614	20%	236	13%
500-999	203	7%	176	9%
1000-2000	18	1%	71	1%
TOTAL	3071	99%*	1862[1]	100%

Note: *Rounding error

[1] Note that the total number of hospitals given in Patient (1989) and Simpkins (1989) differ substantially for the UK (see text)

5.3.3 Regulatory Controls

Most countries have regulations which govern the approval and use of technology in the hospital. The correct functioning of diagnostic, monitoring and therapeutic equipment is obviously essential and mis-function can have fatal consequences - a current as low as thirty micro-amps can kill if inadvertently applied to the heart during surgery. Early medical electronic devices were blamed, in the 1960s, for a number of patient deaths and since that time the medical device industry has been strictly controlled. The number and type of controls vary from country to country but are strongly influenced by the agencies in the US. Consequently, the regulations which are operative in the US will be described, which apply to both manufacturers and users of medical equipment. (Many of these have worldwide legal relevance in any case.)

The development, testing, introduction, manufacturing and use of medical equipment and supplies is controlled. This is mainly by the US Food and Drugs Administration (FDA), through a number of mandatory and voluntary regulations. Other agencies which control the use of equipment are Underwriters Laboratories (UL), Emergency Care Research Institute (ECRI) and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO), the latter's regulations being summarized in their *Accreditation Manual for Hospitals.*

The FDA has a number of manufacturers' guidelines for the design of medical devices, which are known as *Good Design Practices* (GDP); these are likely to become much tougher in the 1990s (Appler, 1990). The reason for this is the recognition that 44% of serious product problems were found, in a FDA investigation, to be due to design flaws (*ibid*). The quality of products is, to a great extent, determined by the design and so it is crucial to ensure a quality design process. This should include a detailed analysis of the product requirements including the type of users (e.g. physicians, nurses or technicians), documentation required, special patient needs, the risks of the intended use, detectability of problems, the regulatory standards and serviceability (Holstein, 1988). In addition, the consequences of equipment failure should be carefully analysed and design changes made to account for these (Doheny, 1988).

Once a design has been developed it must undergo substantial clinical and electrical testing before it can be offered for sale. The results of the device's clinical trials must be submitted for approval to the FDA's *Office of Device Evaluation* (ODE). The approval process is strict and it "*has lengthened substantially. The kind of information being demanded has increased phenomenally. The agency is more demanding in inspections and it is interpreting requirements far more narrowly*" (Appler, 1990). This strictness is the result of concerns from doctors who, in the past, have complained about poor products, which were not only developed too quickly but were also inadequately tested (Ahnefeld, 1987).

The electrical safety of devices is controlled by Underwriters Laboratories (UL), a private non-profit organization who test products to check that they do not exhibit a hazard to the patient or the user. Products which are approved can then carry the UL label; most hospitals in the US will not purchase equipment which does not have this approval. The international equivalent of the UL approval is the International Electrical Commission (IEC) IEC-601 standard for medical equipment and some countries have yet another standard (e.g. the Canadian Standards Association's [CSA] and British Standards Institute's [BSI] medical standards and the German Medical Equipment Safety Law - MedGV [Weber, 1991]).

Once equipment has been approved by the ODE and UL it can be offered for sale. At that time a number of other regulations come into force, which have far-reaching consequences for both manufacturers and hospitals alike. The first of these affects the production of the device by the manufacturer. The FDA has standards for manufacturing known as *Good Manufacturing Practices* (GMP), which cover the quality control and documentation of the manufacturing process. The FDA even has the power to seize equipment which is offered for sale but which does not meet these standards (Appler, 1990).

The next regulation which affects medical equipment is the way problems and hazards occurring when the product is used must be reported. Firstly, the FDA must be informed of any safety problems under the *Medical Device Reporting* (MDR) rules. In addition, manufacturers must inform their customers and if necessary modify or remove equipment from service to avoid these safety problems - a *Safety Recall*. "*Recall, according to the FDA, is a voluntary action on the part of manufacturers and distributors to protect the* *public health and well-being from products that present a risk of injury or gross deception or are otherwise defective*" (Health Technology, 1989). Information on safety problems is published regularly in ECRI reports. These reports are distributed by US embassies to the medical authorities of their host countries and, in this way, the FDA applies pressure to American companies to take global action on equipment safety problems.

The way in which American hospitals use their equipment is regulated by the JCAHO, who may withdraw their accreditation for a hospital which does not meet the "*myriad legal responsibilities related to the selection, management and use of medical equipment*" (Health Technology, 1989). The JCAHO regulations which relate to the use of equipment are comprehensive. For instance, hospitals must consider if their staff have the skills required to operate new equipment and then must make sure that these staff are correctly trained because "*the failure to educate users in the proper operation of equipment has been found to constitute negligence*" (*ibid*). The scope of this training is defined to include the performance of the device, its compatibility with other devices and potential hazards - "*proper training includes not only instruction in operating the equipment, but also information on recognizing malfunctions and signs of deterioration or deviation from safe operation*" (*ibid*). Safety checks and maintenance are also regulated because "*Once equipment has been acquired and put into service, the hospital is under a continuing duty to manage it to enhance patient safety*" (*ibid*). Hospitals must report any safety problems that they discover to the FDA, plus react quickly to the advice given in the published ECRI *Health Devices Alerts*.

5.3.4 The Customers

There are four types of hospital staff who are involved in the purchasing and use of medical equipment and who can be referred to as "customers". These are the doctors (referred to as *physicians* in the US), nurses, biomedical engineers or technicians and hospital administrators.

The doctors who have direct involvement with equipment are usually specialists. For example; the operation of the O.R. monitoring devices is the responsibility of the anaesthetist and lasers are operated by the surgeon. Doctors receive little instruction on technology during their training and therefore are often unable to assess technical product specifications without the assistance of engineers (Ahnefeld, 1987).

Nurses are often directly responsible for connecting monitoring equipment to a patient and operating it in the I.C.U. This can be a difficult task for them since "*the nurse's role model and training are not associated with the mechanics of devices*" (Shaffer and Shaffer, 1990[b]). Nurses place their priority on treating the patient and so their main requirement is for equipment that is simple and quick to use. In the US there is currently a real shortage of nursing staff (Borenstein-Levy, 1990); many other countries also have this problem or that of fast turnover of staff on specialist units.

Most large hospitals have biomedical engineering departments, which include both biomedical engineers and technicians. There are estimated to be over 10,000 biomedical engineers and technicians in US hospitals (Wear and Shastri, 1991). They are mainly responsible for maintenance and repair of equipment (Gasparovic, 1989). In addition, these departments may play a role in the training of equipment users (Shaffer and Shaffer, 1990[b]) and, in university institutions, in research programmes. Technicians and engineers may also be responsible for operating the more complex equipment, such as MRI or radiotherapy machines. The biomedical engineers are the customers who have most direct exposure to the different types of medical equipment in use in a hospital and are closely involved with many of the aspects of support, such as maintenance, repair and user training. In the researcher's experience, they consequently like to have good contact with manufacturers' local support organizations.

Obviously the hospital administrator does not operate equipment but he plays a major role in equipment purchasing decisions. Hospital administrators may have a medical background but the majority have administrative training. Increasingly, and particularly in the US, hospital administrators have a business background and manage hospitals like a normal business, with strict accounting and active marketing. Many larger hospitals have electronic data processing (EDP) departments belonging to their administration, the staff of which are usually computer engineers who have specialized in medical record keeping.

5.3.5 Customer Requirements

The customer requirements for hospital devices are complex and dependent, to an extent, on the device in question. However, a number of key attributes can be identified:-

- Low cost.
- High performance.
- Ease-of-use.
- Reliable and easily repairable.
- Good user training.
- Good documentation.
- Clear, effective performance tests for the user.

Since the equipment is often used in emergency situations and many of the users (e.g. nurses) are not technically skilled, the equipment must be easy to use (Hewlett-Packard, 1991). One traditional requirement is that "*users of clinical equipment consider reliability to be of paramount* *importance*" (Mier, 1980). Modern technology is, however, making it possible to produce extremely reliable devices and consequently the focus on reliability is being replaced by an emphasis on the ease-of-use and the training offered by manufacturers (Clark and Armistead, 1990). Documentation for medical devices is important and it is covered in some of the FDA guidelines discussed previously. The need is for documentation that is clear, concise and based as much as possible on diagrams and not lengthy text (Shaffer, 1987). The testing of equipment, to ensure that it is performing correctly, is essential. This includes preventive maintenance and performance testing.

5.3.6 The Purchasing Process

The buying process for the medical market is complicated by the four types of hospital personnel involved in equipment purchases. The initial ideas for equipment purchases come from the medical staff (doctors and nurses), who are interested primarily in equipment function, technical specifications, compatibility and maintenance required (Ahnefeld, 1987). "*The quality of service provided is a particularly important factor in the decision to buy*" (Blumberg, 1987). The proposed purchase is then normally controlled by the administrative staff, who look at the cost side. An example of the administrator's approach is: "*We take price and service and other criteria and put point values on them. Then we come up with a total value for that vendor that can be compared to another vendor*" (Borenstein-Levy, 1990). Hospitals often include equipment running costs in their pre-purchase cost analysis, as these can be significant for medical technology (Goffin, 1991). Private hospitals in the US will not only evaluate running costs but will compare these to the amount of revenue that a device will raise (ECRI, 1989).

The role of the biomedical engineer in the purchasing decision is normally a "veto" one; he is consulted to see if the equipment under consideration meets his (support) requirements and he can stop the purchase if this is not the case. However, the consultation of the engineer is a step which is often considered as very important by the administrator; "*since our ability to service the equipment is important, we go to the biomedical engineering department to give us an assessment of the quality of the product we're getting*" (Borenstein-Levy, 1990). The exact purchasing process and the decision power of each of the types of hospital personnel involved varies widely.

In addition to the hospital personnel involved in the purchase of equipment, government departments and other outside bodies may be involved. In some countries major purchases are scrutinized by government departments. This is particularly the case in France but also in America, where purchases over $100K are controlled by the Department of Health, Education and Welfare (HEW) [Mier, 1980]. The exact rules for this type of scrutiny of purchases vary widely between different countries. In the US, a non-profit agency the Emergency Care Research Institute gives hospitals advice on equipment purchases including assistance on negotiating the price (ECRI, 1989).

5.3.7 Influences of Costs and Other Trends

As mentioned earlier, cost is a key factor in the medical market which will continue to play a central role in the 1990s, as many countries try to control costs. This will lead to controls on the spending on technological equipment. Balanced against this are two factors that will tend to maintain the high spending on equipment; these are the recognition that monitoring devices can reduce the number of accidents which occur in anaesthesia and the aging population of the developed world.

The cost control developments in the USA are dramatic and they have a strong influence on other countries. (Without control and at the current growth rate the costs of health care would, it is claimed, consume 100% of the GNP by the year 2080! [Sullivan, 1988].) Three changes in the funding of US health care have occurred over the last twenty-five years. From 1965 to 1983 the *Medicare* legislation allowed hospitals to be reimbursed, from medical insurance companies, for all of the treatment that they provided. The 1983 *Diagnostic Related Groups* (DRG) legislation changed this and allowed hospitals to receive only a fixed amount, determined by the type of illness treated (i.e. diagnostic related). Although designed to reduce costs it was found that the DRG approach did not reach that goal; many examples of unnecessary spending on medical technology are given in Fitzgerald (1989). For the 1990s new legislation, based on *Medical Outcomes*, is in preparation. This proposes that insurance companies only must reimburse hospitals for treatment where the medical outcome has been proved. This means that just because technology was used in the treatment, it does not automatically qualify for reimbursement. This will influence the types of devices that are produced, changing today's situation where "*most new medical devices are variations to existing technologies - and they generally cost more than the devices they replace*" (Stephenson and Freiherr, 1990). The industry will have to react suitably to Medical Outcomes; it "*will have to overcome its history of being driven by technology and instead, concentrate on the demonstrated needs of our customers and markets. This means that, in addition to appropriate technologies, we must provide genuine value - offerings that combine equipment, training, service, applications and marketing support, and innovative financial alternatives*" (Stephenson and Freiherr, 1990). Medical outcomes will, almost certainly, be adopted in some form in other Western countries.

The move towards cost control will tend to reduce the amount of medical equipment purchased - only that for which a favourable outcome can be proved will bring reimbursement for the hospital and, consequently only this type of equipment will be purchased. However, balanced against this is a recognition that technology can be an important factor leading to greater survival, less pain and better recovery (Ahnefeld, 1987) plus reducing the chance of litigation (Youngson, 1991). An example of this is in the case of anaesthesia monitoring.

Studies estimate that 2000 people die under anaesthetic, per year in the USA and that half of these deaths are preventable (ECRI, 1985). The use of monitoring equipment *"can make anaesthesia safer by giving early warning of unexpected events or accidents"* (Youngson, 1991) and because of this there is significant interest in which parameters should be monitored. Studies in the US led to the adoption of minimum monitoring standards by the American Society of Anesthesiologists (ASA) in 1986. These recommend the monitoring of the ECG, blood pressure, oxygen, temperature, breathing and circulation of the patient plus the connection of the ventilator attached to the patient (*ibid*).

The implementation of monitoring standards has important legal implications in many countries, particularly the US. Insurance companies will not cover hospitals against litigation unless the minimum standards are met and some insurance companies require even more monitoring (Moyers, 1988). The scope of the standards is a strong point of discussion. Some authors see the ASA standards as not going far enough and argue for the monitoring of more parameters. In the climate of strong cost-control the advantages of this extra monitoring are weighed against their costs; Whitcher *et al* (1988) give both medical and financial arguments for comprehensive monitoring whereas Block (1988) argues that yet even more parameters should be monitored. The development of US equipment standards is likely to have an influence on worldwide purchasing of anaesthetic equipment in the future, as American medical practices are often adopted elsewhere.

The final factor that will strongly influence the purchasing of hospital equipment is the ageing population of most countries, with the associated greater need for health care. Research has shown that the health care costs for the oldest age brackets are very high (Fitzgerald, 1989). Extra spending on health care will be necessary to support this older population but will it lead to big investments in high-technology devices? In specific cases, yes. This is because medical outcomes legislation will promote investment in effective types of equipment. In other words, hospitals will need to be *"more selective about the technology used* ... [and] *to replace all the archaic, ineffective equipment being used in hospitals today"* (Fitzgerald, 1989). The right technology can, when applied efficiently, reduce healthcare costs by reducing the need for traditional but expensive procedures (Berkowitz, 1989).

5.3.8 Product Support in the Medical Market

Several aspects of product support are important for hospital equipment, in addition to training and documentation which were already mentioned. Since the focus of this thesis is product support, its role in the medical market will be explained in detail. For the basis of this discussion the categories of product support defined in the model given in Chapter Four will be used.

These were warranty, support contracts, complaints handling, customer training, documentation, technical advising, design improvement (upgrades), installation, maintenance, repair and parts availability. Several of these points are mentioned in the literature but all will be discussed drawing, in some cases, on the researcher's own knowledge. Most of the evidence in the literature is anecdotal.

5.3.8a Warranty

In the researcher's experience, warranty on most types of medical equipment is given for a period of twelve months. The terms and conditions offered on warranty are similar from most companies. The only recent development in the area of warranty is that some manufacturers are starting to offer longer warranty periods on very selected pieces of equipment. The type of equipment where this is being seen is simple devices which are very reliable and where few operator errors are likely to occur (e.g. defibrillators are being offered with five years warranty). With new technology enabling more reliable equipment, longer warranty periods may follow for other types of equipment. However, manufacturers will probably be cautious about offering longer warranty periods on complex equipment, even if it reliable. This is because medical manufacturers do not normally charge hospitals, during the warranty period, for the cost of an engineer visiting the hospital for a "failure" which turns out to be due to an operator error. Since many problems with new equipment may be due to operator error, this is a significant factor for hospitals. (Many are addressing it by using response centres to screen customer calls before engineers are dispatched.)

As the warranty offered by most manufacturers is identical, this probably leads medical customers to not perceive warranty as a key element of product support. Certainly no references to warranty were found in the review of the literature on the medical equipment market.

5.3.8b Contracts

Hospitals may decide to take out contracts for the support of medical equipment. This can be the case if either they have no biomedical engineering department or if this department considers a contract to be cost-effective. Biomedical engineering departments seldom have the resources to maintain all of the equipment in their hospital. Therefore, normally they choose which types of equipment they can best maintain themselves. (In the researcher's experience, this normally excludes X-ray equipment, as this requires specialized knowledge of not only the equipment's electrical design but also its mechanical design.) The remainder may be contracted to manufacturers (or TPMs in a few cases), with the biomedical engineering departments negotiating an acceptable price. Some hospitals may choose not to have a repair contract with a manufacturer. In this case, though, they may be faced with high repair costs if they want fast repairs (for instance at weekends).

The price of a contract covering the maintenance of medical equipment is typically 10% of the purchase price per year, or possibly more if cover is required at weekends. With expensive imaging devices, costing between $1M and $2M, the revenues from contracts are very high and this prompted the entry of TPM companies into this area, offering slightly cheaper maintenance contracts.. Manufacturers are reacting by expanding the services included in their contracts - for instance equipment upgrades may be included (Buller, 1991).

In the researcher's experience, manufacturers offer discounts on the price of maintenance contracts to hospitals with biomedical engineering departments. The reason for this is that the engineers can inspect equipment which staff report as faulty before the manufacturer's personnel are called out. Since some "faults" may be due to operator errors this can save unnecessary visits to the hospital (and costs to the manufacturer). Many companies are interested in cooperating with the biomedical engineering departments. The reason for this is that, being on-site, the biomedical engineers can respond very quickly to problems.

Some hospitals are now considering the whole issue of equipment cost of ownership. New capital equipment must be economical over its full lifetime. Biomedical engineering departments calculate cost of ownership, including contract fees, and take a leading role in this part of the purchasing decision (Berkowitz, 1989).

5.3.8c Complaints Handling

Most manufacturers of medical equipment, in the researcher's experience, are very responsive to customer complaints. This probably is due to the fact that the equipment is often used in critical situations and the question of liability is always present. Consequently, manufacturers may response with equipment improvements at no cost when customers complain of problems during usage. This responsiveness of companies is likely to continue and it will be reinforced by new guidelines from the FDA and new international standards.

As mentioned in the section on regulatory controls, safety problems must be quickly dealt with under the *Medical Device Reporting* rules of the FDA. New regulations from the FDA now require all problems encountered by operators to be reported. These problems will be tracked by the FDA and if several complaints about a particular device are received, then a manufacturer will have to react by providing improvements.

Less severe complaints (for instance, that a device is not as reliable as expected) are normally dealt with following the manufacturer's own procedures. However, the introduction of the ISO 9000 standard[1] into the medical industry means that companies' complaints handling procedures will be the subject of external audits. For instance, the researcher has heard that the UK Department of Health and Social Security (DHSS) is now auditing manufacturers according to ISO 9000. If manufacturers are found not to have reacted speedily and appropriately to UK customer complaints, then the DHSS can stop sales of that manufacturer's equipment to state-run hospitals.

Complaints are normally, in the researcher's experience, handled professionally in the medical market. Due to this, companies who ignore complaints risk damaging their sales as there is a great deal of contact between the staff of different hospitals and consequently a bad reputation spreads quickly. In addition, failure to react to complaints can bring legal liability in some countries, therefore companies must "*deal effectively with all written and oral complaints about product performance, quality, safety, durability, effectiveness, and misuse*" (Holstein, 1988).

5.3.8d Customer Training

Manufacturers and distributors of medical equipment usually need to provide training for users and biomedical engineers. Users need to learn how to operate the equipment and engineers, in addition, need to learn about the required maintenance.

Training on equipment operation is very important. Hospitals must ensure that their personnel are correctly trained in the use of medical devices or they may be liable if accidents occur. This task is made more difficult because of the high staff turnover in hospitals plus the widespread use of temporary "agency" personnel [Health Technology (1989) and Berkowitz (1989)]. Training is typically provided by manufacturers following the installation of a new device, either by training all users or by training selected staff in depth, who will then be responsible for training their colleagues. Training users can be very time-consuming since many hospital departments have multiple shifts of staff, all of whom must be trained.

The scope of staff training, related to the use of equipment, is defined in the USA by JCAHO. Users should become knowledgeable on the performance of the equipment, the content of the operating manuals, compatibility between the device and other equipment, how best to use the product and possible hazards during use. A key aspect is that "*Proper training includes not only instruction in operating the equipment, but also information on recognizing malfunctions and signs of deterioration or deviation from safe operation*" (Health Technology, 1989). In countries other than the US, the guidelines for the training of hospital personnel are normally based on the International Electrotechnical Commission's IEC-930 document (IEC, 1988). This recommends that training is considered even before the purchase, since

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[1] ISO 9000 is explained in Chapter Two.

it is essential for both users and biomedical engineers.

The task of training hospital personnel "*is a difficult one because physicians, nurses and other device users are often unfamiliar with the technical and engineering aspects of a device's operation*" (Health Technology, 1989). Training new staff on existing equipment is essential since "*the user is an important factor in the safety of any given monitor*" (Moyers, 1988). Although many hospitals give supervised hands-on experience to new staff the quality of this training is not always high; "*the in-service education that they* [new staff] *get is still geared to casual word-of-mouth communication, and so their understanding of equipment technology comes only from outside experiences, which are often inadequate*" (Shaffer and Shaffer, 1990[b]). One way this problem is being addressed is that the biomedical engineering departments in hospitals are becoming active in training users (*ibid*).

Biomedical engineers often attend the user training at installation provided by the manufacturer. This helps them later to train users and also to differentiate between operator errors and true equipment failures. In addition to user training, the biomedical engineers require technical training on the maintenance of the equipment. This training is, in the researcher's experience, not usually included in the purchase price of the equipment and the hospital must pay separately for biomedical engineers' technical training.

5.3.8e Documentation

Documentation is very important in the medical market as "*these are considered an essential part of the equipment*" (IEC, 1988). There are four main types of documentation for medical equipment: sales literature, operating information, application information and technical manuals.

Sales literature (e.g. brochures, data sheets etc) is not part of product support but it needs to be mentioned. Companies need to ensure that the product descriptions given in sales literature are accurate and do not make unrealistic claims about possible product usage. This is essential, otherwise sales literature may encourage inappropriate product usage which can, in the event of an accident, lead to the manufacturer being liable (Holstein, 1988).

Operating information covers the correct use, operation, testing and cleaning of equipment. Operating guides' contents need to be clear and concise (Shaffer, 1987) and the accuracy of the information should be carefully checked as it has legal implications in the event of an incident (Holstein, 1988). A number of countries, including France, Germany and Sweden, have regulations requiring that the operating information for medical products is translated into the local language (IEC, 1988).

Hospitals must make sure that the operating manuals are easily accessible to staff and manufacturers must attach short instructions or labels to their devices (IEC, 1988). Manufacturers often provide hospitals with video tapes giving an introduction to the operation of a machine. These can be used to help new staff learn the equipment.

Application documentation gives the user background information on the use of the equipment. For instance, documentation may be provided on how a certain physiological signal is measured, how it is processed by the equipment's software and what are the limitations of the technique. This type of information is often included in user training classes, to raise the users' knowledge of equipment to such a level that they are less likely to operate the equipment incorrectly. Application information is, like operating information, sometimes provided as a video.

Technical documentation covers the maintenance of equipment. Biomedical engineers, in the researcher's experience, have high expectations of technical documentation and probably perceive it as a key element of product support. They expect detailed descriptions on how equipment works (termed *Theory of Operation* by many manufacturers) and corresponding circuit diagrams. Information on the checks and maintenance necessary for equipment is particularly important. This leads to biomedical engineering departments defining and documenting equipment maintenance as, "*Unfortunately, the majority of firms provide either insufficient guidelines or no guidelines whatsoever on maintenance*" (Ben-Zvi, 1984).

5.3.8f Technical and Application Advice

It is important that advice from engineers to doctors on the use of medical technology is available (Ahnefeld, 1987). Response centres can be effective in solving the problems of medical customers. One study (Lambert, 1989) showed that 35% of medical customer problems were due to operator error and could be solved over the telephone. Most large medical manufacturers now operate a response centre.

In the researcher's opinion, many manufacturers will offer consulting services to hospitals in the future. These services will, most likely, encompass detailed advice on what amount of equipment makes sense for a hospital and how this equipment maintenance can be best maintained.

5.3.8g Upgrades

With some types of medical equipment the pace of technological advance is fast. This, as discussed earlier, leads hospitals to want to exchange their equipment as better machines become available. Due to cost-containment, it is seldom possible to exchange equipment as often as some medical staff would like and so the possibility to upgrade existing equipment is important. Some types of equipment, such as ultrasound or complicated monitors, will be upgraded several times over their working lifetimes.

In ultrasound imaging, the pace of technological advance is so fast that most hospitals buying equipment expect to be able to add additional features later - "*upgradability is the key to a cost-effective ultrasound acquisition*" (ECRI, 1989). The price of equipment upgrades may be covered in manufacturers' support contracts (Buller, 1991), in order to make these more attractive.

Another factor which makes upgrades important is that many hospitals have a separate budget for maintaining equipment and part of this can be spent on upgrading devices to the latest functions. Biomedical engineering departments are, in the researcher's experience, often active in ordering and installing upgrades in equipment, as in this way they can save the cost of a visit from a manufacturer's engineer.

5.3.8h Installation

The complexity of the installation of medical equipment is dependent on the type of device. In the medical market the term installation covers unpacking, equipment assembly, physical and electrical integration followed by functional and safety testing. It can be very easy or it may be extremely complex. For instance, a new cardiograph basically requires only unpacking, since it is not normally connected to other devices. An MRI system, however, requires extensive installation and possible alterations to rooms to accommodate the large equipment. Once installed, extensive testing is required before the device can be used. Installation for MRI can cost up to $2M (Fitzgerald, 1989).

In the researcher's experience, almost all installation work is done by the manufacturer's (or distributor's) support organization. Traditionally the cost of this has been covered by the purchase price, on all but the physically large types of equipment (e.g. MRI installation is not included in the purchase price). The engineer installing the equipment will often, in addition, instruct users in the operation of the machine. Some manufacturers are now attempting to save costs by not sending engineers to do installations of simple machines. Biomedical engineering departments will, in the researcher's view, start performing installations but will demand discounts for this work.

5.3.8i Periodic Maintenance

Preventive maintenance plays a very important role in the hospital since, as mentioned earlier, hospitals are legally responsible to see that their equipment is correctly maintained. In the cost-conscious environment, maintenance is an expense that is now being controlled to make sure that it is effective (King, 1990). Today's trend is for maintenance to consist mainly of cleaning, calibration, performance and safety testing as opposed to the exchange of wear-out components. Consequently, the older term *preventive* *maintenance* is slowly being replaced by *periodic maintenance,* which covers all of these categories of maintenance (IEC, 1988). Much of the periodic maintenance is done by the biomedical engineering departments in hospitals, who may also define regular tests that have to be performed by the actual user. Detailed records of the maintenance of individual pieces of equipment are required by the JCAHO and must be kept for the lifetime of the product (Shaffer and Shaffer, 1990[a]).

5.3.8j Repair

Reliability, as already mentioned, is a key customer attribute for medical equipment and an ideal device would be one that does not fail. With new technologies medical devices are becoming more and more reliable. However, today's machines do fail and so customers still find it very important to know just how quickly and how cheaply equipment can be repaired.

Various authors have noted the importance of quick repair in the medical market. The speed of repair required is dependent on whether replacement equipment is available and, to some extent on the type of hospital in which it is used. Life-support equipment (e.g. ventilators) must be repaired or replaced immediately and for this reason the biomedical engineering departments often hold reserve equipment which can be used until the faulty equipment is repaired. (The reserve equipment is often old equipment which has been taken out of normal service.) More complex devices such as central stations or scanners cannot easily be exchanged because of their size or connections to other devices. Therefore, they must be repaired on-site and quickly. Delays can affect the quality of patient care plus, in privately-run hospitals, have a financial impact. This is because certain devices can be big sources of income, for instance "*a CT scanner produces over $1000 an hour in revenues*" (Buller, 1991). An indirect financial impact of faulty equipment is that local doctors will not refer patients to hospitals where they know that equipment is constantly breaking down (Berkowitz, 1989).

Mathe (1988), in a survey of the X-ray market, found that forty percent of customers had changed equipment supplier because they were not satisfied with the standard of after-sales service (particularly poor repair times). Gasparovic, 1989 says "*in the medical service market ... the need* [is] *for prompt, technical service when and where the problem arises*".

Manufacturers can provide an appropriately fast repair of equipment in two main ways. They can have a field organization which offer quick response[1], readily available spares and, to cover for failed devices, "loaner" equipment. The problem is that, to give a fast response, large organizations are required if the products supported are being sold over wide areas. Alternatively manufacturers can make it possible for the biomedical

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[1] In the X-ray market, a *quick response* is one within four hours (Mathe, 1988).

engineers in the hospital to repair the equipment themselves, by providing good documentation and quick delivery of spare parts (Gasparovic, 1989). In addition to this, quick answers to users' and biomedical engineers' problems are often provided by response centres, covering both technical and application questions.

5.3.8k Spare Parts

The availability of spare parts is an important issue in the medical market. Obviously delays in the delivery of parts can increase instrument downtime and this can affect patient care as discussed in the section above. Long-term availability is also an issue, with some hospitals insisting that the sales contract specifies how many years spare parts will be available for equipment. In addition to the availability of parts, the price is, in the researcher's experience, seen as an important factor by biomedical engineers when they consider new purchases.

5.3.8l Field Support Organizations

Many of the factors of product support, which relate to the type of organization that manufacturers require, have already been raised. For instance, response centres are required to provide technical and application advice and a field organization is required that can quickly respond to and solve technical failures.

The type of personnel required to staff such organizations is discussed be Gasparovic (1989) and summarized as "*they have received intensive training in a variety of technical disciplines and are expected to be able to discuss applications with the technologist and the physician*". Highly-trained and responsible personnel are required because "*When employees service or upgrade a product, the company will be responsible for the quality of that service. Liability can result from the failure to service properly, provide complete service, or warn about defects observed during service*" (Holstein, 1988).

Due to the requirement for medical support engineers to have special skills, it is unlikely that third party companies will easily penetrate the medical support market; maintenance will continue to be done by the manufacturer or biomedical engineers (Roussel and Miller, 1990). One attempt by TPM companies to service anaesthesia machines met with strong resistance from the manufacturer, who argued that equipment safety would be compromised (Knight, 1991). Another resulted in the manufacturer of imaging equipment taking a TPM to court for acquiring and using proprietary diagnostic software (Buller, 1991).

5.3.8m Summary

In summary, it can be seen from the evidence in the literature (anecdotal and from one survey) that product support is important in the medical market. This leads many manufacturers to place an emphasis on support and *"Pertinent manufacturer provisions include the test facilities and self-diagnostics built-into the equipment, quality of the instruction manuals, availability of spare parts, need for special test equipment, and nearness of the service center and its response time"* (Shaffer and Shaffer, 1990[a]).

5.4 THE HEWLETT-PACKARD MEDICAL PRODUCTS GROUP

Hewlett-Packard is an American-owned computer and measurement company, about ten percent of which (in terms of both revenue and personnel) is dedicated to producing medical equipment. The Hewlett-Packard Medical Products Group (HP-MPG) is a major producer of certain types of medical equipment. It earned a revenue of nearly $1 billion in 1989, making approximately 15% profit (Wiegner, 1990). Medical products have been developed and sold by HP over the last thirty years, since acquiring the medical company Sanborn in 1961 (*ibid*). The main types of equipment produced are patient monitors, foetal monitors and ultrasound imaging systems. A total of 8000 employees work in development, and manufacturing (five sites worldwide), field sales and support (300 offices worldwide). Some of the key points about the Hewlett-Packard organization which are relevant to the research will be discussed.

5.4.1 Hewlett-Packard Medical Products

Hewlett-Packard produces a range of products and is a market leader in some segments, such as the ultrasound and monitoring areas. This section will discuss HP products and will show how this range of products compares to the full spectrum of equipment in the medical market.

Table 5.4 shows the four categories of medical equipment discussed earlier in this chapter - diagnostic devices, monitoring devices, therapeutic devices and computer equipment. In the diagnostic category, Table 5.4 shows that HP produces ECG machines and ultrasound scanners. For ECG equipment, HP is one of the market leaders together with the US company Marquette and the medical division of the German company Siemens. In ultrasound, HP is the market leader with approximately 22% market share and just in front of Acuson, which is another American company.

Monitoring equipment is one of the traditional strengths of HP. All three major types of monitoring equipment (patient monitors, central stations and foetal monitors) are produced and HP is one of the leaders for each of these types of equipment.

Table 5.4: The Types of Medical Equipment Produced by Hewlett-Packard / Major Competitors.

Type of Equipment	HP-MPG Products ?	Market Leaders (Market shares)
1) Diagnostic		
ECG Machines	Yes	Marquette (US), Siemens (D), HP
X-ray Devices		
CT Scanners		
MRI		
Ultrasound Scanners	Yes	HP (22%), Acuson (US)
Radioisotope Scanning		
Biomagnetic Devices		
TOTAL MARKET		= 10,000M$
2) Monitoring		
Patient Monitors	Yes	HP, Marquette (US), Siemens
Central Stations	Yes	HP, Marquette (US), Siemens
Foetal Monitors	Yes	HP, Corometrics (US)
TOTAL MARKET		= 1,300M$
3) Therapeutic		
Radiation Therapy Machines		
Surgical Lasers		
Pacemakers		
Internal Defibrillators		
Defibrillators (external)	Yes	
Lithotriptors		Dornier (D), Medstone (US)
Ventilators		
Anaesthetic Machines		Ohmeda (US:60%), Draeger (D:30%)
Infusion Pumps		IMED (US)
TOTAL MARKET		= 5,000M$
4) Computers		
For Administrative Data	Yes	
For Clinical Data	Yes	
TOTAL MARKET		= 200M$
TOTAL HP-MPG REVENUE= 1,000M$		

Note: The market leaders and market shares information was compiled from the following publications: Wiegner (1990), Brown (1987), MIR (1988), BBI (1985), Fitzgerald (1989), ECRI (1989) and Medistat (1990[a], [b], 1991[a], [b] and [c]). The nationality of the leading companies is shown using the standard abbreviations.

In the therapeutic equipment category, which has an estimated size of $5,000M, Hewlett-Packard has only one type of product - defibrillators.

In the hospital computing category HP produces computers for both clinical and administrative data processing. This category is currently relatively a small market but it is expected to grow fast (Froitzheim, 1990).

The major products produced by HP in the last twenty-five years are listed chronologically in Table 5.5. This table will be used to illustrate the development of different generations of medical products by HP-MPG, including foetal monitors, patient monitors and ultrasound. [A fuller explanation of each product can be found in Dale (1986)].

5.4.1a Foetal Monitoring Products

The first product listed in Table 5.4 is the *8020A Cardiotocograph*. This, the first foetal monitor on the market, was introduced in 1968 and was very successful. It was replaced in 1975 by the *8030A* which, in turn, was superseded by the *8040A* in 1982. Finally the 8040A was replaced in 1990 by the *M1350A*. Therefore, in twenty-five years, HP have introduced four generations of foetal monitors, which have enabled them to remain market leader. The monitors from later generations have improved function but are still used in the same applications (monitoring of labour and delivery). This means that newer machines have directly replaced older ones and production of these older machines was quickly stopped. The 1987 *80225A Obstetrical System* was the first computer system on the market which enabled storage of foetal monitoring traces. These, as mentioned earlier, must be stored in some countries for many years because of legal reasons. The 80225A, together with the M1350A, form the mainstay of the products currently being marketed to obstetrical departments.

5.4.1b Patient Monitors

Unlike foetal monitors, newer machines in the patient monitoring area have not necessarily been direct replacements for older ones. Newer monitors may have been introduced to address certain market segments or to offer new parameters. The major developments in the patient monitoring area can be explained by considering the products in Table 5.4.

The *8800 Series* of monitors, introduced in 1971, is used for specialized monitoring of patients with heart disease. This product has not been replaced and is still in production today. The *78200 Series* was a generation of modular monitoring products introduced in 1972. It was used mainly in intensive care but also in operating room monitoring. The introduction in 1978 of the *78341A/2A Patient Monitors* (code-named

"*Rifleshot Series*") largely made the 78200 products obsolete (except for certain specialized parameters). The 78341A/2A was very successful in the intensive care monitoring segment and spurned a family of products culminating in the *78345A/6A*, which was fitted with parameters such as CO_2 which made it particularly suited for use in the operating room. In 1982 a new generation of monitors called the *Compact Configured Monitors* (7835xA/B, 7883xA/B etc) was introduced to replace the Rifleshot Series. The Compact generation was primarily designed for *mid-level* patient monitoring, in which only a limited number of parameters are monitored. Higher level monitors were produced, starting with the *78534A* and *78532A* in 1984 and 1985 respectively. These monitors enabled Hewlett-Packard to capture a significant share of the high-level segment. The momentum of this success was continued when they were replaced by the *M1046A Component Monitoring System*, which offers a full range of parameters. Today (1992) the main monitors marketed by Hewlett-Packard are the M1046A (high-level applications) and the Compact Configured Monitors (mid-level applications).

5.4.1c Central Stations

The central stations introduced over the last twenty-five years came in four main generations. The *78500 Central Station* was introduced in 1979 for the central display of patients' signals. In 1981 this was complemented by the *78525 Arrhythmia System*, which monitored patients' ECGs automatically. In 1984 the *78720A Arrhythmia System* replaced the 78525 and production of this latter product was stopped. The *78560A Central Station* (with optional arrhythmia monitoring capability) is a product for mid-level care and is currently marketed alongside the 78720A, which is generally used for higher-level applications.

5.4.1d ECG Machines

Hewlett-Packard have produced cardiographs since 1961, since their entry into the medical equipment market by the acquisition of the Sanborn Company, who produced cardiographs. Major products over the last twenty-five years include the *4700 Series* (1981) and the *4760AI Interpretive Cardiograph* (1984), with computer analysis of the ECG. The latest ECG product is the *M1700A Cardiograph*, which replaces all previous cardiographs.

5.4.1e Defibrillators

The two generations of defibrillators were introduced in 1981 (*78660A*) and 1985 (*43120A*). Both of these products were designed primarily for hospital use, even though a large market is developing for defibrillators for use in ambulances.

5.4.1f Ultrasound Systems

The first ultrasound scanner from Hewlett-Packard was the *77020AC Ultrasound System,* introduced in 1981. This product, from its concept, was designed for upgradability since this is a key feature for the ultrasound market. The 77020AC product has continually been enhanced over the last ten years, by regular improvements in both hardware and software. This has enabled HP to become market leader in ultrasound imaging.

Table 5.5: Major Hewlett-Packard Medical Products From the Last Twenty-Five Years

#	Product Number	Code Name	Type of Equipment	Year Introduced
1	8020A	---	Cardiotocograph	1968
2	8800 Series	Cath	Catheter Laboratory	1971
3	78200 Series	---	Patient Monitor	1972
4	8030A	---	Cardiotocograph	1975
5	78341A/2A	Rifleshot	Patient Monitor	1978
6	78500	Speakeasy	Central Station	1979
7	77020AC	Ultrasound	Imaging System	1980
8	78525	---	Arrhythmia System	1981
9	4700 Series	Pagewriter	Cardiograph	1981
10	78345A/6A	Capnoshot	Patient Monitor	1981
11	78660A	Quickstep	Defibrillator	1981
12	78351A	Minishot-1	Patient Monitor	1982
13	8040A	---	Cardiotocograph	1982
14	78354A/B1	Minishot-4	Patient Monitor	1983
15	7883xA/B	Wickie	Neonatal Monitor	1983
16	78534A	Clover	Patient Monitor	1984
17	78720A	Crystal	Arrhythmia System	1984
18	4760AI	Interpret.	Cardiograph	1984
19	43210A	Eagle	Defibrillator	1985
20	78532A	Pogo	Patient Monitor	1985
21	78560A	Orion	Central Station	1986
22	80225A	OBMS	Obstetrical System	1987
23	M1046A	Merlin	Patient Monitor	1988
24	M1700A	PagewriterXL	Cardiograph	1990
25	M1350A	Pegasus	Cardiotocograph	1990

5.4.2 The Field Support Organization

The Hewlett-Packard Medical Support Organization is responsible for all aspects of post-sales support for medical products. This support includes equipment installation, user and biomedical engineer training, equipment maintenance and repair (for warranty, contract and "on-request"), response centre support, parts supply, support contracting and application consulting.

Approximately 1000 people work in the HP-MPG support organization, with about 30% of this figure based in Europe. The three main types of support personnel are the:

- *Customer Support Engineers* [CE].
- *Clinical Specialists* [CS].
- *Response Centre Engineers* [RCE].

Of the 1000 support personnel approximately 700 are CEs, one hundred CSs, thirty RCEs, with the rest working in management or administration functions.

5.4.2a Customer Engineers

The bulk of the support organization is made up of CEs, with about 400 in the US and 225 in Europe. The CE is responsible for the installation of new equipment (this is approximately 20% of his workload), plus maintenance and repair (65%). In addition, CEs give a certain amount of training to users (15%), on the equipment for which the CE is responsible.

The range of products on which a CE is trained and on which he therefore works[1] is normally wide, ranging from monitors to ECG machines. The only exception to this is that some CEs are specialized on ultrasound equipment and do not support other types of products. The products on which a CE will actively work depends on the installed base in the area for which he is responsible. If new equipment is purchased by hospitals in his area, then he will receive training on this equipment before the installation.

Depending on the density of the installed base of Hewlett-Packard equipment a CE may have a small physical area to cover (in cities, for instance) or a very large area. In all cases CEs are provided with company cars with car phones and portable computers. This allows them to keep in close contact both with their local office and hospital departments. The normal hospital contact person for the CE is the biomedical engineer, as they normally inspect suspected faulty equipment before the Hewlett-Packard engineer is called. CEs will often be accompanied to faulty equipment by biomedical engineers and consequently there is normally a strong contact between the field support organization and the biomedical engineering departments.

CEs normally have either a technical or biomedical engineering background. Increasingly new CEs are being recruited from biomedical engineering, as they then have a detailed knowledge of medical electronics. New CEs receive extensive medical background and product training before

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[1] Following ISO 9000 guidelines CEs only work on equipment for which they have received training.

they take full responsibility for an area. The detailed product training normally takes place in the manufacturing division and is given by the marketing group in the factory responsible for the support of that product.

The CEs are the group of company employees who have most exposure to products in the post-sales phase. They are involved in most aspects of support from installation, user training to repair and upgrades. In this sense they are a major group of "internal customers" with their own set of requirements relating to product support.

5.4.2b Clinical Specialists

Clinical Specialists are a small but important part of the support organization. They are responsible for training users and biomedical engineers on Hewlett-Packard equipment and advising hospitals on the optimum use of equipment. CSs are either former doctors, nurses or biomedical engineers who have the in-depth understanding of the medical environment required when training users and advising hospitals.

Due to the depth of medical knowledge required for the CS role, most CSs are specialized on a smaller number of products than CEs. They cover larger areas than the CEs and most of their work is post-installation training, which follows-up on the initial user training performed by the CE at installation.

5.4.2c Response Centre Engineers

Both European and American customers can call response centres for advice on medical products. All customer calls are routed to the RCEs, who decide on the best course of action and whether an on-site visit by a CE is necessary. A large number of customer calls can be solved over the telephone, as the RCE has equipment in the response centre which he can use to simulate customer problems. If the problem cannot be solved over the telephone (e.g. it appears that the equipment has failed and an operator misunderstanding is not the cause) then a CE will be contacted by the RCE.

RCEs are responsible for giving both technical and application advice to customers over the telephone on a very wide range of products. They are usually recruited from the ranks of experienced CEs and therefore have much experience of a broad range of products and typical customer problems. Most RCEs spend a regular amount of time each month working with a CE, so that they can also obtain practical experience with new products.

RCEs have very close contact to the manufacturing divisions and the relevant groups in marketing who are available to support the field organization. RCEs will be trained by these factory personnel and refer back to them if they receive customer questions that they cannot answer. In addition, customer complaints and escalations will be handled by close cooperation between the RCE and factory product specialists.

5.4.3 Supportability of the Products

The concept of supportability was discussed in Chapter Two. It refers to the characteristics of a product that make it easy to support, including easy to install, to train customers, to maintain, to repair and to upgrade etc. Do the medical products of Hewlett-Packard have high supportability and how has the supportability of products changed over the last twenty-five years? This section will consider these questions and why they cannot easily be answered.

Supportability is a new concept and therefore the supportability of the products listed in Table 5.5 has not been analysed in the past, either at the design stage or later. At the design stage the equipment failure rate was estimated and suitable quantitative goals set for the finished design. This was monitored once products were released to the market. In addition, a goal was set for the time to repair (MTTR). However, these were the only two aspects of support considered for new designs[1]. Other aspects, such as installation or upgradability were not considered in the past and the only data available related to supportability is the failure rate, as the actual figures for MTTR were not tracked.

Figure 5.1 shows how the failure rate of monitors has dropped over the last twenty-five years. The improvements in reliability of comparable monitors (i.e. similar capability with a similar array of monitored parameters) have been largely due to advances in technology such as the use of the microprocessor (which removed the need for extensive analogue circuitry) and surface mounted components. The drop in failure rate with each new generation (shown by the dotted line in Figure 5.1) means that the number of times that a particular piece of equipment fails over its working lifetime is reduced - newer monitors have to be repaired less times than they will typically be upgraded. As no data is available, it is not clear whether newer monitors are for example easier to install or to train customers on.

As no direct data is available on the supportability of medical equipment, the question arises how can the hypothesis related to supportability be investigated. One hypothesis was that newer products are not necessarily better in all aspects of support. In order to research this an indirect approach was adopted; surveying internal and external customers, to identify their attributes of support and to identify the differences perceived between different products. The results of this and how they compare to the hypothesis are given in Chapter Eight.

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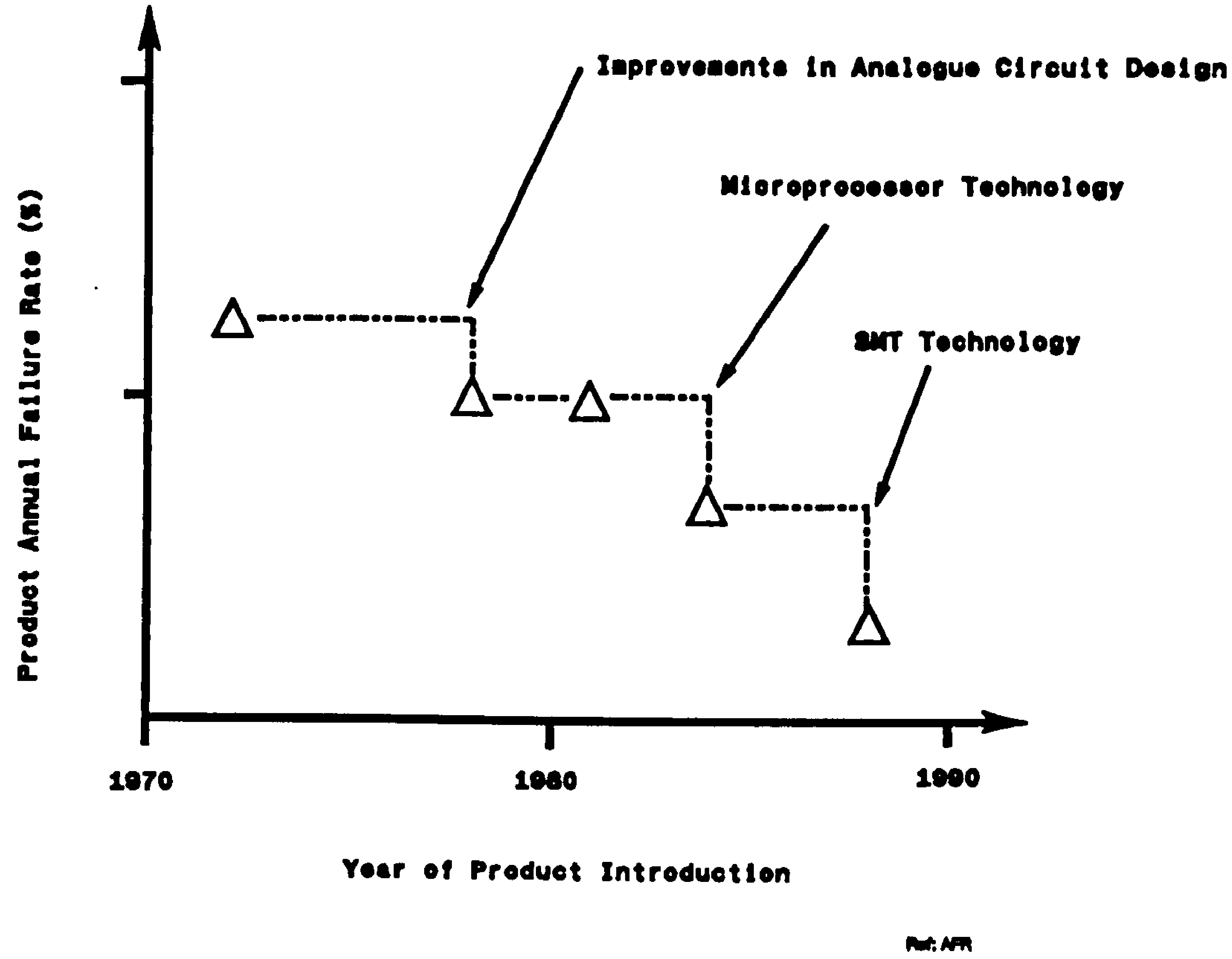
[1] This situation is similar in many companies, as shown by the results of a survey described in Chapter Seven.

Figure 5.1: The Change in Failure Rates of Hewlett-Packard Monitors over the Last Twenty Years (Source: Company Data - as this is confidential the y-axis is not labeled)



5.5 SUMMARY

The medical equipment market was described in detail, with explanations of the four main categories of equipment: diagnostic, monitoring and therapeutic devices plus hospital computer equipment. The medical market was shown to have some key characteristics including:

- Strong regulatory controls.
- Four types of customer involved in the purchase and use of equipment.
- Particular customer requirements for medical devices (including support).
- Strong cost controls.

The Hewlett-Packard Company, which cooperated with the research, was described including the main types of product it produces and its support organization. It was seen that the evidence on the importance of support in the medical market was almost entirely anecdotal and that no research on the attributes of good support in this market have been published.

CHAPTER SIX

Methodology

6.0 INTRODUCTION

Chapter Four explained the choice of the survey style of research and why the other possibilities were rejected. This chapter summarizes firstly why certain methodologies were not chosen and then describes in detail the methodologies selected. In contrast to the other chapters it is divided into two parts; these covering the design of the questionnaire for investigating support planning and the design of the interviews for establishing the attributes of good support. The aims of this chapter are:-

- To describe the methods chosen for the questionnaire and interview stages of the research and
- To discuss the advantages and disadvantages of these methods and explain how these were considered in questionnaire and interview design.

Part One covers the questionnaire design. Part Two explains how the Kelly's Repertory Grid structured interviews were designed. It also gives the background on why this technique was chosen from the various methods available for identifying customer perceptions of abstract concepts.

PART ONE: POSTAL SURVEY DESIGN

6.1 INTRODUCTION

In Chapter Four, which covered the research design, the basic reasons for choosing a postal survey to investigate companies' planning of support were given. However, in that chapter, no explanation was given of how the survey tool itself was developed, or what key points about survey design were considered. This is covered here.

There is a vast literature on the design of questionnaires which was consulted during the design of the postal questionnaire. Since questionnaire design is a well-known topic, it will not be explained in too much detail. Instead, the salient points from the literature and how they were applied will be summarized.

6.2 ADVANTAGES AND DISADVANTAGES OF POSTAL SURVEYS

There are four main advantages to mail surveys. They are comparatively cheap, anonymous, no interviewer bias is introduced and even subjects who are remotely located can easily be contacted by post (Open University, 1979[a]). Moser and Kalton (1979), make a similar analysis of the advantages but add the speed by which a postal survey allows data to be collected.

The main disadvantage of postal surveys, identified in all of the literature (see, for example Open University 1979[a], Moser and Kalton 1979 and Bailey, 1987), is that the response rate can be low. Well-designed questionnaires with good covering letters and reminder letters can help to increase the response rate (Open University, 1979[a]). The other disadvantages of mail surveys are all connected with the type of questions it is possible to ask. The questions must be simple and unambiguous to the respondent (*ibid*) because they are only asked once - a mail survey is a "*one-shot*" attempt at data collection, where later corrections or additions are not possible (Moser and Kalton, 1979). The answers given are not spontaneous and not independent because the respondent can read through the whole questionnaire before beginning his response (Moser and Kalton, 1979). Additionally, there is no control over who answers the questionnaire and no interaction is possible, as is the case with interviews (where, for instance, complex issues can be explained) - *ibid.* The disadvantages of mail questionnaires mean that it is all the more important to ensure good questionnaire design, through extensive testing. "*Pretesting of questionnaires is a virtual necessity. The only way to gain real assurance that questions are unambiguous is to try them*" (Green *et al*, 1988).

6.3 KEY POINTS FOR QUESTIONNAIRE DESIGN

The main points to consider when developing and conducting a postal survey are:-

- The questionnaire must be constructed so that the information that is collected is relevant to the study ("*Before one even thinks of writing questions he should have a clear idea of the information he wishes to collect*", Smith, 1975)[1]
- The questions must be clear and unambiguous to the respondent. Good instructions must be given with the questions.
- The questions must be "*relevant to the individual respondent*" of the intended sample (Bailey, 1987).

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[1] This is a particularly important point in exploratory research. The temptation might be to ask some questions just to see if interesting results are obtained. However, questions need to be considered properly and tested. Only then can the decision be made on whether they will bring relevant results.

- Testing (pretesting and pilot surveying) is essential to obtain information on the adequacy of the questionnaire, the response and the data which will be collected.

- Suitable steps need to be taken to attempt to ensure that a good response is received. Possibilities include offering motivation to subjects to respond and reminder letters.

6.4 QUESTIONNAIRE DEVELOPMENT

The questionnaire was developed over a period of five months with constant reference to the literature and:-

1) Definition of the term *product support*, so that the scope of the questionnaire was clear (the definition was used as a framework for some of the questionnaire - see Chapter Four).

2) Review of the research objectives (Chapter Four) for the survey.

3) Preparation of a preliminary questionnaire covering the above points.

4) Trial runs of the preliminary questionnaire with AFSM International members, to check that the questions were clear and reasonably easy to understand.

5) Further development of the questionnaire, after analysis of the trials and detailed discussions with these respondents.

6) Further trials on specific points with the same respondents.

7) Addition of explanations of why certain questions were being asked (in italics on the questionnaire). This approach was found to make the survey much clearer to all those involved in the trial.

8) A pilot run of the questionnaire. The questionnaire was distributed to 15 AFSM International members who were able to give quick feedback.

9) The results of the pilot-run led to further improvements in the questionnaire (see Appendix C for the final version).

10) Analysis of the results of the pilot run and preparation of coding frames for computer analysis of the final survey.

11) Preparation of a covering letter carrying the logos of both AFSM International and Cranfield School of Management. This explained that the survey was the result of cooperation between Cranfield and AFSM International and that the results would be published in the Association's Journal. The covering letter is included in the Appendix.

12) Discussions with AFSM International on how to obtain the optimum response rate without compromising confidentiality. They felt that their members would be sufficiently interested that a good reply rate would result, if a promise was made to publish the results. In addition, they agreed to the use of a reminder letter to help increase the response rate. (This was designed following the advice on reminders given by Dillman, 1978.) The second letter, sent after three weeks, acted as a reminder to those who had not yet replied, thanked those who had responded and, because it was sent to all subjects, did not affect anonymity.

13) The logistics were organized. These consisted of the printing of the questionnaire, its delivery to AFSM International, the posting to its members and the posting of the reminder letter. The replies were addressed to Cranfield School of Management, where their collection and delivery to the researcher (based in Germany) had been arranged.

6.5 SUMMARY

The postal questionnaire was developed to investigate the hypotheses and research objectives related to how high-technology companies plan product support for new products. The sample chosen was the professional association AFSM International and the questionnaire was developed through extensive testing with this group.

PART TWO: STRUCTURED INTERVIEW DESIGN

6.6 INTRODUCTION

The second stage of the research investigated hypotheses and research objectives related to the characteristics of good product support. Interview technique was chosen for this investigation as this was expected to be more effective than postal surveying.

6.7 THE IDENTIFICATION OF PRODUCT ATTRIBUTES

In attempting to identify important characteristics of a product, from the post-sales support viewpoint, we are in fact looking for specific product *attributes*. There are various methods available for determining attributes; Alpert (1971) gives the following:-

- Direct questioning.
- Indirect questioning and motivational techniques.
- Observation or experiment.

Before a method is chosen an appreciation of the relative advantages and disadvantages of the approaches is obviously important. These will be discussed.

Direct questioning, although simple and the traditional method of investigating customer attributes, has some significant drawbacks. As Myers and Alpert (1968) point out, there is no way of knowing if the respondent either really knows why he buys or if he will tell you honestly. These factors led to problems in the early research on customer attributes. Variations on direct questioning exist. An example is the approach where the respondent is asked to identify "ideal attributes" for a hypothetical product. This, however (Myers and Alpert, 1968), has similar drawbacks to those mentioned above: can the respondent really conceptualize a product with ideal attributes?

In order to avoid the types of problems mentioned above, indirect questioning was developed. Examples of this type of approach include so-called motivational research and covariate analysis. Motivational research consists, in one form, of giving the subject unfinished sentences about the product under investigation and asking him to complete them. Myers and Alpert (1968) quote research which showed this approach to be more effective than direct questioning. Covariate analysis, on the other hand, takes the results of indirect questioning and places them in a covariate model, in order to bring out the key factors under investigation. A typical covariate model in market research would be to compare the answers of product-users and non-users. Covariate analysis has been extensively used in investigating the reasons consumers choose a particular brand of product. Although they are very useful for certain investigations, indirect questioning methods have their limitations. The main one [Myers and Alpert, (1968) and Alpert (1971)], is that indirect questioning can indicate a correlation (e.g. preference for brands with a particular feature) but does not prove causality (i.e. that the consumer will actually buy the product with the preferred feature). The only way to prove causality is of course experimentation.

Direct observation of consumers' buying patterns is one of the oldest techniques of market research. Later, this was extended to have an experimental component, in which the influence of one particular feature is investigated, by isolating the role of other features by holding them constant. This methodology has the advantage of probing for causality but has limitations, especially when investigating the attributes of an ideal product.

6.8 CHOICE OF METHODOLOGY

The previous section discussed the general types of methods used for investigating the attributes of an ideal product. In choosing a methodology for investigating the characteristics of an ideal product, from the product support standpoint, certain factors need to be considered:

- Customers may have difficulty in identifying even the physical features of an ideal product. Product support is more abstract and therefore it is probably harder for customers to identify attributes. Therefore some sort of stimulation is required to prompt customers to identify attributes.

- Comparison between "brands" is difficult for the type of equipment under investigation - it is typically used for ten years and so the customer does not regularly compare and choose between the equipment of different companies (as, for instance, in the case of consumer products).

- Since product support is quite abstract, a method for estimating the attributes of existing products would be useful. This would enable goals for the attributes of new products to be set in relation to existing ones.

The above three factors were crucial in driving the choice of methodology.

One method of identifying attributes that has been successfully utilized in many situations is the Repertory Grid method, developed by Kelly. This method, which was originally used for psychological tests but now has much wider applications, can be used for identifying product requirements. Lunn (1969) states: *"The technique is an especially valuable means of eliciting new product requirements"*. Similar recognition of the method is given by Christopher (1969) who says, *"One tried and tested method of determining constructs or criteria relevant to a product-market is Kelly's Repertory Grid"*. Kelly's method will therefore be described in detail.

6.9 KELLY'S REPERTORY GRID METHOD

This methodology, as mentioned, has it origins in psychological research and has as its basis what is called personal construct theory. This theory is that all individuals attempt to explain or conceptualize the world in which they live, by forming what are called *constructs*.

6.9.1 The Theory of Personal Constructs

Constructs are personal "rules", by which individuals attempt to organize their thoughts about particular elements. Elements can be people, feelings, objects, or almost anything and the constructs about a particular category of elements form a subsystem of an individual's set of constructs. This can be better understood by discussing the original form of Kelly's method, known as the "Rep-test"

The Rep-test, in its simplest form, attempts to identify the personal constructs of an individual, related to his views of other people (e.g. acquaintances). The subject is asked to write down the names of a given number (typically a dozen or more) of people, from his family and friends. The names, which are written separately on cards, are then presented to the subject in groups of three. For each group of three cards (termed a *triad*), the subject is asked to say in what respect two of the people are similar to each other but different from the third. A typical response could be that two of the people were clever, whereas the third is stupid. This approach, repeated with various combinations of three names, extracts information from the subject on the rules by which he views others - his personal constructs. Kelly (1955) defines a construct as, "*a way in which two or more things are alike and at the same time different from one or more things*".

A further development of the technique is the so-called Grid Technique, whereby the elements under discussion are rated against each construct. This will be explained by discussing the example given in Oppenheim (1966).

6.9.2 An Example of Repertory Grid Testing

If a subject is given a set of photographs of people (these are the elements of the test) he can be asked to give his views on triads of the photographs. He may then comment that two photographs are similar, in that the people look intelligent, whereas the third does not. Another triad may lead the subject to say that one person is Jewish-looking, whereas the others are not. The next step in the test is that the subject rates all the elements (photographs) according to each construct. This produces a grid, of the form shown in Figure 6.1.

In Figure 6.1 the ratings are indicated by the boxes; for example Photo. A does not look intelligent, looks tough, not Jewish etc. From Figure 6.1 it is possible to see how constructs are linked; similar ratings on different construct lines can indicate that the subject links constructs (e.g. Jewish-looking and intelligent) together. Analysing the link between constructs and identifying the subject's true constructs (which may not be shown directly in the grid) is described in detail by Levy and Dugan (1956).

Figure 6.1: An Example of a Repertory Grid (adapted from Oppenheim, 1966).

ELEMENTS					
CONSTRUCTS	Photo A	Photo B	Photo C	Photo D	Photo E
Intelligent		■		■	■
Tough	■		■		
Jewish-looking		■		■	■
Likeable		■		■	
Selfish	■		■		

The above example gives the basic form of Kelly's Grid Technique of which Oppenheim (1966) says: "*The most important aspects of the repertory-grid technique are the constructs (attitudes) and the objects (cards, persons, photographs)...*". The method is extremely flexible and many variations exist as to how the test can be designed for a particular purpose. The main variations will be discussed.

6.9.3 Variations on the Test Design

Variations exist in the way in which the elements and constructs of the test are identified or obtained plus, in addition, in the way in which these are administered to the subject. Bannister (1962) states: "*Repertory grid testing is a highly flexible technique and not a single test*". The main categories of these variations will be discussed.

6.9.3a The Elements of the Test

The elements of the test can either be presented to the subject or he might be asked to provide his own, within a given subject. In applications of grid testing both approaches or a mixture of them have been used.

In one of the original forms of the test, the Role Construct Repertory Test [RCRT (Kelly, 1955)] the subject is asked to supply the names of people (the elements) who fit a set number of specified roles such as "mother", "father", "the most intelligent person you know" etc. Another example is in the testing of patients with relationship problems, the elements (people significant to the patient and involved with the patient's problems) can be collected from the subject (patient) - Ryle and Lunghi (1970).

In contrast to the above examples, where the subject provides elements freely or within specified categories, other types of repertory testing supply the elements directly. Many examples exist: see for example Lemon (1975), who in a study of pupils' linguistic skills supplies the names of countries as elements, or Riter (1966) who supplied brand names as the elements in his market research into television sales.

In summary it can be said that the choice of how elements are derived is dependent on the aims of the investigation and is the essential first step in the research design.

6.9.3b Presentation of the Elements

In his original work Kelly presented the elements to the subject in groups of three - triads. The subject then had to decide how two of the elements are similar and how the third differs. The selection of the elements in the triads is normally random, with different triads being presented to the subject until all combinations have been covered. For each triad the subject is encouraged to give a new construct. The combinations in which the elements are presented in the triads is important and should be considered.

Bender (1974) investigated how the sequence of elements in the triads affect the results of repertory testing. He found that if only one element in a triad is changed and if the new element is not particularly striking to the subject, then the resulting construct will be less important than the others collected (since the subject is asked not to repeat constructs). He summarized his findings as: "[If] *The sequential form...only changes one element in each triad; thus, if the new element is not particularly interesting or striking for the subject, since he is forced to repeat himself, he is forced to give a less important construct.*" The relevance of allowing subjects to repeat constructs, which is related to Bender's findings is discussed in the section on constructs.

So far, tests have only been described that present the elements to the subject in groups of three - the triads . However, another possibility exists. Ryle and Lunghi (1970) discuss the so-called Dyad Method, which overcomes an important limitation of the repertory grid testing; that it is too general in its results and not sensitive enough. Ryle and Lunghi point out that, in psychological testing where the elements are people, a construct such as "is understanding" might be applied to rating a subject John. However this rating of John is too general - it is an overall judgement of John, which might encompass a relative lack of understanding of Jill and an exceptional understanding of Elizabeth. To make the test more useful in this case Ryle and Lunghi developed their dyad grid: "*...in which the elements, instead of being individuals, i.e. John or Jill, are the relationships between pairs, i.e. John in relation to Jill, John in relation to Elizabeth and so on.*" The dyad test is a very sensitive variation on repertory testing, which is often used for psychological testing but which remains a specialized test for this area of application.

Now that the elements and their presentation have been discussed it is time to delineate how the constructs are used in repertory testing.

6.9.3c Constructs in Repertory Testing

Two variations exist as to how the constructs are identified. One approach is that the subject produces entirely his own constructs, in another the constructs are provided to the subject, who then uses them to rate the elements. These approaches are known as "own" (or "personal") and "provided" constructs. Investigating the relative merits of these distinct approaches has been the aim of a substantial amount of research.

The conclusions reached by all of the researchers who investigated the relative merits effectiveness of own or provided constructs are similar. The main finding is that subjects are able to express their thoughts better using their own constructs, especially if the research investigation concerns a subject's personal relationships. However adequate data can be obtained using suitable provided constructs, especially in surveys [See for example: Metcalf (1974), Isaacson and Landfield (1965), Adams-Webber (1970), Stringer (1972) or Kuusinen and Nystedt (1975)]. Stringer (1972) summarized his results as: *"either construct system tended to account for a significant amount of the variance in sorting behaviour, but that more was accounted for by personal construct systems"*

The results of the studies referenced have strongly influenced the application of the repertory technique. The approach now commonly adopted for survey type work (e.g. market research) is to conduct pilot interviews to identify the personal constructs by which a number of people categorize products. These are then compared, to identify the "common" constructs. The next stage takes the common constructs and uses them as provided constructs to a representative sample, who rate the products on each of the constructs (Frost and Braine, 1967). The results of this type of research are ratings of different products (elements) against constructs - this can be essential information for marketing plans. A particular point to note is that care must be taken when grouping the personal constructs of the subjects in the pilot work into categories. Subjects may use similar words to describe quite different concepts; an example where not enough consideration was given to this point is the work of Nash (1979) and the subsequent criticism of this by the Open University (1979[b]). (Nash [1979] grouped constructs from school children into his own categories - this may have introduced significant interviewer bias.)

Another factor on the derivation of constructs has been investigated and needs discussion; the effect of allowing (or prohibiting) a subject to repeat constructs. In research quoted earlier, Bender (1974) identified that the order of the elements in the triads influences the responses but only when the subject is encouraged not to repeat himself. Shubsachs (1975) investigated the effect of allowing constructs to be repeated. His results are not conclusive but tentatively suggest that if subjects are allowed to repeat constructs then those repeated are particularly important.

General conclusions can be reached from the review of the different ways that constructs can be elicited. These are that provided constructs will give satisfactory results in survey-type work, as long as the pilot work on collecting common constructs is done correctly.

6.9.3d The Stages of the Technique

Due to the several possible approaches to the determination of the elements and constructs the variations on how the test is administered are high. However, the underlying methodology is the same and consists of six stages (Smith, 1986[a]):-

1) Eliciting the elements.

2) Elicitation of the constructs.

3) Preparing the grid.

4) Grading the grid.

5) Analysing the grid.

6) Interpreting the results.

6.9.4 The Applications of Repertory Testing

Bannister (1962) recognized how versatile the repertory grid can be, saying; "*Repertory grid testing is a highly flexible technique and not a single test. Thus although so far as it has been used to investigate constructs about people, there is no reason why the objects sorted by the subject should not be motor cars, political parties, sexual practices or domestic utensils, therefore allowing a variety of construct subsystems to be investigated.*" Bannister's statement can almost be taken literally; research in many of the areas he predicted can be identified. No research into motor cars can be quoted, however, Fransella and Bannister (1967) used repertory grids for investigating political values. Ryle and Lunghi (1970) scrutinized patients' sexual practices and Riter (1966) looked into domestic equipment (televisions).

In addition to the applications noted above many other areas have been investigated using the repertory technique. Examples include investigations of shopping habits (Hudson, 1974), language skills (Lemon, 1975), pupils' expectations of their teachers (Nash, 1979) and many examples, too numerous to quote individually, from the various areas of normal and abnormal psychology. The large number of examples cited show the flexibility of the test. Particularly interesting is the success with which the test has been used for market research.

6.9.5 The Repertory Grid in Market Research

The use of the repertory grid method for market research is reviewed by Frost and Braine (1967), who enthusiastically promote the effectiveness of the method. They say, *"In our view, the Repertory Grid represents an approach of such fundamental importance that we regard it as having as much potential in market research as any technique since the invention of the questionnaire."* Frost and Braine outline the way in which the method is best applied to market research.

Frost and Braine (*ibid*) see that the repertory grid method is best applied to the marketing situation as a four-step test. Firstly, the elements for the investigation are identified. Typically the elements are products or brands, if a competitive analysis is to be performed. The elements are then presented to a pilot group of subjects, to obtain their reactions - the constructs - to the triads. Usually the subjects will produce between 15 and 30 constructs when they are presented with 10 to 30 brands (elements) whereby the use of different stimuli, such as photographs of the products, can help in this process. The pilot interviews are conducted with up to 40 people, from which a pattern of constructs emerges. These can be categorized and the test redesigned, with provided constructs, for application to a statistical sample of subjects, from the target customer group. The number of times that the same construct is given by different respondents determines whether it should be considered a common construct (*ibid*). The relative importance of that construct to an individual respondent is indicated by how much he discriminates between the elements on that construct (i.e. by the degree of variation in his ratings). *"Thus constructs with a high percentage of variation are ... important, salient, constructs"* (Smith, 1986[b]).

Many examples of marketing applications for the repertory grid method exist and several have already been mentioned. Others include the work of Myers and Alpert (1968) [Airline services] and Lunn (1969) [Brand image]. Drawing-on the results of this work, in particular the way in which the research was designed, allowed the design of a repertory grid test for investigating product support to be made.

6.9.6 The Limitations of the Repertory Technique

The many advantages of the repertory technique have been discussed.

However, there are also limitations to the method (Brenner *et al*, 1987 and Open University, 1979[b]), which need deliberation. Unfortunately, as will be seen, a number of limitations are not expressly mentioned in the literature. The main shortcomings of the method are:-

- The methodology may become almost an end in itself, which may disguise weak research design (by use of complex statistics on the grid results).
- The test tends to generate its own problems, which the technique then becomes involved in solving.
- The interpretation of the data is sometimes problematic.
- The administration of the test can introduce a somewhat artificial situation, where the subject gives responses that he feels are expected of him.
- The test is very time-consuming (the average length of the interviews conducted for this project was about sixty minutes)[1].
- The best method to choose the most important constructs is not identified in the literature[1].
- Subjects of certain nationalities may have difficulties with certain rating scales. This is because they are normally so used to the scale commonly used in schools in their country that they may find it hard to use a different scale[1].
- The technique is, as are all interviews if care is not taken, susceptible to interviewer bias.
- The ratings by the respondents of the elements are susceptible to the "halo" effect[2].

These limitations are obviously important considerations during the research design stage; they are addressed in the next section on the specific test designed.

6.10 THE SPECIFIC RESEARCH DESIGN

The extensive review of the literature gave the necessary background decisions to be made on test design. It was, for instance, obvious that the

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[1] These limitations were not mentioned in the literature but identified during the course of the research. They are described in detail in Chapter 8.

[2] Halo effect is the term used for the influence on results that respondents have who do not rate items objectively. This means that rating values "*as well as telling us something about the* [issue] *in question it also tells us something about the respondent*" (Open University, 1979[a]).

elements of the test should be medical equipment and that the constructs required were support attributes. In addition, Chapter Four already identified the sample for the structured interviews - a group of HP engineers ("internal customers") and a number of biomedical engineers ("external customers"). The question was how the repertory technique could be most effectively applied to these two distinct groups, in order to investigate to research hypotheses and achieve the research objectives. It quickly became clear that one major difference between these two groups necessitated two different test designs. This was that Hewlett-Packard engineers have experience with many different HP products, whereas biomedical engineers only have experience of the products in their hospital. This seldom includes more than four or five Hewlett-Packard products and would limit the number of triads that could be presented to the biomedical engineer. Additionally, if the interview with the biomedical engineers centred on HP products and excluded products from other manufacturers, then valuable information on the attributes of good support could be lost.

6.10.1 Interview Design for Internal Customers

Since Hewlett-Packard engineers (internal customers, from the support standpoint) have a knowledge of a wide range of their company's products, this made it possible to choose Hewlett-Packard medical products as the (provided) elements of the test. (HP engineers do not work in a third party maintenance role and so do not work on equipment from other manufacturers. Therefore no information was lost by focusing the interviews on HP products.)

The twenty-five major products of the last twenty-years were chosen (these are listed in the Appendix). One point to note is that, over the last twenty-five years, Hewlett-Packard have produced several "families" of medical products, consisting of units with different product numbers but very similar design. The approach taken in the repertory test design was that only the first and last members of these families were included as elements. The reasons for this were that in preliminary testing subjects complained that it was hard to think of new constructs when presented with *"too many, very similar products"*[1]. Support for this decision can be found in the literature; Bender (1974) found that subjects who were presented with similar elements produced less important constructs.

Once the elements for the interviews had been chosen the repertory test was developed by reference to the literature and the following steps:-

1) Preliminary interviews with three engineers to establish the viability of the test. These were conducted using twenty provided elements (well-known products), labelled on cards which had been numbered randomly. The subjects sorted

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[1] Quote from the preliminary interview with subject EP.

through the cards and removed products with which they were unfamiliar. Triads were presented to the subjects who then produced their own, *personal*, constructs related to support. All of the elements (products) were then compared against the constructs on a bipolar scale. Five main points emerged from the preliminary interviews. These are: (a) the repertory test is time-consuming (typically about an hour), (b) a bipolar scale is not sufficient to rate products which are not simply either "good" or "bad", (c) very similar products (from the same family) should not be included, (d) a subject will typically identify 8-10 attributes in one hour and (e) a well-designed data collection tool (grid) is required for collecting the constructs and the ratings accurately and efficiently.

2) The test was then re-designed for the pilot stage. This included the modified list of products (elements), a rating scale of 1-5, a grid designed for capturing the constructs and product ratings and a pre-written explanation interview script for the test.

3) A pilot version of the test was used with twelve engineers. These pilot interviews allowed the structure of the interviews to be fully tested and showed that, indeed, a set of common attributes for good support would be identified.

4) The test was again re-designed. This included the final improvements to the data collection grid, the rating scale was changed to 1-9 (as several respondents in the pilot run commented that the 1-5 scale was not wide enough), the explanation to the subject was finalized and data analysis by computer was prepared (see Appendix for details on each of these points).

5) The final test was conducted in two stages. The first stage consisted of twenty-five interviews, where firstly the personal constructs of the respondent were determined and then their ratings of products on the set of common constructs were collected. The second stage (by which time enough personal constructs had been collected to identify the common constructs) consisted of simply having twenty-five respondents rate the products on provided (common) constructs. (The approach taken therefore follows closely that described in Section 6.9.5: The Repertory Grid in Market Research.)

6.10.2 Interview Design for External Customers

Since biomedical engineers (external customers) do not typically have experience of very many Hewlett-Packard products, it means that they cannot be given the same provided elements as internal customers. Therefore, the biomedical engineers were allowed to choose ten different pieces of medical equipment (including the HP equipment in their hospital) with which they were familiar.

The types of equipment chosen were written in the order that they were named on ten separate cards, which had already been numbered randomly. The card numbers were then used to select the triads shown to the engineer to stimulate constructs. After each construct the elements were rated against that construct using a 1-9 scale.

In order to ensure good interview technique and minimize interviewer bias, a written explanation of the test was prepared (the interview script) and read exactly to each respondent. In addition, care was taken to conduct the interviews "*in a neutral manner*" with the answers being "*treated with polite interest but without a response from the interviewer which suggests that* [he or] *she agrees or disagrees*" (Stone, 1984).

The responses to the repertory test interviews with biomedical engineers were recorded on a prepared repertory grid (see Appendix). This also included space for the answers to background questions on the size of the engineer's department, his department's responsibilities etc.

6.11 SUMMARY

This chapter gave the background information on the two research methodologies used; a postal questionnaire and structured interviewing. Both of these methodologies required significant development and testing before they were in a form which was suitable for investigating the research hypotheses. The research methodology was applied to investigate the hypotheses was:

- The postal survey was used to investigate whether companies plan product support in detail or whether they only evaluate product reliability at the design stage.
- The structured interviews were used to investigate the attributes of good support from the customer's standpoint and if newer products are easier to support.

The next two chapters give the results of these two stages.

CHAPTER SEVEN

Postal Survey Results

7.0 INTRODUCTION

This chapter describes the results of the survey investigating how companies evaluate product support during the design stage of new products. The survey, which was conducted in May/June 1989, appears to be the first of its kind - although the importance of planning product support is identified by a number of authors, no one has investigated the practices of companies in this area before. (As mentioned in Chapter Two, Lele and Karmarkar [1983] say "*support needs are considered late in the design cycle*" but give no evidence on this.) The format of this chapter is:-

- A brief resume of the aims of the survey.
- Detailed results of all aspects of the survey.
- A comparison of the results against the hypotheses and objectives.
- A discussion of the limitations of the survey.

7.1 AIMS OF THE SURVEY

The purpose of the survey was exploratory research into when and how product support is evaluated by companies during product development cycles. Two hypotheses were investigated and specifically the questionnaire's aims (repeated from Chapter Four) were:-

1) To identify the range of different support factors which are evaluated by companies at the product design stage.

2) To collate the different support factors which can be evaluated, in order to derive a systematic evaluation of product support at the design stage. To base this on the model of product support derived from the review of the literature.

3) To then determine what approach would be necessary to investigate the causal link between planning and supportability (using similar methodology to that used in management research on other types of planning).

4) To determine the time at which product support planning starts, during new product development cycles, at high-technology companies.

5) To determine the level of planning undertaken by companies.

6) To determine all of the support factors which are quantitatively planned at the design stage by companies.

7) To determine how commonly each of the different goals are used across companies.

7.2 RESULTS

The results are presented in the same order as the respective questions appeared in the questionnaire (the survey instrument is given in Appendix C).

7.2.1 Types of Response

The first part of the questionnaire concentrated on identifying the types of companies in which the respondents were employed. This section of the report gives details of the different categories of respondents who replied to the survey.

7.2.1a Response Rate

The total number of responses was 91, which corresponds to a reply rate of 15%. This was somewhat low but probably to be expected bearing in mind:-

1) That a similar reply rate was noted by Clark (1988) for a survey on support and

2) The complexity of the questionnaire.

With any postal survey the complexity is likely to have a key influence on the reply rate. In the event, a relatively complex questionnaire was used in order to gather the necessary information, even though it was recognized that there was a risk that this would reduce the response rate.

7.2.1b Response by Product Type

Responses were received from a wide range of electronic industries, as would be expected from the membership profile of AFSM International. The results are shown in Table 7.1. Due to the relatively small number of answers per category, detailed analysis per category (industry) is not possible. However, since 25% of the answers are from the computer industry, this allowed these to be contrasted with the grouped other-industries.

Table 7.1: Replies by Type of Industry.

Industry	Replies	
Office Equipment	11	
Computing and PCs	23	25%
Domestic Electronics	1	
Manufacturing Equipment	4	
Medical Electronics	8	
Third Party Maintenance	15	16%
Communications	6	
Networking/Datacom	7	
Vending Machines/Systems	4	
Software	2	
Printing	2	
Security Systems	2	
Analytical Equipment	2	
Other	4	
Total	91	100%

7.2.1c Response by Type of Company

The number of responses is broken down by the type of company in Table 7.2. An important point to note is that not all of the respondents are employed in manufacturing industries. In fact 16% were from third party maintenance companies and 11% from distributors. These type of companies are not directly involved with product development and therefore were only able to answer part of the questionnaire. Some of the respondents from TPM companies commented that they have no influence on product design but that they have ideas on how designs could be improved (an investigation of TPM's views on support is a possible future research topic).

The number of answers from manufacturing industry is 66 (73%) and it is only these cases which could be analysed in detail on the topic of design for support. A check on the type of products produced and the size of the companies revealed that the 66 replies were from *different* manufacturing companies. This means that the survey obtained detailed information on the support planning process at 66 different companies.

Table 7.2: Categories of Companies.

Category	Replies	
Manufacturing Companies	66	73 %
Distributors	10	11 %
Third Party Maintenance	15	16 %
Total	91	100 %

7.2.1d Respondents by their Positions

Table 7.3 gives the analysis of the respondents by their positions within their companies, with the breakdown indicated for manufacturing and non-manufacturing companies.

Table 7.3: Respondents by their Positions.

Position	Number per Type of Company			
	Manufacturing		Non-Manufacturing	
Field Service Manager	31	47 %	14	56%
R and D Manager	2		1	
Quality Assurance Manager	2			
Technical Marketing Manager	7			
Technical Support Manager	4			
Managing Director	3		7	
Support Manager	6			
Support and Customer Services	5			
Other	6		3	
Total	66	100 % cases	25	100% cases

7.2.1e Quality of the Replies

The quality of the replies to the survey was very high, with almost no missing information on the questionnaires from manufacturing companies. This meant that detailed analysis of the 66 cases from manufacturing companies was possible, to establish both the timing and extent of product support planning - both variables which needed to be measured in order to test the research hypothesis.

7.2.2 Characteristics of Respondents' Products

A total of ten questions in the second part of the questionnaire collected information on the "characteristics of a *typical* one" of the respondents' products. The problem was to try to obtain representative information on the type of products supported by the respondents; both for those respondents working with only one type of product and for those working with a range.

The choice of wording for the question (*typical* etc) was deliberate. It was adopted during the questionnaire development phase, when it became apparent that some companies deal with a wide range of products. The request for information on a typical product proved effective during the pilot questionnaire, since respondents with a range of products reported that they gave answers representative of their range. In the final survey three respondents actually commented that they dealt with a wide range of products and therefore found the question quite hard to answer, as it forced them to choose a representative product.

The results of the questions on product characteristics are shown in Table 7.4, broken down by the categories "Computing", "Various" and "All" companies. From the table it can be seen that the average new product development time across all companies is two years, with the prototype being available 10 months (0.8 years) before customer shipments. Typically, products are used for 6 years, develop faults every 4 months and require preventive maintenance twice per year. As might be expected, the category "Various", which includes a range of industries, shows in some cases a wider range of values than the "Computing " companies. All companies manufacture significant numbers of their products over the production lifetimes. Across all categories the number of shipments ranges between tens and thousands and is typically hundreds.

The product characteristics are useful when assessing the significance of the product support planning results presented in later sections. They are not significant in themselves (i.e. the aim of the questions were not to estimate the average development time, average working lifetime etc). The answers were used for individual cross-checking. An example of this cross-checking is the use of the results on preventive maintenance (PM). The information that PM is, or is not, planned by companies during product design is, in isolation, useless. This is because a company which always builds maintenance-free products will no longer plan PM. Therefore, the amount of PM typically required is a key piece of information for cross-checking the respondents' answers on planning.

Table 7.4: Product Characteristics.

Product Characteristics	Answers for Manufacturing Companies					
	Computing		Various		All Replies	
	Range	Av.*	Range	Av.*	Range	Av.*
1) Development time (years)	1 - 5	2 (1)	0.5-5.5	2 (1)	0.5-5	2 (1)
2) Prototype availability (years before shipments)	0 - 2	.9 (.5)	0 - 3	.8 (.5)	0 - 3	.8 (.5)
3) Working lifetime (years)	3.5-7.5	6 (1)	2.5-20	7 (3)	2.5-20	6 (3)
4) PMs per year	0 -12	2 (3)	0 -12	2 (3)	0 -12	2 (3)
5) Failures per year (AFR)	0.3- 5	1.5 (1)	0.5-40	4 (7)	0.5-40	3 (6)
6) Number of shipments	Tens - 1000s	100s	Tens- 1000s	100s	Tens- 1000s	10s

Notes: AFR = Annual Failure Rate

* = Average (figures in brackets indicate standard deviation)

7.2.3 How Products are Supported

A series of questions in the survey were aimed at identifying how products are supported. This was required, similar to the product characteristics, as background information with which the significance of companies' planning processes could be judged. Only the results from manufacturing companies are presented and these, once again, follow the order of the questionnaire.

7.2.3a How Customers Learn about Equipment

Customer training is an important issue for many companies. Table 7.5 shows that over half of companies cite detailed training of the customer by their personnel as the main method by which the customer learns to use the equipment. A number of respondents checked the alternative "Other"; analysis of the details that they gave showed all of them to involve detailed instruction (e.g. "*Classroom instruction*" and "*Combination of above*"). This means that over 60% of the companies give detailed instruction to the customer. (A later section of the questionnaire showed that the training given by some companies is very time-consuming; two respondents reported that their equipment requires users to receive up to two week's training.) Note, in the computing sector no customers learn to use equipment simply by prior knowledge and trial and error (this indicating that the computing equipment produced by companies in the sample is not simple enough to use without instruction).

Table 7.5: How Customers Learn To Use their Equipment.

Learning Method	Product Type					
	Computing		Various		All	
Prior knowledge (of similar equipment) plus trial			7	(14%)	7	(11%)
By reading the documentation plus trial	1	(6%)	3	(6%)	4	(6%)
Short explanation from company personnel	6	(31%)	8	(18%)	14	(21%)
Detailed instruction from company personnel	9	(47%)	27	(57%)	36	(55%)
Other	3	(16%)	2	(4%)	5	(8%)
Total	19	(100%)	47	99*%	66	100 %

Note: * Rounding error

7.2.3b How Equipment is Installed

Table 7.6 gives the results on how equipment is installed. It shows that most of the installation work is carried-out by field service organizations, with few products being customer-installable. Further analysis of the 7 "Other" replies in the "Various" category shows that this consists mainly of specialized installation groups (4 replies), third party installation (2 replies) and installation by sales personnel (1 reply). These results show that installation is an important part of support, for many of the companies in the sample.

Table 7.6: Equipment Installation.

	Product Type		
	Computing	Various	All
By the customer himself	1 (6%)	5 (10%)	6 (9%)
By company service personnel	18 (94%)	34 (72%)	52 (79%)
No installation necessary		1 (2%)	1 (2%)
Other		7 (15%)	7 (11%)
Total	19 (100%)	47 (99%*)	66 (101%*)
Note: *Rounding error			

7.2.3c How Equipment is Repaired

The answers to the survey show that repair of equipment is mainly handled by manufacturers' service organizations. Only a small percentage of companies reported that repairs are mainly carried out by third parties or customers themselves (Table 7.7). This shows that equipment repair is a key aspect of support for most of the sample companies.

Table 7.7: Equipment Repair.

Repair Method	Product Type		
	Computing	Various	All
By the customer himself		2 (4%)	2 (3%)
By company service personnel	17 (89%)	42 (90%)	59 (89%)
By third parties personnel	1 (6%)	2 (4%)	3 (5%)
Other	1 (5%)	1 (2%)	2 (3%)
Total	19 (100%)	47 (100%)	66 (100%)

7.2.3d Available Documentation

The results of the questions on product documentation are shown in Table 7.8. It can be seen that most companies, especially in the computing sector, supply "comprehensive" operating documentation. Some companies supplement this by also offering "Simple Operating Guides". Further checking of the results show that only 10% of the companies surveyed neither have "simple" nor "comprehensive" operating information - these were companies from the manufacturing, communications and vending machines/systems sectors.

Somewhat surprising is the relatively low figure of 43 companies (65%) who have "Detailed service documentation" available. The 23 companies (35%) who do not have this information available included software and non-repairable products (where it is not required), networks and security systems. Of those companies who produce repairable products but replied that they do not publish service documentation, the majority (90%) state that repairs are carried-out by their own service personnel. These personnel are presumably well-trained and can work without documentation, on what is relatively simple equipment.

Table 7.8: Available Documentation.

Type of Documentation	Product Type		
	Computing	Various	All
Simple operating guides	7 (37%)	19 (41%)	26 (40%)
Comprehensive operating guides	17 (89%)	32 (69%)	49 (74%)
Detailed service documentation	12 (63%)	31 (67%)	43 (65%)
Application information	8 (42%)	3 (6%)	5 (8%)
Other	2 (11%)	3 (6%)	5 (8%)

Notes:
1 A number of companies have both "simple" and "comprehensive" operating guides available
2 10% of companies surveyed have neither type of guide available

7.2.4 The Elements of Product Support

Respondents were asked to rank various elements of product support, which were presented to them in tabular form. In addition, respondents were allowed to add and rank any element which they considered to be missing from the list. The idea behind this exercise was to obtain information on how the respondents perceived the significance of the various components of product support.

The results for the ranking are given in Table 7.9. From this it can be seen that "Field service organization (e.g. skills, coverage) was identified by the sample as the element having the most influence on product support. The second most influential factor is the product design for repair (e.g. modular design, diagnostics and reliability), closely followed by cost of ownership, including such factors as warranty etc. The element ranked fourth was customer education.

Table 7.9: The Elements of Product Support.

Element	Ranking
1) Field service organization (skills, coverage)	1
2) Design for repair (e.g. modular, diagnostics etc)	2
3) Cost of ownership(service contracts, warranty etc)	3
4) Customer education (training courses etc)	4
Other elements listed- ranked lower by the sample. The order of these lower rankings is not significant.	
5) Installation (site planning etc)	
6) Documentation (technical, operating etc)	
7) Preventive maintenance (e.g. cleaning, calibration)	
8) Parts availability (delivery time etc)	
9) Technical/application advice (consultation etc)	
10) Design improvement (e.g. upgrades or refurbishing)	

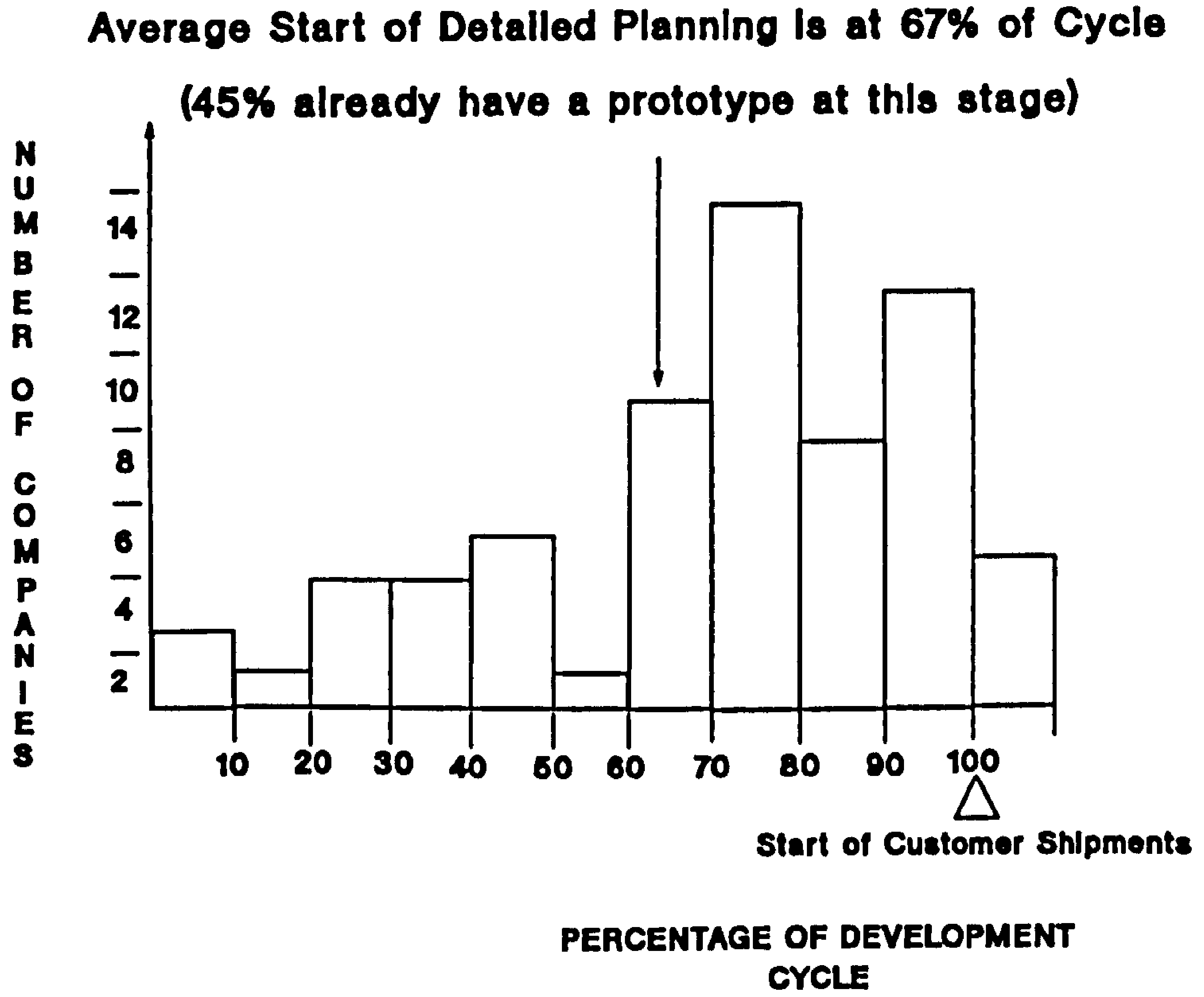
7.2.5 Design for Support on New Products

This section of the survey was designed to identify when, in how much detail and how effectively product support is evaluated during the product design cycle.

7.2.5a The Timing of Product Support Planning

A measure of how much emphasis companies place on evaluating product support for new products is the time at which they start *detailed planning* of support. Figure 7.1 shows the time at which detailed planning starts, expressed as a percentage of the total product development time. There is a heavy bias in the graph towards dates nearer product shipments. From this it can be seen that most companies apparently leave detailed planning until relatively late; on average 67% of the development time has passed when this starts. In addition a number of cases indicated that they did not start their planning of product support until the time of shipments!

Figure 7.1: The Timing of the Planning of Product Support during the Product Development Cycle.



The survey result that support is considered late in the design cycle could be the outcome of a variety of factors. These include that: (a) the respondents had difficulty with the wording *detailed planning* (and in fact do plan earlier in the product development cycle than they indicated) or (b) the respondents are not involved in the early planning and therefore indicate a date later in the development cycle than when the actual planning first occurs or (c) no detailed planning is done at the design stage.

The alternative (a) can, in the researcher's opinion, be excluded because of evidence provided by cross-checking between different sections of the questionnaire. Later questions identified how support is evaluated and showed that the companies who plan earlier also tend to plan in more detail. This tends to exclude alternative (a). Alternative (b) is a possibility but, as the managers surveyed are closely involved with support then this would mean that they were not consulted on the implications of new designs for support. This may be the case at some companies as 9% of respondents answered that they were not well enough informed and involved in new product development, although they should be. At these companies the evaluation of support presumably is carried out on a superficial level by the development engineers or, more likely, not considered (several other results from the survey support this presumption). Therefore, the results from the survey show that, considering all factors, that the evaluation of support is typically late in the development cycle. The next sections discuss the items actually covered by respondents in their detailed planning.

An indication of exactly how late the detailed planning of product support takes place is that 45% of companies do not start until a prototype is already available. At this point it is obviously too late to make fundamental changes in product design, even if this would improve the "supportability" of the product.

7.2.5b The Extent of Product Support Planning

Table 7.10: Use of Formal Support Planning Documents.

Type of Company	Percentage Using Formal Planning Documents	
By computer companies	15	(82%)
By "various" companies	20	(43%)
All companies	35	(53%)

Several pieces of information allow a closer look at the depth of planning undertaken. The first of these is whether a formal document is used to summarize how a product will be supported and how this is reviewed within a company. This type of document (variously called *Product Support Plan, Product Introduction Plan* etc) is only used by 53% of companies. It is interesting to note that the computer industry appears to be more advanced in this area, since this type of document and its review is in wider use. See Table 7.10.

In order to investigate the lengths which are typically taken in support planning, the respondents were asked to give the areas covered by their *detailed planning*. Table 7.11 shows the results. It can be seen that most of the individual items are covered by the majority of companies in their planning. On average, companies cover seven of the items listed in their product support planning.

Table 7.11: Areas covered in Product Support Planning.

Number	Item	Companies Planning	
1	Installation methods	51	(77%)
2	Customer Training	49	(74%)
3	Documentation requirements	54	(82%)
4	Preventive maintenance methods	44	(67%)
5	Repair philosophy (e.g. modular, diagnostics)	47	(71%)
6	Spare parts requirements	57	(89%)
7	Field organization required	53	(80%)
8	Technical/application advice service required	34	(52%)
9	Cost of ownership	30	(45%)
10	Service profit	34	(52%)
11	Design improvements for the future	15	(22%)
12	Other items	11	(17%)

From Table 7.11 it appears that the scope of support planning is reasonably comprehensive, since it covers most of the elements of product support. However, the timing of the planning must be noted. Although 71 % claim to plan the repair philosophy, the effectiveness of this planning must be questioned. The timing of the planning (see Figure 7.1) is, on average, so late that it is unlikely that real changes in the repair philosophy (and product design) can, if necessary, be made. Further analysis on this point though gave an interesting result. The companies which address repair philosophy in their support planning are in fact those which start their planning early in the development cycle - on average after only 33% of the development cycle (c.f. the average of after 67% across all companies).

Some respondents indicated that their companies cover additional items in their evaluation of product support. Details of these items are given in Table 7.12.

Table 7.12: Additional Items covered in Planning.

Number	Item	Number of mentions
1	Internal company training	3
2	Lifetime costs	4
3	Software support	1
4	Product reliability	3
5	Test equipment	1
6	Applications	1
7	Service options	1
	14 points from 11 respondents	

7.2.5c The Effectiveness of Planning

The respondents were asked to rate how well they thought their companies designed products with support in mind. The results are shown in Table 7.13, from which it can be seen that only 3 % thought that this area was very well addressed at their company. 44 % assessed that design for support was "reasonably well planned" and over 50 % thought that the planning could be improved.

The results on the timing of planning and managers' perceptions of its effectiveness form a stark contrast to those of Clark (1988), who found that 40% of his sample (UK manufacturing companies) answered that service requirements were "*fully*" considered at the design stage. The differences in the results of these two surveys could be due to the difference in samples. Clark's sample was from a wide range of very different industries (from shipbuilding to chemicals) with only 17.5% of respondents coming from the electronics sector (no analysis per sector is given by Clark or of the meaning of *fully considered*). More research would be needed to establish if and why differences exist between the way support is planned in various industries.

Table 7.13: The Effectiveness of Planning.

How well planned do you consider that *design for support* (or service) is at your company ?		
Answer	Replies	
"Very well planned"	2	(3%)
"Reasonably well planned"	29	(44%)
"Planned, but not well enough"	18	(27)%
"Poorly planned"	11	(17%)
"Not planned at all"	4	(6%)
"Don't know"	2	(3%)
Total	66	(99%*)
Note: *Rounding error		

7.2.6 Quantitative Planning at the Design Stage

The previous section showed that most of the respondents start to plan the details of product support late in the development cycle, even though product design has a strong influence on product support. This section covers the questions which aimed to establish whether companies set quantitative goals for product support at the design stage. Chapter Three discussed the key role of quantitative goals in planning. Consequently the aim was to identify what goals were used in support planning. The questionnaire broke these goals into two categories which were explained for the respondent; those associated with the traditional aspects of equipment maintenance (termed *serviceability* goals) and those associated with broader aspects (termed *supportability* goals).

7.2.6a Measures for Serviceability

The first questions in the survey on quantitative planning targeted serviceability - the ease with which a product can be installed, maintained and repaired. A key factor in serviceability is product reliability and various measures for reliability, such as mean-time-between-failures (MTBF) and annual failure rate (AFR), are well-known. It was expected that goals for reliability would commonly be set at the design stage but it was not clear if many other measures of serviceability are used by companies.

The results from the survey are shown in Table 7.14. It can be seen that over 70 % of companies set quantitative goals for reliability but other elements are not covered so well. Particularly surprising is that, with cost of ownership being a key factor in the high-technology sector, that only 25 % set a quantitative goal for the average repair price. Equally surprising is that quantitative goals are seldom set for the number of different parts in a design, even though this influences spare parts requirements. The result for the planning of the installation process is also interesting; although over 80% of respondents said that products are installed by their own field organization only 35% set goals for the installation time.

Table 7.14: Goals for Serviceability.

Number	Quantitative Goal (Serviceability)	Companies Implementing	
		Replies	Corrected Value
1	Installation Time	23 (35%)	37%
2	Preventive Maintenance	29 (44%)	44%
3	Failure Rate	47 (71%)	74%
4	Mean-time-to-repair (MTTR)	36 (55%)	55%
5	Disassembly/Reassembly Time	18 (27%)	27%
6	Mean Fault Diagnosis Time	16 (25%)	25%
7	Maximum number of different parts	11 (17%)	17%
8	Average Repair Price	16 (24%)	24%
9	Other quantitative goals	6 (9)%	

The significance which can be attached to the results presented in Table 7.14 requires some discussion. Within the limitations of the sample size, it can be seen that certain factors are evaluated by more companies at the design stage than others. Whether or not a factor is quantitatively evaluated at the design stage is an indication of the degree of formality used in product support planning. However, the use of such measures would not necessarily lead to a better quality of supportability. One of the limitations of the survey is that it does not (and did not even attempt to) show if formal planning causes better quality support. Additionally, comparing the frequency with which various factors on Table 7.14 are evaluated (e.g. failure rate is evaluated twice as often as installation time), must be done with caution. Some factors may be unimportant for certain companies (e.g. disassembly/reassembly time is irrelevant for disposable products) and therefore may not warrant attention. However, a cross-check on the significance of the various factors of product support is available by using information from the section of the survey on product characteristics. This point is important in several of the sections that follow.

Table 7.14 includes a column headed "Corrected Value", which was derived by considering the product characteristics. For instance, only 35% of respondents set quantitative goals for installation. However, is installation important for all respondents' products? Table 7.6 showed that six respondents have customer-installable products - this means that installation is only important for 60 out of the 66 respondents. This information allows the value in Table 7.14 to be corrected. Cross-checking against the product characteristics showed that 22 respondents, who have products which are not customer-installable, set goals for installation. This leads to the corrected value of 37% of respondents who set goals for installation at the design stage. Similar considerations allowed the preventive maintenance figure to be checked. Here it was found some companies have maintenance-free products but that allowing for this the corrected percentage remains the same at 44%. The other values in Table 7.14 show no difference between the initial and corrected value. This is because none of the respondents' products is so reliable that it has no failures over its lifetime and so the goals related to failure and repair (MTTR, Mean Fault Diagnosis Time etc) are relevant for all respondents.

The survey not only asked if quantitative goals are set but also asked for details. This approach had the advantage that those respondents who claimed to set quantitative goals at the design stage also revealed what these were. A review of the answers allowed an assessment to be made on how the respondent really plans aspects of support. Certain answers could be discounted as non-quantitative (e.g. "*guesswork*"), whereas others could be seen to identify both goal setting and later monitoring of the achieved values. Consequently Table 7.14 could be further corrected, for this. However, this was not done as it was felt that any interpretation of the answers was too ambiguous to warrant changing the percentages in Table 7.14. However, the review of the details provided a substantial amount of qualitative data about product support planning, which gave insight into how it is approached by the sample companies. The interesting part of this section of the research is that it identified many different factors used to evaluate each of the elements of product support. Used in combination, these factors offer a possibility to make a comprehensive evaluation of support. The results for each category will be discussed, with the full details being presented where appropriate.

(a) Installation Time

Table 7.15 shows the detailed answers obtained on installation measures. The column headed "*Assessment*" is the researcher's judgement of the planning. A "G" indicates that the answer includes a quantitative goal and "M" that the actual figure is monitored for the released product. Nearly all the answers indicate clearly that the respondents set quantitative goals at the design stage. The exceptions are Case 26 ("*Shows, field tests*") and Case 87, where the goal set is not directly identified.

Four answers in Table 7.15 (indicated by "G/M") show that these companies measure the installation factors both during the design stage and monitor them for actual shipments. Several respondents mention field reporting systems (e.g. "*Field Reports*" or "*Field Activity Reports*"), which gather this information. This shows that these companies have a detailed planning mechanism in place for installation - not only is a goal set but the actual value achieved is monitored. (Both setting a goal and monitoring the achieved value were identified in Chapter Three as important steps in the planning process). The historical data on installation times is probably useful for companies when they come to set goals for new products.

Table 7.15: Measures for Installation.

Case	Type of Quantitative Measure	*Assessment*
19	Minimal on-site setup - each terminal should take minutes to install.	G
22	Cellphone in 3-4 hours, R/T in police car 1 hour, major radio system takes 6-52 weeks.	G
26	Shows, field tests.	M
28	Hours/material costs plus fallback %.	G/M
31	1-14 days dependent on product. Installation report/audit.	G/M
32	Maximum 1 hour.	G
41	1-3 days depending on the product.	G
42	Two weeks, experience analysis.	G
52	Depends much on the 'system'. <5min for a screen and keyboard, <4hours for a processor.	G

59	End-user installable.	G
61	2 hours, service reports.	G
62	# of technicians, hours per technician.	G
64	We say it should be user-installable, first time.	G
67	Varies widely. 2 hours for a medium system. Measured through service reporting.	G
69	Varied but typical installation times 0.5 - 1 hour.	G
75	Estimated time to install, actual time to install.	G
77	1 hour, don't know [how it is measured].	G
81	1-2 days.	G
82	1 day, field reports.	G/M
87	Field Activity Reports (FAR), collated internationally.	M
90	3 weeks , daily log.	G/M
	Total of 21 cases giving details	

Table 7.16: Categorized Goals for Installation.

Number	Quantitative Goals	Units	Example Cases
1	Time required.	Hours	22,28etc
2	Human resource (e.g. customer or technician).	Type	59,62
3	Material or equipment required.	Cost/ Spec.	28
4	Effectiveness	% tage success	28,64

From Table 7.15 it can be seen that some companies not only quantify the actual time required for installation but they also set goals for the resources required (see Case 62, for example). The types of measures applied to installation can be grouped into the four categories (shown in Table 7.16), which together appear to provide a comprehensive evaluation of installation.

(b) Preventive Maintenance (PM)

44% of the respondents indicated that they made a quantitative evaluation of preventive maintenance at the design stage. Their answers on the goals that they set at the design stage are given in the Appendix.

The analysis of the evaluation of preventive maintenance revealed various categories of measures, shown in Table 7.17. Used in combination, these measures give an apparently comprehensive measurement of PM. However, it should be noted that one measure (Resource required) has been added, since it was seen to be an important measure in the previous section on installation, although it was not mentioned by any of the respondents.

Table 7.17: Categorized Goals for PM.

Number	Quantitative Goals	Units	Example Cases*
1	MTBPM**.	Hours-Years	26,31
2	Time per PM.	Minutes	41,44
3	Material or equipment required.	Cost/ Spec.	29
4	Effectiveness.	Repairs avoided	89
5	Resource (e.g. customer or technician).	Type	None

* Refer to appendix for a full listing of the details on PM given by respondents
** Mean-time-between-preventive-maintenance

An interesting approach to preventive maintenance is to express the amount of maintenance required in relation to a key factor of the product performance. Examples are the percentage of operating time for computers and the number of copies available between PMs for photocopiers (Cases 47 and 58).

(c) Failure Rate

The results show that the failure rate is the factor for which a goal is most often set; 71% of companies evaluate failure rate at the design stage. Analysis of the details given by the respondents show that the following process is used by many companies:-

1) The failure rates of new products are initially estimated by analysing the parts/modules in the equipment (e.g. "Lifetime test by R & D", "Soak tests" - see the details of Cases 20 and 57 in the Appendix).

2) The performance of old products is often used as a reference point when setting the design goals for new products (e.g. "Better than product replaced" - Case 31).

3) Many companies closely monitor the failure rates of products following their introduction: these are given in various reports (e.g. "Product Health Statistics", "Service Reports" - Cases 31 and 34).

This process shows that detailed planning methods are applied to the equipment reliability. Details of the goals set are given in the Appendix.

(d) Mean-Time-To-Repair (MTTR)

Fewer companies set a goal for MTTR than they do for failure rate - this is surprising since repair is certainly an important issue for the companies surveyed (over 90% of them repair customers' equipment). The details given by respondents on their planning practices show that MTTR evaluation is approached in a similar way to failure rate. That is, a process is used by which:-

1) An estimate for MTTR is made by considering product complexity, access to components etc.

2) Goals are set for the desired MTTR, using historical data from older products as a point of reference.

3) The MTTR values for new products are monitored after shipments start.

(e) Disassembly / Reassembly Time

This factor is a component of MTTR, as several respondents pointed out. However it can be important as a separate factor. An example of this (Livingston, 1988), is that if the access to components with a comparatively high failure rate is difficult, then the MTTR is longer. From the survey only half of the companies who evaluate MTTR go deeper and check the disassembly / reassembly time. The details provided by these companies (refer to the Appendix) show that most set a maximum time to disassemble/reassemble the product, based on comparisons with other products. No response indicated the degree of analysis recommended by Livingston (1988), from his experience in the photocopier market (analysis of the access time versus failure rate for all components).

(f) Mean Fault Diagnosis Time

The mean fault diagnosis time, similar to the disassembly/reassembly time, is one of the constituents of MTTR. It could also be a useful separate factor (as pointed out by respondents to the pilot questionnaire), since it identifies products that are difficult to trouble-shoot. A quarter of the respondents evaluate this factor separately. The comments given show that some companies not only evaluate diagnosis time at the design stage but also monitor it separately for existing products (e.g. Case 67 - "[Diagnosis time is] *reported as a separate code*").

(g) Number of Different Parts

The number of different parts within a design, together with their reliability, has a direct influence on the parts stocking levels required by a service organization. However, of the companies surveyed only 17% indicated that they evaluated quantitatively the number of different parts at the design stage. Those who do evaluate the type and number of parts gave details, as requested on the questionnaire (this information is listed in the Appendix). A review of these details gave the two categories in Table 7.18; not only is the number of parts considered by some companies but also their cross-compatibility.

Table 7.18: Categorized Goals for Parts.

Number	Quantitative Goals	Units	Example Cases*
1	Actual number of parts.	Number	2,47
2	Number of parts not common to other products.	Number	59
*Refer to Appendix for a full listing of the details given by respondents			

Case 59, for instance, indicates that consideration is already given at the design stage to how many of the parts in a design are currently used in other products. This allows a strict control to be made on the number of parts which must be held in field service inventory.

(h) Average Repair Price

The average repair price plays a key role in determining cost of ownership for products with significant failure rates. For the sample, the average failure rate of equipment was 3 times per year; this means that the cost of ownership for the sample's products is strongly influenced by the repair price. It is therefore surprising that the repair price is only evaluated during the design phase by 25% of companies. Those who do set a goal for the repair price (see Appendix for details) base this goal on the absolute cost to the customer. This is often expressed as a percentage of the product's cost. The cost goal is determined by a number of respondents by what is affordable for the customer (*"Market requirements"* etc).

(i) Other Quantitative Goals

Six respondents (9% of the sample) reported using other quantitative measures at the design stage. These are listed in Table 7.19 and the first (*"National Technical Manager..."*) is a very subjective measure! The next three and the last (Cases 22, 28, 41 and 82) are not connected with product design but rather the evaluation of a field service organization. These measures appear to be similar to some of those discussed in the section on the delivery of support in Chapter Two. Case 22 gives no details of his measures other that they form part of his company's service management system and comments " . . . *and if I had all the answers I wouldn't tell you!*". (This comment demonstrates the confidential nature of support planning.)

Case 75 shows what appears to be a measurement criteria not covered in the questionnaire and not mentioned by any other respondent - the breakdown of the equipment into *"technology units"*. What this exactly means is not clear. However, fortunately Case 75 gave his contact address (even though the questionnaire was anonymous). This allowed him to be contacted and a clear explanation of his information to be obtained. Case 75's company produces high-technology printing equipment which consists of electronic, mechanical and optical components. From his experience he has seen the importance of separating these elements into what he terms "technology units", in order to ensure easy access to similar types of components (e.g. mechanical, electrical or optical). The reason for this is that the presence of mechanical parts, which require constant cleaning, in the vicinity of other technologies can adversely affect system reliability. In addition, the breakdown into modules containing only one type of technology makes troubleshooting easier. To ensure that suitable technology units are chosen, Case 75 analyses this in his review of new product design.

Table 7.19: Other Quantitative Measures.

Case	Type of Quantitative Measure
16	National Technical Manager inspects prototype and advises on improvements.
22	Measurements are based on performance indicators built into our Service Management System.
28	Staff (job satisfaction, enhancement), customer feedback and complaint handling.
41	Parts availability.
75	Separate product into technology units. Separate life sensitive items and known problem areas.
82	Very many measures on Service Units e.g. First time fix rate, customer satisfaction.

7.2.6b Measures for Supportability

Product support is wider than just maintenance and repair issues. What goals do companies set to ensure that products are developed that are easy to support? Are issues such as ease-of-use, training requirements etc (which affect supportability) considered quantitatively? Table 7.20 shows the results from the survey. It can be seen that quantitative methods are less often applied to supportability issues than serviceability ones (compare the results for serviceability with those on supportability, given in Table 7.14)).

Table 7.20: Goals for Supportability.

Number	Quantitative Goal (Supportability)	Companies Implementing	
		Replies	Corrected Value+
1	Product Ease-of-Use	25 (39%*)	<39%
2	Average Time to Train the Customer	13 (20%*)	<20%
3	Documentation Required	27 (42%*)	<42%
4	Cost of ownership	26 (41%*)	<41%
5	Other quantitative goals	3 (5%*)	<5%

Note: * Valid percentage as two respondents failed to answer this question.
\+ See text of later sections for an explanation of this value.

In addition to asking if quantitative assessment was made of supportability factors, the questionnaire probed for actual details of these goals. Review of this information showed that many companies, although claiming to make quantitative assessments, use qualitative approaches which are often very informal. The next sections discuss this.

(a) Product Ease-of-Use

Product ease of use has a major influence on the supportability of high-technology products. Products which are difficult to use are, for instance, likely to lead to a high number of customer calls for assistance.

Details of the measures applied at the design stage for ease-of-use are given in Table 7.21. From this list it can be seen that, although 39 % claimed to set quantitative goals at the design stage, some of these goals are not defined at the design stage (see for example Case 22). This is not surprising since it is difficult to find concrete measures for ease-of-use. However, some of the items mentioned in Table 7.21 show that companies are attempting to find measures which indirectly show ease-of-use. Examples are Cases 67 (*"Number of times ... wrong usage"*), 47 (*"Minimum training time"*) and 41 (*"field calls that require no parts"*). This type of approach may be useful; it would allow an indirect measure of factors which are difficult to quantify directly.

Table 7.21: Quantitative Measures for Product Ease of Use.

Case	Type of Quantitative Measure
16	Operator trials, field trials / experience.
17	Customer comment in Beta Trials.
20	Sales department.
22	Idiot-proof testing by customer survey at introduction.
23	Not measured, reviewed subjectively.
26	IBM compatible.
27	Simplify operator action.
28	Ergonomics safe handling and operation.
29	Product comparison plus product user trials.

31	By customer survey. Goal not known. Experience.
32	Field trials.
36	Not a service issue.
41	Number of field calls that require no parts.
47	Minimal training time.
52	Consistent user interfaces and use of key definitions and documentation.
53	Visits caused by user mis-operation.
59	In-house trials.
61	Surrogate operator tests with pilot training instructions against expected target times.
62	Human Factors Dept. assessment.
66	Tends to be "gut feel" by management team.
67	Measurement difficult as it is a subjective factor. Number of times that an operator has to be instructed on wrong usage could be indicative.
68	Minimum number of keystrokes to retrieve information.
75	Only measure is customer input during field trial.
81	Market requirements.
82	% of calls to service disk by system.
25	Cases giving details (38%[1])

The methods used for assessing ease-of-use can be seen to range from the extremely informal (*"gut feel by management team"* - Case 66) to the formal analysis of product operation (*"number of keystrokes to retrieve information"* - Case 68). Further research would be necessary to ascertain which approach is more effective.

The assessment of the measures in Table 7.21 is not easy, as some of the answers are ambiguous. For this reason it can only be said that the use of quantitative goals for the evaluation of product ease-of use is done by less

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[1] One case indicated using quantitative measures for ease of use but failed to give details.

than 39% of the companies in the sample. Hence the entry for the "Corrected Value" in Table 7.20 is shown as "<39%" and no attempt is made to make a numerical correction. (This shows one of the limitations of the postal survey. In order to make precise judgements on the use of quantitative goals in support planning, the only feasible methodologies would be in-depth interviews or observations of support planning.)

(b) Time to Train the Customer

The topic of customer training is an important one for many of the companies sampled; over 60% of them are involved with giving the customer detailed training on the equipment. The time required to train the customer is obviously related to the ease-of-use and complexity of the equipment, as was seen in the previous section. However, the average time to train the customer is easier to measure than ease-of-use for existing products.

Only 20% of companies indicated that they set a quantitative goal during the design stage for the average time to train the customer. This is low, considering the involvement of the sample with training and means that over half of the companies who give detailed customer training do not set any goal for it during the design. A review of the details on training goals (see the Appendix) showed that some companies were investing significant resources in training customers over several days since the goals for new products were high ("*2 days - 2 weeks. Product dependent*" and "*Depends on product. 4 hours to one week*"). In addition some companies appear to monitor the training on existing products ("*Customer Education reports*").

(c) Documentation Requirements

Twenty-seven respondents (42%) claimed to set quantitative goals for documentation. The details of the goals that they set are given in the Appendix. from these it can be seen that, not surprisingly, many are qualitative as it is difficult to set quantitative goals for a topic like documentation. A review of the answers shows, however, that the goals set include the availability of manuals at release (e.g. Cases 42 and 90), meeting market requirements (e.g. Cases 61, 63 and 81) plus more comprehensive evaluation (e.g. Case 61: *Size and diagnostic times* and Case 61: *Human Factors Dept. assessment*).

(d) Cost of Ownership

Twenty-six respondents (41%) answered that they set quantitative goals for the cost of ownership at the design stage. The details of the goals that they set are given in the Appendix. From these it can be seen that the most of the goals do appear to be quantitative and set as a percentage of product price (8 cases), relative to competitors prices (6 cases) or set with reference to the expected reliability.

(e) Other Quantitative Goals

Four respondents replied that they set goals for other factors related to support; the details are shown in Table 7.22.

Table 7.22: Other Quantitative Measures.

Case	Type of Quantitative Measure
28	1) Time/spares available. 2) Costs. 3) How many times the customer phones.
64	User surveys on product and documentation.
75	Each product is issued with a log book which "should be" completed, so that a complete history is obtained during the initial stages of product launches.
82	Engineering of software for customer: workload in man-hours for a system.
4 cases giving details	

7.2.7 Open - Ended Questions

Three open-ended questions at the end of the questionnaire allowed the respondents to give their opinions on how supportability could be better planned, the trends in support in their industry and the survey in general.

Table 7.23: Answers to the First Open-Ended Question.

How do you personally think supportability could be better planned into products?		
1	More involvement of field service personnel in the planning process.	20 replies
2	More formal design reviews.	6 replies
3	More customer inputs.	5 replies
4	Use of new technologies (self/remote diagnostics etc).	4 replies
5	Modular product designs.	4 replies
6	More spare parts stocking.	2 replies
7	Full consideration of the lifetime support processes.	2 replies
8	Other.	8 replies
	51 answers	

Table 7.23 gives the results of the question on supportability. From the 66 replies from manufacturing companies a total of 51 respondents (77%) answered this open-ended question. The answers were found to fit into eight categories. The need for more involvement of the field service organization in the planning process was mentioned most often. Additionally, more formal design reviews and the need for more customer-inputs were noted by several respondents.

The question on the future directions in the respondents' industries showed response time / uptime and customer training/consultation to be the perceived important factors (Table 7.24).

Table 7.24: Answers to the Second Open-Ended Question.

	Which areas of product support do you think are likely to become particularly important for your customers and industry in the future? Why?	
1	Response time / uptime.	15 replies
2	Customer training / consultation.	14 replies
3	Cost of ownership.	6 replies
4	Self-supporting products (self-diagnostics etc).	5 replies
5	Shift in the scope of field support*.	5 replies
6	Easy-to-use equipment.	3 replies
7	Better service organizations.	3 replies
8	Software support.	2 replies
9	Others.	4 replies
		57 answers

* This category consists of answers which indicated that the respondent thought that the responsibilities of field support organizations are changing with the changes in products and technology.

The third open-ended question allowed respondents to give their opinions on the survey itself; "*Have you any comments you would like to make on this survey or the topic of design for support ?*" Twenty-six respondents (39% of manufacturing companies) gave an answer - the categories are listed in Table 7.25. These show that some respondents thought the questionnaire covered an important topic, that design for support was relevant and that some found the survey difficult to answer.

Table 7.25: Answers to the Third Open-Ended Question.

Have you any comments you would like to make on this survey or the topic of design for support?		
1	Survey addressed an important problem.	4
2	Support is often considered too late in the development cycle.	5
3	Survey was a good idea / thought provoking.	7
4	Survey difficult to answer.	5
5	Market pressures will force design for support.	3
6	Survey should cover broader aspects (e.g. multi -national support, solving the customer etc).	2
	Total answers = 26	

7.3 COMPARING RESULTS WITH HYPOTHESES

This section will interpret the significance of the survey results by comparing them against the research hypotheses and objectives discussed. The postal survey was designed to investigate two hypotheses plus a set of research objectives, which replaced the Background Hypothesis. The two hypotheses will be discussed separately, with conclusions being drawn and limitations identified. (The relationships between all of the hypotheses and their variables are shown in Figure 4.7 in Chapter Four; and it may be useful to refer to this for the following sections.)

7.3.1 Hypothesis 1

Most high-technology companies do not systematically evaluate product support at the product design stage.

Related research objectives:-

1) To determine the time at which product support planning starts, during new product development cycles, at high-technology companies.

2) To determine the level of planning undertaken by companies.

3) To compare the results against the hypothesis and draw conclusions.

(Note that the hypothesis is concerned with the timing of support planning, its quality and its effectiveness. Chapter Three discussed the importance of early, systematic planning.)

7.3.1a Comparison with the Results

How do the results compare to Hypothesis 1? Four variables were chosen for the concept *systematic evaluation.* These were the timing of planning, the extent and formality of planning, the use of planning goals and the resources used in planning and implementation. The results from the survey for each of these variables will be discussed with, in addition, the perception of managers of the effectiveness of the planning of support.

The first variable chosen for the concept *systematic evaluation* was the timing of support planning. The results (Section 7.2.5a) show that most of the respondent companies start their detailed planning of product support late in the development cycle (on average after 67% of the development time has passed). This result supports the hypothesis, within the limitations of the sample which are discussed later.

The second variable investigated was the extent of planning; what factors are evaluated and how formally? The results of this (Section 7.2.5b) showed that the evaluation of support appears comprehensive - Table 7.11 shows that most of the elements of product support are considered. This result does not, on the face of it, support the hypothesis. However, the timing of the planning is such that, although it covers most elements of support, they are being evaluated too late. Additionally, the literature on planning stressed the importance of plans being documented formally and reviewed as the implementation progresses. The use of planning documents was found to be limited to 53% of the respondent companies (see Table 7.10) and only half of these again had this plan formally and regularly reviewed during its implementation. These results tend to support the hypothesis.

The next type of variable which was measured in the investigation of *systematic evaluation* was the factors for which quantitative goals were set at the design stage (since the literature on planning identified goal setting as an essential stage in planning). The meaning of *systematic evaluation* is that all relevant aspects of support are fully considered. The results were interesting; although many of the respondent companies claimed to cover factors in their support planning, only a minority of factors are assigned quantitative goals, even though other factors can be show (by cross-checking with other sections of the questionnaire) to be important aspects of support at the respondents' companies. This is the case both for factors related to serviceability (see Table 7.14) and those related to supportability (see Table 7.20). A particularly good example of the lack of quantitative planning of important support factors is that of training. The background questions to the respondents identified that over 60% of respondents companies (Table 7.5) give detailed instruction to their customers, however, only 20% evaluate training quantitatively at the product design stage (Table 7.20). These results support the hypothesis, for the respondent companies, especially since the background data collected in the survey allowed the significance of each of the individual answers on goal setting to be cross-checked against equipment characteristics.

The variable *resources used* (shown in Figure 4.7) was not investigated by the survey. This was because it was seen as unrealistic to try and measure the resources allocated to support planning and then to try and determine how this compared to the total resources investigated in new product development. To obtain that level of detail, a different methodology would be required.

The final variable investigated was the respondents' view of the effectiveness of support planning at their company. The results (see Table 7.13) show that half of the respondents consider their planning to be inadequate. The way that support planning could best be improved is, according to 39% of respondents, more involvement of field personnel in the planning of support for new products.

Table 7.26: The Results Compared to Hypothesis 1 - A Qualitative Analysis.

	Variable	Supports* the Hypothesis?	Notes (refer to text)
1	Timing	Yes	(limited)
2	Goals used	Yes	(limited)
3	Resources used		Not measured
4	Formality	Yes	(limited)
5	Effectiveness	Yes	(limited)
*The limitations of this are discussed in the text.			

Table 7.26 shows the summary of the analysis of the results compared to Hypothesis 1. The conclusion of this qualitative analysis is that the results for the respondent companies support Hypothesis 1 . The limitations of this conclusion will now be discussed.

7.3.1b Limitations of the Results

The evidence presented showed support for Hypothesis 1 but two limitations must be acknowledged. These are:-

> 1) The hypothesis was related to *most high-technology companies* and the sample is probably not representative. The bias of surveying a professional association (from mainly the electronics field and not, for instance, covering companies in the aerospace industry) and the bias of the low reply rate must be considered.

2) The analysis of the results was difficult as the meaning of some answers had to be judged against the variables chosen.

Each of these points will be discussed in some detail.

The two key questions on sample bias are: (a) what is the bias introduced by surveying AFSM International members? and (b) what is the bias resulting from the low reply rate? Chapter Four discussed the limitations of choosing a professional association for the survey and Figure 4.8 attempted to illustrate the effect of the results on the ability to generalize. The conclusion reached was that it is not possible to generalize. However, it can be said that if a special interest group's members do not plan support systematically, then it is unlikely that industry as a whole evaluates support more thoroughly.

The bias introduced by the low reply rate could have a strong influence. It could, in the worst case, mean that the results have little value outside the respondents' companies. Suppose, for instance, that all those who did not answer made the most detailed evaluation of support. This possibility would completely overturn the hypothesis. In the researcher's opinion, however, this possibility is small, since all the anecdotal evidence is that support is not planned in detail. Further research is, however, required to prove this without doubt.

The analysis of the survey results was mainly qualitative in nature. This was due to the difficulty of evaluating planning processes via a postal survey. The variables were chosen very carefully but are probably not perfect - this is one of the problems of exploratory research mentioned in Chapter Four. The difficulties with the survey led to no attempt being made to measure the variable *resources used.* Future research could attempt to measure this variable by using another style of research.

7.3.1c Conclusions on Hypothesis 1

In an attempt to determine whether support is evaluated in detail by high-technology companies at the product design stage, the members of a professional association were surveyed. The members of this association are managers involved with support at high-technology companies, mainly from the electronics and computing sectors.

The results of the research show that most of the sixty-six companies who answered the questionnaire do not evaluate all of the elements of product support at the product design stage. This conclusion was reached because, although many respondents claimed to evaluate most elements of support, most failed to set goals at the design stage and most do not produce a document summarizing the way the new product will be supported. Whilst the data are in the direction hypothesized, two aspects prevent a firm conclusion being reached. These are sample bias and limitations of the methodology.

Firstly, the sample introduces bias. AFSM International membership does not cover some high-technology industries (e.g. aerospace) and so the results cannot be generalized to these. Then there is potential bias which means that results from AFSM International respondents may not be representative of electronics and computing companies. Although other high-technology companies are probably less likely to plan support as well as at the companies represented in the professional association, this is a presumption which cannot be proved from the results. Secondly, the limitations of trying to evaluate planning processes via a postal survey, are numerous. Great lengths were taken to construct a questionnaire to circumnavigate this, however, the limitations of the results must be acknowledged. Both aspects which prevent a firm conclusion being made point to possibilities for future research. However, despite all of the limitations, this current study has identified a number of key points from the sample and will help form a framework for future research.

On the basis of the research it can be concluded that the sixty-six companies who answered the survey do not systematically evaluate all of the relevant aspects of support and most do not start their planning at the product design stage. Further research is necessary to determine whether this result applies to the high-technology industry as a whole.

7.3.2 Hypothesis 2

Product reliability and ease-of-repair are the factors of product support which are most often quantitatively evaluated at the product design stage.

Related research objectives:-

1) To determine all of the support factors which are quantitatively planned at the design stage by companies.

2) To determine how commonly each of the different goals are used across companies.

3) To compare the results against the hypothesis.

7.3.2a Comparison with the Results

A review of the results showed which were relevant to the above hypothesis and objectives. Tables 7.14, 7.19, 7.20 and 7.22 give the results of the questions identifying the quantitative goals used in support planning. These strongly show, for the respondent companies, that the most common quantitative goals set at the design stage (for support) are product failure rate and mean-time-to-repair (MTTR). Quantitative goals are set for the failure rate and MTTR by 47 (71%) and 37 (55%) companies respectively. The most common other quantitative goal is for preventive maintenance (29 companies - 44%). All other goals are used less, especially those relating to the broader aspects of supportability. For instance, goals for product ease-of-use and the amount of time to train the customer are only set by 39% and 20% of companies respectively (Table 7.27).

Table 7.27: The Six Most Common Goals used for Support Planning at the Design Stage of New Products.

Number	Goal	Percentage Usage by the Sample	
1	Failure Rate	71%	(47 replies)
2	Mean-time-to-repair	55%	(36 replies)
3	Preventive Maintenance	44%	(29 replies)
4	Documentation	42%	(27 replies)
5	Cost of ownership	41%	(26 replies)
6	Product Ease-of-use	39%	(25 replies)

These results support the hypothesis, for the companies who responded to the survey.

7.3.2b Limitations of the Results

The limitations from sample bias discussed for Hypothesis 1 are equally valid for Hypothesis 2. In addition, it should be asked: are the differences in percentages shown in Table 7.27 significant for the sample? For the sixty-six answers, however, a difference of seven replies between MTTR and preventive maintenance goal setting is seen as significant.

7.3.2c Conclusions on Hypothesis 2

The survey of AFSM International attempted to show that the most frequently evaluated factors of support at high-technology companies are the failure rate and MTTR. The results show, for the sixty-six respondents, that this is indeed the case as no other factor is evaluated so commonly. Further research would be necessary to see if this result applies to the high-technology industry as a whole. Considering anecdotal evidence in the literature, however, it probably the case that the results are not dissimilar to industry as a whole.

7.3.3 Other Research Objectives

The Background Hypothesis was rejected in favour of the following research objectives.

> 1) To determine the range of different support factors which are evaluated by companies at the product design stage.
>
> 2) To collate the different support factors which can be evaluated, in order to derive a systematic evaluation of product support at the design stage. To base this on the model of product support derived from the review of the literature.
>
> 3) To then determine what approach would be necessary to investigate the causal link between planning and supportability (using similar methodology to that used in management research on other types of planning).

7.3.3a Comparison with the Results

Which of the results are relevant to these objectives? (i.e. which results were collected to achieve these objectives?) The answer to this question is that much of the questionnaire aimed to collect this information and so most of the results are relevant.

In Chapter Four the definitions of product support in the literature were reviewed and from this a proposed model of support was derived (see Figure 4.2). This model, with its categories for the elements of support will be used as a framework to collate the range of goals used for the planning of support. Table 7.28 shows the goals used for evaluating support, which were identified by the survey, categorized as per the model of support. These goals could be used as a basis for investigating the effectiveness of planning support at the design stage (using a similar approach to the case studies which show the advantage of DFM - see Chapter Three).

The results from the open-ended questions are relevant new pieces of information. Thirty-nine percent of respondents think that the most important contribution to improved supportability planning would be more involvement of field service personnel. This view that field personnel should be involved closely with support planning is exactly the opinion given by Berg and Loeb (1990). The most important factors of support for the future are high uptime and good response time (26% of replies) and customer training or consultation (25% of replies). All of the results from the open-ended questions give ideas for future research.

7.3.3b Limitations of the Results

The limitations of the sample, of course, apply. This means that the information given in Table 7.28 will probably not be exhaustive; other companies may have other goals that they use in their planning, or may approach planning in some other novel way. However, until more research is conducted this will not be known.

7.3.3c Conclusions

The purpose of much of the questionnaire on support planning was to identify as much as possible about how companies approach this issue.

As an exploratory study, the survey unearthed much information on the way companies plan support at the design stage, which has not previously been published. This information was collated with definitions from the literature on the scope of support, to give a listing of both the product design goals and post-introduction measures that companies use in their evaluation of support. This framework would almost certainly be of assistance to researchers wanting to further investigate product support.

Table 7.28: The Collated Goals for Support Used at the Design Stage.

#	Support Category	Design Goals Element	Post-Introduction Measures
	Cost Effective Solution		
1	Warranty		
2	Cost of Ownership	-Average repair price*	-Actual value*
		-Lifetime costs*	-Actual value*
		-% of product price*	-Actual value
		-versus competition*	-Actual value
3	Complaints Handling		
4	Design Improvements		
	Understanding		
5	Customer Training	-Time to train the customer*	-Actual value
6	Documentation		-Diagnostic times
7	Technical/Application Support		
	Maximum Uptime		
8	Design- ease of use	-Ease of use	-Minimum

			training time* -Minimum keystrokes* -No. of visits for operator errors* -No. visits where no parts required*
	Design Improvements	-Time required+ -Human resource+ -Material/equipment+ -Effectiveness+	-Actual value -Actual value -Actual value -Actual value
9	Installation	-Time required* -Human resource* -Material/equipment* -Effectiveness*	-Actual value* -Actual value* -Actual value* -Actual value*
10	Maintenance	-MTBPM* -Time per PM* -Material/equipment* -Effectivness* -Human resource+	-Actual value* -Actual value* -Actual value* -Actual value* -Actual value
11	Repair	-Failure rate* -Fault diagnosis time -Disassembly/* reassembly time -MTTR*	-Actual value* -Actual value* -Actual value* -Actual value*
12	Parts	-Costs* -Number of Parts* -Cross-compatibility*	-Actual value -Actual value -Actual value
	Delivery Mechanism		
13	Field Organization	-Internal training required*	-Actual value -First time fix rate*

Notes: *Indicates a goal or measure identified from the answers to the survey.
+Indicates a goal that was not identified in the survey but for which the idea came from review of the other goals.

7.4 IMPLICATIONS OF THE RESULTS

The main implication of the results is that the companies in the sample and possibly many others in high-technology industry could do more to evaluate product support at the design stage. This would, if planning leads to business success, mean that the quality of product support provided by companies could be improved.

The fact that measures for the elements of support related to the product design have been identified is important. This means that a better understanding of support has been achieved. If these measures are used in planning, it does not automatically mean that the quality of support will directly improve. However, since these variables can also be used to evaluate products after introduction, it means that improvements in support or lack of them are identifiable.

7.5 SUMMARY

The postal survey on product support attempted to determine whether support is evaluated fully at the product design stage by high-technology companies. The results indicate seven main things for the companies in the sample:-

1) The consideration of product support requirements takes place late in the product development cycle at many companies.

2) The planning at 47% of the sample companies is not formally documented and reviewed. Often the planning does not cover all of the aspects of support.

3) Only 47% of respondents thought that support was "Very well" or "Reasonably well" planned at their company.

4) During the planning of support, over half of the sample companies set goals for the reliability and MTTR of products.

5) Less than half of the companies, however, set goals for other aspects of support during their planning.

6) Most companies do not quantitatively monitor how easy products are to support following their market introduction.

7) Over 30% of respondents answered an open-ended question by saying that they thought support planning required greater involvement from field service personnel.

The validity of these results is such that they cannot be generalized to high-technology industry as a whole, because of possible sample bias. However, anecdotal evidence indicates that the planning of support is probably not more systematic at other companies. Further research is needed to confirm this. The exploratory nature of the study meant that new data was uncovered on support; this should help to improve the understanding of this concept.

CHAPTER EIGHT

Structured Interview Results

8.0 INTRODUCTION

This chapter describes the results of the repertory grid interviews. In total over sixty hours were spent interviewing customers and this produced much data on their perception of support. As a consequence of the amount of data collected, this chapter is a long and complex (even though only the most relevant results are presented).

This chapter has five major sections as shown by Figure 8.1, which also gives the relevant section and page numbers. The first section reiterates the aims of the interviews. The second section describes the results of the interviews with support engineers from a medical electronics manufacturer. (These were termed "internal" customers because they had their own expectations and perceptions of product support.) The other group interviewed were actual customers - biomedical engineers working with medical equipment in hospitals. The results from these interviews are given in the third section. The fourth section compares the results with the hypotheses and the final section gives a summary.

Figure 8.1: The Structure of Chapter Eight (only the main sections are shown).

1	Aims of the Interviews	Section 8.1 - Page 188
2	Results of Interviews with Internal Customers	Section 8.2 - Page 188
3	Results of Interviews with External Customers (biomedical engineers)	Section 8.3 - Page 235
4	Comparison of the Results with the Hypotheses	Section 8.4 - Page 254
5	Summary	Section 8.5 - Page 259

8.1 AIMS OF THE INTERVIEWS

The purpose of the interviews was to investigate customers' perception of product support, in the medical equipment market. Specifically, the aim was to test Hypothesis 3 (see Chapter Four) which stated:-

Customers perceive the supportability of a product through a set of common attributes. Customers perceive differences in the supportability of different products.

Related to this were three sub-hypotheses:-

> $H_{sub}3a$: *Newer products are not necessarily better than similar older products on all of the attributes of good support.*
>
> $H_{sub}3b$: *The common attributes differ between the internal and external customers. Internal customers perceive supportability as related to products themselves whereas external customers perceive supportability as also related to the manufacturer's field organization.*
>
> $H_{sub}3c$: *The factors reliability and MTTR (which are frequently evaluated at the design stage) are perceived as the most important ones by all customers.*

These led to the specific objectives for the structured interviews:-

1) To identify the customer attributes of good product support.

2) To contrast the attributes from the two categories of customer.

3) To rate the different products against each of the customer attributes of support.

4) To compare the ratings of old and new products, to see if newer products are better in all aspects of support.

5) To compare the results against Hypothesis 3 and draw conclusions.

8.2 RESULTS FOR INTERNAL CUSTOMERS

The results of the structured interviews with internal customers (Hewlett-Packard Medical Customer Support Engineers) are presented in the order in which they were obtained. The repertory grid methodology used for these interviews was tested in preliminary interviews and then developed to the stage where the actual interviews could start. These took place in two phases:-

- *Phase One Interviews*: these used a repertory test with twenty-five H-P products as the *elements* of the test and collected the *personal constructs* from twenty-five respondents. Phase One included twelve *Pilot Interviews*, during which the rating aspect of the test was still being developed (and a preliminary rating scale of 1-5 was used).

- *Phase Two Interviews*: these asked respondents to rate elements against twelve important common constructs (identified in Phase One). Twenty-five interviews were made in this phase. This allowed a composite grid to be constructed, containing the average ratings from the twenty-five respondents.

8.2.1 The Two Phases of Interviews

Figure 8.2 illustrates the phases of the repertory tests, with both the number of interviews and month shown across the bottom of the diagram.

Figure 8.2: The Phases of the Interviews, the Aims and the Data Collected from Internal Customers.

Phase One Interviews		Phase Two Interviews
Pilot	Remaining	
-Personal constructs -Ratings on 1-5[1] scale -Qualitative data	-Personal Constructs -Ratings on 1-9 scale -Qualitative data	-Elements rated against the provided constructs on a 1-9 scale
Aim: Identify common constructs	Aims: Confirm common constructs. Identify the most important constructs	Aim: Rate elements against the most important constructs

0 12 25 *No. of Interviews* 50
May 1990 Sept. 1990 Jan. 1991 *Month* May 1991

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[1] The first two interviews used a bipolar rating scale which was replaced, from the third interview, by a 1 to 5 rating scale.

The data collected in each phase is also shown in Figure 8.2; the Phase One Interviews concentrated on collecting personal constructs and Phase Two obtained the ratings of the elements against provided constructs. The reason that twenty-five interviews were conducted to identify different personal constructs was that such a number is necessary to make sure that all common constructs are identified (Frost and Braine, 1967). The interviews were time consuming and in total approximately fifty hours was spent interviewing customer engineers.

The Phase One Interviews were all recorded. This allowed a large amount of qualitative data to be collected on the characteristics of products which make them easier for customer engineers to work on.

8.2.2 Phase One Results

The Phase One interviews took place during the nine months from May 1990 to January 1991 and the first twelve of these were designated the *Pilot Interviews*. The results of the Pilot Interviews will be described in detail. (This is because they illustrate customer engineers' perceptions of support and the meaning of the elicited constructs.)

8.2.2a The Pilot Results

The sample for the Pilot Interviews was simply determined by identifying a subset of the complete sample by random selection. The results of the Pilot Interviews are summarized in Table 8.1. The structured interviews lasted an average of 55 minutes and produced, on average, ten personal constructs from each respondent. The length of the interview was determined by when the subject began to have difficulties giving new constructs, or when the interview had exceeded one hour.

Across the top of Table 8.1, the twelve subjects are indicated (H1 to H12) and the total number of constructs produced by each of them is given. The constructs themselves are listed down the left-hand side of the table, with the boxes indicating which constructs were elicited from each respondent. (The figures below the boxes are variability scores, which are discussed later.) The order of the constructs in Table 8.1 follows the frequency with which they were mentioned i.e. *Application Complexity* was mentioned most frequently and *Ease of Troubleshooting* and *Access to Boards* were equal second. Other frequently mentioned constructs included *Installability, Reliability, Mechanical Design* and *Ease of Use.* Less frequently mentioned constructs include, *Ease of User Troubleshooting, Adjustments* etc. The exact meaning of the constructs was identified by asking the respondents appropriate questions.

Constructs mentioned only once are likely to be *individual constructs*, provided that the sample has a reasonable size. A good example of

Table 8.1: The Personal Constructs from the Pilot Interviews with Internal Customers: Hewlett-Packard Engineers (the Variability Values are also shown for Interviewees H3 to H12).

Results of 12 Pilot Interviews													
Respondents	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	Summary / Notes
# Constructs	10	9	10	10	9	13	11	10	7	9	9	5	Total=112, Average No.=10
Length of int.	50	45	50	55	50	55	50	55	55	65	75	35[1]	Average Time=55 minutes
CONSTRUCTS:													
Application Complexity	■	■	■ 9.1		■ 9.5	■ 9.1	■ 6.9		■ 12.1	■ 19.8	■ 7.8	■ 26.1	10 mentions
Ease of troub-leshooting	■		■ 7.6	■ 13.5		■ 6.3	■ 9.3	■ 10.7		■ 11.9	■ 11.2	■ 18.3	9 mentions
Access to bds.	■		■ 7.8	■ 9.8		■ 5.7	■ 10.2	■ 12.1	■ 9.6	■ 14.9		■ 22.0	9 mentions
Installability	■		■ 13.2		■ 10.3	■ 8.6					■ 14.9	■ 16.0	6 mentions
Reliability			■ 7.9	■ 8.9	■ 11.3	■ 7.1	■ 6.9		■ 9.4				6 mentions
Mechanical design	■	■		■ 11.5		■ 9.1				■ 12.5	■ 10.5		6 mentions
Ease of use					■ 10.3	■ 7.0	■ 7.9	■ 5.9	■ 11.5				5 mentions

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[1] This interview was interrupted and could not be continued (therefore it was omitted from the calculation of the averages).

Table 8.1: Continued.

Respondents	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	Frequency
Per. maint.	■				■ 10.0	■ 9.6			■ 11.8		■ 15.2		5 mentions
Documentation				■ 9.3			■ 7.6	■ 7.3			■ 12.9		4 mentions
Ease of user troubleshootg.		■					■ 11.1	■ 12.7		■ 11.9	■ 10.5		3 mentions
Upgradability	■			■ 8.9					■ 11.8				3 mentions
MTTR					■ 10.3					■ 12.3		■ 17.7	3 mentions
Computer hardware		■							■ 9.6		■ 9.3		3 mentions
Parts availability					■ 11.3		■ 10.3	■ 7.1					3 mentions
Service tools available	■							■ 7.6			■ 7.8		3 mentions
Factory support	■			■ 8.2				■ 11.8					3 mentions
Ease of config	■				■ 14.6		■ 13.1						3 mentions
Ease of trg.			■ 11.0			■ 10.1							2 mentions
Adjustments		■				■ 7.5							2 mentions
Loaners poss.		■	■ 13.8										2 mentions

Table 8.1: Continued.

Respondents	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	Frequency
Access to svc kit		■	■ 11.7										2 mentions
Expectations on downtime		■	■ 9.0										2 mentions
Software quality					■ 12.7								1 mention
Size/weight						■ 9.6							1 mention
Supportability							■ 7.2						1 mention
Ease of safety testing						■ 5.7							1 mention
Robust boards						■ 4.6							1 mention
Repair price									■ 11.1				1 mention
Sensor reliability									■ 13.0				1 mention
Aesthetics							■ 9.5						1 mention
Modular Design										■ 16.8			1 mention
Board exchange possible			■ 8.8										1 mention

Table 8.1: Continued.

Respondents	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	Frequency
Board connectors				■ 10.7									1 mention
Test points (access)				■ 11.1									1 mention
Board cross-compatibility				■ 8.3									1 mention
High installed base		■											1 mention
Bench repair possible	■												1 mention
Self-test reliability								■ 11.9					1 mention
Error code reliability								■ 12.9					1 mention
<u>39 Constructs</u>													
Respondents	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	Frequency

this type of construct is *Aesthetics of the Design,* which is only mentioned once (Respondent H7 said that it was easier for him to enjoy working on equipment which *"looks good"* but qualified this by saying that this is *"less important to me than some other criteria"*!)

During the interviews particular care was taken to avoid interviewer bias whilst, at the same time, ensuring that the meaning of constructs was clear. For instance, this approach showed that *Ease of User Troubleshooting* means the ease with which a user can test a piece of equipment on his own. This means that the user can check whether equipment is working properly. Or, if it is faulty, he can obtain an error code which can be used to precisely describe the failure when he calls for assistance. Whenever a construct was named, careful questioning was used to establish if this construct had already been identified. For example, a construct was initially named by Subject H7 as *"Telephone Failure Information"* - referring to the quality of information that the user is able to provide when he calls for assistance. Questioning subject H7 further (*"What exactly do you mean?"*) established that the quality of this information is primarily determined by the ease with which the equipment can be tested by the user (*"I mean the amount of error codes that the user can give me over the phone to describe the problem"*[1]). This construct was first identified by Subject H2 and named *Ease of User Troubleshooting* by him.

A total of thirty-nine different constructs were elicited during the Pilot Interviews.

8.2.2b The Meaning of the Constructs

Determining the meaning of the constructs was, as already mentioned, important. The qualitative data from the interviews allowed a detailed understanding of each construct to be obtained. The twenty most frequently mentioned constructs will be explained, in the order in which they are given in Table 8.1.

1) *Application Complexity:* The degree of complexity of the product from the medical standpoint. Engineers perceived as "complex" both products which monitored many parameters and also ones which gave detailed analysis of patient signals (e.g. arrhythmia systems). Complex products are more difficult to support and were therefore rated lower. They require a greater knowledge from both engineers (*"you cannot take a novice engineer and say: "fix that" "*) and users. The complexity of the medical application is closely related to the technical complexity of the product - more complicated computers are required to run the more complicated application software. However, engineers perceived the *Application Complexity* as playing a much stronger role than the pure technical complexity of the product.

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[1] Several interviewees mentioned that the amount of troubleshooting that a customer can do is subjective - some customers are more technically oriented. However, the ratings were given for a "typical" user.

2) _Ease of Troubleshooting:_ The ease with which a fault can be located by a CE. It depends on the self-tests and diagnostics in the device, the electrical design plus the degree of modularity. All of these influence how quickly the fault can be determined. The reliability of the tests is also important as "*some self-tests are not very reliable*". One respondent (H8) gave a further two constructs related to troubleshooting. These were *Error code reliability* and *Speed of Diagnostics*; these are very specific constructs.

3) _Access to Boards:_ The ease with which the printed circuit boards in products can be exchanged for "*repair or troubleshooting purposes*".

4) _Installability:_ The ease with which a product can be installed. It depends on the "*technical difficulty*" and the "*actual time required*"[1] ("*Some products are not difficult to install but they still take a long time*").

5) _Reliability:_ The probability that a piece of equipment will function without failure. Instruments which seldom fail were given better ratings on this construct.

6) _Mechanical Design:_ Good mechanical design makes servicing equipment easier. Equipment with many moving parts ("*recorders and similar devices*") was perceived as harder for engineers to work on. Newer products were generally perceived as having better mechanical designs and so ratings on this construct "*will be a question of how old the product is*".

7) _Ease of Use:_ The ease with which a user can operate equipment. This was perceived as influencing the work of an engineer strongly. Both by influencing how easy it was to train customers and also by influencing the number of operator errors that are likely to occur. Some products are easy to use, whereas users have "*a hard time to follow the* [operating] *menus*" on some products.

8) _Periodic Maintenance:_ The ease with which the periodic maintenance required can be performed. It depends on the frequency, complexity and time required.

9) _Service Documentation:_ The quality of the service documentation "*for finding part numbers, error codes and so on*".

10) _Ease of User Troubleshooting:_ The amount of testing which can realistically be done by the user. It is dependent on simple self-test routines ("*good tests*") and modularity. "*The amount that the user can do himself* [to test the equipment]".

11) _Upgradability:_ The ease with which a product can, if this is available, be upgraded to enhance function. It depends on the difficulty and time required.

12) _MTTR:_ The mean-time-to-repair was perceived as a key influence on how

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[1] This and all other quotes are taken from the audio tapes of the interviews.

easy a piece of equipment is to support. Some respondents called this construct "*average repair time*".

13) <u>*Computer Hardware:*</u> Whether or not the product includes generic computer hardware. This variable was dichotomous, as products either include computer hardware or do not. Those which do were perceived as harder to support, since they required specialist knowledge.

14) <u>*Parts Availability:*</u> The ease with which engineers can obtain spare parts for equipment. This was perceived as varying between products - the ratings showed that the availability of parts for very old equipment was poor.

15) <u>*Service Tools Available:*</u> Certain products have external configuration and troubleshooting tools available. The ratings were consequently dichotomous, depending on whether or not tools were available for that product.

16) <u>*Factory Support:*</u> Engineers can obtain assistance on technical problems from the factory producing the product. Differences were perceived between the support received from the marketing departments of the five company factories.

17) <u>*Ease of Configuration:*</u> Modern products, especially software-based ones, allow many functions to be configured to meet customer requirements exactly. For example, the alarm settings can be set to levels appropriate for particular hospital departments. The construct is the perception of how easy it is for the engineer to set equipment functions to the appropriate values. Many older pieces of equipment do not have configuration and so this construct is not relevant for all products.

18) <u>*Ease of Training Customers:*</u> The degree of difficulty and time required to train customers in the basic operation of a device.

19) <u>*Loaners Possible:*</u> Engineers perceived that their work is easier when it is possible to loan the customer replacement equipment, for instance "*during the time we have to repair equipment with intermittent faults*". This construct is related to the size, weight and cost of equipment, since small, cheap equipment can easily be loaned by a support organization whereas full systems cannot viably be kept in reserve as loaners. Consequently the ratings against this construct tended to be grouped at the extremes of the scale.

20) <u>*Adjustments:*</u> The number and difficulty of adjustments required following repair or periodic maintenance. The ratings on this construct tended to be related to the age of the equipment: newer products have electrical designs which seldom require adjustments.

Reviewing Table 8.1, it can be seen that some of the constructs are closely related. For instance, as mentioned, subject H8 produced two constructs which were specific on troubleshooting. Other examples of related constructs are *Sensor Reliability* (related to reliability but more specific) and

Board Exchange Possible (related to the ease of repair and a dichotomous variable, since all but the oldest instruments are repaired by board exchange). During the interviews care was taken not to simply put constructs into the existing categories but to identify those which were more specific. Further research would be necessary to identify all of the specific constructs related to each of the more general constructs.

8.2.2c The Remaining Interviews

The remaining Phase One Interviews, with a further thirteen subjects, gave a total of 109 constructs. However, questioning and comparison to the results of the earlier interviews showed that these included only seven new constructs.

Some constructs appeared particularly important from the results of the Pilot Interviews, as they were mentioned frequently [examples are *Reliability* and *Application Complexity* (6 and 10 mentions in the Pilot Interviews respectively)]. The aim of the remaining interviews was to confirm that these were important constructs. One point to note, however, is that a common subset of constructs was not produced by each respondent. Typically an hour's interviewing produced around ten constructs; these consisting of a mixture of the more common and of individual constructs.

8.2.2d The Phase One Constructs

Table 8.2 lists all 218 constructs from Phase One i.e. the constructs from the first twenty-five subjects. The constructs in Table 8.2 are designated $C_{int}n$, indicating that they are the nth most frequently mentioned construct. From Table 8.2 it can be seen that the 218 constructs mentioned consist of 46 different constructs. The review of the methodology (Chapter Six: Part Two) showed the importance of identifying common constructs by surveying a sufficient sample for their personal constructs. The next section explains how the most important constructs were identified from the 46 constructs in Table 8.2.

8.2.2e The Most Important Common Constructs

The literature on repertory testing indicates that the criteria for identifying the most important common constructs is their frequency of mention (e.g. see Frost and Braine, 1967). High frequency indicates that a construct is important to the sample but the question is *what* frequency. The most important constructs to an individual are not necessarily those which are the most frequently mentioned in the sample; the constructs with a high percentage of variation are a respondent's salient constructs (Smith, 1986[b]). Therefore, it was necessary to check both the frequency and the variability of constructs when choosing the provided constructs for Phase Two.

The full listing of constructs in Table 8.2 includes a column headed "?". This column indicates whether a construct was chosen as one of the provided constructs for Phase Two (indicated by a "Y"). From Table 8.2 it can be seen that only the top twelve constructs were chosen (this corresponding to a frequency of mention of at least 25% of the sample). The level of 25% was set arbitrarily but purposively as well - the number of constructs for the Phase Two Interviews had to be kept at a manageable level. Experience of the rating of products (from the Phase One Interviews) showed that the rating of twenty to twenty-five products against about twelve constructs takes about one hour. This was seen as the maximum acceptable length of interview for Phase Two. To check that twelve important constructs had been chosen, an additional analysis was made of the results of the Phase One Interviews.

The variability of a construct is the measure of how great the spread is in the ratings of the elements against that construct, compared to all constructs. High variability, as mentioned, indicates that a construct is particularly important to a subject. "*The main exception to this rule is where the rating scale has been used very crudely and the ratings for the construct concerned consist of, say, only 7's or 1's* [on a scale of 1 to 7]" (Smith, 1986[a]). Therefore, firstly the use of the rating scale was checked and secondly the variability of constructs, to ensure that important constructs were not missed.

Table 8.2: The Phase One Constructs - from the Interviews with Twenty-Five Internal Customers (Hewlett-Packard Engineers).

Results of Phase One Interviews						
Constructs	Desig-nation	Remaining Interviews	12 Pilot Interviews	Total from 25	?	Average Weighted Variabily.
Ease of troubleshootg.	$C_{int}1$	12 mentions	9 mentions	21	Y	10.3
Application complexity	$C_{int}2$	4 mentions	10 mentions	14	Y	10.8
Reliability	$C_{int}3$	8 mentions	6 mentions	14	Y	8.6
Ease of use	$C_{int}4$	8 mentions	5 mentions	13	Y	9.9
Mechanical design	$C_{int}5$	6 mentions	6 mentions	12	Y	10.2
Installability	$C_{int}6$	6 mentions	6 mentions	12	Y	10.5
Customer training	$C_{int}7$	10 mentions	2 mentions	12	Y	11.2
Service documentation	$C_{int}8$	8 mentions	4 mentions	12	Y	9.1
Access to boards	$C_{int}9$	2 mentions	9 mentions	11	Y	10.2
User ease of	$C_{int}10$	7 mentions	3 mentions	10	Y	10.8

troubleshooting						
MTTR	$C_{int}11$	6 mentions	3 mentions	9	Y	9.4
Per. maintenance	$C_{int}12$	2 mentions	5 mentions	7	Y	10.3
Upgradability	$C_{int}13$	4 mentions	3 mentions	7		(10.6)
Ease of configuration	$C_{int}14$	2 mentions	3 mentions	5		(13.3)
Parts availability	$C_{int}15$	3 mentions	2 mentions	5		8.9
Computer hardware	$C_{int}16$	2 mentions	3 mentions	5		-
Factory support	$C_{int}17$	3 mentions	2 mentions	5		7.8
Service tools	$C_{int}18$	1 mentions	3 mentions	4		7.9
Seminar quality	$C_{int}19$	4 mentions	0 mentions	4		9.7
Adjustments	$C_{int}20$	1 mention	2 mentions	3		(9.6)
Loaners possible?	$C_{int}21$	0 mentions	2 mentions	2		(13.8)
Modular Design	$C_{int}22$	1 mentions	1 mention	2		12.8
Expectations on downtime	$C_{int}23$	0 mentions	2 mentions	2		9.0
Board exchange	$C_{int}24$	1 mentions	1 mention	2		8.4
User documentation	$C_{int}25$	2 mentions	0 mentions	2		8.0
Number of software revs	$C_{int}26$	2 mentions	0 mentions	2		-
Access to service kit	$C_{int}27$	0 mentions	2 mentions	2		11.7
Supportability	$C_{int}28$	0 mentions	1 mention	1		7.9
Size/weight	$C_{int}29$	0 mentions	1 mention	1		12.5
Ease of safety testing	$C_{int}30$	0 mentions	1 mention	1		7.4
Robust boards	$C_{int}31$	0 mentions	1 mention	1		6.0
Software quality	$C_{int}32$	0 mentions	1 mention	1		11.4
Repair price	$C_{int}33$	0 mentions	1 mention	1		7.8
Sensor reliability	$C_{int}34$	0 mentions	1 mention	1		9.1
Aesthetics	$C_{int}35$	0 mentions	1 mention	1		10.4
Board connectors	$C_{int}36$	0 mentions	1 mention	1		10.7
Test points (access)	$C_{int}37$	0 mentions	1 mention	1		11.1
Board cross-compatibility	$C_{int}38$	0 mentions	1 mention	1		8.3
High installed base	$C_{int}39$	0 mentions	1 mention	1		-
Bench repair possible	$C_{int}40$	0 mentions	1 mention	1		-
Self-test reliability	$C_{int}41$	0 mentions	1 mention	1		11.9
Error code reliability	$C_{int}42$	0 mentions	1 mention	1		12.9
Meets customer needs	$C_{int}43$	1 mention	0 mentions	1		9.3
Good clear display	$C_{int}44$	1 mention	0 mentions	1		8.5
Experience on product	$C_{int}45$	1 mention	0 mentions	1		12.4
Ease of interfacing (to other products)	$C_{int}46$	1 mention	0 mentions	1		5.4
		109 constructs 27 different	109 constructs 39 different			

Firstly, the ratings from the Phase One Interviews were inspected to see if they included constructs where the rating scale had been used crudely. This was found to be the case with several constructs. The first was the construct *Computer Hardware*, for which the ratings were all 1 or 9 (i.e. a dichotomous variable). The other constructs where the rating scales were used crudely were *Upgradability* (since many products did not allow upgrades), *Ease of Configuration* (as many products do not have this capability), *Loaners Possible?* (almost a dichotomous variable, for reasons already discussed) and *Number of Software Revisions* (as many older products are not software-based).

Secondly, the variation in product ratings for the various constructs was calculated for the results of the Phase One Interviews. To understand how this was done, using the Pilot results as an example, refer to Table 8.1. This shows, for instance, that Subject H3's variability for the construct *Installability* was 13.2%, whereas for subject H5 it was 10.3% for the same construct. However, these two values cannot be compared directly. This is because the variability is dependent on the number of constructs produced by the respondent (i.e. the percentage variability of each construct is higher in a grid with five constructs than in one with ten constructs. This can be seen by comparing the values for Subject H12 with Subject H3). Therefore, the variability values were weighted, as if they came from a grid with ten constructs. The average of these values was then calculated and the value for all Phase One Interviews is shown in the right-hand column of Table 8.2.

The variability values given in Table 8.2, as would be expected, average about 10%. It can be seen that from the twelve most frequently mentioned constructs, *Customer Training* has the most variability (11.2%). *Application Complexity* and *User Ease of Troubleshooting* have the next highest values. Some of the less frequently mentioned constructs have high variability values. *Upgradability* has an average variability of 10.6% and *Ease of Configuration* a value of 13.3%. These values are shown in parenthesis, however, because the ratings were crude (as these two constructs were not applicable to every product). Both these constructs were not chosen for Phase Two because they were not relevant for so many products (and they were not mentioned as frequently as others).

Other constructs which appear important and where the rating scale was evenly applied are *Modular Design* (13.8%), *Size and Weight* (12.5%), *Error Code Reliability* and *Experience on the Product* (12.4%). These three constructs were not selected for Phase Two because, although they had high variability, they were mentioned only once.

One of the limitations of the repertory grid methodology is the lack of pragmatic advice on applying it in marketing research. A particular aspect of this is that there is no recommendation on how both construct variability and frequency should be evaluated, when choosing important constructs from a sample. The *modus operandi* adopted, as described above, reviewed both the frequency and variability of constructs before the most important were chosen. In this way it was attempted to avoid bias at this important stage of the methodology. (Further research, beyond the scope of this thesis, is required to prove the validity of this approach.) !!

8.2.2f Summary of Phase One

The *Phase One* interviews identified the range of constructs through which customer engineers perceive the supportability of different products. The meanings of the individual constructs were determined by careful questioning. In total 46 different constructs were elicited. Of these, twelve were chosen as the most important constructs for use in *Phase Two* (after both the construct frequency and variability had been checked).

8.2.3 An Example Interview (Internal Customer)

Up until now, only the constructs have been discussed, without presentation of a full repertory grid. To illustrate the information that was obtained in interviews and to enable a better understanding of customer engineers' perceptions, a full analysis of one example grid will be given. This grid, from Subject H18, was selected randomly but it is typical of the grids obtained from the interviews.

The repertory grid from engineer H18 is shown in Figure 8.3, with the elements and thirteen personal constructs. The explanations of the majority of the constructs were given in Section 8.2.2b. The format in which the results are analysed follows that adopted by Smith (1986[b]). (Refer to this paper or Green *et al*, 1988 for more explanation of Principal Components Analysis.)

8.2.3a The Elements

The first point to note is that H18 did not have experience with all twenty-five provided elements; Elements 16, 21, 23 and 24 are excluded from his grid (shown cross-hatched). This was typical, in that most respondents did not have experience of more than about eighteen products (depending on the installed base of products in their respective areas). The products themselves can be identified from the element numbers using the table below the grid (Figure 8.3).

8.2.3b The Constructs and Grid

The interview with Subject H18 lasted 75 minutes and produced ratings on the 13 personal constructs shown in Figure 8.3. The triads that elicited each of the constructs are indicated by the stars preceding the ratings (e.g."*5"). Therefore, it can be seen that the first triad, with Elements 1, 2 and 3, produced the construct *Installability*. The subject could not rate every element on every construct. For instance, he could give no rating for Element 11 on *Installability*, as he had not experience of installing this product. Where ratings could not be given, this is indicated by a question mark ("?"). Note that the ratings for all constructs were always given using the scale of 1 ("easy/good") to 9 ("poor/difficult").

Figure 8.3: The Repertory Grid from Engineer H18 (Internal Customer / Personal Constructs).

	THE PRODUCTS (ELEMENTS) BY CARD NUMBER																								
PERSONAL CONSTRUCTS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1) Installability	*4	*1	*1	4	4	3	2	1	5	5	?	2	1	2	2		1	4	3	1		4			2
2) Application Complexity	5	1	1	*3	*6	*2	2	2	6	5	3	2	1	1	2		2	3	2	2		4			3
3) Reliability (MTBF)	3	1	1	3	5	3	*2	*1	*3	2	?	4	3	4	4		1	2	3	3		4			?
4) Ease of Troubleshooting	4	1	1	2	6	3	2	2	5	*4	*3	*2	2	2	2		3	4	5	3		3			2
5) Ease of User Troubleshooting	9	3	3	5	5	6	3	3	5	7	2	3	*3	*2	*3		2	5	6	2		3			4
6) Access to boards	3	2	2	1	3	7	2	4	6	3	4	3	2	2	3		*2	*6	*4	3		2			5
7) Mechanical design	2	2	2	2	4	7	3	5	7	3	5	2	2	2	2		3	5	2	*3		*3			*5
8) Ease of use	*6	1	3	*5	7	2	*3	1	7	6	2	2	3	3	2		1	3	3	2		4			2
9) Adjustments	1	1	2	1	7	4	1	*3	6	3	*4	4	2	*1	5		1	3	4	2		2			?
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
10) Periodic M.	7	1	2	2	6	2	5	2	5	7	3	3	2	2	*3		*2	*4	4	3		3			3
11) Service documentation	3	2	2	4	4	3	3	3	4	4	3	5	2	5	5		2	6	*3	*4		*3			3
12) Ease of training customers	3	1	*1	5	6	*1	2	1	6	5	1	1	1	2	1		1	2	2	1		3			*1
13) MTTR	3	1	1	2	8	4	*2	2	5	6	*3	2	2	2	*2		1	5	5	3		2			2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

SUBJECT: H18 JOB: CE EXPERIENCE: 7 years

DATE: 26/11/91 AUDIO TAPE #:18 LENGTH OF INTERVIEW: 75 minutes

8.2.3c Statistics for the Constructs

Table 8.3 gives the descriptive statistics for the ratings against each construct. From the variability, it appears that the salient constructs for Subject H18 are *5) Ease of User Troubleshooting, 8) Ease of Use* and *13) Mean-Time-to-Repair.* The column of mean values shows that H18 tended to give the best ratings (i.e. lowest values) on construct 12 (*Ease of Training Customers*) and his worst ratings (highest values) on construct 5 (*Ease of User Troubleshooting*). This suggests that H18 perceived training customers to be generally easy and perceived that much could be done to make equipment easier for users to test.

Table 8.3: Descriptive Statistics for an Example Internal Customer's Constructs (calculated from the repertory grid using *Flexigrid 4.2* software).

Construct	Best Rating on this Construct	Mean Rating on this Construct	Worst Rating on this Construct	Spread of Ratings on this Construct	Construct's Percentage of Spread
*	Min.	Mean+	Max.	Std Dev.	Variability
1 Installability	1	2.60	5	1.39	6.00%
2 Application Complexity	1	2.76	6	1.54	7.33%
3 Reliability (MTBF)	1	2.74	5	1.16	4.18%
4 Ease of Troubleshooting	1	2.90	6	1.31	5.27%
5 Ease of User Troubleshooting	2	4.00	9	1.83	10.30%
6 Access to Boards	1	3.29	7	1.55	7.40%
7 Mechanical Design	2	3.38	7	1.62	8.09%
8 Ease of Use	1	3.24	7	1.85	10.57%
9 Adjustments	1	2.85	7	1.74	9.36%
10 Periodic Maintenance	1	3.38	7	1.68	8.68%
11 Service Documentation	2	3.48	6	1.10	3.71%
12 Ease of Training Customers	1	2.24	6	1.72	9.10%
13 MTTR	1	3.00	8	1.80	10.01%
Average		*3.07*			*7.69%*

Notes:
* The headings in this line are those adopted by Smith (1986[b]), whereas the line above attempts to give titles that are easier for the reader to understand.
+ The statistics in this and following tables are reproduced exactly as they are output from *Flexigrid*; the figures are not necessarily significant to this degree (this is discussed in the sections on limitations).

8.2.3d Relationships between Constructs

Table 8.4 shows the correlations between the constructs of Subject H18. A strong correlation shows that constructs are related and, to illustrate this, the correlations of 0.8 or more are shown in bold type. The strongest correlations (greater than 0.8) will be discussed as they indicate eight links. These are:-

- Correlations between *Installability* and the three constructs: *Application Complexity (2), Ease of Use (8),* and *Ease of Training Customers (12).*

- Correlations between *Application Complexity* and the two constructs: *Ease of Use (8)* and *Ease of Training Customers (12).*

- A correlation between *Troubleshooting (4)* and *MTTR (13).*

- A correlation between *Access to Boards (6)* and *Mechanical Design (7).*

- The strongest correlation is between *Ease of Use (8)* and *Ease of Training Customers (12).*

Table 8.4: Correlation Table, showing the Relationships between the Constructs for the Example Internal Customer (calculated using *Flexigrid* software).

	Construct Numbers									
Constructs	1	2	3	4	5	6	7	8	9	10
1 Installability	1.00									
2 Application Complexity	**0.84**	1.00								
3 Reliability (MTBF)	0.39	0.36	1.00							
4 Ease of Troubleshooting	0.70	0.77	0.39	1.00						
5 Ease of User Troubleshooting	0.73	0.59	0.11	0.56	1.00					
6 Access to Boards	0.32	0.27	0.02	0.41	0.34	1.00				
7 Mechanical Design	0.32	0.38	-.05	0.36	0.13	**0.85**	1.00			
8 Ease of Use	**0.83**	**0.84**	0.43	0.66	0.63	0.01	0.08	1.00		
9 Adjustments	0.30	0.50	0.49	0.52	0.05	0.53	0.55	0.31	1.00	
10 Periodic Maintenance	0.70	0.79	0.26	0.71	0.68	0.16	0.09	0.75	0.29	1.00
11 Service Documentation	0.42	0.24	0.50	0.26	0.10	0.26	0.09	0.23	0.40	0.26
12 Ease of Training Customers	**0.84**	**0.83**	0.36	0.65	0.52	-.01	0.16	**0.93**	0.33	0.63
13 MTTR	0.70	0.70	0.39	**0.89**	0.57	0.46	0.39	0.66	0.63	0.69

	11	12	13
11 Service Documentation	1.00		
12 Ease of Training Customers	0.27	1.00	
13 MTTR	0.39	0.66	1.00

Correlations, of course, do not mean that causations exist. (And perceptions do not necessarily accurately reflect product characteristics.) However, from the above results it can clearly be seen that equipment complexity has a key influence on engineer H18's perception of equipment. The correlations are illustrated by Figure 8.4, which clearly shows the three "groups" of correlations. The top "group" is the most complex, as four constructs are involved with six correlations. The lower two "groups" are simple relationships between pairs of constructs.

Figure 8.5 shows how several of the correlations in the results could be a consequence of *Application Complexity* being the main determinant of how the subject perceives products. Causal links would then exist to *Installability, Ease of Use* and *Ease of Training Customers* whereas the two correlations between *Installability* and *Ease of Use* and *Ease of Training Customers* could then be explained to be spurious. Further research would be required to prove whether *Application Complexity* is the central construct. However, the current results suggest that, at least in the perception of Engineer H18, more complex equipment is always associated with more difficulty in installing, training customers and in ease of use.

Figure 8.4: The Correlations between Constructs for the Example Interview (Subject H18).

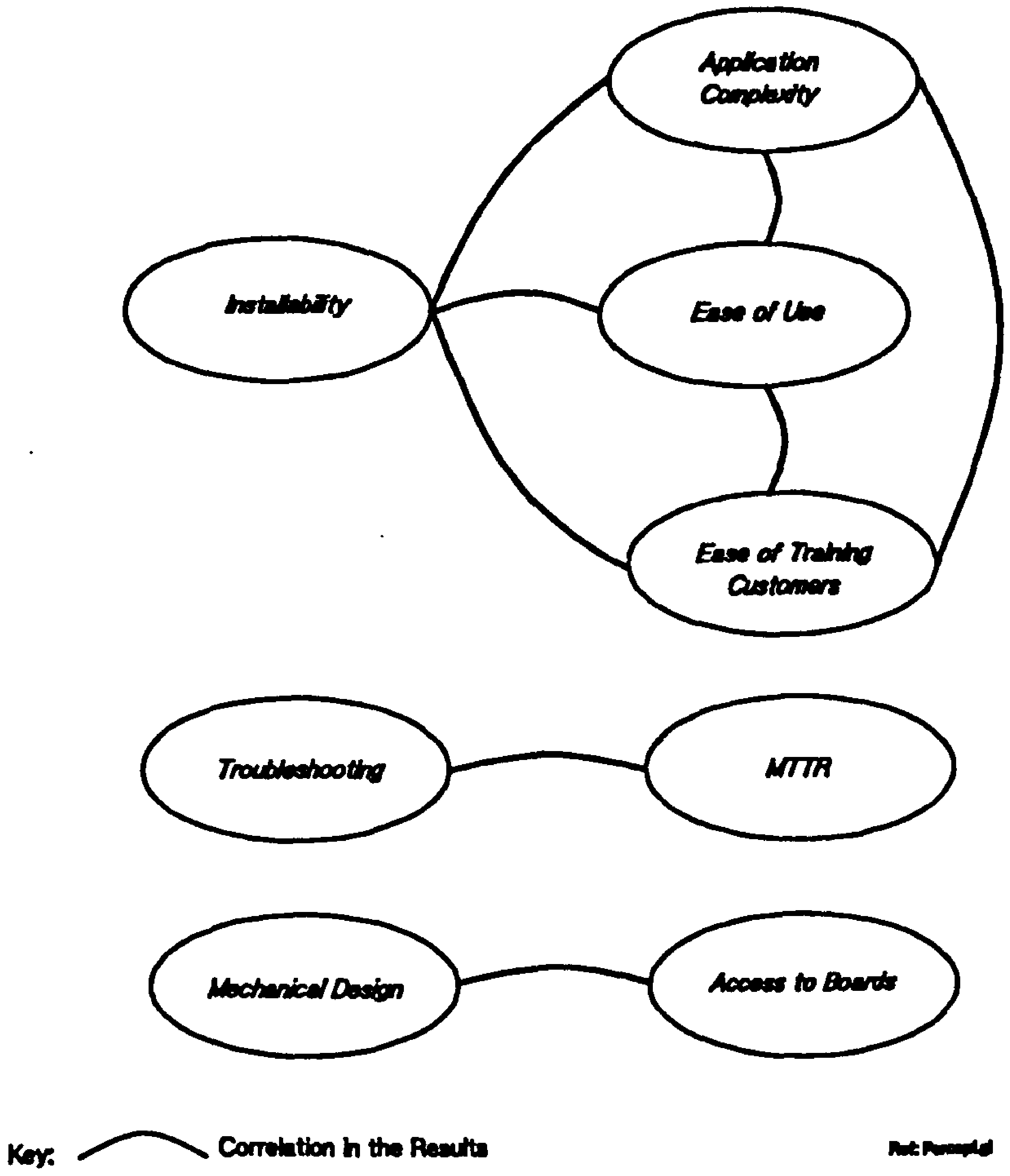
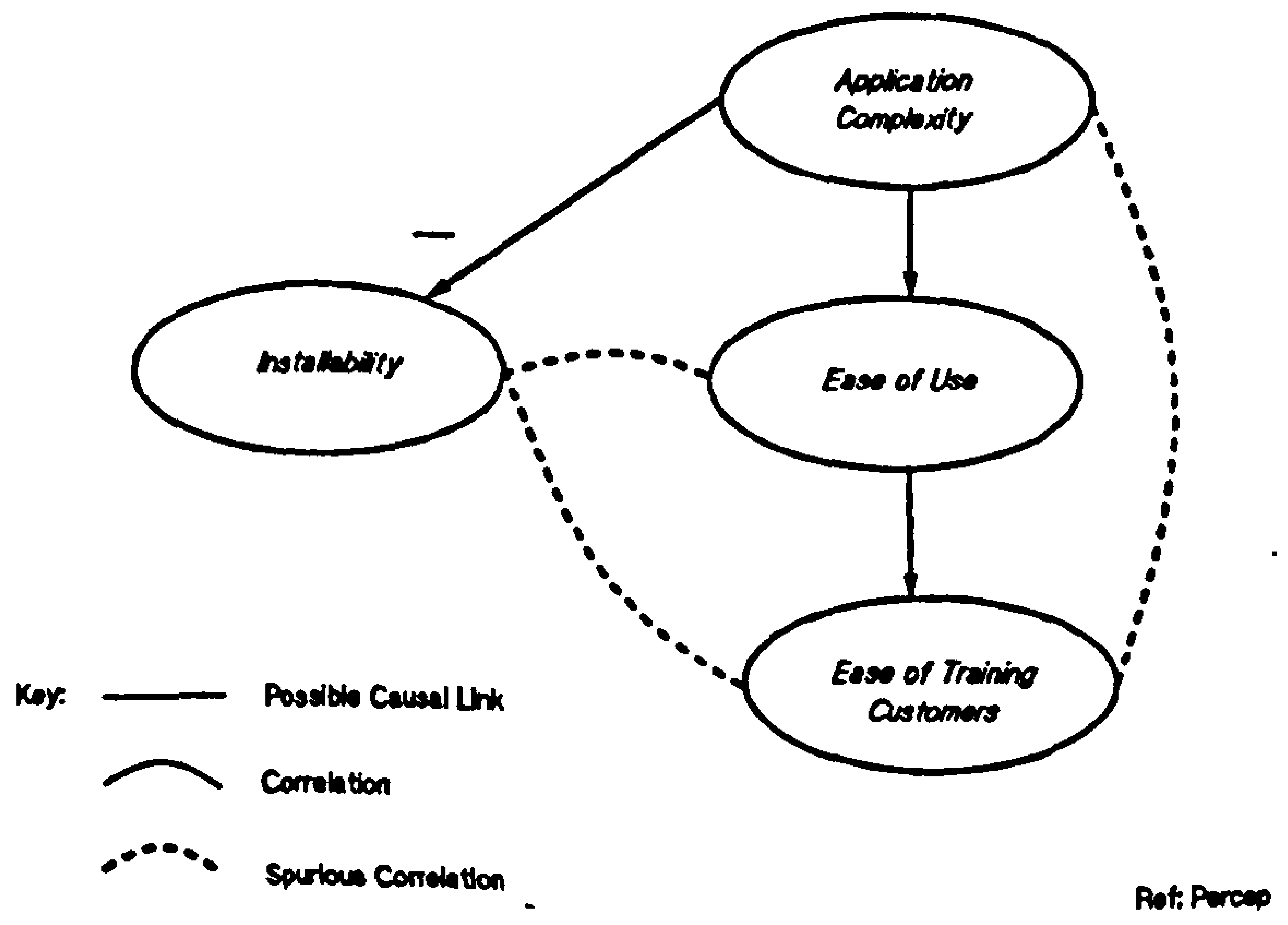


Figure 8.5: Possible Explanation of Some of the Correlations (Subject H18).



8.2.3e Statistics for the Elements

Are the average ratings (across constructs) given to each of the elements useful? This section considers the value of the average ratings across the products. "*This information is not very useful unless the vast majority of constructs have some quality such as goodness or bigness in common*" (Smith, 1986[b]). However, all of the constructs in the results are related to how easy a particular product is for an engineer to work on. This means that the statistics for the elements are interesting, as they allow products to be compared on a "first level". The limitations of this approach are, however, recognized - the mean values can only give an idea of general differences between products and are not absolute values.

Table 8.5 shows these statistics for the twenty-one elements in Subject H18's grid. The elements with the lowest mean values are those which H18 generally perceives as easiest to support - these are Elements 2 (78351A), 3 (7883xA) and 17 (8040A). It can be seen that these three products have good ratings on all constructs and therefore low variability. The *Ideal Product* shown in the first line would have a rating of one on all constructs - this indicating that it was simple in all aspects of support.

Table 8.5: Descriptive Statistics for an Example Internal Customer's Elements (calculated using *Flexigrid* software).

Element		Type of Product	Element's Best Score	Element's Mean Score	Element's Worst Score	Spread in Element's Ratings	Percentage Attributable to Product
*			Minimum	Mean	Maximum	Std Dev.	Variability
		Ideal Product	*1*	*1.00*	*1*		*0.00%*
1	78720A	Arrhythmia System	1	4.08	9	2.09	14.34%
2	78351A	Patient Monitor	1	1.38	3	0.62	1.28%
3	7883xA	Patient Monitor	1	1.69	3	0.72	1.70%
4	M1046A	Patient Monitor	2	3.00	5	1.41	6.55%
5	77020AC	Ultrasound System	3	5.46	8	1.39	6.35%
6	78660A	Defibrillator	1	3.62	7	1.86	11.35%
7	78560A	Central Station	1	2.46	5	0.93	2.83%
8	43120A	Defibrillator	1	2.31	5	1.20	4.73%
9	8800	Catheter Laboratory	3	5.38	7	1.08	3.80%
10	78525	Arrhythmia System	2	4.62	7	1.55	7.83%
11	8020A	Cardiotocograph	1	3.00	5	1.04	3.57%
12	78341/2A	Patient Monitor	1	2.69	5	1.07	3.72%
13	78354A	Patient Monitor	1	2.00	3	0.68	1.51%
14	4700A	Cardiograph	1	2.31	5	1.07	3.72%
15	78345/6A	Patient Monitor	1	2.77	5	1.19	4.61%
16	—						
17	8040A	Cardiotocograph	1	1.69	3	0.72	1.70%
18	78200A	Patient Monitor	2	4.00	6	1.30	5.54%
19	78500	Central Station	2	3.38	6	1.27	5.31%
20	8030A	Cardiotocograph	1	2.62	4	0.92	2.79%
21	—						
22	4760AI	Cardiograph	2	3.08	4	0.73	1.74%
23	—						
24	—						
25	M1700A	Cardiotocograph	1	2.91	5	1.24	5.03%
		Average		*3.07*		*1.45*	

* Note: The headings in this line are those adopted by Smith (1986[b]), whereas the line above attempts to give titles that are easier for the reader to understand.

The elements with a high percentage of variability are distinct in some way (Smith 1986[b]); it can be seen that H18 has pronounced views on Element 1 (78720A). *"Elements can be distinctive in many ways including the possibility of being distinctly bad!"* (*ibid*). The engineer's perception of the 78720A is distinctive. Referring to the grid (Figure 8.3) allows this to be explained. The 78720A has some good ratings (e.g. "2" on *Mechanical Design* and "1" on *Adjustments*) but also some poor ratings (e.g. "9" on *Ease of User Training*). These lead to the high variability and the average rating of 4.08 shows that the 78720A is perceived as relatively difficult to support. Another example of a product with high variability is Element 6 (78660A) - due to some very good and some poor ratings.

8.2.3f Analysis of Component Space

The principal components analysis of the grid from subject H18 gave the results seen in Table 8.6. It can be seen that the first two components account for 68% (52 + 16 = 68%) of the variation in the results. This shows that engineer H18 has a relatively simple perception of the supportability of products - much of his perception can be explained by two trends (components).

Table 8.6: Principal Components Analysis for the Repertory Grid from Subject H18 - An Internal Customer / Provided Constructs (calculated using *INGRID* software).

PCA Component No.	Root	As a Percentage
1	6.80	52%
2	2.13	16%
3	1.49	6%
4	0.84	4%
5	0.57	4%
6	0.48	2%
7	0.24	2%
8	0.20	1%

8.2.3g Analysis of Loadings etc

The principal components analysis (PCA) is the first step in forming a cognitive map of the respondent's perception of the relationships between the constructs and elements (Figure 8.6). PCA shows the number of recurrent trends in the data. The loadings of the elements and constructs against these trends (Table 8.7) allow the nature of the trends to be determined.

The top half of Table 8.7 gives the vectors and loadings for the elements against the two trends (components). The loadings *"have a direct relationship to the vectors; they can be thought of as vectors multiplied by the* *strength of the trend*" (Smith, 1986[b]). The loadings are used as coordinates to draw the cognitive map. For instance, Element 1 has a loading of 0.63 on Component 1 and -0.43 on Component 2. This means that it is in the lower right sector of the map (see Figure 8.6).

Table 8.7: Element and Construct Loadings for the Example Grid from Subject H18 (calculated using *INGRID* software).

		Component 1			Component 2		
Element	Type of Product	Vector	Loading	Residual	Vector	Loading	Residual
1 78720A	Arrhythmia System	0.24	0.63	0.59	-.30	-.43	0.40
2 78351A	Patient Monitor	-.31	-.81	0.08	-.07	-.10	0.06
3 7883xA	Patient Monitor	-.25	-.66	0.12	-.10	-.15	0.10
4 M1046A	Patient Monitor	0.03	0.07	0.50	-.37	-.54	0.20
5 77020AC	Ultrasound System	0.49	1.28	0.30	-.07	-.11	0.29
6 78660A	Defibrillator	0.05	0.12	0.71	0.47	0.69	0.23
7 78560A	Central Station	-.09	-.25	0.15	-.13	-.19	0.11
8 43120A	Defibrillator	-.17	-.44	0.17	0.26	0.39	0.02
9 8800	Catheter Laboratory	0.44	1.14	0.30	0.25	0.37	0.16
10 78525	Arrhythmia System	0.34	0.89	0.22	-.17	-.25	0.16
11 8020A	Cardiotocograph	-.11	-.29	0.41	0.33	0.48	0.18
12 78341/2A	Patient Monitors	-.08	-.21	0.29	-.06	-.08	0.28
13 78354A	Patient Monitors	-.19	-.51	0.13	-.14	-.20	0.09
14 4700A	Cardiograph	-.13	-.35	0.34	-.20	-.29	0.26
15 78345/6A	Patient Monitors	-.07	-.18	0.35	-.04	-.05	0.35
16 80225A	System	—	—	—	—	—	—
17 8040A	Cardiotocograph	-.24	-.61	0.15	0.00	0.00	0.15
18 78200A	Patient Monitor	0.17	0.44	0.44	0.29	0.42	0.26
19 78500	Central Station	0.07	0.18	0.22	-.05	-.07	0.21
20 8030A	Cardiotocograph	-.09	-.23	0.16	0.06	0.09	0.15
21 78534A	Patient Monitor	—	—	—	—	—	—
22 4760AI	Cardiograph	0.04	0.09	0.23	-.21	-.30	0.14
23 78532A	Patient Monitor	—	—	—	—	—	—
24 M1350A	Cardiotocograph	—	—	—	—	—	—
25 M1700A	Cardiograph	-.12	-.31	0.37	0.23	0.34	0.26
Construct		Vector	Loading	Residual	Vector	Loading	Residual
1 Installability		**0.33**	0.87	0.24	-.13	-.20	0.20
2 Application Complexity		**0.35**	0.91	0.18	-.01	-.02	0.18
3 Reliability (MTBF)		0.18	0.47	0.78	-.27	-.40	0.62
4 Ease of Troubleshooting		**0.35**	0.90	0.19	0.10	0.15	0.17
5 Ease of User Troubleshooting		0.27	0.70	0.51	-.08	-.11	0.50
6 Access to Boards		0.15	0.38	0.86	**0.59**	0.86	0.12
7 Mechanical Design		0.14	0.36	0.87	**0.59**	0.86	0.14
8 Ease of Use		**0.34**	0.87	0.24	-.24	-.36	0.11
9 Adjustments		0.21	0.56	0.69	0.26	0.38	0.54
10 Periodic Maintenance		**0.31**	0.82	0.33	-.12	-.18	0.30
11 Service Documentation		0.16	0.43	0.82	0.04	0.06	0.81
12 Ease of Training Customers		**0.33**	0.85	0.28	-.21	-.30	0.19
13 MTTR		**0.34**	0.88	0.22	0.13	0.19	0.19

The bottom half of Table 8.7 gives the data with which the nature of the trends can be determined. The vectors are correlations between constructs and the trends. Therefore, it can be seen that the strongest correlations are between the first trend and constructs 1, 2, 4, 8, 10, 12 and 13 (these vectors are shown in bold type in Table 8.7). The residuals "*show how much of the information remains to be explained after the trends have been extracted from the data*" (*ibid*). It can be seen that *Application Complexity* is the construct which has the most influence on the ratings; after it is removed the residual is only 0.18. The strongest correlations with the second trend are constructs 6 and 7. The correlations with the trends mean that H18's perception of how easy products are for him to support is mainly in terms of mechanical design factors (component 2) and the complexity that they pose for the engineer (complexity of installation, troubleshooting etc).

The loadings for the constructs are used to mark a temporary coordinate on the cognitive map (Figure 8.6). A line from the origin through this point gives the permanent position of the construct on the circle centred on the origin of the two axes. (To illustrate this, Figure 8.6 shows the line drawn through the loadings for Construct 9 - *Adjustments*).

8.2.3h The Cognitive Map

The cognitive map in Figure 8.6 shows two trends (Component 1 horizontally and Component 2 vertically) and the constructs marked around the perimeter of the circle. As mentioned in the analysis of the loadings, it can be seen that the first trend has strong correlation with a number of constructs whilst there are only two constructs strongly related to component 2.

The positions of the elements (products) on the cognitive map are indicated by symbols with numbers inside. The symbols indicate the category of product (triangles for monitors, circles for CTGs etc) and are defined in the key. The numbers are the element numbers used in the repertory tests; the corresponding product numbers are given in the table at the top of Figure 8.6.

The relationships between the elements can be determined from the distances between elements (in component space) given in Table 8.8. The shortest distances, i.e. the strongest links, are shown in bold type and these were used to draw lines on the cognitive map, producing clusters.

Two main clusters are shown on Figure 8.6. These are Elements 2, 3, 13, 17 and 7, plus the out-lying group 8, 11 and 25 the cluster of Elements 12, 15, 14 and 20. The first cluster can be explained as consisting of products which are simple (from the application, troubleshooting and ease of use etc.) and have reasonable mechanical designs. The second cluster is similar, except that the products are not so simple. The products which are outside these clusters are more complex to support but mechanically well designed (4, 22, 1 and 10) or products of increasing complexity which are less well designed (6, 18 and 9). The left hand side of the diagram contains the products which are perceived as easiest to support.

Figure 8.6 shows clearly that Subject H18 perceives differences in the ease with which particular products can be supported. If all products were identically easy or hard to support then only one cluster would have emerged on the cognitive map. It is interesting to note that the clusters on the example cognitive map do not simply consist of product categories. Analysis of the other interviews showed similar results in component space - engineers perceive differences in the characteristics of support of different products.

Table 8.8: The Distances[1] between the Elements in Component Space for the Example Internal Customer H18 (calculated using *INGRID* software).

	Product Numbers								
Products	1	2	3	4	5	6	7	8	9
1 78720A Arrhythmia System									
2 78351A Patient Monitor	1.40								
3 7883xA Patient Monitor	1.29	**0.26**							
4 M1046A Patient Monitor	0.91	0.94	0.87						
5 77020AC Ultrasound System	1.13	1.91	1.79	1.34					
6 78660A Defibrillator	1.24	1.16	1.13	1.20	1.43				
7 78560A Central Station	0.96	0.63	0.52	0.69	1.47	1.03			
8 43210A Defibrillator	1.30	0.57	0.57	1.00	1.64	0.73	0.61		
9 8800 Catheter Laboratory	1.12	1.80	1.68	1.29	0.71	1.10	1.39	1.42	
10 78525 Arrhythmia System	0.57	1.53	1.41	0.93	0.79	1.23	1.05	1.33	0.81
11 8020A Cardiotocograph	1.32	0.79	0.73	1.13	1.53	0.86	0.71	**0.36**	1.34
12 78341/2A Patient Monitor	1.17	0.93	0.78	0.80	1.43	0.97	0.64	0.70	1.40
13 78354A Patient Monitor	1.20	**0.42**	**0.34**	0.81	1.62	1.03	**0.49**	0.60	1.58
14 4700A Cardiograph	1.24	0.76	0.73	0.67	1.56	1.13	0.60	0.79	1.54
15 78345/6A Patient Monitor	1.21	0.88	0.81	0.85	1.41	0.97	0.70	0.72	1.39
16 —									
17 8040A Cardiotocograph	1.30	**0.33**	**0.43**	0.95	1.74	1.08	0.53	**0.49**	1.63
18 78200A Patient Monitor	1.05	1.32	1.27	1.05	1.78	0.73	0.98	0.93	0.93
19 78500 Central Station	0.74	0.96	0.90	0.79	1.16	0.80	0.65	0.83	1.16
20 8030A Cardiotocograph	1.20	0.75	0.63	0.88	1.37	0.88	0.55	0.51	1.34
21 —									
22 4760AI Cardiograph	0.87	0.91	0.83	**0.50**	1.18	1.00	0.56	0.84	1.13
23 —									
24 —									
25 M1700A Cardiograph	1.15	0.72	0.71	1.00	1.69	0.79	0.62	**0.45**	1.39
Products	10	11	12	13	14	15	16	17	18
11 8020A Cardiotocograph	1.29								
12 78341/2A Patient Monitor	1.21	0.84							
13 78354A Patient Monitor	1.33	0.77	0.64						
14 4700A Cardiograph	1.29	0.96	**0.42**	0.59					
15 78345/6A Patient Monitor	1.22	0.95	**0.11**	0.68	0.51				
16 —									
17 8040A Cardiotocograph	1.41	0.61	0.82	**0.46**	0.77	0.86			
18 78200A Patient Monitor	0.88	0.95	0.86	1.19	1.00	0.88		1.20	
19 78500 Central Station	0.80	0.89	0.74	0.73	0.82	0.78		0.87	0.73
20 8030A Cardiotocograph	1.19	0.56	**0.36**	0.53	0.53	**0.37**		0.62	0.85
21 —									
22 4760AI Cardiograph	0.92	0.94	0.66	0.67	0.65	0.71		0.78	0.94
23 —									
24 —									
25 M1700A Cardiograph	1.22	0.58	0.91	0.79	0.92	0.96		0.62	0.88
Products	20	21	22						
22 4760AI Cardiograph	0.66								
23 —									
24 —									
25 M1700A Cardiograph	0.78		0.87						

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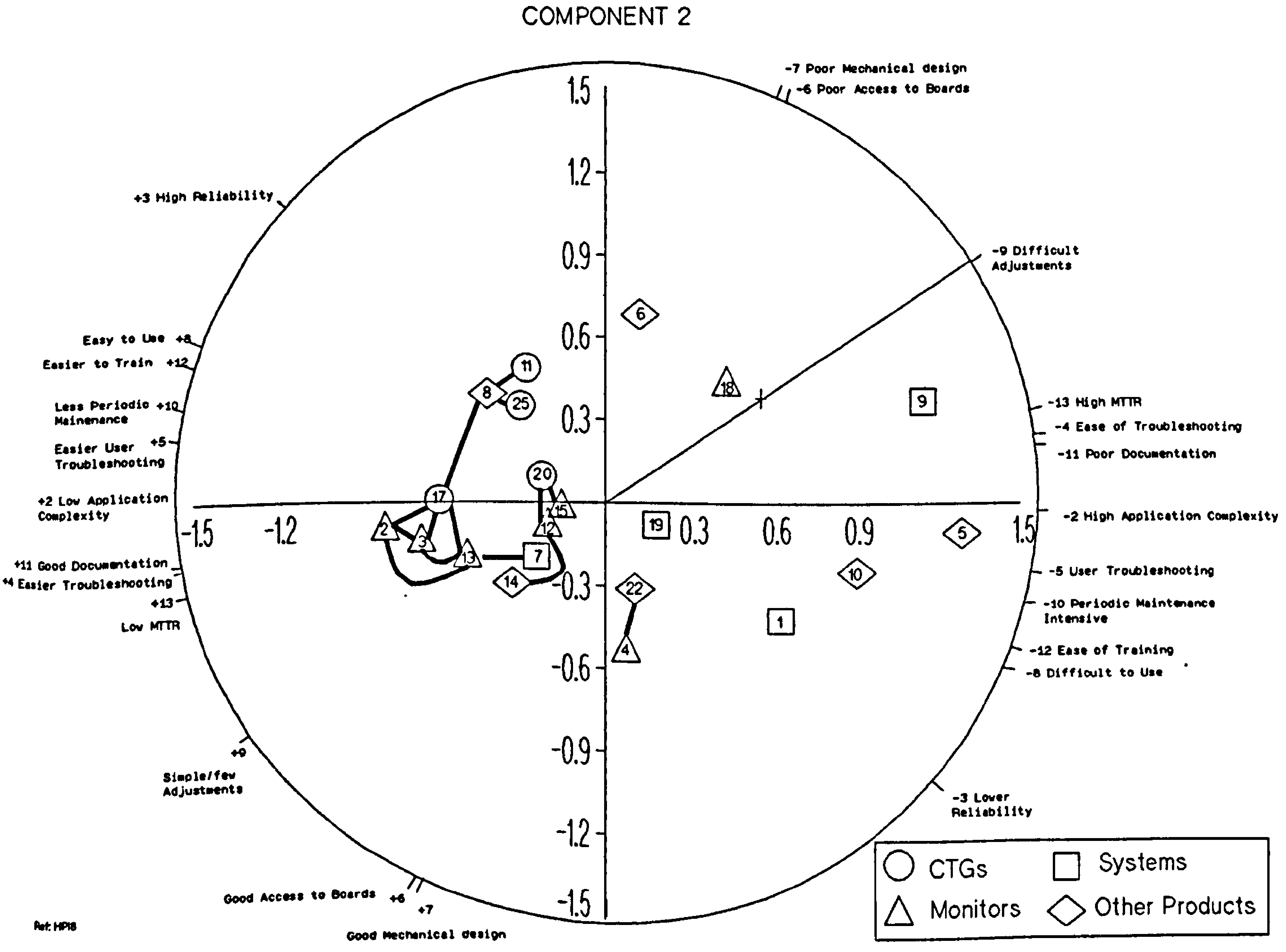
[1] The shortest distances are shown in bold type (0.5 or below was set as the arbitrary level).

Figure 8.6: The Cognitive Map from the Example Interview with an Internal Customer (Engineer H18).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES

No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				



8.2.3i Summary of the Example

The structured interview with Engineer H18 showed that his perception of the supportability of products could be described by thirteen constructs. Products showed differences when rated on these constructs. The cognitive map showed that Engineer H18 perceived the support of products mainly in terms of two factors. These were the characteristics of their mechanical design and their complexity from the troubleshooting and repair, training, maintenance, ease of use and documentation points of view.

The value and limitations of the PCA analysis of repertory grid data should, however, be noted. Although it is widely used in psychological research, the researcher is cautious about making broad conclusions from PCA results. However, because of the exploratory nature of the research and the need to better understand the concept *product support*, it was seen as a useful means of assessing the data. (It is also one of the few methods which allows complex data to be represented in a relatively simple visual form.)

8.2.4 Phase Two Results

The Phase Two Interviews concentrated on collecting the ratings of the elements (products) against the 12 most important constructs identified in Phase One. The Phase Two interviews, although they only collected ratings against provided constructs, were long - typically exceeding one hour per interview[1].

The most important results of Phase Two Interviews were average ratings (across the respondents) of the products against the constructs. Since not every engineer had knowledge of all products, the average ratings for each product were calculated from the number of ratings available for that product (this was a limitation which will be discussed).

8.2.4a The Most Important Constructs

The first evaluation of the results from Phase Two was the check on the variability of the construct ratings, as an indication of their importance. The results are shown in Table 8.9, with the best (minimum), mean, worst (maximum), spread (standard deviation) and variability of each construct.

From Table 8.9 it can be seen that construct *Application Complexity* accounts for most variability in the results. This is not surprising, since the example grid analysis already showed the importance of the complexity of equipment. The next most important constructs are *Ease of Training*

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[1] From the experience gained during the research, collecting ratings on provided constructs took almost as long as eliciting the same number of personal constructs and rating them. Further research, beyond the scope of this project, could investigate the differences in times required to rate personal or provided constructs.

Customers, *Installability* and *Ease of Use*. It is interesting to note that constructs such as *Reliability* and *Service Documentation* exhibit comparatively little variability - this indicates that engineers perceive only small differences between the reliability of various products and between the documentation of various products. Also, because the mean ratings on *Reliability* and *Service Documentation* are good (3.33 and 3.31 respectively), this indicates that all products are perceived as being relatively reliable and as having good documentation.

Reviewing the average values in Table 8.9 gives information on the average perception of support factors. Installation of products is, on average, perceived as relatively easy (a value of 2.97). *User Troubleshooting* and *Ease of Training Customers* have lower mean ratings (4.61 and 4.02 respectively); this indicating that engineers perceive that these aspects of support could be improved. As discussed for the example interview, it could be that *Application Complexity* is the determinant factor and that more complex products are always perceived as harder to support.

Note that the overall average rating is 3.74 and not the midpoint of the rating scale (4.5). This is not unusual - most respondents do not use the rating scales evenly (this is a well-known effect).

Table 8.9: Descriptive Statistics For the Construct Ratings From the Phase Two Interviews (calculated from the repertory grids using *SPSS* software).

Construct	Best Rating on this Construct	Mean Rating on this Construct	Worst Rating on this Construct	Spread of Ratings on this Construct	Construct's Percentage of Spread
*	Min.	Mean	Max.	Std Dev.	Variability
1 Installability	1	2.97	9	1.44	9.98%
2 Application Complexity	1	4.41	9	1.65	11.43%
3 Reliability (MTBF)	2	3.33	8	0.82	5.68%
4 Ease of Troubleshooting	1	3.99	9	1.17	8.11%
5 Ease of User Troubleshooting	1	4.61	9	1.14	7.90%
6 Access to Boards	1	3.64	9	1.17	6.79%
7 Mechanical Design	1	3.97	9	0.98	6.79%
8 Ease of Use	1	3.43	9	1.34	9.29%
—	-	•	-	•	
10 Periodic Maintenance	1	3.21	9	1.27	8.80%
11 Service Documentation	1	3.31	9	0.66	4.57%
12 Ease of Training Customers	1	4.02	9	1.59	11.02%
13 MTTR	1	3.94	9	1.20	8.32%
Overall Average		*3.74*			

* Note: The headings in this line are those adopted by Smith (1986[b]), whereas the line above attempts to give titles that are easier for the reader to understand.

8.2.4b Relationships between Constructs

The recommended method for analysing a series of identical grids is to average the ratings and then analyse the resulting composite grid as a single grid (see for example Fransella and Bannister, 1977). The researcher, because of the large variations in the perceptions of support across respondents, was cautious about this approach. Consequently no full PCA analysis was performed on the composite results. However, the correlations between the ratings were investigated, to see how the constructs were related.

Table 8.9a shows the correlations between the constructs, as indicated by the ratings. It can be seen that the strongest correlations (greater than 0.8 and shown in bold type) are:

- Correlations between *(2) Application Complexity* and three constructs: *(8) Ease of Use* and *(12) Ease of Training Customers*
- A correlation between *(12) Ease of Training Customers* and *(13) MTTR*
- A correlation between *Ease of Troubleshooting* and *Mechanical Design*
- Correlations between *(8) Ease of Use and (12) Ease of Training Customers* and *(13) MTTR*

As discussed for the example interview, further research could aim to establish whether the correlations in the perceptions are the result of causal links in product characteristics or whether they are simply spurious.

Table 8.9a: Correlation Table, Showing the Relationships between the Constructs for the Phase Two Results (calculated using *INGRID* software).

	Construct Numbers									
Constructs	1	2	3	4	5	6	7	8	9	10
1 Installability	1.00									
2 Application Complexity	0.73	1.00								
3 Reliability (MTBF)	0.28	0.30	1.00							
4 Ease of Troubleshooting	0.64	0.35	0.46	1.00						
5 Ease of User Troubleshooting	0.75	0.40	0.40	0.77	1.00					
6 Access to Boards	0.46	0.30	0.37	0.59	0.51	1.00				
7 Mechanical Design	0.44	0.38	0.52	**0.81**	0.55	0.76	1.00			
8 Ease of Use	0.74	**0.84**	0.48	0.60	0.59	0.57	0.64	1.00		
—										
10 Periodic Maintenance	0.60	0.51	0.58	0.75	0.64	0.52	0.77	0.67		1.00
11 Service Documentation	0.64	0.46	0.36	0.72	0.70	0.55	0.59	0.61		0.49
12 Ease of Training Customers	0.78	**0.94**	0.35	0.53	0.53	0.42	0.50	**0.88**		0.57
13 MTTR	0.69	0.75	0.42	0.71	0.68	0.65	0.75	**0.87**		0.72
	11	12	13							
11 Service Documentation	1.00									
12 Ease of Training Customers	0.54	1.00								
13 MTTR	0.58	**0.87**	1.00							

Note: to make this table easier to compare to that from the example interview (Table 8.4), the constructs are listed in the same order and construct 9 is omitted as it was not a *provided construct* in Phase Two.

8.2.4c Product Ratings

Figure 8.7 is the first graph showing results of the ratings of the products against the constructs. It shows the ratings of products against the construct *Installability.* Note that a rating of "1" is "easy/good" and a rating of "9" is "poor/difficult" on each construct.

To simplify Figure 8.7 (and those following), only the ratings for three categories of product have been included; monitors, systems and cardiotocographs. The same symbols as used earlier (i.e. triangles for monitors etc.) indicate the category of product. Where space permits the ratings are labelled, otherwise the products can be identified by their element number [refer to the table of element numbers above the graph]. The x-axis of Figure 8.7 is the introduction date of the product (i.e. a measure of the age of the design of the product).

It should be remembered when interpreting Figure 8.7 that it shows the perceptions of products designed at different times but that the perceptions were all measured at the same time. Hence the perception of the *Installability* of the 78525 (Element 10, introduced in 1981) was estimated in 1990/91, as shown by the dotted lines. The fact that the estimates were all made at the same time is important; Figure 8.7 and following ones do not show true historical data. (Chapter Five noted that this type of historical data on product performance from the support standpoint is not available.)

It can be seen that the ratings have large standard deviations. This is discussed later in the section on limitations but it is basically the result of different engineers having different perceptions of equipment.

Figures 8.8 to 8.18 show the rest of the results of the Phase Two Interviews. These graphs are, to make them easy to compare, all presented in the same scale and format as Figure 8.7. In addition, the order of the graphs follows the order of constructs presented in the previous discussions.

8.2.4d Interpretation of the Ratings (Figures 8.7 to 8.18)

This section will discuss each of the graphs of product ratings (Figures 8.7 to 8.18) in turn. To make the presentation easy to follow the discussions of each graph are presented on the same page as the graph itself. On all of the graphs the ratings have large standard deviations, which limit the depth of interpretation. Consequently, statistical analysis of the trends in the ratings is out of place and the following discussions are qualitative in nature. (The reason for the high standard deviations is discussed in the next section.)

Note: the main text of section 8.2.4e continues after Figures 8.7 to 8.18.

Figure 8.7: The Product Ratings against the Construct *Installability* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

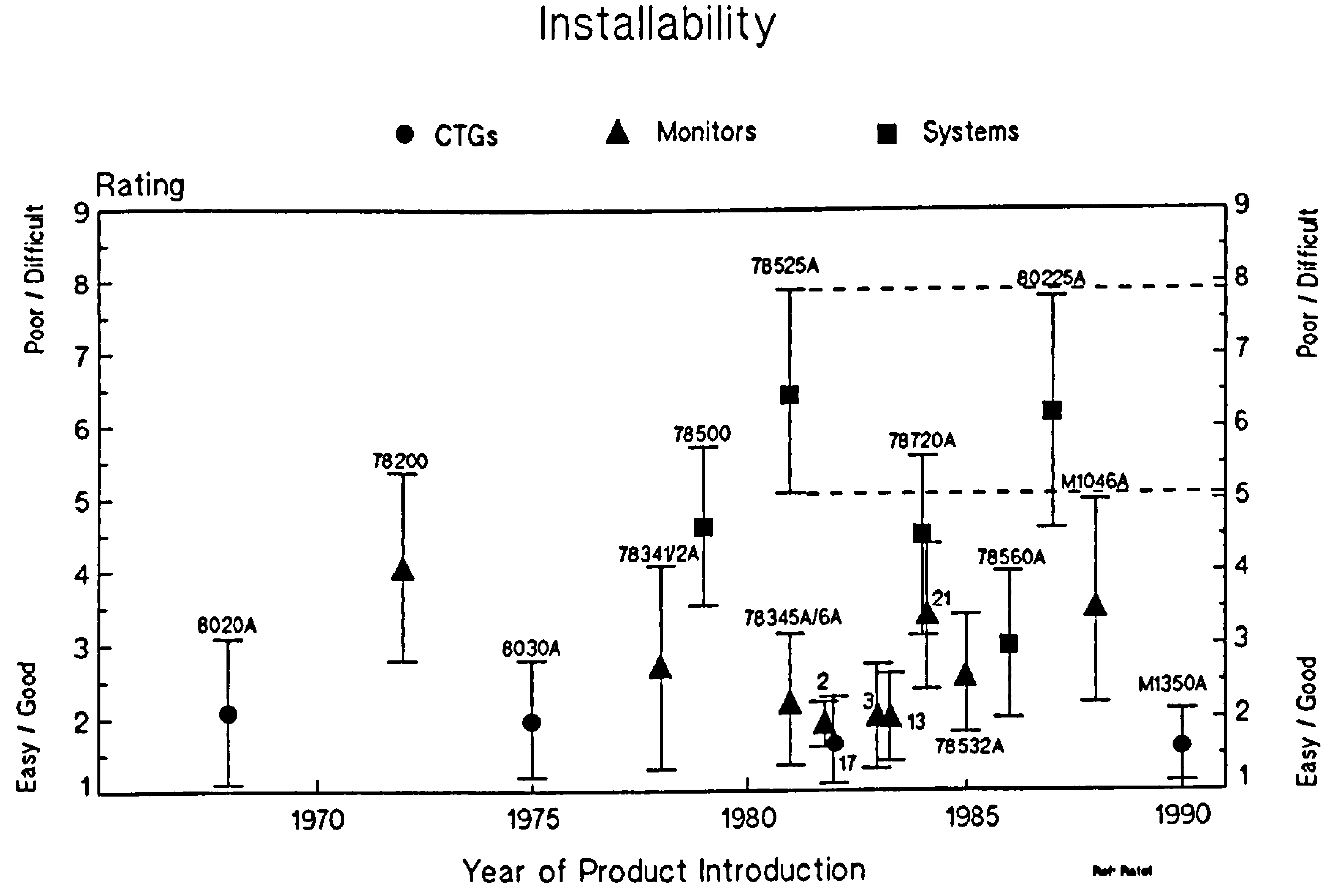

Figure 8.7: *Qualitative Assessment*

1) Spread in Individual Ratings: Typically each individual product rating has a standard deviation of between 1 and 2 units on the scale. This limits the conclusions that can be made from the ratings.
2) Spread of Products Across Rating Scale: The average perceived ratings are from approximately 1.5 (best value) to 6 (worst value). The average rating is approximately 3.
3) Trends Over Time: Apparently none. All CTGs are perceived as easy to install. It does not appear that newer products are perceived as easier to install.
4) Differences Across Product Categories: Systems (boxes) tend to be more difficult to install. Monitors (triangles) lie in the mid-range whereas all cardiotocographs (CTGs - circles) are perceived as easy to install.
5) Note: To make this and later diagrams clearer, the products introduced in the same year have been slightly separated (e.g. 78720A and the 78534A monitor introduced in 1984). These offsets are for clarity only and do not indicate different introduction dates.
6) Conclusions: Limited due to the standard deviations in perceptions. Tentatively it appears that the product category influences the (perceived) *Installability*. This would be expected - systems are more complicated than CTGs and more difficult to install.

Figure 8.8: The Product Ratings against the Construct *Application Complexity* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES

No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

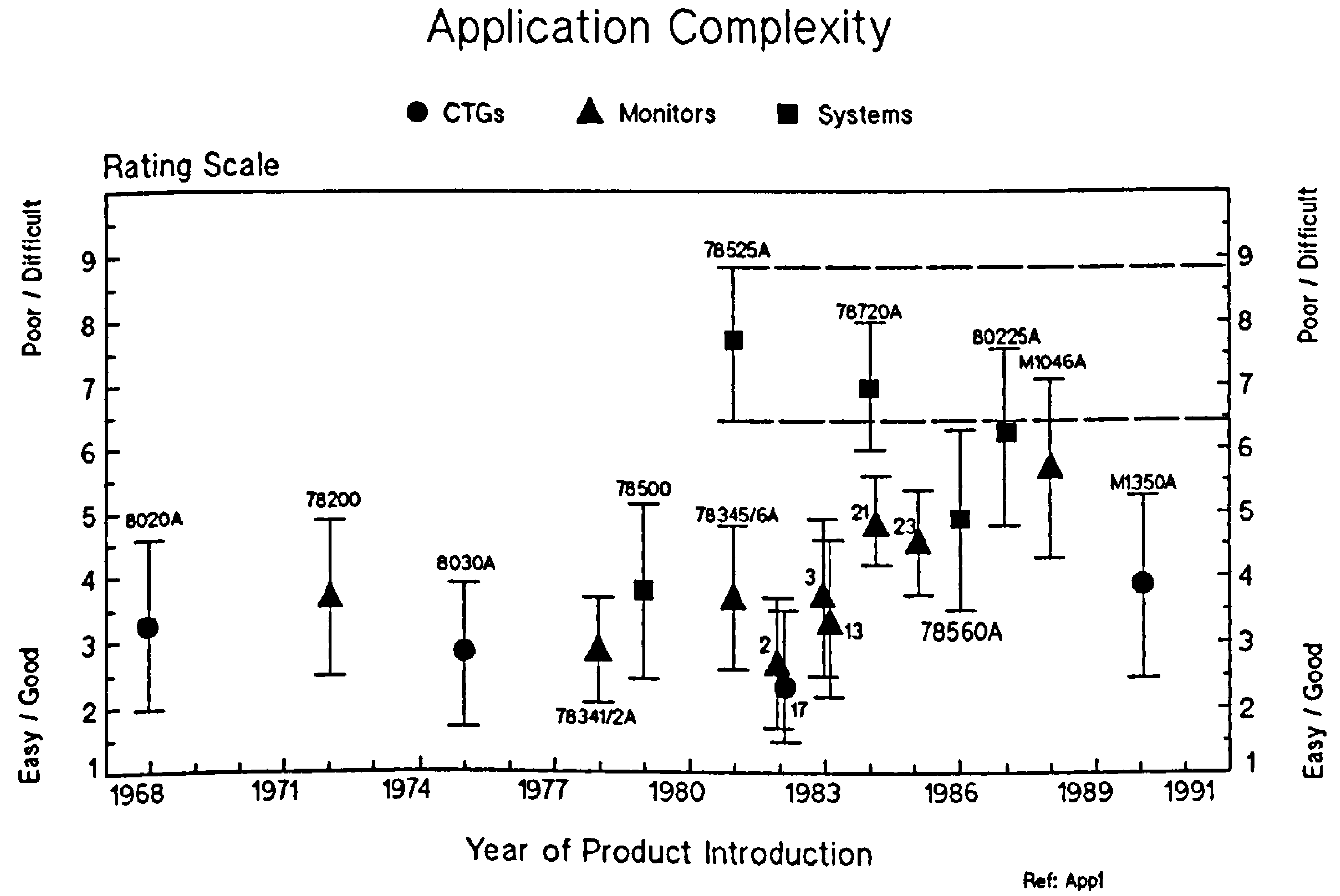

Figure 8.8: *Qualitative Assessment*

1) Spread in Individual Ratings: The average is somewhat lower than in Figure 8.7 but still high.
2) Spread of Products Across Rating Scale: The average perceived ratings range from approximately 2 (simplest product) to approximately 8 (most complex product). Average rating is 4.4.
3) Trends Over Time: Some of the newer monitors (triangles e.g. M1046A) are perceived as more complex than older products in the same category.
4) Differences Across Product Categories: CTGs (circles) are perceived as the most simple. Patient monitors (triangles) cover the mid-range and systems (boxes) are generally perceived as more complex (an exception being the 78500 introduced in 1979).
5) Conclusions: Tentatively it appears that *Application Complexity*, as would be expected, is dependent on the category of equipment in question. Correlations in the results indicate that *Application Complexity* is a key determinant of how easy a product is to support. Technological advances have enabled newer products to have more features. The results possibly show that the M1046A (1988) is perceived as the most complex monitor.

Figure 8.9: The Product Ratings against the Construct *Reliability [MTBF]* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES

No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

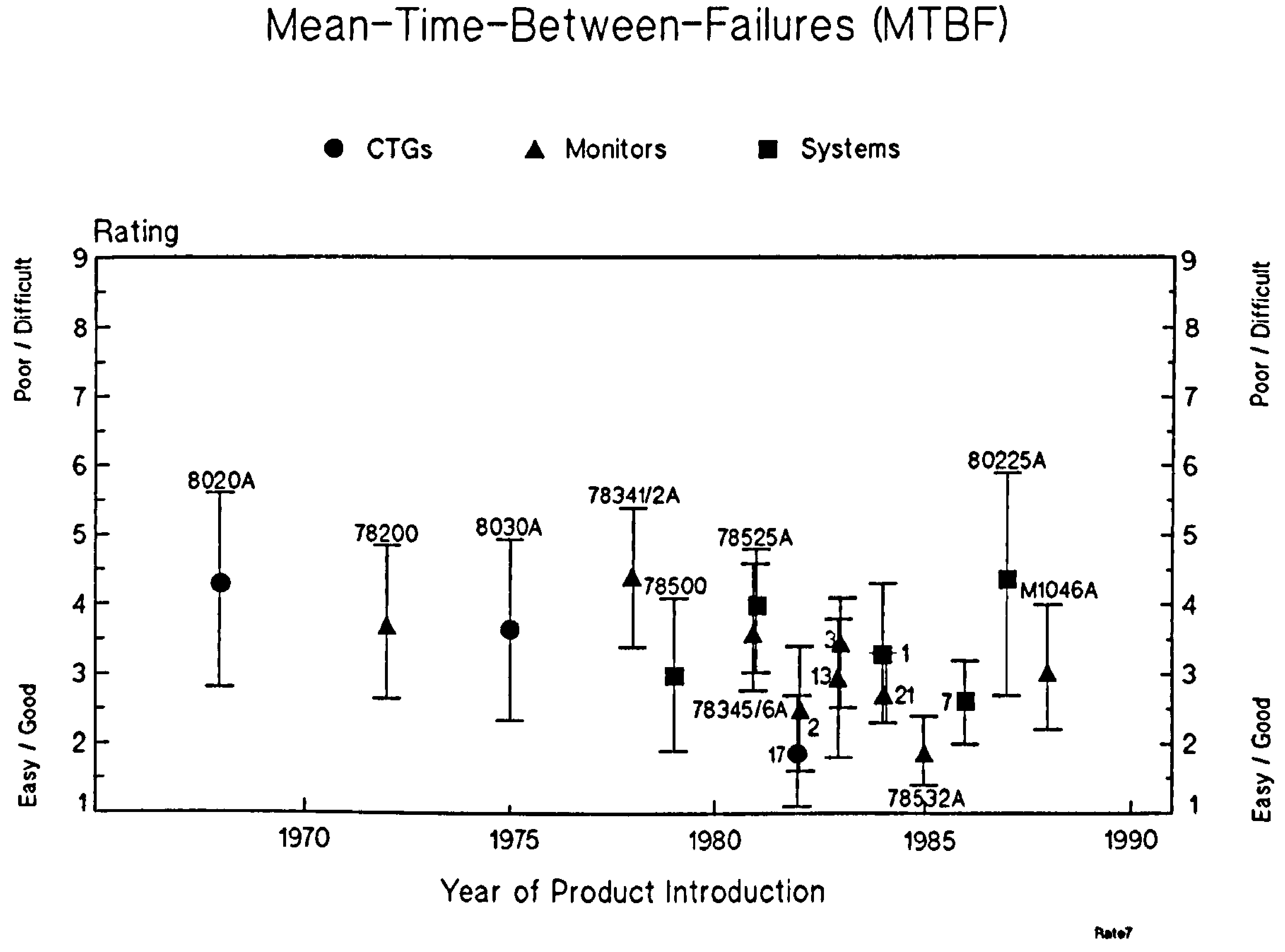

Figure 8.9: *Qualitative Assessment*

1) Spread in Individual Ratings: Large standard deviations as on many other constructs.
2) Spread of Products Across Rating Scale: From approximately 2 (best value) to 4 (worst value). Most products have average ratings below the overall average i.e. products are generally perceived as reliable. Average rating is 3.3.
3) Trends Over Time: No significant trends in the perceptions can be seen because of the standard deviations. Note that the perceptions were all measured in 1990/1991 and true historical data is not shown.
4) Differences Across Product Categories: No clear differences across product categories.
5) Note: No products introduced later that 1989 are rated on *MTBF* or later constructs. This is because the respondents had too little experience of these and could not give ratings.
6) Conclusions: Reliability is generally perceived as good. No conclusions can be reached about differences between products or product categories. Comparison with real reliability data (Figure 5.1) does not show if the perceptions accurately reflect the product characteristics.

Figure 8.10: The Product Ratings against the Construct *Ease of Troubleshooting* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	**Number**	**Type of Product**	**Year**	**No.**	**Number**	**Type of Product**	**Year**
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

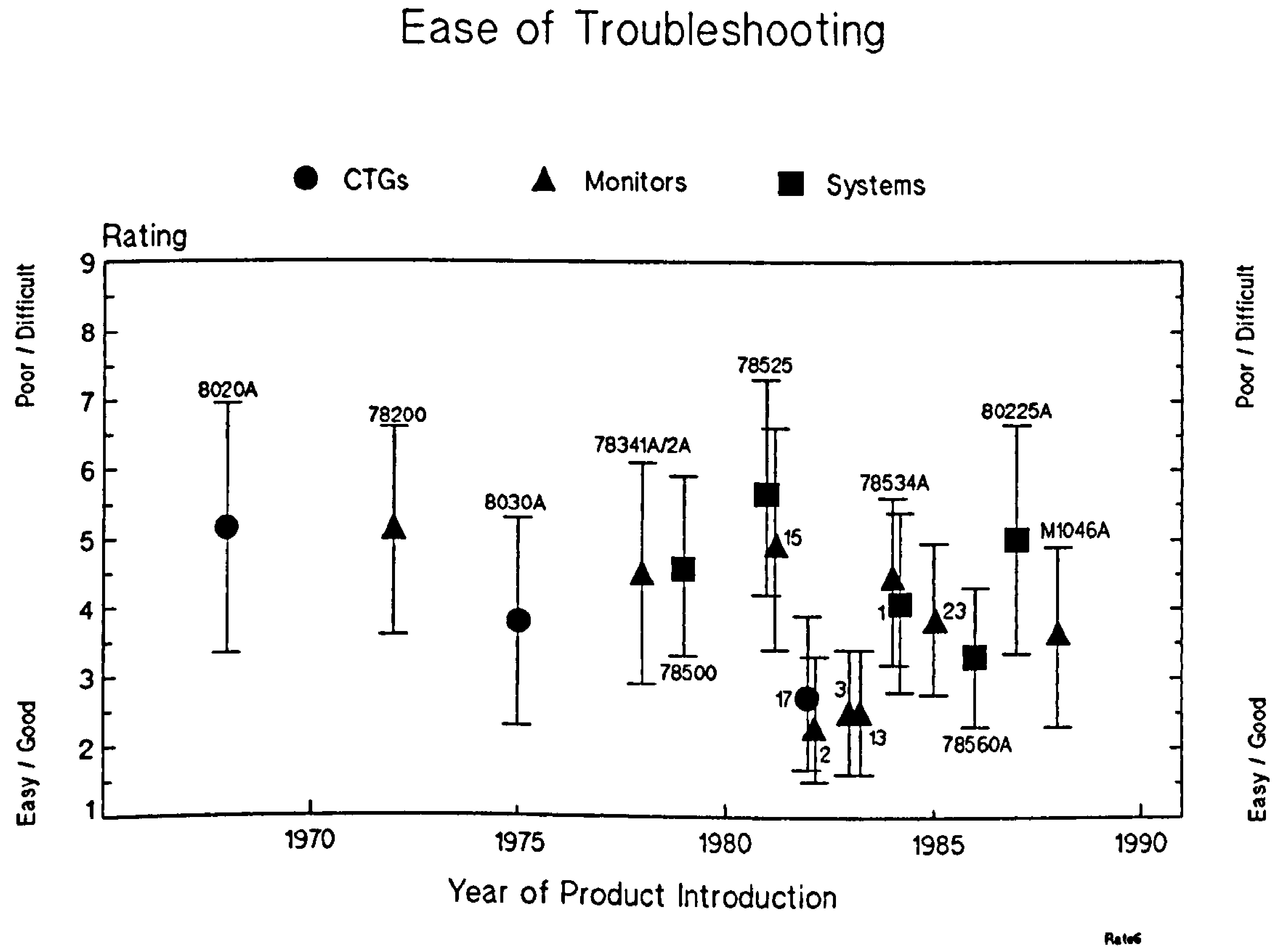

Figure 8.10 : *Qualitative Assessment*

1) Spread in Individual Ratings: High compared to previous diagrams - typically 1.5 units. The wide spread could well be due to halo effects (*Ease of Troubleshooting* is dependent not only on the product design but also on the skill of the engineer).
2) Spread of Products Across Rating Scale: From approximately 2 (best value) to 6 (worst value). About half the products lie above overall average rating (3.7) and half below. Average rating is approximately 4.
3) Trends Over Time: The standard deviations on the ratings are too large to allow any analysis on this point.
4) Differences Across Product Categories: The standard deviations on the ratings are too large to allow any analysis on this point.
5) Conclusions: The ratings on this construct are slightly poorer than the overall average rating (3.7). The spread in the individual product ratings is comparatively high.

Figure 8.11: The Product Ratings against the Construct *Ease of User Troubleshooting* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

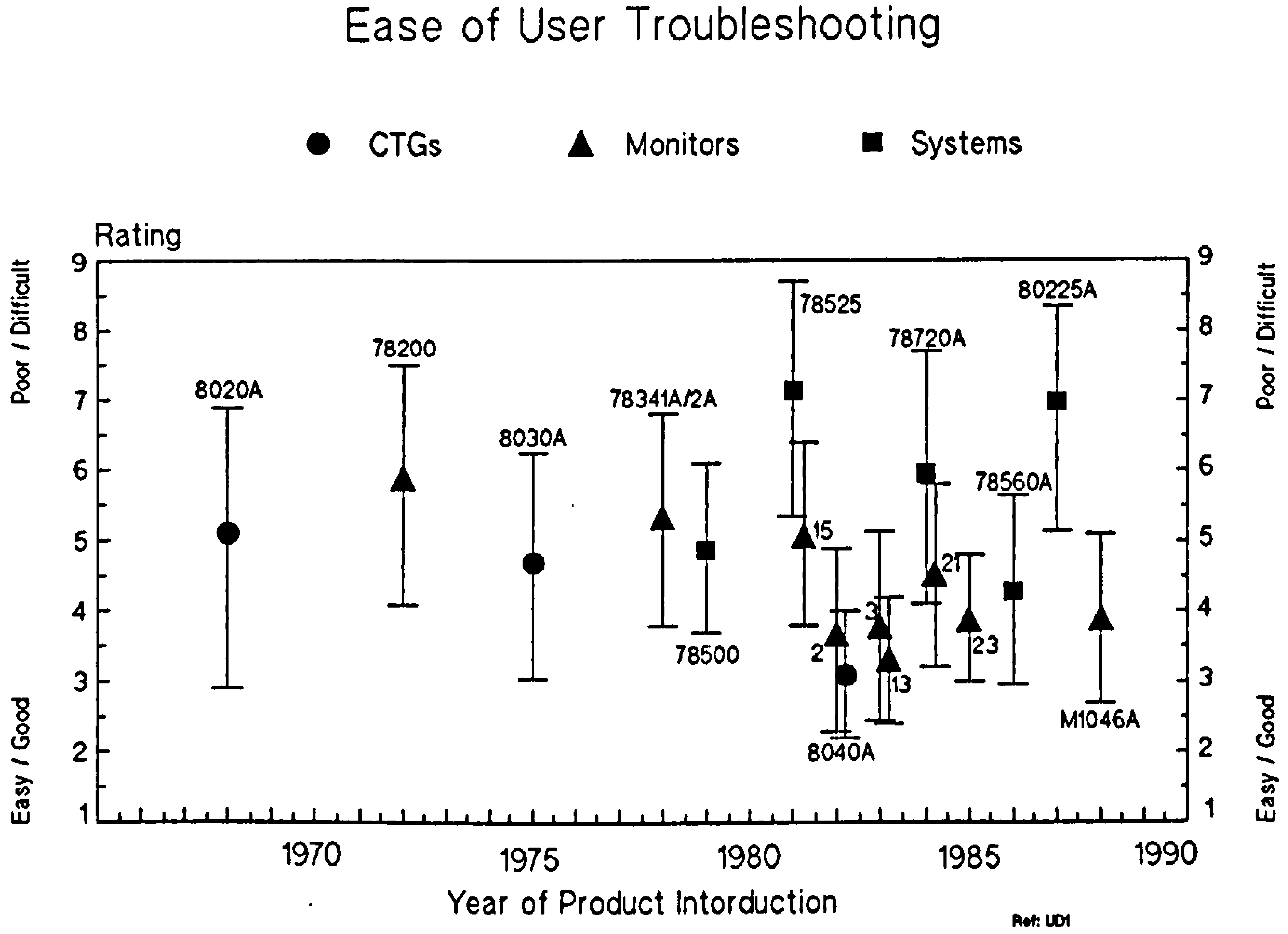

Figure 8.11: *Qualitative Assessment*

1) Spread in Individual Ratings: High variation - also a possible result of the halo effect (this construct depends on both the "typical" user and the product design).
2) Spread of Products Across Rating Scale: From approximately 3 (best value) to 7 (worst value). More products are in the top half of the diagram. Average rating is 4.6.
3) Trends Over Time: The standard deviations on the ratings are too large to allow any analysis on this point.
4) Differences Across Product Categories: The standard deviations on the ratings are too large to allow any analysis on this point.
5) Conclusions: On this construct generally products are perceived as poor - the implication is that design improvements could be made across the products to make it easier for users to test equipment.

Figure 8.12: The Product Ratings against the Construct *Access to Boards* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

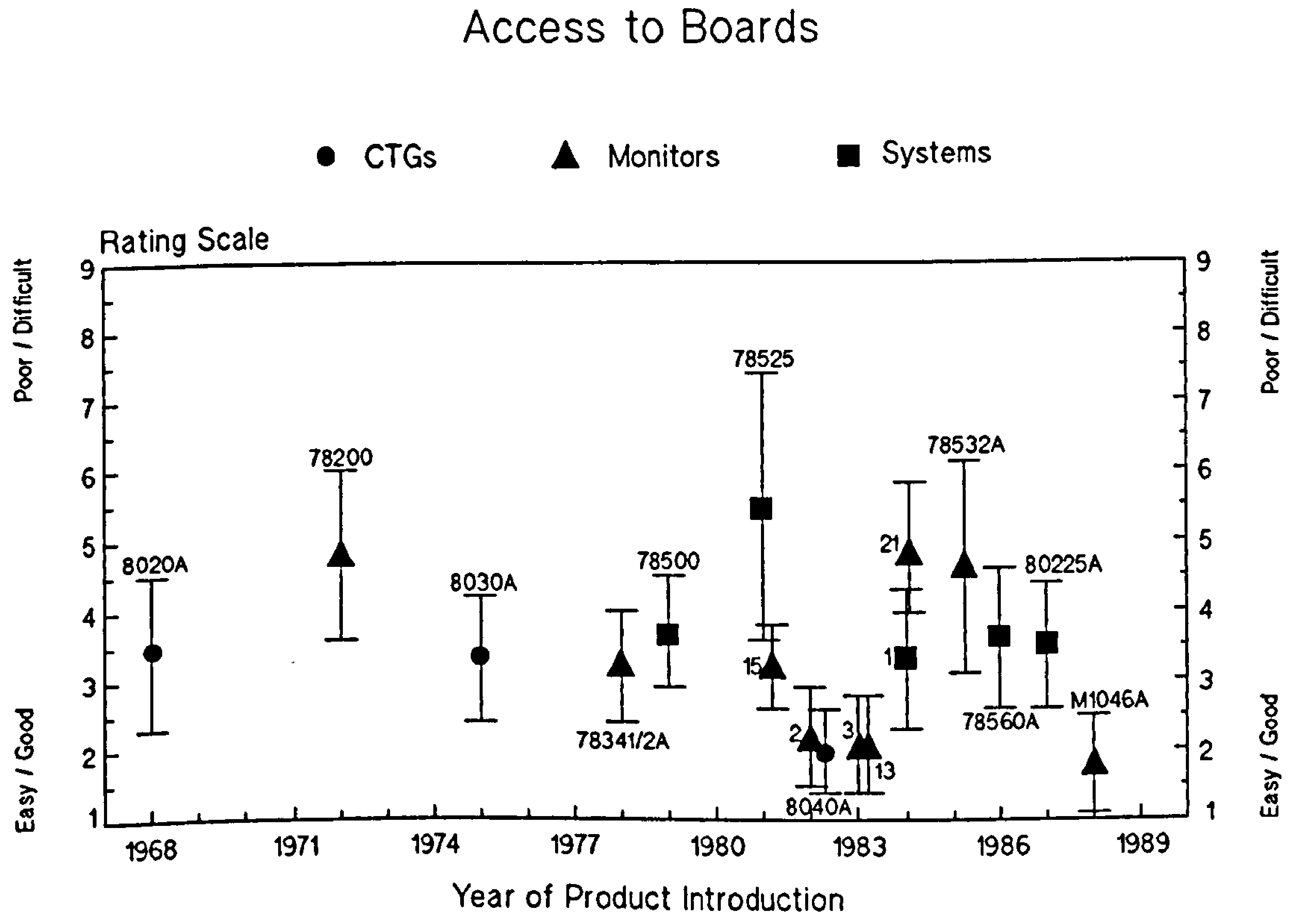

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Figure 8.12: *Qualitative Assessment*

1) Spread in Individual Ratings: Lower than for some other constructs but still high on certain products (e.g. 78525).
2) Spread of Products Across Rating Scale: From approximately 2 (best value) to 5 (worst value). Most products lie below the average overall rating. Average rating is 3.6.
3) Trends Over Time: The standard deviations on the ratings are too large to allow any analysis on this point.
4) Differences Across Product Categories: The standard deviations on the ratings are too large to allow any analysis on this point.
5) Conclusions: The *Access to Boards* is generally perceived as "average" (i.e. close to the overall average rating).

Figure 8.13: The Product Ratings against the Construct *Mechanical Design* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

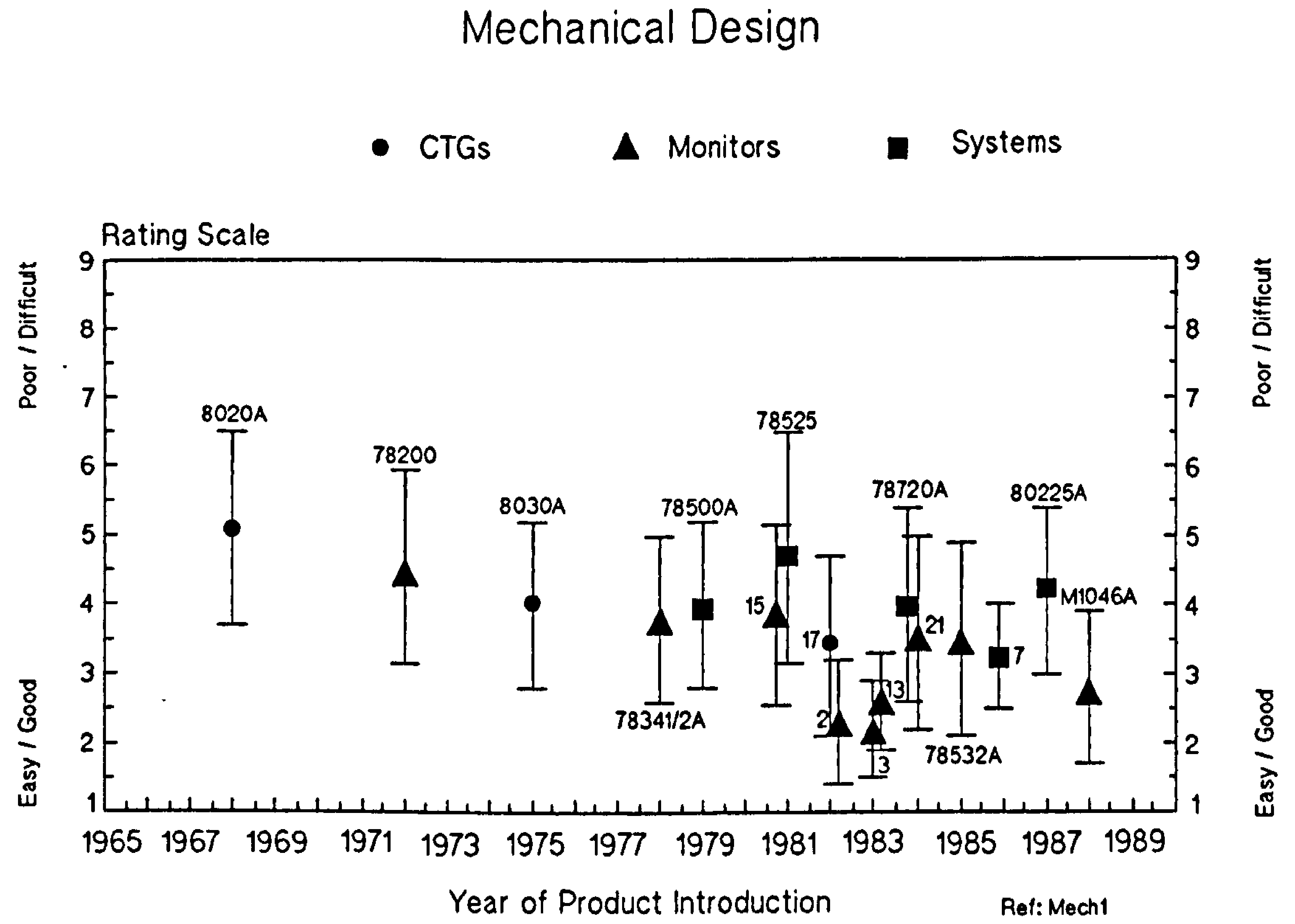


Figure 8.13: *Qualitative Assessment*

1) *Spread in Individual Ratings:* The standard deviations on the ratings are on average 1 unit in magnitude.
2) *Spread of Products Across Rating Scale:* From approximately 2 (best value) to 5 (worst value). Average rating approximately 4.
3) *Trends Over Time:* A slight improvement in all products over time is possibly shown in the results (e.g. CTGs). This is, however, equivocal because of the error bars.
4) *Differences Across Product Categories:* The standard deviations on the ratings are too large to allow any analysis on this point.
5) *Conclusions:* The standard deviations on the ratings are too large to allow any analysis on this point.

Figure 8.14: The Product Ratings against the Construct *Ease of Use* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

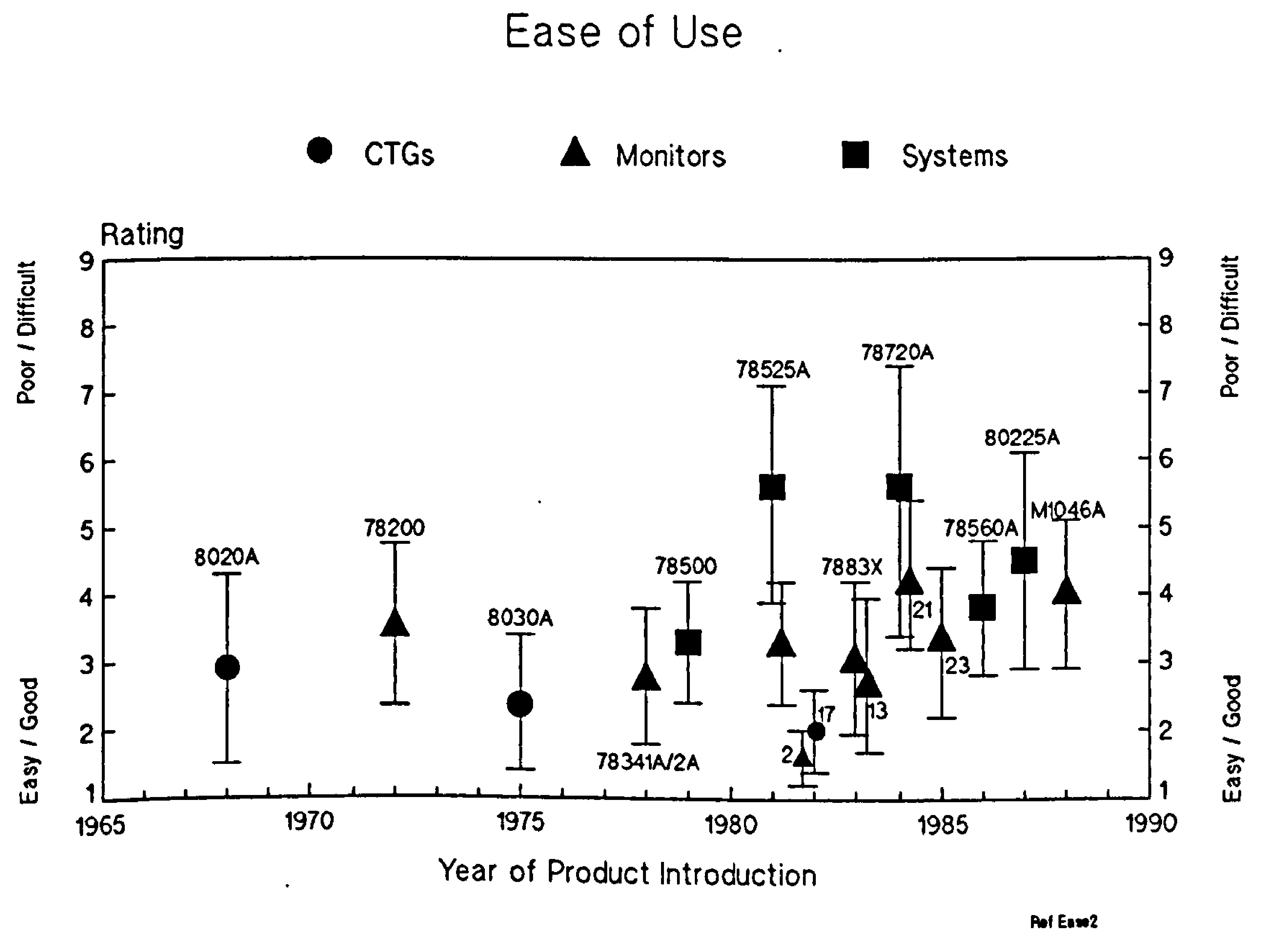


Figure 8.14: *Qualitative Assessment*

1) *Spread in Individual Ratings:* The standard deviations are typically over 1 unit in magnitude.
2) *Spread of Products Across Rating Scale:* From approximately 1.5 (best value) to 6 (worst value). Average rating 4.3.
3) *Trends Over Time:* The standard deviations on the ratings are too large to allow any analysis on this point.
4) *Differences Across Product Categories:* CTGs are perceived as easier to use than systems. Monitors cover the mid-range of the graph.
5) *Conclusions:* This construct is probably closely related to the category of product in question.

Figure 8.15: The Product Ratings against the Construct *Periodic Maintenance* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

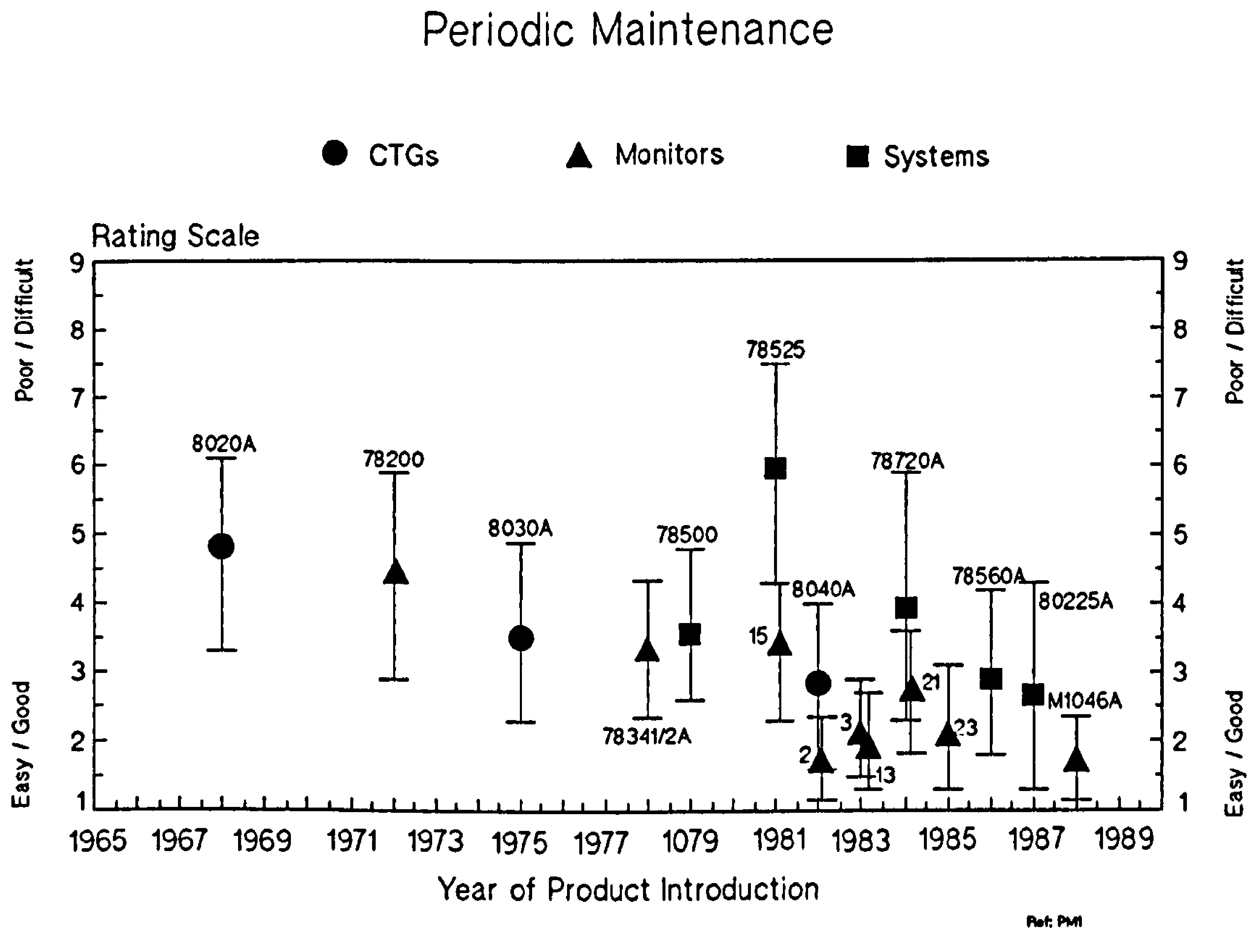


Figure 8.15: *Qualitative Assessment*

1) *Spread in Individual Ratings:* Typically 1.3 in magnitude.
2) *Spread of Products Across Rating Scale:* From approximately 1.5 (best value) to 6 (worst value). Average rating 3.2.
3) *Trends Over Time:* Possible improvements with newer products but the standard deviations make this equivocal.
4) *Differences Across Product Categories:* The standard deviations on the ratings are too large to allow any analysis on this point.
5) *Conclusions:* Possible trend in perceived values - this would be to be expected with the improvements in technology which have reduced the need for periodic maintenance.

Figure 8.16: The Product Ratings against the Construct *Service Documentation* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES

No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

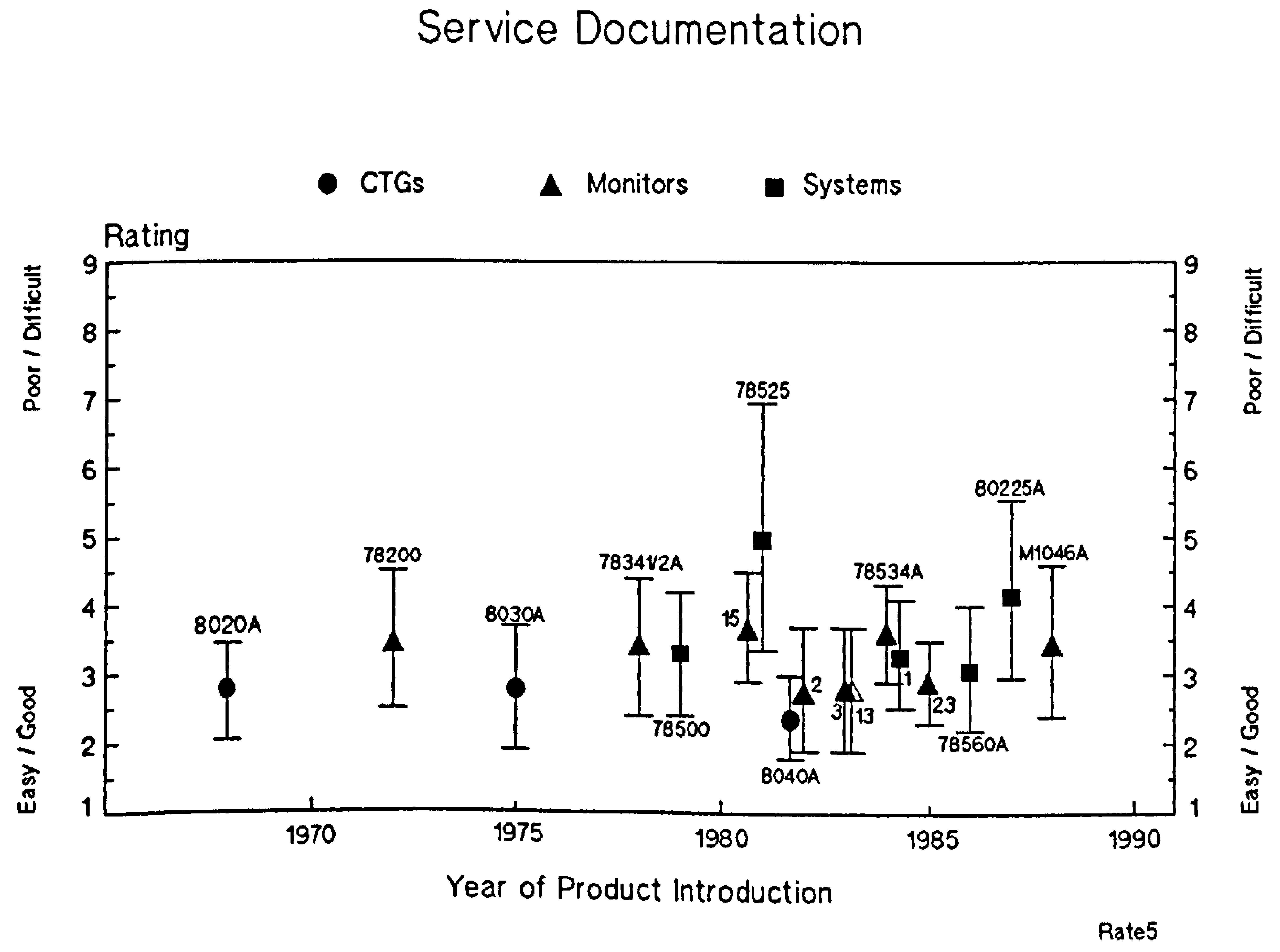


Figure 8.16: *Qualitative Assessment*

1) Spread in Individual Ratings: Small standard deviations on this construct (average 0.7). An exception is the 78525 where the engineers' perceptions vary more strongly.
2) Spread of Products Across Rating Scale: From approximately 2 (best value) to 5 (worst value). Average is 3.3.
3) Trends Over Time: Probably none - these ratings appear relatively stable.
4) Differences Across Product Categories: None - all appear fairly similar.
5) Conclusions: Documentation on all products is apparently perceived as similar and relatively good (it is better than the overall average).

Figure 8.17: The Product Ratings against the Construct *Ease of Training Customers* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	**Number**	**Type of Product**	**Year**	**No.**	**Number**	**Type of Product**	**Year**
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

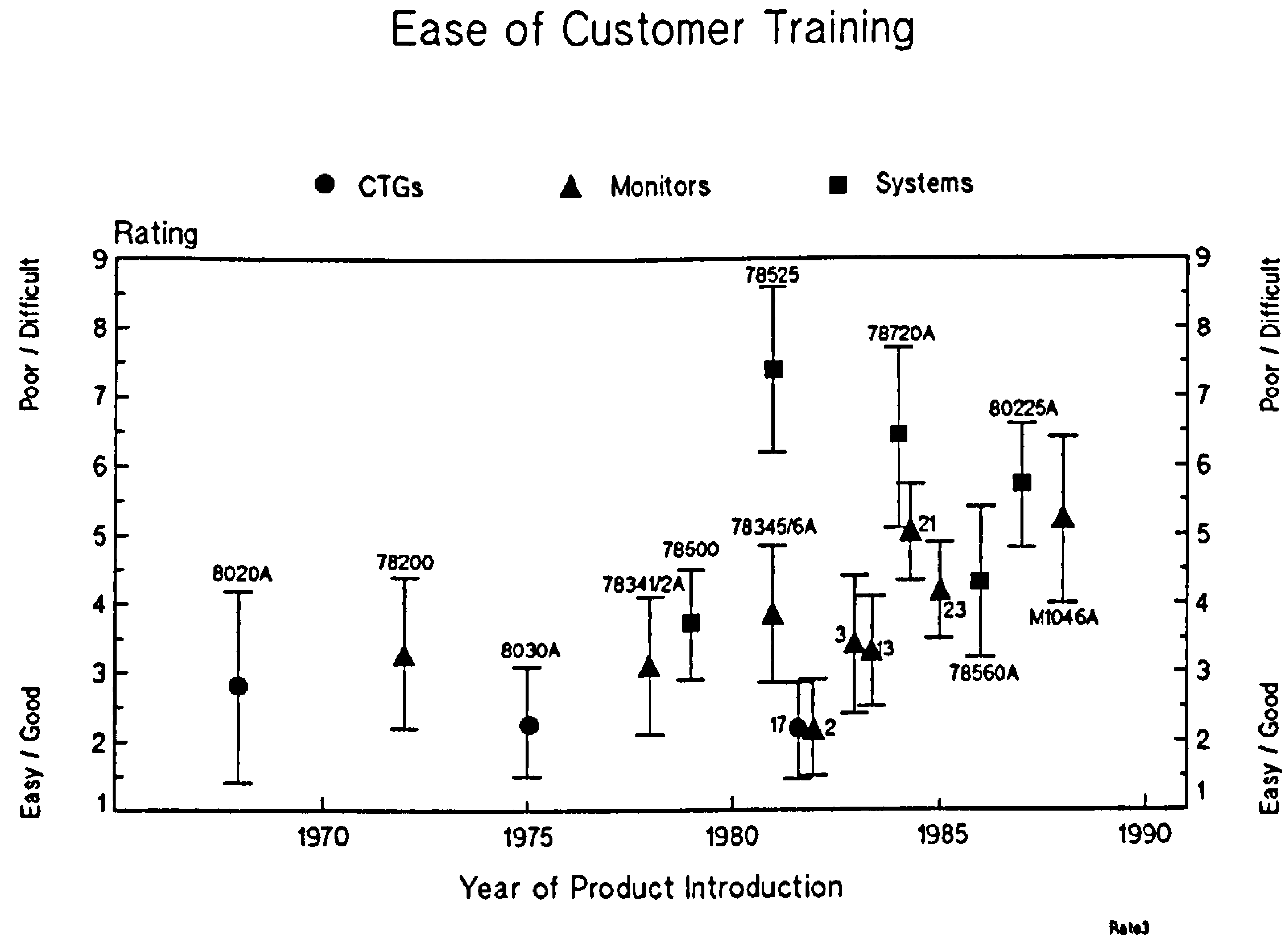


Figure 8.17: *Qualitative Assessment*

1) *Spread in Individual Ratings:* High, on average about 1.6 in magnitude.
2) *Spread of Products Across Rating Scale:* From approximately 2 (best value) to over 7 (worst value). Average is 4.
3) *Trends Over Time:* The standard deviations on the ratings are too large to allow any analysis on this point.
4) *Differences Across Product Categories:* The CTGs are all perceived as easy to instruct customers on. Monitors lie in the mid-range and the hardest products to instruct customers on are some of the systems.
5) *Conclusions:* The results indicate that perceptions of *Ease of Training Customers* are functions of the product category and complexity.

Figure 8.18: The Product Ratings against the Construct *MTTR* (from the Phase Two results).

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				

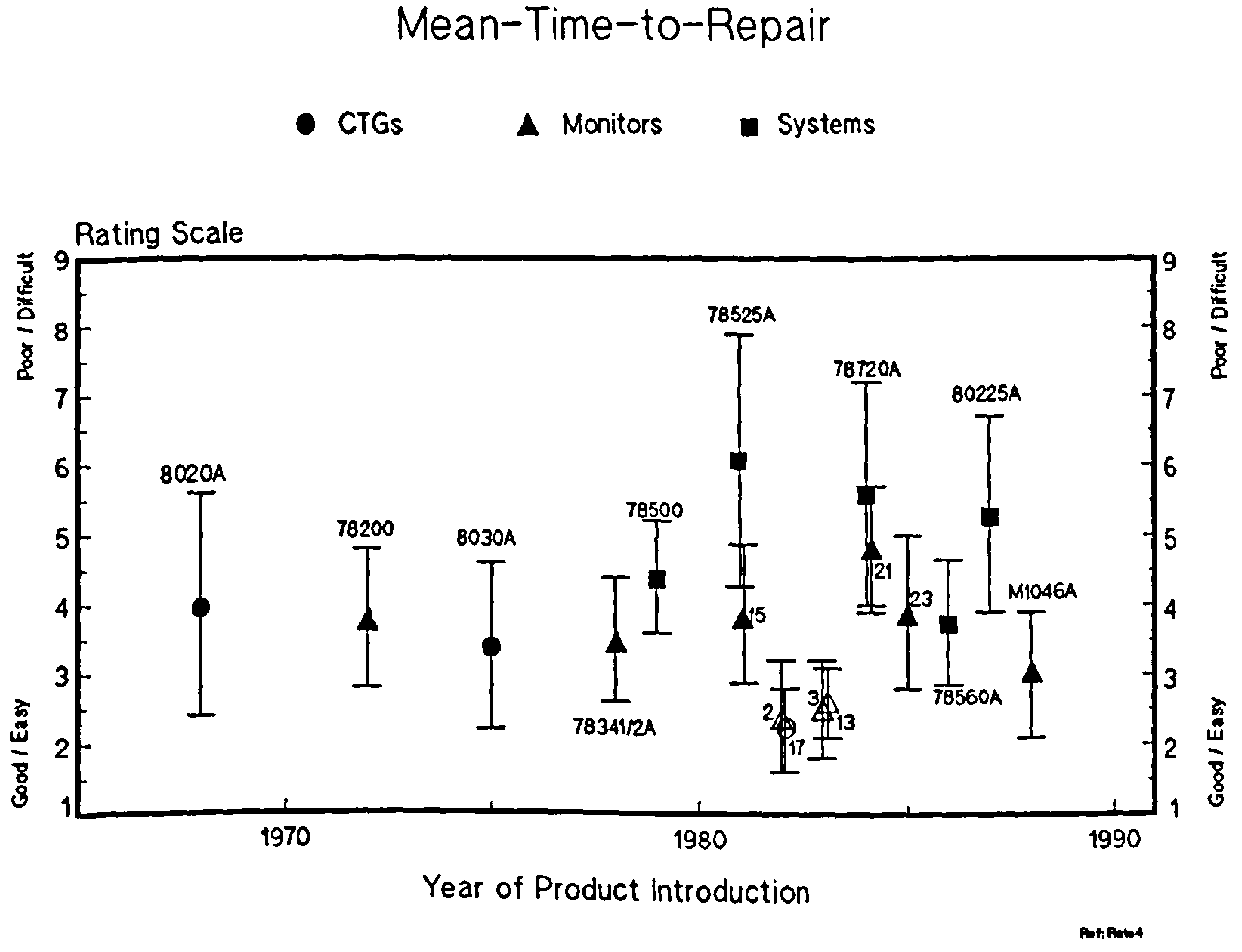


Figure 8.18: *Qualitative Assessment*

1) *Spread in Individual Ratings:* Very high on some products - possibly the result of halo effects.
2) *Spread of Products Across Rating Scale:* From approximately 2.5 (best value) to 6 (worst value). Average 3.9.
3) *Trends Over Time:* The standard deviations on the ratings are too large to allow any analysis on this point.
4) *Differences Across Product Categories:* The standard deviations on the ratings are too large to allow any conclusive analysis on this point -although there is a correlation (see Table 8.9a).
5) *Conclusions:* There is possibly a slight relationship between the complexity of equipment and the *MTTR*.

8.2.4e Limitations of the Ratings

One of the main limitations of the results is the spread of the ratings given to products by engineers. The standard deviations on some of the composite ratings (shown in the graphs Figure 8.7 to 8.18) are about 2 units on the 1 to 9 rating scale. The average deviation is in the order of 1 to 2 units, which means that the results are difficult to interpret. The source of the spread in the ratings is:-

1) Not every engineer had knowledge of every product. This means that the standard deviations tended to be greater on less well-known products (this is seen to a lesser extent on the rating graphs, as these only include the better known types of products).

2) The halo effect; those who are more experienced know products better and therefore are more likely to give a better rating on constructs such as *Ease of Troubleshooting.*

3) Halo "memory effects" - some of the older products are now less common and engineers' memories of their characteristics may be less accurate.

4) Engineers of different nationalities tended to give their ratings on slightly different sections of the scale.

5) Personal preference for a certain part of the scale. For instance some respondents never gave the rating "1", as they perceived no product deserved this rating, whereas others used it freely. [To an extent, this combined with (1).]

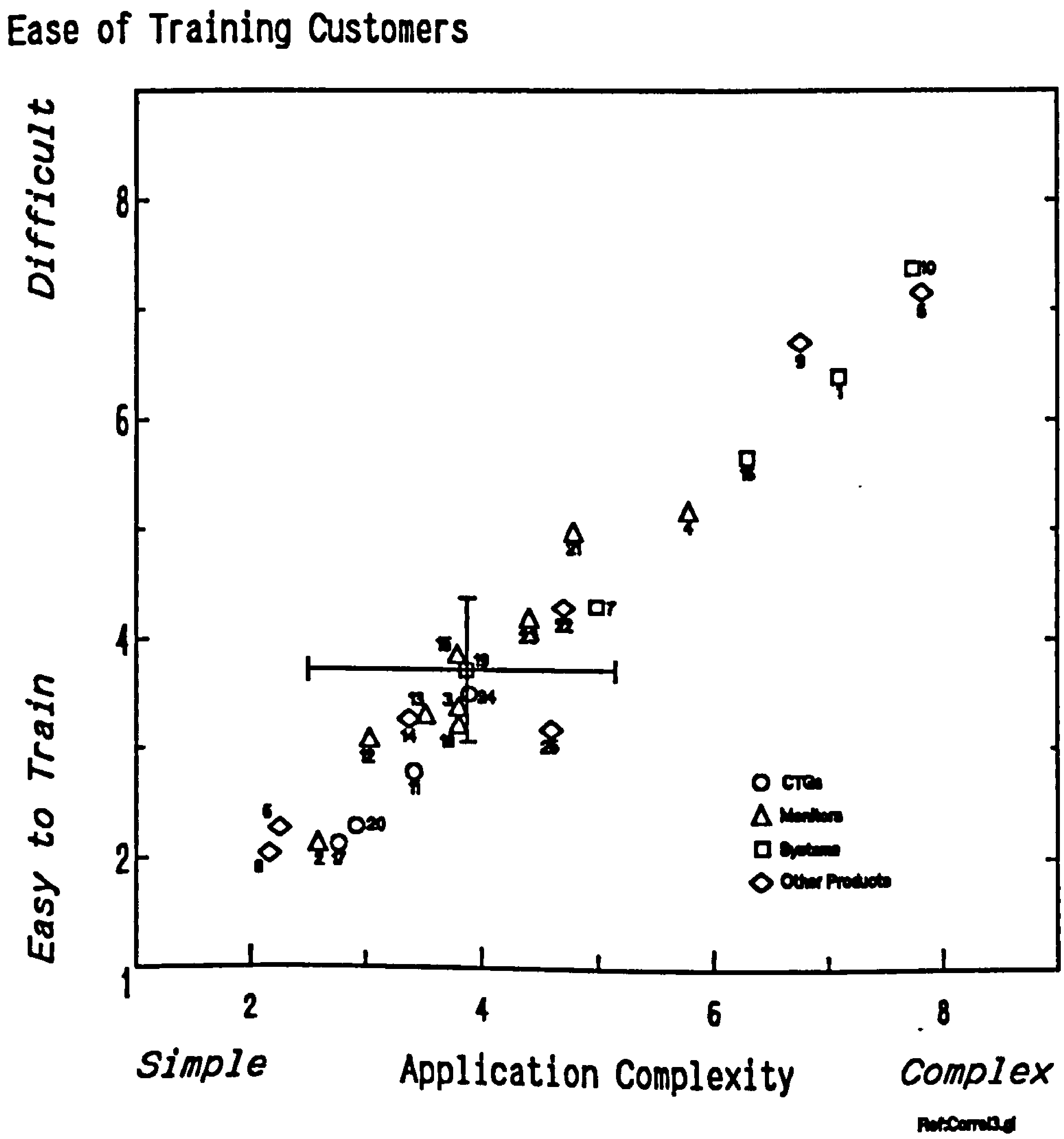
The deviation, even with a sample size of 25 engineers was high. The question arises: *what would be the result if more respondents were interviewed, so as to obtain more estimates of product ratings?* This can be answered, since we know the population and sample sizes (215 and 25 engineers respectively). Calculation shows that the standard deviations for ratings from the whole population would drop to about one third of their value for the sample (assuming that the actual spread in individual ratings remains similar). This would make the results easier to interpret but it would be extremely time consuming to collect the data.

All of the factors mentioned above contribute to limiting the usefulness of ratings for giving data on the historical performance of products. The best example of this is *Reliability*, where true historical data exists for products (see Figure 5.1). Comparison of Figure 8.9 to Figure 5.1 shows that engineers' perceptions do not appear to follow the historical data (This comparison cannot be fully illustrated because of the confidential nature of the reliability figures). This leads to the conclusion that the repertory grid method, because of limitations on the ratings, is pushed to the limit of its usefulness in this context.

Figure 8.19: The Correlation between *Ease of Training Customers* and *Application Complexity.*

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES

No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				



Consequently the question arises; *how useful are the results on the ratings?* The answer is they are useful, since they indicate the aspects of product design that are important and where improvements could be made. An example of this is *Ease of User Troubleshooting*, where the ratings are all relatively poor and improvements could be made. Another is *Ease of Training Customers*. In addition to indicating aspects of product design which could be improved, the ratings also reveal correlations between constructs. Two examples of this are shown in Figures 8.19 and 8.20; these show the two strong correlations between the complexity and the perceived difficulty of operating equipment and the perceived ease of training users. (Note, to make comparison easier, these diagrams use the same symbols as introduced earlier for the different categories of products - triangles for monitors etc.)

Figure 8.19 shows the strong correlation in the results between *Ease of Training Customers* and *Application Complexity*. The products themselves can be identified from the element numbers on the diagram and referring to the table above the graph. The high standard deviations of the individual ratings are illustrated by the error bars shown on one product. Even allowing for the error bars, there appears to be a correlation in the results. When the product categories (indicated by the symbols) are more closely inspected, it can be seen that different categories of products are generally spread over different areas of the diagram. Systems (boxes) tend to be perceived as more complex and consequently more difficult to train customers on. CTGs are perceived as simple and easy to explain. Patient monitors are in the mid-range of the diagram. These results indicate that the category of product in question largely determines the perception of the *Ease of Training Customers*.

Figure 8.20 shows the correlation between *Ease of Use* and *Application Complexity*. Once again, if the product categories are considered, it can be seen that the category of product is perceived as influencing the perceived *Ease of Use*.

8.2.4f Conclusions on the Ratings

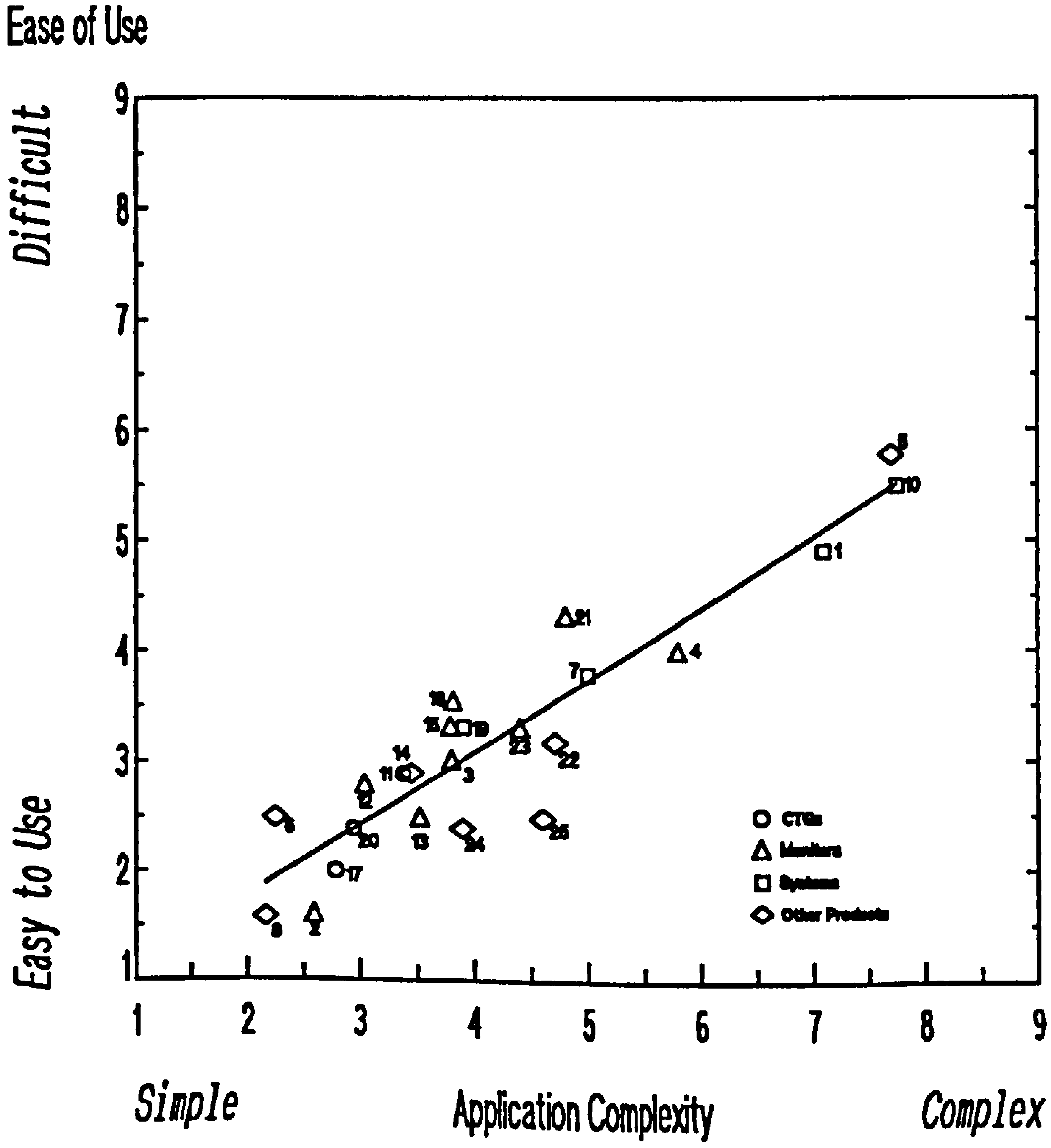
The product ratings (Figures 8.7 to 8.18) gave insight into engineers' perceptions of products but the conclusions which can be reached are limited. However, some tentative points can be extracted from the results. These are:-

1) The perception of *Installability* is apparently determined largely by the product category. Newer products do not appear to be perceived as easier to install than comparable older ones.

2) The perception of *Application Complexity* appears to be determined largely by the category of product in question.

Figure 8.20: The Correlation between *Ease of Use* and *Application Complexity.*

KEY TO PRODUCTS AND MARKET INTRODUCTION DATES							
No.	Number	Type of Product	Year	No.	Number	Type of Product	Year
1	78720A	Arrhythmia System	1984	14	4700A	Cardiograph	1981
2	78351A	Patient Monitor	1982	15	78345A/6A	Patient Monitor	1981
3	7883xA	Patient Monitor	1983	16	80225A	Obstetrical System	1987
4	M1046A	Patient Monitor	1988	17	8040A	Cardiotocograph	1982
5	77020AC	Ultrasound	1980	18	78200A	Patient Monitors	1972
6	78660A	Defibrillator	1981	19	78500	Central Station	1979
7	78560A	Arrhythmia System	1986	20	8030A	Cardiotocograph	1975
8	43120A	Defibrillator	1985	21	78534A	Patient Monitor	1984
9	8800	Catheter System	1971	22	4760AI	Cardiograph	1984
10	78525	Arrhythmia System	1981	23	78532A	Patient Monitor	1985
11	8020A	Cardiotocograph	1968	24	M1350A	Cardiotocograph	1990
12	78341/2A	Patient Monitor	1978	25	M1700A	Cardiograph	1990
13	78354A	Patient Monitor	1983				



Ref: Correl4.gl

[Note: The line shown is the least squares fit through all of the elements]

3) The reliability of products is generally perceived as relatively good.

4) The average ratings on *Ease of Troubleshooting* are slightly poorer than on other constructs. This possibly indicates that the perception of equipment is that it could be made easier to troubleshoot. The large standard deviations on this construct probably indicate that the ratings are susceptible to halo distortions.

5) Products are generally perceived as poor on the construct *Ease of User Troubleshooting.* This indicates that engineers perceive that improvements could be made. The large standard deviations on this construct probably indicate that the ratings are susceptible to halo distortions.

6) There is possibly a perceived improvement in the mechanical design of newer products.

7) The perception of *Ease of Use* is related to the product category and complexity.

8) There is possibly a perceived improvement in newer products against the construct *Periodic Maintenance.*

9) *Service Documentation* is generally perceived as good and similar for all products.

10) The complexity of equipment influences how the *Ease of Training Customers* is perceived.

11) The perception of *MTTR* is possibly influenced by the product complexity.

8.2.5 Summary of Internal Customer Interviews

The interviews with internal customers identified the support factors that they perceive as being the most important. Twelve key constructs were identified, all of which were related to product design. The most important constructs appear to be *Application Complexity, Ease of Training Customers, Installability* and *Ease of Use.*

Different types of products were found to be rated differently against these constructs. However, although the same sorts of products received different ratings, the limitations of the measurement (a *perception*) meant that the differences were not substantial enough to differentiate between designs. The *Application Complexity* appears from the results to be the key factor which determines the ease with which a product can be supported. *Application Complexity* was seen to be determined by the use and complexity of the equipment. Assuming that equipment is not unnecessarily complicated (which could well be the case if designs include unnecessary features) then *Application Complexity* is a "fixed factor" for a particular product. In the perceptions, this then leads to a pre-defined supportability of that product. This begs the question: *must more complex products always be harder to support?* More research would be required to answer this question.

8.3 RESULTS FOR EXTERNAL CUSTOMERS

Interviews with 15 biomedical engineers were conducted from March 1991 to October 1991. The aim of these interviews was to identify the main constructs from a sample of external customers, so that these could be compared to the results from internal customers.

The interviews with biomedical engineers lasted on average eighty-five minutes and produced on average ten personal constructs. The sample included biomedical engineers from a range of sizes of hospital, from a three-thousand bed university hospital to a two-hundred bed district general hospital. The biomedical engineering departments ranged in size from a single person to thirty-two engineers and technicians in the university hospital. The responsibilities of departments includes equipment repair (on average nearly half of departments' work), periodic maintenance (about one quarter of an average department's role), user training, administration and the majority of departments were involved in the purchasing decision for new equipment.

Each interview produced much quantitative and qualitative data. To illustrate this an example repertory grid analysis will be presented before the full listing of constructs is discussed.

8.3.1 An Example Interview (External Customer)

Respondent B11 was supervisor of a three-man biomedical engineering department at a 200 bed hospital. This department is responsible for maintenance and repair of medical equipment and for the training of medical personnel on the operation of the equipment. The training of medical personnel is currently a small part of the department's responsibilities but one which is increasing in importance. (Due to the hospital administration's strict rulings, a large amount of the department's time - approximately 30% - is spent on the paperwork required to document equipment maintenance repair and safety testing.)

8.3.1a The Elements

Respondent B11 named the products shown in Table 8.10 as his personal elements. These can be seen to consist of patient monitors, infusion pumps, a ventilator and four other types of equipment. The broad range of equipment nominated as elements by Respondent B11 was typical of the interviews with biomedical engineers. This is not surprising, since it reflects that biomedical engineering departments are normally responsible for many different types of equipment. Note that the elements in Table 8.10 are listed by the assigned "Element Number" (a randomly assigned number) and not the order in which they were named.

Table 8.10: The Personal Elements from Respondent B11 (ten different pieces of medical equipment in his hospital).

	Personal Elements
1)	Siemens[1] Patient Monitor
2)	Berchtold[1] Electro-Surgery Device
3)	Braun[1] Infusion Pump
4)	Draeger[1] Anaesthesia Machine
5)	Hewlett-Packard 78834A Patient Monitor
6)	Air Shields[1] Incubator
7)	Braun[1] Micro Infusion Pump
8)	Hellige[1] Patient Monitor
9)	Weyer[1] Heated Bed
10)	Bear Medical[1] Ventilator
	[1]Medical equipment manufacturers' names

8.3.1b The Constructs and Grid

The repertory grid resulting from the interview with Respondent B11 is shown in Figure 8.21. The random assignment of element numbers, resulting from the order in which the elements are named, is shown at the top of this form. For example, the first element named (*"H-P 78834A Patient Monitor"*) was assigned element number 5 and appears under this number in the grid (and in Table 8.13, the element).

The first triad of products presented to the respondent was Elements 1, 2 and 3 and these stimulated Construct 1: *"Amount of Periodic Maintenance Necessary"*[1]. All ten elements were rated against this construct and the values are shown in the grid. Those elements which were included in the triad are indicated by the rating being enclosed by stars (e.g. the rating of Element 1 is shown as *1*). The ratings given by B11 on Construct 1 can be seen to range from one (Elements 1, 5, 8, and 9 receive this rating) to four (Elements 3, 6 and 7 receive this poorer rating), out of the possible range of

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[1] This and all other quotes are taken from the audio tape of the interview.

one to nine.

The ratings for the first triad on the first construct elicited were 1, 2 and 4 (*1*, *2* and *4*) i.e. the respondent did not consider any two of these products as being the same on this criterion. He said, "*No two are the same from these three, we really have three very different types of equipment in this bunch... a patient monitor, an electro-surgery device and an infusion pump*". He then continued and identified his construct; "*But when I consider ... [pause] the amount of work that we have with each of these... [pause] we have a lot of work with the infusion pumps and electro-surgery devices. With these there are much more intensive maintenance and inspection procedures to be carried out and documented*".

The second triad (Elements 4, 5 and 6) enabled the Subject B11 to identify Construct 2: "*Ease of Repair*". Note, however, that the elements of the triad were rated identically (with *5*) although "*they are, once again, three absolutely different types of equipment*". He continued, comparing the products; "*patient monitoring is the easiest for us - we have the least trouble with it - but there is one small point of criticism: on the transcutaneous board of the H-P monitor is a small accumulator, which could be better placed so that it would be easier to exchange. The parts which need to be changed regularly, also those from H-P, should be better designed so that they are more "service-friendly". And all parts that you know will fail should be easy to access*".

Subject B11 continued during the course of the ninety minute interview[1] to produce nine more constructs. These others were:-

- Construct 3: *Ease of Cleaning (Decontamination)*. This construct is very important in the hospital setting, where cleanliness is obviously important. ("*A criteria is..., it doesn't affect us directly but it is a key point for the clinical personnel, is the ease of decontamination - cleaning and disinfection. With some products you have to be more careful. But you can design a product so that it is easy to clean and not a disaster!*". "*What poses problems are the cooling fins of the back of the monitor. No nurse could clean those properly, even with a toothbrush!*")

- Construct 4: *Ease of Training Users*. ("*Card number 10, that requires really intensive training for the users - that leads to user errors*".)

- Construct 5: *Availability of Spare Parts*.

- Construct 6: *User Training From the Manufacturer*". ("*One thing that occurs to me as being a weak point for H-P monitors - it's not that bad but it is a weak point - the amount of user training provided. There we are spoilt by competitive companies.*

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[1] This included several interruptions due to telephone calls.

That is to say, we don't receive as much user training as we would like. For one monitor we receive one training and with sixty nurses on some units, that's not enough.")

- Construct 7: *Service Documentation.* The quality of this plays a key role in making maintenance and repair easy.

- Construct 8: *Contact to the Manufacturer.* Respondent B11 explained that this construct covered the personal relationships to the company representatives and the quality of information provided for biomedical engineers in newsletters etc. (e.g. service notes detailing product problems and modifications).

- Construct 9: *Repair Costs.*

- Construct 10: *Technical Training for Biomedical Engineers.* Respondent B11 had attended several technical seminars given by manufacturers and considered the quality of these very important for biomedical engineers.

- Construct 11: *Material for User Training.* ("*We are now beginning to instruct all new nurses and to give regular trainings for the anaesthesia department. We need better material and graphics to be able to explain the equipment simply. As a biomedical engineer your completely on your own on this one... it would be very useful to have good training material*". Note that the ratings given on this construct were all nine - the lowest possible rating as no manufacturer offered good documentation for training purposes.

Note that certain products could not be rated against certain constructs by the interviewee. For instance, Element 8 was not rated against Construct 6 (*User Training from the Manufacturer*) as the respondent had no knowledge of the training offered by this manufacturer. This is indicated on the grid by a question mark.

From B11's eleven constructs it can be seen that some are related to the product itself (e.g. *Ease of Cleaning* and *Documentation*) whereas others are related to the manufacturers' support organizations (e.g. *Contact to the Manufacturer*). This mixture of constructs is typical of the interviews with external customers.

Figure 8.21: Repertory Grid for Biomedical Engineer B11

Order of Personal Element	1	2	3	4	5	6	7	8	9	10	
Element (Card) Number	5	1	8	6	9	10	4	7	3	2	

REPERTORY GRID FOR BIOMEDICAL ENGINEERS

	THE PRODUCTS (ELEMENTS) BY CARD NUMBER										
PERSONAL CONSTRUCTS	1	2	3	4	5	6	7	8	9	10	
1) Periodic Maintenance Necessary	*1*	*2*	*4*	3	1	4	4	1	1	3	
2) Ease of Repair	5	1	5	*5*	*5*	*5*	1	1	1	5	
3) Ease of Cleaning (decontamination)	4	4	3	5	3	6	*3*	*3*	*4*	6	
4) Ease of Training Users	*2*	*5*	2	7	5	4	2	2	2	*6*	
5) Availability of Spare Parts	2	3	*1*	3	3	*6*	1	2	*3*	6	
6) User Training from the Manufacturer	?	*3*	1	2	*8*	3	1	?	5	*3*	

	1	2	3	4	5	6	7	8	9	10	
7) Service Documentation	5	2	*1*	5	2	*7*	1	2	3	*7*	
8) Contact to Manufacturer	3	4	*1*	2	*5*	3	*1*	5	2	3	
9) Repair Costs	6	3	3	*7*	*9*	8	3	*8*	3	9	
10) Technical Training for Biomedical Engineers	*?*	1	1	2	5	8	*1*	?	*2*	2	
11) Material for User Training	9	9	9	9	9	9	9	9	9	9	
	1	2	3	4	5	6	7	8	9	10	

RESPONDENT:xxxxx HOSPITAL:xxxx NO. BEDS:200 NO. BIOMEDS: 3
DEPT.RESPONSIBILITIES: [Repair 30%, Maintenance 10%, Training 10 %, Administration 50%, Other (n/a) %]
DATE:8/3/91 AUDIO TAPE #:1 LENGTH OF INTERVIEW:90min

KEY TO PRODUCTS BY CARD NUMBER

1) Siemens Patient Monitor
2) Berchtold Electro-Surgery Device
3) Braun Infusion Pump
4) Draeger Anaesthetic Machine
5) HP 78834A Patient Monitor
6) Air Shields Incubator
7) Braun Micro Infusion Pump
8) Hellige Patient Monitor
9) Weyer Heated Bed
10)Bear Medical Ventilator

8.3.1c Statistics for the Constructs

Table 8.11 shows the descriptive statistics for B11's constructs. For example, against Construct 1 (*Amount of Periodic Maintenance Necessary*) the elements were rated from a minimum of 1 to a maximum of 4 and had a mean of 2.40 (standard deviation of 1.28). Construct 1 accounted for 4.54 percent of the variability of Respondent B11's ratings, across all constructs. The variability is an indication of a respondent's most important constructs and so it can be seen, on this criterion, that B11's salient constructs are *Repair Costs* (17.41% of variability), *Technical Training for Biomedical Engineers* (15.05% of variability), *Service Documentation* (13.42%) and *User Training from the Manufacturer* (12.97%).

Table 8.11: Descriptive Statistics for Respondent B11's Constructs (calculated from the repertory grid using *Flexigrid 4.2* software).

Construct	Best Rating on this Construct	Mean Rating on this Construct	Worst Rating on this Construct	Spread of Ratings on this Construct	Construct's Percentage of Spread
*	Min.	Mean	Max.	Std Dev.	Variability+
1 Periodic Maintenance Necessary	1	2.40	4	1.28	4.54%
2 Ease of Repair	1	3.40	5	1.96	10.63%
3 Ease of Cleaning	3	4.10	6	1.14	3.57%
4 Ease of Training Users	2	3.70	7	1.85	9.44%
5 Availability of Spare Parts	1	3.00	6	1.67	7.75%
6 Manufacturer's User Training	1	3.25	8	2.17	12.97%
7 Service Documentation	1	3.50	7	2.20	13.42%
8 Contact to Manufacturer	1	2.90	5	1.37	5.32%
9 Repair Costs	3	5.90	9	2.51	17.41%
10 Technical Training for Biomeds.	1	2.75	8	2.33	15.05%
11 Material for User Training	9	9.00	9	-	
Average		*3.49*			

Notes:
+ Construct 11 has identical ratings for all elements and so it was omitted from this analysis.
* The headings in this line are those adopted by Smith (1986[b]), whereas the line above attempts to give titles that are easier for the reader to understand.

8.3.1d Relationships between Constructs

Table 8.12 shows the correlations between the personal constructs of Subject B11. The strongest correlations (greater than 0.8) will be discussed and these are shown in bold type. There are four of these:-

- A negative correlation between *Periodic Maintenance* and *User Training from the Manufacturer.*
- Correlations between *Ease of Cleaning* and the two constructs: *Availability of Spare Parts* and *Service Documentation.*
- A correlation between *Availability of Spare Parts* and *Service Documentation.*

Obviously a correlation does not show that there is causation. The above correlations are probably spurious because of other factors. For instance, a manufacturer normally produces only one type of medical equipment (e.g. ventilators) which require a characteristic amount of maintenance. The more maintenance that a device requires is dependent on its complexity and manufacturers probably offer better training on these devices.

Table 8.12: Correlation Table, showing the Relationships between B11's Constructs+.

	Construct Numbers									
Constructs	1	2	3	4	5	6	7	8	9	10
1 Periodic Maintenance Necessary	1.00									
2 Ease of Repair	0.26	1.00								
3 Ease of Cleaning	0.32	0.43	1.00							
4 Ease of Training Users	0.14	0.42	0.59	1.00						
5 Availability of Spare Parts	0.14	0.37	0.89	0.58	1.00					
6 Manufacturers' User Training	-.84	0.09	-.12	0.18	0.24	1.00				
7 Service Documentation	0.14	0.56	0.94	0.48	0.84	0.00	1.00			
8 Contact to Manufacturer	-.66	-.06	-.06	0.22	0.26	0.78	0.05	1.00		
9 Repair Costs	-.17	0.54	0.42	0.49	0.60	0.45	0.59	0.61	1.00	
10 Technical Training for Biomeds	0.02	0.47	0.42	0.15	0.62	0.43	0.53	0.46	0.64	1.00
11 Material for User Training										

+ Construct 11 has identical ratings for all elements and so it was omitted from this analysis.

8.3.1e Statistics for the Elements

Table 8.13 shows the statistics for the elements, with the best, average and worst scores, plus the standard deviations and variabilities.

Table 8.13: Descriptive Statistics for Respondent B11's Elements.

Element	Type of Product	Element's Best Score	Element's Mean Score	Element's Worst Score	Spread in Element's Ratings	Percentage Attributable to Product
*		Minimum	Mean	Maximum	Std Dev.	Variability
	Ideal Product	*1*	*1.00*	*1*		*0.00%*
1	Siemens Patient Monitor	1	3.50	6	1.66	8.98%
2	Berchtold Electro-surgery Device	1	2.80	5	1.25	5.09%
3	Braun Infusion Pump	1	2.20	5	1.40	6.40%
4	Draeger Anaesthetic Machine	2	4.10	7	1.87	11.39%
5	HP 78834A Patient Monitor	1	4.60	9	2.37	18.41%
6	Air Shields Incubator	3	5.40	8	1.80	10.57%
7	Braun Micro Infusion Pump	1	1.80	4	1.08	3.79%
8	Hellige Patient Monitor	1	3.00	8	2.24	16.32%
9	Weyer Heated Bed	1	2.60	5	1.20	4.70%
10	Bear Medical Ventilator	2	5.00	9	2.10	14.36%
	Overall Average		*3.50*			

* Note: The headings in this line are those adopted by Smith (1986[b]), whereas the line above attempts to give titles that are easier for the reader to understand.

It can be seen that Element 7 (Braun Micro Infusion Pump) has a good average rating of 1.80 and low variability (3.79%). This shows that everything about this product and manufacturer is perceived positively from B11's perspective. The product with the poorest average rating is Element 6 (Air Shields Incubator) with 5.40.

Note, however, the average ratings of the elements cover a wide range of constructs - some of which are product related, some price related and some related to the manufacturer's support organization. Therefore, a rating in the mid-range could be due, for example, to a product that was well perceived but from a manufacturer without a very good support organization. The elements which have very good ratings on some constructs but poor ones on others can of course be recognized by their high variability.

8.3.1f Analysis of Component Space

Table 8.14 shows the PCA results for the Phase Two average ratings. It can be seen that 67% of the variation in the results can be explained by two trends. This indicates that Subject B11 has a fairly simple perception of products as the trends in the ratings can be largely explained by two PCA components.

Table 8.14: The Analysis of Component Space for Biomedical Engineer B11.

PCA Component No.	Root	As a Percentage
1	4.56	46%
2	2.15	21%
3	1.15	12%
4	0.82	8%
5	0.64	6%
6	0.46	5%
7	0.13	1%
8	0.09	1%

8.3.1g Analysis of Loadings etc.

Table 8.15 gives the element and construct ratings that allow the cognitive map to be drawn. The top half of the table gives the loadings which allow the positions of the products on the cognitive map to be drawn.

The bottom half of the table shows the relationships of the constructs to the two main PCA components. It can be seen that the strongest correlation with Component 1 is *(5) Availability of Spare Parts* [-0.43]. The strongest correlation to Component 2 are *(1) Periodic Maintenance Necessary* and *(8) Contact to the Manufacturer* [0.58 and -0.60 respectively].

Table 8.15: Element and Construct Loadings for the Grid from Subject B11 (Calculated using *INGRID* software).

	Component 1			Component 2		
Element	**Vector**	**Loading**	**Residual**	**Vector**	**Loading**	**Residual**
1 Siemens Patient Monitor	0.10	0.21	0.52	-.00	-.00	0.52
2 Berchtold Electro-Surgery Device	0.13	0.29	0.40	-.16	-.24	0.34
3 Braun Infusion Pump	0.33	0.70	0.58	0.40	0.58	0.24
4 Draeger Anaesthetic Machine	-.22	-.46	0.37	0.21	0.31	0.27
5 HP 78834A Patient Monitor	-.17	-.37	1.30	-.64	-.94	0.41
6 Air Shields Incubator	-.54	-1.15	0.43	0.24	0.36	0.31
7 Braun Micro Infusion Pump	0.42	0.89	0.36	0.33	0.48	0.12
8 Hellige Patient Monitor	0.25	0.54	0.75	-.39	-.58	0.42
9 Weyer Heated Bed	0.18	0.38	0.50	-.11	-.16	0.47
10 Bear Medical Ventilator	-.48	-1.02	0.21	0.13	0.18	0.18
Construct	**Vector**	**Loading**	**Residual**	**Vector**	**Loading**	**Residual**
1 Periodic Maintenance Necessary	-.07	-.16	0.98	0.58	0.85	0.25
2 Ease of Repair	-.30	-.63	0.60	0.15	0.22	0.55
3 Ease of Cleaning	-.40	-.86	0.27	0.24	0.35	0.14
4 Ease of Training Users	-.34	-.72	0.48	-.04	-.06	0.48
5 Availability of Spare Parts	-.43	-.92	0.15	0.01	0.01	0.15
6 Manufacturers' User Training	-.18	-.38	0.85	-.36	-.53	0.57
7 Service Documentation	-.40	-.86	0.26	0.16	0.24	0.20
8 Contact to Manufacturer	-.12	-.27	0.93	-.60	-.87	0.16
9 Repair Costs	-.35	-.75	0.44	-.26	-.37	0.30
10 Technical Training for Biomeds	-.33	-.71	0.49	-.02	-.03	0.49
11 Material for User Training						
+ Construct 11 has identical ratings for all elements and so it was omitted from this analysis.						

8.3.1h The Cognitive Map

Table 8.16 shows the distances between the elements in component space, which allow the links between elements to be drawn onto the cognitive map. The cognitive map is shown in Figure 8.22, the main features of which will be discussed.

Table 8.16: The Distances between the Elements for Subject B11 (Calculated using *INGRID* software).

	Product Numbers								
Elements (Products)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1 Siemens Patient Monitor									
2 Berchtold Electro-S. Device	0.78								
3 Braun Infusion Pump	0.79	0.88							
4 Draeger Anaesthetic Machine	0.77	0.78	0.93						
5 HP 78834A Patient Monitor	1.07	0.93	1.27	1.00					
6 Air Shields Incubator	1.16	1.19	1.34	0.83	1.15				
7 Braun Micro Infusion Pump	0.90	0.76	0.43	1.03	1.34	1.41			
8 Hellige Patient Monitor	0.66	0.69	1.02	1.07	1.03	1.40	0.92		
9 Weyer Heated Bed	0.75	0.54	0.86	0.94	0.98	1.20	0.74	0.83	
10 Bear Medical Ventilator	0.76	1.02	1.30	0.54	1.09	0.61	1.37	1.23	1.12

The circle drawn from the origin of the two components is annotated with ten of B11's constructs (the eleventh construct had identical ratings for all products and was therefore omitted from this analysis). Three constructs (4, 10 and 5) have strong correlations with Component 1, whereas two (1 and 6) are strongly correlated to Component 2. In general the right hand side of the map includes the products which are perceived as good and from manufacturers with good support organizations. Three pairs of products are perceived as similar from the support viewpoint. These are:-

- The Bear Ventilator (10) and Draeger Anaesthetic Machine (4) - this similarity is not surprising as both pieces of equipment are of comparable complexity and have a similar medical application.

- The Braun Infusion Pump (3) and Braun Micro Infusion Pump (7) are clearly perceived as very similar and easy to support.

- The Weyer Heated Bed (9) and Berchtold Electro-surgery Device (2) are also perceived as easy to support.

Element 5's (HP 78834A) position on the map is distinctive for B11 - this product is perceived as having high repair costs and being supported by an organization who provide too little training for the users and have too little contact with the respondent's biomedical engineering department. This, and the other products positions, have implications for the respective manufacturers. Obviously the perceptions are from a single biomedical engineer but if the results were confirmed for a representative sample then they would indicate areas of the support strategy that could be improved.

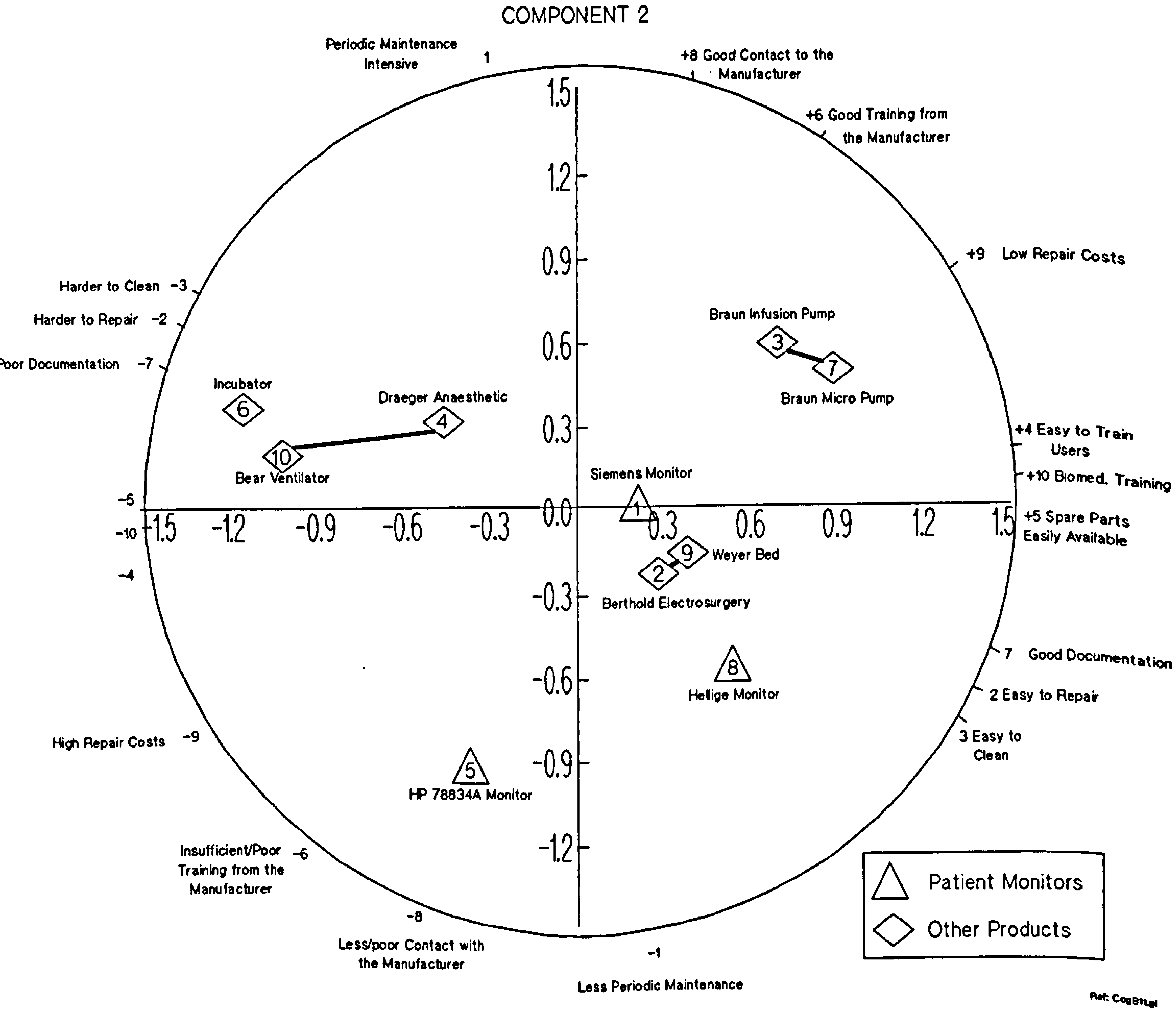
Similar results were obtained from the other grids from structured interviews with biomedical engineers. These, of course, cannot be directly compared to each other as both the elements and the constructs were personal.

8.3.1i Summary of the Example

The interview with Biomedical Engineer B11 identified ten constructs through which the subject perceives product support. Some of these constructs were directly dependent on product design (e.g. *Ease of cleaning, Ease of Repair* and *Periodic Maintenance Necessary*) whereas others were related to the services offered by the manufacturers' support organizations (e.g. *Contact to the Manufacturer* and *User Training from the Manufacturer*) and the associated costs (e.g. *Repair Costs*). The cognitive map illustrated how the different products and their respective manufacturers' support organizations are perceived differently.

Figure 8.22: The Cognitive Map from the Example Interview with a Biomedical Engineer (B11).

KEY TO PRODUCTS BY CARD NUMBER			
1)	Siemens Patient Monitor	6)	Air Shields Incubator
2)	Berchtold Electro-Surgery Device	7)	Braun Micro Infusion Pump
3)	Braun Infusion Pump	8)	Hellige Patient Monitor
4)	Draeger Anaesthetic Machine	9)	Weyer Heated Bed
5)	HP 78834A Patient Monitor	10)	Bear Medical Ventilator



8.3.2 The External Customers' Constructs

The full list of constructs from the interviews with biomedical engineers is given in Table 8.17. Across the top of this table, the respondents are identified (B1, B2 etc) and details are given of the working responsibilities of their departments. In addition, the numbers of constructs elicited in each interview are given with the constructs themselves being listed down the left-hand side of the table. The boxes indicate which constructs were elicited from each engineer and below the boxes are the variability figures for the constructs.

The constructs are listed in the order of the frequency with which they were mentioned. The four most frequently produced constructs were *Service Documentation, Reliability, Ease of Use,* and *Training for the Biomedical Engineer* - these consequently appear at the top of the table. The less frequently mentioned constructs appear lower in the table, with those mentioned only once (e.g. *Legal Advice Available*) at the bottom. The constructs mentioned only once are, of course, possibly *individual constructs.*

Table 8.17 illustrates that the biomedical engineers sometimes elaborated on a particular construct. For instance, three respondents mentioned that the robustness of equipment influences its reliability, since equipment often receives rough treatment in the hospital environment. Similarly, one respondent expanded on the *Training for the Biomedical Engineer*, by mentioning not only the quality of this training (which he rated, as did the other respondents who mentioned this construct) but also the cost (which he rated separately).

A total of forty different constructs were elicited from the interviews with external customers. Inspection of these shows that many of them were elicited in interviews with internal customers (compare Table 8.17 with Table 8.2). [It was not assumed that the constructs from internal and external customers were identical just because the were given the same name. Careful questioning was required to identify whether they were identical.] However, many others are new and there are differences in the main focus of the perception of product support between the two categories of customer. The list of external customers' constructs includes many which are related to the respective manufacturers' support organizations and the costs of maintaining equipment. Examples of the former are *Local Service Organization (Quality), Company Technical Support* (response centre support) and *User Training from the Manufacturer.* Examples of constructs related to maintenance costs are *Repair Costs* and *Price of Spare Parts.* This mixture of different types of constructs illustrates the broad view of support from biomedical engineers. Anecdotal evidence from the interviews strongly indicated that biomedical engineers consider the product itself, the manufacturer's service organization and support costs when making recommendations on new purchases.

Table 8.17: Summary of the Interviews with External Customers.

Results of Interviews with Biomedical Engineers (B1 to B15)	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	Summary
Hospital																
-Beds	1000	600	900	3000	1500	2000	490	600	430	550	200	470	480	830	480	
-Biomeds.	10	6	13	32	25	25	3	6	1	10	3	2	2	2	1	
Responsibility																
-Maintenance	10%	30%	45%	30%	30%	25%	15%	20%	25%	20%	20%	60%		5%	20%	Average =22%
-Repair	80%	50%	30%	30%	40%	65%	60%	50%	25%	70%	40%	30%	50%	40%	40%	Average =47%
-User trg.		10%	5%	25%	10%			10%	5%	5%	10%		10%	5%	20%	Average = 8%
-Admin.	10%	10%	10%	15%	10%		25%	10%	25%	5%	30%	10%	20%	40%	20%	Average =16%
*Purchasing	Y	Y	Y	Y	10%	10%	Y	10%	20%	Y	Y	N	Y	Y	N	
-Other			10%										20%			
# Constructs	10	12	8	12	12	8	10	12	11	9	10	12	8	6	7	Average =10
Length of int. (minutes)	70	75	105	110	90	95	110	80	55	65	90	75	65	110	95	Average =86
CONSTRUCTS:																
Service documtation		■ 13.5	■ 17.3	■ 8.9	■ 6.0	■ 13.4		■ 9.6	■ 15.4	■ 4.7	■ 13.4	■ 0.7	■ 11.6			11 mentions
Reliability	■ 5.2	■ 5.2	■ 8.3	■ 7.2	■ 7.9	■ 6.5	■ 2.3	■ 5.5	■ 7.7			■ 1.9				10 mentions
(robustness)				■ 9.8	■ 5.7									■ 19.2		(3 mentions)

Table 8.17: Continued.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	Summary
Ease of use	■ 3.4			■ 3.2	■ 6.7	■ 15.0	■ 15.0		■ 6.4			■ 2.8	■ 9.6	■ 12.3	■ 7.7	10 mentions
Trg. for the biomed. (level/avail)		■ 9.2	■ 5.6		■ 23.3	■ 16.5		■ 15.1	■ 13.8	■ 5.8	■ 15.5	■ 45.4				9 mentions
(cost)										■ 32.3						1 mention
Ease of troub-shooting		■ 9.7		■ 9.7	■ 7.2	■ 13.1	■ 8.1		■ 9.1	■ 8.0		■ 1.0			■ 9.7	9 mentions
-diagnostics										■ 6.0						1 mention
Local service organization (quality)	■ 14.2				■ 5.8	■ 9.3	■ 5.2	■ 3.4	■ 5.7	■ 4.2		■ 1.9	■ 11.6			9 mentions
-response time	■ 13.9															1 mention
Amount of maintenance	■ 17.3		■ 7.8		■ 6.9			■ 7.5	■ 11.0	■ 9.9	■ 4.5			■ 24.0		8 mentions
Ease of obtaining parts		■ 13.0		■ 7.1		■ 18.9	■ 16.8	■ 7.4			■ 7.7	■ 5.3			■ 16.2	8 mentions
Ease of repair (MTTR)	■ 20.3					■ 6.5	■ 12.2	■ 3.0			■ 10.6	■ 33.2	■ 19.5			7 mentions

Table 8.17: Continued.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	
Ease of cleaning (decontamination)		■ 9.7	■ 14.3	■ 6.5	■ 4.2		■ 7.7				■ 3.6			■ 4.7		7 mentions
Repair costs				■ 6.3					■ 11.1		■ 17.4	■ 1.9		■ 36.2	■ 13.6	6 mentions
Mechanical content/design			■ 11.1				■ 12.9		■ 3.8			■ 5.9			■ 4.5	5 mentions
Price of spare parts					■ 20.2		■ 11.4	■ 9.8	■ 10.2							4 mentions
Company technical support		■ 7.5							■ 5.7		■ 5.2		■ 7.2			4 mentions
Equipment Complexity												■ 1.9	■ 14.8		■ 28.7	3 mentions
User documentation		■ 1.8						■ 13.9								2 mentions
Value for money	■ 5.2			■ 8.6												2 mentions
Good design	■ 3.4									■ 5.8						2 mentions
User trg. from the manufacturer	■ 6.9										■ 13.0					2 mentions

Table 8.17: Continued.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	
Contact with salesman				■ 12.8												2 mentions
Service contracts		■ 7.5			■ 0.0											2 mentions
Compatability		■ 4.8		■ 0.0												2 mentions
Cost of supplies							■ 8.3								■ 19.6	2 mentions
Special calibration tools needed					■ 6.1											1 mention
Equipment size /weight			■ 11.1													1 mention
Adjustments required													■ 23.8			1 mention
Accuracy														■ 3.6		1 mention
Delivery quality				■ 19.9												1 mention
Ease of trg. the user											■ 9.4					1 mention

Table 8.17: Continued.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	
Quality of manufacture	■ 10.1															
Number of spares needed in service kit			■ 24.6													1 mention
Electrical safety		■ 8.0														1 mention
Upgradability								■ 8.7								1 mention
Equipment lifetime								■ 14.1								1 mention
Acceptable downtime										■ 22.8						1 mention
Legal Advice available		■ 10.4														
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	

8.3.2a The Most Important Constructs

The most important constructs are those that are mentioned frequently or, as discussed earlier, show large variability. Both of these factors will be considered for the external customers' constructs. The magnitude of the variability figures in Table 8.17 are partly dependent on the number of constructs elicited from the respective interviewees. Therefore, to calculate an average variability, the figures from Table 8.17 need to be first weighted and then averaged. The results of this procedure are shown in Table 8.18.

Table 8.18 shows the twenty most frequently mentioned constructs from biomedical engineers, with their frequencies and average weighted variabilities. Although the validity of calculating average weighted variabilities could be challenged (due to the sample size, averaged across non-identical grids etc.), it allows more information to be obtained on the importance of the individual constructs. For instance, some constructs may be mentioned frequently but there may only be small perceived differences between products on these constructs. An example of this appears to be reliability - this was the second most frequently mentioned construct but the perceived differences between products are small (the average weighted variability is 5.9%).

Reviewing Table 8.18 it appears from the variability that the *Training for the Biomedical Engineer, Ease of Repair (MTTR), Price of Spare Parts, Repair Costs* and *Service Documentation* are the most important constructs. (*Contact with the Salesman* had a large variability but was only mentioned once.) Further research with biomedical engineers, using grids with *provided constructs*, would be required to confirm this.

Table 8.18: The External Customers' Constructs with Frequencies and Variabilities.

No.	Construct	Mentions	Frequency	Av. Wt. Var.	Order
1	Service Documentation	11	73%	11.8%	=4
2	Reliability	10	67%	5.9%	
	-Robustness	3	20%	10.0%	
3	Ease of Use	10	67%	7.3%	
4	Training for the Biomedical Engineer	9	60%	18.4%	1
5	Ease of Troubleshooting	9	60%	8.4%	
6	Local Service Organization	9	60%	6.2%	
7	Periodic Maintenance Necessary	8	53%	10.1%	
8	Parts Availability	8	53%	11.3%	
9	Ease of Repair (MTTR)	7	47%	15.3%	2
10	Ease of Cleaning (Decontamination)	7	47%	7.0%	
11	Repair Costs	6	40%	11.8%	=4
12	Mechanical Design	5	33%	7.9%	
13	Price of Spare Parts	4	27%	14.6%	3
14	Company Technical Support	4	27%	6.6%	
15	Equipment Complexity	3	20%	11.4%	
16	User Documentation	2	13%	9.4%	
17	Value for Money	2	13%	7.8%	
18	Good Deign	2	13%	4.3%	
19	User Training from the Manufacturer	2	13%	9.9%	
20	Contact with the Salesman	1	7%	15.3%	-

8.3.3 Summary of the External Interviews

The interviews with biomedical engineers enabled a different perception of support to be measured. The biomedical engineers saw support through constructs related to both the design of products and the services offered by manufacturers. From the interviews it appears that biomedical engineers place emphasis on both good product design and on good support from the manufacturer's support organization.

The fundamental findings of the interviews with external customers were:-

1) A set of common constructs could be identified.

2) Customers perceived differences between medical products and their respective manufacturers' support organizations against these constructs. (The example interview showed the variations in the perceptions of different products and their manufacturers' support organizations. Similar results were found for other respondents.)

3) The most important constructs from biomedical engineers appear to be *Training for the Biomedical Engineer*, *Ease of Repair (MTTR)*, *Price of Spare Parts*, *Repair Costs* and *Service Documentation.*

8.4 COMPARING RESULTS WITH HYPOTHESES

This section will compare the relevant results of the structured interviews with the hypotheses. A hypothesis and three related sub-hypotheses were investigated; they will each be discussed and then the limitations will be presented. Hypothesis 3 and its related sub-hypotheses fit closely with the research objective of obtaining a better understanding of the concept product support. This is illustrated by Figure 4.7 and it may be helpful to refer to this diagram to see the results in context.

8.4.1 Hypothesis 3

Customers perceive the supportability of a product through a set of common attributes. Customers perceive differences in the supportability of different products.

The results of the structured interviews showed well that a common set of attributes for support could be identified. This was the case for both internal customers and external customers. For the former, a total of forty-six different constructs were identified, of which twenty-seven were repeated and therefore could be termed as common constructs. For the latter, forty different constructs were elicited of which twenty-four were repeated and could therefore be termed common constructs. The methodology for investigating the attributes of support worked particularly well.

The second part of the hypothesis was investigated by analysing the repertory grids from customers. Both the grids from internal and external customers showed differences in the perceptions of different types of products against the constructs. On certain constructs, significant differences in the perceptions of products were found.

8.4.2 Sub-Hypothesis 3a

Newer products are not necessarily better than similar older products on all of the attributes of good support.

This hypothesis was only investigated with internal customers for one companies medical equipment products. This is because the age of equipment in use could not be accurately determined (biomedical engineers know the physical age of equipment but not the age of the design).

The results show that Hewlett-Packard Customer Support Engineers do not perceive newer products to be better than similar old products on all aspects of support. In fact, engineers perceive the supportability of products as largely dependent on the complexity of the application for which they are used. The limitations of using perceptions to investigate supportability were apparent (see Section 8.4.5). Although the results are equivocal, there is some indication that they support the hypothesis.

8.4.3 Sub-Hypothesis 3b

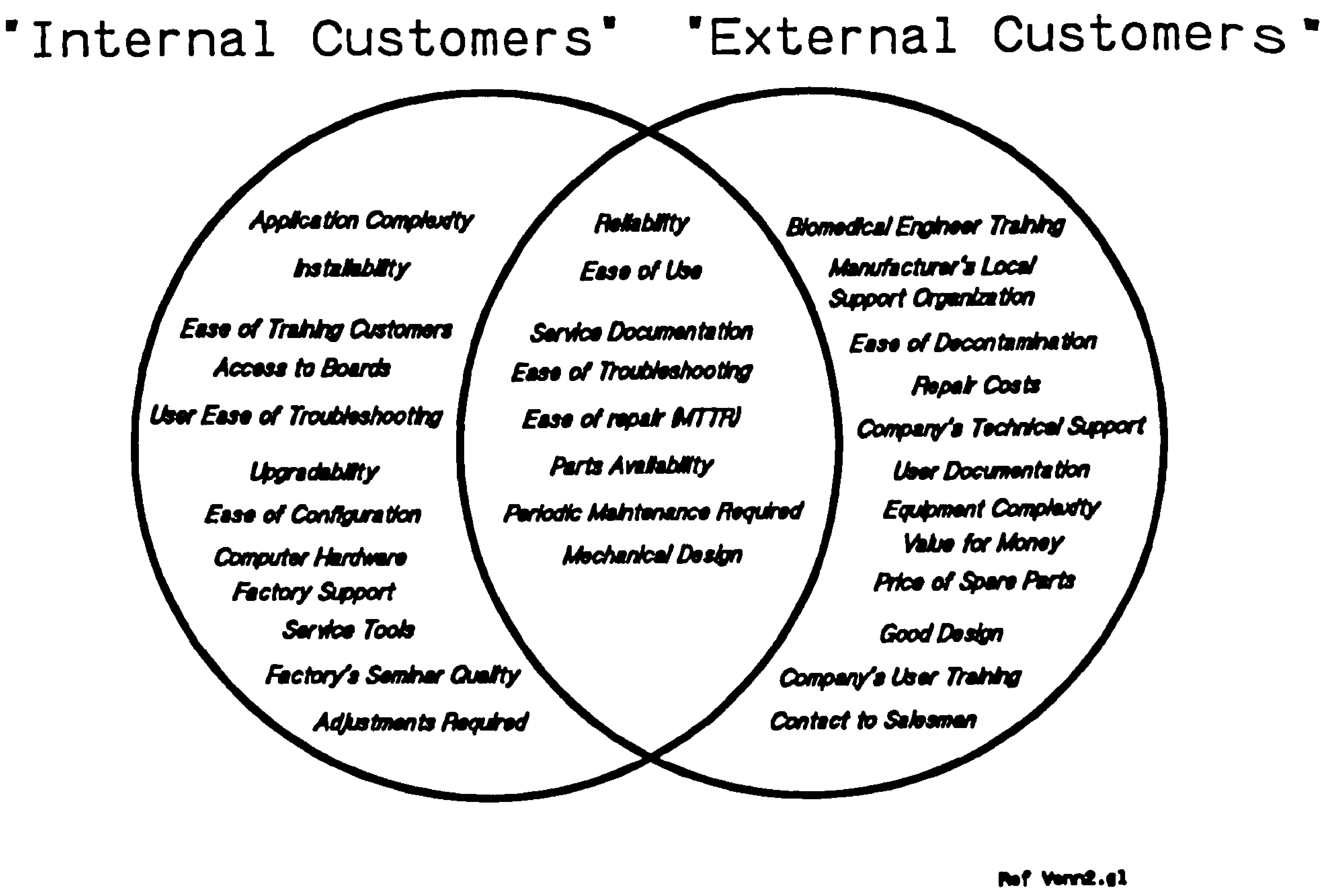
The common attributes differ between the internal and external customers. Internal customers perceive supportability as related to products themselves whereas external customers perceive supportability as also related to the manufacturer's field organization.

To understand how the results compare against this hypothesis, the common constructs from the interviews with internal and external customers must be compared. Figure 4.3 (Chapter Four) showed the expected relationship between the attributes of the two types of customer. This type of distribution was, in fact, found as shown by Figure 8.23. Figure 8.23 shows the twenty most frequent constructs from the two categories of customer. Since eight of these constructs (e.g. *Reliability, Ease of Use* etc.) were mentioned by both groups, these are shown in the middle of the Venn diagram. Twelve constructs (*Application Complexity, Installability* etc.) were only mentioned by the internal customers whereas twelve (*Biomedical*

Engineer Training etc.) were elicited only from external customers.

The internal customers most important constructs were all related to the product design (including mechanical, documentation, troubleshooting and training aspects). In contrast the biomedical engineers perceived not only design aspects but also the manufacturer's support organization and support costs as important.

Figure 8.23: Venn Diagram of the Relationship Between the Twenty Most Frequent Constructs from Each of the Two Categories of Customer. [Refer to Tables 8.2 and 8.17 for the full listings of constructs for each category of customer.]



The differences between the internal and external customers' views are not surprising - the internal customers all work for the same organization and therefore generally do not see differences in the organization for different products (one exception was the construct *Factory Support Available*, which was identified by five subjects). The fact that the external customer's viewpoint is not the same as that of the internal engineer has important implications for both new product development and improvements in the support organization - external customers' views should be checked and not just those within the organization.

8.4.4 Sub-Hypothesis 3c

The factors most frequently evaluated at the design stage (reliability and MTTR) are perceived as the most important ones by all customers.

The most important constructs for internal customers were *Application Complexity*, *Ease of Training Customers*, *Installability* and *Ease of Use*. The most important perceived aspects of supportability from the biomedical engineers were *Training for the Biomedical Engineer*, *Ease of Repair (MTTR)*, *Price of Spare Parts*, *Repair Costs* and *Service Documentation*. These results disprove the hypothesis - only the external customers perceive one of the two factors in the hypothesis as one of the most important. [Note, reliability was often mentioned by both categories of customer but they both perceived relatively small differences between the reliability of products.]

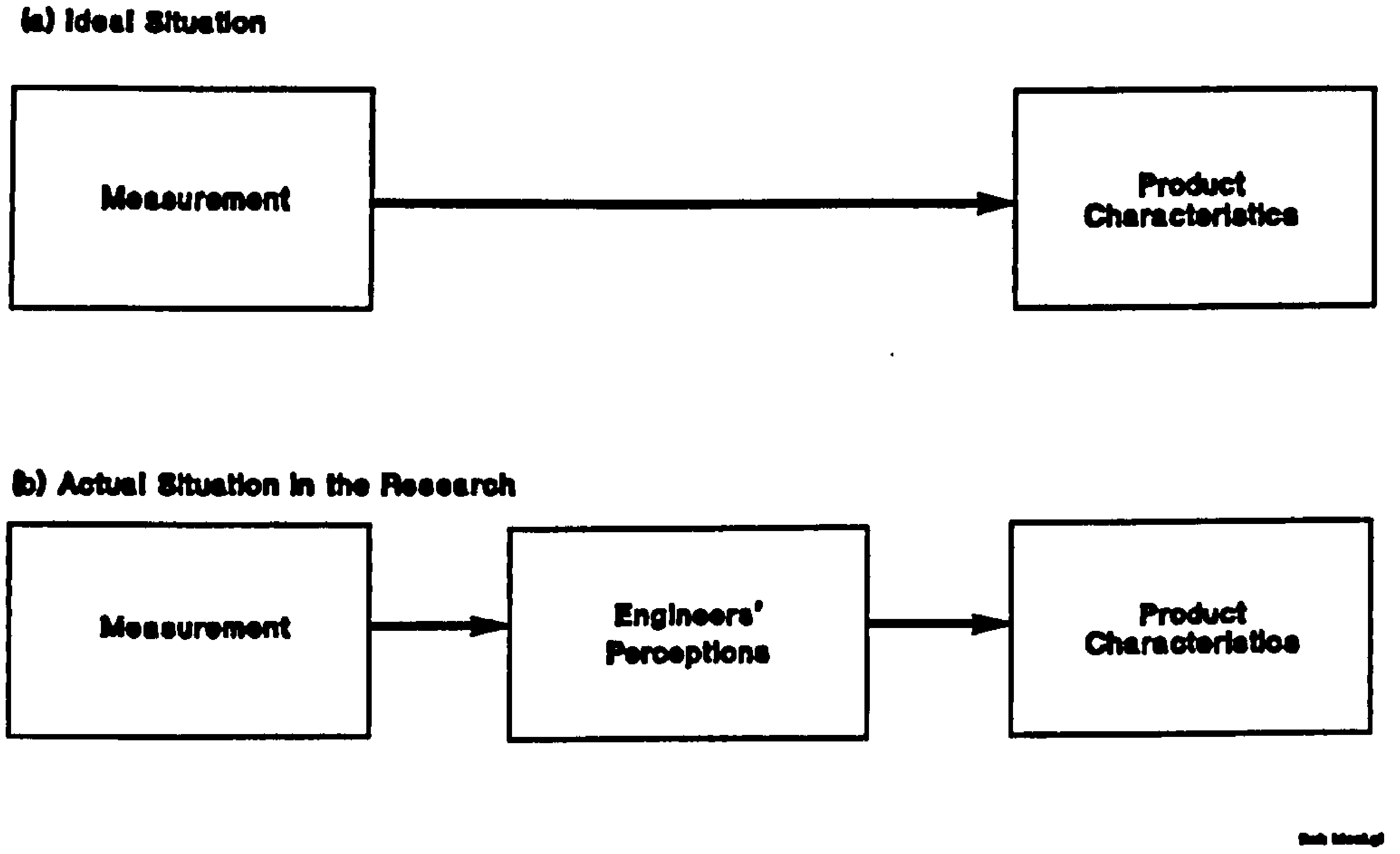
8.4.5 Limitations of the Results

The major limitation of the results is that they are specific to the medical equipment market and therefore cannot be generalized. However, the same approach could be used to investigate product support in other markets.

In identifying common attributes of good product support the structured interviews were successful and the results have only one real limitation. This is that the choice of the most important constructs from a sample of respondents is not well defined in the literature.

The key factor that should not be forgotten is that ratings are not actual measurements of product characteristics. Rather, they are measurements of engineers' perceptions of product characteristics. This is illustrated by Figure 8.24, which indicates that the ideal situation would be that where the characteristics of a product which determine how easy it is to support would be measured directly. (This is the case in some companies who measure and record the support characteristics of products - as identified in the survey described in Chapter Seven.) The actual situation in the research was different, as shown in the lower half of Figure 8.24. This shows that the measurement is of engineers' perceptions of product characteristics. As discussed earlier, there may be significant differences between the perceived and actual product characteristics because of halo and other effects.

Figure 8.24: The Limitation of the Product Ratings - They are Measurements of Perceptions



The value of the perceptions should not, however, be forgotten. Perceptions, although subjective, allow a possibility of obtaining some idea of the general differences, from the support standpoint, between categories of products.

The question of how accurately perceptions reflect actual product characteristics cannot be answered from the results of this study. This is because other than for reliability there is no actual information on the actual supportability of products. At a company where such information was available, it would be interesting to check whether the perceptions and the actual values of supportability would be correlated. (Research by Hudson, 1974 showed that perceptions of simple factors closely correlated to the true values.)

8.4.6 Comparison of the Results to the Model

In Chapter Four a model of product support was proposed (Figure 4.2). Although not directly related to the hypotheses, it is interesting to compare this to the constructs from biomedical engineers. If this is done, it can be seen that eight of the eleven proposed elements of product support were mentioned by biomedical engineers (the exceptions were *Warranty, Installation* and *Complaints Handling*). This tentatively shows that the model may fit the medical equipment market. Further research could test this and also investigate if the model applies to other markets.

8.5 SUMMARY

Structured interviews were conducted with both internal and external support customers in the medical equipment market. These elicited the attributes of good product support from the perspective of both these categories of customer. These showed that:-

- Both types of customer perceive the quality of support through sets of common constructs (attributes), which were identified.

- Key differences exist between how support is perceived by company support engineers and how it is perceived by biomedical engineers.

- Company support engineers perceive significant differences between the ease with which different product categories can be supported.

- Company support engineers do not perceive that all aspects of newer products make them easier to support .

- Biomedical engineers perceive significant differences between the quality of different manufacturers' products and support organizations.

- Reliability and MTTR are not perceived by all customers as the most important factors of product support. Only for biomedical engineers is one of these two factors (MTTR) perceived as one of the most important ones.

- The set of constructs elicited from biomedical engineers covers nearly all of the elements of product support in a proposed model (discussed in Chapter Four).

- The repertory grid interviews were successful at identifying factors of *product support* perceived as important by customers, despite the fact that product support is not a simple or well understood concept.

The next and final chapter gives the full summary of the research and the conclusions.

CHAPTER NINE

Research Summary and Conclusions

9.0 INTRODUCTION

This concluding chapter summarizes the results of the research, their contribution to the knowledge and draws conclusions. The presentation is in four main sections:-

- The results are summarized, compared to the research hypotheses and discussed.
- The research conclusions are given. These include the contributions of the study, its implications, limitations, an assessment of the effectiveness of the research design and suggestions for future research.
- Further conclusions are presented - but these are given from an inductive perspective, in order to demonstrate that the results could have wider implications and form the basis for theories. In addition, a number of practical recommendations are made for managers involved with the marketing of high-technology products.
- A short summary of the full research project is given.

9.1 SUMMARY OF THE RESULTS

The research results were discussed in detail and compared to the hypotheses in the relevant chapters. However, the overall results of the complete study remain to be reviewed. This section will review the results and how they compare to the research hypotheses.

9.1.1 Summary of the Survey Results

The postal survey of managers involved with product support made the first quantitative assessment of product support planning at high-technology companies. Since the importance of considering support requirements at the product design stage has been recognized by a number of authors, it is surprising that this has not previously been investigated. However, this is the case and therefore the results open up a new area.

There are seven main results from the postal survey which apply to the sample companies. These are:-

1) The consideration of product support requirements takes place late in the product development cycle at many companies. On average it is 67% into the development cycle.

2) The planning at 47% of the sample companies is not formally documented and reviewed. Typically the planning does not cover all of the aspects that are important for that type of product (for instance, the evaluation of installation and training requirements is often neglected).

3) Only 47% of respondents thought that support was "Very well" or "Reasonably well" planned at their company.

4) During their planning of support, over half of the sample companies set goals for the reliability and MTTR of products.

5) Less than half of the companies, however, set individual goals for each of the other aspects of support during their planning.

6) Most companies do not quantitatively monitor how easy products are to support following their market introduction.

7) Over 30% of the total respondents, in an answer to an open-ended question, thought that the planning of support should include more involvement of field service personnel.

9.1.2 Summary of the Interview Results

Sixty-five interviews with customers from the medical equipment market established how support is perceived. Both company support engineers (internal customers) and biomedical engineers (external customers) were interviewed. In total these interviews gave seven key results for the company and products investigated:-

1) Both types of customer perceive the quality of support through sets of common constructs (attributes), which were identified.

2) Key differences exist between how support is perceived by company support engineers and how it is perceived by biomedical engineers.

3) Company support engineers perceive differences between the ease with which different categories of products can be supported.

4) Company support engineers do not apparently perceive that newer products are easier or simpler in all aspects of their support.

5) Biomedical engineers perceive differences between the quality of different manufacturers' products and support services/organizations.

6) Reliability and MTTR are not perceived as the most important factors of product support by all customers. (MTTR is perceived as important by biomedical engineers but reliability is not perceived as one of the most important factors by either type of customer.)

7) Comparison to a proposed model. Biomedical engineers' perceptions of support cover a wide range of the factors introduced in a proposed model of support.

9.1.3 Summary of the Comparisons to the Hypotheses

This section summarizes the comparisons of the results with the hypotheses. It therefore illustrates the dimensions of the study and the degree of success in reaching the research goals.

Table 9.1 summarizes the main results, compared against each of the hypotheses. The first hypothesis, that support is not systematically planned at the design stage by most companies, could be shown to apply to the sample but cannot be generalized. Measurement of the variables chosen to represent planning showed that most companies do not plan systematically. For instance, most companies failed to consider such issues as installation or training at the product design stage, although these aspects are important ones (as indicated by the characteristics of the respondents' products). Another example of the lack of systematic planning was that planning typically starts late in the product development cycle. This result confirms, in the case of the sample, something postulated by several authors - that support is typically considered late in the development cycle.

Hypothesis 2, that the most commonly evaluated aspects of support are the equipment reliability and MTTR, was also shown to be true for the sample. Obviously the same comments apply as above; this result cannot be generalized. Once again, however, much anecdotal evidence exists in the literature that the main goals set at the design stage are reliability and MTTR.

Table 9.1: Comparison of the Results Against the Hypotheses.

SUMMARY OF THE RESULTS VERSUS THE HYPOTHESES			
No.	Hypothesis	Proved?	Notes
1	**Hypothesis 1:** *Most high-technology companies do not evaluate product support at the product design stage.*	Yes (limited to sample)	Hypothesis proved for the sample but cannot be generalized. See Section 7.3.1.
2	**Hypothesis 2:** *Product reliability and ease-of-repair are the factors of product support which are most often quantitatively evaluated at the product design stage.*	Yes (limited to sample)	As above. Refer to Section 7.3.2 for details.
3	**Hypothesis 3:** *Customers perceive the supportability of a product through a set of common attributes. Customers perceive differences in the supportability of different products.*	Yes (medical market)	Common attributes were identified from customers. See Section 8.4.1.
4	**Sub-hypothesis 3a:** *Newer products are not necessarily better than similar older products on all of the attributes of good support.*	Equivocal (medical market)	Inconclusive for the products of one manufacturer. See 8.4.2 + 8.4.5.
5	**Sub-hypothesis 3b:** *The common attributes differ between the internal and external customers. Internal customers perceive supportability as related to products themselves whereas external customers perceive supportability as also related to the manufacturer's field organization.*	Yes (medical market)	This was proved for one case. See Section 8.4.3.
6	**Sub-hypothesis 3c:** *The factors reliability and MTTR (which are frequently evaluated at the design stage) are perceived as the most important ones by all customers.*	Disproved (medical market)	This hypothesis was disproved for internal customers but partly proved for external ones. See Section 8.4.4.

Hypothesis 3 was tested for the medical equipment market using the repertory grid methodology. Hypothesis 3 supposed that good support is perceived through a set of common customer attributes and that customers discern differences in products on these attributes. The first part of this hypothesis, as shown in Table 9.1, was proved for what were termed internal customers (company customer engineers) and external customers (biomedical engineers) in the medical equipment market. The repertory grid interview technique successfully identified customers' views on products from the support standpoint and the samples showed that a common set of attributes could be identified across respondents. Customers rated products against these attributes and analysis of these ratings showed that differences were perceived between products, or product categories, by both internal and external customers.

Related to Hypothesis 3 were three sub-hypotheses. The first of these was that newer products are not necessarily perceived as better on all of the attributes of good support. For the medical products of one manufacturer this was seen to possibly be the case. For instance, the ease with which a particular piece of equipment can be supported was not perceived by company engineers to be related only to its age. More important was found to be the complexity of the equipment. This shows that supportability is perceived largely as a function of the type of equipment (and therefore its complexity). The proof of this hypothesis is, however, equivocal due to the limitations discussed in Chapter Eight. The main limitation of the research was that the perceptions of supportability appear not to be a sensitive enough method of establishing differences between the support characteristics of different products.

The second sub-hypothesis supposed that there would be differences between the perceptions of internal and external customers. This was shown to be the case in the medical equipment market by the comparison of the results of the structured interviews with internal and external customers. The external customers can be said to have a "broader view", in that they perceive support in terms of the whole offering from a company - both the product and the quality and costs of the services of the support organization.

The final sub-hypothesis was that the product support factors reliability and MTTR (which are most frequently evaluated at the design stage) are perceived as the most important by customers. The results allowed this hypothesis to be disproved. For the internal customers the hypothesis was disproved whereas for the external customers it was partially disproved (since MTTR was found to be a key attribute for external customers).

In addition to the hypotheses investigated, the research aimed to identify as much as possible about how support is evaluated at the design stage and which aspects of support are perceived as important by the customer. Specifically, a goal was to increase the understanding of the concept product support. In this area the study made, in the researcher's opinion, a contribution as it produced the first list of product support factors evaluated by companies and the first information on customer perception of support. These, together with the results of the investigation of the hypotheses, have implications for high-technology marketing.

9.2 RESEARCH CONCLUSIONS

Management research into the planning and perception of product support has been almost non-existent. This is particularly clear from the literature review, which contained anecdotal information on support but little concrete data on how it is evaluated by companies. Additionally, no published data considered how customers perceive support. As a result of this study, the knowledge of product support has been increased.

9.2.1 Contributions of the Research

The research made five main contributions which have already been discussed indirectly. These are:-

1) It made the first quantitative analysis of how companies plan product support at the design stage.

2) It investigated the perception of good support from the viewpoint of the customer. This brought a better understanding of the concept *product support* (and identified possible variables for measuring this concept in future research).

3) It identified a more comprehensive way in which product support could be evaluated at the product design stage. (These will have practical applications at the company which supported the research and at some of the companies whose managers are members of the Association for Services Management - International.)

4) It showed the viability of the research design for investigating the concept of product support in one market. This design could be applied in other markets.

5) It established a structure for research into product support. This could form a basis for further investigations (for instance, aimed at establishing theories on support).

9.2.2 Implications of the Research

Chapter Two showed the importance of support, including its role as a potential source of revenue, its influence on customer satisfaction and its use as a source of competitive advantage. Therefore the results, as they are some of the first on product support management, have implications for the marketing of all high-technology products. This is probably true despite the limitations of the research and the inability to generalize all of the results. (More research would be required to determine this exactly.) The implications of the postal survey and interview results will be discussed separately.

9.2.2a Implications of the Survey

The key result of the survey was that the companies in the sample do not systematically plan all of the aspects of product support for new products. If one accepts that planning can enhance business success (as was discussed in Chapter Three), then the implication of this is that the companies in the sample could improve the quality of their product support. This could potentially allow companies to earn more from their support business, promote customer satisfaction and gain a competitive advantage.

The survey showed that the sample companies did not plan in detail some of the aspects of support which are important for their products (e.g. installation and training). The research produced a list of aspects of support which are planned by the sample companies. The aspects most commonly evaluated were found to be reliability and MTTR. However, perhaps these are not the most important factors for some types of equipment. The implication is that if the most important features of support were evaluated early enough, the quality of support could be improved.

One key point from the survey results was that certain companies monitor the performance of existing products on various aspects of support. For instance some respondents mentioned that they measured and reported the average times required to install or maintain products. This information can be used to set goals for new products and the implication is that companies who do not monitor the performance of current products are losing key information that could be used to gauge improvements in new products.

The fundamental implication of the survey is that because companies are not evaluating all of the aspects of support they are missing an opportunity to improve their performance in this area i.e. missing potential opportunities to maximize their competitive advantage, their profit and customer satisfaction!

9.2.2b Implications of the Interviews

The interviews showed that customers for medical equipment perceive differences in products from the support standpoint. The perception of these differences was found to be through a set of common attributes.

The perception of product support from external customers, in the medical market, was found to be clearly different from that of company support engineers. This was because, not surprisingly, external customers tended to assess the whole offering from a company and not just the products themselves, as did the company engineers. This means that product support, in order to be well perceived by the customer, needs to be good in all its aspects - both those related to the product and those related to the support organization. The implication of this is that companies in the medical equipment market (and possibly other high-technology markets) need to carefully plan their support offering as a total package. (This relates closely to the recommendations of Vandermerwe, 1990 that companies need to provide products and services which together closely meet customer needs.)

Another result of the interviews with biomedical engineers is the possible importance of involving customers in the delivery of some aspects of product support. This was shown by the importance placed by bio-engineers on such constructs as *Contact to the Manufacturer* and on being involved in the training and repair processes. By involving biomedical engineers in support delivery, companies may be able to reduce cost of ownership. (Lovelock, 1988 recognized the importance of what he termed *Customer involvement in production* for service industries but did not recognize that this could be important for support of high-technology products.)

The result that newer products are probably not simpler in all aspects of their support is an important one, although it strictly only applies to the products of one manufacturer (once again, anecdotal evidence suggest that this is the case at many companies). Newer, more complex products were found in some aspects to be harder to support. Since significant costs can be involved with supporting products this has strong implications: more complex products may have higher support costs unless new design contributions are made. The result that company support engineers do not perceive reliability and MTTR as the most important aspects of support also has an implication: if support planning is based on these measures alone (as it was at the company investigated), then it will probably not be effective. The other factors which are perceived as important by each type of customer need to be considered and their relative importance estimated.

The differences between the perception of support by internal and external customers has implications, for the market and company in question. The fact that there are differences shows that it is important to consider both groups' needs - if either is neglected the quality of support may not be optimum. Several articles in the literature (e.g. Berg and Loeb, 1990) and many respondents to the postal survey stressed that field support engineers must be involved in the product development cycle, so that they can comment on design from the support aspect. The fact that actual customers may have different perceptions is important; the views of internal and external customers and their relative importance must be established.

9.2.2c Implications for the Researcher's Company

The title of this thesis is *Planning Product Support for Medical Products* and a large amount of the research was concentrated on the medical equipment market. Therefore, it is in this area that the results have the strongest implications, particularly for the researcher's company.

The results of the postal survey have implications for the researcher's company. In particular, the planning of product support at the researcher's company will be compared against the "template" of the collated goals for support planning identified in the survey (Table 7.28). The implication is that any deficiency in current evaluation and planning of support could be compromising the quality of support.

The repertory grid methodology provided much information on internal and external customers' perceptions. It indicated the aspects of designs which were perceived as making products easier, or more difficult, to support. These have implications for both future designs and, in some cases, for improvements of existing products. In addition, it clearly showed that company engineers' attributes have significant differences from those of actual customers.

The interviews with biomedical engineers identified constructs and a measure of their importance. This is useful information on the relative importance of the product design compared to the field support organization. In addition, much information on competitive companies can be extracted from the grids. (The ratings of various companies and their products against the constructs are very useful. However, since this data was not required for testing the hypotheses, it is not presented in this thesis.)

The findings of the research have been instrumental in causing a change in attitude to product support at the researcher's company. This has, in turn, led to two main changes. Firstly, much greater attention being given to planning support at the design stage ("Design for Supportability"). Secondly, there is more emphasis on the importance of surveying customers' views on the "mix" of products and services they receive from Hewlett-Packard Medical Products Group. Further details of the steps being taken to manage support are company confidential and so cannot be described here. It can only be said that the raised awareness of the importance of product support will give some exciting opportunities for investment and that they are receiving management attention.

One of the real successes of the research project was that it managed to achieve results which were of interest from both an academic and practical management (in the researcher's company) standpoint.

9.2.3 Conclusions on the Research Design

The research used two survey methods to investigate product support; the postal survey and structured interviews with customers. These allowed the research objectives to be met. However, hindsight allowed possibilities for improvements in the research design to be identified. Some of these have already been discussed, however, an appraisal of the overall research design and the chosen methods still needs to be made.

Three hypotheses were chosen to be tested. The results of this testing, although not without limitations, have implications for the planning and knowledge of support. In addition to the three research hypotheses, Chapter Four discussed a so-called Background Structural Hypothesis. This was seen to be important and its proof, or rejection, of key significance to the planning of product support (whether or not planning would improve the quality of product support). Therefore, the question arises: *as this Structural Background Hypothesis was not tested, were the alternative hypotheses of significance and do the results contribute to the knowledge?* The answer is that the hypotheses tested have their own value without the Background Hypothesis - they provide the first data on support planning and perception. Also, using the collated results allows a more comprehensive evaluation of support to be made. Whether or not this will directly improve the quality of support remains to be seen. However, a pragmatic management approach would call for the results to be applied even before unequivocal proof is available that systematic planning at the design stage leads to higher quality of support.

The choice of a postal survey to investigate the practices of companies in planning product support was the right one in the circumstances - where there was a need for confidentiality and to obtain a wide sample on a complex subject. The methodology was, however, pushed to its limit as the resulting questionnaire was long and complicated. That said, the questionnaire did provide the first data on support planning and because the range of data was comprehensive this allowed a more objective understanding to be achieved.

The repertory grid interviews were very successful at identifying the attributes of products that make them easier to support. An anticipated problem was that, since support is not a well understood concept, it would be hard to obtain customer attributes. However, the repertory grid interviews were effective in stimulating responses. This confirmed the claims in the literature that Kelly's test can be used to investigate difficult concepts successfully and avoid many of the problems of direct questioning. Although the interviews successfully identified common constructs, they were very time consuming. This is certainly a limitation of this methodology. Another limitation was the difficulty in deciding if personal constructs from different interviewees had the same meaning - many of the constructs were complicated and could easily be interpreted differently. Great care was taken, as mentioned in Chapter Eight, to establish by questioning if constructs were the same but without introducing interviewer bias.

In contrast to the success of the interviews in collecting attributes (constructs), there were limitations on the conclusions which could be drawn from the results of the product ratings, due to the spread in the results. This, however, is due to the indirect nature of the measurement - the variables measured were customers' *perceptions* and not "hard" values. Surprisingly, very little was found in the literature about the limitations of the repertory grid methodology. The measurements of perception themselves may have been accurate and the spread in the ratings a function of the group surveyed. This was particularly clear to the researcher during the interviews. Certain products were generally given poor ratings and the researcher became used to hearing these. However, certain engineers gave these products excellent ratings. (An example is the 78720A Arrhythmia System which was generally rated as complicated to install. However, several engineers still rated the 78720A as very easy to install as they had not experienced problems.) The researcher avoided questioning the interviewees on this point for fear of introducing interviewer bias. A technique whereby the rating values assigned could be "checked" without introducing bias would be the Delphi methodology.

An aspect of the research design that could be criticized is the qualitative nature of much of the analysis of the results (although the repertory grid analysis used statistical methods, the interpretation itself of the results is qualitative). In particular, the hypotheses themselves were not tested using statistical analysis. This criticism probably applies to many theses from marketing, the sociological and behavioural sciences, which by their nature do not always lend themselves to statistical hypothesis testing. Further research into product support could, however, attempt to choose hypotheses which could be more "tightly" tested.

In assessing the research methodology it is probably useful to ask the question: *what would be done differently if the same research was being re-done?* This can be simply answered by three main points:-

1) The postal questionnaire would be streamlined where possible and individual questionnaires would be numbered (so that individual reminder letters could be sent). These steps would probably help increase the reply rate.

2) The investigation of the product ratings would be re-designed so as to reduce the problems with the spread in the ratings. A possible method would be the Delphi Methodology to obtain a consensus of opinion on product ratings.

3) An alternative method would be used for the analysis of the product ratings (the advice in the literature on forming composite grids was found to be of limited value).

In total, it is felt that the research design was valid and that the chosen methodologies generally functioned well. However, as perhaps is normal with such a project, the researcher now feels that he has a better appreciation of the possible pitfalls in research design, particularly when applied to a new area like support!

9.2.4 Suggestions for Further Research

As the study was largely exploratory, it uncovered a broad range of issues warranting further research. These include both ideas for research into the topic of product support and, in addition, some ideas for research into the methodology used.

9.2.4a Research into Product Support

The field of product support has much potential for management research. The main topics which could be investigated include:-

1) Investigation of product support planning for a representative sample of companies, across a range of industries. This could be done using a questionnaire designed to eliminate the disadvantages of the one used in this study. If time and resources permitted this questionnaire would be applied in interviews, to avoid any ambiguity in the answers. (Obviously caution would be required to prevent interviewer bias.)

2) Identification of the types of planning which lead to high quality products, from the support standpoint. This could use a case study approach to check how the acknowledged market leaders plan support. Although case studies have their limitations, they are a useful method in exploratory research (Yin, 1989).

3) Identification of the significance of actually setting quantitative goals for support at the design stage and monitoring them for established products[1].

4) Investigation of how third party maintenance companies (TPM) perceive that product designs could be improved, to enable better support.

5) Investigation of the attributes of good support across various high-technology industries.

6) Investigation of the perception of support across the different types of customer in the medical equipment market[1] (or in other markets).

7) Investigation of the importance of product support relative to product features in the purchase decision[2].

8) Investigation of the influence of product complexity on product support. Must more complicated products *always* be

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[1] These topics will be further investigated by the researcher's company.

[2] This topic is being investigated for a segment of the medical equipment market. The work is being carried out by the researcher's company and the Product Engineering Department of the Fachhochschule Furtwangen, Germany.

harder to support?[1]

9) Investigation of the influence of an engineer's experience on his perception of the difficulty of supporting products (investigation of the halo effect).

10) Investigation of the validity of the proposed model of product support given in Chapter Four.

11) Investigation of customers' acceptance of their staff being directly involved in the support of high-technology products. (This approach may offer the possibility to cut the cost of support delivery without compromising the quality of services.)

The area of research which would most enrich the results of the current study is, in the researcher's opinion, case study research into the product support planning process of actual products (number 2 above). This would be an ambitious task but would potentially provide information of high practical value to management.

9.2.4b Research into Other Areas

In addition to the ideas for research into product support, some ideas on investigating the methodology resulted from this study. The five ideas for further research were:-

1) Investigation of the influence of subjects' nationalities on the average ratings given to elements well-known to all subjects. (The cause of the use of different sections of the rating scale appeared to be due to a mixture of both personal preference and experience of a scale from a national educational system[1].)

2) Investigation of how effective the Delphi Method would be in avoiding halo effects on measurements of perceptions.

3) Investigation of the relationship between construct frequency and variability for samples. This could lead to a methodology for choosing the most important common constructs from a series of repertory grid interviews.

4) Investigation of the time taken by respondents to rate elements against provided constructs contrasted against the time required to produce and rate the same number of personal constructs.

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[1] For instance Germans are used to a scale of 1 (very good) to 6 (poor) from their school system, whereas Dutch are used to a scale of 10 (very good) to 1 (poor). A preliminary review of the results in from this research did indeed show an effect due to interviewee nationality.

5) Research aimed at identifying the best method for analysing multiple identical repertory grids.

9.3 RESEARCH CONCLUSIONS - AN ALTERNATIVE VIEW

This thesis has, up until now, deliberately followed a strictly scientific or conventional approach i.e. hypotheses were chosen, variables identified, measurements were made, data was analysed and conclusions were drawn. In the conclusions given in the previous section, particular care was taken to acknowledge the limitations introduced by the samples surveyed. However, in management research, some researchers argue for a more inductive approach saying for instance, "*inductive inferences cannot be proved true, but we need to use them to construct theories until we have evidence to the contrary*" (Dane, 1990). Consequently, it can be argued, that the research should be reviewed from an inductive standpoint.

The goal of this section is to give an alternative perspective on the value of the results, with less emphasis on the limitations (in contrast to the discussions in Section 9.2). It therefore gives takes the opportunity to step outside the confines of a strict scientific approach and to speculate on whether the research can have any wider, more exciting implications.

9.3.1 Broader Contributions of the Research

Five main contributions of the research were identified earlier (Section 9.2.1). From these the final one, that it established a structure for research into product support and could form a basis for establishing new theories, is the most significant one from an inductive standpoint.

Inductive inferences need to be made on product support even though little research has previously been conducted and the current research cannot be generalized. This is because we cannot wait until "*all of the facts are in, nor can we wait for all the facts before we begin to construct theories*" (Dane, 1990). Using directly the results of the current study, the following possible theories were identified:-

- The importance of product support in the marketing of high-technology products is still not widely understood by management. This is compromising the effectiveness of "total quality" initiatives for these products. [An even wider issue is that, if a key factor like support is not yet understood, then high-technology marketing as a discipline could well have potential for further significant developments - particularly as most marketing theories have come from the sphere of consumer products.]

- In the post-sales phase, the customer's view of a high-technology product is influenced by his experience of the quality of not only that product but also the manufacturing company's support services. The customer's opinion of a product could potentially be very strongly biased by his experience of services. Therefore any market investigation of customers' opinions on products (e.g. for the purpose of designing new products) must take account of this. (The implication is that many market surveys, that do not take account of the influence of post-sales support on customers' opinions, give inaccurate results.)

- The quality of product support is not improving as fast as it could, as many companies are now focusing their efforts on internal company viewpoints of support and not the actual customer's needs.

(An example of inductive reasoning applied to research into customer service is the book *Delivering Quality Service* by Zeithaml *et al*, 1990. This book develops the theory that the customer's view service quality can be categorized in ten attributes. In this case inductive reasoning is probably taken too far, as the theory is presented without any reference to the limitations of the focus group research on which it was based and the theory is applied as though it were proven.)

9.3.2 Broader Implications of the Research

The second point to note about the conclusions given up until now (in Section 9.2) is that the implications discussed were strictly limited to the field studied i.e. product support. Is this approach not too narrow? It could be argued that the results may well have implications for other areas.

The topic for which the results have real implications is marketing in general. A new approach to marketing - relationship marketing - recognizes that total quality can only be achieved if companies are organized so that both their products and services are customer focused (Christopher *et al*, 1991). *"Relationship Marketing is as much about keeping customers as it is about getting them in the first place"* (*ibid*) and so an even stronger emphasis is placed on ensuring that all of a company's post-sales output is customer focused. However, relationship marketing can only be effective if the services provided are customer focused. For high-technology products, at least, this cannot be the case today because of the lack of understanding of product support.

The importance of the mixture of products and services offered to biomedical engineers emerged from the research. The broader implication of the research could be that, as the relationship marketing approach is applied to high-technology products, it will become obvious that a fundamental prerequisite - a good understanding of product support - is necessary before improvements can be made. If this is the case, then much of the market research done today is far less effective than it could be!

9.3.3 The Practical Value of the Research

What can be said in final conclusion as to the practical value of the research? Two main points emerge.

Firstly, the results enable a number of practical recommendations to be made for managers involved with the marketing of high-technology products:-

- Monitor the effectiveness of product support strategies for current products.
- When designing new products, consider the importance, from the customer perspective, of both product attributes and support services.
- Measure customers' perceptions of not only competitive products but also competitive support services. (Do not rely on company-internal views of the effectiveness of your product support programmes - survey real customers.)
- Set quantitative design goals for all aspects of product support (see Table 7.28). Check that these are implemented during product development.
- Promote the right mix of product and support services to gain a competitive advantage.
- Check whether customers are willing to participate in some aspects of support delivery - this can lower costs-of-ownership.

Secondly, the results have broad implications for high-technology marketing. The empirical data demonstrate the importance to customers (biomedical engineers) of the mixture of products and services offered and therefore support the arguments of much of the emerging literature on relationship marketing. This is a particularly valuable result, since most of the literature on relationship marketing has been based on anecdotal evidence. Perhaps the results of this study have therefore made a step towards raising the perceived importance of product support for high-technology products. However, there is still a long way to go before the most important aspects of high-technology marketing are recognized to be not only "the four Ps" (product, place, price and promotion) but also an additional one - product support[1].

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[1] *The idea of adding extra factors including support to "the four P's" comes from Christopher et al (1991).*

9.4 SUMMARY

A management study of product support for high-technology products made a detailed investigation of this facet of marketing. Two particular aspects were investigated - the planning of support at the product design stage and the customer's perception of support in one market.

The results show that the majority of the companies in the sample do not systematically evaluate all of the elements of support at the product design stage. The elements most commonly evaluated are product reliability and Mean-Time-to-Repair (MTTR). Other elements of support such as training and installation were found to be important for the sample companies but were typically not fully evaluated at the design stage. The implication of these results is that support could be better planned at the product design stage.

Customers perceive differences in the quality and ease of support of different products. These differences, on various attributes of good support, give indications of the areas of support which are perceived as most important. Company engineers in the medical equipment market distinguish support between products largely in design terms whereas biomedical engineers' criteria cover both the product and the respective company's support organization. These results, for this particular market, have strong implications for the planning of the product support. A similar investigation of product support in other markets would, very probably, produce results with equally strong implications.

The contribution of the research was the identification of how support is planned at the sample companies, which is an advance on the data previously available - all of which was anecdotal. In addition, customers' perceptions of support were measured and this lead to a better understanding of the concept *product support*. Many areas were identified for further research and some of these are being actively pursued.

Viewed from a broader perspective, the research made significant steps forward in investigating the relationship, in the customer's mind, between products and services. The empirical results could form a basis for further investigations of these relationships using representative samples in various markets. In addition, they indicate possible theories that can be developed to explain the importance and perception of support. These have significant implications for the marketing of high-technology products.

The research broadened the knowledge of product support not only in theoretical but also in practical terms. Consequently, a number of important recommendations can be made to managers who are involved with the marketing of high-technology products. These could potentially increase the quality of product support and lead to increased customer satisfaction.

It is hoped that the conclusions of this research will find practical applications and lead to improvements in the quality of product support.

Whether this is the case or not, will be the real measure of the value of the research since, "*At all times... it should be remembered that the main aim of management research is to help improve the practice of management*" (Bennett, 1983).

References

ADAMS-WEBER, J.R.
Elicited versus Provided Constructs in Repertory Grid Techniques
British Journal of Medical Psychology, Vol. 43, 1970, pp349-354.

AHNEFELD, F.W.
Versuch einer Bestandsaufnahme (An Attempt to Portray the State-of-the-Art)
Medizintechnik, 107. Jg. 3/87, 1987, pp78-84.

AIRD, E.G.A.
An Introduction to Medical Physics
Heinemann, London, 1975.

ALBRECHT, K. and ZEMKE, R.
Service America! Doing Business in the New Economy
Dow Jones-Irwin, 1985.

ALBRECHT, K. G.
Successful Management by Objectives
Prentice-Hall Inc., New Jersey, 1978.

ALPERT, M.I.
Identification of Determinant Attributes: A Comparison of Methods
J. Marketing Research, Vol. 8, May 1971, pp184-191.

AMARA, R. and LIPINSKI, A.J.
Business Planning for an Uncertain Future
Pergamon Press Inc., 1983.

AMES, B.C.
Marketing Planning for Industrial Products
Harvard Business Review, Vol. 45, No. 5, September-October 1968, pp100-111.

ANDERSON A. and CO. with AFSM INTERNATIONAL
Linking Service Strategy to the Bottom Line
Special report from the Association of Field Service Managers International, Fort Myers 1988.

ANONYMOUS
Acronyms from A/D to ZTAT
Electronic Products, November 1st 1987, pp65-85.

ANONYMOUS (COMPUTING-UK)
Making the Most of Motorway Mileage
Computing (UK), 8th March 1990, pp24-26.

APPLER, W.D.
FDA Notes - What Device Manufacturers Need to Know
Medical Device and Diagnostic Industry, Vol. 12, No. 7, July 1990, pp32-35.

ARMISTEAD, C. and CLARK, G.
A Framework for Formulating After Sales Support Strategy
Proc. OMA-UK Conference on Manufacturing Strategy, Warwick 25-26th June 1990.

BAILEY, K.D.
Methods of Social Research
3rd Edition, The Free Press, 1987, Chapter 6, pp105-146.

BALDWIN, S.R. and McCONNELL, M.
Strategic Planning: Process and Plan Go Hand in Hand
Management Solutions, Vol. 33, June 1988, pp29-36.

BANNISTER, D.
Personal Construct Theory: A Summary and Experimental Paradigm
Acta Psychologica, Vol. 2, 1962, pp104-120.

BAYLISS, J.S.
Marketing for Engineers
Peter Peregrinsus Ltd., London, 1985.

BBI (BIOMEDICAL BUSINESS INTERNATIONAL)
Anesthesiology Products Report #7050
First Printing June 1985, Tustin USA.

BEAVER, J.E.
A New Balance In User Support
Computer Decisions, Vol. 18, No. 14, June 30, 1986, pp62-66.

BENDER, M.P.
Provided versus Elicited Constructs: An Explanation of Warr and Coffman's Anomolous Finding
British Journal of Social and Clinical Psychology, Vol. 13, 1974, pp329-330.

BENNETT, R.
Management Research: A Guide for Institutions and Professionals
International Labour Office, Management Development Series Number 20, Geneva, 1983 (ISBN 92-2-103303-1).

BEN-ZVI, S.
Development of Preventive Maintenance Procedures
J. Clinical Engineering, Vol. 9, No. 2, April-June, 1984, pp103-112.

BERG, J. and LOEB, J.
The Role of Field Service in New Product Development and Introduction
AFSM International-The Professional Journal, Vol. 14, No. 9, May 1990, pp25-30.

BERKOWITZ, D.A.
Strategic Technology Management
Healthcare Forum, Vol. 32, No. 5, September/October 1989.

BESSANT, J.R.
Influential Factors in Manufacturing Innovation
Research Policy, Vol. 11, No. 2, April 1982, pp 117-132.

BLEUTEL, W.H. and PATTON, J.D.
Service Management - Principles and Practices
Instrument Society of America, 1986.

BLOCK, F.E.
A Proposed Standard for Monitoring Equipment: What Equipment Should Be Included?
J. Clinical Monitoring, Vol. 4, No. 1, January 1988, pp1-4.

BLUMBERG, D.F.
An Inside Look at the Pricing of Maintenance Services
Data Communications, Vol. 13, No. 10, September 1984, pp203-209.

BLUMBERG, D.F.
Developing Service as a Line of Business
Management Review, Vol. 76, No. 2, 1987, pp58-62.

BLUMBERG, D.F.
Strategies and Analytical Models for Improving Field Service Force and Logistics Productivity
AFSM International-The Professional Journal, Vol. 14, No. 1, August 1989, pp14-28.

BOOTHROYD, G.
Design for Assembly - The Key to Design for Manufacture
International Journal of Advanced Manufacturing Technology, Vol. 2, No. 3, 1987, pp3-11.

BOOTHROYD, G. and DEWHURST, P.
Product Design for Manufacture and Assembly
Manufacturing Engineering, Vol. 100, No. 4, April 1988, pp42-46.

BORENSTEIN-LEVY, R. (ed.)
An Administrator's Perspective on Capital Equipment Decision Making
Advances for Medicine (Hewlett-Packard Co.), Vol. 10, No. 5, January 1990, pp5-8.

BREILING, H-G.
Qualitaet im Kundendienst (Quality in Customer Service)
Management Circle Conference, 30-31st May 1990, Wiesbaden, West Germany, Section 10b.

BRENNER, M., BROWN, J. and CANTER, D.
The Research Interview: Uses and Approaches
The Academic Press, 1987, pp84-85.

BREWSTER, L.S.
End-User Product Support- Who is Responsible?
Interface Age, October 1984, pp32-33.

BROWN, P.W.
Ultra Ultrasound
In Vivo: The Business and Medicine Report, January/February 1987, pp35-36.

BRYMAN, A. and CRAMER, D.
Quantitative Data Analysis for Social Scientists
Routledge, London 1990.

BSI (BRITISH STANDARDS INSTITUTION)
Quality systems. Part 1. Specification for Design /Development, Production, Installation and Service
BS 5750: Part 1: 1987, ISO 9001-1987.

BSI (BRITISH STANDARDS INSTITUTION)
Quality Assessment Schedule to BS 5750 Part 1 1987/ISO 9001
Document QAS 3302/187 Issue 2, September 1987.

BULLER, M.
The Service Component
In Vivo: The Business and Medicine Report, January 1991, pp1-6 (ISSN 0773-1396).

CACERES, C.A.
Transferring Technology into the Health Care Delivery System
Biomedical Instrumentation and Technology, Vol. 24, No. 2, March/April 1990, pp93-98.

CARROLL, S.J. and TOSHI, H.L.
Management by Objectives
The MacMillan Company, New York, 1973.

CHISNALL, P.M.
Marketing Research
3rd Edition, McGraw-Hill, 1986.

CHRISTOPHER, M.
Cluster Analysis and Market Segmentation
British J. of Marketing, Vol. 3, Summer 1969, pp99-102.

CHRISTOPHER, M., PAYNE, A. and BALLANTYNE, D.
Relationship Marketing: Bringing Quality, Customer Service and Marketing Together
Cranfield School of Management Working Paper, SWP 31/91, 1991.

CLARK, G.
After Sales Service in UK Manufacturing
Cranfield School of Management Working Paper, April 1988.

CLARK, G.
Chairman's Welcome and Brief Introduction
Proc. 1st Int. Conf. After Sales Success, London 29-30th November 1988, pp3-10 (ISBN 1-85423-0289).

CLARK, G.
Strategies for Product and Customer Support - A Research Report
Cranfield School of Management Working Paper, SWP 2/91, October 1990.

CLARK, G. and ARMISTEAD, C.
Service with a Smile
Manufacturing Engineer, Vol.69, No. 8, September 1990, pp18-19.

COOKE, E.F.
Post-Shipment Services: Turning Customer Complaints Into Assets
Journal of Business and Industrial Marketing, Vol. 2, No. 3, Summer 1987, pp17-22.

CROSS, R.H.
Strategic Planning: What It Can and Can't Do
Advanced Management Journal, Vol. 52, Winter 1987, pp13-16.

CUNNINGHAM, M.T. and ROBERTS, D.A.
The Role of Customer Service in Industrial Marketing
European Journal of Marketing, Vol. 8, No. 1, 1974, pp15-28.

DALE, J. (ed.)
The Products
Monitor (Hewlett-Packard Co.), Vol. 7, No. 4, July-August 1986, pp10-14.

DANE, F.C.
Research Methods
Brooks/Cole Publishing Co., Pacific Grove, USA, 1990.

DAVIDOW, W.H.
Marketing High Technology
The Free Press, 1986.

DAVIDOW, W.H. and UTTAL, B.
Total Customer Service
Harper and Row, New York, 1989.

DAVIDOW, W.H. AND UTTAL, B.
Service Companies: Focus or Falter
Harvard Business Review, Vol. 67, No. 4, July-August 1989, pp77-85.

DAVIDOW, W.H. and UTTAL, B.
Why You Need a Service Strategy
Planning Review Journal, Vol. 18, No. 1, January /February 1990, pp10-14.

DILLMAN, D.A.
Mail and Telephone Surveys
Wiley, New York, 1978.

DIXON, B.R., BOUMA, G.D. and ATKINSON, G.B.J.
A Handbook for Social Science Research
Oxford University Press, 1987.

DJURDJEVIC, B.
The Service Game
Computer & Communications Decisions, Vol. 19, No. 14, November 1987, p21.

DOHENY, K.
FMEA: A Route to Better Devices
Medical Device and Diagnostic Industry,Vol. 10, No. 10, October 1988, pp42-45.

DOWNTON, S.
Taking the Cost out of Service Using JIT Techniques
Proc. 4th European Service Management Conf., 27-28th February and 1st March 1990, London, Session B.

DU BOIS, J.
Quality Function in the Service Function
Proc. Conf. on Customer Care, London 4-5th July 1990, pp50-57 (ISBN 1-85423-081-6).

ECRI (EMERGENCY CARE RESEARCH INSTITUTE)
Deaths during General Anesthesia
Technology for Anesthesia, Vol. 5, No. 9, March 1985, pp1-10.

ECRI (EMERGENCY CARE RESEARCH INSTITUTE)
Technology Opportunities for the 1990s
Emergency Care Research Institute (ECRI), Plymouth USA, 1989.

EISENBERG, J.M., SCHWARTZ, J.S., McCASLIN, C., KAUFMAN, R., GLICK, H. and KROCK, E.
Substituting Diagnostic Services
J. American Medical Association (JAMA), Vol. 262, No. 9, 1989, pp1196-1200.

ELLIS, D.
Motivating the Service Engineer
Proc. 1st Int. Conf. After Sales Success, London 29-30th November 1988, pp83-90 (ISBN 1-85423-0289).

FISHER, A.B.
Is Long-Range Planning Worth It?
Fortune, April 23, 1990, pp137-140.

FITZGERALD, K.
Technology in Medicine: Too Much Too Soon?
IEEE Spectrum, December 1989, pp24-29.

FLOYD, M.
The Role of New Technology in Improving After - Sales Service
Proc. 1st Int. Conf. After Sales Success, London 29-30th November 1988, p39 (ISBN 1-85423-0289).

FODOR, G.M.
Staying Live After Going Live
Industrial Distribution, Vol. 78, No. 75, March 1989, p75.

FRANSELLA, F. and BANNISTER, D.
A Validation of Repertory Grid Techniques as a Measure of Polital Construing
Acta Psychologica, Vol. 26, 1967, pp97-106.

FRANSELLA, F. and BANNISTER, D.
A Manual for Repertory Grid Technique
Academic Press, 1977.

FROITZHEIM, U.J.
Operation Krankenhaus ("Operation Hospital")
High Tech (Germany), 2/90, 1990, pp65-84.

FROST, W.A.K. and BRAINE, R.L.
The Application of the Repertory Grid Technique to Problems in Market Research
Commentary, Vol. 9, No. 3, July 1967, pp161-175.

GARVIN, D.A.
Managing Quality
The Free Press, 1988

GASPAROVIC, W.
Servicing the High-Technology Healthcare Industry
AFSM International-The Professional Journal, Vol. 14, No. 2, October 1989, pp14-15.

GILMORE, F.G.
Formulating Strategy in Smaller Companies
In: Harvard Business Review On Management, Volume 2, Harper and Row Inc., 1986, pp42-57.

GOFFIN, K.
Planning for Support
Proc. Conf. on Customer Care, London 4-5th July 1990, pp71-79 (ISBN 1-85423-081-6).

GOFFIN, K.
Design for Support: Results of a UK Survey
AFSM International-The Professional Journal, Vol. 14, No. 10, July 1990, pp24-29.

GOFFIN, K.
Factors Influencing the Cost of Ownership of Medical Equipment
Proc. 26th Meeting of the Association for the Advancement of Medical Instrumentation (AAMI), Washington, May 11-15, 1991, p36 (ISBN 0-910275-54-8).

GREENLEY, G.E.
Managerial Perceptions of Marketing Planning
J. Management Studies, Vol. 25, No.6, November 1988, pp575-601.

GREEN, P.E., TULL, D.S. and ALBAUM, G.
Research for Marketing Decisions
5th Edition. Prentice-Hall, 1988.

GRENIER, R.
Total Quality Assurance, Part III
Quality, Vol. 24, No. 6, June 1985, pp44-50.

HAMMERMESH, R.G.
Making Planning Strategic
Harvard Business Review, Vol. 64, No. 4, July-August 1986, pp115-120.

HAUSER, J.R. and CLAUSING, D.
The House of Quality
Harvard Business Review, Vol.66, No. 3, May-June 1988, pp63-73.

HAYES, R.H.
Strategic Planning - Forward in Reverse?
Harvard Business Review, Vol. 63, No. 6, Nov.-December 1985, pp111-119.

HEALTH TECHNOLOGY
JCAHO Equipment Requirements
Health Technology, Vol. 3, No. 3, Fall 1989, pp12-23.

HECKMAN, R.F.
Disk Drive Reliability: Increasing Product Quality is an Industry responsibility
Proc. of "Mini/Micro 82" conference, Anaheim USA, September 14-16, 1982, Western Periodicals Co., pp1/3[1-5] (NDN 047-0015-7720-7).

HESKITT, J.L.
Lessons in the Service Sector
Harvard Business Review, Vol. 65, No. 2, March-April 1987, pp118-126.

HEWLETT-PACKARD
"Human Factors": A Personal Approach to Systems Design
Nursing and Technology (Hewlett-Packard Co.), Vol. 2, Issue 1, January 1991, pp4-5.

HOLDEN, P.E., FISH, L.S. and SMITH, H.L.
Top Management Organisation and Control
Stanford University Press, 1941.

HOLSTEIN, H.N.
Designing Quality In
Medical Device and Diagnostic Industry, Vol. 10, No. 10, October 1988, pp32-35.

HUDSON, R.
Images of the Retailing Environment: An Example of the Use of the Repertory Grid Methodology
Environmental Behaviour, Vol. 6, No. 4, December 1974, pp470-494.

HUGHES, M.
The Diary of an Evolving Methodology
Graduate Management Research, Vol. 5, No. 2, Autumn 1990, pp25-36.

HUMBLE, J.W.
Management by Objectives in Action
McGraw-Hill Publishing Company Ltd., 1970.

IEC (INTERNATIONAL ELECTROTECHNICAL COMMISSION)
IEC 930 Report,
First Edition 1988.

ISAACSON, G.I. and LANDFIELD, A.W.
Meaningfulness of Personal and Common Constructs
Journal of Individual Psychology, Vol. 21, 1965, pp160-166.

IVES, B. and VITALE, M.R.
After the Sale: Leveraging Maintenance with Information Technology
MIS Quaterly, March 1988, pp 7-21.

JAVIDAN, M.
Where Planning Fails - An Executive Survey
Long Range Planning, Vol. 18, No. 5, October 1985, pp89-96.

JOSHI, D.C.
Advantages of Simultaneous Design of Product and Processes
Proc. of the National Electronics Conference (USA), Vol. 39, October 1985, pp650-657.

JOY, K.
Retailers Lose by Neglecting Product Support
High-Tech Marketing, January 1987, pp44-45.

JOYCE, E.D.
Dialing for Help
Datamation, Vol. 35, January 1, 1989, pp53-55.

JURAN, J.M. and GRYNA, F.M.
Juran's Quality Control Handbook
4th Edition McGraw-Hill, 1988

KARMARKAR, U.S. and KUBAT, P.
Modular Product Design and Product Support
European Journal of Operational Research, Vol.29, No. 1, 1987, pp74-82.

KARMARKAR, U.S., UDAY, S. and KURBAT, P.
The Value of Loaners in Product Support
IIE Transactions, Vol. 15, No. 1, March 1983, pp 5-11.

KASTIEL, D.L.
Service and Support: High Tech's New Battleground
Business Marketing, Vol. 72, June 1987, pp54-56.

KELLY, G.A.
The Psychology of Personal Constructs (Vol. 1 and 2)
Norton, New York, 1955.

KEMP, G.
Software-Maintenance
Computer/Electronic Service News, March/April 1983, pp58-59.

KERR, S.
Overcoming the Dysfunctions of MbO
In: Management Centre Europe-Annual Journal 1989, pp87-91.

KING, D.D.
Administrators and Computerized Maintenance Management Systems: A Case Study
Biomedical Instrumentation and Technology, Vol. 24, No. 4, July/August 1990, pp254-258.

KING, W.R.
Evaluating the Effectiveness of Your Planning
Managerial Planning, Vol. 33, September/October 1984, pp4-8 & 26.

KNIGHT, K.R.
High Stakes Service
Second Source Biomedical (USA), Vol. 2, No. 3, May/June 1991, pp18-22 (ISSN 1053-6868).

KORET, R.J. and BOUDREAU, N.
The Leading Edge Need Not Be the Bleeding Edge
AFSM International-The Professional Journal, Vol. 15, No. 1, August 1990, pp11-13.

KOTLER, P.
Marketing Management
5th Edition, Prentice-Hall Inc., 1984.

KUMPE, T. AND BOLWIJN, P.T.
Manufacturing: The New Case for Vertical Integration
Harvard Business Review, Vol. 66, No. 2, March-April 1988, pp75-81.

KUUSINEN, J. and NYSTEDT, L.
The Convergent Validity of Four Indices of Cognitive Complexity in Person Perception
Scandinavian Journal of Psychology, Vol 16, 1975, pp131-136.

LALONDE, B.J. and ZINSZER, P.H.
Customer Service: Meaning and Measurement
National Council of Physical Distribution Measurement, Chicago, 1976.

LAMBERT, G.
Towards Professionalism- Service Moves in the Right Direction
Service Management (UK), November 1988, pp15-21.

LAMBERT, G. (ed.)
Remote Diagnostics - A Strategic Tool for Field Service
Service Management (UK), January 1989, pp40-42.

LANDFIELD, A.W.
Meaningfulness of Self, Ideal and Other Related to Own vs Therapist's Personal Construct Dimensions
Psychological Reports, Vol. 16, 1965, pp605-608.

LAWRENCE, K.
Improving After-Sales Service
Data Processing, Vol.26, No. 6, 1984, pp28-29.

LELE, M.M.
Product Service: How To Protect Your Unguarded Battlefield
Business Marketing, Vol. 68, No. 6,June 1983, pp 68-76.

LELE, M.M.
How Service Needs Influence Product Strategy
Sloan Management Review, Vol. 28, No. 1, Fall 1986, pp63-70.

LELE, M.M. and KARMARKAR, U.S.
Good Product Support is Smart Marketing
Harvard Business Review, Vol.61, No.6, November-December 1983, pp124-132.

LELE, M.M. and SHETH, J.N.
The Customer is Key
John Wiley and Sons, 1987.

LELE, M.M. and SHETH, J.N.
The Four Fundamentals of Customer Satisfaction
Business Marketing, June 1988, pp80-94.

LEMON, N.
Linguistic Developments and Conceptualisation
Journal of Cross-Cultural Psychology, Vol. 6, No. 2, June 1975, pp173-188.

LEVINE, R.
Remote Diagnostics Today
Computer/Electronic Service News (USA), May 1986, pp26-30.

LEVITT, T.
The Industrialization of Service
Harvard Business Review, Vol. 50, No. 5, September-October 1972, pp63-74.

LEVY, L.H. and DUGAN, R.D.
A Factorial Study of Personal Constructs
Journal of Consult. Psychology, Vol. 20, No. 1, 1956, pp53-57.

LITTLE, D., MOSQUERA, J. and WILD, A.M.A.
Logistics for Service Support in the Computer Industry
Focus on Physical Distribution and Logistics Management, Vol. 7, No. 2, March 1988, pp30-35.

LIVINGSTON, I.
Design for Service
Proc. 1st Int. Conf. After Sales Success, London 29-30th November 1988, pp45-71 (ISBN 1-85423-0289).

LORANGE, P.
Corporate Planning: An Executive Viewpoint
Prentice-Hall, New Jersey, 1980.

LOVELOCK, C.H.
Services Marketing
Prentice-Hall International, 1984.
LOVELOCK, C.H.
Managing Services
Prentice-Hall International, 1988.

LOVETT, P.D.
Meetings That Work: Plans Bosses Can Approve
Harvard Business Review, Vol. 66, No. 6, Nov.-December 1988, pp38-44.

LUNN, J.A.
Perspectives in Attitude Research: Methods and Applications
J. Market Research Society, Vol. 11, No. 3, 1969, pp201-213.

MACINNIS, M. and HESLOP, L.A.
Market Planning in a High-Tech Environment
Industrial Marketing Management, Vol. 19, 1990, pp107-116.

MARR, N.E.
The Meaning and Measurement of Customer Service in International Marketing
Unpublished Ph.D. Thesis, Cranfield Institute of Technology, 1983.

MATHE, H.

Field Service Management: A Means to Competitive Advantage
International J. of Physical Distribution & Materials Management, Vol. 16, No. 7,1986, pp13-21.

MATHE, H.

Integrating Field Service Management and Product Policy with Corporate Strategy
Unpublished Ph.D. Thesis, Cranfield Institute of Technology, 1988.

MCDONALD, M.H.B.

The Theory and Practice of Marketing Planning for Industrial Goods in International Markets
Unpublished Ph.D. Thesis, Cranfield Institute of Technology, 1982.

MCWILLIAMS, G.

Users Report Service Problems With Digital's High-End Systems
Datamation, October 1, 1987, pp17-19.

MEDISTAT

Outlook for Electro-Medical and X-Ray Equipment
Medistat (World Medical Market Analysis- McGraw Hill), Vol. III, Issue 4, April 1990, pp1-2.

MEDISTAT

Trend Towards Less Invasive Procedures Stimulates Therapeutic and Surgical Equipment Markets
Medistat (World Medical Market Analysis- McGraw Hill), Vol. III, Issue 8, August 1990, pp1-2.

MEDISTAT

Ultrasound Sales Bouyant Despite Health Cut Backs
Medistat (World Medical Market Analysis- McGraw Hill), Vol. IV, Issue 4, June 1991, pp1-2.

MEDISTAT

Patient Monitoring Projected to Reach US$1.2 Billion by 1996
Medistat (World Medical Market Analysis- McGraw Hill), Vol. IV, Issue 6, July 1991, pp1-2.

MEDISTAT

Cardiac Monitoring Equipment Market to Reach US$3 Billion by 1995
Medistat (World Medical Market Analysis- McGraw Hill) Vol. IV, Issue 7, July 1991, pp2-3.

MENDELSON, B.

Tele-Maintenance
Computer/Electronic Service News, May/June 1983, pp60-64.

METCALF, R.J.A.
Own versus Provided Constructs in a Reptest Measure of Cognitive Complexity
Psychological Reports, Vol. 35, 1974, pp1305-1306

MIER, E.
The Rise and Fall of the EMI Scanner
Cranfield School of Management, Case Study No. ML/02:87/01/EMIS, 1980.

MILLS, D.Q.
Planning with People in Mind
Harvard Business Review, Vol. 63, No. 4, July-August 1985, pp97-105.

MIR (MARKET INTELLIGENCE RESEARCH)
Ultrasound Imaging Markets
Market Intelligence Research, Mountain View USA, 1988.

MITCHELL, C.
Motivation of Technical Service Staff
Proc. Conf. Customer Care, London 4-5th July 1990, pp58-65 (ISBN 1-85423-081-6).

MIYAKAWA, S. and OHASHI, T.
The Hitachi Evaluation Method
Proc. 1st Int. Conf. on Production Design for Assembly, April 1986.

MOSER, C.A. and KALTON, G.
Survey Methods in Social Investigation
2nd Edition, Gower, Aldershot, 1979.

MOYERS, J.
Monitoring Instruments Are No Substitute for Careful Clinical Observation
J. Clinical Monitoring, Vol. 4, No. 2, April 1988, pp107-114.

MUNN, R.C.
New Directions in Field Service
Computer/Electronic Service News (USA), Sept. 1985, pp47-59.

MYERS, J.H. and ALPERT, M.
Determinant Buying Attitudes: Meaning and Measurement
Journal of Marketing, Vol. 32, October 1968, pp 13-20.

NASH, R.
Pupils' Expectations for Their Teachers
In: WILSON, M. (ed.), Social and educational Research in Action, Longman 1979, pp291-307.

NIXON, F.
Managing to Achieve Quality and Reliability
McGraw-Hill, 1971

NIXON, B.R., BOUMA, G.D. and ATKINSON, G.B.J.
A Handbook of Social Science Research
Oxford University Press, 1987.

OPEN UNIVERSITY
Research Methods in Education and the Social Sciences: Research Design (DE304 Block 3A)
Open University, 1979.

OPEN UNIVERSITY
Research Methods in Education and the Social Sciences: Data Collection Procedures (DE304 Block 4)
Open University, 1979, pp23-31.

OPPENHEIM, A.N.
Questionnaire Design and Attitude Measurement
Heinemann, 1966.

OTTO, T.
Sub-assembly Repair - Should It Be Performed In Customer Service?
Field Service Manager, Vol.13, No. 1, August 1988, pp57-58 (ISSN 0199-8889).

PATIENT, D.A. (ed.)
Healthcare Equipment International
Longman, UK, 1989.

PATTON, J.D.
Maintainability and Maintenance Management
Instrument Society of America, 1980.

PATTON, J.D.
Service Parts Management: A New Perspective for the 1980s
Field Service Manager, February 1980, pp71-82 (ISSN 0199-8889).

PATTON, J.D.
Service Parts Management
Instrument Society of America, 1984.

PHILLIPS, S., DUNKIN, A., TREECE, J.B. and HAMMONDS, K.H.
King Customer
Business Week, March 12, 1990, pp50-56.

PITTIGLIO, T. and HOOLE, R.
Service: A Strategic Weapon in Electronics
Electronic Business, February 15th, 1987, pp123-125.

POPE, M.L. and KEEN, T.R.
Personal Construct Psychology and Education
Academic Press, 1981.

POTTS, G.W.
Managing Service Revenues
Field Service Manager, Vol. 12, No. 5, April 1988, pp27-35 (ISSN 0199-8889).

POTTS, G.W.
Exploit Your Product's Service Life Cycle
Harvard Business Review, Vol. 66, No. 5, September-October 1988, pp32-36.

POWERS, T.L.
Identify and Fulfill Customer Service Expectations
Industrial Marketing Management, Vol. 17, Nov. 1988, pp273-276.

QUINN, J.B., DOORLEY, T.L. and PAQUETTE, P.C.
Beyond Products: Services-Based Strategy
Harvard Business Review, Vol. 68, No. 2, March-April 1990, pp58-67.

RANDOLPH, W.A. and POSNER, B.Z.
What Every Manager Needs to Know about Project Management
Sloan Management Review, Vol. 29, Summer 1988, pp65-73.

RAUTMANN, H.
Service Support Strategy
Field Service Manager, Vol. 12, No. 5, April 1988, pp43-46 (ISSN 0199-8889).

RHYNE, L.C.
Contrasting Planning Systems in High, Medium and Low Performance Companies
J. Management Studies, Vol. 24, No. 4, July 1987, pp363-385.

RICHARDSON, H.W.
Designing for Customer Set Up
Quality, Vol. 20, No. 10, October 1981, pp62-65.

RITER, C.B.
What Influences Purchases of Color Televisions?
Journal of Retailing, Vol. 42, Winter 1966-1967, pp25-31 & 63.

ROUSSEL, C.J. and MILLER, J.
Experts Offer Perspectives on the International High-Techn. Services Industry in the Nineties
AFSM International-The Professional Journal, Vol. 15, No. 2, September 1990, pp8-12.

RYLE, A. and LUNGHI, M.W.
The Dyad Grid: A Modification of Repertory Grid Technique
British Journal of Psychiatry, Vol. 117, 1970, pp323-327.

SHAFFER, M.J.
Development of Biomedical Equipment Operator's Manual
Medical Instrumentation, Vol. 21, No. 1, February 1987, pp44-46.

SHAFFER, M.J. and SHAFFER, M. D.
Biomedical Equipment Maintenance: Adjusting to the Demands of a Changing Environment
Biomedical Instrumentation and Technology, Vol. 24, No. 2, March/April 1990, pp85-91.

SHAFFER, M.J. and SHAFFER, M.D.
Strategies for Improving Clinical Engineering In-Service Instruction
Biomedical Instrumentation and Technology, Vol. 24, No. 5, September/October 1990, pp336-342.

SHANK, J.K., EDWARDS, E.G. and SANDALLS, W.T.
Balance "Creativity" and "Practicality" in Formal Planning
In: Harvard Business Review On Management, Volume 2, Harper and Row Inc., 1986, pp29-41.

SHORES, A.R.
Survival of the Fittest: Total Quality Control and Management Evolution
ASQC Quality Press, Milwaukie, 1988.

SHUBSACHS, A.P.W.
To Repeat or Not Repeat? Are Frequently Used Constructs More Important to the Subjects? A Study of the Effect of Allowing Repetition of Constructs in a Modified Kelly Repertory Test
British Journal of Medical Psychology, Vol. 48, 1975, pp31-37.

SIMPKINS, K.
Medical Markets in the EEC (Volumes One and Two)
WMI Publications Ltd., Chichester, UK, 1989.

SMITH, H.W.
Strategies of Social Research
Prentice-Hall, 1975.

SMITH, M.
Introduction to Repertory Grids - Part One
Graduate Management Research, Vol. 3, No. 1, Summer 1986, pp4-17.

SMITH, M.
An Introduction to Repertory Grids - Part Two: Interpretation of Results
Graduate Management Research, Vol. 3, No. 2, Autumn 1986, pp4-24.

SPICKERNELL, D.G.
Design for Quality
IEE Proceedings, Vol. 130, Pt. A, No. 4, June 1983, pp159-161.

STALK, G.
Time - The Next Source of Competitive Advantage
Harvard Business Review, Vol. 66, No. 4, July-August 1988, pp41-51.

STEPHANSON, G.M. and FREIHERR, G.
Cost-Effectiveness: New Yardstick for Medical Device Evaluation
Medical Device and Diagnostic Industry, Vol. 12, No. 3, March 1990, pp71-73, and 110.

STEWART, G.
Market Trends
Proc. 4th European Service Management Conf., 27-28 February and 1 March 1990, London, Session A.

STOLL, H.W.
Design for Manufacture
Manufacturing Engineering, January 1988, pp67-73

STOLL, H.W. and COLE, J.H.
DFM Aids Manufacturing Priorities in the Design Cycle
Computerworld, Vol. 19, No. 36, September 1985, pp107-113.

STONE, S.
CRUS Guide Number 6: Interviews
British Library Board, Sheffield, 1984.

STRINGER, P.
Psychological Significance in Personal and Supplied Construct Systems: A Defining Experiment
European Journal of Social Psychology, Vol. 2, 1972, pp437-447.

SULLIVAN, L.P.
Quality Function Deployment
Quality Progress, Vol.19, No. 6, June 1986, pp39-55.

SULLIVAN, S.
In Dire Need of Surgery
Newsweek, June 27, 1988, pp44-49.

TAYLOR, B.
The Concept and Use of Corporate Planning
In: TAYLOR, B. and SPARKES, J.R., (eds.), Corporate Strategy and Planning, Heinemann, 1977, pp3-13

THORBORG, W.
Supplier Support: A Vital Component of Digital Switch Conversions
Telephony, Vol. 204, No. 22, May 30, 1983, pp82-88.

TSCHUDI, F.
Flexigrid: An Integrated Software for Elicitating and Analyzing Grids
University of Oslo, Norway, 1984.

VANDERMERWE, S.
The Market Power is in Services: Because the Value is in the Results
European Management Journal, Vol. 8, No. 4, December 1990, pp464-473.

VOSS, C.A.
Strategies for Field Service Management
Proc. DSI Conference, Boston November 1987.

VYAKARNAM, S.
Introduction to Personal Construct Theory for Application in Management
Graduate Management Research, Vol. 4, No. 2, Summer 1989, pp7-19.

WAGNER, B.R.
Ist Kundendienst nur Wartung? (Is Customer Service Just Maintenance?)
Management Circle Conference, 30-31st May 1990, Wiesbaden, West Germany.

WALKER, C.F.
Medical Electronics
IEEE Spectrum, January 1990, pp52-54.

WALLOWER, D.R.
Good Servicing Requires More Than Technical Skills
Communications (USA), Vol. 16, No. 11, November 1979, pp54-56.

WALTERS, D.
The Logistics Implications of Changes in Retailing
Unpublished Ph.D. Thesis, Cranfield Institute of Technology, 1973.

WEAR, J.O. and SHASTRI, N.K.
Profile of a Hospital BMET
Proc. 26th Meeting of the Association for the Advancement of Medical Instrumentation (AAMI), Washington, May 11-15th, 1991, p96.

WEBER, M.
Functional and Software Safety- The German Approach
Medical Device and Diagnostic Industry, Vol. 13, No. 4, April 1991, pp22-25.

WELLEMIN, J.H.
The Handbook of Professional Service Management
Studentlitteratur, Lund, Sweden, 1984.

WHITCHER, C.W., REAM, A.K., PARSONS, D., RUBSAMEN, D., SCOTT, J., CHAMPEAU, M., STERMAN, W. and SIEGAL, L.
Anesthetic Mishaps and the Cost of Monitoring: A Proposed Standard for Monitoring Equipment
J. Clinical Monitoring, Vol. 4, No. 1, January 1988, pp5-15.

WHITNEY, D.E.
Manufacturing by Design
Harvard Business Review, Vol.66, No. 4, July-August 1988, pp83-91.

WIEGNER, K.K.
A Doctor's Son had a Vision
Forbes, April 30, 1990, pp182-183.

YIN, R.K.
Case Study Research
Rev. Edition, SAGE Publications Inc, California, 1989.

YOUNGSON, R.
Why Anaesthesia Can Still Kill
New Scientist, 9 February 1991, pp53-56.

ZEITHAML, V.A., PARASURAMAN, A. and BERRY, L.L.
Delivering Quality Service
The Free Press, New York, 1990.

ZEMKE, R. and BELL, C.R.
Service Wisdom - Creating and Maintaining the Customer Service Edge
Lakewood Books, 1989.

ZEMKE, R. and SCHAAF, D.
The Service Edge
New American Library, 1989.

Appendices

Contents:

APPENDIX A: GLOSSARY OF TERMS

This glossary includes most of the terms specific to product support which have been used in this thesis. It was compiled from five main references: Wellemin (1984)[1], Anonymous (1987)[2], Patton (1980)[3], Patton (1984)[4] and Bleutal and Patton (1986)[5], - the source of each definition is identified by the superscript numbers. Certain terms are given which, although also common in the literature, have not been previously defined. These were defined by the researcher and are indicated by the use of italics, as are any additions or modifications to the definitions taken from the above references.

Access[5]	To gain entry to contact part of a system
Availability[4]	With reference to parts, the fact that the part is on hand and in usable condition
Calibrate[3]	To verify the accuracy of a piece of equipment and ensure operation within tolerance, usually by comparison to a reference standard that can be traced to a primary standard
Component[5]	A constituent part
Configuration[3]	The arrangement and contour of the physical and functional characteristics of systems,equipment, and related items of hardware and software.
Consulting	*This is a fairly new term to product support. It applies to advice given to the customer on how he can better reach his objectives, utilizing the resources and equipment that he has. It requires specialist knowledge of the customer's type of business on the part of the support engineer.*
Consumables[1]	Materials which are being used up in the normal operation of a product (e.g. petrol in a car or ink in a pen)
Cost of Ownership	*A term which originated in the computer industry. It refers to all of the costs faced by a customer which result from owning and using a particular piece of equipment or system, over its full lifetime. These costs result from running costs (power and*

	supplies), costs of trainingspecialist staff, maintenance costs, upgrade costs etc.
Customer Engineer (CE)	*In high-technology companies this is the name given to the engineers who install and support customers' equipment. They often have a broad range of responsibilities for customer support. The same name is also applied in some companies to engineers who are only responsible for installation and service*
Customer Support Engineer	*Modern name given at some companies to the engineers responsible for supporting products*
Design for Testability (DFT)[3]	Designing a product so that it is easy to test its correct function (either by internal or external test devices)
Design to Life Cycle Cost (DTLCC)[2]	Designing a product with consideration of the full costs over its complete lifetime
Down Time[1]	The time an equipment is not available to perform its function
Economic Repair[5]	A repair that will restore the product to sound condition at a cost less than the value of its estimated remaining useful life
End User[5]	The individual or organization that employs an article or system to accomplish the purpose for which it was designed and intended
Essentiality[4]	Importance of an item to performance of the mission
Failure[3]	Inability to perform the basic function, or to perform it within specified limits
Failure Modes, Effects and Criticality Analysis (FMECA)[3]	Identification and evaluation of what items are expected to fail and the resulting consequences of failure
Failure Rate[1]	The number of failures per unit of measurement (cycles, miles, time units, etc.)
Hardware[1]	Physical product, equipment, or their parts
Human Engineering[5]	The application of knowledge about human

	capabilities and limitations to the planning, design, development, and testing of systems, equipment, and facilities to obtain the best mix of safety, comfort, and effectiveness compatible with established requirements
Human Factors[5]	All scientific biomedical and sociological facts and considerations that constitute characteristics of mankind. These include principles and applications in the areas of human engineering, personnel selection, training, life support, job performance aids, and human performance evaluation
Identification[3]	Means by which items are named or numbered to indicate that they have a given set of characteristics
Independent Service Organization (ISO)	*See Third Party Maintenance*
Installability	*Characteristics of an item, equipment or system that make it easy to install at the customer site*
Installation[3]	Period of initial setup, adjustment, and checkout of a product in the customer's environment
Inventory[4]	Physical count of all items on hand by number, weight, length, or other measurement; also any items held in anticipation of future use
Lead Time[1]	The period of time estimated to be needed to accomplish a task
Life Cycle[3]	The series of phases or events that constitute the total existence of anything
Life Cycle Costs[3] **(LCC)**	All costs associated with the system life cycle
Maintainability[3]	The inherent characteristic of a design that determines the ease, economy, safety, and accuracy with which maintenance actions can be performed. Also, the ability to restore a product to service or to perform preventive maintenance within required limits

Mean Down Time (MDT)[1]	The average time an equipment cannot perform its task
Mean Logistics Delay Time (MLDT)	Downtime while necessary replacement parts, supplies, tools or data are being obtained
Mean Time Between Failures (MTBF)[1]	The average time (or operations, distance etc.) between breakdowns
Mean Time Between Maintenance (MTBM)[1]	The average time (or operations, distance etc.) between maintenance calls (corrective and preventative maintenance)
Mean Time Between Service Calls (MTBSC)[1]	The average time (or operations, distance etc.) between service calls (i.e. MTBM plus calls caused by faulty customer operation)
Mean Time To Install (MTTI)[1]	The mean time to install an equipment
Mean Time To First Failure (MTTFF)[2]	The mean time before a piece of equipment fails for the first time
Mean Time To Repair (MTTR)[1]	The mean time to perform a repair task
Mean Time To Travel (MTTT)[1]	The mean time to travel from one customer to the next
Nonrepairable[4]	Parts or items that are discarded upon failure for technical or economic reasons
Obsolete[4]	Designation of an item for which there is no replacement.
Operational Availability[1]	The time or percentage of time an equipment is functionally available to a customer (also known as up-time)
Part Numbers[4]	Unique identifying numbers and letters that denote each specific part configuration; also called stock numbers or item numbers
Periodic Maintenance	*A new term being used in the medical*

	equipment field. It refers to maintenance that must be performed periodically to ensure that equipment is working correctly (e.g. calibration and safety testing), as well as preventive maintenance as such. Modern equipment, which is reliable and contains few or no wear-out components, require little preventive maintenance as such.
Product Support	*The range of items, methods and organizations that companies employ to help customers obtain maximum value from their products*
Predictive Maintenance[4]	Subset of preventive maintenance that uses nondestructive testing such as spectral oil analysis, vibration evaluation, and ultrasonics with statistics and probabilities to predict when and what maintenance should be done to prevent failures
Preventive Maintenance[1]	Maintenance carried out to avoid the breakdown of equipment (also known as scheduled maintenance)
Reaction Time[3]	See Response Time
Redundancy[3]	Two or more parts, components, or systems joined functionally so that if one fails, some or all of the remaining components are capable of continuing with function accomplishment
Reliability[4]	Probability that any item will perform its intended function without failure for a specified time under specified conditions
Repair[3]	The restoration or replacement of components of facilities or equipment as necessitated by wear, tear, damage, or failure. To return the facility or equipment to efficient operating condition

Repairables[4]	Parts or items that are technically and economically repairable. A repairable part, upon becoming defective, is subject to return to the repair point for repair action
Repair Level Analysis (RLA)[2]	Analysis of whether a piece of equipment will be disposable or repaired to a certain level (e.g. component or board level)
Response Time[1]	The number of working hours between receipt of a customer's request for a service visit and the arrival of a service engineer at the customer (also called reaction time)
Retrofits[5]	Modifications to a machine to correct a deficiency or modernize it to improve performance. *See also Upgrades*
Scheduled Maintenance (SM)[1]	See Preventive Maintenance
Serial Number[5]	Number or letters that uniquely identify an item
Service[3]	Helpful acts. Useful labour that does not produce a tangible commodity. The maintenance and support of equipment and operations. *In high-technology industries the term is typically applied to maintenance and repair only and not to issues such as user training*
Serviceability[3]	Characteristics of an item, equipment, or system that make it easy to maintain after it is put in operation. Similar to maintainability
Service Engineer[5]	The person that installs and maintains equipment. Also called Customer Engineer. *In high-technology companies the term service engineer is being discarded, as engineers normally have broader responsibilities than just service*

Software[1]	The activity required to operate a piece of hardware, often applied specifically to computer programs [*sic*]
Spare Parts	See Spares
Spares[3]	Components, assemblies, and equipment that are completely interchangeable with like items and can be used to replace items removed during maintenance
Support	*In high-technology industries this term is applied to all of the post-sales services that a company offers to customers. Typically this includes installation, user training, maintenance and repair (service), documentation, technical and application advising, and upgrading.*
Supportability	*Characteristics of an item, equipment or system that make it easy to support after it is put into operation*
Third Party Maintenance[1] **(TPM)**	An outside company without a formal agreement with the manufacturer or dealer acting as a service sub-contractor; often working in competition with the manufacturer. *Also called Independent Service Organizations (ISOs)*
Training[3]	The pragmatic approach to supplementing education with particular knowledge and assistance in developing specific skills
Troubleshooting[3]	Locating or isolating and identifying discrepancies or malfunctions of equipment and determining the corrective action required
Unscheduled Maintenance[4]	Corrective maintenance (CM), emergency maintenance (EM), or repairs to restore a failed item to usable condition; contrasts with scheduled maintenance

Upgrade[1]	Bringing a product to a more recent state of modification or increasing its capabilities by additional modules or by supplying a more powerful model
Upgradability	*Characteristics of an item, equipment or system that make it easy to upgrade after it is put into operation*
User Training	*Training of end-users in the correct operation of equipment. High-technology companies often provide this to customers included in the product price*
Warranty[1]	A guarantee by the manufacturer or supplier to effect repair free of charge to the customer, if the fault is due to faulty workmanship or material
Wear Out[4]	Deterioration as a result of age, corrosion, temperature, or friction that generally increases the failure rate over time

APPENDIX B: LITERATURE SEARCHES

1) Introduction

During the course of the research, literature searches were conducted on five main topics. These were product support, business planning, Design for Quality (DFQ), the medical equipment market and the repertory grid testing. This appendix includes an analysis of the categories of references cited. Additionally, it explains how each of the literature searches was conducted with relevant facts for future researchers in these areas.

2) An Analysis of the References Quoted

The total number of references cited in this thesis is two hundred and twenty-eight. Note that many references were cited several times, sometimes on different topics (e.g. some papers on Design for Quality were also cited on aspects of product support). Grouping the references into the categories of literature researched (articles which are cited on multiple topics are categorized under their main subject) gives the following breakdown of references:-

- 89 references on product support/customer service.
- 29 references on business planning.
- 16 references on Design for Quality.
- 21 references on general research methodology.
- 26 references on repertory grid methodology.
- 46 references on the medical equipment market.
- 1 miscellaneous reference.
- 228 references in total.

3) The Literature Search on Product Support

As the research was focused on this area, it was essential to perform a comprehensive review of the publications on support. Therefore, considerable time was invested to make a thorough initial investigation of the literature and then to subsequently monitor for new publications. This enabled a list of papers and articles which was as comprehensive as possible to be obtained. The *modus operandi* adopted for this review of the literature was varied and its key elements were:-

1) An initial computer search, which identified only six articles.

2) A second, independent computer search which identified twenty-eight relevant articles.

3) Cross-checking to see if any article cited literature which had not yet been identified. This identified another twenty articles.

4) Manual checking of the entries in the *Business Periodicals Index*, *Anbar* and the *European Index of Business Periodicals*, during the four years of the research. This identified over one hundred and fifty articles.

5) Checking the reference lists in related research (e.g. Mathe, 1988).

The first approach to identifying the literature on product support was to start a computer search of business literature using suitable key terms. The first search was performed in August 1988 using the *Lockheed Company* computer search available through the Cranfield School of Management Library. This was performed using six key terms (*product support, after-sales service, post-sales support, customer service, servicing/repairing and post-sales support*), listing one known paper (Lele and Karmarkar, 1983) and searching management publications and trade journals from the last thirty years. The results of this were disappointing. Although it was not thought that much had been published on product support as a previous computer search had not identified any articles[1], the list of only six articles seemed to the researcher almost "too short". Consequently it was decided to run a second, independent search plus to manually review the relevant entries in the *Business Periodicals Index* for the years for which it is available. (Note that the manual search alone would not have been sufficient. This is because the *Business Periodicals Index* does not index conference proceedings [Fisk *et al*, 1986[2]].)

The second computer search was initiated through the Hewlett-Packard Medical Products Group Library in the USA during September 1988. This search was made by *Dialog Information Services Inc.* using the key terms *product support, after-sales service, post-sales support, customer service, servicing/repairing and post-sales support.* This produced a list of 101 references together with useful short abstracts (the original list of 500 articles was pre-screened by library staff for its revelance to product support, as opposed to customer service in general). This list was reviewed and it was found that twenty-eight articles were relevant, whereas seventy-three were not. The reason that so many articles were identified which were not relevant is that the term *customer service* is applied to both product support and the quality of service provided by service industries (e.g. banks).

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[1] A computer search into *product support* was conducted by Graham Clark of Cranfield School of Management in 1987.

[2] This reference is listed at the end of this section and not in the main reference list.

Many new trade journal articles, which were listed in neither of the computer searches, were identified using the *Business Periodicals Index* and the other indexes (using the terms *customer service* and new ones that were found: *Computers -Installation, Computers -Maintenance and repair, Computers -Training* and *Computers -Service*). That these articles had not been identified by the computer searches showed the limitations of the computer searches; their dependence on knowing the key terms in advance (which is not always possible during exploratory research). For researchers investigating product support, the heading *Computers*, with its sub-terms -*Installation* etc, are obviously key ones.

During the four years of the research, the "current listing" of references and a "key word abstract" of their content was maintained in *Hewlett-Packard Executive Card Manager* software running on a personal computer. The current listing was compared against the references given in each new article found plus against the references given by Mathe (1988), Graham Clark's own reference list (Cranfield School of Management) and Lalonde and Zinszer (1976). In order to maintain the "current listing" at an up-to-date level, both relevant publications (e.g. AFSM International- The Professional Journal) and the business publications indexes were monitored, up until December 1991.

Eighty-nine of the articles, papers and books on product support found in the literature search are cited in this thesis. Those chosen were, in the researcher's opinion, either key publications on the topic (e.g. Lele and Karmarkar, 1983) or trade journals which well illustrate aspects of the product support market (e.g. Beaver, 1986). The breakdown of the eighty-nine references into (somewhat arbitrary) categories chosen by the researcher is as follows:-

- 32 articles from trade journals (e.g. *AFSM International- The Professional Journal).*
- 22 articles from business journals (e.g. *Harvard Business Review, European Journal of Marketing*).
- 15 business books on service/support.
- 11 conference papers.
- 6 pieces of unpublished academic research (including Ph.D.s and working papers).
- 2 documents on international standards.
- 1 market report from a business consultancy.

The articles on support which were reviewed but not quoted in the text are, for completeness, listed below in what forms a bibliography on service / support (when used with the articles on support quoted in the main reference list):-

BIBLIOGRAPHY OF SERVICE / SUPPORT (159 ARTICLES)

ALLYNE, J.
Sick Computers: Do You Need Medicare
Canadian Business, Vol. 60, January 1987, pp27-28.

ANONYMOUS
Product Service Management: Getting Down To The Nuts And Bolts
Sales Management, Vol 114, No. 4, 1975, pp11-14 (ISSN 0361-2570).

ANONYMOUS
Guaranteed High-Speed Service for Micro Computer Users
Industrial Management, July 1980, p10.

ANONYMOUS
DEC Ahead of IBM in Quality of Mainframe Maintenance?
Computer Decisions, Vol. 12, July 1980, p14.

ANONYMOUS
Special Report: Diagnostics and Maintenance
Mini-Micro Systems, Vol. 13, July 1980, pp89-130.

ANONYMOUS
Radio Paging Brings Faster Service to DEC's Customers Around Chicago
Communications News, Vol. 17, August 1980, pp58-59.

ANONYMOUS
Videotape Used for Computer Repair
Training and Development Journal, Vol. 34, December 1980, pp7-8.

ANONYMOUS
Users' Hidden $3 Billion Expense
Computer Decisions, Vol. 12, December 1980, p22.

ANONYMOUS
"Tell Me Where It Hurts': Remote Diagnostics areWithin Grasp
Data Management, April 1983, p21.

ANONYMOUS
Computerland, Businessland and Now - Serviceland
Infosystems, Vol. 31, May 1984, p28.

ANONYMOUS
IBM Software Support Center Speeds Service, Cuts User Costs
Infosystems, Vol. 31, June 1984, p14.

ANONYMOUS
ADR's Support Team: A Winner
Infosystems, Vol. 31, June 1984, pp19-20.

ANONYMOUS
IBM Revises PC Maintenance Program
Electronics News, Vol. 30, July 23, 1984, p42.

ANONYMOUS
Do-it-yourself Computer Repairs
Computer Decisions, Vol. 16, August 1984, p18.

ANONYMOUS
Service Contracts Keep Computers Healthy
Purchasing, Vol. 97, October 4, 1984, p74.

ANONYMOUS
Service Managers Offer Tips for Decreasing Computer Downtime
J. Accounting, No. 158, October 1984, pp24-26.

ANONYMOUS
Third Party Maintenance Provides a Cost-Effective Alternative
Data Management, Vol. 23, February 1985, pp14-15.

ANONYMOUS
IBM's Services: Not Merely Super
Data Communications, Vol. 14, April 1985, p84.

ANONYMOUS
Facing the Foe: Third-Party versus First-Party
Electronics Business, Vol. 12, March 15, 1986, p76.

ANONYMOUS
Sperry, CompuPro Sign Servicing Pact
Electronics Business, Vol. 32, August 4, 1986, p30.

ANONYMOUS
Helping IS Integrate Users, Systems is Part of Vendor's Job
Infosystems, Vol. 33, August 1986, pp14-15.

ANONYMOUS
Businessland, Inc.
Computer / Electronic Service News, February 1987, pp57-61.

ANONYMOUS
On Computer Maintenance Contracts
Office, Vol. 105, March 1987, p110.

ANONYMOUS
Tables Turn for IBM sales Strategy
Purchasing, Vol. 103, July 16, 1987, pp19-20.

ANONYMOUS
IBM Moves Press Svc. Firm Margins
Electronics News, Vol. 33, September 28, 1987, p20.

ANONYMOUS
IBM Services to Cover Rival Lines
Electronics News, Vol. 34, February 8, 1988, p20.

ARMISTEAD, C.
Productivity and Effects on Quality in Service Operations
Cranfield School of Management Working Paper SWP17/89.

ARMISTEAD, C., JOHNSTON, R. and VOSS, C.A.
Introducing Service Industries in Operations Management Teaching
IJOPM, Vol. 6, No. 3, 1986, pp21-29.

BARRY, T.
IBM's Corporate Service Amendment
Datamation, Vol. 34, January 1, 1988, p66.

BARTER, P.
Counting the Costs in Medical Service
AFSM International-The Professional Journal, Vol.
16, No. 4, November 1991, pp62-63.

BENOIT, E.
Microcomputer Maintenance: Where to Find it and What it Costs
Pract. Account., Vol. 18, January 1985, p49.

BENOIT, E.
If It Looks Like a Duck
Forbes, October 21, 1985, p156.

BERGER, J.
Turnkey or Turkey
Audiovisual Communications, Vol. 20, June 1986, p32.

BERGLUND, E.G.
Third Party Maintenance: Pitfalls and Benefits
American Printer and Lithographer, No. 187, August 1981, pp61-62.

BERTRAND, K.
High-Tech Product Sales Create Niche for Services
Business Marketing, Vol. 32, No. 2, p25-26.

BIGELOW, R.P.
Memorandum on Maintenance
Infosystems, Vol. 28, May 1981, pp128-129.

BLUMBERG, D.F.
Remote Diagnostics Seeks to Aid Field Services
Data Communications, Vol. 13, August 1984, pp175-176.

BLUMBERG, D.F.
Satisfying Your Service Needs
Manage. World, Vol. 16, April-May 1987, pp13-14.

BOSTON UNIVERSITY and NEW ENGLAND PARTNERS CONSULTING
Towards An Understanding of Medical Equipment Cost of Ownership
A Report Sponsored by: Hewlett-Packard Company,
Part Number 5091-1463E, 1991.

BOUDETTE, N.E.
Computers Out of Order: Contracts Keep Buyer-Supplier Disputes
Out of Court
Ind. Week, Vol. 238, June 5, 1989, pp58-59.

BRADY, S.E.
Getting a Hand on Maintenance Costs
Datamation, August 15, 1987, pp62-71.

BRITTAINE, R.
Computer Maintenance- Speed and Quality are Vital
Ind. Manage. Data Systems, September/October 1986, pp3-4.

BROUSELL, D.R.
Software Maintenance - Controlling A Costly Service
Electronics News, Vol. 27, No. 26, May 25, 1981, pp26-29.

BROUSELL, D.R.
Computer Servicing: Complex Systems Spur Remote Testing Software
Electronics News, Vol. 28, May 31, 1982, pp68-69.

BROUSELL, D.R.
Firms Offer No-run No-pay Pledge
Electronics News, Vol. 29, January 24, 1983, p42.

BROUSELL, D.R.
IBM Hikes Maintenance, Cuts Some Tags
Electronic News, Vol. 28, August 23, 1982, p16.

BROUSELL, D.R.
All Major Sales Channels for Microcomputers Competing for
Burgeoning Maintenance Dollar
Electronics News, Vol. 29, April 11, 10983, p1.

CARLINER, S.
Help on a Shelf: Developing a Customer Service Manual
Technical Communications, Vol. 32, No. 2, 1985, pp8-11.

CHAMBERLAIN, M.B.
Taking the Sting Out of Computer Repair
Off. Adm. Autom., Vol. 46, July 1985, pp48-50.

CHISMON, N.
Field Service Reporting and Spares Control
Ind. Manage. Data Systems, March-April 1987, pp23-24.

COFFEY, M.
High Pressure to Maintain
Management Today, December 1987, p110.

COLONY, G.F.
Maintenance is an Imperative in Automated Office Operation
Office, Vol. 92, October 1980, p168.

CONLON, T.
Diagnostics: Key to Self-Sufficiency
Computer Decisions, Vol. 18, June 30, 1986, pp50-51.

CONLON, T.
New IBM Plan Puts Users to the Test
Computer Decisions, Vol. 19, January 26, 1987, p20.

COOPERS & LYBRAND AND AFSM INTERNATIONAL
Service Operation Strategies of the 90s
Coopers and Lybrand, Uxbridge UK, 1991.

COX, R.C.
Predictive Maintenance: "HiTech" Service Option
AFSM International-The Professional Journal, Vol. 16, No. 4,
November 1991, pp56-57.

DAVIDOW, W.H.
The Ultimate Marketing Weapon
Business Marketing, Vol. 32, No. 9, October 1990, pp56-64.

DAVIDOW, W.H. and UTTAL, B.
Coming: The Customer Service Decade
Across the Board, Vol. 26, No. 11, November 1989, pp33-37.

DAVIS, D.B.
Diagnostics Improve as Computer Systems Proliferate
Mini-Micro Systems, Vol. 15, August 1982, pp115-123.

DAWSON, G.E. and RIEKER, E.J.
Phone Companies at Your Service
Computer Decisions, Vol. 18, February 11, 1986, p50.

EDSAC, L.
Hardware Breakdowns can be Costly
Accountancy, Vol. 97, June 1986, p124.

EISENHART, T.
Breaking Away from the Faceless Pack
Business Marketing, June 1988, pp74-78.

ELY, E.S.
Third Party Maintenance Grows Up
Datamation, Vol. 32, September 15, 1986, p121.

EMMETT,R.
User Rebellion Worked
Datamation, Vol. 26, August 1980, p57.

ESPARZA, M.S.
Computer Maintenance: Bypassing Politics
Infosystems, Vol. 34, September 1987, pp51-53.

FIELD, A.R. and SCHARES, G.E.
The Next Boom in Computers: Services
Business Week, July 7, 1986, pp72-73.

FINK, G.
On-Board Diagnostics Lower Service Costs for OEMs and System Integrators
Mini-Micro Systems Vol. 17, May 1984, pp153-154.

FISK, R.P., TANSUHAJ, P.S. and HROMAS, J.G.
Assessing the Services Marketing Literature
In: VENKAICSAN, M. (ed.), Creativity in Services Marketing,
American Marketing Association, 1986.

GROTTOLA, M.G.
Hassle-Free System Repair
Syst. Integr., Vol. 22, August 1989, pp29-30.

HARGADON, T.J.
After-Sale Support from Retailers? Not Too Much
Office, Vol. 101, April 1985, p48.

HAUG, H.
Qualitaetsmanagement soll IBM wieder an die Spitze fuehren
(Quality management should restore IBM to the top)
VDI Nachrichten (Germany), No. 49, 7 December 1990, p25.

HOFMANN, M.A.
Data Processing Firms Face Special Risks
Business Insurance, Vol. 21, November 16, 1987, p110.

HOFFBERG, A.
The Scout's Motto Be Prepared Works Well in the Computer
Room as It Does in the Outdoors
Office Administrator and Automation, Vol. 44, January 1983, p113.

JACOBSON, L.
What, When, How of Hardware Monitors
Data Management, Vol. 19, March 1981, pp31-33.

JONES, K.
On-call in Europe: Soaring Sales Mean More Maintenance
Electronics Business, Vol. 10, February 1984, p212.

JONES, K.
European PC Users Demand High-Quality, On-site Maintenance
Mini-Micro Systems, Vol. 17, August 1984, pp101-102.

KASPER, H. and LEMMINK, J.
After Sales Service Quality: Views between Industrial Customers
and Service Managers
Ind. Mark. Manage., Vol. 18, August 1989, pp199-208.

KASTIEL, D.L.
Where the Repair Experts get their Repairs
Business marketing, Vol. 72, June 1987, p64.

KEEFE, O.F.
Field engineering: From Back Door Maintenance to Front Door Design Input
Data Management, Vol. 18, July 1980, pp31-34.

KELLEY, N.D.
Give Heed to the Computer's Environment
Infosystems, Vol. 28, January 1981, p60.

KERR, J.
MRO Sales: Going Strictly by the Hand
Electronics Business, Vol. 13, February 15, 1987, pp39-40.

KERTH, T.
Voice Messaging Saves the Day for 3Com
Telephony, Vol. 211, November 117, 1986, p62.

KNOWLES, A.
Third-Party Maintenance: One Stop Shopping
Electronics Business, Vol. 12, March 15, 1986, p73.

KRUPKA, W.S.
When it comes to Cleaning, Don't rely on Service Contracts Alone
Data Management, Vol. 22, November 1984, p56.

KULL, D.
Cutting the System Message Glut
Comput. Commun. Decis., Vol. 19, September 1987, p35.

LACOB, M.
Coddling your Computers
Computer Decisions, Vol. 17, June 18, 1985, p76.

LASDEN, M.
Testing Your Mettle
Computer Decisions, Vol. 14, October 1982, pp162-164.

LOANNOU, L.
In Computer Service, Three's a Crowd
Venture, Vol. 9, April 1987, pp30-31.

LOGAN, W.
An Edge from a Competitor
Venture, Vol. 8, May 1986, pp118-119.

LOOMIS, J.
IBM's Big Blues: A Legend tries to Remake Itself
Fortune, January 19, 1987, p34.

MAHER, P.
What's Behind the Boom in Electronic Product Service?
Business Marketing, Vol. 69, November 1984, p70.

MCKIBBIN, W.L.
IBM and the PC Maintenance Puzzle
Infosystems, Vol. 31, May 1984, pp24-25.

MCKIBBIN, W.L.
Single Source PC Maintenance
Infosystems, Vol. 31, July 1984, p104.

MCLOED, D.
Maintenance
Datamation, Vol. 35, June 15, 1989, p156.

MERIT, D.
Customer Service Reps Need Patience, Self Control and Skill to Properly Handle and Satisfy Irate Customers
American Printer, Vol. 203, July 1989, p82.

MEYER, B.D.
The Hardware Conspiracy
Technical Communications, Vol. 32, No.2, 1985, pp12-14.

MICOSSI, A.
Micro Hot Lines: Help or Hesitation?
Computer Decisions, Vol. 17, March 26, 1985, p16.

MICOSSI, A.
Keeping Downtime Down
Computer Decisions, Vol. 17, April 23, 1985, p16.

MILLER, F.W.
Hand Holding or Cutting 'em Loose
Infosystems, Vol. 30, May 1983, p52.

MILLER, J.
Back to the Future
Computer / Electronic Service News, December 1986, pp24-30.

MORAN, R.
Maintenance Moves in on MIS
Comput. Commun. Decis., Vol. 19, December 1987, pp75-78.

MOSKOWITZ, R.A.
Stepping Up CICS Operations
Computer Decisions, Vol. 18, September 9, 1986, p36.

MUELLER, J.
Refurbishment: Does Your Computer Need a Face Lift?
Data Management, Vol. 25, September 1987, p28.

MUNN, R.
Weighing the heavies
Computer / Electronic Service News, February 1987, pp23-31.

MYERS, E.
Spare Parts Blues
Datamation, Vol. 32, March 15, 1986, p32.

MYERS, E.D. (ed.)
Maintaining Fairness
Datamation, Vol. 32, September 15, 1986, p23.

OLCOTT, W.A.
Take a Closer Look at Equipment Service
Office Administration and Automation, Vol. 46, No. 7, July 1985, p7.

OLIVER, J.A.
Insuring your Computer's Lifespan
Adm. Manage., Vol. 47, September 1986, pp57-60.

PARIKH, G.
Software Maintenance: Question and Answer
Data Management, Vol. 22, June 1984, pp25-26.

PARIKH, G.
Software Maintenance Strategies for Success
Data Management, Vol. 23, March 1985, p30.

PARIKH, G.
Logical Retrofit can save Millions in Software Maintenance
Data Management, Vol. 22, September 1984, pp46-47.

PARIKH, G. and ZVENGINTZOV, N.
The Politics of Software Maintenance
Infosystems, Vol. 31, August 1984, pp78-80.

PATTERSON, W.P.
Computers: Too Much of a Good Thing
Industrial Weekly, Vol. 211, October 19, 1981, pp117-118.

PATTERSON, W.P.
Who Will Keep the Computers Running?
Industrial Weekly, Vol. 211, November 2, 1981, pp46-49.

PAYNE, P.H. *et al*
The Future Challenge in Field Service
Computer / Electronic Service News, April 1986, pp20-30.

PERRY, W.E.
A Plan of Action for Software Maintenance
Data Management, Vol. 23, March 1985, pp44-45.

PORT, O.
Detecting Breakdowns Before They Occur
Business Week, March 3 1986, p89.

QUINN, J.B., DOORLEY, T.L. and PAQUETTE, P.C.
Beyond Products: Services-Based Strategy
Harvard Business Review, Vol.

QUINN, T.
When Good Can Go Bad
Management World, Vol. 15, March 1986, pp38-39.

RAMIREZ, A.
A New Industry is Fixing to Fix your Personal Computer
Fortune, Vol. 111, March 18, 1985, pp150-152.

REID, I.
How to Win the Software Project Game
Management Today, October 1984, p43.

RHODES, W.L.
Making The Machine Feel At Home
Infosystems, 2/80, 1980, p44-50.

RHODES, W.L.
Preventive Maintenance: Finding a Cheaper Way
Infosystems, Vol. 28, May 1981, p86.

ROBBINS, R.M.
Data Center Environments: What You Don't See Can Hurt You
Infosystems, Vol. 33, September 1986, pp60-61.

ROBERTSON, J.A.
Analyzing Field Failure
Quality Progress, January 1969, pp12-13.

ROHM, W.G.
A Taxing Business
Infosystems, Vol. 33, November 1986, pp70-72.

ROSS, T.M.
Some Steps towards Decreasing Computer System Downtime
Superv. Manager, Vol. 30, January 1985, pp10-13.

ROWLAND, M. and MATTHEWS, N.
Designing for Service Throw Away or Repair?
AFSM International- The Professional Journal, Vol. 16, No. 5,
December 1991, pp42-48.

RUNYAN, L.
Users and Vendors: Bound to Win?
Datamation, Vol. 32, May 15, 1986, p62.

SERLIN, O.
Computer Maintenance Goes On-Line
Datamation, Vol. 32, September 15, 1986, p91.

SHERRID, P.
Check Your Diodes, Sir?
Forbes, February 1, 1982, pp90-91.

SLEETER, M.
How Product Usability Impacts the Service Organization
AFSM International- The Professional Journal, Vol. 16, No.2, September 1991, pp59-61.

SMITH, R.P.
Research and Other Data in the Monitoring of Product Quality
J. Market Research Society, Vol. 21, No. 3, 1979, pp189-205.

SMITT, E.
Remote Support
Computer / Electronic Service News, May 1985, pp30-39.

STAMPS, D.
Who's Maintaining the Micros?
Datamation, Vol. 32, April 15, 1986, p82.

STONE, P.S.
Micro Service Shakeout
Datamation, Vol. 31, January 1, 1985, p52.

STONE, M. and WILD, A.
Field Service Management
Gower, Aldershot, UK, 1985.

SUBY, C.
One-Stop Solutions for Multivendor Problems
Electronics Business, Vol. 13, February 15, 1987, pp46-47.

SYNDERS, J.
Getting the most out of your systems
Computer Decisions, Vol. 13, June 1981, p30.

SYNDERS, J. and ESPARZA, M.S.
Problem Prevention Pays Off
Infosystems, Vol. 34, July 1987, pp38-39.

THOMAS, A.
The Field Service Numbers Game
Computer / Electronic Service News, February 1986, pp33-36.

TERAZONO, E. and BRADSHAW, D.
Motor Servicing Goes in for Repair
Financial Times, Thursday June 6th 1991, p6.

TRIFARI, J.
Printer Maker Turns to Service Organization
Mini-Micro Systems, Vol. 14, May 1981, p46.

TURLSTRA, C.J. and REID, S.T.
Structural Design for Serviceability
Proc. 11th Congress of the International Association for Bridge and Structural Engineering (IASBE), Vienna August 31 - September 5, 1980 (ISBN 3-85748-025-4).

VALIGRA, L.
IBM Personal Computer may be Boom to Service Revenues
Mini-Micro Systems, Vol. 14, October 1981, p63.

VALIGRA, L.
Sorbus Moves Cautiously to Expand Service Base
Mini-Micro Systems, Vol. 15, February 1982, p67.

VANDERMERWE, S. and GILBERT, G.
Internal Services: Gaps in Needs/Performance and Prescriptions for Effectiveness
Paper presented to the 1st International Research Seminar in Service Management, June 1990 in Toulon, France.

VANDERMERWE, S. and RADA, J.
Servitization of Business: Adding Value by Adding Services
European Management Journal, Vol. 6, No. 4, Winter 1988.

VOSS, C.A.
The Service Dispatcher / Receptionist Role
IJOPM, Vol. 3, No. 3, 1983, pp35-39.

VOSS, C.A.
Where Should Service Quality Be Measured?
Conclusions From a Process Based Model
Paper presented at QUIS Conference, Norwalk, Conneticut, July 1990, 7pp.

VREDENBURG, H. and WEE, C-H.
The Role of Customer Service in Determining Customer Satisfaction
J. Acadamy of Marketing Science, Vol. 14, No. 2, Summer 1986, pp17-26.

WADE, P.V.
Relearning Customer Service at the U.S. Auto Dealer
Proc. of Seminar on Strategies for Service Management: Marketing in Today's Competitive Environment (European Society for Opinion and Marketing Research),
11th-13th November 1987, Paris, pp123-141.

WELLES, N.
Raising Orphans
Datamation, Vol. 31, January 15, 1985, pp85-86.

WHIELDON, D.
Coping with Rising IBM Service Costs
Computer Decisions, Vol. 18, July 29, 1986, pp44-45.

WHIELDON, D.
Make a Third-Party Deal
Computer Decisions, Vol. 19, January 26, 1987, p50.

WHITAKER, L.A.
Maintenance: The Simple Cure for Computer Woes
Office, Vol. 101, May 1985, pp106-108.

YASAKI, E.K.
Support Costs Soar
Datamation, Vol. 27, February 1981, p42.

ZELDIS, N.
In Telemarketing, Stay Straight, Simple
Advertising Age, Vol. 58, May 18, 1987, ppS26-S27.

ZVEGINTZOV, N.
Immortal Software
Datamation, Vol. 30, June 15, 1984, pp170-172.

4) The Literature Search on Business Planning

The problem with conducting a literature review of the subject of business planning was to identify the key publications from the mass of literature concerned with planning.

A *Dialog Information Services Inc.* search using the term *business planning* produced a list of over 5000 articles. This was obviously an unmanageable number[1] and so a different approach was then taken. Two theses which also considered planning (Walters, 1973 and McDonald, 1982) plus the references that they quoted were obtained. To ensure that a representative picture of the literature on planning was obtained, these were supplemented by reviewing all of the books on planning identified by an on-line computer search of the Cranfield Institute of Technology Library's catalogue. Finally, all of the articles on planning listed in the *Business Periodicals Index*, under the headings *planning* and *strategic planning* were obtained from the last twenty years. Very many of these were found to give anecdotal evidence of the effectiveness of planning but no concrete proof. The twenty-nine articles cited in Chapter Three were chosen because they either: a) explained the history of planning or b) gave details of research probing the effectiveness of planning or c) illustrated particular points well, including the anecdotal nature of much of the literature.

---

[1] In addition, the cost of abstracts for this number of articles from *Dialog* was prohibitive.

The chapter on the literature on planning gives, in the researcher's opinion, a representative picture of the topic. It is not, however, exhaustive as there are many articles not quoted (an exhaustive treatment of planning being beyond the scope of this thesis).

5) The Literature Search on Design for Quality

This was made in December 1988 by the Hewlett-Packard Medical Products Group Library using two agencies for computer searching. These were the *Dialog Information Services Inc.* (Connecticut, USA) and *Information Retrieval Service* (*IRS,* London). Both used the key terms *Design for Quality (DFQ), Design for Manufacture (DFM), Design for Manufacturability (DFM) and Design for Assembly (DFA).*

The two agencies identified 171 (*Dialog*) and 11 references (*IRS*), after preliminary screening by Hewlett-Packard library personnel. Since each list included one hundred and fifty-word abstracts, it was easy to identify the most relevant articles, 40 of which were obtained. These articles were supplemented by checking the references listed in the 40 articles and using a list of references on manufacturing provided by Professor J.P. Blaesing of the Steinbeis Transferzentrum fuer Qualitaetssicherung in Ulm, Germany. From the 40 articles, books and papers identified on Design for Quality and Manufacture, sixteen were cited in this thesis. Those chosen were selected because of their importance (i.e. often cited by other articles) or because they (in the researcher's opinion) illustrated particular points well. Various papers (e.g. those from Boothroyd) were chosen as particularly well written explanations of aspects of Design for Quality. The review of the literature on manufacturing and quality was deliberately chosen not to be as exhaustive as that on product support (this being beyond the scope of this thesis).

6) The Literature Search on the Medical Equipment Market

Obtaining a good coverage of the literature on the medical equipment market was the easiest of the investigations of published material. This was because the researcher was, in his full-time employment, constantly in receipt of articles on this market (from Hewlett-Packard Medical Library who monitor all relevant publications).

The most relevant articles were collected over a period of three years, before Chapter Five was drafted. At the time of the first draft, to ensure that a true picture of the medical equipment market could be drawn, a literature search was run to identify other relevant material. The search, in March 1991, was run by *Dialog Information Services* using the key terms *medical equipment market* and *medical electronics*. Additionally, a manual search was made of the *Business Periodicals Index* under the key terms *Medical equipment and supplies industry*. The fourty-six articles cited on the medical equipment market (Chapter Five etc) were chosen by the researcher for their clarity on particular relevant points. The large number of references quoted was, in the researcher's opinion, required to give a full explanation of the medical equipment market with all of its complexities.

7) The Literature Search on Repertory Grid Testing

The choice of the methodology is explained in Chapters Four and Six. A review of the literature on research methodology (twenty references of which are cited in this thesis) led to the choice of the repertory grid method for the identification of customer attributes. The development of the specific interview design required a detailed understanding of repertory grid testing. This was obtained by extensively reviewing the literature. Initially, a thesis was identified which used this methodology (Marr, 1983) which gave a number of references, including Fransella and Bannister (1977). This latter book includes an annotated bibliography of repertory testing, which led to many more key references. Finally, an on-line search of Cranfield Institute of Technology Library's catalogue identified newer publications such as Pope and Keen (1981) and Tschudi (1984), which both include details of the literature on repertory grid testing. In total over fifty articles, papers and books on repertory testing were reviewed from which twenty-six were cited in this thesis.

APPENDIX C: POSTAL SURVEY DETAILS

1) Aims

These are the research objectives which were explained in Chapter Four.

> 1) To determine the range of different support factors which are evaluated by companies at the product design stage.
>
> 2) To collate the different support factors which can be evaluated, in order to derive a systematic evaluation of product support at the design stage. To base this on the model of product support derived from the review of the literature.
>
> 3) To then determine what approach would be necessary to investigate the causal link between planning and supportability (using similar methodology to that used in management research on other types of planning).
>
> 4) To determine the time at which product support planning starts, during new product development cycles, at high-technology companies.
>
> 5) To determine the level of planning undertaken by companies.
>
> 6) To determine all of the support factors which are quantitatively planned at the design stage by companies.
>
> 7) To determine how commonly each of the different goals are used across companies.

2) Method

a) Choice of Survey Method

Refer to Chapter Six.

b) Survey Sample

The 600 members of the U.K. Branch of AFSM International. This choice is explained in Chapter Four.

c) Questionnaire Development

Refer to Chapter Six.

d) Ethical Considerations

During the development of the questionnaire the ethical aspects of the survey was considered and discussed. AFSM International were keen to see an anonymous survey and were not concerned about the researcher's company affiliation, as long as the results would be published and available to all members. For this reason they thought it appropriate that the researcher's affiliation to a company need not be identified in the covering letter.

In the event, the results were presented at both a AFSM Intenational meeting and printed in the Association's journal.

e) Survey Form

The questionnaire was posted, with a covering letter, to all AFSM International members. In order to increase the reply rate a reminder letter was sent out three weeks later. Since the survey was completely anonymous, this reminder letter was sent to all AFSM International members.

f) Survey Logistics

The questionnaire, covering letter and the reminder letter were printed at Cranfield Institute of Technology's printers. The finished copies were dispatched in bulk to AFSM International, who added their mailing list address labels, posted the questionnaire and three weeks later posted the reminder letter. The survey was conducted in May/June 1989. Significant assistance on the logistics of the survey was given by members of both Cranfield School of Management and AFSM International.

g) Survey Analysis

The results of the postal survey were entered into a framework prepared on *Data Entry II* and analysed using the computer statistical package *SPSS/PC+ V2.0* (both these programmes are from *SPSS Inc.*).

h) Survey Tool and Letters

Reproduced on the next pages are the survey covering letter, reminder letter and the questionnaire itself. Note that: (i) the questionnaire is reproduced in its actual size and therefore the page margins are not 3cm (as normally required for Cranfield theses) and (ii) the page numbers run consecutively with the rest of the thesis whilst on the actual questionnaire they began at one.

AFSM
INTERNATIONAL
ASSOCIATION FOR SERVICES MANAGEMENT INTERNATIONAL
UNITED KINGDOM and EIRE REGION

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AFSMI (UK) IN ASSOCIATION WITH CRANFIELD SCHOOL OF MANAGEMENT: SURVEY ON THE DESIGN OF PRODUCTS FOR SUPPORT

Dear AFSMI Member,

You have probably at some time been confronted with a product that was difficult to service. How much easier would it have been if service requirements had been planned into the product ? This question is of interest to AFSMI and therefore we would like your help in investigating it further.

In cooperation with the Cranfield School of Management, the U.K. Branches of AFSM International are conducting a survey of all its members on the subject of product support. The aim of this survey is to obtain ideas on how products can be better designed to meet not only *service needs* (for high reliability and ease-of-repair etc) but also the wider *support needs* (for ease-of-use, software support, customer training requirements etc). Your assistance in completing and returning the enclosed questionnaire would be greatly appreciated and it may help you too - the results and conclusions will be published in the Association's journal. Your reply will of course be treated confidentially and presented in summary form only, without a name or company affiliation.

We believe that adequate planning for *service / support* is essential during product design and feel that it is important to collect ideas on this subject, from you and other managers concerned with supporting products. It is therefore hoped that you will reply to this survey.

We thank you in anticipation.

Yours sincerely,

Mark Kiteley,
Regional Director,
AFSMI UK & Eire Region.

Keith Goffin,
Cranfield School of
Management

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AFSMI (UK) IN ASSOCIATION WITH CRANFIELD SCHOOL OF MANAGEMENT: SURVEY ON THE DESIGN OF PRODUCTS FOR SUPPORT

Dear AFSMI Member,

Three weeks ago we sent you a questionnaire on the subject of planning product support, during the design stage of new products. If you have not already completed and returned this questionnaire we would like to remind you - it is important for us to obtain a high proportion of replies, so that the results are representative.

Due to the confidential way that the survey is being conducted (The questionnaires are <u>not</u> numbered and respondents cannot be identified) this reminder letter is being sent to everyone who received the questionnaire. Therefore it may well be the case that you have already replied. If this so, we would like to thank you for your cooperation.

Yours sincerely,

Mark Kiteley,
Regional Director,
AFSMI UK & Eire Region.

Keith Goffin,
Cranfield School of
Management

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DESIGN FOR SUPPORT QUESTIONNAIRE

General Instructions: This survey is designed to identify how companies approach the problem of designing products that are easy to support. Therefore please answer the questions for the current situation in your organization.

Please note that all information gathered by this survey will be treated confidentially and presented only in a summary form without the name or affiliation of the respondent.

COMPANY/POSITION INFORMATION

This information will be used to categorize the answers.

1) Which category best describes your company's products ? (Tick as appropriate)

- ☐ Office equipment
- ☐ Computing
- ☐ Personal computers
- ☐ Domestic electronics
- ☐ Manufacturing equipment
- ☐ Medical electronics
- ☐ Third Party Maintenance
- ☐ Other- Please specify ....

2) Which category best describes your position ?

- ☐ Field service manager
- ☐ R & D manager
- ☐ Quality assurance manager
- ☐ Technical marketing manager
- ☐ Other- Please specify ....

3) What is the size of your company (total employees worldwide) ?

....

PRODUCT CHARACTERISTICS

This section is designed to gather information about the characteristics of a "typical" one of your products.

4) How long is the typical development cycle for new products at your company (ie from conception to shipment of the product) ? (Place a cross X on the time-line below)

|-----|-----|-----|-----|-----|-----|-----|
0 1year 2 3 4 5 6 7years

5) When is prototype equipment available ?

|-----|-----|-----|-----|-----|-----|-----|
0 1 2 3 4 5 6 7years before first customer shipments

First customer shipments

Number of years before shipments

6) How many years does a customer typically use one of your products before replacing it ?

................years working lifetime

7) How often does a typical product require preventive maintenance ?

................times per year

8) How often does a typical product develop faults during its working lifetime ?

................times

9) What is the main method by which your customers learn how to use their equipment ? (Tick <u>one</u> of the boxes)

☐ Prior knowledge (of similiar equipment) plus trial

☐ By reading the documentation plus trial

☐ Short explanation from your personnel

☐ Detailed instruction from your personnel

☐ Other- Please specify ....

10) How is your equipment installed ?
(Tick the most appropriate box)

- ☐ By the customer himself
- ☐ By one of your service personnel
- ☐ No installation necessary
- ☐ Other- Please specify ....

11) Who normally repairs your products, in the event of a failure ? (Tick one box)

- ☐ The customer himself
- ☐ One of your service personnel
- ☐ Third party maintenance companies
- ☐ Other- Please specify ....

12) What documentation is written for your products ?
(Tick the appropriate boxes below)

- ☐ Simple operating guides
- ☐ Comprehensive operating guides
- ☐ Detailed service documentation
- ☐ Application information
- ☐ Other- Please specify ....

13) How many units/systems do you ship of a typical successful product during its total production lifetime?
(Tick one box)

- ☐ Less than ten units/systems
- ☐ Tens of units/systems
- ☐ Hundreds of units/systems
- ☐ Thousands of units/systems
- ☐ Tens of thousands of units/systems

THE ELEMENTS OF PRODUCT SUPPORT

This section is designed to see how you rank the different elements of product support.

14) Product support can be defined as the range of items, methods and organizations that a company employs to help customers obtain maximum value from their purchased product. Bearing this definition in mind:-

a) Check if the following list of elements of product support is complete. If not, add the items which you think have been missed.
b) Rank the elements in their order of importance (Most important =1, second most important =2 etc). Do not give equal rankings. You may add any comments on your choices in the space provided.

Elements of Product Support	Ranking	Comments
1) Installation (site planning etc)	....	....
2) Customer education (training courses etc)	....	....
3) Documentation (technical, operating etc)	....	....
4) Preventive maintenance (eg cleaning, calibration	....	....
5) Design for repair (eg modular, diagnostics etc)	....	....
6) Field service organization (skills, coverage)	....	....
7) Parts availability (delivery time etc)	....	....
8) Technical/application advice (consultation etc)	....	....
9) Cost-of-ownership(service contracts, warranty etc)	....	....
10) Design improvement (eg upgrades or refurbishing	....	....

See next page **No equal rankings please!**

Additional elements (that you want to add)	Ranking	Comments
11)	....	....
....		....
12)	....	....
....		....
13)	....	....
....		....
14)	....	....
....		....

No equal rankings please!

DESIGN FOR MANUFACTURE OF NEW PRODUCTS

15) How well planned do you consider that "design for manufacture" is at your company ? (Tick one box)

☐ Very well planned

☐ Reasonably well planned

☐ Planned, but not well enough

☐ Poorly planned

☐ Not planned at all

☐ Don't know

16) Which quantitative measurements do you know to be applied by your company to assess how efficiently a product can be manufactured ?

☐ Taguchi's methods

☐ Design for assembly (DFA) scoring

☐ Don't know

☐ Other- Please specify ....

DESIGN FOR SUPPORT ON NEW PRODUCTS

17) How well planned do you consider that "design for support" (or service) is at your company ?

- ☐ Very well planned
- ☐ Reasonably well planned
- ☐ Planned, but not well enough
- ☐ Poorly planned
- ☐ Not planned at all
- ☐ Don't know

18) How long before first customer shipments does *detailed* planning on how a product will be supported start (ie at what time is someone responsible for and spending significant time on this planning) ? (Place a cross X on the time-line below)

```
----|-----|-----|-----|-----|-----|-----|-----|-----|
   -1     0     1     2     3     4     5     6     7
Years     First                Number of years
after     customer             before customer
first     shipments             shipments
shipments
```

19) How much are you, or members of your team, involved in planning how new products will be supported ?

- ☐ Very involved and informed
- ☐ Reasonably well involved/informed
- ☐ Involved/informed, but not enough
- ☐ Not involved/informed, but should be

20) What does the planning of how a product will be supported cover ? (Please tick the list below as appropriate)

- ☐ Installation methods
- ☐ Customer training
- ☐ Documentation requirements
- ☐ Preventive maintenance methods
- ☐ Repair philosophy (eg modular, diagnostics)
- ☐ Spare parts requirements
- ☐ Field organization required (skills, coverage)
- ☐ Technical/Application advice service required
- ☐ Cost-of-ownership (for the customer, per year)
- ☐ Service profit
- ☐ Design improvements for the future
- ☐ Other items, please specify

....

....

....

....

21) Is the planning of how a product will be supported summarised in a formal document ?

☐ Yes ☐ No

What is this document called ?

....

How and by whom is it reviewed ?

....

....

....

MEASURING THE SERVICEABILITY OF A PRODUCT

"Serviceability" covers the characteristics of equipment which make them easy to maintain and repair. This section is designed to find out which quantitative goals you set for serviceability during the design stage.

22) Which of the following measurements do you use to set **quantitative goals** for new products **during the design stage** ?

Installation time [] Yes [] No

|__What is the typical goal for a new product? How do you measure it?

....

....

Preventive Maintenance [] Yes [] No

|__What is the typical goal for a new product? How do you measure it?

....

....

Failure rate (or Mean time between failures) [] Yes [] No

|__What is the typical goal for a new product? How do you measure it?

....

....

Mean-time-to-repair (MTTR) [] Yes [] No

|__What is the typical goal for a new product? How do you measure it?

....

....

Disassembly/reassembly time [] Yes [] No

|__What is the typical goal for a new product? How do you measure it?

....

....

Mean fault diagnosis time [] Yes [] No

|__What is the typical goal for a new product? How do you measure it?

....

....

Maximum number of different parts [] Yes [] No

|__What is the typical goal for a new product?

....

....

Average Repair Price [] Yes [] No

|__What is the typical goal for a new product?

....

....

Others [] Yes [] No

|___Please specify and note how you set goals and measure these factors

....

....

....

....

MEASURING THE SUPPORTABILITY OF A PRODUCT

"Supportability" covers all of the characteristics of equipment which make them easy to support (ie not only service, but also ease-of-use, documentation level required etc). This section is designed to find out which quantitative goals you set for supportability during the design stage.

23) Which of the following measures do you use to set **quantitative goals** for new products **during the design stage** ?

Product ease-of-use ? ☐ Yes ☐ No

How do you measure it? What is the typical goal for a new product?

....

....

The average time to train a customer ? ☐ Yes ☐ No

How do you measure it? What is the typical goal for a new product?

....

....

Documentation requirements ☐ Yes ☐ No

How do you measure it? What is the typical goal for a new product?

....

....

Cost-of-ownership (contract prices etc) ☐ Yes ☐ No

How do you measure it? What is the typical goal for a new product?

....

....

Others [] Yes [] No

|__Please specify and note how you set goals and measure these factors

....

....

....

....

Please turn to next sheet

24) How do you personally think *supportability* could be better planned into products ?

....

....

....

....

25) Which areas of product support do you think are likely to become particularly important for your customers and industry, in the future ? Why ?

....

....

....

....

....

26) Have you any comments you would like to make on this survey or the topic of design for support ?

....

....

....

....

....

Thank you for your cooperation in completing this questionnaire. Please return in the enclosed FREEPOST envelope as soon as possible.

APPENDIX D: DETAILED POSTAL SURVEY RESULTS

This appendix includes the full answers not included in the text of Chapter Seven. Where given, the column headed "*Assessment*" gives the researchers's appraisal of the type of planning done by the respondent. A "G" indicates that a goal can be identified and "M" that the values for existing products are monitored.

Table D-1: Details on Preventive Maintenance.

Case	Type of Quantitative Measure	*Assess-ment*
19	Modular designs with less PMs.	G/M
26	1/2 hour per year, field updating.	G
27	As low as possible, reduce mechanical content.	G
29	Less than last model, number of tests involved and their complexity.	G/M
31	0.25% switched-on time. Product Health Statistics.	G/M
36	Target is always 0 P.M. hours.	G
40	<3 hours. Service reporting with spreadsheet programme.	G/M
41	# of visits, time of visits.	G
42	8 days per year, analysis of experience.	G/M
44	PM call time and MTBPM.	G
47	System downtime %tage of operating time.	G
52	Zero PMs.	G
56	2 per year (<4 hours), field service report.	G/M
61	Monthly, prints between/hours activity.	G
62	10 hours per year. Frequency & hours / call from service reporting system.	G/M
67	2 PMs for products with electro/mechical content. Field reporting.	G/M
69	Don't know.	?
70	Maintenance-free or once yearly.	G
77	2-3 hours and 4x per year.	G
81	Zero preventive maintenance.	G
82	No PMs.	G
84	PMs required per year.	G
87	Field Activity Reporting (FAR).	M
89	6 months to PM. Process performance of equipment.	G/M
90	Up-time / MTBF.	G
	25 Cases giving details	

Table D-2: Details on Customer Training.

Case	Type of Quantitative Measure
14	No measurement.
19	We carry out initial on-site training and then ongoing training each time the engineer visits.
22	15 practical lessons / customer complaints.
27	One week.
31	2 days-2 weeks (Product dependent). Customer Education Reports.
41	Broken into training modules, previous instrument types.
47	Too many variables for a single answer.
61	Two hours.
62	Human Factors Department assessment.
67	Varies widely. On hardware operation one day.
75	Depends on product, 4 hours to one week.
82	Varies too widely (This is also part of the business case for training revenue.
	12 Cases giving details (18%)

Table D-3: Details on Parts

Case	Type of Quantitative Measure
2	About 120 parts.
29	Product comparison.
42	Cost <1% of sales value. Service record analysis.
44	No goal but minimise.
47	Less than 36.
52	Can't say, products vary too much.
59	Parts commonality through range of products.
61	25% of machine parts.
81	100 parts in design.
	9 Cases giving details

Table D-4: Details on Repair Price.

Case	Type of Quantitative Measure
2	$500-600.
14	To keep as low as possible.
20	Via service agent's information.
22	Average repair price over lifetime. 1.5 to 5% of selling price.
28	If new price>50% then we put it on exchange.
32	100% of call-out charge.
50	20% factory cost of product (not measured).
56	<8% of capital costs per year.
59	Via market requirements.
61	40 pounds sterling per service call.
63	Should be affordable to customer, within his repair overheads.
75	5 hours including verification.
81	3,500 UK pounds (average level).
90	Quality / competitiveness.
14 Cases giving details	

Table D-5: Details on Documentation.

Case	Type of Quantitative Measure
14	Ask the customer.
16	Service and parts manuals, training manuals, PM manuals.
21	Via R&D and Service Department.
22	Simple user guide, customer survey / acceptance B site testing.
23	Op. guide, service manual, instruction manual, service training manual.
28	Warranty claim forms measure qualitatively and quantitatively.
32	Sub-contracted to technical author.
42	Completion at product release.
48	Second party assessment of user manual.
52	Standard set reviewed for applicability.
59	End-user support, from past experience.
61	Size and diagnostic times, customer surveys.
62	Human Factors Dept. assessment.
63	Where applicable UL/CSA, TuV etc.
70	Supply and distribution to customer with system.
75	Manuals prepared for each area, user, engineer, application.
81	Market requirements.

82	No. of manuals etc.
89	Industry driven
90	Customer review, available for Beta sites.
91	Not really a quantitative goal.
	21 Cases giving details

Table D-6: Details on Cost of Ownership.

Case	Type of Quantitative Measure
16	Measured monthly on field MTBF, MTTR and parts. 7% of sales price for new products.
18	% of list price.
19	To fit with the industry average for the type of machine.
22	Pre-calculation. Customers pay 8-15% for support
25	Less than IBM.
26	Determined by the competition.
28	Depends on sales volume and product life i.e. special offers etc.
36	Competition and equivalent products.
40	MTBF and MTTR, <7% of sales price.
41	Market acceptance versus cost (surveys).
47	Profitability 15%.
52	<10% of list price.
53	Guesswork.
59	Competitive analysis.
61	FSMA 20% p.a. of MC cost.
62	Cost estimate from parts failure analysis. Margins based on comparisons with existing models.
67	Over 7 years period ca 8% of HW value p.a. for on-site support.
70	% of installed base.
75	Dependability to customer reliability and %tage of selling price of product (Mix of mechanical vs electronic etc).
77	Calculation- various factors- spares / no. engineers/ etc.
81	550,000 pounds (mainframe).
82	About half the previous product.
90	Throughput / beat competitors.
91	Approximately 4% of product price per year.
	24 cases giving details

Table D-7: Details of Other Goals.

Case	Type of Quantitative Measure
28	1) Time/spares available 2)Costs 3)How many times the customer phones.
64	User surveys on product and documentation.
75	Each product is issued with a log book which "should be" completed, so that a complete history is obtained during the initial stages of product launches.
82	Engineering of software for customer: workload in man hours for a system.
	4 Cases giving details

APPENDIX E: REPERTORY TEST FOR INTERNAL CUSTOMERS

1) Introduction

The repertory test for internal customers was developed by extensive testing with HP engineers. The steps of this development are described in Chapters Six and Eight. This appendix gives additional information.

2) Aims

These are repeated from Chapter Four, which explains how the research objectives were derived.

1) To identify the internal customer attributes of good product support (i.e. to determine the attributes of "supportability").

2) To contrast the attributes with those from external customers.

3) To rate the different products against each of the attributes of support.

4) To compare the ratings of old and new products, to see if trends in supportability can be identified.

3) Method

a) Choice of Survey Method

Structured interviews using the repertory grid methodology - refer to Chapters Four and Six.

b) Survey Sample

A total of fifty HP European customer support engineers (CEs) were interviewed. They were selected from lists of company personnel, using a simple random procedure. More details on the background to this choice are given in Chapters Four. Chapter Five describes the working responsibilities of a CE.

c) Structured Interview Design

Refer to Chapter Six.

d) Choice of the Elements

The list of the products chosen as elements are shown in Table E-1. The selection of these products was made using the following criteria:-

1) The products are well-known to most HP engineers.

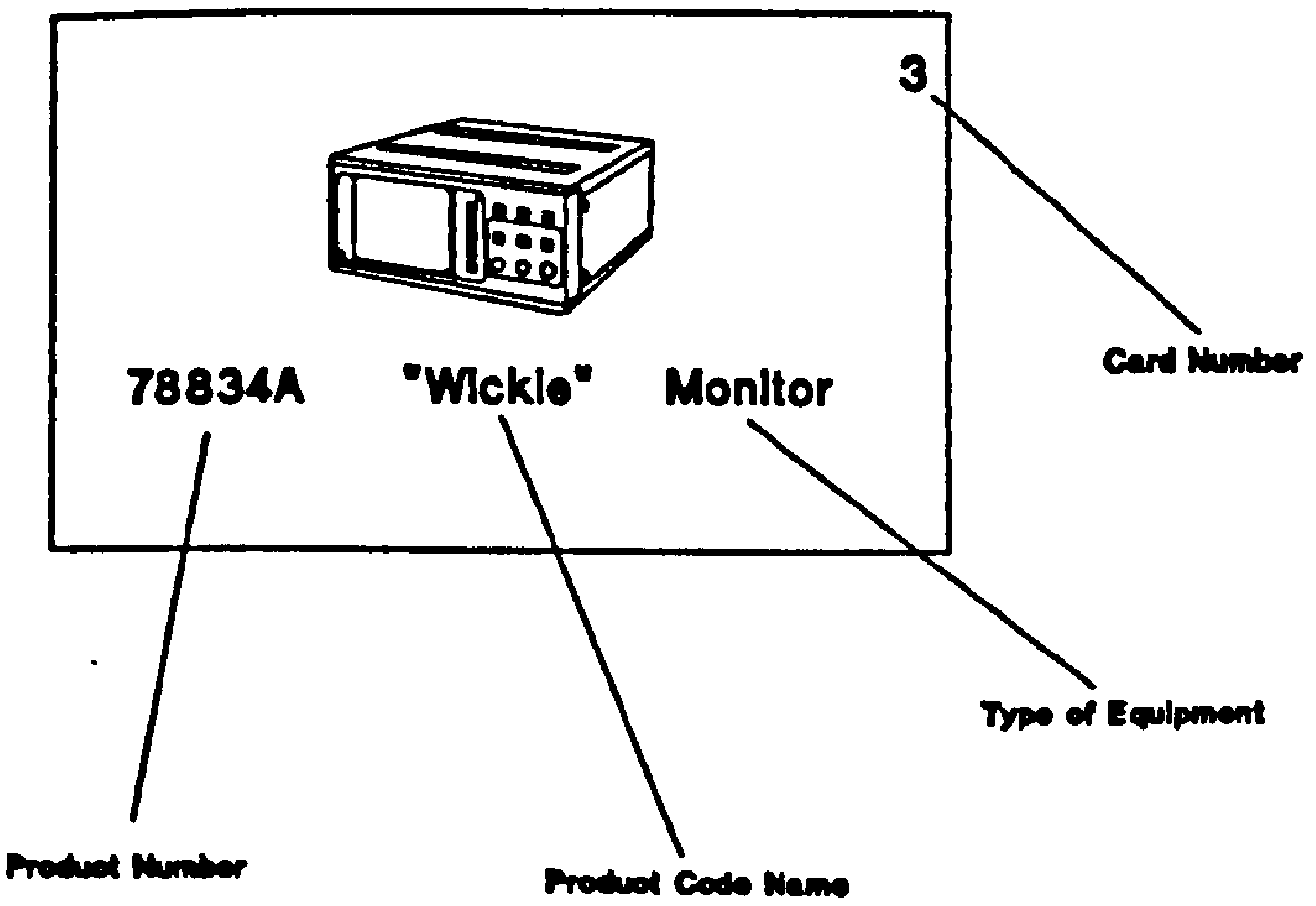
2) They cover the full range of products from HP Medical Products Group.

3) Where large families of similar products exist the first and last members of these families were chosen. The logic behind this is that members of the same families are too similar and would produce less important constructs. This is explained in detail in Chapter Six.

e) Presentation of the Elements

Each of the elements (products) was given on a separate card, which included the product number, code name (commonly used by HP CEs) and a line drawing of the product (see Figure E-1). The picture of the product acted as an additional stimulus for eliciting constructs.

Figure E-1: Example of the Cards used for the Presentation of the Elements.



f) Selection of the Triads

The selection of the cards in the triads was random. This was achieved by selecting the triads using the card numbers, which had been assigned randomly. The triads presented to different subjects were not identical, since each subject sorted out the elements with which he was not familiar.

Table E-1: List of the Products used as Elements for the Interviews with HP Engineers.

#	Product Number	Code Name	Type of Equipment	Card#*	Year of Introduction
1	8020A	-	Cardiotocograph	11	1968
2	8030A	-	Cardiotocograph	20	1975
3	8040A	-	Cardiotocograph	17	1982
4	M1350A	Pegasus	Cardiotocograph	24	1990
5	78200 Series	-	Patient Monitors	18	1972
6	78341A/2A	Rifleshot	Patient Monitor	12	1978
7	78345A/6A	Capnoshot	Patient Monitor	15	1981
8	78351A	Minishot-1	Patient Monitor	2	1982
9	80225A	OBMS	Obstetrical System	16	1987
10	77020AC	Ultrasound	Imaging System	5	1980
11	78354A/B	Minishot-4	Patient Monitor	13	1983
12	78534A	Clover	Patient Monitor	21	1984
13	78532A	Pogo	Patient Monitor	23	1985
14	M1046A	Merlin	Patient Monitor	4	1988
15	7883xA/B	Wickie	Neonatal Monitor	3	1983
16	78525	-	Arrhythmia System	10	1981
17	78500	Speakeasy	Central Station	19	1979
18	78560A	Orion	Central Station	7	1986
19	78720A	Crystal	Arrhythmia System	1	1984
20	4700 Series	Pagewriter	Cardiograph	14	1981
21	4760AI	Interpret.	Cardiograph	22	1984
22	M1700A	Page. XL	Cardiograph	25	1990
23	78660A	Quickstep	Defibrillator	6	1981
24	43210A	Eagle	Defibrillator	8	1985
25	8800 Series	Cath	Catheter Laboratory	9	1971

***Note:** The assignment of card numbers was done using a randomization procedure.

g) Handling of the Constructs

During the Phase One Interviews the subjects were stimulated to produce their own (personal) constructs. After these interviews the collected constructs were analysed. These were found to consist of a number of constructs which were repeated by most subjects - the so-called *common* constructs. These common constructs then became *provided* constructs for the main survey. This is explained in Chapter Eight.

h) Stages of the Interview

The main stages of the interview were:-

1) Explanation to the subject.

2) Presentation of the elements. Removal of products with which the subject is unfamiliar.

3) Presentation of the triads to the subject.

4) For each triad the subject gives a construct or constructs.

5) After each construct, the subject rates all the elements on a scale of 1-9 against that construct.

6) When new triads stimulate no new constructs, or if the interview has lasted much longer than one hour, the test is terminated.

7) Background information on the experience of the customer engineer is collected (entered at the bottom of the repertory grid).

i) Explanation to the Subject

The subjects in the pilot and second phase interviews were informed of the purpose and format of the test as detailed below. The explanation was simplified in the *Second Phase* interviews, as no personal constructs were collected in these interviews.

Interviewer. I am investigating the factors which determine whether products are easy to support or not - the factors about products that make the job of customer support engineers (like yourself) easier or, in some cases possibly harder. To do this, I am interviewing a number of experienced engineers to ask their opinions on various products[1].

Firstly I would like you to check through these cards and remove any product with which you are, from the support standpoint, totally unfamiliar.

---

[1] Note that this introduction deliberately avoided using the term *supportability*, in order not to bias the interview.

Subject. [Sorts through the cards and removes those which are unfamiliar]

Interviewer. Now that you have selected the products which you know, we come to the second stage of the test. Please look at these three cards and think about the three products on them. How are two of them similar to each other, from the support standpoint, and different from the third?

Subject. [Gives his first construct][1]

Interviewer. You decided that two of the products were similar to each other, from the support standpoint, and different from the third in that ...{Construct}. Now I want you to rate these products on a scale of one (which is good) to nine (which is poor) [places an extra card, with the scale of 1 to 9 written on it, in front of the subject]

Subject. [Rates the cards in the triad]

Interviewer. Now let us sort through the other cards and rate them on the same scale, for their {construct 1}. How does this product [shows another card] compare to {Construct number 1}? And this card [shows next card]? ...

Interviewer. Now we will consider another group of three cards. How are two of them similar, from the support standpoint, and yet different from the third? Remember that you have already identified an/(several) important support point(s): [Names previous constructs]. Can you think of another criteria for these three cards?

[Test continues until either no more constructs can be elicited or the length of the interview well exceeds one hour]

j) The Repertory Grid

The adoption of the rating scale of 1 to 9 was found to bring several advantages. Firstly it allowed the subjects to compare and contrast the products much better that a bipolar approach. Secondly it brought more data on the product support characteristics ("supportability") of the elements. Thirdly it appeared to add, from the subjects' point of view, more authority to the test (subjects using the bipolar scale were bemused by the cards "*What sort of test is this*" asked one respondent).

k) Data Collection

The data collection tool itself was designed to facilitate the collection of error-free data. Two versions are shown in the following pages; one for the identification of personal constructs (Figure E-2) and one for recording ratings of elements against provided constructs (Figure E-3). Note that the order of provided constructs on Figure E-3 is random and not by frequency of mention. In addition to notes from the interviews, written in the margins of the data collection tools, most of the interviews were recorded using a

---

[1] At this point in the interview, depending on the construct produced, extra questions would be asked to objectively but precisely determine whether the construct was the same as one of the previously identified common constructs.

portable cassette recorder. This allowed for transcripts to be prepared of the interviews, which provided much qualitative data on the attributes of good support.

l) Data Analysis

The data collected was entered into a framework prepared on the *Data Entry* software from *Norusis/SPSS Inc.* for calculation of average product ratings etc. Additional analysis of the grid characteristics was carried out using *Flexigrid 2.1* software from the University of Oslo and the *INGRID* programme from the *Grid Analysis Package (GAP).*

m) Survey Logistics

All of the interviews were conducted personally by the researcher over a period of 18 months. All HP engineers attend training each year at the location where the researcher is based. This meant that the subjects who had been chosen randomly could be interviewed over the period of eighteen months.

n) Ethical Considerations

Since the interviews were being conducted for the purpose of research supported by Hewlett-Packard, there were no ethical problems (obviously company confidential data such as reliability figures could not be included directly in the thesis).

Figure E-2: The Repertory Grid (Internal Customers / Personal Constructs)

	THE PRODUCTS (ELEMENTS) BY CARD NUMBER																								
PERSONAL CONSTRUCTS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1)																									
2)																									
3)																									
4)																									
5)																									
6)																									
7)																									
8)																									
9)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
10)																									
11)																									
12)																									
13)																									
14)																									
15)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

SUBJECT: JOB: EXPERIENCE:

DATE: AUDIO TAPE #: LENGTH OF INTERVIEW:

Figure E-3: THE Repertory Grid (Internal Customers / Twelve Provided Constructs)

	THE PRODUCTS (ELEMENTS) BY CARD NUMBER																								
PROVIDED CONSTRUCTS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1) Access to boards																									
2) Installability																									
3) Application complexity																									
4) Service documentation																									
5) Ease of use																									
6) Ease of Troubleshooting																									
7) Ease of User Troubleshooting																									
8) Mechanical design																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
9) Reliability (MTBF)																									
10) Preventive Maintenance																									
11) Ease of training customers																									
12) MTTR																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

SUBJECT: JOB: EXPERIENCE:

DATE: AUDIO TAPE #: LENGTH OF INTERVIEW:

APPENDIX F: REPERTORY TEST FOR EXTERNAL CUSTOMERS

1) Introduction

The repertory test for the derivation of the most important attributes of products, from the product support standpoint, was designed after the review of the literature. It was significantly different from the structured interviews conducted with HP engineers. This is explained in Chapter Six, with extra background information and data collection tools given in this appendix.

2) Aims

1) To identify the external customer attributes of good product support standpoint (i.e. to determine the attributes of "supportability").

2) To contrast the attributes with those from internal customers.

3) To rate the different products against each of the attributes of support.

4) To compare the ratings of different products, to see if there are significant trends in supportability.

3) Method

a) Choice of Survey Method

Structured interviews using the repertory grid methodology - refer to Chapters Four and Six.

b) Survey Sample

The survey covered external customers; these were 15 biomedical engineers, working in hospitals in Germany and England. The sample is discussed in detail in Chapter Four - it was essentially purposive but stratified to reflect the various sizes of hospital.

c) Structured Interview Design

Refer to Chapter Six.

d) Choice of the Elements

The personal elements approach was used for the repertory test of biomedical engineers. This was because biomedical engineers, in any one hospital, are not familiar with enough different Hewlett-Packard products to make the test effective. (For instance, if the engineer is only familiar with five HP products then ten[1] triad combinations can be made. However, these ten combinations are all similar and so will tend to produce less important constructs.)

One affect of using personal elements was that the market introduction dates of these products could not be determined. Although the biomedical engineers could say how long the equipment had been in service, they could not say how old the design was. This meant that, for the external customers ratings, the "supportability" of products could not be compared to the date of their design.

e) Presentation of the Elements

Each of the ten products named by the biomedical engineers was written on a separate card, which had been pre-numbered randomly. As the elements were personal no extra stimulation (such as a picture of the equipment) could be given on the cards.

f) Selection of the Triads

The selection of the cards in the triads was random (but pre-determined). This was achieved by selecting the pre-selecting triads using the card numbers, which had been assigned randomly. The triads presented to different subjects consisted of equivalent combinations of card numbers but were not identical, since each subject had personal elements.

g) Handling of the Constructs

The constructs elicited from the biomedical engineers were personal constructs.

h) Stages of the Interview

The stages of the interview were:-

1) Explanation to the subject.

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[1] From the formula for the number of combinations (C) when selecting x items from a total of y:

$$C = \frac{y!}{x!(y-x)!}$$

2) Naming of his elements by the respondent. Each product was written on a separate card.

3) Presentation of the triads to the subject.

4) For each triad, one or more constructs was elicited.

5) After each construct was elicited, all products were rated against it using a 1-9 scale.

6) When new triads stimulated no new constructs, or if the interview lasted much longer than one hour, the test was terminated.

7) Background information on the role of the biomedical engineer was collected (entered at the bottom of the repertory grid).

i) Explanation to the Subject

The subjects were informed of the purpose and format of the test as follows:-

Interviewer. I am from the marketing department of Hewlett-Packard Medical Products. I am Technical Marketing Manager for monitoring products and am responsible for deciding how our products will be supported. This includes deciding what services we offer to customers after they have purchased our products. We are conducting a survey to determine which factors about our products are important for biomedical engineers. As part of this, I am interviewing a number of biomedical engineers to ask their opinions on various products and, as you were told in advance, I would like to interview you.

The interview will last approximately one hour and, if you have nothing against it, I would like to record it - then I will not have to take so many notes. The recording will only be used to produce a transcript of the interview. Do you mind if the interview is taped?

Subject. {Gives answer}[1]

Interviewer. The type of interview that we are using for the survey of biomedical engineers is standardized, so that we can compare the results. It involves discussing different products that you have in this hospital and has two stages.

For the first stage, I would like you to name ten medical electronics products used in your hospital and with which your department has experience. I will write the name of each piece of equipment on a separate card [Writes the name of each product on a card and keeps the cards in the

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[1] All biomedical engineers agreed to the interview being recorded.

order in which the products were named. Cards are then numbered, using the prepared random number process. The cards numbered 1 to 3 are selected.] Now I am going to show you three cards. Please think about these three products and how two of them are similar, from your point of view as a biomedical engineer, and different from the third.

Subject. [Splits the three cards into two similar and one different.] {Gives Construct 1}

Interviewer. You decided that two of the products were similar to each other, from the support standpoint, and different from the third in that ...{construct}. Now, as the second stage with these three products, I would like you to rate these products on a scale of one (which is good) to nine (which is poor) [places an extra card with the scale of 1 to 9 written on it in front of the subject]

Subject. {Rates the cards in the triad}

Interviewer. Now let us sort through the other cards and rate them on the same scale, for their {Construct 1}. How does this product [shows another card] compare to {Construct number 1}? And this card [shows next card]? ...

Interviewer. Now we will consider another group of three cards. How are two of them similar, from the support standpoint, and yet different from the third? Remember that you have already identified an/(several) important support point(s): [Reads previous constructs]. Can you give another support characteristic for these three cards?

j) The Repertory Grid

The repertory grid from the biomedical engineers was always ten elements wide and had a length which depended on the number of constructs produced.

k) Data Collection

The data collection tool was designed to facilitate the collection of error-free data. It is shown in the following pages. Note that it includes the random numbers for the elements ("Element Number"), which enabled triads to be presented to the respondent which were not simply the same as the order in which he thought of the products ("Order of Personal Element").

A number of background questions on the size of the subject's hospital etc were asked; the answers were recorded on the back of the grid. All interviews were recorded using a portable tape recorder.

l) Data Analysis

The data from the interviews with biomedical engineers was analysed by computer using the *Flexigrid 2.1* software from the University of Oslo and the *INGRID* programme from the *Grid Analysis Package (GAP).*

m) Survey Logistics

All of the interviews were conducted by the researcher, over a period of ten months. They took place at the biomedical engineer's hospital, during visits organized for the purposes of the research. The biomedical engineers were told in advance that the interviews would take approximately an hour and a quarter and were asked if they were willing to cooperate.

n) Ethical Considerations

In advance, the biomedical engineers were told the purpose of the research and were asked if they were willing to cooperate. None of the information that they provided during the interviews was hospital-confidential. In addition, the interviewees were told that their hospitals would not be directly named in any subsequent publication of the results. Therefore, there were no ethical problems with this stage of the research.

One subject expressed an interest in the results of the survey and was promised a copy of the results - these will be sent.

Figure F-1: The Repertory Grid for Biomedical Engineers

Order of personal element	1	2	3	4	5	6	7	8	9	10	
Element number	5	1	8	6	9	10	4	7	3	2	

	THE PRODUCTS (ELEMENTS) BY CARD NUMBER										
PERSONAL CONSTRUCTS	1	2	3	4	5	6	7	8	9	10	
1)											
2)											
3)											
4)											
5)											
6)											
	1	2	3	4	5	6	7	8	9	10	

	1	2	3	4	5	6	7	8	9	10	
7)											
8)											
9)											
10)											
11)											
12)											
13)											
PERSONAL CONSTRUCTS	1	2	3	4	5	6	7	8	9	10	

RESPONDENT: HOSPITAL: NO. BEDS: NO. ENGINEERS:
DEPT.RESPONSIBILITIES: [Repair %,
Maintenance %, Training %,
DATE: AUDIO TAPE #: LENGTH OF INTERVIEW: Administration %, Other(.......) %]

APPENDIX G: EXTERNAL CUSTOMERS' ELEMENTS

The following table lists the personal elements nominated by the fifteen biomedical engineers (external customers) interviewed.

Table G.1: The Personal Elements given by the External Customers.

Personal Elements by Subject	
Biomedical Engineer	Elements
B1	1) Ohmeda[1] Anaesthesia Machine CPU 2) Maquet[1] Operating Tables 3) General Electric[1] X-Ray Machines 4) Diasonics[1] Ultrasound Imaging 5) Hewlett-Packard M1046A Monitor 6) Abbott[1] TDX Analyser 7) Siemens[1] Servomed[2] Ventilator 8) Siemens[1] Ultrasound Imaging DRH1 9) Vial[1] Infusion Pumps 400b 10) Toshiba[1] Ultrasound Imaging
B2	1) Hewlett-Packard[1] M1046A Monitor 2) Kendall[1] Vapourizer 3) Fisher & Paykel[1] Vapourizer 4) Haemonetics[1] Cell Saver 5) Draeger[1] Cicero 656[2] Anaesthesia Machine 6) Fresenius[1] 2008C Dialysis Machine 7) Braun[1] Infusiomat[2] Infusion Pump 8) Siemens[1] Serro[2] Ventilator 9) Nellcor[1] N200 Monitor 10) Hamilton[1] Veolar[2] Ventilator
B3	1) Hewlett-Packard 78354A Monitor 2) Welmed[1] Syringe Pump 3) Ivac[1] Infusion Pump 4) Hewlett-Packard 4700A Cardiograph 5) Hewlett-Packard M1046A Monitor 6) Hewlett-Packard 47210A Monitor 7) Dinamap[1] Pressure Monitor 8) Hewlett-Packard 78560A System 9) Hewlett-Packard 43120A Defibrillator 10) Hewlett-Packard 1500B Cardiograph

B4	1) S & W[1] Defi II Defibrillator 2) Hewlett-Packard 8040A Cardiotocograph 3) Hewlett-Packard 78354A Monitor 4) Dinamap[1] 845 Pressure Monitor 5) Hewlett-Packard 43120A Defibrillator 6) Nellcor[1] N100 Oximeter 7) Valley Lab[1] Electro-surgery Machine 8) Physio-Control[1] Defibrillator (LP9) 9) Novametrics[1] 505 Oximeter 10) Datex[1] Normocap[2] $CO_2/0_2$ Monitor
B5	1) Hewlett-Packard 43120A Defibrillator 2) Medix[1] Traveller Nebulizer 3) Siemens[1] External Pacemaker 4) Cobe[1] C3 Haemo-dialysis Machine 5) Imed[1] 960 Infusion Pump 6) Hewlett-Packard 78352A Monitor 7) Hospal[1] BSM22 Haemo-dialysis Machine 8) Bloom[1] Electrophysiology Machine 9) Graseby[1] MS2000 Syringe Driver 10) Eschmann[1] Electro-surgery Machine
B6	1) Marquette[1] 7000 Series Monitor 2) Marquette[1] MAC Cardiographs 3) PPG[1] Bio VR12/6 Angiography Lab. 4) Hewlett-Packard 1500 Cardiograph 5) Hewlett-Packard M1046A Monitor 6) Siemens[1] Sirecuse[2] 1281 Monitor 7) Hewlett-Packard 8800 Catheter Lab. 8) Hewlett-Packard 43120A Defibrillator 9) Spacelabs[1] PC-2 Monitor 10) Physio-Control[1] LifePak[2] Defibrillator
B7	1) Spiedel[1] Blood Pressure Cuff (Manual) 2) Mitsubushi[1] Video Printer 3) Hewlett-Packard 8040A CTG 4) Siemens[1] Ventilator 5) Hewlett-Packard M1046A PM 6) Braun[1] Infusion Pump 7) Draeger[1] Anaesthetic Machine 8) Hewlett-Packard 78352A PM 9) Siemens[1] Sirecuse[2] PM 10) Hellige[1] PM
B8	1) Hewlett-Packard 78354A PM 2) Megamed[1] Anaesthesia Machine 3) Draeger[1] Anaesthesia Machine 4) Draeger[1] Ventilator 5) Hewlett-Packard M1046A PM 6) Braun[1] Infusion Pump 7) Bennet[1] Ventilator 8) Hewlett-Packard 43120A Defibrillator 9) Fesenius[1] Infusion Pump 10) Siemens[1] X-Ray Workstation

B9	1) Perfuso[1] Secura[2] Infusion Pump 2) Vingmed[1] Ultrasound Scanner 3) Hellige[1] EK36 Cardiograph 4) Hewlett-Packard 8040A CTG 5) IVAC[1] 591 Infusion Pump 6) Radiometer[1] ABL330 Blood Gas Analyser 7) Oxford[1] Medilog 4000 Holter System 8) Bennet[1] 720 Ventilator 9) Hellige[1] SMS181 PM 10) Hewlett-Packard M1046A PM
B10	1) IMED[1] Infusion Pumps 2) Alm[1] Operating Tables 3) Hewlett-Packard 8040A CTG 4) General Electric[1] X-Ray Machines 5) Vial[1] Infusion Pumps 6) Siemens[1] Ventilator 7) Siemens[1] X-Ray Machines 8) CFPO[1] Ventilators 9) Datex[1] Patient Monitors 10) Toshiba[1] Ultrasound Imaging
B11	1) Siemans[1] Patient Monitor 2) Berchtold[1] Electro-Surgery Device 3) Braun[1] Infusion Pump 4) Draeger[1] Anaesthesia Machine 5) Hewlett-Packard 78834A Patient Monitor 6) Air Shields[1] Incubator 7) Braun[1] Micro Infusion Pump 8) Hellige[1] Patient Monitor 9) Weyer[1] Heated Bed 10) Bear Medical[1] Ventilator
B12	1) IVAC[1] Infusion Pump 2) AVL[1] Blood-gas Analyser 3) Hettich[1] Centrifuge 4) Braun[1] Infusions Pump 5) Gambro[1] Dialysis Machine 6) Siemens[1] ECG Monitor 7) Phillips[1] Diagnostic X-ray Machine 8) Hellige[1] ECG Monitor 9) Hewlett-Packard M1046A Monitor 10) Hellige[1] Defibrillator
B13	1) Hospal[1] Dialysis Machine 2) Hewlett-Packard 77020AC Ultrasound 3) Hewlett-Packard 8040A 4) Hellige[1] SCP 844 Defibrillator 5) Gambro[1] Dialysis Machine 6) Siemens[1] Servo C Ventilator 7) Hellige[1] EK53 Cardiograph 8) Braun[1] Infusion Pump 9) Siemens[1] Sirecuse Monitor 10) Hellige[1] SMK155 Monitor

B14	1) Hewlett-Packard 8040A CTG 2) Draeger[1] Anaesthetic Machine 3) Hitachi[1] Ultrasound System 4) Medap[1] Ultrasound Humidifier 5) Braun[1] Infusion Pump 6) Hellige[1] SMS Monitor 7) Erbe[1] Electrosurgery Machine 8) Kranzbuhler[1] FM5005 CTG 9) Hewlett-Packard M1046A Monitor 10) Datex[1] OR Monitor
B15	1) Freseneus[1] Infusion Pump 2) Draeger[1] Anaesthesia Machine 3) Acuson[1] Ultrasound System 4) Siemens[1] Cardiograph 5) Braun[1] Infusion Pump 6) HP 43120A Defibrillator 7) ATL[1] Ultrasound System 8) HP 78354A Monitor 9) Baxter[1] Dialysis Machine 10) Hellige[1] Cardiograph
Key:	[1] Medical Equipment Manufacturers' Names [2] Equipment Trade Names PM = Patient monitor