THE UNIVERSITY OF STRATHCLYDE

PRODUCT STATUS AND THE MANAGEMENT OF PRODUCT DESIGN

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ABSTRACT (Single line spacing: do not exceed 300 words):

Changes in product design occur either innovatively where new concepts are used (Dynamic Design Status) or incrementally where changes are made without altering the existing concept (Static Design Status). This thesis identifies the factors that make a product static or dynamic and then proposes the disciplines that should be emphasised when designing a product of a particular status. This is then used in the development of Design Process which is recommended as a user "tool" for directing the Design Manager through the stages of design from the market need, or product idea, through to the stage where detail design commences.

Several publications have resulted from this research.

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TITLE

ABSTRACT

ACKNOWLEDGEMENT

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1 INTRODUCTION

1.1) The Aims of the Research

The broad aim of this research is to improve the management of product design through the principle of product status, that is, through the identification of whether a product design is likely to be innovative (dynamic) or incremental (static).

From the literature survey gaps in knowledge were found and from these the following research objectives have been identified relating to product status.

1) Show the existence of product status.

2) Show how to determine the status of a product.

3) Show which design disciplines should accompany a particular product status.

4) Show product status as a method for forecasting.

It was also hoped that the research would lead to a design process that could be used to direct design managers through the front end of product design to reduce failure rate. This design process would be written to emphasise the more important aspects of design and diminish the less important thus limiting the work necessary to produce a successful product.

The following pages show the development of the case that fulfil these research objectives. The literature survey describes the origins of product status and shows how it fits into the broad structure of the management of design.

This research also describes how various 'disciplines' that have been attributed to the product life cycle (PLC) and S shaped curves can be read across to the product status. Whereas the position of a product on the PLC and S curve cannot be identified this is possible with product status. The factors that make a product's status static or dynamic have been determined, from the research in companies (chapters 3 - 6) and then by reverse synthesis these findings have been put in the form of a questionnaire. It is believed that this will enable those responsible for design to identify the status of their products (chapter 7).

The disciplines determined from the literature search and added to by additional ones found from the analysis of results, are then compiled into an improved design process (chapters 8 and 9). This gives a sequence to the research findings so that they then become a usable "tool" for the management of product design.

The findings and conclusions are summarised in chapter 10.

1.2) Limitations to the Field of Research

The initial area of research was restricted to manufactured mechanical products but it became apparent as the research progressed that the results obtained were applicable to a much wider area of product design. It is believed that the basic principles identified and incorporated in the design process hold good with all products although for service industries and architecture it would need significant adaption in content, but not sequence.

The design of products covers a very wide area and to enable research to be undertaken in sufficient depth, this work has been restricted to that part of design where the unexplained and little researched problem area of design is known to exist. This is the part of design between the market research input to the start of detail design. This area cannot be taken in isolation and, therefore, recommendations are also made for market research and aspects of production.

The generation of new concepts (Design Methods) has not been considered, or how their worth is judged, beyond whether new concepts are necessary and how they should be viewed in relation to existing products.

2. LITERATURE SURVEY

2.0 Introduction

The purpose of the following literature survey is to investigate the current state of the art of the management of product design and to identify the main area of research. Having identified the principle of product status as a suitable area for research the literature is further reviewed in order to pick out aspects that can be used in conjunction with product status.

What many technical books refer to as 'Design' is often termed 'New Product Development Process' (N.P.D.) in marketing and management books. These terms may be considered to mean the same.

The key to the whole research lies in being able to identify the factors that would keep a product static, keep a product dynamic, or possibly more important, show when the product status was likely to change. Therefore the principle of Product Status is introduced right at the start of this literature survey .

One important part of the literature survey was to compile clear and accurate definitions that could be used throughout the period of the research, these are listed in section 2.2.

After showing that the rate of failure of product design is high and the likely reasons for success and failure, it is shown that design management can be most effective if directed towards the early stages, or front end of the design process. (Sections 2.3, 2.4).

This is followed by a brief description of the effective organisation of teams to undertake design and product status is then related to the product life cycle and "S" shaped curve. (Sections 2.5, 2.6, 2.7, 2.8). The subsequent stages of the literature review show how product status relates to other aspects of the design process and company organisation.

2.1 Product Status

The concept of product design being different at two boundaries was hypothesised in the work of Pugh and Smith (1976).

In Pugh (1983) the two boundaries are called the static and dynamic boundaries and maximum innovation and synthesis occur at the dynamic boundary and the conventional and minimum synthesis occurs at the static boundary. This is shown on fig 2.1.a.

On a macro level, quite independently, Klein (1977) has used the same terms to describe a similar process shown using S-shaped curves of 'performance function' against a base of time. Klein (1977) describes dynamic behaviour as that:

> "associated with pioneering new products and processes" (p.4).

He later continues

> "The key difference between static and dynamic process is that whereas the former involves types of change that can be predicted on the basis of initial conditions the latter involves quite unpredictable changes in initial conditions". (p.12)

Several others have observed a similar process of some products being dynamic designs, but using words such as 'innovative', 'radical', 'fast', and even 'high tech.', and other products being static designs using words such as 'evolutionary', 'incremental', 'dominant', 'mature', 'slow', or 'traditional'. For example Kuhn (1982); Johne (1985).

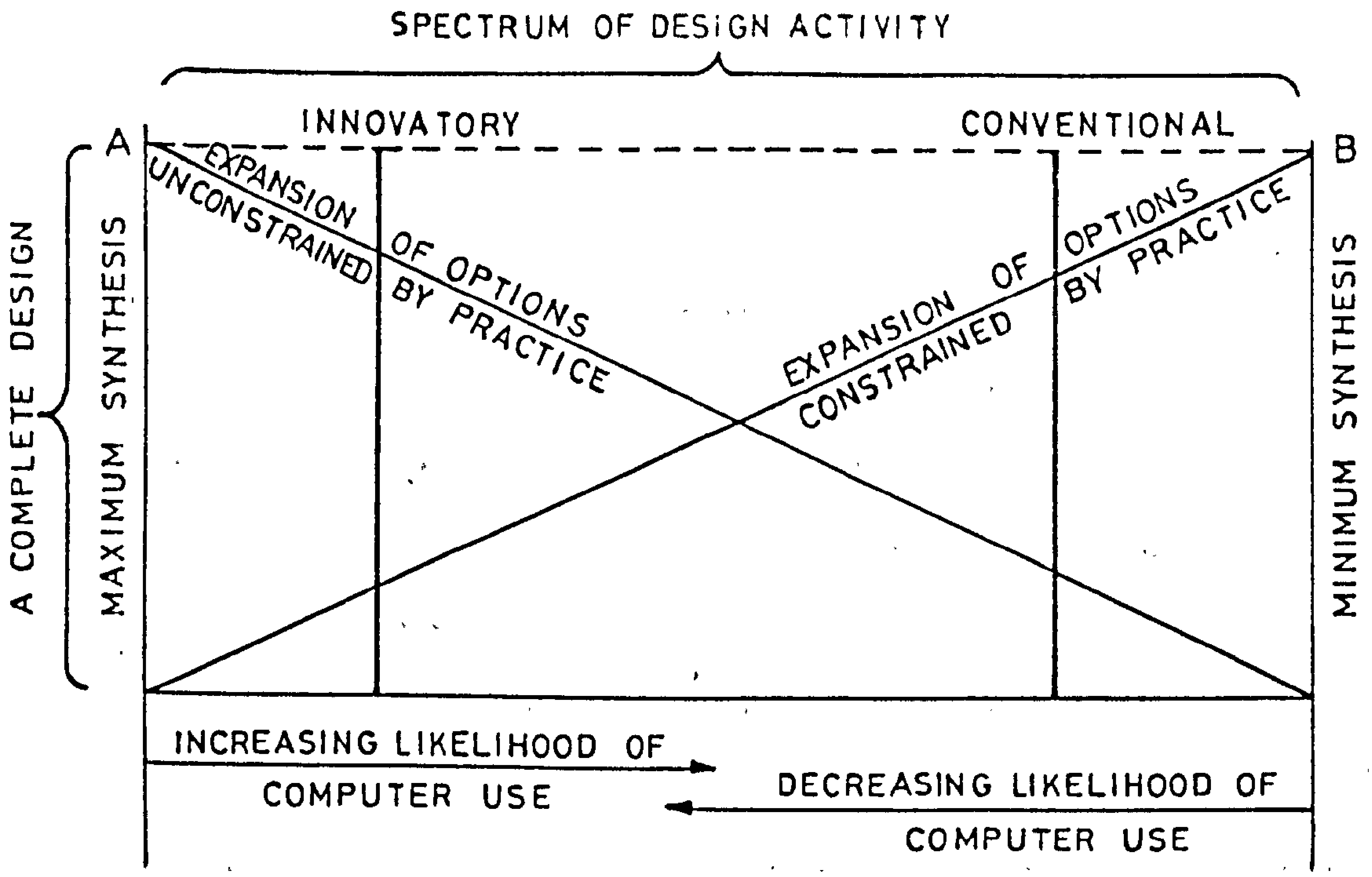


FIG. 2.1 a.
(PUGH 1983)

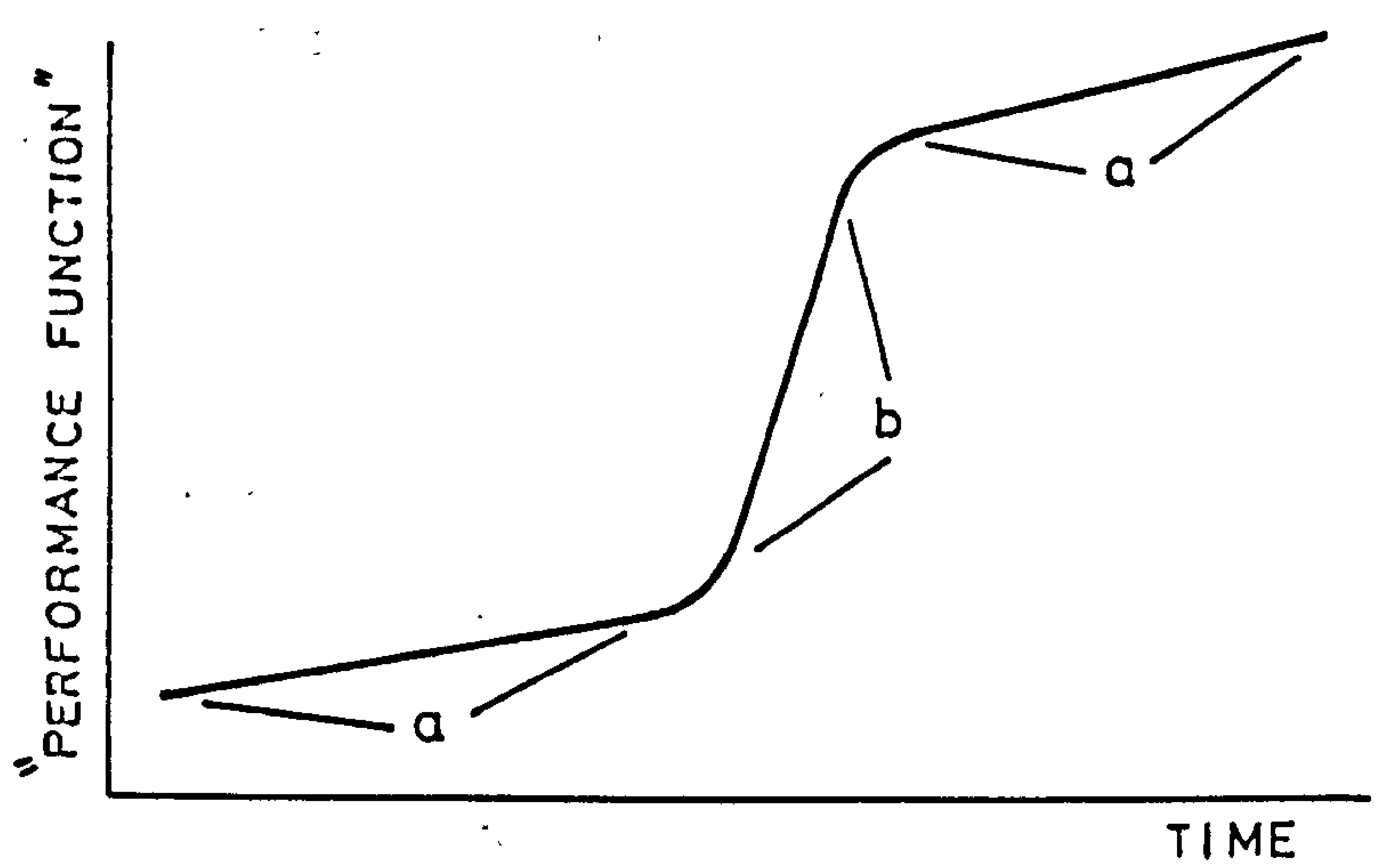


FIG. 2.1 b

Therefore, over a period of time, changes occur to gradually improve a product design. Occasionally a new design appears and the 'performance function' is improved quite considerably, but then these improvements again become gradual until the next new radical design appears. So with some products design changes are of a radical nature where changes occur in the basic concept and these types of products can be said to have a 'Dynamic Product Status'. In other products design changes are more of an incremental nature, that is, the basic concept remains unchanged. These products can be said to have a 'Static Product Status'.

It can be deduced that, at any one time, a product has either a static product status or a dynamic product status, but, over a period of time, products move between the static and dynamic boundaries. Some products (as described by Pugh (1983) using the example of the differential) stay at, or near, the static boundary for long periods of time. Whereas, other products move between the boundaries in shorter periods of time, requiring new concepts to be considered in their design.

Product status is demonstrated with the S-shaped curve shown on fig. 2.1.b. Now, with different products and at different times, the rise in performance function may be greater or less when the product is dynamic (b) or periods when the product is static (a) may be shorter or longer. The S-shaped curve, therefore, demonstrates the principle of product status but, in itself, is of little value for two reasons. Firstly, it may be possible to put some value on the performance function, as has been attempted by Klein (1977) and others, but even this is doubtful. For example, how can the aesthetics of, say, a watch be measured or graded next to its weight?

Secondly, even if the performance function could be measured, the time base could only be provided with hindsight.

On the other hand, if it was possible to demonstrate that a particular product at a particular time was either static or dynamic, or changing status either now or in the near future, then the whole study of product status takes on new value.

In its basic form, if a product can be identified as being static, then only incremental changes would be needed, whereas, if it was identified as being dynamic, then it would be known that new concepts need to be considered. This would be valuable in itself to a product designer, but the principle can be taken much further. In the paper by Pugh and Smith (1976) it was shown that computer aided design was more likely to be applicable for designing a product demanding 'minimum synthesis'. Therefore, if a particular product's status could be identified as dynamic the company management would know that investment in computer aided design, for this product, would, probably, not be worthwhile as conventional draughting is likely to be more adaptable and more effective. This reasoning could be taken further with many other design activities or 'disciplines' that are used in product design, production and marketing. If these could be broadly divided into activities that are more suited for, 1) products which are dynamic, 2) products which are newly static, 3) products which are static for a long time and, also, 4) those activities that are important in a company irrespective of the product status, the design manager would know which disciplines should be emphasised and which could be diminished at that time when designing that particular product. This is one aspect this research will endeavour to cover.

There is sufficient evidence to show that technology is changing faster than ever before (Glasser 1982; Carpenter et al 1986; Ansoff 1982; Nystrom 1979) and certainly company management must be aware that innovation may become necessary to keep their products competitive. But, it has been estimated (Ingersoll 1985) that, about seventy per cent of Britain's engineering output comes from 'traditional' engineering industries who have well established products where incremental design improvements may be more effective than innovation. Having a traditional, well established, product, though, does not mean that a company can ignore innovation all the time.

> "when faced with a technological threat, dominant firms frequently have responded with even greater reliance on obsolete technology (e.g. telegraph/ telephone; vacuum tube/transistor; core memory/ semiconductor memory)."
>
> (Tushman and Nadler 1986).

By appreciating product status it will be possible to show when innovation is required.

There are several further advantages for a company in knowing their product status and these are described in section 3.1.

This author believes that Product Status can be a powerful tool for directing design management towards areas which are of greater importance in product design. Product Status has, therefore, been identified as a worthwhile area for further research.

2.2 Definitions used in the Research

This author has compiled this list of definitions which are used in this research.

Note: QMS numbers refer to BSI committee meeting compiling the proposed standard 'Design Management Systems'.

Business Plan

Overall aims of an organisation in whatever terms are appropriate. For example, financial, social, ecological. (QMS/4/2 June 1987)

Conceptually Vulnerable Design

Where a product is treated as static when it is potentially dynamic, or the concept chosen is under threat from a 'better' product concept (such as, a new innovation) or when the wrong concept is chosen. (derived from Pugh 1981)

Conformance Standard

A requirement by law, standards institution or insurance company. (Pugh 1981)

(Total) Design

A multi-disciplinary, iterative process that takes an idea or market need forward into a product. Design does not end with production.

Design Disciplines

Those activities which are to be found in the design and manufacture of a product.

Design Efficiency

$$\frac{\text{Quality of Design}}{\text{Time (man hours)}} \quad \text{or} \quad \frac{\text{Quality of Design}}{\text{Total Cost of Design}}$$

Design Model

A diagram showing the general procedure for the design of a product or service. (W.J.H - BSI QMS/4/2)

Design Plan

A 'route map' to guide the user through the design process.

Design Review

A formal, documented, comprehensive and systematic examination of the capability of a design to meet the product design specification, to identify problems and propose solutions. They should be held whenever necessary and involve all who can make a contribution.

Dynamic Company

One that has the attributes associated with the design and/or the production of a dynamic product.

Dynamic Product

A product where design changes are (or should be) innovative. The product concept is likely to change.

Elements of the Product Design Specification

The areas of investigation that are included in the product design specification.

Evolutionary Design

Continuous product improvement to meet slowly changing market needs or evolving science and technology aimed at sustaining or expanding existing markets. (Parker 1980)

Front End of Design

That part of the design process that precedes the detail design stage.

Imitators

A company that copies the design of another company's product (sometimes known as "me too" type products).

Innovation

The process of taking an invention forward into the first marketable product.

Invention

Invention is the act of insight by which a new and promising technical possibility is recognised and worked out (at least mentally and, possibly, physically) in it's essential most rudimentory form. (Schener 1971)

The Management of Product Design

The planning, organisation and control of money, men, materials and time to achieve the objectives of the project. (SEED 1985)

Marketing

The management function responsible for identifying, anticipating and satisfying customer requirements profitably. (The Institute of Marketing)

Partial Design

Part of the design which contributes to the whole (for example, industrial design, engineering design, design for manufacture etc.). (Pugh 1987)

Partial Product Design Specification

A full written document that covers the relevant aspects of the product from which part of the product should be designed.

Performance Function

An overall measure of all aspects of a product which allows it to be compared with another similar product.

Process Design

Design of the method of manufacture.

Product/Company Status Mismatch

When a company is structured for or treating a product as static when the product is dynamic or, the reverse, a company is structured for or treating a product as dynamic when the product is static.

Product Design Specification

A full written document that covers all aspects required of the product from which a product should be designed, (called 'pre-design specification' in the research questionnaire).

Product Failure

A product failing to live up to its company expectations in the market. (Foxall 1984)

Product User Standard

One that customers are used to, prefer or may require to fit or interface with their existing products.

Product Status

A term used to describe static or dynamic products. (Pugh 1983)

Reliability

The ability of an item to perform a required function under stated conditions for a stated period of time. (ISO 8402 - 1986)

Standard Design

Standard design is a product design that fixes the concept for a period of time. It fulfils the market requirements more closely than other designs available at that time. It sets the static plateau.

Static Company

One that has the attributes associated with the design and/or production of a static product.

Static Product

A product where design changes are (or should be) incremental or non-existent. The concept is unlikely to change.

Static 1

The static design disciplines that are necessary to enable a product to be produced competitively.

Static 2

The static design disciplines that can be introduced when the production volume reaches a level that makes their inclusion viable.

Research Criterion

Principle or standard by which a thing is judged. (Oxford Dictionary)

2.3 Failure of Product Design

Very broadly, the purpose of the research was to reduce the rate, or chance, of failure in design.

Failure of a new product has been defined by O'Shaughnessy (1984) thus:

> "As occurring whenever management regrets the new product introduction".

Foxall (1984) defines it as:

"A product failing to live up to its Company expectations in the market".

The findings of various researchers have shown that, almost without exception, the failure rate of new product designs is unacceptably high and should be reduced if possible, (Booz Allen and Hamilton 1968 and 1982; Mansfield et al 1971; Dieter 1983; O'Meara 1961; Schorr 1961). The figures obtained by these researchers vary and are summarised in figure 2.3a.

Although it has been necessary for authors to show the high rate of failure, the reasons for new product failures are, probably, of greater interest in any attempt to improve the design of products and their management.

Cooper (1983), in his very useful paper, has investigated various case studies by others on the reason for success and failure of new products. He has ascertained that new products are more likely to be successful if the Company understands user requirements and provides 'market pull' type products. It is also an advantage to have a product champion and effective communications both inside and outside of the organisation. The most common reason for product failure was found to be" overwhelmingly" due to inadequate market analysis and this main reason for failure had not altered over seventeen years in research studies. Conversely, for product success, "correct identification of an existing demand was the critical common ingredient", was a typical main finding along with efficient development, key individuals and a clear product advantage over the competition. Although there were "no easy explanations for what

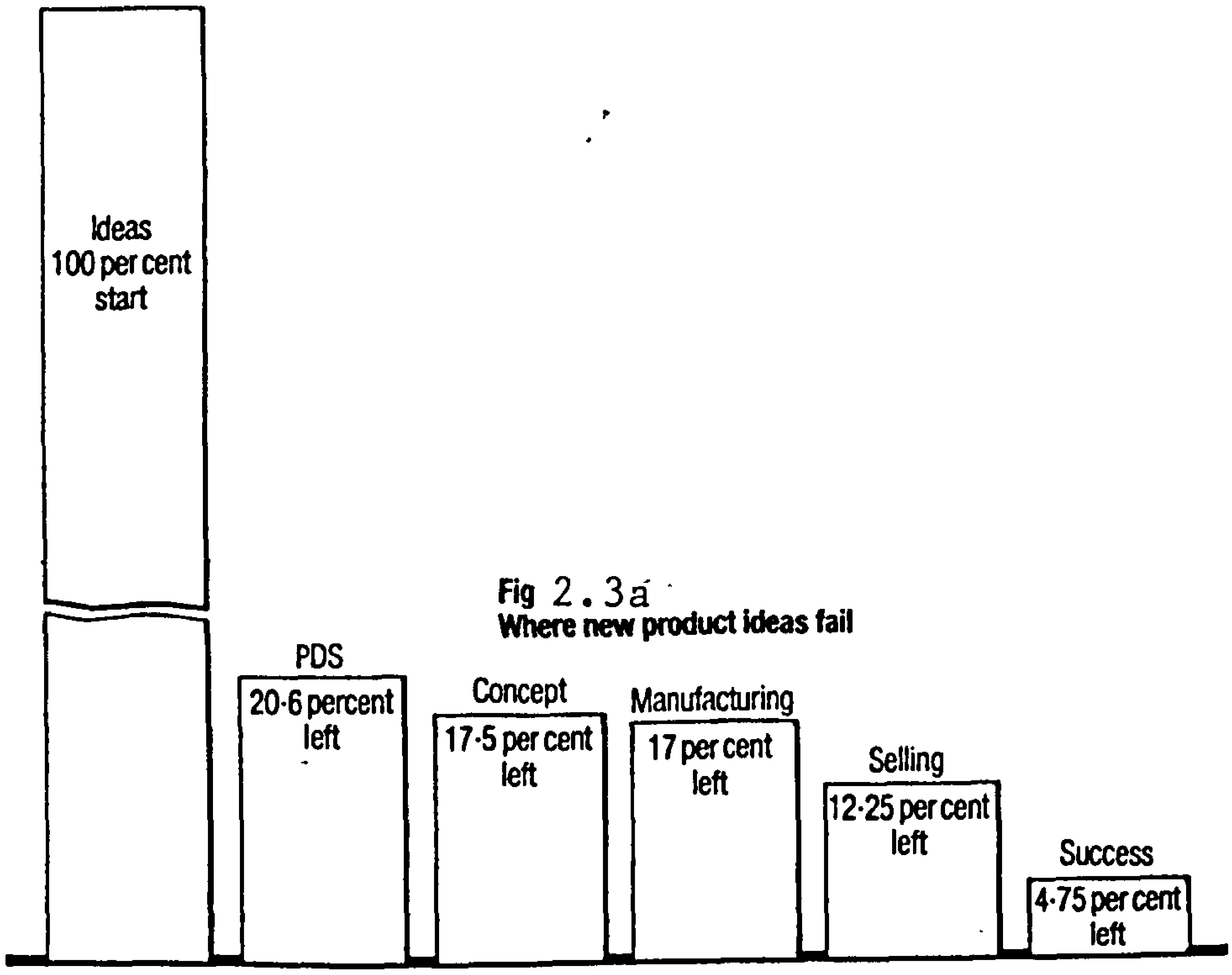


Fig 2.3a
Where new product ideas fail

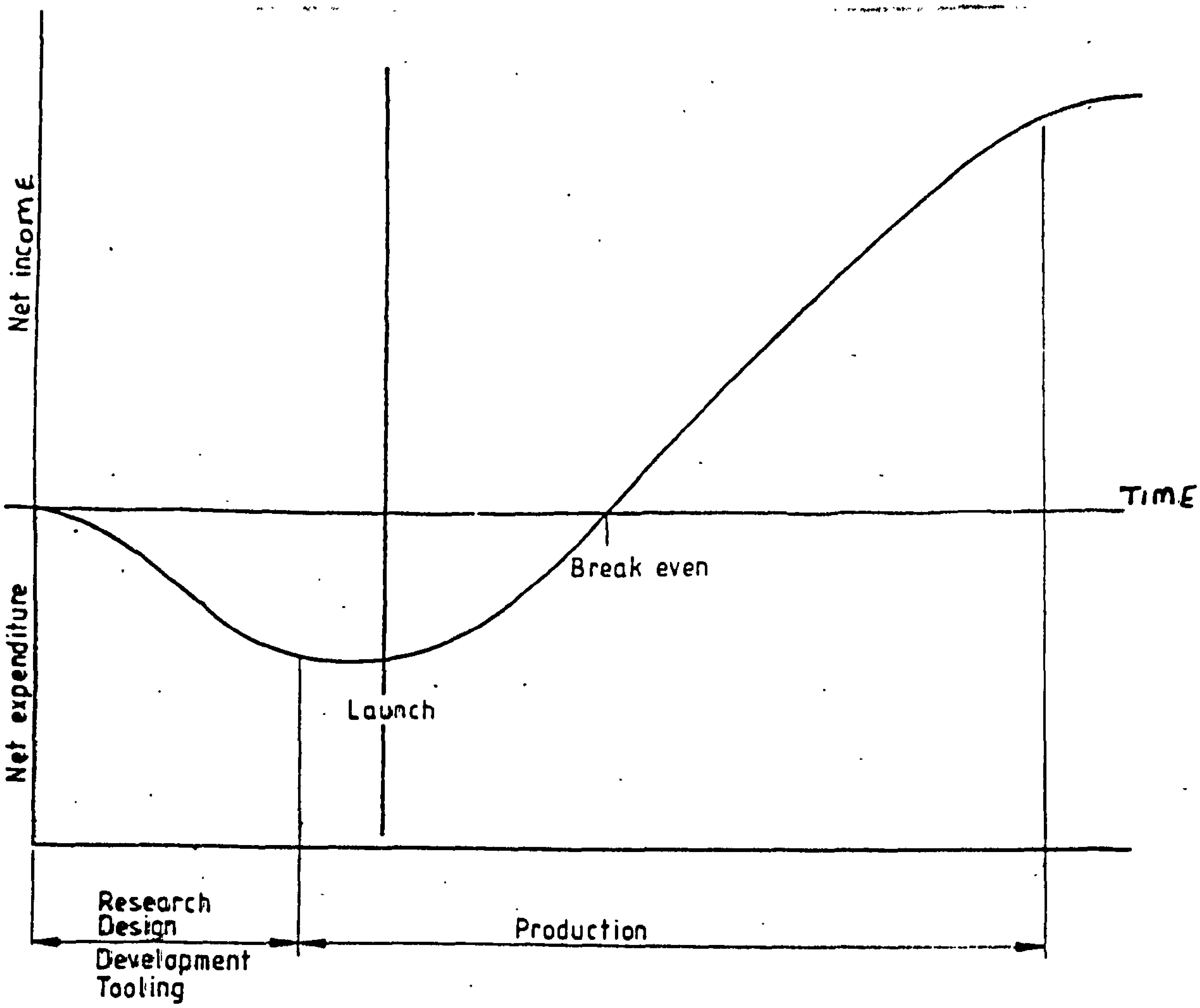


Fig 2.3b

makes a new product a success" (Cooper op. cit.).

Looking at other studies Turner (1983) states that:

"Surveys have shown that about two thirds of all products considered to be technical successes are commercial failures".

This suggests that failure lies in the original market research, 'concept vulnerability' (Pugh 1984), or failure in the way that the final product is marketed.

In 1979 Sir Kenneth Corfield identified the separation of design and marketing in British Industry as a major contributory factor to the country's poor achievement in commercially successful innovative product design and Twiss (1980) observed:

"There is substantial evidence from both sides of the Atlantic that a market orientation is still woefully absent in many decisions and that is a major source of failure".

Bright (1968) has listed the causes of success and failure from his research of technical innovation.

"The most critical of these are:

1) Market orientation
2) Relevance to the organisation's corporate objectives
3) An effective project selection and evaluation system
4) Effective project management and control
5) A source of creative ideas
6) An organisation receptive to innovation
7) Commitment by one or a few individuals".

J. Bjoihsten (in Neibel and Draper 1984); Rockwell and Particelli

(1981); and Dieter (1983) have also investigated this area.

Such findings have been of use in this research to guide towards important areas of investigation and provide a framework on which to structure the prescriptive design process manual.

Buggie (1981) shows a typical curve of cost of design against time (fig. 2.3b). This demonstrates that a high investment needs to be made before the product is placed into the market and that a period of rising sales is needed before the new product becomes profitable. As many products do not become profitable the overall success and survival of a company often depends on the profitability of a few products whose success must recoup not only the investment made in its design, but also the investment made in new product failures. This argument has been taken further by Starr (1963) who says:

> "A company which fails with a new product must consider not only the lost investment, but also the cost of lost opportunities due to not having used that investment in another way".

Therefore, reducing new product failures would improve the profitability and perhaps the survival of the company. The next section demonstrates where the effort to obtain improvement should be concentrated.

2.4 The Low Cost End of Design

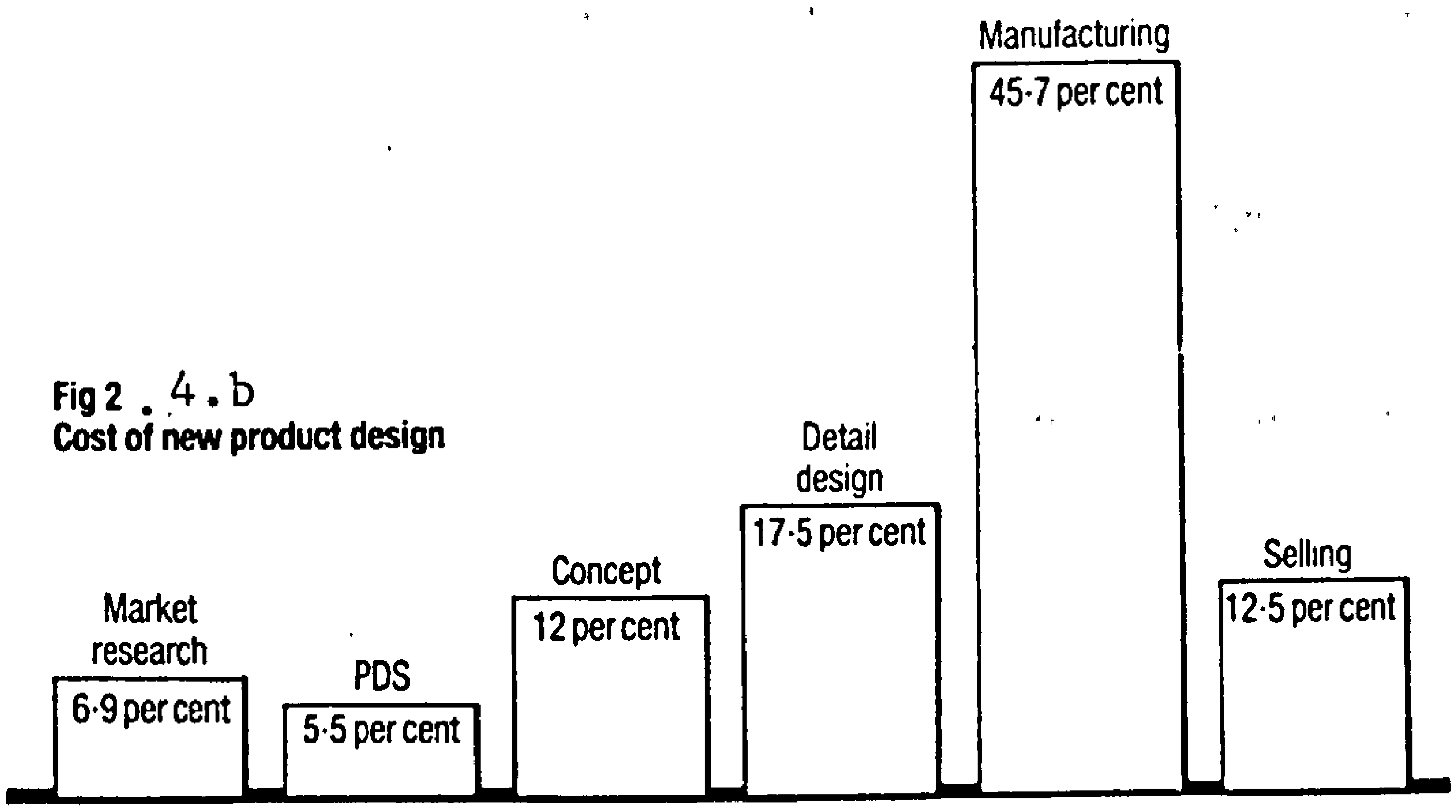
Some researchers have compiled tables showing the cost of various stages of design. These have been shown next to the main steps on the Design Activity Model for ease of comparison in figure 2.4.a and are summarised on figure 2.4.b. This figure demonstrates that the

COST OF NEW PRODUCT DESIGN

FIG .2.4a

Terms Used Market	% Mansfield Et Al (1971)	SOURCE % U.S. Dept. Commerce (Mansfield) 1968	% Viewing (1980)	BASS (1969)	% Buggie (1981) P.27	% Buggie (1981) P.28		BOOZ ALLEN & HAMILTON (1968) Success	Failures	% Total
Applied Research	9.5									
Business Analysis		5-10				30		2	14	16
Specification	7.6		10-15	22	83					
Concept										
Verification										
Development			10-25							
Detail Design								12	45	57
Testing /	29.1	10-20	20-30			13		4	6	10
Prototype or Pilot										
Plant				58						
Tooling & Manufacturing Facilities	36.9	40-60	30-60							
Manufacturing	9.1	5-15								
Start Up						67				
Marketing Start Up	7.7	10-25		11	17					
Sell Commercialisation								12	5	17

Fig 2 . 4 . b
Cost of new product design



cost of the early stages of the process of product design, where the main design direction is taken, is the low cost end and costs are much greater in the later stages.

Johne (1985) refers to work at the front end of design as being relatively low cost,

> "We regard the increased emphasis given to 'up front analysis', in many firms as a particularly important refinement of product innovation initiation procedures".

It can be argued that, if the problems and possible sources of error could be confronted at the early stages of design there would be a greater possibility that errors in the product, be they in the market research, design or production, could be eliminated at this stage and that these errors, or even wrong products, would be prevented from being carried through into the high cost end of design or into production.

Therefore, out of the literature on product failures, where these failures occur and the cost of various stages of design, we can distil that the overall emphasis in design management should be at the front end of design.

2.5 Organic and Mechanistic Structure

It is necessary to show what type of organisational structure is needed to operate product status effectively. This is described in this and the next section.

In the mechanistic system the problems can be broken down into specialisms "as if it were the subject of a subcontract" (Burns and

Stalker 1961) and direction is by formal rules and is typified by a pyramid type of communication and organisational chart. The organic system has a more 'lateral' type of communication and "tends to resemble lateral consultation rather than vertical command". (Burns and Stalker op cit.)

Research or comment by Ansoff and Stewart (1967); Design Council (1985); Herriot (1985); Woodward (1965); Parker (1982); Johne and Snelson (1988); Takeuchi and Nanaka (1986); Cooper (1984), all confirm the findings of Burns and Stalker.

It appears that the mechanistic structure is more efficient, faster and easier to operate where change is limited, but as design, by its very nature, involves constant change it would appear that an organic structure should be proposed throughout and all should be involved, even though it may be more difficult to operate. It has also been shown in some studies that the organic system is also more popular with workers (e.g. Fullan 1970).

2.6 The Design Team Structure

Since 1962 the idea of Quality Circles has been found an effective way to improve the quality of products. Quality circles have been defined by The Institute of Quality Assurance as:

"Small groups of employees who meet regularly to solve problems and find ways of improving aspects of their work".

In essence the quality circle may be thought of as a process design circle that considers aspects of the manufacturing process and design of the product with a view to improving its production.

Oakley (1984), referring to reviewing products, states:

"the most effective way is often to use small groups of employees drawn from different parts of the company to evaluate products and designs. For some time this approach has been increasingly used with success to tackle manufacturing problems - readers will be familiar with the term 'Quality Circle' often used to describe this group activity. There is no reason why 'Design Circles' should not operate in the same manner and, in fact, they have been for many years, but they are usually called value analysis groups". (p123)

Oakley does not further expand on these Design Circles.

This author also uses the term Design Circle to describe small groups of people, these groups not only look at existing products, but also look at the design of new products from the market research phase downwards through the whole design process. This is described in section 3.1

2.7 The Product Life Cycle and S-Shaped Curve

The purpose of the next three sections is to find the link between product status and the Product Life Cycle (PLC) and S-shaped curves and then to apply the disciplines associated with the PLC and S-curve to the theory of product status.

The PLC has been used by many writers to describe the market characteristics of a product over it's life. There is general agreement that products pass through four phases, introduction, growth, maturity and decline, although the terms used to describe each phase may vary. The usual shape of the product life cycle curve is shown on figure 2.7.A.

Abernathy and Utterback (1975) have proposed that the product life cycle affects the management process and leads to the adoption of different structural forms at different points of the product life cycle based on the varying tasks needed at each phase. This has been expanded by other writers who have also added product characteristics that accompany a product at the four phases of the product life cycle (Doyle 1976; Parker 1978; Hirsch 1965; Tracy 1980; Cowell 1984; Abernathy 1978; Dowdy and Nikolchev 1986). These are shown in table 2.9.A

Unfortunately, the general shape of the product life cycle curve is not consistent. McLeod (1969) shows various forms of the curve, with explanations and in empirical studies of the product life cycle, Rink and Swan (1979); Nichols and Roslow (1986); Midgley (1981) have determined a variety of shapes that occur in practice.

Doyle (1976) believes the product life cycle is not a "foundation for decision making" but is "vacuous, empty of empirical generality and positively dangerous if used as a guide for action".

The S-shaped curve has been shown in various forms by writers for example, Klein (1977) figure 2.7.B; Deasley (1986) figure 2.7.C; Parker (1978) figure 2.7.D. Nichols and Roslow (1986) show one by Fox and Wheatley (1978) figure 2.7.E. Like the PLC various writers have commented that too many variables and inconsistencies occur that make the S-shaped curve unsuitable for prediction, among them Nichols and Roslow (1986); Klein (1977); Thackray (1983).

Therefore, the PLC and S curve provide little benefit, as they stand, in product design, but if they can be related to product

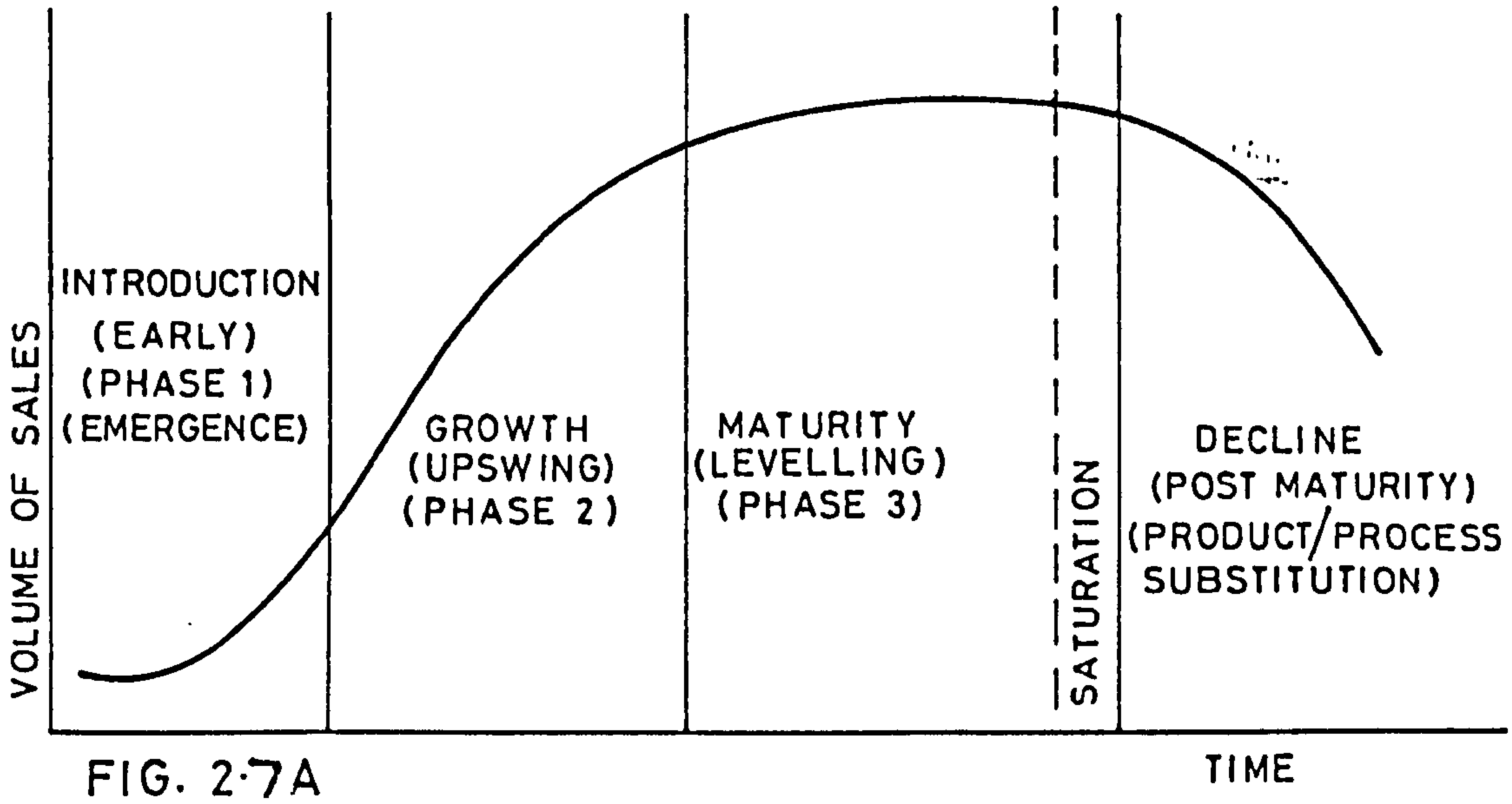


FIG. 2·7A
(FOR EXAMPLE
PARKER 1978)

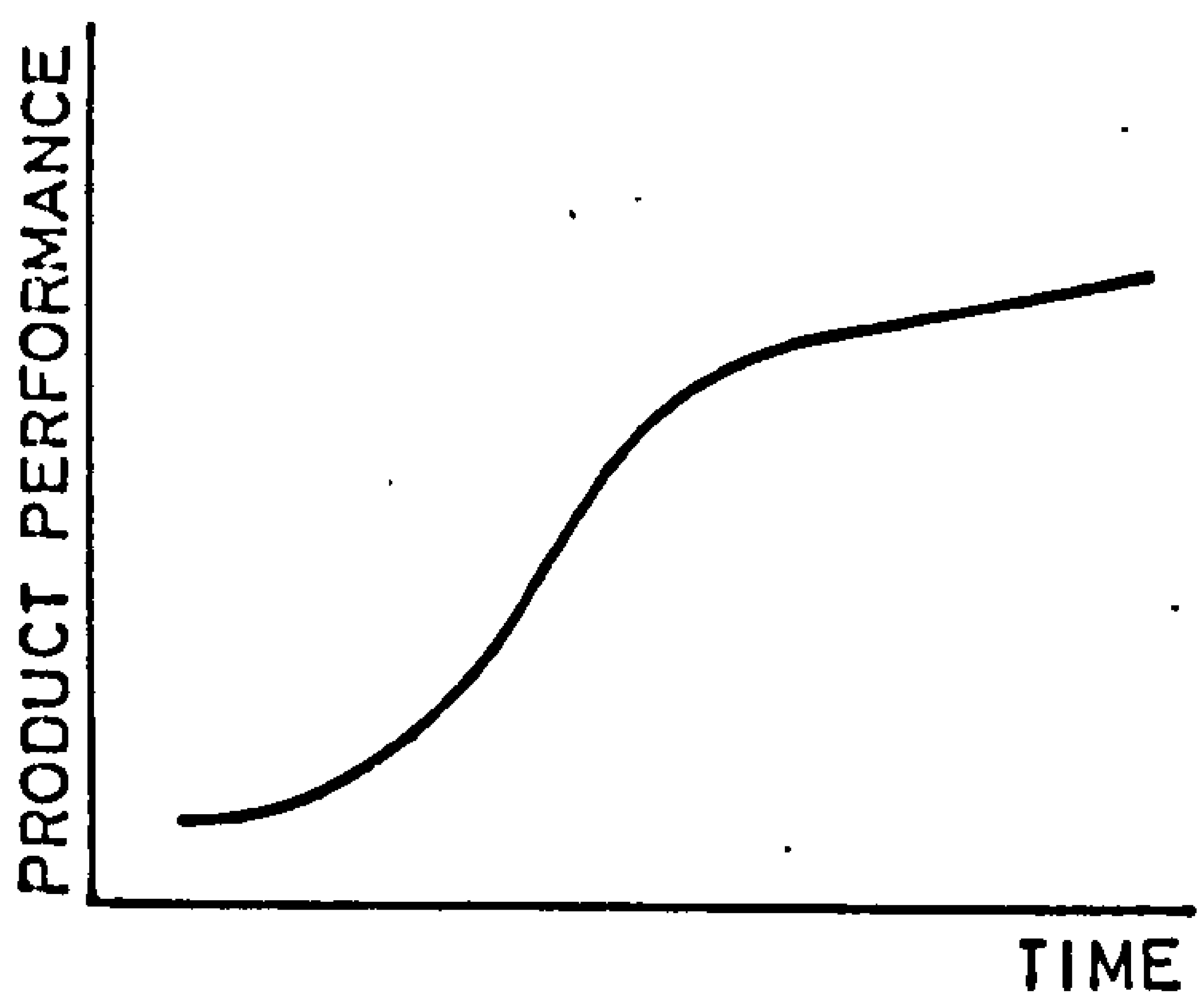


FIG. 2·7B
(KLEIN 1977)

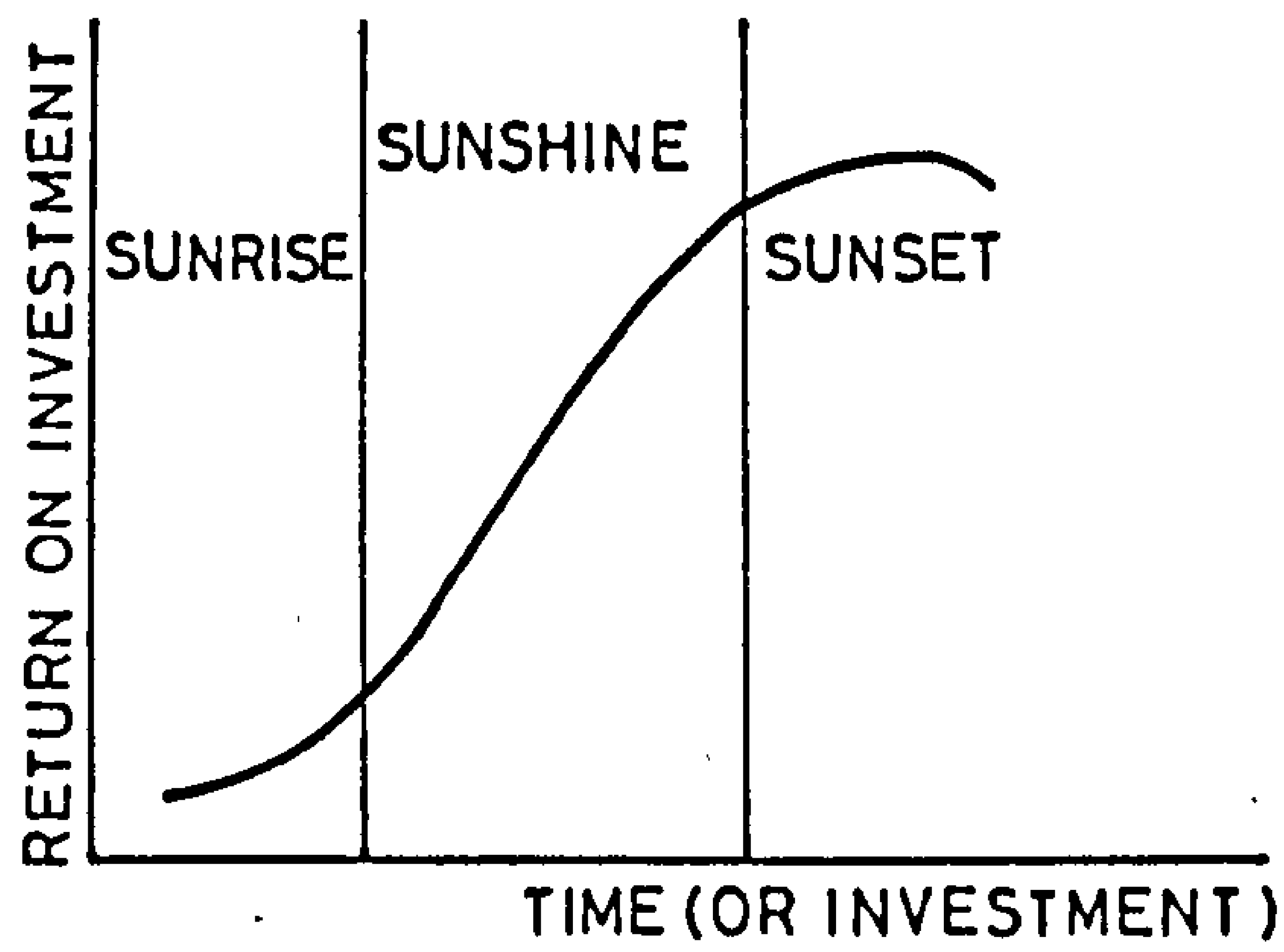


FIG. 2·7C
(DEASLEY 1986)

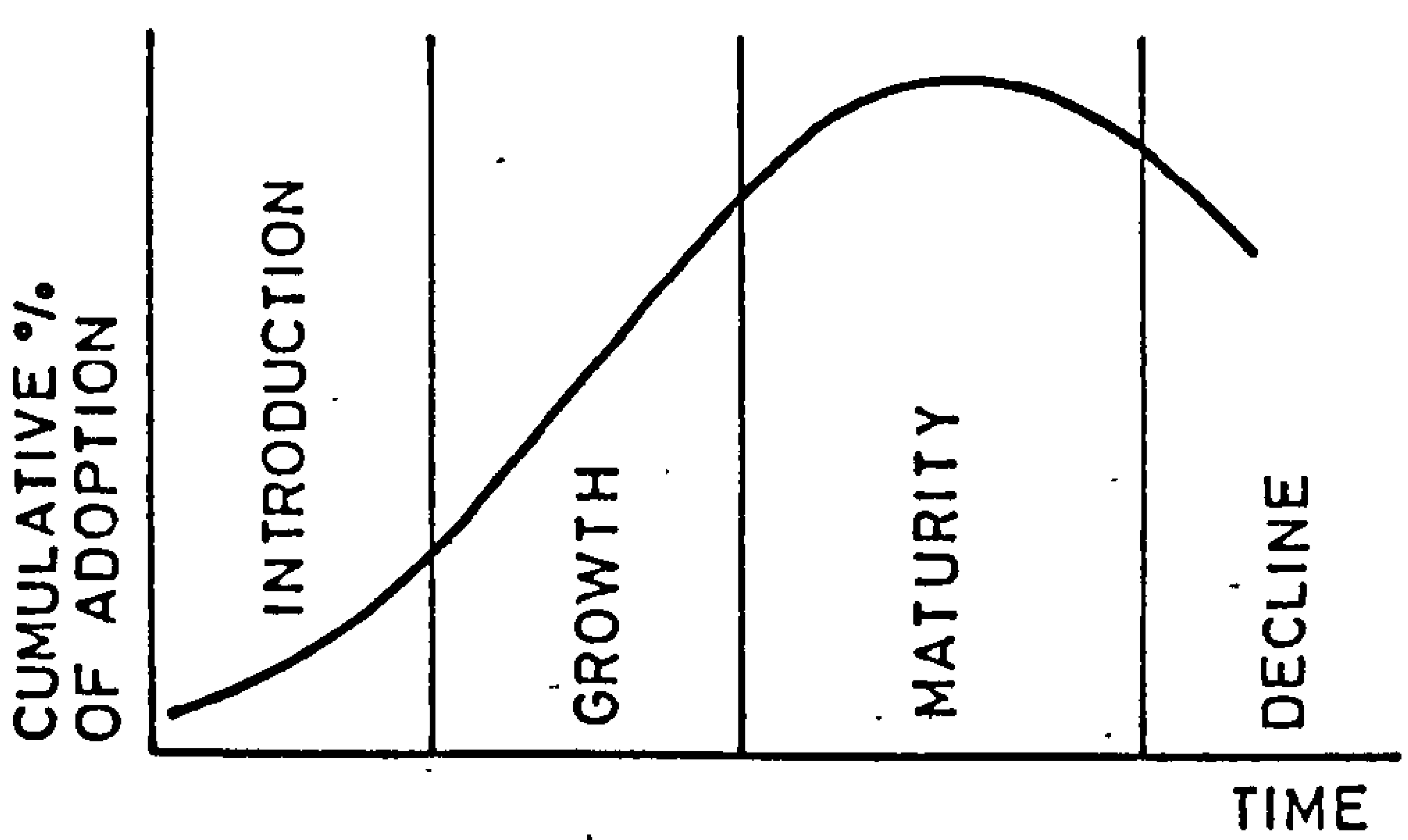


FIG. 2·7D
(PARKER 1978)

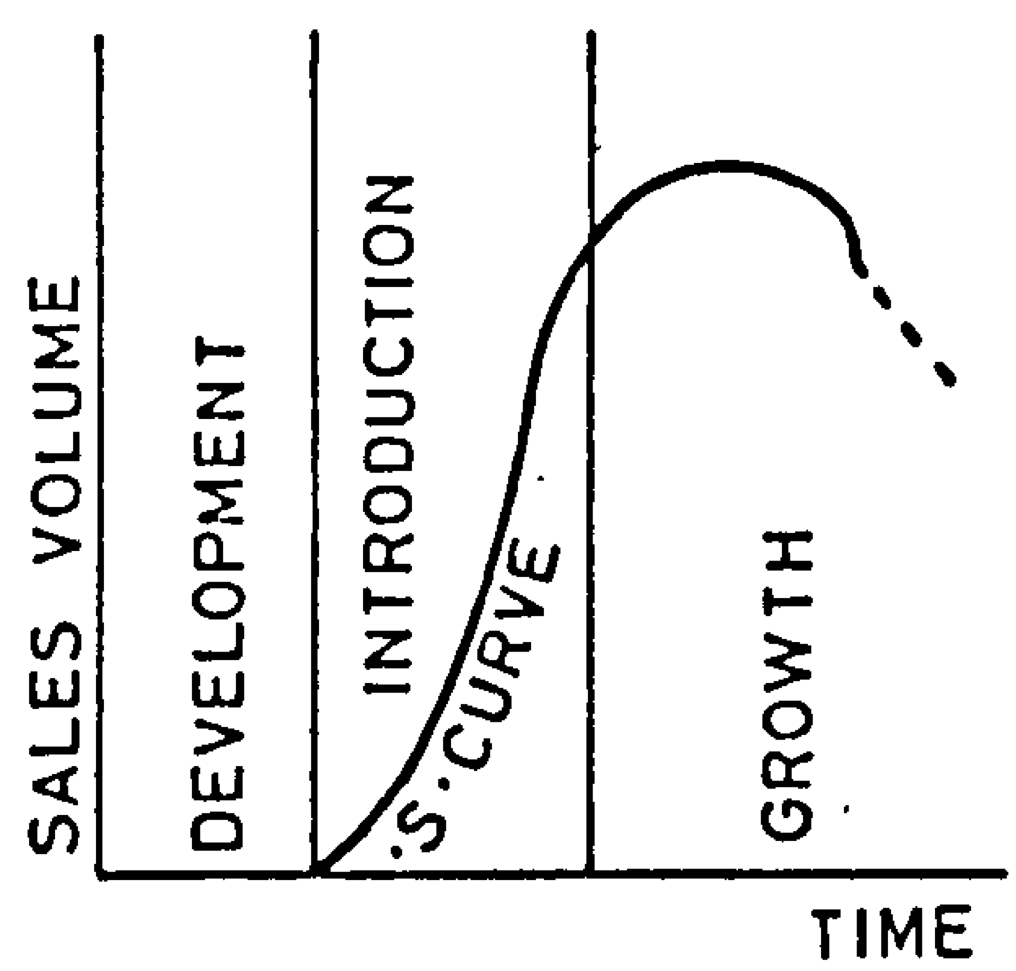


FIG. 2·7E
(FOX AND WHEATLEY (1978)
IN NICHOLS AND ROSLOW (1986)

status then product and company characteristics associated with these curves could become usable tools in the design process. This relationship is discussed in section 2.8 and the identification of useful characteristics related to status is shown in section 3.1

2.8 Relating the Product Life Cycle and 'S'-Shaped Curve to Product Status

Nichols and Roslow (1986), referring to the product life cycle, note that:

> "In the first three absorption stages - product introduction, market growth and market maturity - a so-called 'S-shape' curve is recognisable".

Certainly both curves have a base of time, but, whereas, the product life cycle has a vertical axis of sales, several vertical axes are used when S-shaped curves are described. For example, 'sales volume' is used by Nichols and Roslow (1986), 'cumulative percentage of adoption' (Parker 1978 p125), 'return on investment' (Deasley 1986), 'performance function' (Klein 1977). Nichols and Roslow (1986) argue that if sales is used as the vertical axis the 'S' curve shows the distributions due to market forces etc. and becomes as inaccurate as the product life cycle. 'Return on investment', though, must be related to sales, whereas, 'cumulative percentage of adoption' can also be related to 'sales', until the product reaches maturity whereupon factors are introduced which can confuse the issue. For example, with televisions the cumulative percentage of adoption of this mature product remains high, although, potential sales are generally in the replacement market and may be declining due to increasing product reliability.

Dowdy and Nikolchev (1986) show a curve of the product life cycle (figure 2.8 A) which shows that a product may decline or be renewed. This renewal ties in well with Klein (1977) who, by using 'performance function' as the vertical axis, allows for products to be conceptually changed and improved over an indefinite period. Unfortunately, performance function is an unclear measurement of product improvement and may mean an increase, such as, speed of an aircraft or a reduction, such as, fuel consumption or weight. This being so, it is still possible to compare Klein's (1977) S-shape curve form with other S curves and, with the 'absorption' stages, with the PLC.

The declining phase of the PLC is of no interest in this research, as a product at this position is probably dynamic or potentially dynamic and a company, perhaps, should not be considering designing a product with a declining demand but be designing the product that is to replace it to restart the next introductory phase of the curve.

Jones (1970) has suggested that products improve in steps followed by a stable period. (Figure 2.8 B). He also uses the 'performance of the system' as the vertical axis but has a base of 'complexity of system'. It is argued that the complexity need not increase and with certain aspects of partial design, such as Value Analysis, may actually decrease.

The status curve uses Klein's (1977) denominations of axis of performance function to a base of time, but, whereas, S curves and the PLC are considered by writers to be important in themselves to show progression of a product, in the principle of product status no

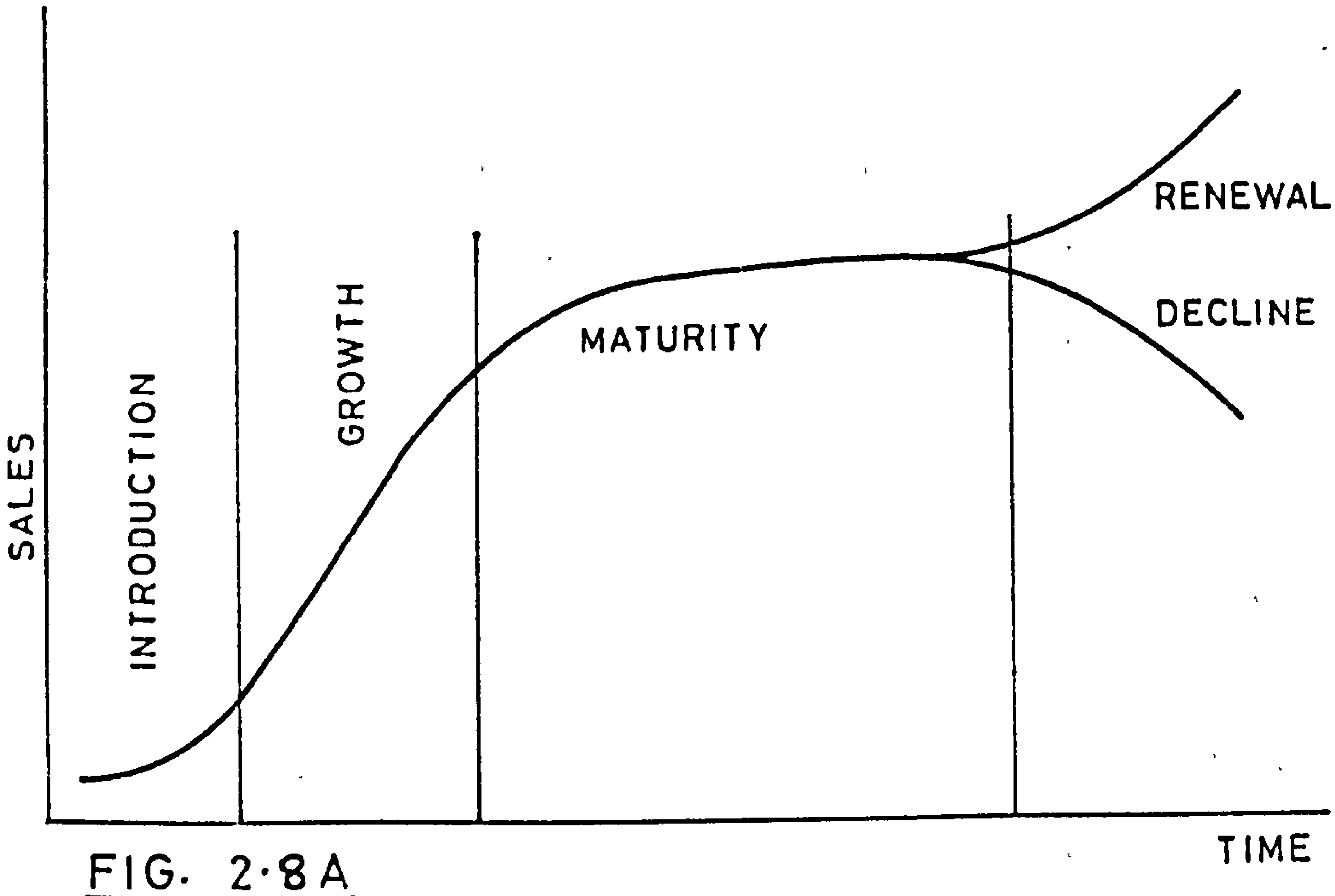


FIG. 2·8A
(DOWDY AND NIKOLCHEV 1986 p.39)

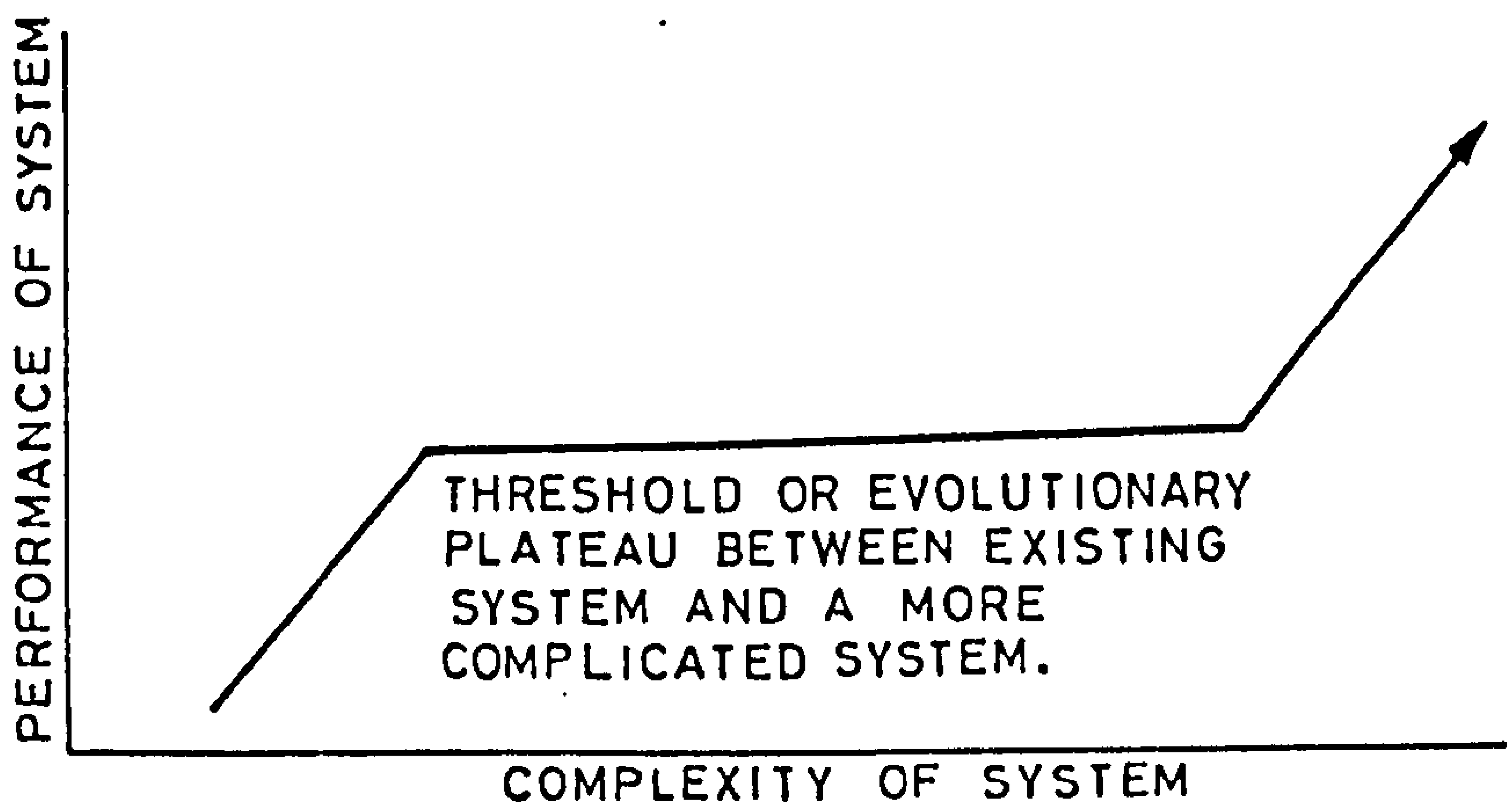


FIG. 2·8B
(JONES 1970 p.33)

attempt is made to measure the status curve and it is used only to provide clarity in demonstrating where a product is positioned at any point in time. As it will be shown how to identify if a product is static or dynamic (section 7.3) it is worthwhile relating the status curve to the PLC and S curves and to then read across the product and organisational features of these to show the advisable course of action to be followed when designing a product at the known position on the status curve. These are shown on table 3.1.B.

The early or introduction phase is equivalent to a dynamic product. In the growth phase the product may still be dynamic or newly static (Static 1) and in the mature phase the product is on the static plateau (static 2)but may be approaching conceptual vulnerability especially if it is beginning to decline.

The curves being inconsistent, a product may continue to grow or become mature, the length of the mature phase may be short or long and may be followed by decline or renewal. This very inconsistency highlights the strength of product status where the curve itself is of little importance, what is important is the situation that exists within companies and the environment at that particular time.

2.9 Design Disciplines that Accompany a Type of Design

Throughout this research various techniques that accompany design have been identified that are of benefit in the organisation and process of design. There is no one word that accurately describes all these packages of techniques but the one chosen and used throughout is 'Discipline', the dictionary definition of this includes the words 'system, rule, method and arrangement'.

Therefore, although certain activities cannot strictly be termed disciplines, such as financial control, seeking innovations outside of industry and emphasising market pull products, these and other activities are referred to under the heading of 'Design Disciplines'.

Having established the link between product status and the product life cycle and 'S' shaped curve (section 2.8) it is now possible to 'tease out' relationships that others have made for the design, production and marketing of products at certain positions in the product life cycle and 'S' curve and include these in a list of disciplines associated with the relevant product status. (Table 2.9.A)

The contents of table 2.9. A has been rearranged to show what should be emphasised in the design and this time it is related to product status. This is shown on table 3.1.B.

There is disagreement in some of the literature on what is found in companies producing products at certain points in the product life cycle. For example, Tushman and Nadler (1986 p25) suggest that during the growth period only minor product design is undertaken. This author would argue that during the growth period the design emphasis may alternate between process or product and product design is important during this stage. Further during the mature period they state that only minor process design is carried out. There is clear evidence to show that process design is of prime importance when the product is mature and this exceeds product design. This is covered more fully in section 2.12.

In the production of a mature product authors (e.g. Parker 1982, Cowell 1984) have emphasised the importance of mass production, which

Table 2.9.A
What Researchers have Observed Occurs at Different Stages of the Product Life Cycle and 'S' Shaped Curves

Introduction	
Concept Generation and R & D Support	Technical push and customer pull will operate to generate change, uncertainty. Short, rapidly changing techniques, radical concepts, many attempts, dependence on external economies, prototypes, key patents, concern for secrecy, alternative uses of available science, special investigations.
Design & Product Characteristics	Improving but poor quality and reliability, innovation, major product design. Primary emphasis on technical/functional design. Imaginative leaps and rapid change, competing design philosophies and strategies. No standards, some disasters, attractive functional performance.
Management Industry Structure and Competition	High commitment to change. Entry is know-how determined, numerous firms providing specialised services. Competition innovative. No close substitutes.
Capital Intensity	Low, high risk. R & D costs considerable, speculative, minimum commitment of resources. Cash flow negative.
Critical Human Inputs	Scientific, engineering and technological. Labour intensive, organic structure, lateral communication, flexible communication.
Price/Demand Structure and User	High price, price inelastic, sellers market, demand high, novelty performance and price, exploratory user early adaptors. Profits low.
Distribution and Marketing	Poor distribution. Reliance upon internal use, close customer linkage. Uncertainty of market needs. High promotion costs.
Production	Minor process design, short runs, limited production equipment, flexibility, low cost production less important, labour intensive.

<u>Growth</u>

Concept Generation and R & D Support	Uncertainty of technology largely dispelled. Technology stabilised. Intensive applied research for design and production back up. Search for new product uses. Variations in techniques still frequent.
Design and Product Characteristics	Minor product, design improvements and new development. Designed additions and subtractions for market segment, pressure for standardisation but with flexibility to out do emerging competitors.
Industry Structure and Competition	Growing competition entry causing pressure on prices and costs. Product competition stronger and based on minor improvement in product. Many casualties and mergers. Growing vertical integration.
Capital Intensity	Great demand for new investment. Problem of containing expenditure relative to inward cash flow. High capital intensity due to high obsolescence rate.
Critical Human Inputs	Scientific and technical personnel less important. Management.
Price/Demand Structure and User	Higher demand, price declines, knowledge and use of the product becomes more widespread. Use penetration price elasticity. Customers purchase more on price considerations. Early majority, profit margin peak.
Distribution and Marketing	Widening market, promotion costs spread over a larger volume. Uncertainty of market largely dispelled. Increased availability, market segmentation. Rapid reliable improved distribution.
Production	Larger volume production, cost reduction, capital investment, longer runs, product standardisation, major process. Standardised production techniques. Mass or volume production becomes sensible. Larger batches and flow processes if applicable. Economies of scale.

Maturity

Concept Generation and R & D Support	Few innovations of importance. Technology stabilised, innovation under growing pressure. Stability in core concepts. Technical solutions known, continuing emphasis on cost saving, increase concern with behavioural aspects, methods used.
Design and Product	No significant improvements. Cost dependent. Design for minimum user costs. Product developments largely exhausted. Minor product design. Cost economies are used up. Product attributes known. Technical change still rapid but increasing emphasis on human design. Stress on cost of design and it's effectiveness. Stress on use of standards.
Management	Political considerations may become important. Management and financial systems. Attention to group size.
Industry Structure and Competition	Market saturation, overcapacity, substitutes prevalent, number of firms declining, fierce competition. Monopoly or cartel structure. Large sized companies may yield sufficient economies of scale to drive rivals out of business. Commonly accepted precepts of competitive advantage. Market segmentations. Specialisation.
Capital Intensity	High, due to large quantity of specialised equipment, major inward cash flow. Profit decline.
Critical Human Inputs	Unskilled, semi-skilled labour. Scientific and technical manpower becomes progressively less important. Mechanistic structure most appropriate, specialisation. Engineering personnel.
Price/Demand Structure and User	Inelastic demand, customer sophistication, buyers market. Information easily available. Sales growth slows. Impact on society. Late majority.
Distribution and Marketing	Stability of market needs. Market attributes known. Product 'images' for designed features of quality etc. Emphasis on purchasers lifestyle.

Production	Application of computers. Long runs and stable technology. Capital intensive and mass production methods are virtually obligatory for survival. Low wage cost factory location for multinationals. Minor process design. Synergy.

<u>Decline</u>

Concept Generation and R & D Support	Technical advance may cause decline. Decay or transformation. Withdrawal of R & D but watch for features to prolong or transform product life.
Design and Product Characteristics	'Model' changes. Minor improvements.
Management	Pressure to shut down inefficient plants.
Industry Structure and Competition	Overcapacity. Reduction of Manufacturers. Inexpensive ways of beating competition. Failures.
Capital Intensity Price/Demand Structure and User	Problems with maintaining profitability. Fashion and tastes changing, price competition may cause decline. Product substitution. Social impact on item. Laggards.
Distribution and Marketing	Stress on user appeal. Low price and up market. Design - ongoing standards.
Production	Level of output declines.

<u>Sources</u>
Abernathy W J, Clark K B and Kantrow A M (1983); Abernathy W J (1978); Cowell D W (1984); Dowdy W L and Nickolchev J (1986); Hirsch S (1965); Parker J E S (1978) p10-14; Tushman M and Nadler D (1986); Utterback J M and Abernathy W J (1975); Doyle P (1976); Gregory S (1985); Tracy P (1980); Donaldson L (1985).

is correct for certain products, but many products that are mature and have been for many years, never reach the production volume that justifies mass production techniques. This research allows for this by using 'Static 1' for all products and introducing the disciplines of 'Static 2' only when production volume makes them viable.

Some writers (e.g. Nystrom 1979) have simply viewed a product design as innovative or evolutionary, or two similar terms that can be equated with dynamic or static design. In many cases these writers then proceed to describe the organisational, production or marketing features that would be associated with these types of design. It has been observed that survival is the main aim of a company (Drucker 1954) and, therefore, it may be assumed that these structures give the greatest "fitness for survival" (Darwin 1859) in their environment and also their methods and structures are "the best way" (Taylor 1911). Nystrom (1979) shares this viewpoint,

> "The classification of companies as more or less positional or innovative thus reflects the company's overall structure to achieve it's objectives".

Therefore, these may be advantageous disciplines that can be linked to a product which is either static or dynamic.

Parker (1982) exhibits a table, drawn from Nystrom's writings, which is reproduced on table 2.9.B, showing company disciplines that might be expected to be found in the two extremes of a company. The features shown compare well with the features drawn from the writings of the product life cycle and 'S' curves. In the text, additional factors are given and these have been extracted and shown in table 2.9.C.

Table 2.9.B Parker (1982) p20.

Function	Positional Company	Innovative Company
Board	Emphasis on financial control	Innovation - orientated future perceived as uncertain
or Organisation	Impersonal, hierarchical status dependent	Dual structure - vertical and horizontal
Marketing	Re-active - stability based on attractiveness of product. Closed marketing strategy	Constructively creates an unstable environment
R & D	Defensive evolutionary	Agressive innovative
Production	Efficiency, rationalisation and long runs	Openness to change

Table 2.9.C constructed from the text of Parker (1982)

Function	Positional Company	Innovative Company
Board	Corporate plans based on extrapolated trends of financial statistics	Corporate plans must generate new insights, be dynamic and reiterative
Marketing		Create new opportunities
R & D	Re-active. Economies of scale	Important
Production	Automation, group technology, standardisation specialisation	Designed for the possibility of introducing new production methods, flexible

Parker R C (1982) The Management of Innovation. Wiley.

The survey of the literature has identified various relevant disciplines which, in many cases, have only been briefly touched on by writers, but from these a structure of disciplines can be built to which will subsequently be added other disciplines determined from the research and incorporated into the Design Process.

Foxall (1984) describes the observations made by Abernathy and Utterback (1975) regarding the need for distributive economies of scale with static design,

> "The evolution of a dominant design enforces standardisation and permits high volume production based upon scale economies in production (and frequently distribution too)".

Kuznets (1959) has observed the need for "training of the labour force" when introducing a new (dynamic) product design as well as "entrepreneurial talent and skills to overcome a series of unexpected obstacles" (p.31).

McLeod (1969) identifies four company design types that can be equated with static and dynamic designs. He then proceeds to give several disciplines that can be associated with these company design types. His 'First in the Field' is dynamic design and for this is required a "large basic research team" and "a large number of people being involved in the design process". Design protection, such as patents, is important to this type of company.

'Follow my Leader' is an imitator which McLeod suggests still needs quite a large research team to improve the product through cost, performance or some other parameter. This is a company concentrating on static design.

'Applications Engineering' is a dynamic company.

The 'Me Too' type of company is at the static boundary and emphasises low cost production and aesthetics. Patents are unimportant. The design department, McLeod believes, will be smaller than the other types of company and pure research will not be undertaken but detail design is stated to be important. Cooper (1984) also confirms the 'me too' findings of McLeod. This author suggests that very few companies, even dynamic companies, tend to do pure research and this was confirmed in the research.

The disciplines discussed in this chapter are largely management concepts and overlook the technological aspects of product design. All these disciplines are related to and feed into the design activity model.

2.10 The Design Activity Model

For product status to be used in design it must be linked to other features that explain and make up product design. The following two sections describe the relationship of product status to the design activity model and the product design specification.

The design activity model gives direction to the design process. Over the past twenty five years many different models have been proposed to describe the stages of design from market to product for all, or particular, products (e.g. Ehrenspiel 1984; Wallace 1986; Clausing 1985 etc.). These vary in effectiveness and clarity. It is considered necessary to show a widely accepted design model that describes the area where the research has been concentrated and what the effects of the research makes to such a model.

The design model chosen was developed by S.Pugh in 1977, a later version of which is shown on fig. 2.10.A (1982 Engineering Design Centre, Loughborough). This model has been adopted by an increasing number of bodies (e.g. S.E.E.D.). The main design flow is from market to selling but demonstrates iteration.

The area of the research is concentrated at the top end from the market down but stopping before the detail design stage, although defining the disciplines that accompany a product of a particular status means that parts of the subsequent stages are also relevent in this research. The subsequent improved design process 'stretches' this model between the market and specification stage by including various layered procedures at the low cost, front end of design.

Further, identification of the product status, showing a static product will indicate that concept design is of much less importance

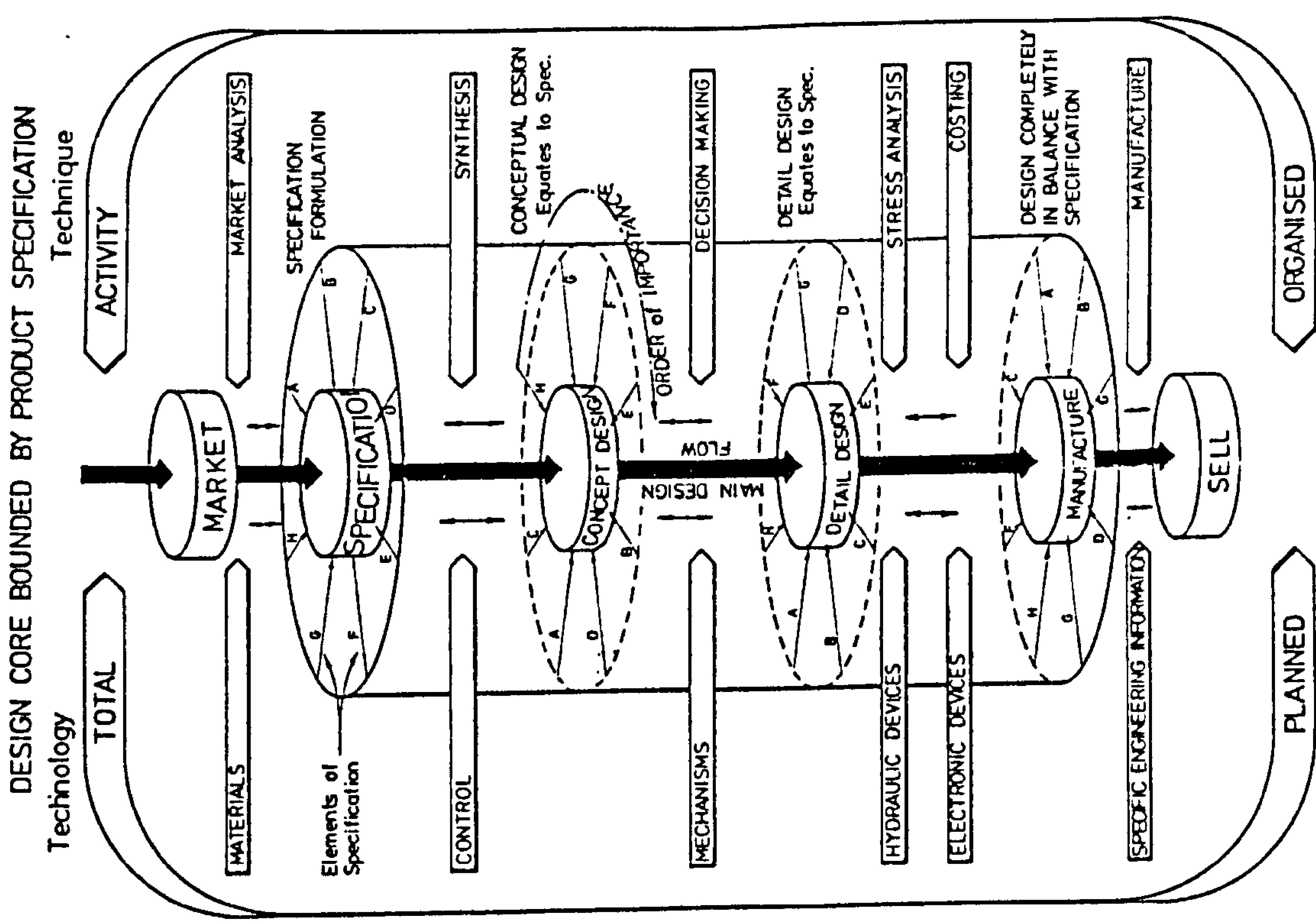


fig. 2.10.A

as the basic concept is unlikely to alter, although consideration of subconcepts in component parts may be important (the status of these may need to be identified in some products).

The outcome of the research, although changing the emphasis of various parts of the model, does not affect it's basic structure.

2.11 The Product Design Specification

The product design specification (P.D.S.) gives 'breadth' to the design and must be a full and thorough written document which covers all aspects of the design.

Corfield (1979) gave a high priority to the P.D.S. in the NEDO report and Lock (1968) found irrelevence and diversification in the design of products caused by substandard specifications.

The Institution of Production Engineers (1984) went further observing that:

"The majority of companies do not compile and therefore do not work to formal specifications and thus are not in control of their product development and ergo are not in control of their business".

Pugh (1974 and 1983) produced a diagram showing the elements that should be considered in a P.D.S. which is shown in fig.2.11.A.

The product design specification is sometimes known as 'target specification', 'design brief', or 'primary specification'. These names do not convey the importance or completeness necessary in the document. Product status in no way diminishes the importance of the P.D.S.

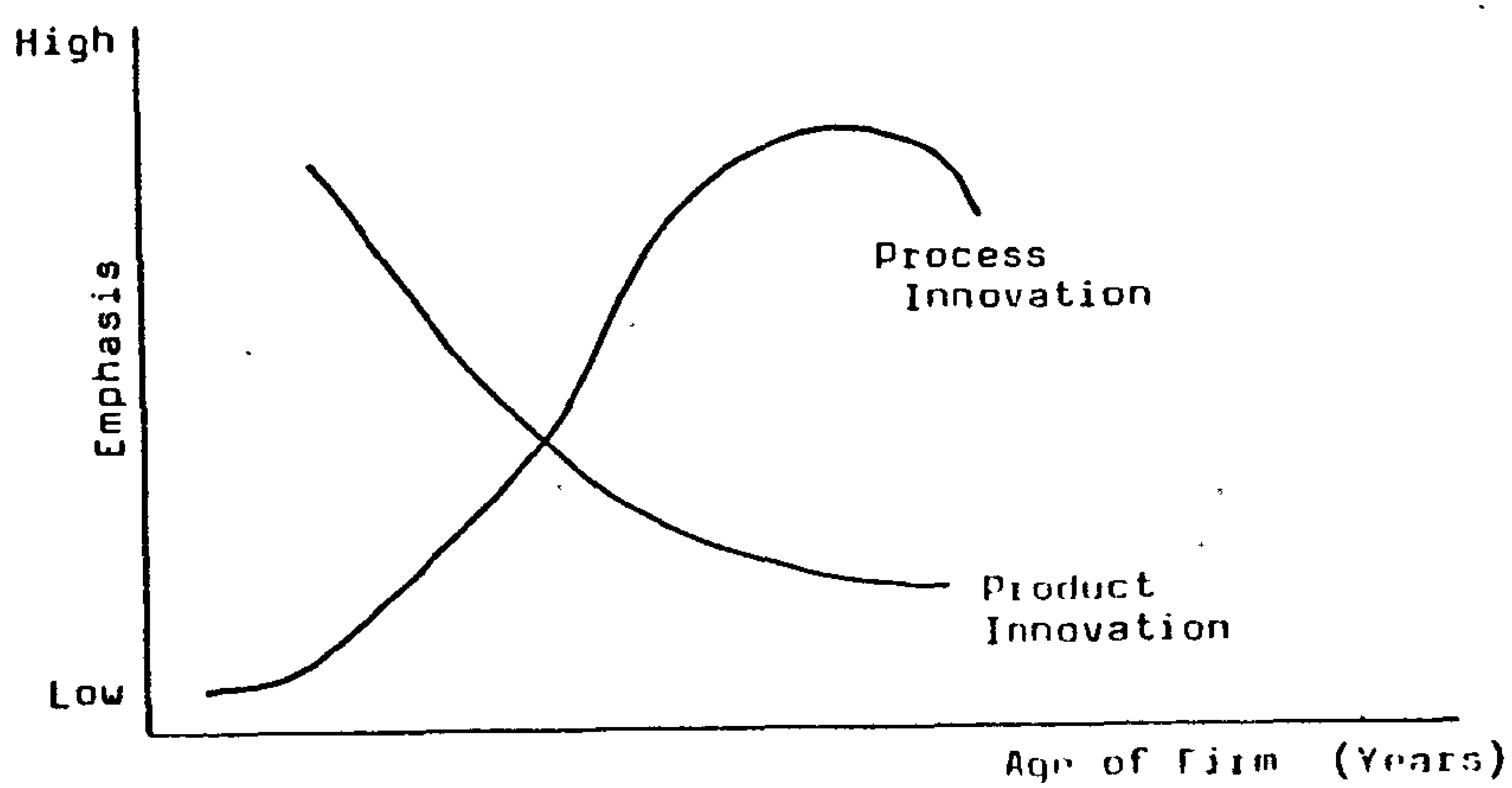


fig. 2.12.A
(Johne 1985 p.6)

ELEMENTS OF PRODUCT DESIGN SPECIFICATION

©1987. S.Pugh

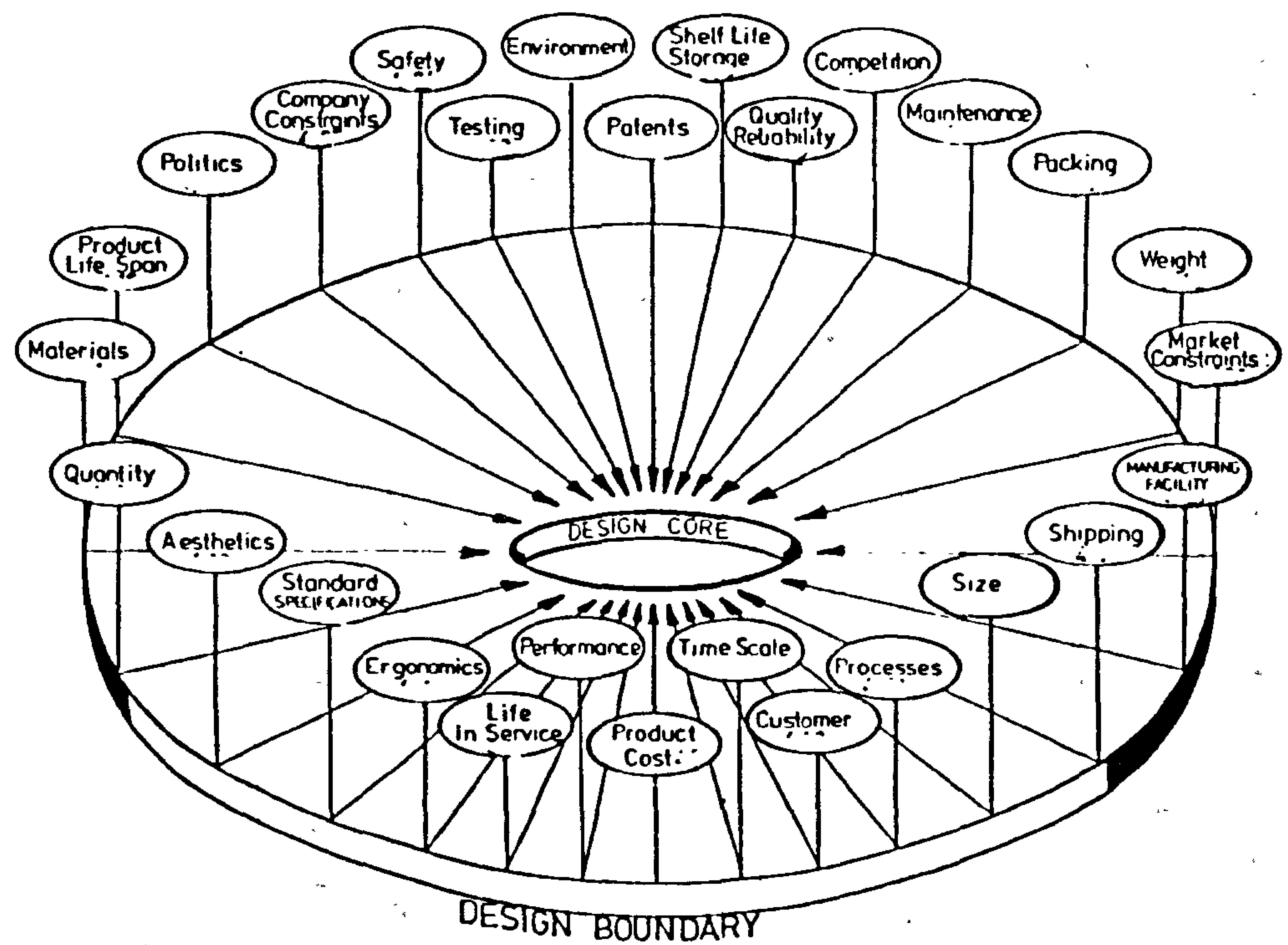


fig. 2.11.A

2.12 The Change of Emphasis from Product Design to Process Design

Allied to the design of products is the design of their method of manufacture. This section discusses this process design and where it becomes dominant over product design.

Process design is the design of the method of manufacture rather than the design of the actual product. Possibly the earliest form of process design was prescribed by F W Taylor (1911) who described optimising the tools (and operators) in the production process, "get an ox to do an ox's work".

Throughout this century various practitioners have continued to ascribe methods for increasing production from employees; amongst them Gilbreth (1916); Fayol (1949); Mayo (1933); Hertberg (1959). More recently with the increase in automation, research has been directed away from maximising the individual operator's output from the manufacturing process and towards technology and this has resulted in considerable process design. It has been estimated that in certain industries, such as the car industry, more is spent on process design than product design.

As the design of a product becomes static, process design often becomes more important than product design as stability in the product design makes investment in manufacturing process more viable. The relative change from product to process design has been known for some years as, Abbot Payson Usher (1929) noted, sixty years ago, when considering the design of lathes in the 19th Century.

Johne (1985) includes the diagram 2.12.A which shows that process innovation increases as product innovation decreases, although he shows the base of the graph to be the age of the firm rather than the age of the product, perhaps overlooking the fact that a firm may have several products, some of which may be quite new. He appears to be describing a single product company or 'Process Segment' (Abernathy and Utterback 1978). Even so the trend is clear, that over time, process innovation is more emphasised than product innovation.

2.13 Company Size and Product Status

It is often stated that small companies are more innovative than large companies. For example, a study by the US National Science Foundation in 1979 and reported in Parker (1980) showed that small US firms produced 24 times as many innovations per unit of expenditure as large ones and many large organisations were seeking ways to motivate a more entrepreneurial behaviour. Few explanations are given as to why this should be. Rothwell (1985) states:

> "It appears that new firms, initially, are better adapted to exploit new techno-market regimes, breaking out from existing regimes within which established corporations for historical, cultural and institutional reasons might be rather strongly bound".

Peters and Waterman (1982) make the following observation:

> "We strongly believe that the major reason big companies stop innovating is their dependence on big factories, smooth production flow, integrated operation, big-bet technology planning and rigid strategic direction setting. They forget how to learn and they quit tolerating mistakes. The company forgets what made it

successful in the first place, which is usually a culture that encouraged action, experiments, repeated tries".

One explanation for this could be the organic design team structure found in small companies aids communication. The principle of product status also helps to explain why small companies may be more innovative than large companies by showing that it is in the interests of a large company to have a static product, whereas it is in the interests of a small company to have a dynamic product. Andrews (1975) refers to these interests:

"It is in the interest of the small company to disturb the status quo in the market, whereas it is in the interests of a large company to preserve the status quo".

With a static product companies that can achieve the disciplines associated with increased process design and low cost production are most likely to succeed. Rothwell (1985) has identified that this can also keep small companies out. "Late entry to markets is only possible by large companies". Having made the investment they are not only likely to be lower cost producers than their competitors, they are also less likely to want to change the design which may render this process machinery less efficient, or obsolete.

Ehrlenspiel (1984) has drawn the same conclusions:

"High expenditure on production facilities can limit the designer through not allowing him to change the production method until the equipment has been paid off".

It is in their interests, therefore, to keep the design of the product static.

But Parker (1978) has provided two advantages that a large company has over a small company in the field of innovation:

> "The argument indicating the advantage of large companies in the Research and Development process tend to include a degree of market power as a beneficial influence. The large company should have a marked advantage in technical activity:-
>
> 1) raising additional capital cheaper
> 2) market power should allow large firms to secure high returns and recoup expenses fast". (p67)

In spite of these exceptions this author believes that the previous pages may help to explain why small companies decline and fail as their product becomes static and they can no longer compete with large companies. This is discussed further in section 3.1.

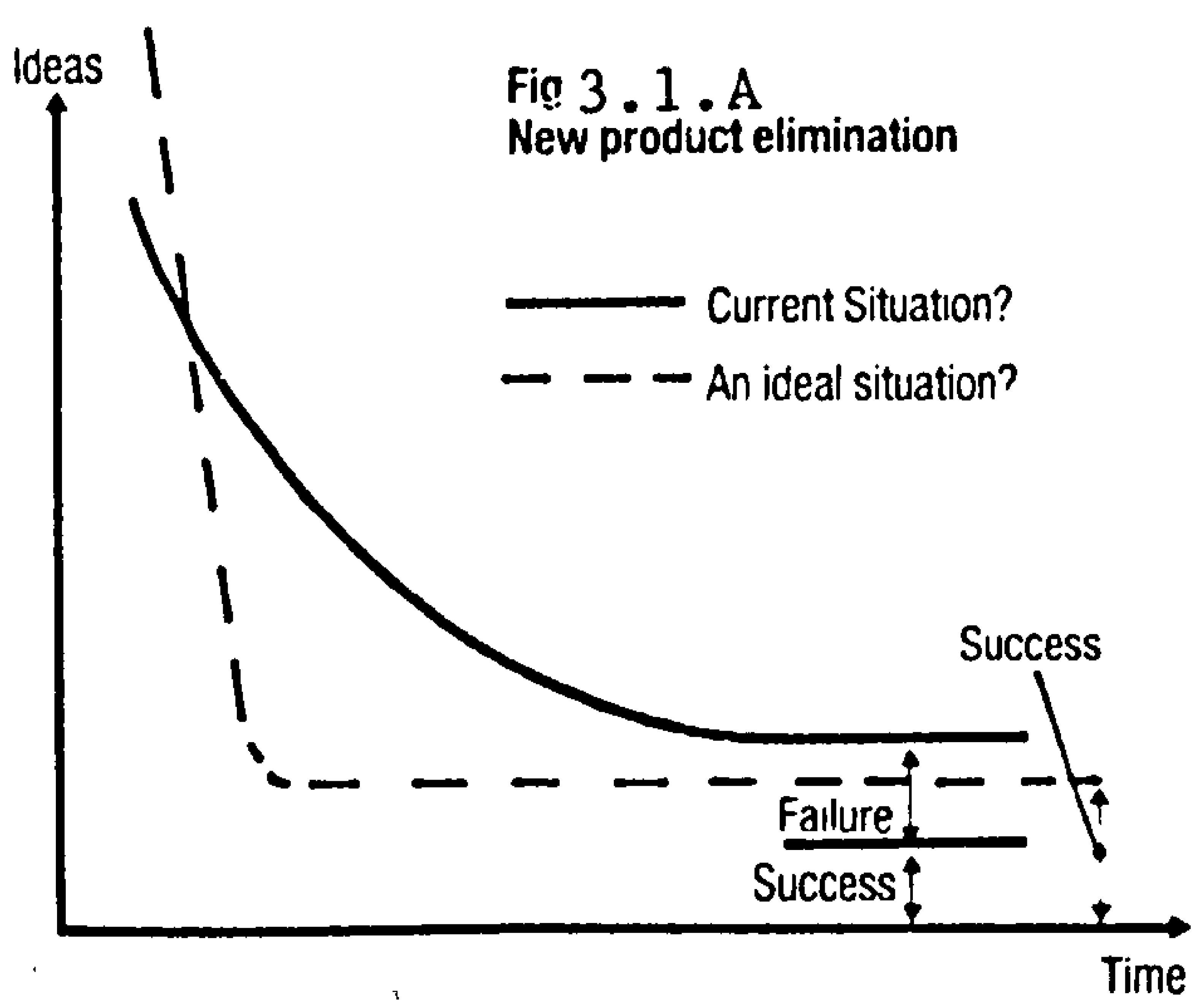


Fig 3.1.A
New product elimination

3 INFERENCES DRAWN FROM THE LITERATURE REVIEW AND LEADING TO THE RESEARCH CRITERIA

3.1 Comments on the Literature Review

This author has identified several areas worthy of discussion from the review of the literature that will now be addressed.

In section 2.4 it was argued that, if design problems were confronted at an early stage, they could be eliminated and not carried forward into the high cost end of the process. If this was taken further and an effective process of product screening was developed a large number of product ideas could be considered, but most would be eliminated at this low cost end of design and those that were not eliminated would have a greater chance of success.

The failure rate of new product ideas would continue to be high, in fact it may increase, but the failure rate of designs actually developed in a product and successfully put on to the market would decrease. This is shown on fig. 3.1.A. 'Weeding out ' of potential design failures before the stage when high development costs are incurred would reduce the overall cost of new product design, even though a larger number of new product ideas had been considered.

With this in mind, it was believed that a method for eliminating the 'wrong product' and ensuring that only products with potentially a greater chance of success should be designed, was an essential part of this research into the front end of product design and its management.

The front end, being also the low cost end of design, could be expanded without a significant increase in the overall design project cost or time. This would lead to a more 'efficient' design process, that is, retaining product quality but reducing overall design cost and time.

In section 2.5 Organic and Mechanistic organisational structures were described, the organic form being beneficial where change is occuring, in which all should be involved. But as was said in one large company in this research if everybody had a say in design "you would never get anything done". This valid argument has been answered by the proposal for a 'Design Circle'. This is an extension of the comment by Oakley mentioned in section 2.6. This author suggests that the Design Circle should not only look at existing products but at the design of new products from the market research phase downwards through the whole design process.

The personnel in the Design Circle will change as the design process moves through its various stages with new members joining, as their various expertise becomes relevant and others leaving as their expertise is no longer required. Membership of the Design Circle will, therefore, be fluid and will include those best suited to meet the objectives which is to progress the design to the next stage. The Design Circle, in the context of this research, does not take the role of design review only, as in Oakley's terms, but also actively designs the product.

The Design Circle will be restructured after each stage of the design and will transform into a Quality Circle when the product is established in production.

Using a Design Circle allows an 'organic' design team structure, even in a large company, that is, all will have an input into the design process. This organic structure should be retained throughout the design process, up to Static 2, whereupon, the necessary disciplines may be thought of as a series of subcontracts within the business, that is, each discipline is operated as a separate 'cell' receiving an input and processing it to produce an output and this may be organised in a more mechanistic manner through the use of, and constrained by, rules.

The optimum size of any such group has been determined by Schein (1969) as nine or under. One person, or 'product champion' should lead the group and remain in the group throughout to coordinate the design process. He should be a person with high authority within the organisation, such as the Design Director, or another senior person from a relevant discipline. The level of seniority in the Design Circle tends to reduce as the design approaches production.

The relation between the product life cycle curve, S-shaped curves and the status curve was discussed in section 2.8. and the design disciplines that accompany a type of design taken from writers is listed in table 2.9.A. The contents of table 2.9.A has been rearranged in table 3.1.B to show what should be emphasised in design but this time it is related to product status. The literature on the product life cycle and S curves has not always made the point that certain aspects of the 'treatment' of product design, production and marketing may or may not be advantageous for an organisation in competing in a market at a particular point in a product's life. Table 3.1.B overcomes this as only useful factors are shown.

Section 2.13 showed that generally small companies are more innovative than large ones. In this research 'G' said that large

Table 3.1.B

Disciplines that Accompany a Product Status

Status Dynamic

Concept Generation and R & D Support	Technical push and customer pull. Uncertainty. Short, rapidly changing techniques, radical concepts, key patents, alternative uses of available science.
Design and Product Characteristics	Competing design philosophies and strategies. Innovation. Major product design. Primary emphasis on technical/functional design. No standards, imaginative leaps and rapid change.
Management	High commitment to change.
Industry Structure and Competition	Numerous firms providing specialised services. Competition innovative. No close substitutes.
Capital Intensity	Low, high risk. R & D costs considerable, speculative.
Critical Human Input	Scientific, engineering and technological. Labour intensive, organic structure, lateral flexible communications.
Price/Demand Structure and User	High price, price inelastic, sellers market, demand high, novelty performance and price. Exploratory user.
Distribution and Marketing	Close customer linkage. Uncertainty of market needs. High promotion costs.
Production	Minor process design, short runs, limited production equipment, flexibility, labour intensive.

Status Static 1

Concept Generation and R & D Support	Uncertainty of technology largely dispelled. Technology stabilised. Search for new product uses. Applied research for design and production back up.
Design and Product Characteristics	Product improvements and new developments. Designed additions and substractions for market segments. Pressure for standardisation but with flexibility.
Industry Structure and Competition	Growing competition. Pressure on prices and costs. Competition based on minor improvements in product. Casualities and mergers. Growing vertical integration.
Capital Intensity	Great demand for new investment.

Critical Human Inputs	Management
Price/Demand Structure and User	Higher demand. Price elasticity. Price declines. Knowledge and use of the product becomes more widespread. Customer purchase more on price considerations.
Distribution and Marketing	Widening market. Promotion costs spread over a larger volume. Uncertainty of market largely dispelled. Increased availability. Market segmentation. Rapid reliable distribution.
Production	Larger volume production, cost reduction, capital investment, longer runs, product standardisation. Process design. Economies of scale. Larger batches and flow processes if applicable. Standard production techniques.

<u>Status Static 2</u>

Concept Generation and R & D Support	Few innovations. Technology stabilised. Technical solutions known. Continuing emphasis on cost saving. Increased concern with behavioural aspects.
Design and Product Characteristics	Product attributes known. Design for minimum user cost. Minor product design - stress on cost of design and it's effectiveness. Use of standards 'model' changes.
Management	Political considerations may become important. Management and financial systems. Attention to group size.
Industry Structure and Competition	Market saturation, specialisation. Substitutes prevalent. Number of firms declining. Fierce competition. Large sized companies may yield sufficient economies of scale to drive rivals out of business. Market segmentation.
Capital Intensity	High due to large quantity of specialised equipment. Major inward cash flow.
Critical Human Inputs	Engineering personnel. Unskilled, semi-skilled labour, mechanistic structure most appropriate, specialisation.
Price/Demand Structure and User	Inelastic demand, customer sophistication, buyers market, information easily available. Impact on society. Sales growth slows.
Distribution and Marketing	Stability of market needs. Market attributes known. Product 'images' for designed features of quality etc. Emphasis on purchaser's life-style and user appeal.
Production	Application of computers. Long runs and stable technology. Capital intensive. Mass production. Synergy.

companies "are slow on their feet" and Lansing Henley commented that large companies are "slow to react to change". One explanation could be the organic design team structure in small companies that aids communication, but as shown earlier in this section this is now possible in large and small companies through design circles.

Product status helps to explain why small companies may be more innovative than large companies. With a static product companies that can achieve the disciplines associated with increased process design and low cost production (automation, rationalisation, specialism, dedicated machinery etc.) are most likely to succeed. These static disciplines require a large production volume and the volume which makes these disciplines viable is more likely the longer a product remains static. A larger company in an industry, or a company that has a large market share, is most likely to have the necessary production volumes to achieve the economies of scale and make the investment in automation and dedicated machinery.

On the other hand, a small company, or a company with a small market share, is unable to compete directly with the large company in low cost production whilst the product is static. But if they can make the product dynamic, so that flexible production is required and dedicated manufacturing equipment is unsuitable or unviable, they can diminish the advantage of economies of scale and can compete on more equal terms (if still at a disadvantage) with the larger companies in the industry. Innovation is expensive and time consuming and companies will not innovate unless that have to, to prevent loss of market and eventual decline. It would appear that small companies have to innovate to compete or, otherwise seek a market niche in areas which do not interest the larger companies in the industry (for example, specialist sports car companies). Large companies do not need to innovate with such urgency to compete with other large companies in their industry. The fewer the product design changes and the more stable the production the greater is their advantage. In short, a small company needs to keep a product dynamic, a large company needs to keep it static, therefore, by following their own interests, small companies are more innovative than large companies.

An exception to this occurs in certain industries, such as the drug industry and aerospace industries, where innovation is led by large companies. This is because the high costs incurred during a long period of product development without any financial return for some years precludes all but the largest companies from being involved. In such industries, therefore, innovation is limited to these large companies. Even so, the type of design undertaken in these industries is generally of a static nature.

3.2 Product Status as a Method For Forcasting and Prediction

In the main body of this research it will be shown that various factors that make a product status static or dynamic have been determined (section 6.5) and these are than developed into a questionnaire in which a company may determine the status of its own products (section 7.3). This essentially gives the product status at the current point in time, which is hardly prediction. What determination of product status can do, though, is to highlight the areas where, if changes do occur, the product status is likely to alter. Alteration of a product status from dynamic to static, or static to dynamic, is all important.

"What is of most value about the S curve is its limits" (Foster 1986).

The product can continue to be assumed to retain its current status until the 'circumstances' alter sufficiently to change the product status. This is prediction but must continue to be viewed periodically to detect early signs of change. Prediction is only useful if it is possible to act on it, knowing tomorrow's horse race winners would allow one to place winning bets, knowing the world will end tomorrow doesn't allow much scope for individual beneficial action. Knowing that a static product has become potentially dynamic, or vice versa, will generally allow a company to act to benefit from this status, or defend themselves against it, often with sufficient prior warning to allow the company's action to be planned and implemented. For example, to reconsider an electric car if a new lightweight, highpower, low cost battery breakthrough had been made, or end development of compact disc players in the light of digital tape developments.

Product status, therefore, is not a panacea for prediction but it can be more effective than S shaped curves or product life cycle curves in determining when changes are likely to occur and often in sufficient time to plan for these changes.

3.3 The Advantage of Knowing the Product Status

There are several advantages for a company to know their product status and these are described below.

1) Knowing the product status indicates whether changes need to

be, or are likely to be, innovative or incremental.

2) Knowing if changes need to be, or are likely to be, innovative or incremental allows a company to direct it's emphasis in design, production and in aspects of marketing.

3) Knowing the product status makes certain elements of the Product Design Specification more important and other elements less important. (For example, status dynamic, standards less important, patents more important).

4) Knowing the product status can simplify the design process. (For example, seeking new concepts will be of less importance and sometimes of no importance with a truly static design).

5) A static product which again becomes dynamic indicates when design and research should cease on the old concept. For example, the major developments in thermionic valves were made by the Mullard Company some years after the invention of the transistor. Design effort could have been redirected to an area with a greater long term potential.

6) If a product is known to be static it is possible to identify the extent of an innovation necessary to end the static plateau. This can direct a company:-

(a) when not to develop a new technology, eg. battery driven cars.

(b) when they should develop the new technology, eg. Sony Walkman.

7) If a company does not have sufficient disciplines (see fig. 1A page 57 and fig.1 in Appendix 1) associated with the product status of the new design, it can aid the decision on whether:-

(a) they should not attempt to enter a market (eg. a batch production company should not enter the match industry),

<u>Or</u>

(b) when a company should consider leaving a particular product market.

8) Knowing the product status can show if investment should be directed by the company towards process or product design (eg. telescopic handler producers should should direct investment towards process design). (See section 2.12).

9) Knowing the product status can show if investment should be directed by an outside funding source (eg. NRDC) into the research direction being considered by a company or academic institution.

10) A large company (relative to the competition) benefits from a design being static, whereas, a small company, though not being at an advantage, is at less of a disadvantage when a product design is dynamic. A large company should aim for static products and a small company should aim for dynamic products. (See Sections 2.13, 3.1).

11) If a product design is static and looks like remaining static for some time, market share becomes increasingly more important. This allows for greater production volumes and greater economies of scale, improved learning curves, larger (bulk) purchases of materials and better machine usage, provided demand does not fall. A greater degree of static design, therefore, can be included to enhance their competitive edge.

12) Knowing that a competitive company is operating with a particular status can indicate if their new products are likely to be static or dynamic and can, therefore, aid planning of the defence against competition.

13) If a product is known to be static the future is more

predictable and, therefore, corporate planning is easier and can be undertaken with a greater confidence of it's accuracy. Furthermore, the Product Design Specification is easier to write.

3.4 The Original Research Criteria

Criteria were written around the theories of product status. Some other aspects of design were also considered to be worthy of investigation in order to provide a framework for the subsequent design process and, therefore, some additional criteria were listed.

Next to each criterion is shown the numbers that refer to the questions that were given in the two studies (shown in section 4.5 for the pilot study and Appendix 2 for the main study). These questions endeavour to show that the particular criterion was, or was not, supported. The final criteria are shown in Appendix 1.

Company

C1) That companies holding certain positions at, or between, the static and dynamic boundaries have, or should have, the features shown in Fig. 1A. (Certain company structures and features will predominate) B5, B7, C3, C5, D1, D2, D3, F3, F7 *

C2) That companies take up a position at, or between, the static and dynamic boundaries, which maximises their chance of survival in their environment at any particular point in time. B5, B6, B7, C5, F7

C3) That certain companies should concentrate on static products and some on dynamic products. B5, B6, D1, E13, F2, F5, F7, E4, F3

C4) That some companies concentrate on static design, using the

* See page 78 for definitions.

FIG. 1A

Maximum Synthesis | Innovatory — Dynamic | Conventional — Static | Minimum Synthesis

→ Increasing Likelihood of:-

C.A.D.
Imitation
Good aesthetics
Good ergonomics
Use of reputation
Market pull

Low risk
Low profit
Short model cycle
Long product life cycle
Lower or equal research with competition
Low cost production
Quality
Reliability
Size reduction
Maintainability
Evolution
Use of materials
Effective purchasing
Stable environment
Long production runs/ small product range
Mechanistic (bureaucratic) structure
Value analysis
Reactive marketing
Cost reduction
Automation
Group technology
Rationalization
Defensive R&D
Business planning
Financial control
Standardisation
Specialisation
Economies of scale
Finish
Dedicated machinery
Assembly aids
More process design than product design

↑ STATIC ELEMENTS

← Increasing Likelihood of:-

Innovation
Technology push
Patents/Design protection
High risk
High profit
Short product life cycle
Higher research than competition

Seeking new concepts
Non croduct related research

Changingenvironment
Flexible production
Short production runs/ large product range
Dynamic and reiterative planning
Creative marketing
Innovation seeking outside of industry

Organic structure

↑ DYNAMIC ELEMENTS

design of others and this is an effective successful policy and predetermined strategy. B5, D1, D2, D3, E4, E5, E6, F3

C5) That certain (Japanese) companies have been successful largely through:-

a) early recognition of the static plateau

b) using innovations from the West

c) by maximising static design and production technology

E14

C6) Appreciation of the product status can enable a company to organise its management strategy for optimum efficiency. B4, B5, B6, B7, B8, B11, C3, E1, E2, E3, E4, F3

C7) Companies with static products tend to be large, whereas companies with dynamic products tend to be small. (Companies move from innovative to positional as they grow) E2, E3, F3, F4, F6

C8) Having a truly static product and stable technology makes it unnecessary for a company to innovate that product. A4, B5,B6, B11, D1, D2, E12, E13, F3, E5

C9) Design must be coupled with efficient marketing (research and sales) and production. Weaknesses in any one of these areas will cause a product to fail. B8, E6, E7, E9, F3

Product

P1) That some products are static and some dynamic. A4, A5, B4, B5, B6, C2, C5, E4, E6, E13, F7

P2) That statically designed products have more success in the market place (over the mature period of the product when sales are highest). A1, A3, B3, B6, B7, B9, E6, D2

P3) Products that are still dynamic fail in the market through insufficient attention to the disciplines of static design. A3, B7, B12, C5, E6

P4) That early recognition of the static plateau can, in some cases, enable a company to set standards. A1, A3, B6

P5) That is is possible to create/predict the static plateau. D3, E7, E14, D1

P6) That it is possible to identify/quantify the value of innovation necessary to cause a static product to again become dynamic. A5, B11, B12, D1, F2, D4, D5

P7) Maximising market share must inextricably be tied up with maximising static design, in order to be successful. B3, B7, B9, B10, C3, D3

P8) Innovation of a product follows a curve, Fig.2. C1, C2

P9) Product price of new product follows a curve, Fig.3. C6

P10) A product design iterates to one common design and the speed of this iteration is related to the effectiveness of the original P.D.S. within existing technology. A4, B6, C4, E7, E8, E9, E10

P11) That it is possible to list in order the value, or importance, of elements in the the P.D.S. for certain categories of products (eg. price, aesthetics, ergonomics etc.). C3, C5

P12) The importance of innovation in the West is overrated and is less important than static design, marketing and production for nearly all companies. B5, E5, F3, F7

Management

M1) Appreciation of the product status highlights strengths and

FIG. 2

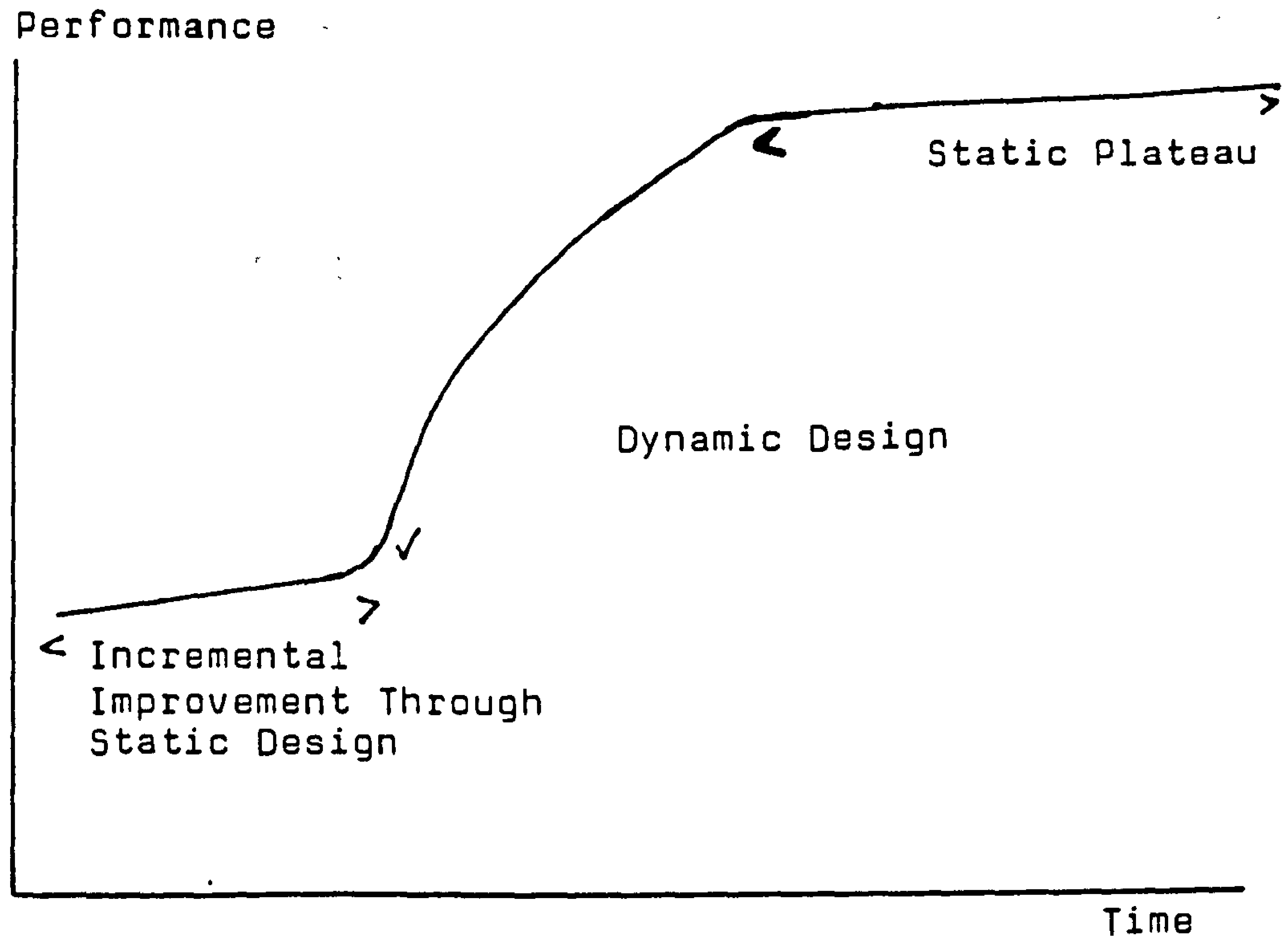
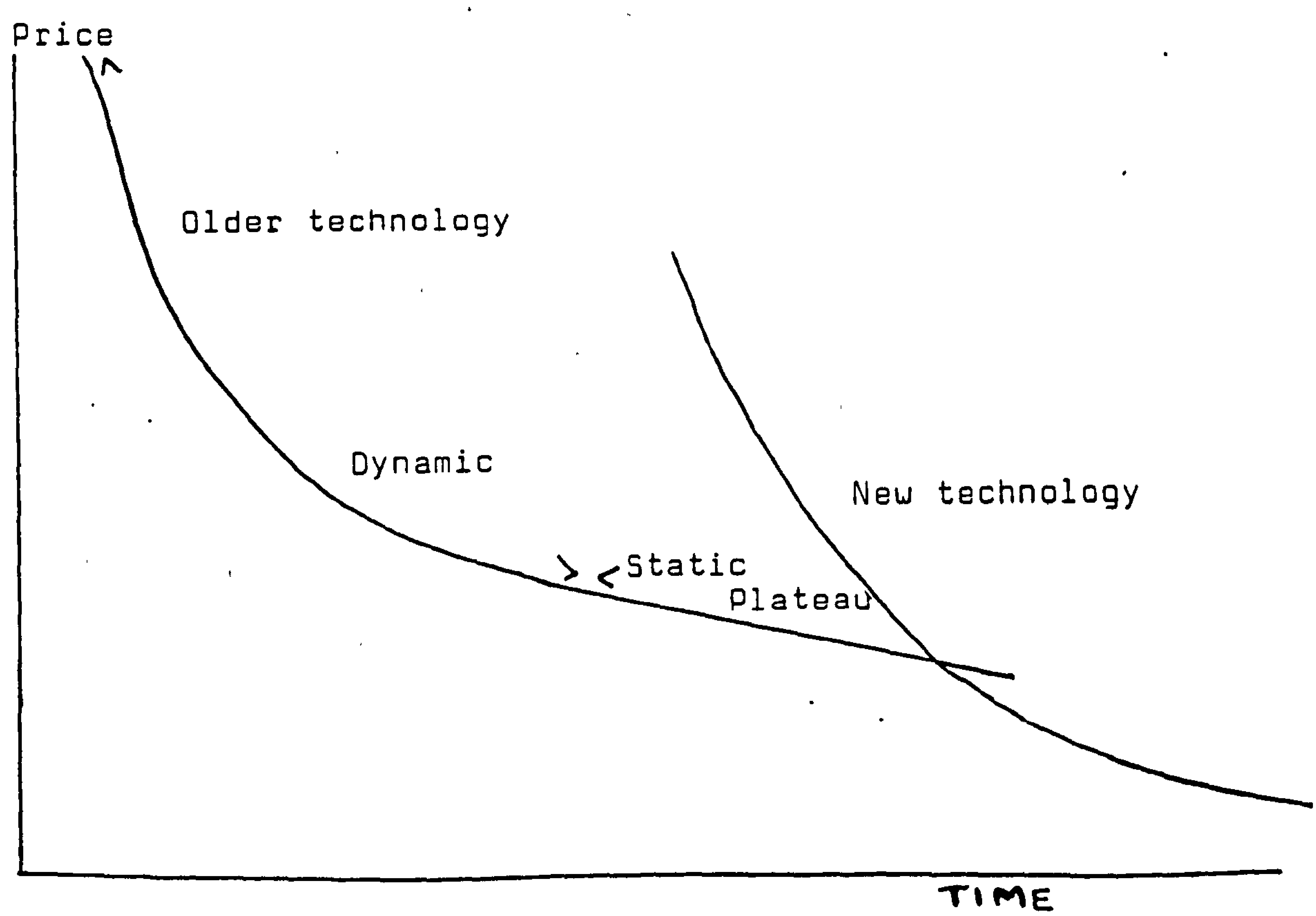

Performance
Static Plateau
Dynamic Design
Incremental
Improvement Through
Static Design
Time

FIG 3


Price
Older technology
Dynamic
New technology
Static
Plateau
TIME

weaknesses in the product design group and other areas of company operation (marketing production etc.). B7, C5, D1, D2, F3, F6

M2) That company personnel must seek and evaluate new innovations to determine if a product is to again become dynamic. B2, E12

M3) That static design benefits from/requires a mechanistic structure and dynamic design benefits from/requires an organic structure. E1, E2, E3, F4

M4) That the company structure provides a mantle in which design operates and this determine what type of design is undertaken. E11, F1, F2, F5

3.5 Reasons for the Research Criteria

Company (C)

C1,C2) As products change from being static to dynamic and back to static, over a period of time, the company structures that succeeded or failed will indicate the optimum structure, at each stage, which could then be specified in terms of disciplines most suitable for that product with this status. (Sections 2.9, 2.13, 3.1, 3.3)

C3) If a company has a certain structure and, for whatever reason, cannot, or will not, change, it can be suggested on which type of design that company should concentrate. For example if a company has purchased dedicated machinery they may be advised to concentrate on static design. (Sections 2.1, 2.9, 3.3)

C4, C5) These criteria describe the 'imitators', which are companies that adopt a recently static product and improve it through static design to take the market. These criteria attempt to show that this can be both a successful and effective company policy. (Section 2.9)

C6) This is the most important criterion in this section and, by analysis of strong companies and through recognition of product status, it is believed to be possible to formulate a management strategy to guide a company through the process of product design. (Section 8)

C7) It has been stated in the literature (Burns and Stalker 1961; Andrews 1975; Ohmae 1983) that large companies are unable to respond quickly to change due to:-

a) their proliferation of dedicated machinery and

b) their bureaucratic structure.

This study may reinforce this or refute this. (Sections 2.5, 2.6, 2.9, 2.12, 2.13, 3.1, 3.3)

C8) If a product status is known to be static there may be no need for a company to seek new concepts, as long as they keep a search for, and are aware of, the prospects of a product, again, becoming dynamic. (Sections 2.9, 2.10, 3.3)

C9) Differing reasons for success and failure were sought, in the study, to show if any one area in marketing, production and design is any more important than any other. (Sections 2.12, 2.13,3.1, 6.7)

Product (P)

The criteria, in this section, are considered to be the most important of the three sections as they are more concerned with the design of products.

P1) It was believed that the recognition, that some products are dynamic and some are static at certain times, is not sufficiently well appreciated by manufacturers. As differing strategies for design are thought to be required for each type of status, it is considered important that companies understand the difference between the two in order to direct and optimise their design management. (Sections 2.1, 2.6, 3.2, 3.3, 7.1)

P2, P3) It was believed that statically designed products have more success in the market place and companies that concentrate more on the disciplines in design of static products appear to survive, whereas the innovators of many products have failed to capitalise on their innovations (eg. calculators, video recording machines, digital watches, computers). Companies that innovate or invent appear to fail to appreciate when products have reached a static plateau and, therefore, continue working as if the product is dynamic, thereby, not sufficiently emphasising those static disciplines, which are needed to produce effectively. This results in them losing their market to other companies that do inject more static design into their products. (Sections 2.6, 2.7)

P4, P5) The setting of standards and the creating of a static plateau is thought to be important for a company in deciding when to concentrate on static design and low cost production. This may be more important with mass production where dedicated machinery is used, but this research has attempted to show if this was also important for batch produced products, where the production machinery tends to be more flexible. This project also attempted to identify how companies set the static plateau. (Sections 2.12, 2.13, 6.5)

P6) This research involved a determination of what causes a product's design to change and, also, the degree of improvement required to overcome the infrastructure built around the existing design. For example, a change in the shape of the packet of soap powder is more likely to be easily accepted, by the market, than a more radical change, such as a proposed introduction of LPG for car motivation. (Sections 3.3, 7.1, 6.5)

P7) This criterion is to do with economies of scale and the cost reduction brought about by static design. Maximising static design may not be so important for a batch produced product in a small market. The research attempts to make comparisons between production technology, market size, competition and the extent to which static design should be undertaken. (Sections 2.9, 2,12, 2.13, 3.1)

P8) A measure of performance had to be determined to show this criterion. In shock absorbers it was damping force. (Sections 2.1, 6.3)

P9) The accuracy of this criterion depended on the selling or manufacturing price, making allowances for inflation. (Sections 2.9, 2.12, 6.3)

P10) The variation in the designs over a period of time can be shown up, partly through the results from the interviews, but also by parametric analysis (Section 6.8), to detect if the designs from various manufacturers were iterating to one design. This is more likely to be shown with a product which has been static for a number of years. It was also thought that it could be observed in one company's changes to a product over time. (Sections 2.11, 2.12, 2.13)

P11) It was hoped to show an order of importance for various elements in the P.D.S., by finding what the various manufacturers consider important in their product's design in that market and then see if there was any consistency between answers from the various manufacturers of the same product and then between products. As design is usually a compromise between the various elements in the P.D.S., this will allow the important elements to be recognised and given a greater emphasis in product design. This would also confirm, or not, the importance of 'non-price' factors in engineering design, as outlined in the Feilden Report (1963). (Section 6.6.)

P12) There is a general call for companies to innovate. This criterion attempted to show that some companies would be advised not to innovate their product at certain times and that incremental design would be more advisable. (Sections 2.1, 2.6, 3.1)

Management (M)

M1) The study of products shows what type of managment and design teams operate most efficiently, as the product moves from dynamic to static and, therefore, the optimum structure to be specified, depending on the product status. (Sections 2.1, 2.6, 2.9, 3.1)

M2) Even if a product is static, one must be aware of any innovations that are likely to again cause the product to become dynamic. Threfore, people will be needed to search out likely innovations, unless it can be demonstrated that a product is certain to stay static in the foreseeable future. This study attempts to show if companies were consciously searching for inventions that were likely to cause their products to become dynamic again and the manner in which they sought these innovations and inventions.

M3) It was thought to be possible to verify the work of Burns and Stalker (1961) in this study. (See Sections 2.5, 2.6)

M4) Whether a company chooses to continue designing or manufacturing a product, when the design becomes static or dynamic and whether they will be successful, depends on the Management structure, which must direct resources into the most beneficial areas. This research attempts to highlight if the companies involved decided what policy they were going to take and whether they were providing the right and sufficient resources, so that these plans could be fulfilled. Also, it attempted to show that, when a product status was changing, whether the management appreciated the fact and changed the structure to match the changing environment. (Section 2.9)

4.0 THE RESEARCH METHOD

4.1 Description of the Research Method

Having identified a suitable research area the literature under surveillance narrowed and included more specialist academic papers.

A list of criteria was written concerning the existence of product status, how it could be determined and how it could be of benefit in the management of design.

It was believed to be important to look at actual products in the research rather than broad company strategy. Looking at company strategy, especially a company with several different products in it's range which may require differing organisation of their design, could well blur the existance of product status and indicate that a company should concentrate on all aspects of design all the time. By looking at a particular product these differences could be identified and highlighted.

A product well defined and well understood by this author was chosen for the pilot study i.e. heavy duty shock absorbers for military vehicles. At that time no thought was given as to whether this product was likely to be static or dynamic, there was no attempt to prejudge the issue.

Various methods were considered that could be used to obtain the necessary information before the structured interview was chosen (section 4.2). This required a complete questionnaire to be compiled and this was duly written (section 4.5) and refined throughout the two studies. The final questionnaire is shown in Appendix 2.

All possible U.K. manufacturers of heavy duty shock absorbers for military vehicles were contacted by letter and a senior member of the management concerned with product design interviewed.

The pilot study encompassed four companies. One other company (Dunlop) were testing a hydropneumatic military vehicle damper in South America but they refused to be interviewed and they have not, subsequently, produced for this market. Dowty Rotol have a design of a rotary damper and hydropneumatic suspension but they have not been granted a development order from the Ministy of Defence nor have they, as yet, a product and therefore they were excluded from the study.

Several other companies were contacted but they confirmed that they have never, or no longer, make dampers for military vehicles. The Armstrong Patent Company do manufacture shock absorbers for military vehicles but all the dampers they supply are standard units with slightly uprated valve opening pressures. Special designs have not been undertaken for many years, nor are planned in the future for this market, which the company considers is too small and they prefer to concentrate on large quantity mass production. Armstrong were, therefore, excluded from this study after a discussion with their Applications Executive Engineer.

The interviews, in each case, took about one hour. An exception to the interview method occured with 'D' deciding at the first interview that they would like prior knowledge of the questions, in order to consider their answers. This was made a condition for doing the interview and, therefore, a copy of the questionnaire was left with the Technical Director for a period of two months.

The results were fully analysed and written up before proceeding to the main study. The results were as good as this author hoped and very few changes were considered necessary in the approach taken for the main study. A more formal collection of feedback from the interviewees was introduced.

The pilot study had shown that heavy duty dampers for military vehicles was a dynamic product and, therefore, for balance in this research, a product suspected of being static was chosen for the main study, which was rough terrain telescopic handlers. After analysis of the pilot study results, the criteria and questionnaire were revised, which reduced the interview time to, approximately, forty-five minutes.

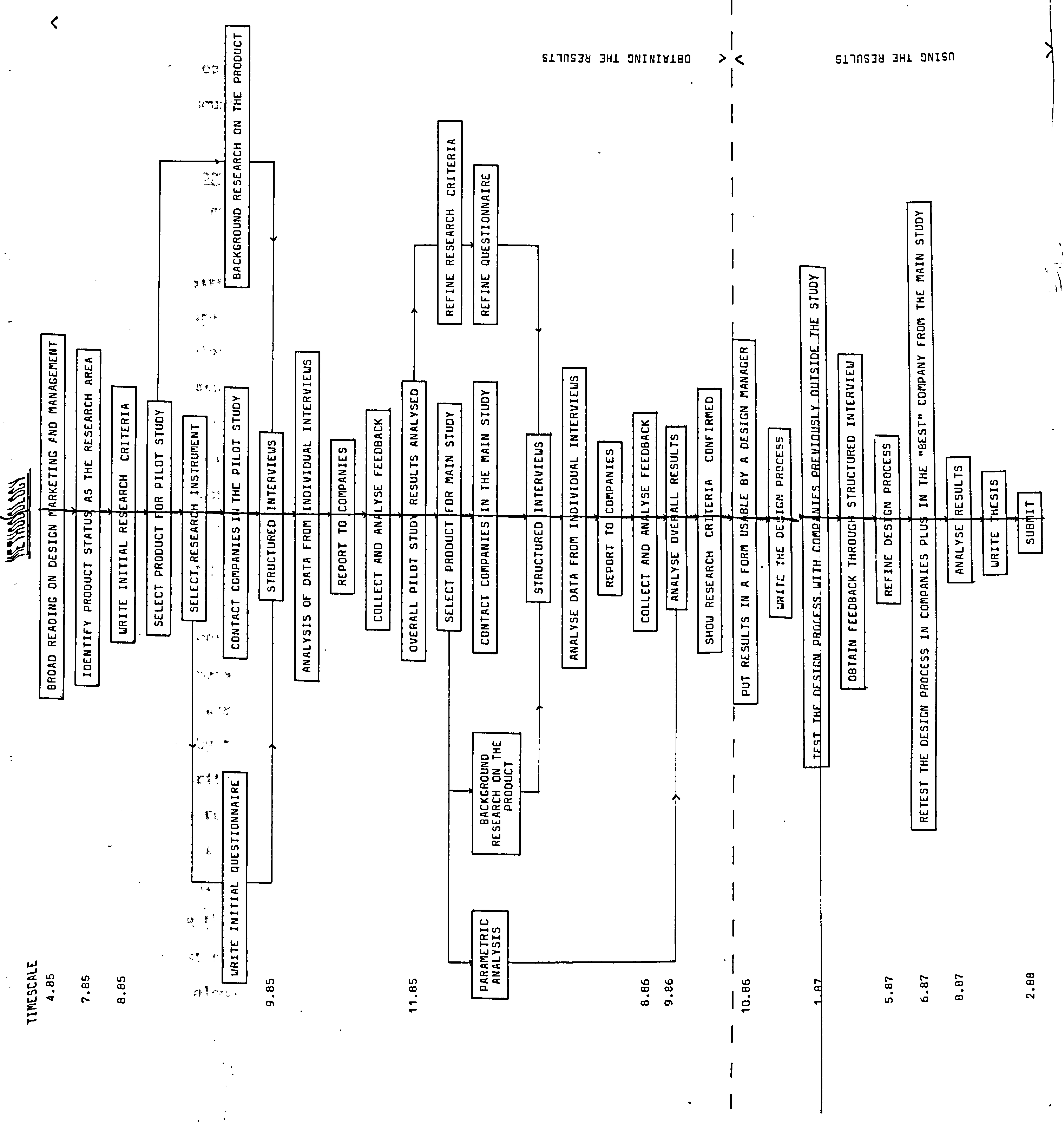
All twelve companies that manufacture or sell rough terrain telescopic handlers on the British market were contacted by letter and a senior member of the design or marketing management was interviewed in all these companies, with the exception of Finlay. This small company manufactures a few telescopic handlers for the construction industry and is based in Northern Ireland. It was not possible to arrange a meeting with anybody from this company. 'G' required additional information on the study before agreeing to be interviewed. The most senior person available to be interviewed in Britain from Sambron was not directly involved with design at a senior level (Regional Manager), but the answers he gave are considered acceptable to this author.

During this period parametric analysis of telescopic handlers was carried out, after a collection of information from catalogues and magazines (mainly Contract Journal, P.M.J. and Construction Weekly) over the period that companies had been manufacturing telescopic handlers. This information was plotted and graphs analysed (Section 6.8). Competition analysis of all the manufacturers was also undertaken, to compare aspects of the design and the changes that have occured over time, noting when the various competitors entered the market with the product and their subsequent success and progress. From this it could be seen that the product manufacturers had certain features that were an advantage or detrimental at certain times over the life of the product design and these were the more or the less successful companies at these times, as identified by a review of relative market standing (section 6.7, Appendix 3).

The overall results were analysed to show the evidence of product status, how it could be determined and what disciplines should accompany the design of a product with a particular status.

The next stage of the research was to put these findings into a form, which could be used by design managers. To show when and how she/he should find her/his product's status, the status questionnaire shown in Section 7.3 and for directing her/his product's design, an improved Design Process, which is described in chapter 8.

This Design Process was then offered to the type of people that were likely to use it in order to gauge their opinion. Three firms were chosen, who manufacture products quite different to those from which the system was developed and this is described in chapter 9. The purpose of this being to show that this Design Process was suitable for use with a wider range of products. Having gained approval the final version was supplied to the Product Engineering Manager from one of the companies in the main study, which was known to be successful in the market place and were well organised in


TIMESCALE
4.85
BROAD READING ON DESIGN MARKETING AND MANAGEMENT
7.85
IDENTIFY PRODUCT STATUS AS THE RESEARCH AREA
8.85
WRITE INITIAL RESEARCH CRITERIA
SELECT PRODUCT FOR PILOT STUDY
BACKGROUND RESEARCH ON THE PRODUCT
SELECT RESEARCH INSTRUMENT
WRITE INITIAL QUESTIONNAIRE
CONTACT COMPANIES IN THE PILOT STUDY
9.85
STRUCTURED INTERVIEWS
ANALYSIS OF DATA FROM INDIVIDUAL INTERVIEWS
REPORT TO COMPANIES
COLLECT AND ANALYSE FEEDBACK
11.85
OVERALL PILOT STUDY RESULTS ANALYSED
REFINE RESEARCH CRITERIA
REFINE QUESTIONNAIRE
SELECT PRODUCT FOR MAIN STUDY
BACKGROUND RESEARCH ON THE PRODUCT
PARAMETRIC ANALYSIS
CONTACT COMPANIES IN THE MAIN STUDY
STRUCTURED INTERVIEWS
ANALYSE DATA FROM INDIVIDUAL INTERVIEWS
REPORT TO COMPANIES
8.86
COLLECT AND ANALYSE FEEDBACK
9.86
ANALYSE OVERALL RESULTS
SHOW RESEARCH CRITERIA CONFIRMED
OBTAINING THE RESULTS
USING THE RESULTS
10.86
PUT RESULTS IN A FORM USABLE BY A DESIGN MANAGER
WRITE THE DESIGN PROCESS
1.87
TEST THE DESIGN PROCESS WITH COMPANIES PREVIOUSLY OUTSIDE THE STUDY
OBTAIN FEEDBACK THROUGH STRUCTURED INTERVIEW
5.87
REFINE DESIGN PROCESS
6.87
RETEST THE DESIGN PROCESS IN COMPANIES PLUS IN THE "BEST" COMPANY FROM THE MAIN STUDY
8.87
ANALYSE RESULTS
WRITE THESIS
2.88
SUBMIT

design. His opinions of the process were gauged by questionnaire and telephone discussion.

4.2 Methodology to Investigate the Research Criteria

(How the evidence was collected)

In choosing what is believed to be the most effective method, several different methodologies were considered.

1) Unstructured Interview. The advantage of this is that it is direct and relatively quick, but can produce a large amount of unusable or unnecessary data and, furthermore, there may be a lack of consistency due to the same questions not being asked, or not being asked the same way of each interviewee, which would almost certainly affect or distort the results obtained. This method was, therefore, considered inefficient at probing the areas of interest.

2) Postal Questionnaires. These have a poor response rate and, in this research, it was necessary to obtain answers from practically all the producers in both studies for the results to have any validity. Generally postal questionnaires are supplied with an indication of the answer and, with the area under investigation, it was believed by this author to be necessary not to imply an answer with the majority of the questions. Furthermore, a postal questionnaire restricts questioning or querying the interviewee and, therefore, could necessitate a follow up questionnaire. This method was, therefore, considered inadequate for this research.

3) Combining the above two methods into a structured interview overcomes most of the aforementioned disadvantages of either the methods used alone. An interview structured around a questionnaire

ensures that each interviewee is asked the same question, but there is little restraint on their answers and follow up questions to aid clarification may be asked. The structured interview was chosen. The wording of the questions was carefully chosen to avoid bias or implied answers. This was written after reference to several books on interviews and on questionnaire construction (Canell and Kahn 1968; Kerlinger 1973; Krech et al 1962; Zimbardo and Ebbeson 1970; Eiser 1980).

Kerlinger (1973) proposed the following guidelines, which were followed:

> "Make sure each question has a purpose related to the research problem",

which, in this case, was to probe the criteria and

> "Use vocabulary which is familiar to the respondent. Sequence questions and prefactory material to facilitate the respondent's organisation of thought".

The questions were simply worded and followed a logical sequence and no difficulty was expressed by the interviewees with these.

The questions were mostly of the 'open' type, where the respondent could offer answers he felt were suitable. This allowed the introduction of ideas that may not have been considered by this author and the advantages of this were considered to outweigh the extra difficulty in analysing the answers that this type of questionnaire brings.

Part of the questionnaire included attitude measurement of the importance the interviewee considers on certain aspects of design. For this a "summated rating" scale, as developed by Likert (1932) was used. Other such attitude measurements were considered (Thurstone 1929, Osgood 1955, Haire 1950, Kutner 1952 in Oppenheim 1966), but the Likert scale is the most compact, simplest and has been shown to give repeatable results that correlate highly with other methods.

The structured interview achieved results in a relatively short time and it was possible to tell the interviewee that the session would take lass than one hour (although some sessions took longer if the interviewee gave long answers or wished to discuss this research).

The advantage of meeting the individuals in their companies was that it allowed this author to explain this research work and it's purpose and to answer any questions that they may have had and to put them at ease. They were also able to question this author's experience.

The disadvantage of the structured interview technique was that the accuracy of the entire process relied on the accuracy of the answers given by the interviewee. The interviewee may not have given accurate answers, perhaps due to individual bias or grudge, but also many of the questions were open to individual interpretation. Checks against this were included in the questionnaire and some questions were asked in two different ways, in order to detect any drift from accuracy. Before the interview, a written undertaking was made, that all information would be treated in the strictest confidence, which may have added to the accuracy of the answers given, as a company had nothing to gain by supplying false information, whereas they may have had something to lose, as all were promised a report on this author's findings concerning their company. Such a report would be worthless to them had it been based on false inputs.

The broadest view of design in a company was believed by this author to be obtained from the most senior person who had day to day dealings with product design. In most every case this person was interviewed.

4.3 Reinforcement to the Main Research Method

To reinforce the results of the structured interviews an analysis of the product was undertaken. This gave allied information, which confirmed or refuted the interview answers. This product analysis was undertaken in parallel with the structured interviews in the main study and took three forms:- parametric analysis, which enabled similar products to be compared, parametric analysis over time, which showed trends and changes in the market and showed what companies were the design leaders and which were the followers. These are shown in Section 6.8. Market size and companies' share of that market was also found, which showed the leaders and also shows which companies were growing and which were contracting. (Appendix 3).

To confirm that the use of the structured interview was the correct choice it was necessary to look at alternative methodologies for collecting the research data. A case study may have given more accurate answers than the structured interview. The disadvantages of this are threefold:- it is unlikely that some of the companies used in the research would have given permission to allow sufficient access to make a case study worthwhile. The case studies for all the companies would need to be made in parallel, which would have been difficult to organise, even if the companies were in agreement to this and confidentiality may have been difficult to maintain.

As this author was only looking at one product within a company product range the case study would have to coincide with a period when the company was actually designing the product. In certain companies design of the product was in progress, but in others it had temporarily ceased and two companies undertook their design abroad.

For the above reasons the methodology was chosen, which, it is believed, shows that the chosen area is researchable and gives accurate and valid results.

4.4 Evidence of Care and Accuracy

The accuracy of the results obtained was confirmed through cross checking and through the use of feedback. After each company visit a report was written to the company describing the findings. This was followed by a telephone discussion with the person interviewed to identify any areas of the report which were unclear or wrong. A feedback questionnaire was also sent and these were filled in and returned by the interviewees (Section 6.9).

After the pilot study and the initial questionnaire had been restructured to improve the quality and accuracy of the results, an attempt was then made to check the accuracy of the second questionnaire. Prior to the research period this author had been employed in product design in the company Castell Safety International Ltd. from February 1978 until the end of August 1984. The operation of design and the company structure was, therefore, well understood. The second questionnaire was completed by this author as if he were still holding this position in this company. An attempt was then made to have the same questionnaire answered by the Technical Director of Castell Safety International Ltd. This, it was believed, would highlight differences in interpretation, any questions that were unclear, subject to individual bias, as well as show any areas that could be misinterpreted by the interviewer or interviewee. The intention was to compare the answers as predetermined by this author with those obtained at the interview. Unfortunately, this could not be arranged.

In the event in two of the study companies ('D' and 'G') answers were obtained from two people in each company, which highlighted the affects of individual bias. It was felt, though, that a rare opportunity to confirm the accuracy of the questionnaire under controlled conditions was lost.

Company 'H' had undergone considerable changes in their management personnel in the previous few years and, therefore, there was nobody in the company of sufficient status who could describe first hand experience of the company five years ago. To overcome this the questionnaire was given to the current Marketing Manager, who had been with 'H' for 2½ years and the questionnaire was also given to the former Managing Director, now working elsewhere, who could answer the questionnaire as the situation existed five years previously.

Manitou were visited twice with a five month gap between the interviews and the questionnaire was given in two parts, but some of the questions were asked at both of the interviews, this enabled a cross check to be made for consistency and, fortunately, answers were consistent. An example was in the interview the questions was asked (E5), "Indicate on table 3 the elements you consider in your predesign product specification". At the second interview the question was asked, "Indicate on table 3 the elements you do not consider in your predesign product specification".

Finally, during the writing of this thesis all reference to the companies mentioned were sent to these companies with a request to use their name and also asking for any comment on these references. This gave the companies an opportunity to identify or indicate any parts that they felt were inaccurate.

The questionnaire used in the pilot study is shown in the next section and the one in the main study is shown in Appendix 2.

4.5 Original Questionnaire

Interviewee

Position

Years in the Company

	Criteria No. *
(A) History of the Product	
1) Who was the first company to bring this product onto the market? Were they the inventors?	P2,P4
2) When did your company start manufacturing this product?	
3) Was the design improved here? In what way?	P2,P3,P4
4) How has the product design changed or been modified since it entered production? And why?	C8,P1,P10
5) What events in the past have made the biggest change to your market for this product?	P1,P6

* See Original Research Criteria on page 56.

(B) Competition

1) What companies do you consider are your competitors?	
2) How do you determine what your competitors are doing in the field of new products?	M4
3) Are the number of your competitors increasing or decreasing?	P2,P7
4) Which of your competitors do you consider are innovative? (Or the design leaders?) In what way?	C6,P1
5) Are your company's product designs innovative?	C1,C2,C3,C4, C6,C8,P1,P12
6) Has the design of this product from all the competition tended to one basic design or have there been some radical changes? When did these occur?	C2,C3,C6,C8, P1,P2,P4,P10
7) Is your market share for this product increasing, remaining static or decreasing?	C1,C2,C6,P2, P3,P7,M1
8) Why do you think this is?	C6,C9
9) What percentage market share do you estimate you have for this product in Britain? Worldwide?	P2,P7
10) Do you consider that market share is more or less important than securing a profitable segment of that market?	P7
11) How long do you consider it will be before this product will be replaced by another product from you or your competitors?	C6,C8,P6
12) What do you think are the major threats for this product market?	P3,P6

(C) Product

1) How do you measure the performance of this product? P8

2) How has the performance improved in the past (five) years? P1,P8

3) Indicate on table 1 the level of importance you place on this particular product's features. C1,C6,P7,P11

4) Are design changes or modifications ever made to the product on the production line? For what reason? Do you have a formalised design change procedure? P10

5) What type of changes are you making to this product to increase, maintain or prevent a decline in it's market position:- C1,C2,P1,P3, P11,M1

a) Cost reduction?

b) Improved reliability?

c) Changes in material?

d) Seeking a new concept?

e) Seeking an alternative market for the product?

f) Product size reduction?

g) Improved appearance ?

h) Greater financial control?

i) Improved distribution or selling methods?

j) Reduction of scrap (improved quality)?

6) Do your price rises for this product follow a similar rise to general inflation or does it follow a different curve? If different please draw it. P9

TABLE ONE PRODUCT QUESTION 3

	VERY IMPORTANT	IMPORTANT	NEITHER IMPORTANT OR UNIMPORTANT	UNIMPORTANT	VERY UNIMPORTANT
Reliability					
Low Price (In comparison to Competition)					
Advanced Technical Features					
Appearance					
Ease of Use					
Colour					
Strength					
Maintainability					
Finish					
Other?					

(D) Production

1) Is any dedicated machinery used in the production of this product by you or your subcontractors? Is the production becoming more flexible? C1,C3,C4,C8, P5,P6,M1

2) Is more process design undertaken than product design? C1,C4,C8,P2, M1

3) Were any new machines obtained for the production of this product? C1,C4,P5,P7

4) Are some design improvements not undertaken to avoid disruption of production, catalogues, replacement parts, interchangeability or because you haven't the machinery to produce them etc? P6

5) Are some of these design improvements quite fundamental or innovative? P5

(E) New Product Design

1) Which departments and who from these departments decide on the designs that will be undertaken? C6,M3

2) Draw a 'family tree' showing the relationship of those in design/development/research. C6,C7,M3

3) Has the structure of this 'family tree' altered in the past (five) years? C6,C7,M3

4) Is any research undertaken which has no clearly defined product direction? C4,C6,P1,C3

5) Do the designs of your competitors ever influence you? C4,P12,C8

6) With these products do you ever achieve a greater success than the originators and if so to what do you put this down? C4,C9,P2,P3,P1

7) What is included/considered in the predesign specification? C9,P5,P10

8) Indicate on table 2 the elements you consider in your predesign specification? E8

9) Is it a written document? P10,C9

10) Who is involved in compiling this specification: a) design b) sales c) production d) finance e) market research f) others? P10

11) Do you follow a set process or model for design? Could you draw this model? M4

12) Do you look at innovations outside your industry which you can incorporate into you products? C8,M2

13) Do you use C.A.D? If so do you use it for all new product design? C3,C8,P1

14) Does a new product stay in the design stage until all the specification criteria are reached or is a date set for production and the product produced on that date regardless of whether the product can be further improved? C5,P5

(F) Management

1) What guidelines are laid down by management for the design of products? Do you have a design policy and who makes it? M4

TABLE TWO NEW PRODUCT DESIGN QUESTION 7A

ELEMENTS OF SPECIFICATION

Quality		Packing	
Materials		Weight	
Product Life Span		Market Constraints	
Politics		Manufacturing Facility	
Company Constraints		Shipping	
Safety		Size	
Testing		Processes	
Environment		Customer	
Patents		Time Scale	
Shelf Life + Storage		Product Cost	
Reliability		Performance	
Quantity		Life in Service	
Competition		Ergonomics	
Maintenance		Standard Specifications	
Selling Price		Aesthetics	
Climatic Influences		Energy Consumption	
Chemical Influences		Installation	
Other?			

TABLE THREE MANAGEMENT QUESTION 3

	VERY STRONG	STRONG	NEITHER STRONG NOR WEAK	WEAK	VERY WEAK
Design					
Distribution					
Purchasing					
Good Reputation with Customers					
Design Protection					
After Sales Service					
Market Research					
Sales Force					
Financial Control					
Economies of Scale					
Corporate Planning					
Value Analysis					
Assembly Aids					
Use of New Materials					
Production Flexibility					
Low Energy Use on Production					
Cost Reduction Techniques					
Automation					
Improving the Design of Others					
Technical Advance					

TABLE THREE MANAGEMENT QUESTION 3/Contd...

	VERY STRONG	STRONG	NEITHER STRONG NOR WEAK	WEAK	VERY WEAK
Dadicated Machinery					
Research					
Formal Inter-Departmental Communication					
Other?					

2) Must any design undertaken be manufactured by the production facilities available?	C3,P6,M4
3) Indicate with a tick on table 3 the level of strength or weakness you consider on this company's performance.	C1,C3,C6,C7, C9,P12,M1,C4
4) Does regular formal communication (eg. design review meetings) occur between all levels of staff in all departments or only between heads of department?	C7,M3
5) Does management encourage or support innovation or incremental design only?	C3,M4
6) How many people are employed in the company? What number in a) production b) sales c) financial d) design?	C7,M1
7) Does this company generally protect new designs for example by patents?	C1,C2,C3,P1, P12

The question numbers between the original and revised questionnaire were altered. The comparison is shown below with the original question numbers and next to it the equivalent number in the revised questionnaire.

Original Questionnaire	Revised Questionnaire
1A	1A
2A	2A
3A	)3A
4A	)
5A	4A
1B	1B
2B	2B
3B	3B
4B	4B
5B	Dropped
6B	5B

7B	6B
8B	7B
9B	8B Enlarged
10B	9B
11B	10B
12B	11B
1C	Dropped
2C	Dropped
3C	1C
4C	2C
5C	3C,4C Enlarged. Also with changes over time
6C	Dropped
1D	) Included elsewhere
2D	) (5F)
3D	1D
4D	2D
5D	3D
1E	1E
2E	Dropped
3E	Dropped
4E	Included elsewhere (5F)
5E	2E
6E	3E
7E	4E
8E	5E
9E	6E
10E	7E
11E	8E
12E	9E
13E	Included elsewhere (5F)
14E	10E
1F	Included elsewhere (6F)
2F	Included elsewhere (6F)
3F	1F,2F Enlarged. Also with changes over time
4F	3F
5F	Included elsewhere (6F)
6F	4F
7F	Included elsewhere (5F)

11E,5F and 6F are new questions that include the components of the questions designated 'included elsewhere'.

4.6 The Structured Interview Questionnaire

Reasons for the Questions

The combination of several answers may be necessary to confirm a criterion, which explains why the same criterion number appears next to several questions. Likewise, the questions have been structured so that the answers will go part way to upholding or rejecting several criteria.

Care was taken in constructing the questions, so that the interviewee would not feel that he was disclosing sensitive information. As the pilot study concerned products used on military vehicles often these products are subject to the Official Secrets Act, it was gratifying to find that no question was refused an answer, albeit a declaration of confidentiality was provided before the interview began.

The basis of the questionnaire was aimed at discovering if the companies involved in the product appreciated the product status and whether they structured themselves to benefit from this product status. This involved questions on the presence of static and dynamic design disciplines and also if the management and organisation encouraged and optimised the situation, considering the status of the product. Questions were also asked on the success of the company to see if the more successful companies were better organised for the current status of the product.

The whole questionnaire was designed to give a picture of the company and product design operating within management constraints.

(A) History

In this section questions were asked to determine the product history and whether the changes made were static or dynamic (1A, 2A, 3A).

(4A) to find if the changes were technology or market led or whether there was a market shift or change in specification.

(5A) aimed to determine if the company gained or lost by the action of a competitor, legislation etc. and whether they were caught out by the change.

(B) Competition

The questions were aimed at determining the extent that the company considers competitive products and how they determine what their competitors are doing, as well as looking at the market for the product.

(1B) to find out if they know who their competitors are; and why they consider them competition. How wide ranging they consider their competition and, maybe, to mention any competitors that this author may have overlooked.

(2B) to find out how important they consider competition analysis and how they go about it.

(3B) this was to show if the market is growing or declining or if a few dominant companies are emerging, also if the company was growing relative to the competition.

(4B, 5B) aimed to find out what the interviewee considers is innovation and whether any companies, making the product, actually are innovative.

(6B) was to find if the product is dynamic or static or has iterated to one design.

(7B) was to show if the company is improving upon or being outpaced by the competition. This was compared with company strengths and weaknesses to suggest the optimum structure.

(8B) this showed the interviewee had analysed the situation and had developed a management strategy.

(9B) knowledge of the market share, or lack of it, by the interviewee indicated the importance he placed on it.

(10B) it has been noted that Japanese companies tend to seek a large market share, whereas British companies seek profitable segments in that market. It was hoped to discover the most successful policy.

(11B) it was hoped that this would show if the company was seeking the end of the static plateau.

(12B) this question was to find out if the interviewee considers competition, legislation, economic climate etc., as affecting viability.

(C) Product

In this section questions were asked about the product now, including design changes currently being undertaken.

(1C) was to determine what the producer considers important for his product and to place in order of importance some elements of mainly static design.

(2C) this question showed production stability and examples of change in specification and static design.

(3C) to see if the elements in the P.D.S. can be graded for importance.

(4C) to judge production stability.

(5C) the current situation was questioned to show static design (a,b,c,f,g,j) dynamic design (d), perhaps, stagnant or no design (e,h,i,).

(6C) this was to see if there was a price/time curve for this type of product. It was suspected that certain products follow a particular curve - the reduction in price of electronic products is often cited.

(D) Production

This section determined the static and dynamic disciplines and whether the static plateau was created or extended.

(1D) this gave an indication if the product was being treated as static and to detect a possible 'bar' to the product again becoming dynamic.

(2D) this was to verify that process design becomes increasingly important with a static product.

(3D) this could indicate the creation of a static plateau.

(4D) this could indicate the extension of a static plateau.

(5D) again, this could indicate the extension of a static plateau through prevention of the product again becoming dynamic. It also indicated the degree of improvement required to change the design.

(E) New Product Design

In this section enquiries were made as to the way the company operates product design, regarding methods, specification and people involved in the design process, as well as finding out if design is formally organised.

(1E) was to find the inputs to the design process and if the structure is organic or mechanistic.

(2E,3E) was also to indicate the flexibility of design organisation, as well as changes that have occurred over time.

(4E) suggested technology led dynamic design and nonproduct related research.

(5E) could show up the 'imitators' and (6E) would show if these imitators achieve more success than the originators and whether this was due to static design, better marketing or some other reason.

(7E) shows possible areas of design weakness through various areas not being considered in the design specification.

(8E 9E,10E) this would show if the specification is formalised, thorough and it's importance appreciated.

(11E) shows if the design process is understood and formalised.

(12E) this shows if the company is seeking innovations that could make the product again become dynamic and how they are going about it.

(13E) a static design discipline.

(14E) this implied the creation of an unreal static plateau.

(F) Management

In this section the broad mantle of design allowed or organised by management was considered as more elements of static and dynamic design.

(1F) this shows the area in which design must operate.

(2F) an indication of production led design, possibly static design only.

(3F) this can be compared with the success of the company and with the discipline of static and dynamic design to show if the interviewee understands the design situation in his company and areas where improvement can occur.

(4F) this determined if the structure is organic or mechanistic.

(5F) this seeks the management mantle which may allow static and/or dynamic design.

(7F) a dynamic design discipline also showing evidence of innovation.

5. THE PILOT AND MAIN STUDY

5.1 Why The Products Were Chosen

The pilot study was undertaken on a well defined product manufactured by a few companies, the heavy duty shock absorber used in military vehicles. In the main study the product chosen was the rough terrain telescopic handler, manufactured by more companies than that used in the pilot study. These products were chosen for the following reasons.

1) Heavy duty shock absorbers are well understood by this author who had been employed in their design for 3½ years (1974-78) and subsequently kept up to date with the changes that occured with the product and the companies manufacturing it.

Telescopic handlers were less well known to this author but he had experience with vehicles, diesel engines, hydraulic pump and ram design, and the construction industry and, therefore, was familiar with the technology used. Also as the original design was undertaken at Loughborough University the original PDS was available.

2) There were only a few companies that manufactured the dampers in the U.K. and a senior member of each, in the management of design, was available to be interviewed.

At the start of the research there were ten suppliers, or manufacturers, (later eleven) of telescopic handlers in Great Britain of which two imported from France and one manufactured in Northern Ireland. It was, therefore, possible to visit all the U.K. manufacturers and importers based in Britain to provide an input.

3) Especially in the pilot study the companies in the market were sufficiently different from each other that clear comparisons could

be made between them.

4) For the pilot study a product was chosen that had few outside influences on it that may affect the results. The effect of foreign competition is minimal and there is only one customer, the M.O.D.

There are more outside influences on the telescopic handler. This was more likely to make it difficult to relate 'cause' to 'effect' but though the results were more difficult to interpret, this situation was more like that experienced by most product designs on the market. The product was subject to international influences and there were two distinct types of customer, the agricultural and the construction user. Both product types, being for industrial users who (generally) make their purchases for a particular application, are less prone to fashion and impulse buying as might be the case with consumer products. It was thought that industrial users were more likely to be logical and rational in their purchasing habits.

5) Both of the product types used in the research have a suitable design 'content', they are not subject only to partial design.

6) The heavy duty shock absorber design was found to be dynamic and, therefore, it was believed that investigation of a probable static product in the main study would give balance to the research. Although no attempt was made to prejudge the situation, from what had been learned in the pilot study it was possible to anticipate that the telescopic handler design was likely to be static.

7) This author's experience with the technology enabled him to discuss the two product types which, it is felt, gave the interviewees confidence that their answers would be understood perhaps more than if this author was new to the subject.

5.2 Areas Of Analysis

Having completed the interviews the results from both of the studies were presented in five ways.

1) The answers given at interviews were written up under each question number in a readable form.

2) The answer from each question was analysed against the relevant criteria to show if the criteria was upheld, not upheld, or the question did not show either ('not shown').

3) The criteria were taken in turn and the data obtained in '2' above were compiled against the criterion to show if the criterion was, or was not, upheld.

4) The questions which gave 'not shown' answers were reconsidered to see if they could be modified to give clearer answers which resulted in small changes to the questionnaire and criteria.

5) The differences and similarities of each company were compared with each other and with their success in design and the market. The differences between the companies in the main study were not as marked as those in the pilot study but certain strengths and weaknesses were clearly apparent. It was found to be possible to construct the first stages of an 'ideal' company for designing particular products. This eventually provided the input for the design process.

6) To assist with accuracy and clarity of the results some additional stages were undertaken in the main study. In conjunction with the interview data collection and analysis, desk research was carried out which involved collecting statistics on telescopic handlers dating back to their introduction in 1974. Assessments were

also made on the actual market size and the individual company shares of these markets as well as whether companies were increasing or decreasing in their market share. (Appendix 3).

7) From the knowledge gained from the pilot study it was thought possible that a considered opinion could be given to each company in the form of a written report. These full reports were sent to one company in the pilot study and all the companies in the main study, coupled with a feedback questionnaire. These are discussed more fully in the next section and the results of these are shown in section 6.9. All the companies in both studies were also telephoned to discuss their opinion of the research and the report.

8) Various parameters of telescopic handlers were taken from the catalogues of producers and from magazine articles covering all years of production. These were listed and then plotted against each other in an attempt to discover any general design rules, or exemptions, as well as market trends and niches.

Parameters were also plotted against time to detect any trends and show who were the design leaders and who were the followers. It was also believed that this would help to identify if the product was dynamic, or becoming dynamic. These results are described in section 6.8.

Both of the studies showed several factors that make a product static or dynamic. These results were crucial in order to make product status predictable and therefore enable a company to be directed in their emphasis in the management of design.

5.3. Report and Feedback

Before each interview it was explained that the research was into the management of design, the eventual aim being to provide a process to direct the design manager through the process of product design. A written declaration of confidentiality was given to each company and a request made that this work would be kept confidential by the interviewees. Nothing further was explained until after the questionnaire had been given, the exception being 'D', in the pilot study, who insisted on seeing the questions and considering them for a period of two months before being interviewed and 'G', in the main study, who required fuller information on the purpose of the study as a condition for doing the interview.

On completion of the structured interview this author then explained the principle of static and dynamic design and how it was believed that knowledge of product status could be used to direct and improve product design in companies. The interviewee was encouraged to ask questions, state what status he believed his product to be and make comments concerning this work. There was no discussion regarding other companies involved in the research.

After each of the first three company visits in the pilot study and after analysis of the data, a short report was sent to each of the companies involved. This was followed by a telephone call to the person interviewed to determine if their was any disagreement with this author's interpretation of their design performance and if there were any points on which they needed clarification. The report given to the companies concentrated on what status this author considered their heavy duty shock absorber to be and also how it was believed the company should be structured, or changed, to benefit from this company status.

By the fourth visit, which was to company 'D' this author was sufficiently confident with the handling of the data to provide a full report, the format of which was to remain consistent throughout the main study.

Also by this fourth company visit the feedback questionnaire had been prepared in order to gain some consistency in the feedback obtained between companies on their opinion of certain aspects of accuracy and reporting of the findings described in the report. It has, therefore, been possible to compare the opinion of all the companies in the main study regarding the research and the report, and this is shown in section 6.9. The feedback received was generally very favourable on the accuracy of the findings and the validity of product status.

5.4 Revisions to the Questionnaire After the Pilot Study

The questionnaire used in the pilot study was found to be effective in that it provided most of the information sought but did not produce a significant amount of unnecessary or unusable data. The interviews took about one hour and it was believed that this time could be reduced by better questionnaire construction such as incorporating more tables in which the interviewee could place a tick in an appropriate box. This was included for the main study and reduced the number of questions by allowing several questions to be combined onto the same table. This also made the general analysis of the questionnaire more easy.

Two problems arose from the pilot study interviews. In Oceonics Vehicle Technology (O.V.T.) the interviewee gave answers that were contradictory to those he gave to similar questions given earlier - these check questions being incorporated in the questionnaire. It appeared that he was attempting to give a better picture of his company than was, in fact, the case. The second problem concerned the table supplied with the question:

"Indicate on table 3 the level of strength or weakness you consider on this company's performance."

Interviewees tended not to commit themselves, placing their tick in the 'neither strong nor weak' box. It was considered that this may also have resulted in an inaccurate appraisal. The chart was left much as it was, although some features in it now appear on other tables where a more committed answer is demanded. This problem did not arise in the main study.

The interview results could be improved by gauging the effect of changes over time by, in some cases asking the same questions "as the company was five years ago" with these answers being marked with a cross and the current situation being marked with a tick.

Three areas that were believed to need improvement after the pilot study, were:

1). The clarification of the method and depth of market research.

2). Determination of an organic or mechanistic design team structure.

3). Clarification of the effectiveness of the product design specification.

These were generally achieved by adjustments to the questionnaire.

The questionnaire was shortened from 49 to 39 questions with 4 additional 'check' questions if required and the quality improved. It was subsequently found that the time to answer the revised questionnaire was reduced to about 45 minutes, although, such was the interest in product status, that the subsequent discussion often continued for quite some period.

6. RESULTS AND THEIR ANALYSIS

6.1 Analysis of Pilot Study Interviews

In the pilot study the actions of the producers, in the manner that they treated their product as static or dynamic, was clearly shown. Newton and Bennett was probably the most interesting as they are positioned firmly at the static boundary and, therefore, their features made a suitable point of reference from which to view the other companies.

The producers of the heavy duty dampers for military vehicles were in the unusual situation of being able to rely on the main customer to supply most of the Product Design Specification (P.D.S.) The P.D.S. set the static plateau with the original design but also a radical change in the P.D.S. caused the product to again become dynamic when the new specification could not be met by the existing concept. The producers all appreciated that the product status was dynamic although none had considered this aspect of design previously.

In the pilot study it was quite apparent to Newton and Bennett that the product was again becoming dynamic some years before the new product appeared. Laser (OVT) produced their first prototype at the end of 1974 and Newton and Bennett knew details of the design in early 1976, as well as knowing that the M.O.D. would purchase it if it was satisfactory. Therefore Newton and Bennett knew for about six years that their product would start to be replaced. This is an unusually long time gap but in most markets the latest developments are heralded two or three years before the product becomes widely available and this does give the competition time to plan a defence against it. Whether they are able to take advantage of this knowledge depends on the company. In this study Newton and Bennett planned, in view of their demise, to maximise profit as their product declined. More normally a company would be expected to restructure for the new dynamic era of the product.

As long as the existing product fully meets the customer needs, as identified by market research and described in a full Product Design Specification, there is unlikely to be a change in the product status. This was shown in the pilot study where Newton and Bennett's design fully met the Ministry of Defence requirements from 1948-74 and stayed static due to lack of competition, a stable P.D.S. and lack of investment into design.

It has been observed by Klein (1977) that most major innovations originate from outside the recognised producers. Laser and Horstman were not in the damper market before their developments - thus supporting this observation.

As one company was operating at the static boundary and one company was operating at the dynamic boundary, it was possible to identify some disciplines of static and dynamic design that also suited their particular status. It was also possible to detect that certain disciplines should exist in all companies involved in design and production whatever their product status. Therefore, before consideration of product status, management should make provision to incorporate these disciplines.

Patents were considered important by the two innovative companies and OVT, at the time of the interview, were in a legal dispute over the infringement of one of their patents. Patents are believed to be a facet that prevents designs iterating to a common design and also preventing imitation by other companies.

Fig. 6.1.A shows the results of the question:
"Indicate the importance on table one for this product in this market".

'Reliability' was clearly shown to be the most important feature in the product. 'Advanced Technical Features' was the third most important, perhaps, reflecting the dynamic status of the product. Not unexpectedly, 'Colour' and 'Appearance' were given little importance as the damper is hidden from view in most applications.

Fig. 6.1.B shows the results of the strength and weakness that companies considered on their performance. Financial control came out as being the overall major strength showing that companies consider it important with a dynamic product as would be expected, for when a product is in a state of change the costs of design and innovation can be high and must be kept in firm control. Research was shown to be the overall weakness mainly due to the effect of Newton and Bennett who gave the only tick in 'Very Weak' box that appeared on the table.

All companies knew their immediate competition in their market and most agreed that Laser (OVT) were the most innovative. Also, all companies noted that innovative or radical changes were occurring as shown on fig. 6.1.C and 6.1.D. This was confirmed by what the producers believed to be the major threat to their product market where three of the four companies cited innovation (fig. 6.1.E). The results provided a framework which was expanded for the main study.

TABLE ONE PRODUCT QUESTION 3

MARKS	2 VERY IMPORTANT	1 IMPORTANT	0 NEITHER IMPORTANT OR UNIMPORTANT	-1 UNIMPORTANT	-2 VERY UNIMPORTANT	TOTAL MARKS
Reliability	4✓					8
Low Price (In comparison to Competition)		2½✓	½✓	✓		1½
Advanced Technical Features	2✓	✓	✓			5
Appearance			3½✓		½✓	-1
Ease of Use		2½✓	✓		½✓	1½
Colour			1½✓		2½✓	-5
Strength	1½✓	2½✓				5½
Maintainability		4✓				4
Finish		✓	2✓	✓		0
Other?						

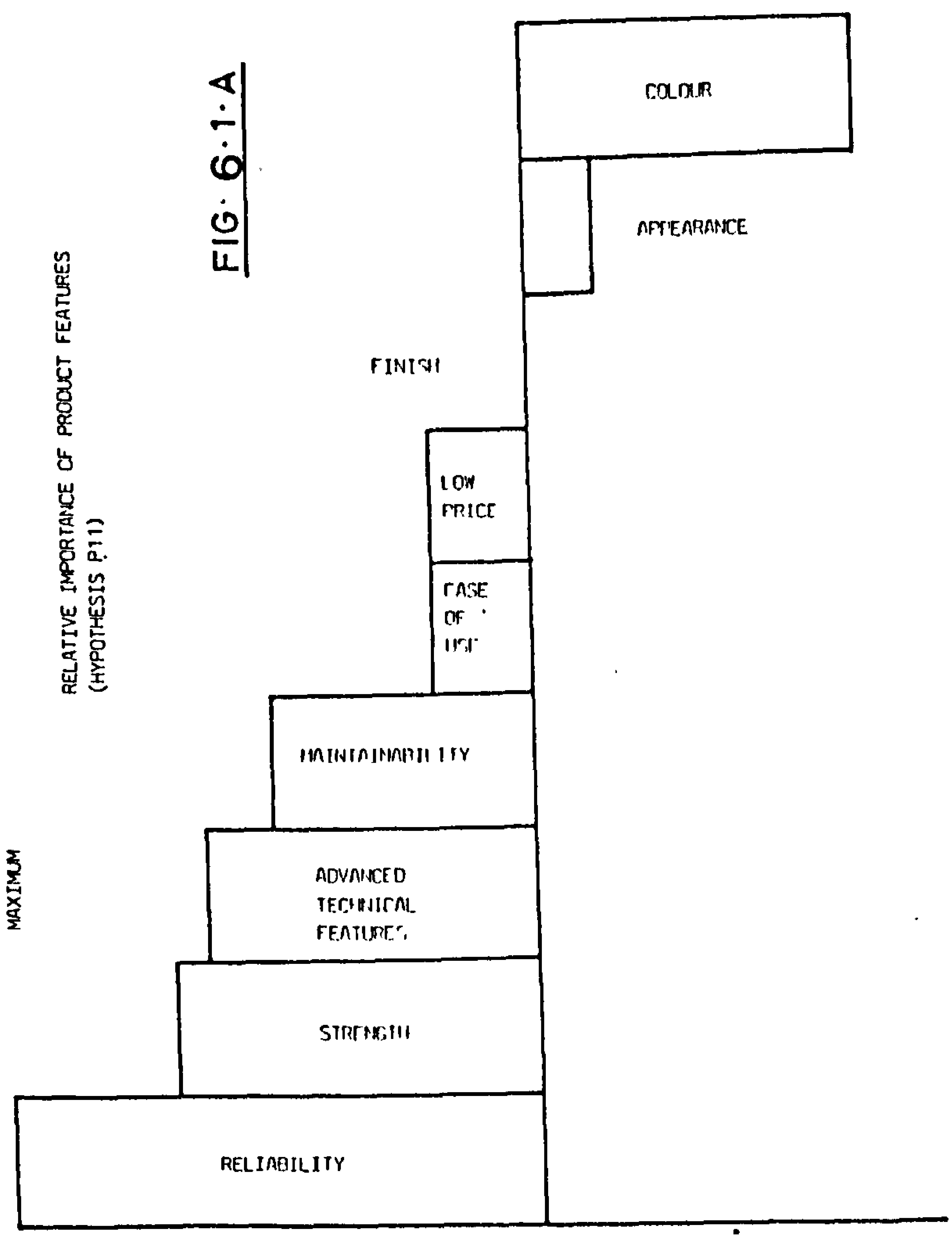


FIG. 6.1.A

TABLE THREE MANAGEMENT QUESTION 3

6.1.B

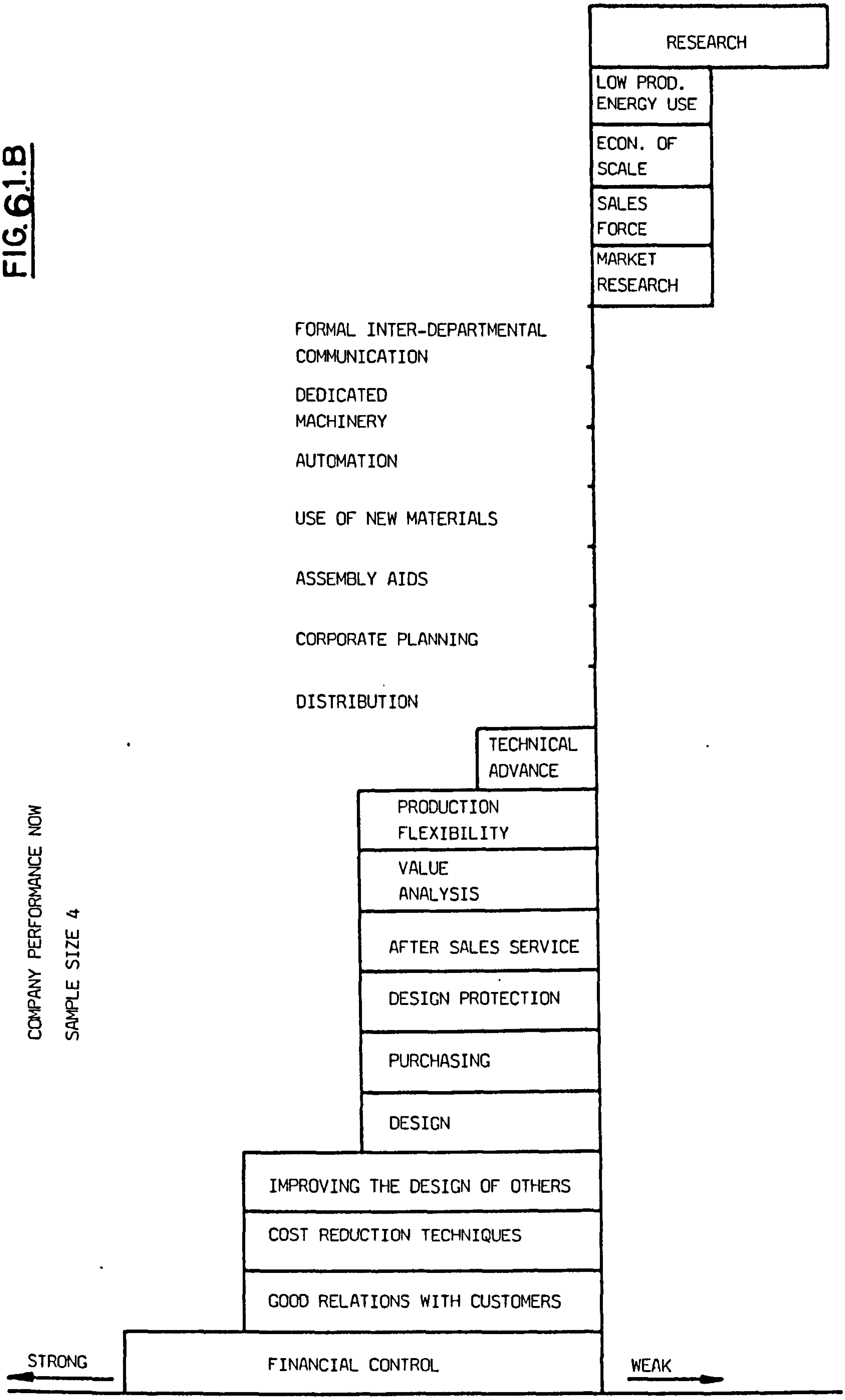
MARKS	2	1	0	-1	-2	
	VERY STRONG	STRONG	NEITHER STRONG NOR WEAK	WEAK	VERY WEAK	TOTAL MARKS
Design		3✓		✓		2
Distribution			4✓			0
Purchasing		2✓	2✓			2
Good Reputation with Customers		3✓	✓			3
Design Protection		2✓	✓			2
After Sales Service		2✓	2✓			2
Market Research			2✓	✓		-1
Sales Force		✓	✓	2✓		-1
Financial Control	✓	2✓	✓			4
Economies of Scale			3✓	✓		-1
Corporate Planning			4✓			0
Value Analysis		2✓	✓			2
Assembly Aids		✓	2✓	✓		0
Use of New Materials		✓	2✓	✓		0
Production Flexibility		3✓		✓		2
Low Energy Use on Production			3✓	✓		-1
Cost Reduction Techniques		3✓	✓			3
Automation		✓	✓	✓		0
Improving the Design of Others		3✓	✓			3
Technical Advance		2✓	✓	✓		1
Dedicated Machinery			3✓			0
Research		✓		✓	✓	-2
Formal Inter-Departmental Communication			4✓			0
Other?						

FIG.6.1.B

PILOT STUDY TABLE 3

COMPANY PERFORMANCE NOW

SAMPLE SIZE 4



PILOT STUDY

Fig 6.1C

WHICH COMPANIES WERE CONSIDERED INNOVATIVE BY THEIR COMPETITORS

Quest. B4

Newton and Bennett

Both our competitors are innovative, Laser especially, as they are spending money in research into new ways of improving suspension systems.

Horstman

Horstman are design leaders. Dowty Rotol, Mersier and the German competitors are innovative.

OVT (Laser)

All the competitors are, in some ways, innovative. We are the most innovative.

"D"

27.9.85. We are the design leaders. Laser are innovative.

26.11.85. None are innovative. The innovation comes from the end user.

PILOT STUDY

Fig 6.1D

KNOWLEDGE OF STATUS OF THE HEAVY DUTY DAMPER USED IN MILITARY VEHIC LES

Quest. B11, B12

Newton and Bennett

Radical changes now occurring. The biggest change to the market, the invention of Hydragas.

Horstman

The major threat is new innovations in vehicle suspension of which there is a lot of work going on at the moment.

OVT (Laser)

All the competitors are in some way innovative. There continues to be 'flashes of insipiration' which alters the design.

"D"

Dampers are in a phase of change.

The above shows that, without using the word, the manufacturers appear to know that their product is dynamic.

Fig 6.1E

CONSIDERED TO BE MAJOR THREATS TO THE PRODUCT MARKET

Quest. B12

"D"

Elaborate systems may be introduced. No real threats unless there is a durability failure of a current system which will cause change.

Newton and Bennett

Innovation by competitors.

Horstman

Major threats will be new innovations in vehicle suspensions of which there is a lot of work going on at the moment. Hydropneumatic systems have created a lot of interest. Active adaptive suspension systems may also cause problems if they can be made to read across to our market.

OVT (Laser)

No direct threats, only disarmourment or defence budgets being slashed.

Three of the four companies cited innovation as being the major threat to the product market. The exception was the most innovative company.

6.2 Analysis of Main Study Interviews

The revised questionnaire was more effective and faster to deliver than the one used in the pilot study.

Two of the three areas which were thought to require improvement were significantly better namely:

1) The clarification of the method and depth of market research.
2) Determination of an organic and mechanistic team structure.

The third, 3) Clarification of the effectiveness of the P.D.S., was most successfully ascertained by asking to see it. Their mere size was a sufficient indication of their thoroughness. It did become apparent that two distinct types of product specification are used by companies;

1) An on-going production specification which details minor (static) changes as part of the product improvement. This sometimes, as in the case of R.W.C., was a single sheet of paper.
2) A major specification which is compiled when an initial design or second generation of a product begins. The former is brief and retains the static plateau, the latter is bulky.

The questions asked, noting the effects of changes with time, showed up the 'direction' for different aspects of the design.

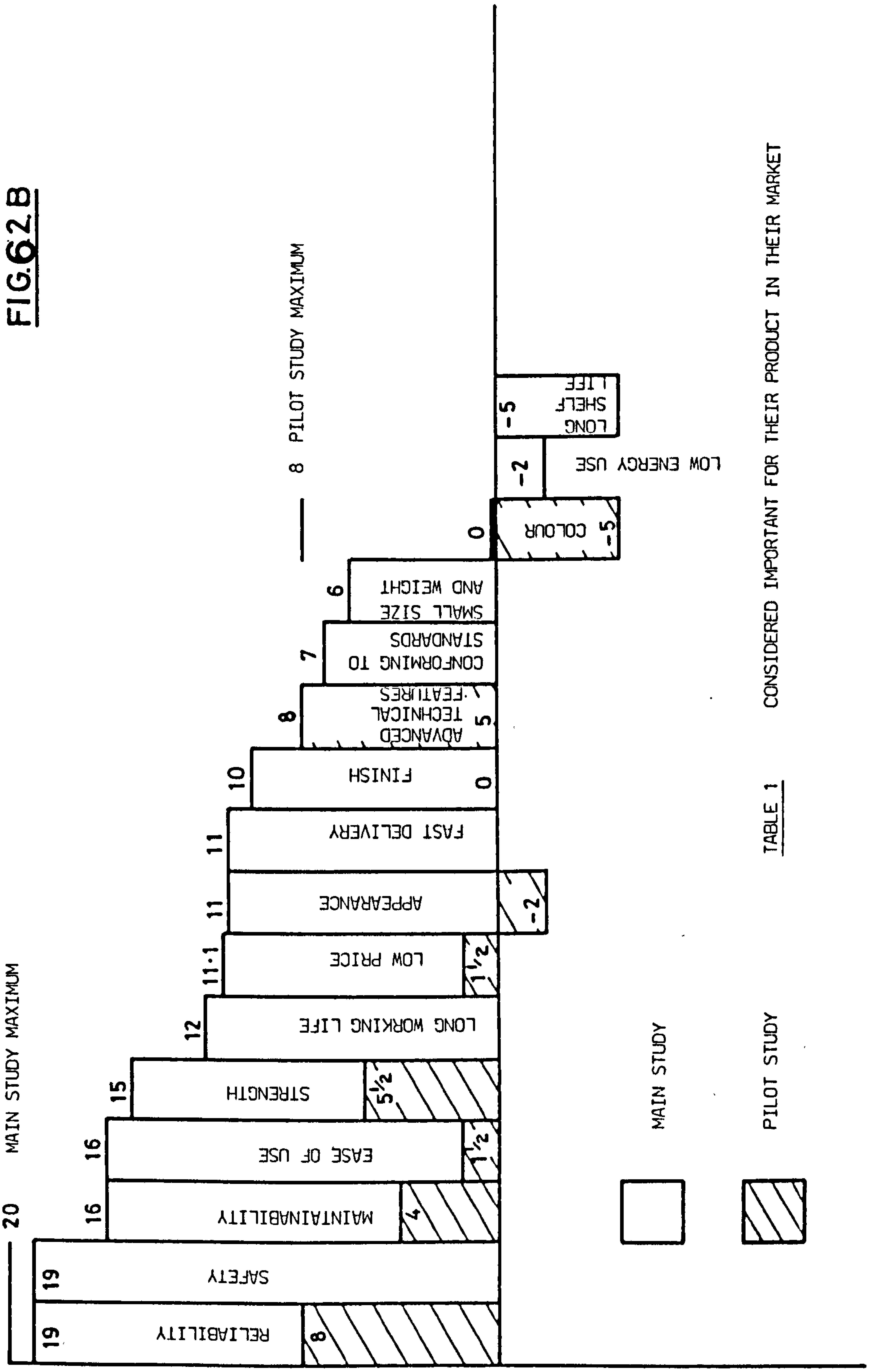
The result to the question 'Indicate the importance on table one for this product in this market' (Q.1C) has been compiled on to a chart (6.2.A) and shown on fig. 6.2.B. With the dynamic product in the pilot study 'Advanced Technical Features' was considered of much greater importance than with the static telescopic handler, where more static disciplines were assessed to be of greater importance. This may indicate that, if a company considered static disciplines

TABLE ONE PRODUCT QUESTION 1

FIG. 6.2. A

MARKS	2	1	0	-1	-2		
	VERY IMPORTANT	IMPORTANT	NEITHER IMPORTANT OR UNIMPORTANT	UNIMPORTANT	VERY UNIMPORTANT	MARKS	POSITION
Quality and Reliability	9	1				19	1=
Low Price (Compared to Competition)	3	5		1		10 (11-1)	7
Advanced Technical Features	1	7	1	1		8	11
Appearance	2	7	1			11	8=
Ease of Use (Good Ergonomics)	6	4				16	3=
Colour		2	7		1	0	14
Strength	5	5				15	5
Maintainability	6	4				16	3=
Finish	1	8	1			10	10
Long Working Life	3	6	1			12	6
Safety	9	1				19	1=
Long Shelf Life		3		4	2	-5	16
Small Size and Weight	1	5	3	1		6	13
Low Energy Use		1	6	3		-2	15
Conforming to Standards	3	3	3		1	7	12
Fast Delivery	2	7	1			11	8=
Other?		SERVICE AND PARTS, BUILD CONFIGERATION					

FIG.62B


MAIN STUDY MAXIMUM
20
8 PILOT STUDY MAXIMUM
RELIABILITY 19 8
SAFETY 19
MAINTAINABILITY 16 4
EASE OF USE 16 1½
STRENGTH 15 5½
LONG WORKING LIFE 12
LOW PRICE 11·1 1½
APPEARANCE 11 -2
FAST DELIVERY 11
FINISH 10 0
ADVANCED TECHNICAL FEATURES 8 5
CONFORMING TO STANDARDS 7
SMALL SIZE AND WEIGHT 6
COLOUR 0 -5
LOW ENERGY USE -2
LONG SHELF LIFE -5
MAIN STUDY
PILOT STUDY
TABLE 1 CONSIDERED IMPORTANT FOR THEIR PRODUCT IN THEIR MARKET

more important, they may put more effort into that direction which may keep or make a product static and, conversely, if they put more effort into dynamic disciplines, they may keep or make a product dynamic.

In the main study some of the interviewees were asked what they meant by 'strength'. The answers given were "Robustness", "Fitness for Purpose", "Strong Enough to do the Job" and one said, "It's the same as reliability".

The histogram on fig 6.2.B shows the relative importance of 'Safety' in the features listed in the main study. It is often stated that safety does not sell products. A suitable analogy may be found in the work of Herzberg et al (1959) with his satisfiers or 'motivating' factors and dissatisfiers or 'hygiene' factors.

A satisfier is a feature in a company that, if it is present, the employee is pleased about but if it is not the employee will not complain. An example could be if free coffee is supplied. A dissatisfier is the opposite, an employee, for example, expects clean toilets so will say nothing if they exist but will complain if they do not. Safety in design may be considered the same way. A user expects a product to be safe and, therefore, it is a very important part of design even though the user may not comment on it. But should a design be unsafe considerable outcry will be made. An example being the fire hazard of the Ford Pinto or the 'invisibility' of Sinclair C5 users to other road traffic.

Therefore, although safety may not sell a product, it is a vital part of design and warrants its position as one of the most important features in a design.

Shifts in Product Design Specification Over Time

Two questions were asked in the interviews (product question 3 and 4). On Table 2 (6.2.C) and Table 3 (6.2.D) the total answers from the telescopic handler companies are compiled. On Table 2 the most important result to be observed is that companies are not seeking a new concept as much as they were in the past five years when most were at the start of design. This suggests that the majority did consider a new concept when they started design but have now decided to keep to the existing concept, to keep the product static. In figure 7.2.E the next most noticeable change is that more companies are seeking methods to reduce manufacturing costs and increasing group technology than they were five years ago. In absolute terms most companies are currently working on improved maintainability, followed by easier product use and improved reliability and then aesthetics (fig. 6.2.F).

Table 2 (6.2.C) questions K - M were only asked in the last four interviews and in these nobody was seeking a completely new product either now or during the past five years, but all four were working on reducing manufacturing costs. Cost reduction was also stated under the heading 'other' by three companies of the first six interviewed.

Table 4 (6.2.D) is more difficult to interpret. All companies are likely to indicate that they are 'stronger' now than they were five years ago and apart from this, answers generally were on the 'optimistic side'. The 'optimistic' answers tend to be cancelled out when looking at the trend where the result for 'five years ago' is subtracted from that for 'now'. It is, therefore, believed that the

TABLE TWO PRODUCT QUESTION 3 AND 4

		NOW ✓	LAST 5 YEARS ✗	TREND
a)	Improved Reliability	7	6	1
b)	Seeking A New Concept	2	6	-4
c)	Seeking an alternative market for this product	5	4	1
d)	Product Size Reduction	1	2	-1
e)	Improved Aesthetics	6	5	1
f)	Reduction of Scrap	3	3	0
g)	Easier Product Use	7	5	2
h)	Rationalisation of the Product Range	4	4	0
i)	Improved Maintainability	8	6	2
j)	Group Technology	5	2	3
*k)	A Completely New Product (First on to the market)	0	0	0
*l)	Improved Finish	1	2	-1
*m)	Reduced Manufacturing Costs	4	1	3
n)	Other? COST REDUCTION	3	1	2

* Asked only in the last four interviews

FIG. 6.2.C

TABLE FOUR MANAGEMENT QUESTIONS 1 + 2

FIG 6.2.D

✓ NOW
✗ FIVE YEARS AGO

MARKS	2		1		0		-1		-2		
	VERY STRONG		STRONG		NEITHER STRONG NOR WEAK		WEAK		VERY WEAK		TREND
	✓	×	✓	×	✓	×	✓	×	✓	×	
Design	4	2	5	6	1	2					3
Distribution	2	2	4	3	4	1		4			5
Purchasing	1		6	3	3	4		2			7
Good Reputation with Customers	1	1	7	4	2	3		2			5
Innovation	4	2	2	3	4	4		1			4
After Sales Service	1		5	3	4	5		1			5
Market Research			1	1	7	5	4	2			2
Sales Force			4	4	4	4	2	1			1
Financial Control	3		6	4		4		1			9
Economies of Scale	2	1	5	1	2	4		3			9
Corporate Planning	1	1	2		4	3	2	5			5
Fast Delivery	1	1	2		6	6	1	3			4
Assembly Aids			3		6	6	1	3			5
Use of New Materials			3		4	4	2	5			6
Production Flexibility	2	1	5	4	2	4	1	1			3
Low Energy Use on Production					6	6	4	4			0
Cost Reduction Techniques	1	1	3		6	6		3			6
Automation			1	1	5	1	3	6	1	2	5
Improving the Design of Others			6	3	2	4	3	2			4
Technical Advance	1	1	6	5	3	2		2			3
Customer Training	1	1	3	1	5	6	1	2			3
Quality and Reliability	1	1	3			3					3
Low Cost Production			2		1	2	1	2			3
Other? FORMAL INTER DEPT. COMMUNICATION	1		1	2	3	3	1	1			1

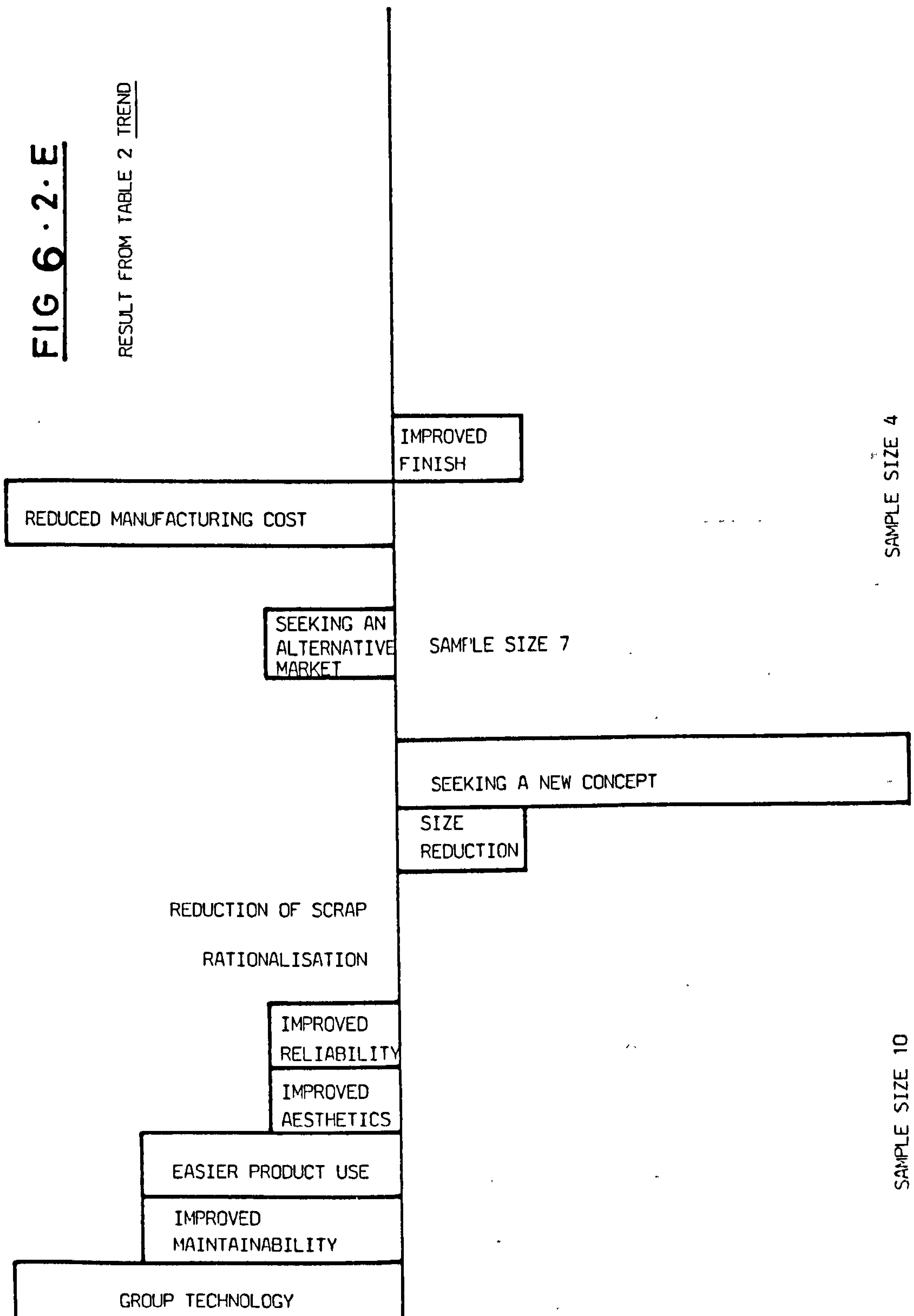


FIG 6·2·E

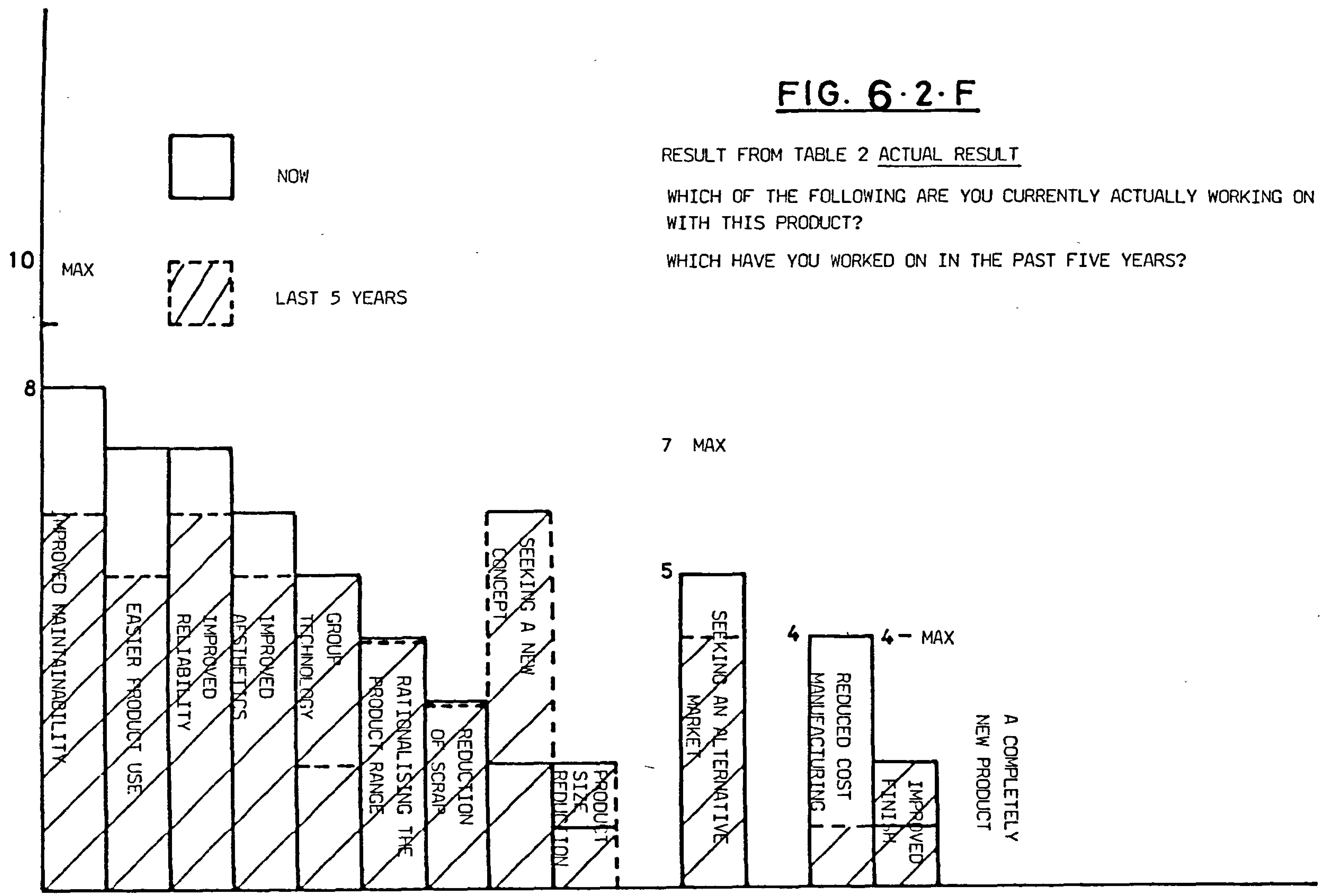
RESULT FROM TABLE 2 TREND

FIG. 6·2·F

RESULT FROM TABLE 2 ACTUAL RESULT

WHICH OF THE FOLLOWING ARE YOU CURRENTLY ACTUALLY WORKING ON WITH THIS PRODUCT?

WHICH HAVE YOU WORKED ON IN THE PAST FIVE YEARS?



The assessment was made by allocating two marks for the 'Very Strong' box and this was reduced by one mark with each box to -2 for 'Very Weak'. These totals for the situation 'five years ago', when subtracted from the totals for 'now', are shown on fig. 6.2.G. These are as expected for a static product showing a greater emphasis on low cost production. The result for 'Innovation' is unexpected showing that more innovation appears to be undertaken now even though the product is static. This may be due to companies wishing to appear innovative or, perhaps, they do not understand the meaning of the word, which, by definition, must include an invention. Innovation is a much misused word which may be the outcome of it being used wrongly in advertising.

Certain design disciplines are necessary in all companies irrespective of the status of their products and, therefore, the 'trend' of these disciplines should not alter, but remain at zero. Two such disciplines are in table 6.2.G, financial control and market research. Financial control has the highest increased emphasis of the trends. Also, as the product became static, production flexibility would be expected to reduce which it does not.

In absolute terms (fig. 6.2.H) design was indicated by the interviewees as being the strongest feature when looking at the industry as a whole, but, as those being interviewed were mainly design managers, perhaps, this is not surprising. This was followed by financial control and good reputation with customers. In absolute terms the weakest features were automation and low energy use on production, suggesting that the telescopic handler has not reached the Static 2 level yet. Static 2 is mainly a function of large

TABLE 4

TREND SAMPLE SIZE 10 EXCEPT WHERE STATED

COMPANY STRENGTH NOW - COMPANY STRENGTH FIVE YEARS AGO

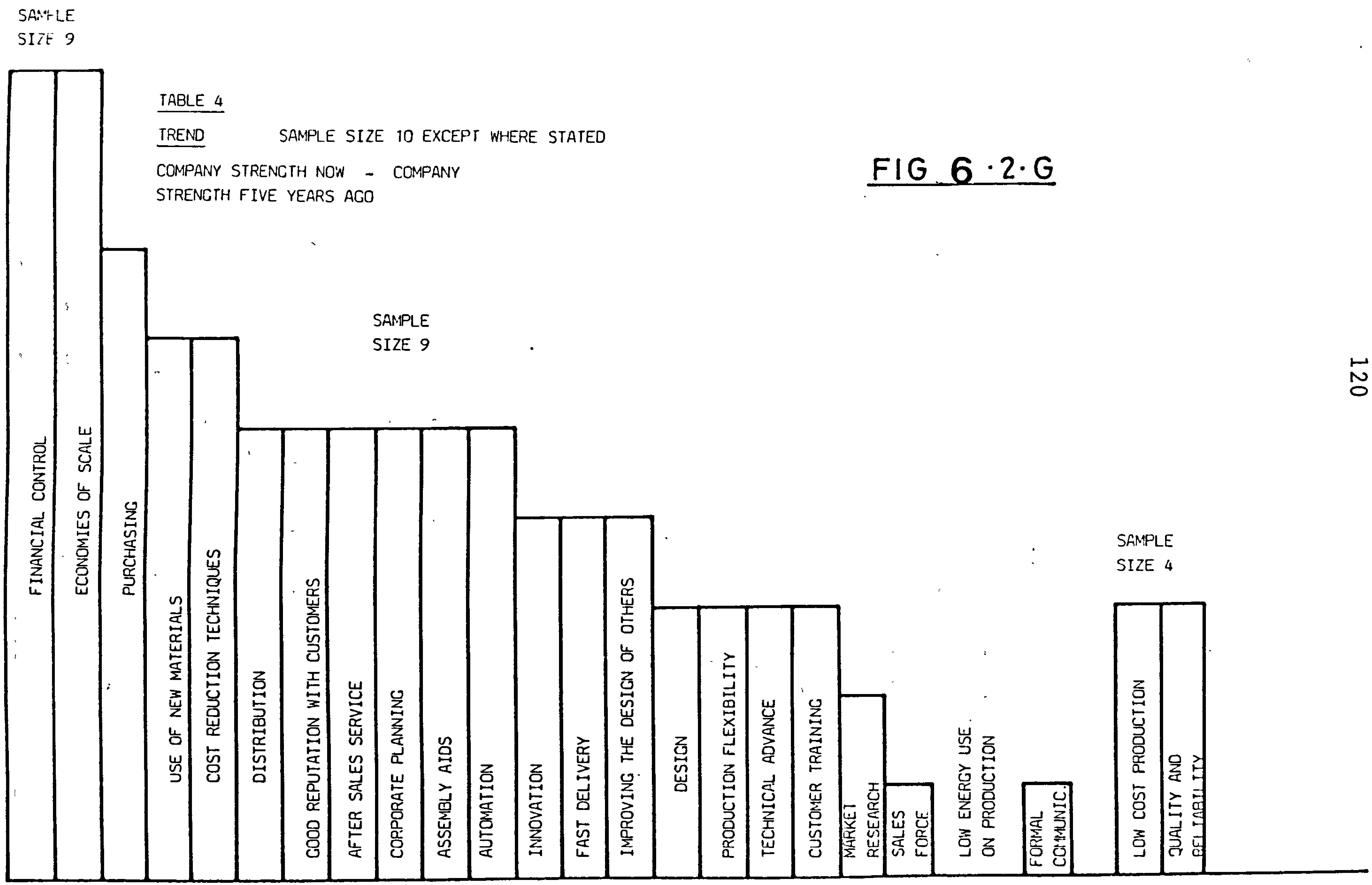
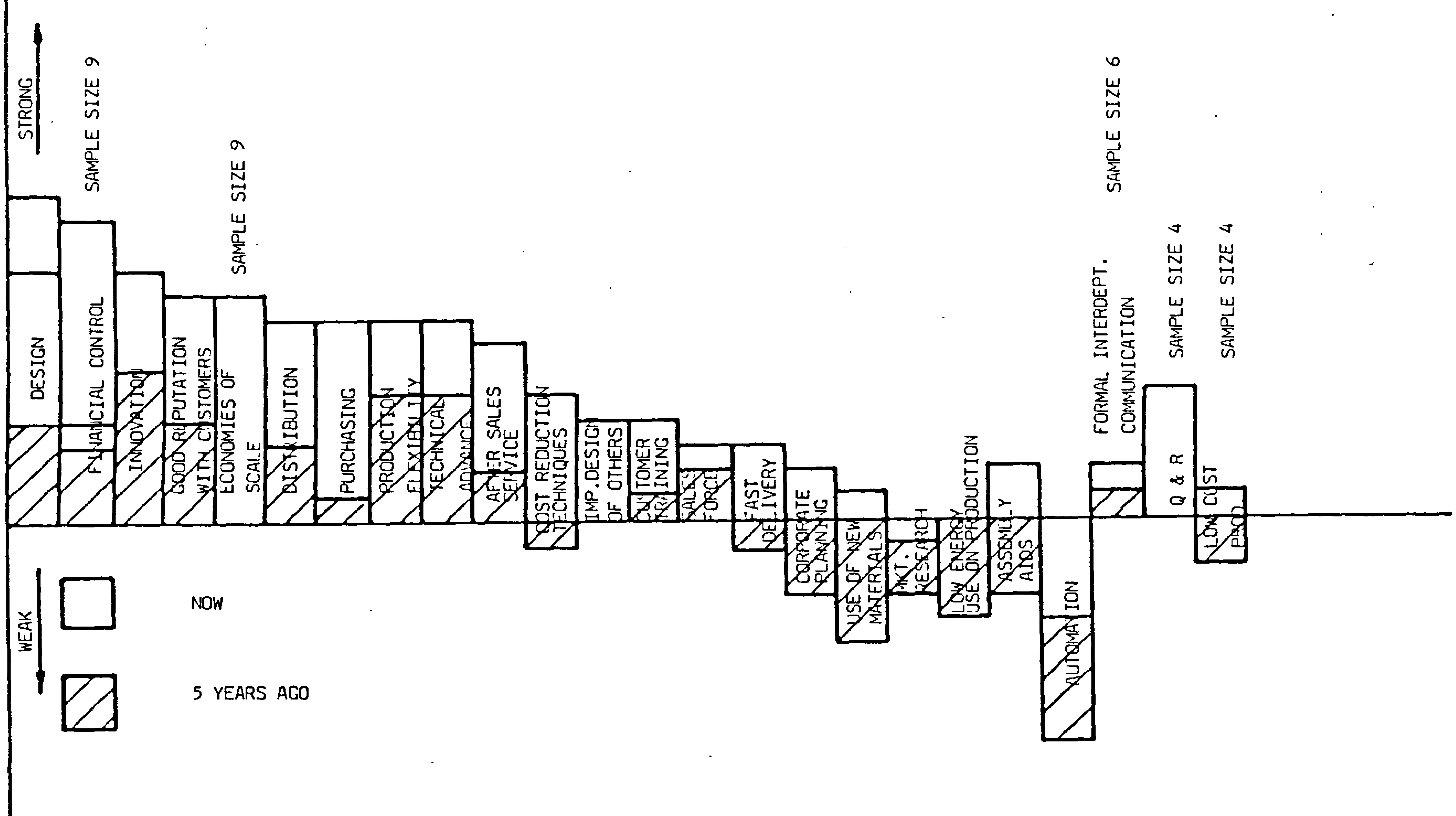


FIG 6·2·G

FIG 6·2·H

TABLE 4

INDICATE THE STRENGTH OR WEAKNESS OF THE COMPANY'S PERFORMANCE NOW AND FIVE YEARS AGO (ABSOLUTE RESULT)



volume production and the limited market size prevents this for all but the market leader. Market research came next as being the weakest. It is apparent that market research, though undertaken by all companies, is not done well. The result may also indicate the common feeling amongst Design Managers that they are not being provided with the correct and sufficient input from the marketing department to enable them to effectively design the right product. In other words they are not operating Total design.

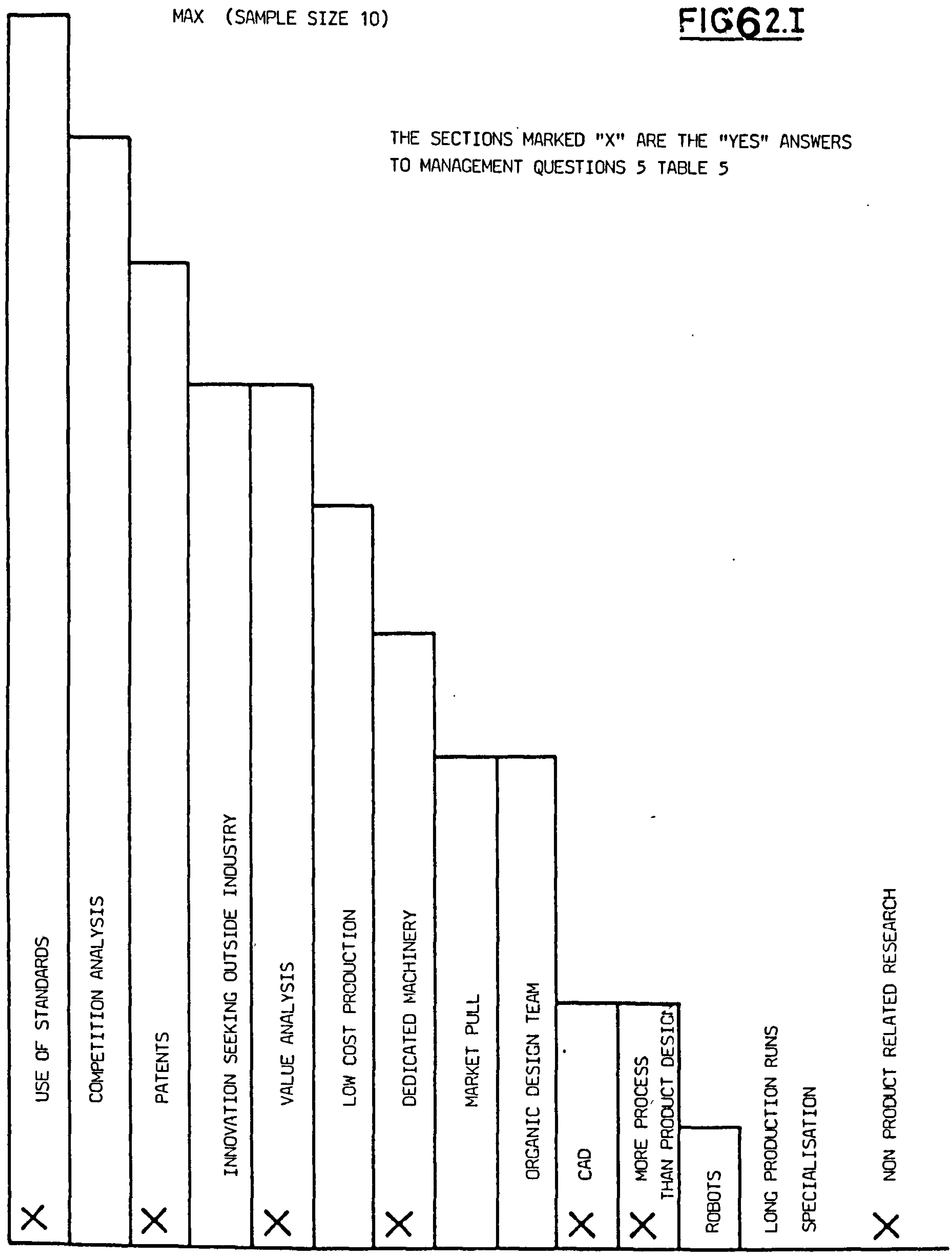
The results from the questionnaire table 5 are shown in the histogram on figure 6.2.I. This shows that standards in design were used by all the companies interviewed, an implication being that the product is treated as static. Competition analysis came next and then innovation seeking outside of their industry which are disciplines that should be undertaken by all companies. Patents were considered by 8 out of the 10 companies, although only Manitou and 'E' had patents for telescopic handlers and 'E's' patents are approaching completion of their term. It is believed that patents are of less importance with a static product.

Long production runs and specialisation are Static 2 Features and did not appear in any results, as did non-product related research which is at the top of dynamic disciplines.

These aforementioned results can now be compared with that which the companies considered important for their product in their market. Reliability came out as most important and most companies put a lot of effort into this. Safety was also most important, but no specific discipline exists for this, it may also come under reliability.

It may also be possible to link in these results with the elements

FIG 62.I


MAX (SAMPLE SIZE 10)
THE SECTIONS MARKED "X" ARE THE "YES" ANSWERS TO MANAGEMENT QUESTIONS 5 TABLE 5
USE OF STANDARDS
COMPETITION ANALYSIS
PATENTS
INNOVATION SEEKING OUTSIDE INDUSTRY
VALUE ANALYSIS
LOW COST PRODUCTION
DEDICATED MACHINERY
MARKET PULL
ORGANIC DESIGN TEAM
CAD
MORE PROCESS THAN PRODUCT DESIGN
ROBOTS
LONG PRODUCTION RUNS
SPECIALISATION
NON PRODUCT RELATED RESEARCH
X
X
X
X
X
X
X

that should be considered on the P.D.S. These have been assembled from table 3 and the question 'Indicate the elements you consider in your predesign product specification'. (Fig. 6.2.J).

Another way to study and detect shifts in the P.D.S. has been shown in the parametric analysis, where one aspect has been to note changes over time by looking at telescopic handler models in relation to their features and year of introduction (section 6.8). When asked which of their competitors were considered innovative most named companies and their innovations which often had appeared on the original design of 1974, but several indicated that changes were generally static and few are innovative. These results are shown on figure 6.2.L. Figure 6.2.M confirms that all companies appreciate that the product status was static (without using the word) but they do not always act in their best interests regarding this status. Regarding the major threat to their product market (fig. 6.2.N) various facets were mentioned but a new innovation was only mentioned by two companies and one of those added predominantly static threats.

Product Design Specification

Figure 6.2.P shows the elements that were not considered by the companies in their P.D.S. Only four companies consider processes although the product is static and process design is probably more important than product design. This is further highlighted when the factors considered important for their product in their market are written (results of fig. 6.2.A), where low price was seventh in importance and processes have the major influence in price/cost reduction. Also, politics was not often considered, although several

TABLE 3 INDICATE THE ELEMENTS YOU CONSIDER IN YOUR PRE-DESIGN SPECIFICATION

FIG. 6·2·J

THE WRITTEN NUMBERS INDICATE THE RELATIVE IMPORTANCE FROM FIG. 6

Q B.4 FIG. 6.2.L

WHICH COMPANIES WERE CONSIDERED INNOVATIVE BY THEIR COMPETITORS

J.C.B.	'G' - 4 wheel steer (actually first done by 'H' 10 years earlier) 'E' - Articulated
'G'	Manitou - unusual boom arrangement Lansing Henley - Twin booms. Most others show minimal innovation. (Original done by R.W.C.)
R.W.C.	Perhaps 'G' and J.C.B. None are innovative they tend to follow tradition.
Lansing Henley	'G' got into the initial product faster. Keep extending their specifications - have four wheel steer. 'E' also innovative.
Manitou	'G' are innovative with their crab steer. 'E' also have a different concept but again fairly static.
Sambron	The majority of the competitors are innovative.
M.F. Industrial	None of the major manufacturers are innovative. Smaller, such as R.W.C. are. Innovations come from small companies.
'B'	J.C.B. certainly are innovative and so are other Companies to a lesser extent Most tend to follow J.C.B. but occasionally another Company try something different.
'E'	'G' are the only ones who have had a good look at what they are doing and improved it, others (including ourselves) are going in the same direction as before.
'H'	1986 "We led the field in innovation The Manitou maniscopic is a diabolical machine but innovative with its top telescopic boom extension". The Lull Highlander moves the top workings on its chassis. The Merlot can skew round like a crane.
'H' (1980)	Not many. 'G' in a way with their twin boom. "The innovations was the original concept". J.C.B. are never innovative.

Q. B.11 B.10 FIG.6 .2.M

KNOWLEDGE OF STATUS OF TELESCOPIC HANDLER (WITHOUT ACTUALLY USING THE WORD)

'E'

Very little has basically changed in the design recently and "these were all down to detail".

Most of the competition "have stuck to one basic concept". The product appears to be static "for the foreseeable future".

'G'

The telescopic handler "was at the beginning it its life". Machines based on the tractor skid are all very similar. "Telescopic handlers made on our drive system have more chance for innovation."

R.W.C.

Basically tended to one design. Entirely replaced some considerable time - 10 years.

LANSING HENLEY

When will it be replaced? "A long time yet, I don't know". Two different products emerging - U.K. agricultural cheap and cheerful, export construction stronger higher lift.

MANITOU

Two markets construction and agricultural, there is a separation of the type of machine used in these markets. I don't think the handler will ever be replaced. Five years for a product to subdivide the market further.

SAMBRON

"We are now on a design plateau. We have done the major design work and are now getting back our money selling the product", and "there have been no changes in the market". Also "there are no basic differences ... no differences in manufacture". "I think it will be replaced in the agricultural market in about twenty years. I don't know about the construction market".

M.F. INDUSTRIAL

There were "not many radical changes" design "refined since the mid 70's". None of the major manufacturers were innovative and could not foresee any major change in the design in the next "5 to 10 years".

'B'

The telescopic handler would remain basically the same for at least the next five years. Most follow J.C.B. but occasionally companies do something different. The competition have tended to one design in 90% of the market.

'E'

Very little has basically changed in the design recently and "these were all down to detail". Most of the competition "have stuck to one basic concept". "'G' have had a good look at what they are doing and improved it, others are going in the same direction as before. I can't see the telescopic handler being replaced in the foreseeable future."

J.C.B.

Design for manufacture in high volumes. JCB has the standard way of doing things and others follow. Some radical changes.

'H' 1986

"The basic concept remains the same"... "At this time I cannot see another product replacing the telescopic handler. Like the ubiquitus dumper. There will just be operational changes and the design will become more versatile. I can't see any threats to the market".

'H' 1980

"The innovation was the original concept". In broad terms all designs are tending to one basic concept but there are variations within it. Twenty years before the concept is replaced.

Q. B 11 FIG. 6.2.N

CONSIDERED TO BE MAJOR THREATS TO PRODUCT MARKET

J.C.B.

If the Japanese produce vehicles of this type.

'G'

Agricultural - More ingenious multi-purpose machine.
Major recession (mainly in U.K.)

Construction - Major recession (mainly in export)
Exchange rates
Changes in Safety Regulations

R.W.C.

Improved methods of materials handling.

MANITOU

Very few threats. The construction market is very slow and there would be problems if the bottom fell out of the agriculture market. Legislation on safety - nothing on the horizon to threaten the market. The Japanese are not making telescopic handlers yet.

M.F. INDUSTRIAL

Maybe legal requirements will be increased as they were with the back hoe loader in the 70's with quiet and safety cabs.

'B'

The only real threat is a loss of purchasing power on the part of customers. As over 50% of the market is in agriculture any change in government allowances etc mean that the potential telescopic handler customers could revert back to the cheaper masted machines as telescopic handlers are more expensive. Little other threats. H.S.E. safety requirements could increase costs.

'E'

The reduction in the agriculture market. The centre pivot machine is too exotic for the building industry.

'H' 1986

"I can't think of any threats to the market".

'H' 1980

In 1980 the market was opening up and had not reached saturation. It was too early in the product life to talk about threats as there was nothing on the market to threaten it. On the Continent possibly the tower crane in the construction industry. Nothing in the agricultural industry.

TABLE 6.2.P NEW PRODUCT DESIGN

ELEMENTS OF SPECIFICATION (NOT CONSIDERED)

Quality	1	Packing	7
Materials	5	Weight	3
Product Life Span	6	Market Constraints	2
Politics	8	Manufacturing Facility	1
Company Constraints	0	Shipping	6
Safety	1	Size	2
Testing	2	Processes	6
Environment	1	Customer	1
Patents	3½	Time Scale	0
Shelf Life + Storage	9	Product Cost	0
Reliability	1	Performance	1
Quantity	0	Life in Service	4
Competition	0	Ergonomics	1
Maintenance	2	Standard Specifications	1
Selling Price	1	Aesthetics	1
Climatic Influences	4	Energy Consumption	6
Chemical Influences	7	Installation	9
Other?	STABILITY	MAX. 10	

interviewees expressed a political based fear as being their biggest threat to their product market (eg. changes in farming subsidies).

There generally needs to be an improvement in the P.D.S. Even companies that did consider elements often did not consider them sufficiently well enough. The list of elements to be included in the P.D.S. has been increased as a result of this research by adding 'Installation', 'Sales Potential', 'Energy consumption' (in production and use), and 'User training'.

International Product Design Specifications

There is some evidence in the results to show that some companies have been structuring their Product Design Specifications for an international market, which is sensible as they sell much of their product to markets abroad. 'H' sold 80-85% to the United States in 1985 and J.C.B. sold 70% of their telescopic handlers abroad in 1985. M.F. Industrial exported 50-60 of their first years production of 150 telescopic handlers to the United States in 1985 and 'G' sell approaching 50% of their product abroad, mainly to the United States (FT 12 July 1985).

Manitou and Sambron, on the other hand, are made in France and export to the UK. Manitou said "Specifications are compiled generally in France and, therefore, we have a limited say". "Our input is proportional to our size", (France 900 employees, UK 37 employees). "If we have a product made in France we see if it works here". "With the telescopic handler we had to have it to stay in the Rough Terrain market". In spite of Manitou claiming that they have a design input, two telescopic handler models were introduced in 1986, at two exhibitions without their prior knowledge, or data, being provided to the British subsidiary before the launch ("The first we knew about them was when we opened the crates", Salesman on the stand at Materials Handling Exhibition).

Sambron also have products foisted on them, but have some design input "we take note in competitors' reports which are sent to the factory in France and they improve the design". "The UK market required and adopted a more reliable and driveable machine than the original French product".

Lansing Henley took a great deal of notice of the requirements of the European market when designing the ill-fated 'Workhorse'. The European market research indicated a demand for a higher lift and more sophisticated machine for the European construction market, whereas, the British market research identified a "cheap and cheerful", lower cost, lower lift machine for the agriculture market. The attempt to satisfy both markets in one machine design resulted in failure.

Clearly, J.C.B., 'H' and M.F. Industrial have considered the US market in their P.D.S. and 'G' have stated that they considered the US and other markets. Lansing Henley clearly identified differences in the British and Foreign market at the start of design and this affected the P.D.S. It is not known how the P.D.S. was affected by consideration of overseas markets in J.C.B, M.F. and 'G'.

In magazine articles (P.M.J. April 1983) the, then, Managing Director of 'H' stated that he was designing telescopic handlers for the US market and certainly the majority of their output was exported there (80-85%, 18-26 per month, P.M.J. 1985).

Perhaps, rather than designing for a world market it is best to design for the market that can be reached. From the lesson of Lansing Henley, it may not always be possible to design one product that can meet the requirements of a world market and more than one product may be needed.

J.C.B. mentioned telescopic handler manufacturers who do not manufacture or sell in this country as being amongst the companies considered as 'competitors', they also stated that the US market wanted bigger machines with all wheel steer. 'G' also commented on US competitors without mentioning company names. 'H' mentioned two US competitors and Merlot of Italy, even though none of these three sell on the British market as yet.

6.3 Assessment of Research Criteria - Pilot Study.

In this section the criteria are analysed against the findings from the interviews undertaken with the manufacturers of heavy duty shock absorbers for military vehicles.

Company

C1) This criterion generally appears to be supported. It was fortunate that in the pilot study there was a very dynamic company in O.V.T. and the ultimate static company in Newton and Bennett, therefore, it is possible to extract the features of these companies from the questionnaire answers (fig. 6.3.A) and show them alongside the criterion (fig. 6.3.B). The other two companies, being between the two boundaries, demonstrate a combination of static and dynamic disciplines. Fig. 6.3.A has been modified by crossing out the features that are inappropriate for this product and for batch manufacture. The results show that static design disciplines are

RESEARCH CRITERION C.I. **Fig. 6.3A**

Proposed Features

Dynamic

Static

Dynamic Disciplines

Innovation
Technology Push
Design Protection (e.g. Patents)
High Risk
High Profit
Short Product Life Cycle
Higher Research than Competition
Non Product Related Research
Changing Environment
Flexible Production / Short Production Runs
Large Product Range
Dynamic and Reiterative Planning
Creative Marketing
Competition Analysis
Innovation Seeking Outside of Industry

Organic Structure

Disciplines Deleted - are inappropriate to this product and batch production

Static Disciplines

CAD
Imitation
~~Good-Aesthetics~~
~~Good-Ergonomics~~
Use of Reputation
Market Pull
Low Risk
Low Profit
Short Model Life Cycle
Long Product Life Cycle
Low or equal Research with Competition
-Low Cost Production
Quality +
Reliability
Evolution
Use of Materials
Effective Purchasing
Stable Environment
~~Long-Production-Runs~~
Small Product Range
Mechanistic Structure (bureaucratic)
Value Analysis
Reactive Marketing
Cost Reduction
~~Automation~~
~~Group-Technology~~
Rationalization
Business Planning

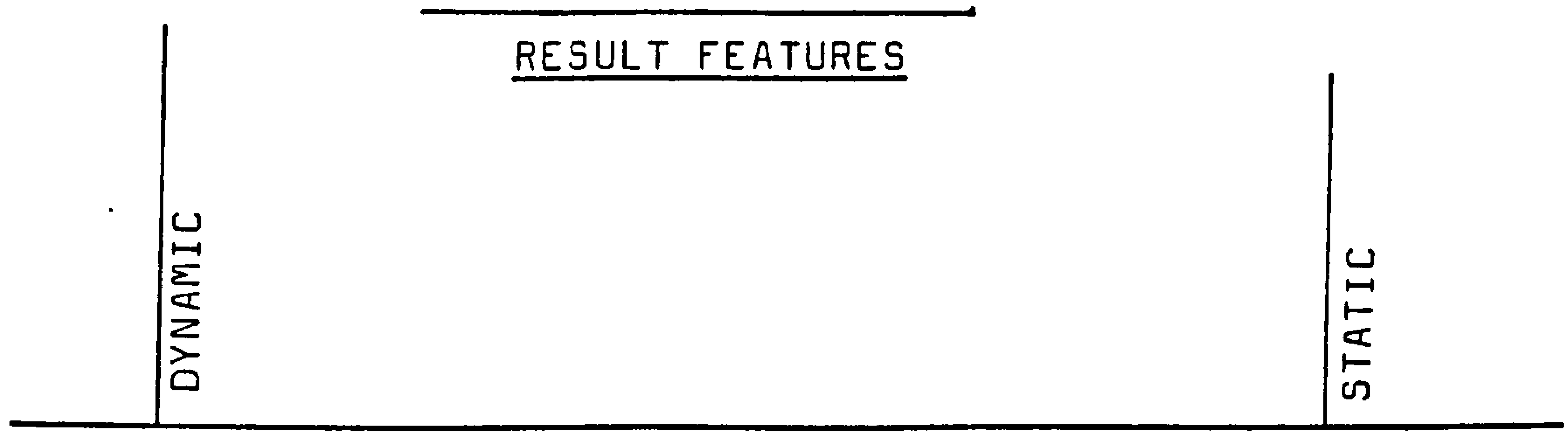
Static Disciplines

Financial Control
Specialisation
~~Economies-of-Scale~~
~~Finish~~
Dedicated Machinery
Assembly Aids
More process design than product design
size reduction
Maintainability

FIG. 6.3.B

RESEARCH CRITERION C1

RESULT FEATURES



O.V.T.

STATIC DISCIPLINES

RELIABILITY

REPUTATION WITH CUSTOMERS

COST REDUCTION TECHNIQUES

ASSEMBLY AIDS

USE OF NEW MATERIALS

STRONG FINANCIAL CONTROL

VALUE ANALYSIS

IMITATION

MORE PROCESS DESIGN THAN PRODUCT DESIGN

(NO CAD BUT WOULD GET IT IF IT COULD BE AFFORDED)

DYNAMIC DISCIPLINES

PATENTS AND DESIGN PROTECTION

SEEKING NEW CONCEPT

INNOVATION

DESIGN

RESEARCH HIGHER THAN COMPETITION

FLEXIBLE PRODUCTION

ORGANIC STRUCTURE

TECHNOLOGY PUSH

HIGH RISK

LOOKING AT OUTSIDE INDUSTRY INNOVATIONS

NON PRODUCT RELATED RESEARCH

NEWTON AND BENNETT

STATIC DISCIPLINES

RELIABILITY

REPUTATION WITH CUSTOMERS

MARKET PULL

LOW RISK

LONG PRODUCT LIFE CYCLE

LOW COST PRODUCTION

NO RESEARCH

IMITATION

QUALITY

MAINTAINABILITY

EVOLUTION

EFFECTIVE PURCHASING

STABLE ENVIRONMENT

STRONG FINANCIAL CONTROL

SMALL PRODUCT RANGE

MECHANISTIC STRUCTURE

SPECIALISATION

ECONOMIES OF SCALE (WITHIN BATCH CONTEXT)

RATIONALISATION

DEDICATED MACHINERY

DYNAMIC DISCIPLINES

NONE

important, even for a highly innovative company, in order to be able to produce effectively for the market.

As a result the questionnaire was refined to further accentuate these features.

C2) Newton and Bennett have taken up a position which does not maximise their chance of survival, quite the reverse, profit is maximised in the acceptance that they have a dying market which they expect to lose in twelve years. This refutes P.F. Drucker (1954) and others who have said that a company's main aim is to survive and, also, refutes the criterion that companies take up a position between the static and dynamic boundary that maximises their chance of survival. This was an isolated case showing Newton and Bennett to be the exception rather than the rule.

O.V.T.'s product had been dynamic but is now entering a static plateau for production stability and there is evidence that they are moving the area of design towards more static disciplines. Their market share is slowly increasing.

Horstman, are treating their product as static but are aware that it is still potentially dynamic so do appear to be maximising their chance of survival. Their market share is increasing suggesting that their chances of survival are also increasing.

'D' treat their product as static and concentrate their design on telescopic dampers and cost reduction.

This criterion was not supported.

C3) Newton and Bennett must either concentrate on a different product which is static or change radically if they are to survive in the shock absorber market. The evidence suggests that they will continue to treat the dynamic shock absorber product as static and decline as a result.

Likewise O.V.T. should concentrate on dynamic products as their structure would not suit a static product. It remains to be seen if, they continue to change their structure towards static or seek a different product to design.

Regarding the criterion, it is supported, as the structures of these two extreme companies suggest that they should concentrate on static or dynamic products. Horstman should not and do not concentrate on static or dynamic design. 'D' are beginning to realise that their product is dynamic and are moving slowly to take advantage of this knowledge, but are better structured to concentrate on static products.

C4) None of the companies, investigated in the the pilot study, were 'imitators' as such, but all were prepared to copy the design of others. Newton and Bennett certainly took the Horstman design and copied it, producing it more efficiently than any other competition in 1947 and were able to keep their market without further significant design until 1975. With static design they were able to keep their market until 1983, when the hydropneumatic design from Laser (OVT) started to replace them. (Note, the Horstman system has nothing to do with the present Horstman company.)

Regarding the criterion, 38 years production, albeit in an uncompetitive market, suggests that static design is an effective successful policy but, when the market changed, Newton and Bennett were unable to adapt. The policy can only be successful and effective if a continuous search is made for new innovations or newly dynamic products and the company then is prepared to take these new innovations, add to them static design, efficient production and marketing to take the market.

This criterion was better supported with a more static product in a more competitive market, as described in the main study.

C5) As none of the companies were Japanese and the results can only be obtained by observation and inference this criterion was removed from the study.

C6) This criterion was supported by the results. All the companies appreciated that the product status was dynamic and, by different means, had organised their management strategy towards efficiency, but all could have been a lot more efficient. Newton and Bennett, had taken the decision, based on the realisation that the product was dynamic, that they could/would not compete and, therefore, maximised profit through eliminating design and investment on the product. Horstman appear to have design well organised for the product status. Management encourages innovation, patents, flexible production, and an organic structure, although their initial market research and P.D.S. was weak, as is sales. They perhaps spend too much time on dynamic design, but do sufficient static design to produce a good product, but the initial specification (or lack of it) may have resulted in a high cost product limited to the M.O.D. market. O.V.T. encourage innovation, patents and organic structure, but are, perhaps, too unstructured to be altogether efficient. Horstman and O.V.T. seek new innovations and accept change in 5-15 years. 'D' encourage patents, but do little original design, although they are putting increased emphasis into dynamic disciplines.

C7) The results do not support or reject this criterion. All the companies were small. O.V.T. employs twelve people as a design and prototype producer, but, for production of the product, they involve Airlog and R.O.F. Leeds and production is undertaken with the product being treated as static. Newton and Bennett are small and getting smaller as the product declines, yet they are fixed in a very static position. They were at their largest when the product was static.

'D' are also becoming smaller.

C8) The criterion could not be supported, as the product under investigation is not static. All the companies needed to innovate.

C9) All the companies showed relative strength in production which was flexible in the innovating company and more dedicated in the non-innovating company, within a batch production context, and all showed weakness in market research and sales. If this is not causing the product to fail, it has limited the effectiveness of wide market acceptance as well as reducing the effectiveness of design.

In the case of Newton and Bennett weakness in design is causing the product to fail. In Horstman and O.V.T. (to a lesser extent) design is a strength. Horstman, 'D' and, possibly, O.V.T. concentrate too much on the engineering aspects of the product and too little on the wider market aspects. This criterion has been upheld.

PRODUCT

P1) The damper is clearly dynamic so that this part of the criterion was supported. The companies are all producing on a static plateau for production stability, but are aware that it will again become dynamic. It was static for 28 years (1945-1973).

P2) It is too early to say if the product has been a success for Horstman and O.V.T., although both have an increasing market. 'D' are stagnating with their static products.

Newton and Bennett had a great deal of success in the market place with a statically designed product. One example did not sufficiently support this criterion, the main study is more conclusive.

P3) With the two products that were recently dynamic it is too early to say that they were successes or failures, but the early indications are that with an increase in their market share they are not certain failures. The market is very limited though. Both companies have an input of static design, Horstman more than O.V.T., which may preclude their product from being relevant to this research criterion.

In short, all the companies included an injection of static design and none had failed in the market place yet through insufficient attention to this. The criterion appears to be upheld.

P4) Newton and Bennett set a standard that lasted until the introduction of the hydropneumatic suspension, but even then the retrofitting to the Chieftain and Centurion tanks used the existing hull fixings. The hydropneumatic system is now the standard for the Challenger and all subsequent systems will need to be designed to this standard fitting. In this market the spares and replacements infrastructure must be kept to a minimum enforcing this standard.

This criterion is upheld.

P5 + P6) Newton and Bennett created the static plateau and it was apparent that this plateau was coming to an end when Laser (O.V.T.) started to develop the hydropneumatic system for tank, from the Alex Moulton (1962) design, in the mid 70's. This was some years before Laser produced a saleable product.

Both Horstman and O.V.T. have 'frozen' the design of their dampers to give stable production and thus creating a static plateau in these companies. In all companies the design was frozen on a particular date and not when design was complete or, in the case of Horstman, all the requirements of the P.D.S. met. Purchase of some new and dedicated machinery also helps with the creation of the static plateau and in this case the M.O.D's reluctance to change the design keeps the product static.

The end of the static plateau may be predicted by a change in P.D.S.

that cannot be met by the existing design. Such was the case when the M.O.D. required a damper performance outside that possible with the Horstman system This requirement specified the changes of performance needed, therefore, the innovation necessary was both identified and quantified. The demand for a compact high performance damper superior to the Horstman system caused the product to become dynamic. The beginning and end of a static plateau appears to be dependent on:

(1) New or available technology.

(2) A change in P.D.S. caused by customer demand.

(3) Time available for design.

(4) The amount of capital tied up in the existing design (eg. dedicated machinery).

(5) The desire for the customer to change (eg. the disinclination for the M.O.D. to hold large stocks of spares).

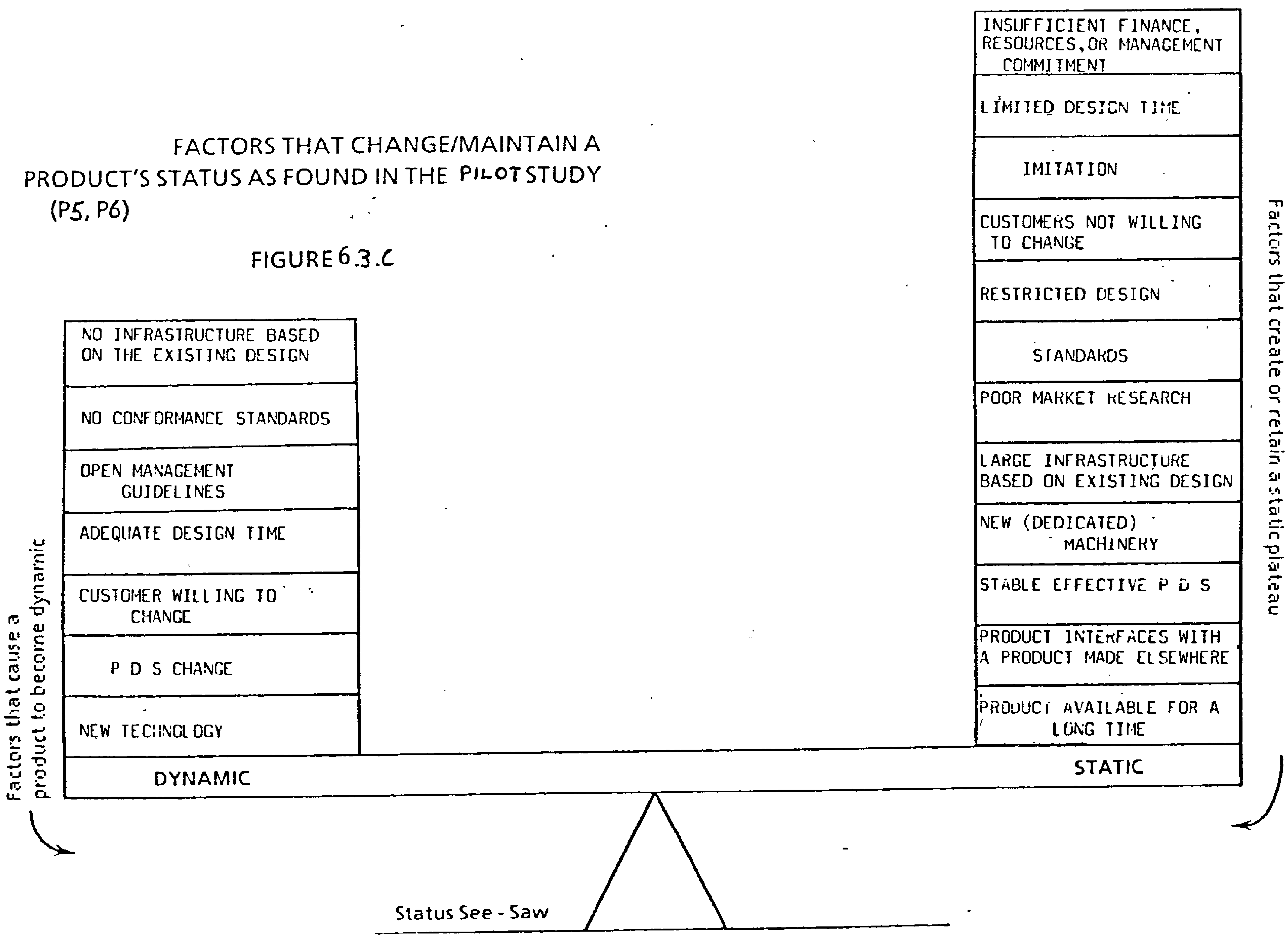
(6) An effective product design specification (as supplied by the M.O.D.) can create a static plateau. These contributory factors to changing status are shown on fig. 6.3.C.

The companies involved in the pilot study believe that the static plateau will end in between 5-10 to 10-15 years. The criterion has been upheld.

P7) No company in the pilot study maximised market share or static design, all sought profitable segments in that market. All the companies were batch producers which limited their static design. Their market share was not clearly known by any company in the pilot

FACTORS THAT CHANGE/MAINTAIN A PRODUCT'S STATUS AS FOUND IN THE PILOT STUDY (P5, P6)

FIGURE 6.3.C



study.

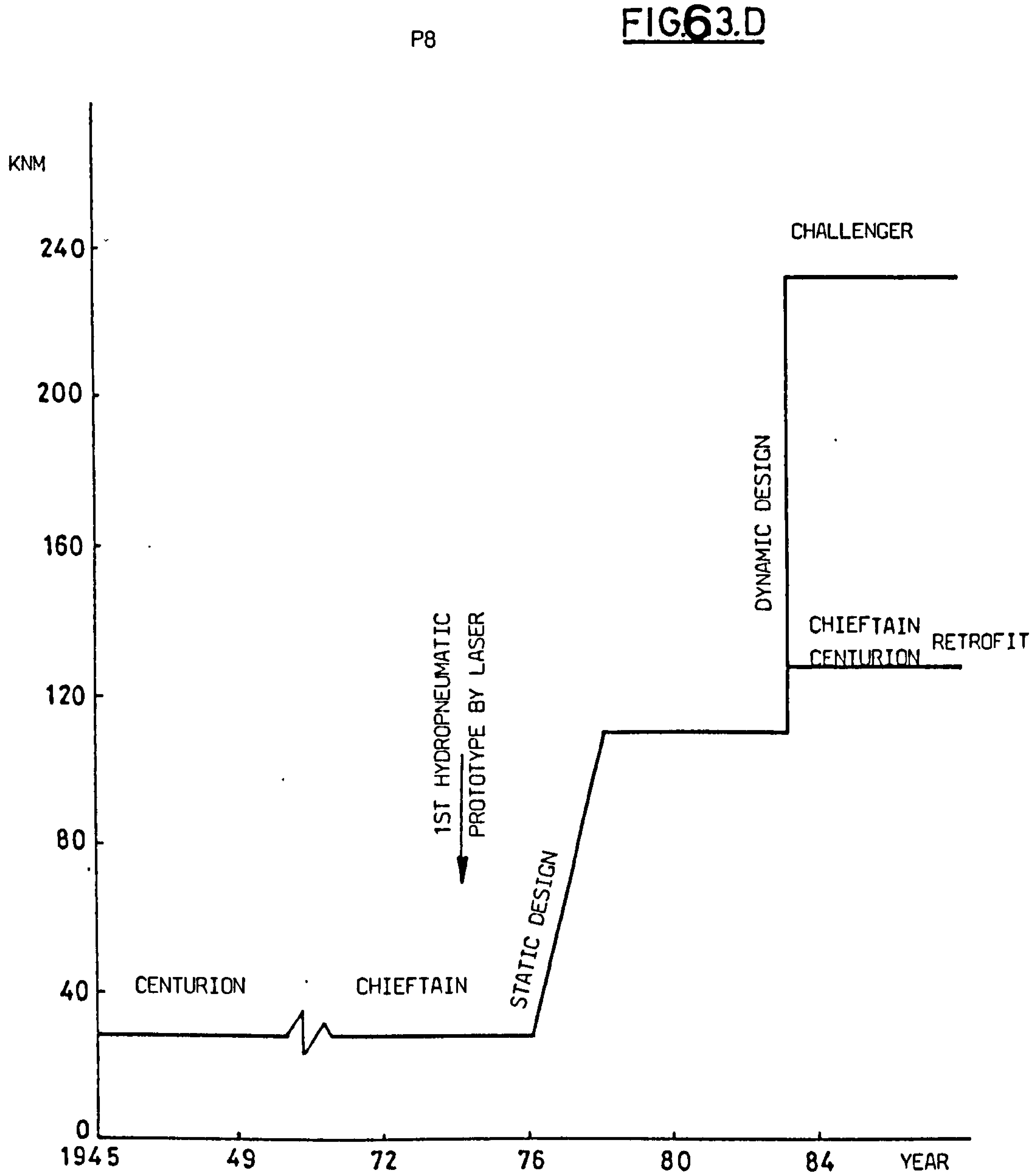
O.V.T. and Horstman have been increasing static design and their market share. With this product the static discipline of reliability was all important and maximising this is necessary to have any chance of increasing market share. At this stage of the study the criterion appeared to be upheld. This was more clearly confirmed in the main study.

P8) The performance of dampers is measured by the damping force at different wheel speeds (which increases up to the blow off pressure) and the length of travel of the damper stroke. With the Horstman system the static design changes only altered the damping force, but, with the hydropneumatic system, the damping force and length of travel were increased. Consider the development of the Centurion, Chieftain and Challenger tank suspension system since 1945, by multiplying the total damper force with the damper travel a measure of overall performance is obtained and this has been plotted against time on fig. 6.3.D. On it have been marked the static and dynamic design changes. This shows a quite considerable difference to the curve shown on fig.2 of the criterion. This curve, or similar, is shown in several texts (eg. Jones 1970 p22) and the results of this pilot study indicate that such curves should be viewed with suspicion. The criterion is, therefore, not supported in this case.

Other products may not have such a clear cut measure of performance or, more likely, several criteria may be taken to judge performance and it is felt, therefore, that an artificial result may be obtained. This criterion was removed from the research.

DAMPER PERFORMANCE

FIG.63.D



1945-76	8 Units	x 23 KN	x .1524 m Travel	= 28	KN.M
1978-83	8	x 90	x . 152	= 109.7	
1983->	12	x 38.8	x . 275	= 128	
1983->	12	x 43	x . 450	= 232	

The hydropneumatic system also has improved 'rising rate' damping which is nearer to the ideal characteristics than the conventional system.

P9) The price curve postulated originally was taken from those that occurred with calculators and video recording machines. The product did not follow the price curve shown in fig.3 of the criterion. With this particular product the price is set by the M.O.D. based on the hours worked and increases are related to general inflation. The criterion was unproven. There are, probably, too many 'other factors' which would generally prevent this curve from being followed.

P10) The design of this product has changed from one to three concepts. It is, perhaps, too early to detect if these will, within the broad concept, iterate to one design as happened first with the friction damper and then the telescopic damper. An effective P.D.S., as in this case, certainly could fix a design especially when supplied by the customer and based on empirical test results. The companies each produced poor product design specifications for their own products.

Newton and Bennett must have had a pretty effective original P.D.S. as there was very little iteration in the design for many years.

With Horstman the original P.D.S. must have also been effective as there has been few subsequent changes. The P.D.S. was supplied by G.K.N. Sankey, who made one significant change which caused a lot of design changes and this was an alteration in the vehicle gearbox, which resulted in a need to reduce the overall size of the damper unit. Had this requirement been known earlier the design would have been finalised earlier. Worldwide the design of rotary dampers appears to be similar.

O.V.T. took 12 years to produce their product which suggests that the original P.D.S. was far from effective, or, possibly, difficulties in meeting it caused the delay.

There are still iterations between designs of the hydropneumatic suspension worldwide and, in this case, patents are preventing iteration to one design.

'D' are stuck in a rut of producing variations of their telescopic dampers to full product design specifications supplied by the M.O.D. They do produce dampers where they compile a P.D.S. in conjunction with customers from the automotive industry. Their declining share of the market suggests that their product design specifications are not absolutely effective.

This criterion was not upheld in the pilot study.

P11) The results obtained show a trend, that is investigated more fully in the following study, that certain products in certain markets do appear to have an order of importance for various criteria. In the short list used on fig. 6.1.A it can be seen that reliability was considered as most important followed by advanced technical features and strength. This could lead to grading of the various elements in the P.D.S. As design is often a compromise between features in the specification, this grading could help the designer to decide which features to accentuate and which to diminish.

Management

M1) This criterion has been upheld. When the product was static Newton and Bennett were successful, but, when the product again became dynamic, company deficiency in design, especially innovation, became apparent, causing a decline in the company. Horstman and O.V.T. both appreciated the product status and their market is growing, but, now the product is entering a static plateau, are looking weak in the area of sales and marketing, Newton and Bennett had, in a batch context, dedicated machinery and inflexible production which suited a static product, Horstman and O.V.T. have kept their production flexible whilst their product has been dynamic.

All the companies in the pilot study appreciated the status of the product and this does appear to have affected their decisions, the most surprising was Newton and Bennett who, when the product again became dynamic and innovation was required, took the alternative option of appreciating that they could not innovate and were not prepared to put in the resources required and maximised profit. They did this by contracting design and, in stages, this whole section of the company. The companies, with the exception of 'D', have a weakness in depending on the very limited market of military vehicles. Horstman admitted that their product was too expensive for general market acceptance. All the companies treated the product as static for production.

All the companies appeared to be held on a tight financial rein, although only Newton and Bennett were prepared to admit it. O.V.T. seemed unprepared to make any commitments on table 3, an example is 'financial control' which was ticked to be 'neither strong nor weak' even though it was given as the reason for limiting work in other areas (eg. research, C.A.D.).

Generally table 3 shows the companies which were static and those which were dynamic.

M2) Three of the companies sought new innovations to determine if the product was again to become dynamic, even Newton and Bennett evaluated the designs of Laser. 'D' looked only at telescopic dampers. The four companies were fairly ineffective in both searching and evaluation, and all underestimate the number of competitors. This criterion has been upheld.

M3) Horstman and O.V.T. both had an organic structure in their design department and it appeared to benefit the dynamic design. 'D' and Newton and Bennett were mechanistic and were less able to innovate. With any dynamic design static disciplines are also required and Horstman especially seemed effective at static design even with their flexible design structure. O.V.T. appeared to be too flexible, lacking any design organisation, whereas, Horstman maintained flexibility within a well organised design model.

This criterion was neither verified nor disproved in the pilot study, during the main study, the picture became clearer.

M4) This criterion has been upheld. Innovation or, in fact, design occurs only when it is allowed to by management in a clear commitment of intent. Newton and Bennett prevented design. O.V.T's company structure emphasised innovation and Horstman's company structure allowed both innovation and effective production. 'D' allowed design only of telescopic dampers.

Production facilities in all the companies was not a limitation on design. O.V.T. and Horstman encourage patents which suits their innovative nature. Strong financial control of all the companies is a major but necessary restriction.

6.3 ASSESSMENT OF CRITERIA - PILOT STUDY

CRITERION NUMBER	OUTCOME
Company	
C1	Supported
C2	Not Supported
C3	Supported
C4	Not Supported or Rejected
C5	Removed as not applicable
C6	Supported
C7	Not Supported or Rejected
C8	Not Supported
C9	Supported
Product	
P1	Partly Supported
P2	Not Supported or Rejected
P3	Supported
P4	Supported
P5	Supported
P6	Supported
P7	Supported
P8	Removed as not widely Applicable
P9	Not Supported
P10	Not Supported
P11	Supported
Management	
M1	Supported
M2	Supported
M3	Not Supported or Rejected
M4	Supported

6.4 Assessment of Research Criteria - Main Study

In this section the criteria are compared with the findings from the interviews undertaken with the manufacturers of telescopic handlers.

Criteria Number	Outcome
Company	
C1	Supported
C2	Supported
C3	Supported
C4	Supported
C5	Supported
Product	
P1	Supported
P2	Not Supported
P3	Supported
P4	Supported
P5	Supported
P6	Supported
P7	Not Supported
P8	Supported
Management	
M1	Supported
M2	Supported
M3	Modified
M4	Supported
Criteria from the pilot study reconsidered	
was C7 now C6	Modified
was P2 now P9	Modified

Company

C1) That companies holding positions at or between the static and dynamic boundaries have, or should have, the factors shown in figure 1. (See Appendix 1 for fig. 1).

The contents of figure one was increased and refined as the research continued. This was due to further background reading, but also due to the interviews where additional factors became apparent through the discussions or the various circumstances where the company features could be linked to the company success. Also, the form was changed to show disciplines necessary for all companies irrespective of its status and also a second level of static disciplines, Static 2, to be introduced when a product is static and the production volume increasing.

It was shown that the growing companies were becoming less flexible. All the companies were increasing static disciplines and these were generally aimed at reducing production costs through the addition of improved factory equipment. It was not difficult to judge those companies which were successful by looking at their position in the 'league table' of companies in the market (Appendix 3) and how they had altered their position over the years. Also, in spite of not knowing accurately their market share, most interviewees did state if the company's market share was increasing, decreasing or remaining static.

Only M.F. Industrial had equal process design and product design, though J.C.B. said that process design would have exceeded product design, except that they had just started work on an update of the telescopic handler range. Thorough market research and competition analysis was poorly undertaken by the majority of the companies.

This criterion, with the latest list of disciplines, has, therefore, been upheld.

C2) Certain companies should concentrate on static products and some on dynamic products.

This has shown to be true. In broad terms the larger telescopic handler manufacturers have been treating the product as static and have generally flourished. The smaller companies (eg. R.W.C., 'H', Finlay) have been less successful now that the product is static and these should, perhaps, concentrate on dynamic products, where they can better compete with larger companies. The exception is J.C.B. who have the capacity and the strength to do both static and dynamic designs for this product, although they are better organised for and likely to be more successful in, concentrating on static products.

None of the companies in the main study were forced to concentrate only on static products by their production facilities and most were prepared to sub-contract a fair degree of their manufacture (or all as in the case of one), if they did not have the necessary production facilities. The management and design structure did not allow or encourage innovation in Manitou, 'B', 'G', M.F. Industrial and 'H',the last being surprising when it is considered that they were the original innovators and are now too small to survive in competition with the larger companies with a static product, as has been apparent by their recent performance and takeover by 'E'.

The criterion has been upheld.

C3) Some companies should concentrate on static design, using the designs of others and this is an effective, successful policy and predetermined strategy.

Of all the companies in the main study only 'E' and 'H' do not admit to imitating features from their competitors' designs. This evidence of imitating is also apparent from the clustering in the parametric analysis. The only company in both the studies that concentrates on this aspect as a predetermined strategy was M.F. Industrial. They accept the product as static and are treating it as such. They are a relatively new company in this market but they took 7% of the market in their first year and appear to be successful.

Manitou admit to copying the design of J.C.B.'s telescopic handler and they sell more of these than J.C.B. do in France.

During the interview at Lansing Henley their policy was decribed for a forklift truck design, where the company "took the best features of a competitor's product and incorporated these" into their design "to take the market from our competitor."

Therefore, on this evidence the criterion is upheld.

C4) Appreciation of product status can enable a company to organise it's management strategy for optimum efficiency.

When the principle of product status was explained to the manufacturers of telescopic handlers all stated that they considered the product was static and it would continue to be so for at least five years and also most considered that the majority of the competition were not innovative. In spite of being aware that the concept of the product was unlikely to change in the near future almost none of the companies were fully organised for maximum efficiency in the light of their product status, although J.C.B. came closest with an "all front assault" on the market, ie. effective process design, production, distribution dealer network and marketing and this, perhaps, demonstrates why they have been market leaders since they entered the market in 1977.

Most of the other manufacturers, through not optimising the efficiency of their management strategy, appear vulnerable in one or more areas. The criterion, therefore, has been upheld.

C5) Design must be coupled with efficient marketing (research and sales) and production and weaknesses in any one of these areas will cause a product to fail.

This appears to have been upheld as J.C.B., the market leader, are very strong in production and marketing (sales) and stronger than all other companies. They are followed by M.F. Industrial, who are also very strong in these areas. J.C.B., if they are weak in any areas, it is in the area of market research. Although they were early on to the market, second only to 'H', they had some serious deficiencies in their original P.D.S., the most important of these was the omission of four wheel drive and this did not become available on the J.C.B. telescopic handler until 1980. M.F. Industrial may also be weak in this area leaving it late before entering the market. Only their strength in other areas (distribution, manufacturing, salesforce) enabled them to be a success, in spite of their late entry.

'H', initially, had very effective market research for their original product, but then did not continue market research and, coupled with poor marketing, their market share declined. Although strong in production their product became unreliable and their reputation for unreliability continued after the actual reliability of the product improved. Their sales effort was thinly spread, which should improve after their merger with 'E'.

The smaller companies, such as R.W.C. and Finlay, are too small to make the large investment in production facilities which makes them weak in comparison to the competition. They are also weak in market research and selling. 'G' were relatively early to recognise the market potential of the telescopic handler and have good sales outlets and low cost production. They have a strong position in the market.

Lansing Henley failed with their first design, which can be clearly blamed on poor market research (and detailed design) for failing to identify two quite separate markets that could not be met by one machine.

Manitou put selling effort down as the main reason for their growth, but stated that they had instability in production, which is now improving.

Sambron blame a weakening salesforce for their failure to keep up with the market leaders.

'B' claimed that production could not keep up with demand, which suggests strong sales but weak production and production was engaged in producing many 'specials', which must have hindered production stability. They are strong in distribution and market research.

'E' are weak in market research and slightly weak in sales, but had stable production.

Most companies appear to be better organised than they were five years ago.

J.C.B. fear only low cost Japanese competition, which suggests that a company with improved static disciplines linked to production could be a threat. Manitou also stated a fear of a company emerging with lower cost production, such as the Japanese.

This criterion has been upheld.

C6) Companies with static products tend to be large in relation to the competition whereas companies with dynamic products tend to be small. (Companies move from innovative to positional as they grow.- Nystrom 1979).

When a company becomes larger it is better able to increase disciplines of static design such as economies of scale, or make dedicated machinery viable. Therefore, it is in the interests of a large company to have a static product and a small company to have a dynamic product as a small company is at less of a disadvantage if the product is dynamic. Therefore, successful companies with a static product would be expected to be the largest.

In the main study the product was static and the most successful companies were those who could incorporate more disciplines of static design and these were certainly the largest. The smaller companies seemed to be in decline and some were trying to operate more as larger companies through merger ('E' and 'H') or combining on a product (Lansing Henley/'B')('E' and M.F. Industrial). All but two of the main study companies (R.W.C and Finlay) were larger than the companies, or the parts of companies, that were involved in the military vehicle damper product of the pilot study, but this has much to do with the nature of the product and the size of the potential market.

There is insufficient evidence to show from the study that companies were large because their product was static or that they were concentrating on a static product because they were large. Most joined the market after the product became static and the largest has been most successful. The criterion has been modified to

'When a product is static the larger companies, compared to the competition, are likely to be more successful. When a product is dynamic the advantage of a company being large are diminished.'

Product

P1) At any point in time some product designs are static and some dynamic.

All the manufacturers considered that the telescopic handler was static, after the principle had been explained to them. They further believed that the product would remain static for at least five years (fig. 6.4.A) and most improvements will be made on static lines, although there may be some sub-innovations within the static concept. In view of the results of the pilot study, where all manufacturers considered that the product was dynamic, this criterion has been upheld.

The manufacturers are generally treating the design of the telescopic handler as static, by not seeking a new concept and by increasing static disciplines and generally reducing dynamic disciplines (though not as fast as perhaps they should).

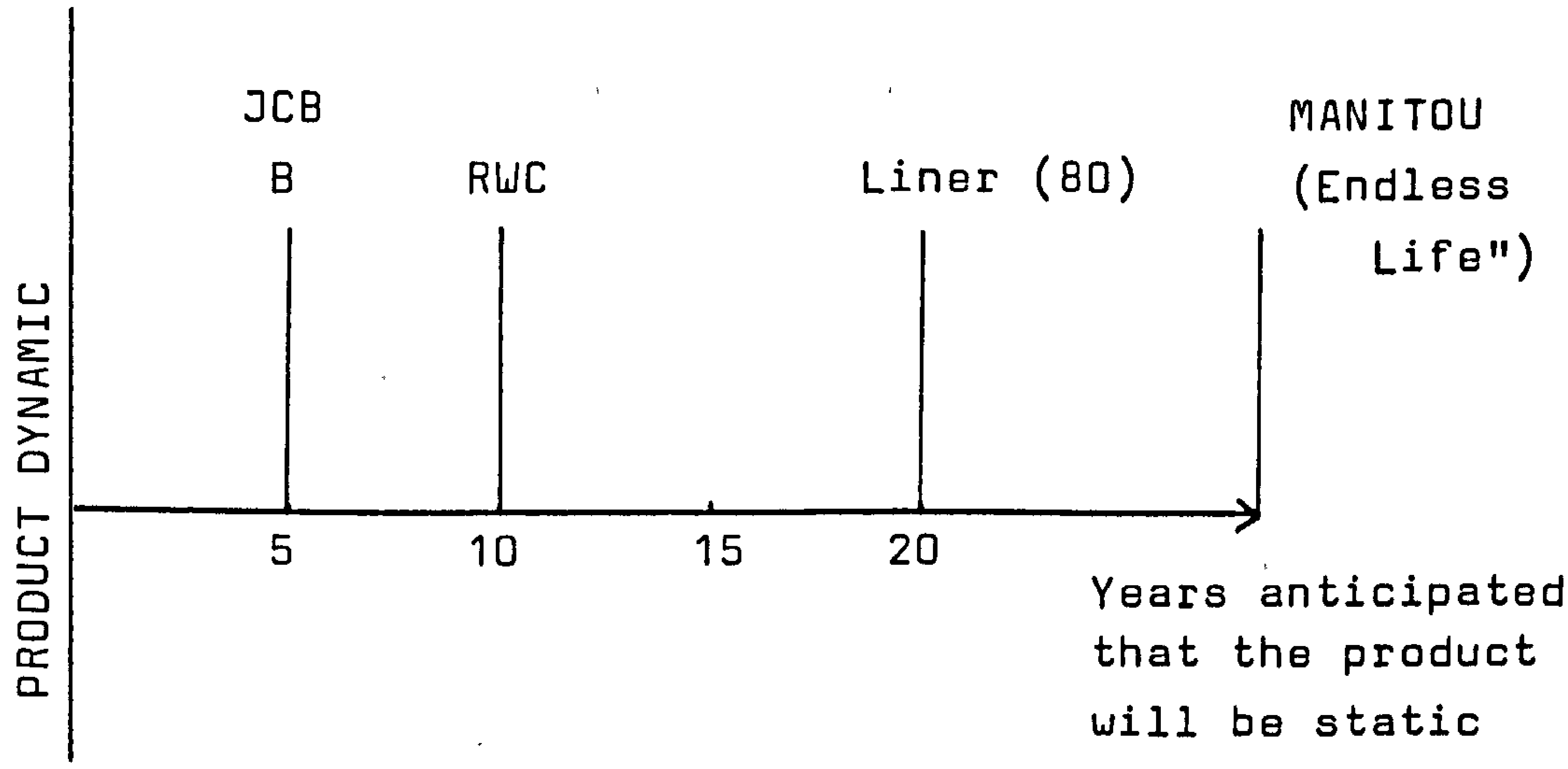
P2) Products that are dynamic fail in the market through insufficient attention to the disciplines of static design.

As the product in the main study was not dynamic it is difficult to uphold this criterion, although it was upheld in the pilot study.

The criterion was not upheld in the main study.

P3) Early recognition of the static plateau can, in some cases, enable a company to set standards.

FIG. 6.4.A



UNSPECIFIED

'G'	"The product is at its beginning of life"
LANSING HENLEY	"For a long time yet"
M.F. IND.	Static for "some time in the future"
'E'	"For the foreseeable future"
'H' 1986	"At this time I can't see another product replacing the telescopic handler"
'H' 1980	"No threat to the market"
MANITOU	Five years for a new market sub division there is no market pressure to change the design

'H' set the static plateau for the telescopic handler in Europe and, therefore, they set the standard which other manufacturers are still following. J.C.B. believe that they set the standard for this design and some other manufacturers also named them as such. For the original design 'H' built a factory to produce the product, but they failed to capitalise on their lead.

The criterion has, therefore, been upheld, although merely setting the standard does not necessarily result in company success.

P4) It is possible to create and predict the static plateau.

'H' created a static plateau with their well researched design. During the interviews, although the manufacturers considered the product was static, several possible reasons emerged as to what could keep a product static for longer and these factors can be used to predict a static plateau or its continuation. (fig. 6.4.B).

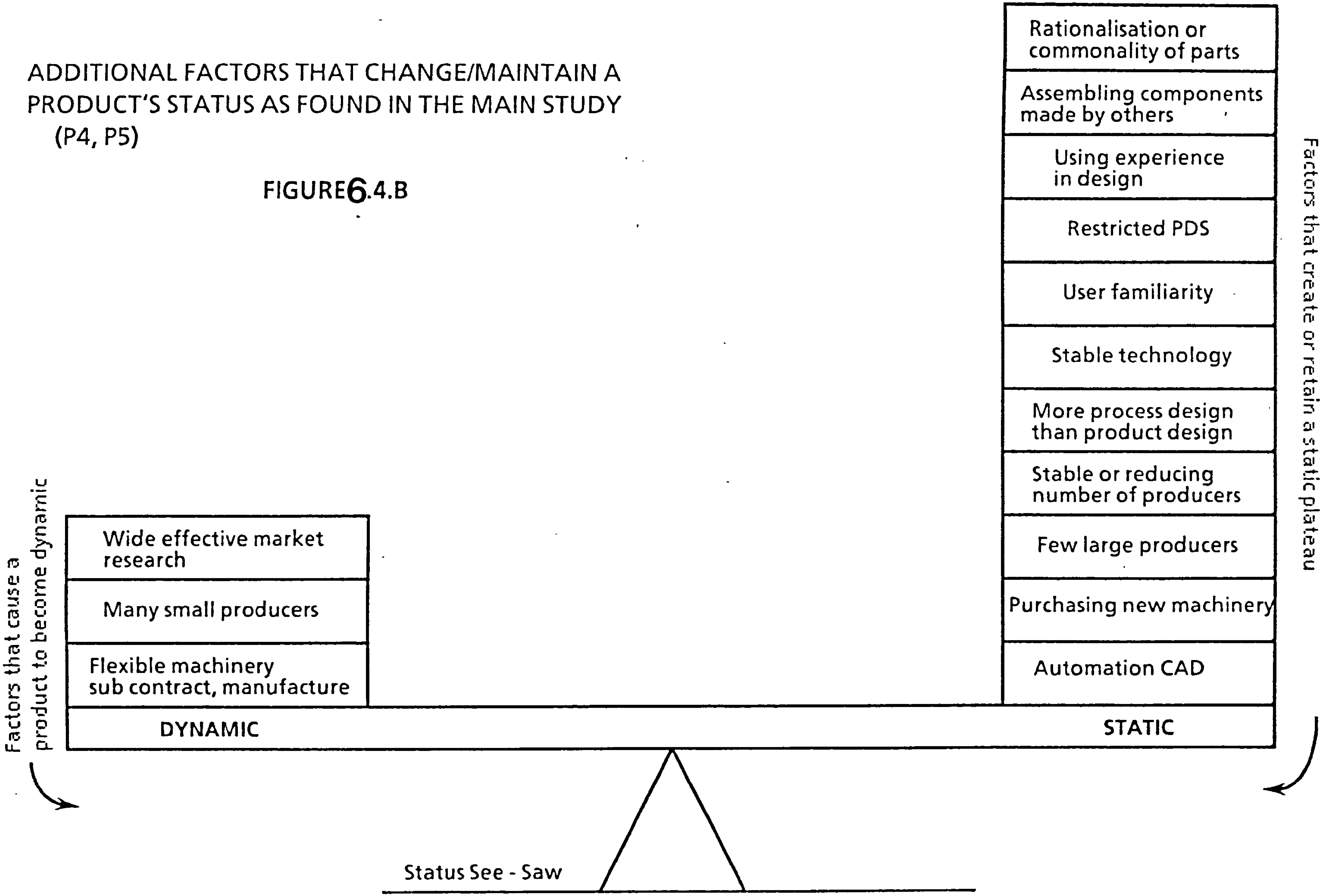
One clearly apparent feature was that none of the companies were seeking a new concept and, therefore, there is less likelihood of a new concept emerging within the industry. Lack of time for design was quoted by several manufacturers and this must tend to keep a design static, as innovation requires more time than incremental product improvements.

A limited P.D.S. was used by 'G' which almost forced a continuation of the existing concept and an inadequate P.D.S. was used by others from which they would be unable to design anything but an extension of the existing product.

Several companies had purchased new machinery, sometimes dedicated machinery, for the production of the existing product and two, a

ADDITIONAL FACTORS THAT CHANGE/MAINTAIN A PRODUCT'S STATUS AS FOUND IN THE MAIN STUDY (P4, P5)

FIGURE 6.4.B



factory and they may be reluctant to design a new product, which would render the machinery obsolete. Although none of the companies said that this would restrict their design freedom it is probably still a factor that could keep a product static.

Two companies used C.A.D. and two further companies were considering it for the design of telescopic handlers. Creating new concepts on C.A.D. is not efficient, but C.A.D. is effective at producing incremental changes. The effect of C.A.D., therefore, is similar to dedicated machinery in its effect of extending the static plateau.

Several companies stated that they undertook Value Analysis. Value Analysis can only be used to improve the design of an existing concept and cannot end a static plateau.

The very effective P.D.S. of the original vehicle apart from setting the static plateau also overcame the need for significant design changes at a later date. M.F. Industrial appeared to have the most thorough and effective P.D.S., and it appears that it was good enough to avoid subsequent changes.

Market acceptance of the existing product as a reason for helping to make the product static was quoted by some manufacturers (although this took some years). Some others also said that there was no pressure from the market to change the product. Most companies stated that they would delay the introduction of small design changes, so as not to disrupt production, spares, handbooks etc. and three said that this would also apply to major innovations. This would help to retain the static plateau.

Some companies' management structure actually prevents innovation, for example, using the same sales force. This criterion is upheld.

P5) It is possible to identify/quantify the value of innovation necessary to cause a static product to again become dynamic.

This was less easy to determine with a static product. The reverse of the factors noted in the previous section may be an indication, for example, companies actively seeking new concepts is likely to lead to an end of the static plateau. All of the companies said that their existing production facilities would not prevent them producing a new concept as they would subcontract where necessary. Technical change was quoted as a factor that was likely to make the product again became dynamic as was legislation (especially safety legislation), recession or changes in Government allowances, but any changes caused by these were thought to be most likely to be incremental.

The management structure and design structure and policy of the majority of the companies did not restrict innovation where it was thought to be necessary.

Effective market research could identify factors that could make a product dynamic. An example was 'B' who designed their sub-innovation, the twin boom handler, after market research had identified a visibility problem with the existing design. This was confirmed by video films of users operating competitors' machines.

Factors have been identified and, therefore, the criterion has been upheld, in so far as it is possible to identify the innovation(s) necessary to cause a static product to again become dynamic. As to 'quantifying the value', it has not been possible to put a firm value on them, although this has been attempted in the status questionnaires (section 7.3).

P6) Maximising market share is inextricably tied up with maximising static design in order to be successful.

The most successful companies had progressed furthest in implementing static disciplines and none further than the market leader. Most of these static design disciplines were in the area of production to reduce costs. The more successful also appeared to be more effective at distribution and selling.

But, of all the companies in both studies, only J.C.B. stated that maximising market share was more important than seeking a profitable segment of that market and they have gone furthest of all the competition in maximising static design and, therefore, this criterion is upheld.

P7) A product iterates to one common design and the speed of this iteration is related to the effectiveness of the original product design specification within the existing technology.

The original P.D.S. by company 'H' was undoubtedly very thorough and based on good market research. Certain elements in this specification were only later copied by the competition eg. four wheel drive in 1980 by J.C.B. and four wheel steer in 1985 by 'G' and a year later by J.C.B. and Manitou. The original specification, therefore, within the technology available at that time, would still produce a fairly marketable machine today. The 'H' machine was too sophisticated for the first time user back in 1974 and in that respect, the P.D.S. was deficient and the product was not the success that it could have been. A less sophisticated lower priced machine would, probably, have been more successful.

The competition copied the broad concept of the machine, the fact that makes the product static and they have also copied certain aspects of the original specification, but, in seeking successful market niches, they have veered away from many aspects of the original specification. Therefore, it has not been shown that the design iterated to one common design. The broad subdivisions have been between the construction and agriculture markets, the latter requiring less lift height, more engine power to machine weight, four wheel drive in generally a smaller machine than required by the construction industry. These markets have been further subdivided as some manufacturers base their designs on tractor skids for cheapness or on their own chassis in more sophisticated machines.

A second aspect to this criterion is the speed at which a design iterates to a common design in one company. 'H' did make some changes, some of which were later reversed, indicating that the original P.D.S. was better than some of their later changes, but, in spite of this, the company lost market share. This suggests that the market was shifting, although their P.D.S. was not and indicating that, even an effective original P.D.S. is unlikely to last for an indefinite period and must develop and change as the market matures. Therefore, in the main study not only did the product not iterate to one design (accepting the fact that the basic concept must be consistent to be a static design), but also it should not have done so as this is not what the market required. It is suspected that this may be true for many products. All the companies did generally agree that there was only one basic design of telescopic handler but the different specifications within this one basic concept are sufficient for this criterion not to be upheld.

P8) It is possible to list in order the value or importance of elements in the product design specification for certain categories of products in certain markets.

This has been shown on the histograms 6.1.A and 6.1.B that the various companies showed consistency with each other in their answers. Although a larger list of elements was used in the main study than in the pilot study, there is generally consistency between the two studies with reliability being shown to be the most important element in a design. This is consistent with previous studies of this nature and, therefore, this criterion is upheld.

Knowing which elements are relatively more important in the P.D.S. for a particular product in a particular market can allow a designer to emphasise the important elements in a design. This should be useful as design is always a compromise between various elements. The results surrounding this criterion are further discussed in section 6.6.

P9) That statically designed products have more success in the market place (over the mature period of the product when sales are highest).

Sales are highest when the product is at the mature phase and this is when it is static (though it may be potentially dynamic).

Successful companies in the research appear to have put a greater emphasis into static design, without actually appreciating the difference between static and dynamic design. It could be seen that the most successful company (J.C.B.) and the company that achieved 7% of the market in their first year (M.F.) incorporated more static disciplines. It was also shown that the majority of the companies sought a profitable segment of the market rather then maximise market share, but to do this a product must also have a fair degree of static design to be successful even with their reduced aspirations. This criterion is, therefore, valid but the wording has been changed to;

'With a static product a greater emphasis on maximising static design disciplines is most likely to lead to market success'.

Management

M1) Appreciation of the product status highlights strengths and weaknesses in the product design group and other areas of company operation (eg. marketing and production).

This criterion has been upheld. Having ascertained that the product was static, it was then possible to identify the disciplines that a company should emphasise with the design and production of their telescopic handler. Companies with more of these disciplines were expected to be stronger and those with fewer of these disciplines were expected to be weaker and this has indeed been shown.

None of the companies matched to the ideal, but, when these deficiencies were pointed out to the company, there was almost universal agreement on almost every point, although, for other reasons, it was not always possible or appropriate to implement these disciplines described in this author's report to the companies.

All companies, although they had not previously considered product status, when the principle was explained to them, they stated that their product was static. The factors they were currently considering now, compared with five years ago, showed that they were putting greater emphasis into static design disciplines, whilst generally reducing dynamic design disciplines. Some companies were moving faster in this direction, surprisingly company 'G' was moving more slowly than most, although they are one of the market leaders. The smaller companies, such as R.W.C., were also moving in the right direction, but are restricted by resources from fully implementing static disciplines.

'E', since taking over 'H', have now the most complete product range of telescopic handlers on the British Market, which would suggest that they should be seeking market share, but it appears as if they are not from the interview answers and they do need a greater emphasis in the disciplines of static design, even though they have moved in the right direction over the past five years. Their acquisition of 'H', with their emphasis on production may improve things.

Generally, all companies needed to put more effort into process design and less into patents, innovation and flexible production with this product. Also, most companies were weak at market research, which is important, whether the product is static or dynamic.

M2) That company personnel must seek and evaluate new innovations to determine if a product is again becoming dynamic.

The telescopic handler is a static product and all the competition are treating it as static and none are working on a new concept for the telescopic handler.

It has been shown that it is important to seek outside a company's own market for new concepts that may make a product again dynamic, as this is where they most often occur. Therefore, the manufacturers, in the study, were asked if they were seeking innovations inside or/and outside of their competitors and market and how they went about this. Nearly all undertook competition analysis and were aware of what was happening in their industry, which, of course, would only show incremental improvements. J.C.B. were the most thorough at competition analysis and were the only company to purchase competitors' machines to test.

Looking outside their own industry was not undertaken in a structured manner and was not done well by Manitou, Sambron, M.F. Industrial and 'H'.

It is difficult to state that this criterion is important with this product, with no evidence that it is likely to become dynamic in the near future, but the criterion is upheld.

M3) That static design benefits from/requires a mechanistic structure and dynamic design benefits from/requires an organic structure.

With the telescopic handler being a static design it is only possible to verify the first part of this criterion, just as the second part was verified in the pilot study. Since writing this criterion this author's views have modified in the light of further background reading and research. It is now believed that, within constraints set by management requirements, an organic structure is preferable in all stages of design down to the layer Static 2.

The study showed that an organic structure existed in the smaller companies, but as was stated at M.F. Industrial:

> "How can you get everybody involved (in design in a large company) you would never get anything done?".

From this has been the development of 'Design Circles' (see section 3.1) in which the organic design structure can be retained and made to work, even in a large company. At Static 2 design is more restricted by rules and the mechanistic structure is more suitable.

The following appear to have an organic design structure: J.C.B., R.W.C, 'B', 'E' and the following have a mechanistic design structure: 'H', 'G' and M.F. Industrial. Not shown either way: Lansing Henley (but tending towards organic), Sambron, Manitou (tending towards mechanistic).

The criterion has been modified to:

Dynamic design benefits from/requires an organic structure, some static design disciplines benefit from/requires a mechanistic structure.

M4) That the company structure provides a mantle in which design operates and this determines what type of design is undertaken.

This criterion was upheld in the study. In all the companies was demonstrated a structure that indicated the type of designs that was allowed and this was confirmed by the type of design that was undertaken. The structure did, in fact, provide a mantle round design.

The mantle restricted all design to static or an extension of the existing product range in 'G', Manitou, M.F. Industrial, 'B' and (now) in 'H' and this was also shown, surprisingly, in R.W.C. previously a very innovative company who were restricting design "to developments of the present machine", perhaps, realising that the product design was now static. Lansing Henley, on the other hand, made almost no restriction on new design, although the Technical Director would like to limit new designs to static. In all the companies there was no restriction placed on designers to use the existing production equipment with any new design.

6.5 Factors that make a Product Static or Dynamic

In this section the various factors that make a product static or dynamic, as found from the pilot and main studies, are discussed. These are also reinforced with examples from outside the study.

There is some overlap between the various headings but, broadly, the following have been identified.

Factors That Make a Product Static

1) Limited Design Time.
2) Customers not willing to change.
3) Stable effective Product Design Specification.
4) Dedicated machinery, automation, CAD, purchasing new machinery.
5) Few large producers.
6) Reducing or stable number of producers.
7) More process design than product design.
8) Poor market research.
9) Stable technology (product static for a long time).
10) Market infrastructure based on existing designs.
11) Stable/improving environment for existing design.
12) Conformance standards.
13) User familiarity.
14) Restricted design (at any level, e.g. V.A.)
15) Relying upon experience in design.
16) Relying upon imitation in design.
17) Restricted Product Design Specification, (e.g. same sales outlet, extension of existing range).
18) Using rationalisation or commonality of parts between several product components in design.

19) Assembling components made by others.

20) Product interfaces with, or is part of, an assembly made elsewhere.

21) Product available in its present form for a long time (static).

22) Insufficient design/finance resources, management commitment.

Factors that Make a Product Dynamic

1) Adequate time allowed for design.

2) Customers willing to change.

3) Change in Product Design Specification.

4) Flexible machinery, sub contract manufacture.

5) Many small producers.

6) Increasing number of producers.

7) More emphasis upon product design than process design.

8) Wide effective market research (innovation seeking, market pull.)

9) Technology change.

10) No market infrastructure or infrastructure capable of accepting a new design.

11) Changing external environment (legislation, economic climate, resources).

12) No conformance standards.

13) Open management design guidelines.

14) Companies seeking new concepts.

A) Status Static or Likely to Become Static

Macro (Look Outwards)

1) Infrastructure Based on Existing Design

If this is large and based on the existing design there is less chance of a new design replacing it. This was demonstated in the pilot study, where new designs, especially those of Laser Engineering Developments Ltd., were difficult to get accepted as the M.O.D were holding large stocks of the existing product. The M.O.D. also had trained operators on servicing the existing telescopic damper and have a policy of not doubling up on component spares for any particular vehicle. Their policy extends to keeping a component design for ten years. Of course, the M.O.D., being a monopoly purchaser, is a special case, but the principle has been demonstrated. In the main study the telescopic handler and rough terrain forklift truck (R.T.F.L.). shared very much the same infrastructure.

Outside of the study it can be seen that the existing infrastructure based on the internal combustion engined car is very strong, which restricts change. This includes fuel supply, skills, servicing, spares, sales and manufacturing facilities.

2) Conformance and Performance Standards

With most products there has to be an interface with other products and changes in the design of one can mean that other products must also be changed. This will usually mean an inconvenience to potential customers or loss of familiarity which may result in non-acceptance of the new design and an extension of the static plateau.

This was seen in the pilot study, where the new hydropneumatic damper design would not fit on to the existing military vehicles initially (without considerable modification) and was rejected until a new vehicle was introduced (the Challenger tank replacing the Chieftain), whereupon, the vehicle was designed to accept the new damper. This new damper design is now the new standard. The original damper (Newton and Bennett) continued to be specified for some six years after the new improved design became available.

Outside of the study there are many examples where an improved design has not been accepted as it does not interface with a popular standard. The new and superior 9mm Sony Video tape can be supplied with a dummy cartridge case to fit the existing and now standard VHS system. The technically superior Philips Video 2000 system failed as it was incompatible with the VHS standard. Conformance standards (such as British Standards) also limited design freedom, helping to retain a static plateau.

3) <u>Product Being Available in its Present Form for a Long Time</u>

The existence of a product on the market a long time appears to generate a 'momentum' that extends its potential design life further. This is probably an effect of the combination of other factors described in this section.

This was not seen in the pilot study as the damper design was again dynamic. In the main study the telescopic handler has been available in this country for 15 years, long enough for this 'momentum' to be clearly identified and the other factors that make up this momentum are apparent (eg. familiarity). The slow initial acceptance of the telescopic handler over the R.T.F.L. may partly have been due to customers being familiar with the R.T.F.L., which had been on the market 26 years before the telescopic handler was introduced.

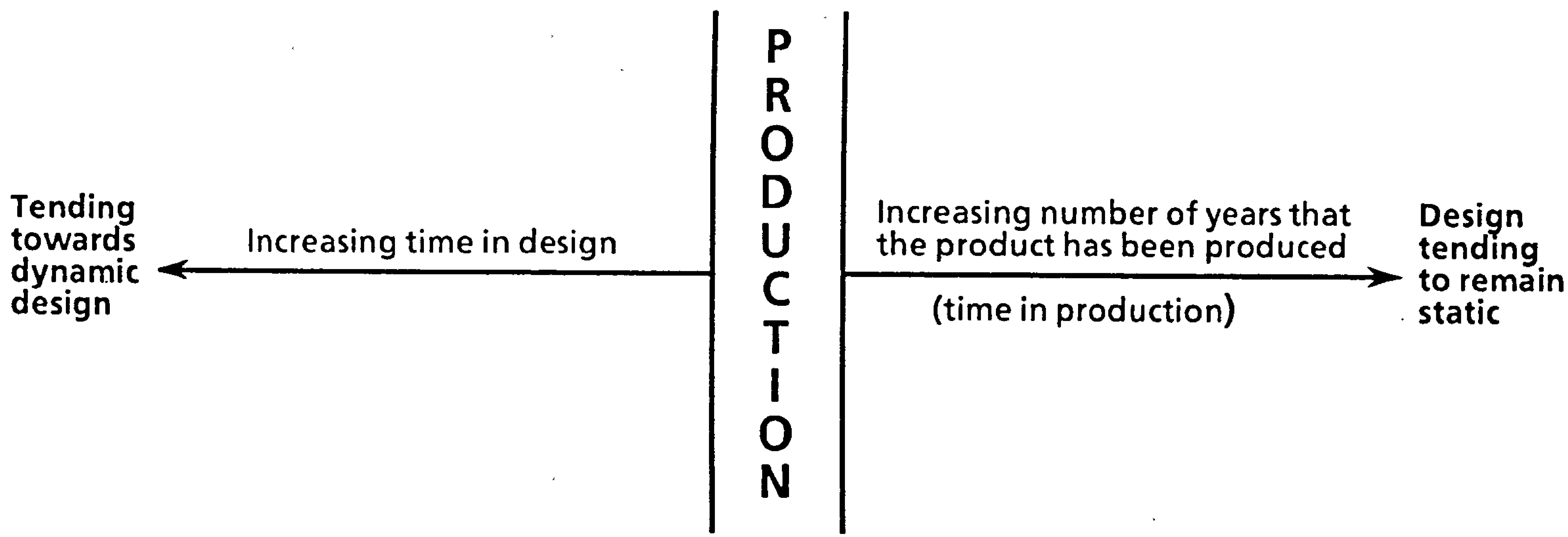
It will be shown that it is in the interests of companies with dedicated machinery to keep the product static. The longer a product is static the more likely it is that the producers will have dedicated machinery, resulting in limited change. (Fig. 6.5.A).

4) Stable Effective P.D.S.

In the pilot study it can be seen that Newton and Bennett had an effective damper specification that allowed them to make the product profitably, almost unaltered for over 25 years, until new technology finally overtook the design. Although this new technology took some years to make an impact, when the new design was announced the end of the static plateau was inevitable.

With the telescopic handler the original 'H' P.D.S. was very effective in many aspects that have only more recently been copied by other manufacturers (the basic shape and operation, four wheel drive, four wheel steer). The P.D.S. was deficient in being overpriced and underpowered for the eventual main market of agriculture, rather than construction for which it was designed. With continuing market research it would have been possible to have updated the specification that would have lasted to this day as the majority of the features have not been altered.

Outside of the study familiar products best demonstrates how the effective P.D.S. can extend a static plateau almost indefinitely. Paperclips, safety pins and staples are good examples.



THE EFFECT OF TIME ON PRODUCT STATUS

FIGURE 6.5A

P5 P6

5) Using Imitation in Design

If all the competitors are copying each other it is unlikely that a design will progress from being static.

In the pilot study this was not shown as the manufacturers of military dampers were progressing with their own designs and the product was dynamic. Only 'D' of those developing new products were looking to remain with the basic telescopic design.

In the telescopic handler market only 'H' do not admit to imitation in the design of their products. The remainder admit the practice to a varying degree and with the M.F. Industrial it is a predetermined strategy and, with the help of parametric analysis, evidence of this can be seen. The designs from the manufacturers appear to have been influenced from three directions,

a) a desire to rationalise using components from other products (eg. tractor skids)

b) an attempt to match their product increasingly for the growing agriculture segment of the market and

c) imitation of their competitors, mainly J.C.B.

Outside of the study the car industry is a good example of how each manufacturer tends to copy each other, thereby, keeping the design basically static.

Of course, it only requires one of the larger manufacturers to accept a dynamic design for all to copy. "J.C.B. made the market for telescopic handlers", has been an often heard comment in the interviews, which caused the companies to extend their range beyond the R.T.F.L. Company 'H', the innovators on the UK market, were ignored, probably, through being on the edge of the main producers and through being poor at marketing.

6) Reducing or Stable Number of Manufacturers
(tending to be larger)

When a product becomes static process design becomes increasingly important. More efficient manufacturing reduces costs and the larger companies, through economies of scale, are in a position to reduce their costs most. So as a product becomes static the larger companies benefit and the smaller companies either decline, find a market niche or get swallowed up in the larger companies. A declining number of manufacturers, who are increasing in size, is an indication of a static product or of a product that is likely to be treated as static.

In the pilot study there was little evidence of this. Newton and Bennett, the most statically structured company, undertaking almost no design, were declining as the damper design had again become dynamic. 'D' also have been declining and this may be due to concentrating their efforts on an out of date design.

In the main study, now the product has become static, the larger companies with relatively lower cost manufacture are benefiting and the smaller companies are either declining or combining to achieve economies of scale.

J.C.B. are the largest and fastest growing in actual sales, 'G' are the second largest. 'E' have taken over 'H' and Lansing Henley had combined with 'B' for their telescopic handler. Sambron are in relative decline and R.W.C. are seeking a market niche away from the main producers. M.F. Industrial have entered the market, benefiting from economies of scale, by using their tractor skid and 'E's' top workings and they have made an immediate impact on the market.

Outside of the study the clearest example is again the car industry, where smaller companies have been swallowed up to make a few very powerful conglomerates producing a static design with a broad emphasis on low cost.

7) Customers Not Willing to Change

A dynamic design may be produced, but it will not end the static plateau unless customers are prepared to accept it in preference to the existing design. This effect overlaps some of the factors mentioned previously. In the pilot study the M.O.D. were not prepared to accept the improved hydropneumatic damper for some years.

The first British telescopic handler, initially, made very little impact on the construction market. Marketing was poor and purchasers were not prepared to pay the higher price for the extra benefits that a telescopic handler would give over a R.T.F.L. They were also more familiar with the R.T.F.L., which had been on the market for 26 years. Agriculture users took to the product when it was adapted for their needs by other companies.

Outside of the study an obvious example is the Sinclair C5, which was a new concept in personal transport, which customers were not prepared to accept for various reasons, for example, safety, image, reliability etc.

A new design must be what the customers want and, therefore, demonstrably better than the product it is trying to replace.

8) Stable Technology

This is the opposite of changing technology causing a product to become dynamic, but it is a factor in itself. A company needs to believe that the technology associated with a particular product is stable or changes can be built into the existing product (sub innovation) to make investment commitments, which leads to other static factors (as above). It is clear from the actions of several companies in the main study that they considered the product to be static and the technology associated with the telescopic handler was stable.

In the pilot study on a micro level a stable technology was assumed for a set period to allow production, even though the product was dynamic. The product was static within the individual company eg. Horstman. Also from 1946-60, the technology of dampers was stable allowing Newton and Bennett to survive with basically an unchanged product.

9) Stable or Improving Environment for the Existing Design

If a product design is acceptable in a particular market and if there are no changes to that market environment, there is less pressure to alter the design. An improving environment may even enhance the attraction of the existing design and extend its static plateau. The recent fall in the price of oil has given the oil fired power stations a new lease of life, which has resulted in lower investment in new 'alternative' power generation (wind, wave etc.) and caused coal powered stations to be less viable. It also makes other forms of transport less attractive securing the product status of oil/petrol vehicles. This 'environment' may include legislation, economic climate or resources.

In the main study changes to allowances to farmers, coupled with an upturn in the construction industry, as noted by 'E' and 'B', has very recently changed the emphasis in design towards the construction market. Although the status of the design for both product markets is the same, the emphasis (higher load, more lift height, smaller engine for the construction market) demonstrated the effect.

B) Status Static or Likely to Become Static

Micro (Look Inwards)

1) Using Experience in Design

There is a difference between a product being truly static and being treated as static when it may be potentially dynamic. When designing it is common to use existing or extensions of practice that has been tried and is known to work. This can keep the product static.

In both of the studies it was commented at the interviews that experience was used in design. In the main study when asked the question "Must new designs be tried and known concepts?" M.F. Industrial and 'H' 1986 ticked agreement and both of these plus Manitou, 'B', R.W.C. and 'G' now restrict their design to generally being an extension of the existing product range.

Outside of the study Klein (1977) shows that reliance on experience is one of the reasons why technical change often occurs away from the existing producers.

2) Products Made by Assembling Components Made by Others

When a company is making a product using components made by others they have less design freedom to allow them to produce a dynamic design. With telescopic handlers quite a few manufacturers have based their design on an existing tractor skid and this has determined many of the characteristics of their vehicle. 'G' stated that they have moved away from using a tractor skid on their latest machine to give "greater design freedom". The telescopic handler manufacturers that use a tractor skid are 'G', M.F. Industrial, Lansing Henley/'B' and R.W.C.

Outside of the study many manufacturers rely on assembling a series of components from outside suppliers and this tends to determine the overall configuration of the design eg. T.V. sets.

The reverse could be argued that it is easier to 'switch off' an outside supplier to allow a dynamic design, as implied by 'G'. This effect does not appear to be as clearly demonstrated or having such a great effect.

3) Dedicated Machinery

If a company has invested in machinery, which can only be used to produce the existing product or similar products, it will not be in the interest of the company to design a product that cannot use this, unless the machinery is approaching the end of its life or the new dynamic design has a significant advantage over the existing static design. This includes C.A.D., which is less effective when dealing with new concepts.

In the studies none used C.A.D. for damper design and only 'B' and

M.F. Industrial used C.A.D. and Manitou and 'E' were considering it on the design of telescopic handlers. J.C.B. used C.A.D. for other products but not telescopic handlers. Some had dedicated machinery and using this machinery was stated to be of importance and thus, this is considered an additional factor that may retain a static plateau.

Outside of the study examples may be seen in the process industries. Product changes (or changes in balance with cracking plants) may require very large changes in expensive process equipment. Product changes are, therefore, made with some reluctance and then only when absolutely necessary.

4) Limited Design Time

Just as a long time in production tends to enforce the static plateau, the same is true if only a short time is allowed for a design. This tends to encourage the designer to use experience, existing methods and components. An extreme example of this was with Lansing Henley, who realised that they required a telescopic handler to prevent further loss of sales in the rough terrain market, took the fastest possible 'design' option (time being the main criteria) by purchasing a complete product from 'B'.

In the main study, in the eleven interviews, short time allowed for design was mentioned by R.W.C., 'G', Lansing Henley, M.F. Industrial and 'E'. (Fig. 6.5.A).

5) Insufficient Design Resources/Management Commitment

Seeking a new concept and then developing it into a product is generally more expensive than making some incremental improvements to an existing design. To seek a new concept requires both management commitment to allow it to happen, supported by sufficient resources, if either is absent the design is likely to remain static in a company (or may not change at all).

This was demonstrated in the pilot study where Newton and Bennett had contracted their design department and the management policy was to only make small changes to the existing products. Laser and Horstman had management commitment and had produced dynamic designs, but Laser were given insufficient design resources to fully capitalise on their new design. 'D' had a stated objective to only develop telescopic damper designs and, therefore, incremental changes to their existing design are all that can be expected from this company.

In the main study J.C.B.'s management have said that their designers do not innovate enough and they are backed by adequate resources and, therefore, J.C.B. are potentially capable of producing dynamic designs. It is known that they are eager to lose their reputation of being a 'One product company' and recently have emerged from this position.

'G' are structured and have product specification sheets, which very much restrict their designs to R.T.F.L. and telescopic handlers. The management appear to be committed to growth through acquisition, although their latest telescopic handler has a more adaptable design not being based on a tractor skid. They had the resources but not the commitment.

R.W.C. had little financial resources but lots of commitment, as their Managing Director has produced some very innovative designs in the past. Lansing Henley also had the financial resources but an overloaded design department, which indicates insufficient design resources, (or direction). Their designs are undertaken in a manner that can produce dynamic designs, but their design brief, from the holding company, restricted designs to rough terrain diesel powered vehicles mainly for agriculture.

Manitou do no design in the UK, but their design policy is "an extension of the existing product range", which is likely to limit design. Sambron also do no design in this country and are only prepared to make incremental changes to their products for the UK market.

'E' have a reputation for innovation within the industry (they are often quoted by others as being innovative) and their Chairman designed the first R.T.F.L. in 1948 and also the centre pivot steer telescopic handler and dumper truck. M.F. Industrial now have the resources and design organised to produce a dynamic design, but prefer not to be first on to a market. 'B' and 'H' had not the financial resources but the situation may change now that both of these have been taken over. It appears that J.C.B. and 'E' are the only companies which are likely to end the static plateau and, for other reasons, J.C.B. would not wish to (eg. economies of scale). This factor has been well demonstrated in this research.

6) Restricted Design

This overlaps much of the previous section but, even with sufficient resources and management commitment, the designs are often limited within certain actual or self imposed restrictions, which can extend the static plateau. Designing which depends on C.A.D. or Value Analysis is unlikely to end a static plateau. A less profound restriction is designing a product that can be sold by the existing salesforce or through the existing distribution method.

In the pilot study three of the manufacturers stated that they were only interested in producing dampers for the military market. 'D', by only designing telescopic dampers, had restricted their design to static.

In the main study several manufacturers undertook V.A. and some stated a commitment to produce only rough terrain handlers or an extension to their existing range, which could keep the product static.

7) Process Design Dominant

The longer a design is static the more important becomes process design over product design, (sections 2.12, 3.1). A company concentrating more of its design effort on the manufacturing process is most likely to already have a static product, but also it is likely to want to extend the static plateau because of the costs already incurred by the process design. Also the reduced time spent on product design is less likely to find a new concept.

In the pilot study Newton and Bennett undertook almost no product design and a little process design. The other companies undertook more product design and had a dynamic product. In the main study none did more process design but M.F. Industrial said they did equal process design and product design. It may be the nature of the product, being batch produced, which limits the advantages that can be accrued from process design. At the time of the interview J.C.B. were just starting design on a new vehicle, it was stated that otherwise they would have indicated more process design.

Outside of the study the car industry is, again, an example, where more design effort is concentrated on the method of manufacture. Most chemical and petrochemical plants are a further example of dominant process design.

8) Using Rationalisation or Commonplicity of Parts Between Several Products in Design

In an attempt to obtain economies of scale, companies often try to use the same components or assemblies in a range of their products. This limits the design freedom and can make a product design continue as static.

In the main study 'B', 'E', M.F. Industrial, J.C.B., Manitou and Sambron were currently working on rationalisation and components are used in as many products as possible. M.F. Industrial have taken this to the point that even door handles are common throughout their product range.

9) Large Company

Similar to (6A) a large company tends to benefit from economies of scale which generally makes it in their interest to have a static product. They are at less of an advantage, when compared with a small company, when a product is dynamic.

In the main study the larger companies can be seen to be benefiting more with the static product. Both 'G' and Lansing Henley stated that a large company was "slow on its feet" and "slow to react to change", which indicates a definite disadvantage to a company being large when the product is dynamic. Furthermore organic communication is more difficult in a large company.

In the pilot study Newton and Bennett were the largest company in the industry but have declined considerably as the military damper design became dynamic.

10) Poor Initial or Continuing Market Research

A company weak at market research is more likely to miss out on trends, changes in the market, technology changes and even fashions. With a greater chance of missing factors that could make a product design become dynamic they are more likely to keep their product static.

Perhaps, from the study 'H' is an example. Having developed the telescopic handler from effective market research, they did not continue market research and failed to notice the increasing agriculture market and did not adapt their design, which may have been a major factor in their eventual decline. The changes necessary would have been static design, but it demonstrates the point.

Outside of the study, the advent of the digital watch was 'missed' by the Swiss watch industry who, at its advent, were rich enough to have purchased any of the digital watch manufacturers. Their failure to undertake effective market research caused their decline, which only now is being reversed.

11) Stable Effective Product Design Specification

If a company had a perfect P.D.S. they could create a static plateau with a new design. This has not been seen in the study, although the original P.D.S., developed by Liner, in most aspects is still relevant and set the static plateau regarding the telescopic boom, which has not been radically altered in subsequent designs.

Outside of the study the compact cassette, designed by Philips in the mid 60's, has remained virtually unaltered and, within the technology available at that time, must have been a very effective P.D.S. Eighteen years later (Jan 1987) a new smaller cassette standard was agreed for digital audio tapes (the tape equivalent of compact discs) and these will become available in 1989 in the U.K.

12) Automation

This is similar to the effect of dedicated machinery or C.A.D. but, whereas use of these actually keeps a product static by keeping the production the same in the case of dedicated machinery or restricting new concepts in the case of C.A.D., automation may, in theory, allow dynamic design but, in practice, this tends not to occur. The adaptability and flexibility of new automated machinery is claimed to allow easy variation of a product so that 'one offs' become viable. Two factors, though, go against this claim and makes automation a factor that is likely to keep a product static.

Initially the cost of automation is high and, prior to an investment decision being made, this investment must be justified. This cannot be done on the basis of 'one offs', unless a great number of these can be assured. It is usually made on the projected production of a particular product, which means that the product must be a static design for a period sufficiently long for the automation to be written off.

Secondly, although 'one offs' can be made by the new automation, reprogramming of the system takes time and is, therefore, expensive and it is not lightly undertaken, but, more important, this reprogramming generally only allows a product which is a variation of a fixed concept. These may be subinnovations, but the product is still a static design.

In the main study J.C.B. were investing in automation including automated welding for the telescopic handler booms (P.M.J. May 1986). This automation allowed variation in the type of booms being manufactured, but only telescopic booms can be welded on the equipment. This investment decision was made on the existing telescopic handler production and the anticipated growth in J.C.B.'s market for this product, This suggests that the product is considered static and that J.C.B. do not intend to phase out the existing design in the near future. 'E' have also invested in a welding robot and M.F. Industrial use a great deal of automation in the manufacture of their telescopic handler.

13) <u>Restricted P.D.S.</u>

With several companies it was noticed that the chance for a product to again become dynamic was limited by restrictions imposed in the P.D.S. 'D' stated that they were only interested in telescopic dampers, even though most of the recent innovations had moved away from these. 'G' used a chart in their P.D.S., which asked specific questions, or asked for data, that limited the design to a forklift truck or telescopic handler, thereby ensuring that the main concept would be retained. Similar restrictions imposed on the P.D.S. will keep a product static.

14) Product Interfaces With, Or Is Part Of, An Assembly Made Elsewhere

If a product must fit or interface with a product made elsewhere, the manufacturer is dependent on the associated company agreeing to change to accept a dynamic design. This can act against a product becoming dynamic as the manufacturers of the interfacing product (often the purchaser) may refuse to change or impose restrictions.

In the pilot study the design changes allowed were very limited. Newton and Bennett were not allowed to change any external dimensions of their damper though they had complete freedom with the internal component design.

Laser (OVT) could not get the Ministry of Defence to accept their improved damper until a new tank was designed. As the M.O.D. has a policy of keeping the chosen design for 10 years to reduce the level of stock, the manufacturer is almost forced to keep their design static or design the new dynamic innovation to interchange directly with the old. The alternator is an example that had to be a direct replacement with the dynamo.

C) Status Dynamic Or Likely to Become Dynamic

Macro (Looking Outwards)

1) Technical Advancement

This is the main factor that can make a design again become dynamic. It can be technical advancement inside or outside of a company, or inside or outside of an industry.

In the pilot study the product was dynamic, mainly due to two new concepts emerging in the field of vehicle damping, the rotary damper by Horstman Ltd. and the hydropneumatic damper of Laser Developments. Outside of the study many examples are available, slide rules to calculators, clockwork watches to digital watches etc.

2) Customers Willingness to Change

The reverse has been discussed in the previous section (7A). A static plateau can only end if customers are prepared to purchase the new product. In the pilot study G.K.N. were very willing to adopt the new dynamic design of the rotary damper and some parts of the vehicles were adapted to allow for the different, more bulbous, shape of the new damper when compared to the telescopic type.

The success of most dynamic designs depends, ultimately, on customers' willingness to change to the existing product concept eg., the acceptance of cassette players over tape players or central heating over open fires.

3) Government Action/Legislation

The government may create or reduce the competitiveness or desirability of certain products through, for example, taxation or safety legislation or legal acceptability. This can create a potential new market for a dynamic design that avoids these problems. It can also create a market for new designs that service this market.

In the pilot study, two of the companies expressed a fear that, if government spending was reduced on arms, the fall in potential orders would jeopardise their viability and this would, perhaps, cause them to seek a new market, which could result in a dynamic design. In the main study two companies said that the design of the telescopic handler would, probably, be altered, though only statically, if expected safety legislation was introduced, as happened with R.T.F.L. trucks. The change in farming subsidies, that occured towards the end of the research, was quoted by 'E' as having reduced the farmers' capital available for buying machinery. This had seriously affected demand for telescopic handlers in the agriculture segment of the market and emphasised design for the construction sector.

Outside of the study the Health and Safety Act of 1974 and BS 5740 'Safeguarding Machinery' spawned a whole new industry of safety products, many of which involved entirely new concepts using infra red light guards and optical fibres, replacing the slower mechanical methods. Likewise, legislation on driving hours caused the market and design for tachographs.

4) Changing Environment

Relative changes between the costs of certain commodities, the availability of some resources and even the general economic climate can cause a product to again become dynamic. Higher disposable incomes can cause many new products to be designed where none existed before.

In the main study the slow take off of telescopic handlers in the late 70's and early 80's could be partly explained by the flat economic environment in the construction industry. With less available finance and generally less use for such vehicles, as fewer building contracts wre available, the entire rough terrain market was low (approx 1700 in 1982 to 2530 in 1984) and the finance that was available tended to be spent on the cheapest vehicle, the R.T.F.L. Now that the market is more buoyant the demand for the telescopic handler is growing.

Outside of the study one has only to look at the increase in the demand for consumer products and dynamic designs, over the past twenty years - tumble driers, microwave ovens, video recording machines, colour televisions. Such products are generally not widely available in developing countries where disposable incomes are less.

5) Increasing Number of (Small) Producers

This is the reverse of (6A). Small manufacturers have a history of producing more technological breakthroughs than large companies, as they have less to gain from a product design being static and they can adapt and change faster than larger companies. An increasing number of small manufacturers of a particular product is an indication that the design is dynamic or potentially dynamic.

In the pilot study the number of companies involved had risen from two, Armstrong and Newton and Bennett, to six in ten years. None of companies now manufacturing are as large as Newton and Bennett were thirty years ago ('D' is larger but the majority of their production is automotive dampers).

With telescopic handlers the product is static and the reverse is happening.

Outside of the study it can be seen that the mini computer manufacturers tended to be small, but over the past five years, as the product has been on a static plateau, the number of manufacturers has quickly declined and mergers have made these companies larger. The main frame industry reached this point some fifteen years earlier.

6) The Same or No Infrastructure Based on Existing Designs

This is the opposite of (1A). If an existing static design can be easily replaced without the need to alter any peripheral or mating products, it is potentially better able to become dynamic.

In the pilot study it could be seen that there were problems in replacing the new damper systems into the space left by the original telescopic design. In the main study, although there is an infrastructure of distribution, servicing, manufacture, skill etc., the telescopic handler can fairly easily use the same infrastructure as the R.T.F.L. and, therefore, can replace it as if no infrastructure existed.

Outside of the study the ease of acceptance of tumble driers over spin driers, or transistor portable radios over valve radios, and even the acceptance of lead free petrol could partly be due to the previous design having the same or no infrastructure associated with it.

7) <u>No Conformance or Performance Standards</u>

(The opposite of 2A)

If there are no standards to which a product must conform, there is more freedom for the designer to break out from the existing concept and introduce a dynamic design.

The telescopic handler must conform to various standards in order that it can be used on the roads e.g., braking, lights, types of tyres etc. and this limits various aspects of the design.

Outside of the study it is easier to see the designs, which have been limited by standards, which determine shape and materials used. Art objects are generally free of standards, which allows freedom of design. It also takes time to write a standard and, therefore, these tend to be written for static design products. A lack of standard, is itself, an indication that the product may be dynamic.

D) <u>Status Dynamic or Likely to Become Dynamic</u>

<u>Micro</u> (Looking Inward)

1) <u>Change in Product Design Specification</u>

A significant change in the P.D.S. by a customer, or from market research, may end the static plateau.

This was clearly demonstrated in the pilot study where the M.O.D. changed the damper requirements outside those possible with the existing Horstman system on the Chieftain tank. This was the result of experimentation that showed tank drivers were damaging their backs if the tank was driven at top speed across country. These results were the basis which resulted in the Laser design and the same results were later used when Horstman Ltd. were designing their innovation for GKN Sankey.

The initial telescopic handler designed for 'H' was the result of a P.D.S. compiled from market research, which indicated the requirement for a vehicle different from a R.T.F.L. in having forward reach.

2) Management Commitment to Allow Change

This also requires adequate resources to be made available. It is the opposite to (5B). In the pilot study both Laser and Horstman were given adequate management commitment to allow their dynamic designs to be undertaken, though only Horstman were given adequate resources to complete the design properly (to include thorough testing and ease of manufacture). Newton and Bennett were given no resources for new designs which is the main reason behind them staying with the existing telescopic design. In the main study J.C.B. management considered that the company did not innovate enough. Of the other companies in only three the management encouraged innovation.

Management commitment may not produce a dynamic design, but the reverse will keep it static.

3) Adequate Time Allowed for Design

This is the opposite of (4B). A dynamic design will generally take longer than a static design, as new concepts will require longer testing to show their reliability in comparison to known static designs (experience cannot be used). It is, therefore, necessary that an adequate time is allowed to produce the innovation. (Fig. 6.5.A).

In the pilot study Laser took ten years to get their dynamic hydropneumatic damper system into production, although some of this time was due to design inefficiency and poor management of design.

Concorde is an example, where many years were needed before a 'suitable' product was manufactured. (Concorde first proposed at Paris Air Show June 1959, entered service 1975, first flight 1969. (Belbin 1981)).

4) Process Design Small

This is the opposite of (7B). If process design is limited, more time may be directed towards product design and there will be less special production equipment likely to be made obsolete. There is, therefore, a greater incentive to produce a dynamic design than if process design dominated.

In both of the studies there was not a large degree of process design. Laser did no process design and concentrated all their effort on product design and dynamic design at that. Manufacture of their products was undertaken by a separately run company and also by R.O.F. Leeds, who, it is known, were unhappy at the small amount of production consideration given in the Laser damper design.

5) Flexible Machinery

This is the opposite of (3B). If the production process are kept flexible, they are better able to cope with new designs and, especially, dynamic designs. Most of the manufacturers in both studies had mainly flexible machinery, though nearly all, also, had some dedicated machinery. Small companies tend to have more flexible machinery that can be used on a variety of products, subcontract toolmakers being and obvious example.

A known example, outside of the study, is of a cocktail stick manufacturer who has to change the range of his novelty sticks monthly to keep in fashion. Any dedicated tooling must be written off within one month and, therefore, is not purchased, unless unavoidable. Therefore a company with flexible machinery is more predisposed to making a product become or stay dynamic than a company with dedicated machinery.

In theory robots should be used as flexible tools, in practice the justification of their cost generally means that large production quantities are needed and they tend to be used as dedicated machinery - as in car plants. Furthermore a welding robot can only weld, therefore, designs need to be welded rather than glued together, restricting the designer's freedom.

6) Wide Effective Market Research

It is only possible to detect what is happening in ones industry and outside through effective market research and, if effective, the factors, which make a product dynamic or keep it static, can be noticed. The market research undertaken for 'H' for their R.T.F.L. discovered the demand for the telescopic handler, which created a new dynamic design.

7) Companies Seeking New Concepts

Unless a company makes a conscious effort to seek a new concept the design will remain static, but once a company starts to seek a new concept there is a chance that a new dynamic design will result. In the pilot study, when it was discovered by M.V.E.E. that the existing Horstman suspension was inadequate, Newton and Bennett set about improving the dampers by static design, which resulted in significant improvements, but their results were limited by the design concept. Laser (OVT) sought a new concept, which would achieve the necessary improvement required in higher loads and longer suspension travel.

No companies in the main study were actively seeking a new concept.

6.6 Grading the Elements of the P.D.S.

The Feilden Report (1963) stressed the importance of non-price factors, which include reliability, appearance, ease of use, maintenance, comfort, safety, prompt delivery and performance. In this research an attempt has been made to determine the relative importance of these elements in the P.D.S.

Criterion P8 states that:

> "It is possible to list in order the value or importance of elements in the P.D.S. for certain categories of products in certain markets".

Rothwell and Gardiner (1984) looked at the important factors in machinery purchasing decisions of 105 British Farmers (mixed farms) (table 6.6.A). These were listed and signified as price (P) and non-price (NP), factors NP (I) being convenience and NP (II) quality.

Their results were:-

	Factor	Average	Ranking
6.6.A	Reliability in Use	1	NP (II)
	Overall Technical Quality	2	NP (II)
	Speed of Spares Supply	3	NP (I)
	Work Capacity/Speed	4	NP (II)
	Ease of Maintenance	5	NP (II)
	Ease of Use	6	NP (II)
	Quality of After Sales Service	7	NP (I)
	Sales Price	8	P
	Ability to Meet Quoted Delivery	9	NP (I)
	Choice Offered by Local Agents	10	NP (I)

In another study by Parkinson (1981) comparing British and West German machine tool manufacturers the question was asked,

"How important do you believe the following factors are when you are considering the purchase of a new machine tool of relatively standard design?"

The results were as follows:- (table 6.6.B)

Overall rating of Product Attributes. Analysis of West German and UK Users.

Table 6.6.B

Product Attribute	very important 1	3	5	7	not important 9	
Accuracy	76	23	0.8	0	0	%
Reliability	91	9	0	0	0	
Flexibility	33	39	23	4	0	
Price	33	37	25	5	0	
Delivery	33	40	24	3	0	
Power	36	28	25	9	1	
Max. size of workpiece	23	40	24	7	5	
Rigidity	48	36	14	1	1	
Standardisation of Parts	30	36	23	10	2	
Technical Sophistication	36	26	26	10	3	
Speed of Operation	53	29	16	2	1	

In this author's research a ranking was sought from the manufacturers of the relative features they considered important for their product in their market. The manufacturers were asked to rank the features between 'very important' and 'very unimportant' in five steps. 'Very important' was given two marks, reducing by one mark at each step to -2 for 'very unimportant'. The results are shown on table 6.6.C.

The total number of factors questioned is shown, the list of factors for the heavy duty damper was much shorter than that for the rough terrain telescopic handlers.

Table 6.6.C.

Rough Terrain Telescopic Handlers

Factor	Ranking
Quality	= 1
Safety	= 1
Maintainability	= 3
Ease of Use (Ergonomics)	= 3
Strength	5
Long Working Life	6
Low Price	7
Appearance	= 8
Fast Delivery	= 8
Finish	10
Advanced Technical Features	11
Conforming to Standards	12
Small Size and Weight	13
Colour	14
Low Energy Use	15
Long Shelf Life	16

The table 6.6.E. compares the factors that appear in Rothwell and Gardiner's study and this study. Not many factors appear in both tables and some have been considered as the same without being exactly so eg. 'Speed of Delivery' = 'Speed of Spares Supply', 'Strength' = 'Overall Technical Quality'. Of the six features directly comparable 'Reliability' is shown to be most important in all three cases.

Heavy Duty Military Vehicle Dampers

Factor	Ranking
Reliability	1
Strength	2
Advanced Technical Features	3
Maintainability	4
Low Price	= 5
Ease of Use (Ergonomics)	= 5
Finish	7
Appearance	8
Colour	9

'Sales Price' appears to be relatively unimportant as does 'Ease of Use'. It must be remembered, though, that these six factors are probably more important than many others that have not been listed, eg., 'Colour' and 'Long Shelf Life' are of significantly less importance than 'Low Price'.

The product status can also aid the designer in grading the elements of the P.D.S. for greater, or less, importance.

6.6.D.

Dynamic Product Elements relatively more important than in a static product design. Increased activity:-

Product Design Features	Company Design Features
Design Protection (eg. Patents)	In-house Training
Market Definition	Customer Training
Customer Definition	Niche Marketing
Seeking New Concepts	Flexible Production
Innovation	
Advanced Technical Features	

Static Product Elements relatively more important than in a dynamic product. Increased activity:-

Product Design Features	Company Design Features
Aesthetics	Product Design
Ergonomics	Purchasing
Incremental Improvements	Competition Analysis
Product Cost Reduction	Parametric Analysis
Energy Use with Product	Energy Use on Production
Imitation	Rationalisation
Value Analysis	Mass Marketing
Conformance Standards	
C.A.D.	

Extracting the product attributes from the studies by Rothwell and Gardiner (R & G) and Parkinson (P) that can be compared to this author's research and then put them in order of importance the following result is obtained:-

6.6.E.

Overview of the 3 Studies

Factor	Ranking P (1981)	R&G (1984)	Damper	Telescopic Handler
Reliability	1	1	1	1
Overall Technical Quality/ Power/Rigidity/Strength	4	2	2	4
Speed of Spares Supply/ Fast Delivery	3	3	-	6
Ease of Maintenance/ Standardisation of Parts	5	4	4	=2
Ease of Use	-	5	6	=2
Sales Price	2	6	5	5
Advanced Technical Features/ Technical Sophistication	6	-	3	7

This demonstrates the overall importance of product reliability in product design and emphasises why it should be considered early in the P.D.S. Reliability has been much quoted as one of the reasons for the success of Japanese products.

Apart from grading the elements of the specification, for importance in the manner described, certain elements are clearly more or less important depending on the type of product being designed. If the product cannot easily be seen in use, as the damper, colour and appearance are of less importance (and low energy use for a damper is anathema). Likewise, a low volume of sound is an advantage in a car, but a disadvantage in a radio, so performance features must be viewed in relation to the product under review.

6.7. Analysis of Company Success in the Pilot and Main Study

Analysis of Success in the Pilot Study

Horstman came across as being the best organised in design with a suitable input of static and dynamic disciplines and an organic design team structure suited for its product status. They had a weakness in marketing, which they know about and a poorly defined P.D.S. One month after the interview Horstman were awarded a £7 million contract for their rotary damper confirming current market success.

O.V.T. have been sold and 'D' were the subject of a management buy out and like Newton and Bennett are in decline. The companies operate at quite different positions between the static and dynamic boundaries and this, due to their differing objectives, explains the differences obtained in the results. The overall result is that the companies all appreciate their product's status, but have different ways of coping with it. O.V.T. was positioned near the dynamic boundary and Newton and Bennett were positioned firmly at the static boundary. 'D' and Horstman were between the boundaries, but 'D' is closer to the static boundary and Horstman closer to the dynamic boundary. As the product is dynamic, but must be treated as static for efficient effective production, it would appear that Horstman were at the optimum position. All the companies treated their product as static for production.

All the companies were weak at competition analysis, market research and in their P.D.S's. As these are the most important features of the front end of design it is, perhaps, not surprising that the success of these companies is small and that their designs do not fulfil a wide market need.

All the companies in the pilot study rely very heavily on a few customers, which is partly due to the nature of the product but very little effort appears to have been taken to widen the market with this product. The weakness at the front end of design confirms the need for better design management and for this research.

Market

The limited market and few customers, as well as the uncertainty of defence contracts, suggests that this is a poor market to be in and a company with good market research would not make such a market an important product base. So, perhaps, the finding of poor market research by all the companies is not surprising.

As shown in the literature search (2.3) poor market research has been shown to be one of the main causes of new product failure and each of the companies is vulnerable to product failure from this cause.

The Product

The status of the product clearly fits into a time frame and the success of the design and the companies producing them must be related to time and the technology available. This product remained static from 1948 to 1972 then became dynamic, The newer technology of hydropneumatic suspension, designed by Alex Moulton, promised a design that could meet new requirements.

Laser, then O.V.T., took the sophisticated 'engineering' solution, where these optimum damper characteristics have appeared to be the major requirement and this has been achieved, although the solution took ten years (1972-1982). Newton and Bennett have not made any design changes after the static designs of the mid seventies treating the design as absolutely static, maximising profit and accepting decline of this product area as a result. A third direction was taken by Horstman, who have developed a new concept, but an easier one than Laser, providing improved damping performance and a reliable prototype in two years. (Another comparison is from start of design to customer acceptance of the product, five years for Horstman (1977-1982) and twelve years for Laser (1972-1984).) This suggests that the innovative step should not be too great if companies wish to get a successful new product on to the market quickly.

Analysis of Company Success in the Main Study

Company success was less obvious in the main study as it was in the pilot study and, therefore, this section was expanded to include a search into the total market size, its change in total size over time and the postion of producers in that market.

It has been difficult to estimate the total market, market share and company growth for each company for the telescopic handler for the following reasons:-

1) Companies are reluctant to divulge the number of machines they manufacture or their market share.

2) Some companies do not know their market share (eg. Manitou).

3) When figures were supplied in the interviews, in spite of the promise of confidentiality, they were generally an exaggeration. This was apparent as total market shares given exceeded 100% by a large amount and total sales far exceeded what few official figures that did exist.

4) The British Industrial Truck Association do keep statistics but this information was refused.

5) Various statistics are given in trade magazines, but these tended to be rounded up and, often, inaccurate eg. 'G' made 1000 vehicles in 1985, exported 50% and claim 30% of the rough terrain market (F.T. 12.7.85), This would make the total market in the UK for rough terrain vehicles 1500, which is low by over 1000 vehicles.

6) There were no accurate official figures held for this market sector by Government bodies. The official figures held for the 'Business Monitor Quarterly' omitted two significant manufacturers showing UK manufacturers only and were, therefore, low and these figures did not differentiate between telescopic handlers and rough terrain forklift trucks.

The best figures were compiled by the Corporate Intelligence Group and displayed in 'British Construction Equipment Supplement to Contract Journal' March 1986. These only gave the total UK market and not company shares in this market. From this author's research these appear high and this was agreed by Mr C. Taylor, who compiles the Business Monitor Quarterly. It was, therefore, agreed with this author that the official figures, which are now supplied, would be a reduction of 5% on the Corporate Intelligence Group's figures.

Figures for years prior to 1982 have been estimated by this author from various magazine articles of the day, which gave production, turnover, market share etc.

Market position has also been estimated over the years since the product's introduction. These are shown in Appendix 3.

6.8 Main Study - Results and Analysis of Parametric Analysis

Using magazine articles and manufacturers brochures, dating back to the introduction of the first telescopic handler in Britain in 1974, it has been possible to investigate model changes to compare telescopic handler designs.

Various parameters of the telescopic handler, from all manufacturers, were plotted against a base of time, to detect the general trends in design. Also random parameters or combination of parameters, were plotted against other parameters, to again detect trends, market niches, or a 'hardening' of the design format.

The number of models of all manufacturers has also been plotted against a base of time, showing the rise in the number of companies supplying the market.

Model Changes Over Time

Like the R.T.F.L. (introduced by 'E' in 1948) the telescopic handler took a long time to be accepted. When the market began to take off in 1982 it was the agriculture users that took to the machine first. It is clear that they required a machine with four wheel drive, not a great deal of lift height, a lower basic cost machine with digging capability, but more engine power (approx. 15% more for the same size of vehicle). The manufacturers responded by offering larger engines as optional or standard and, as a result, the power/weight ratio has increased over time. Four wheeled drive is included on all new designs introduced since June 1984. 'E' was the last to introduce a telescopic handler without a four wheel option in January 1984, although a lot of construction users still opt for two wheel drive, one reason (apart from lower price) has been given as this gives "better site discipline".

Most machines fit into the mid range 5.6-7.0 m lift, although construction, generally, requires a lift of over 7m, to reach three storey buildings and, although 6.7m is the absolute minimum for this, the majority of the vehicles have a lift maximum below this. P.M.J. (September 1981) noted that the 4.5m lift, of the Manitou Manireach (now ceased production), was too limited for construction. The maximum lift of a R.T.F.L. is 5.5m (but, of course, does not have a forward reach). Over time there has been a shift to greater 'risk' in the telescopic handler design, probably due to learning and experience. This is shown with an increase in the specified load and reach and lift height in relation to the unladen weight of the vehicles.

Current Designs

Usual lifting requirements, in both markets, is between 2-3 tonne, but more recently the larger manufacturers are extending their ranges with higher loads and higher lift capacities, but there is little evidence that the main market requires these machines, except for the occasional application in the construction industry. This does indicate, though, that manufacturers are increasingly seeking out market niches, especially in the past four years.

With the exception of 'H' all companies admit to looking at and copying the competition. It is probable that most did their competition analysis on the J.C.B. 520, 'G' and 'H'. The first two were making a significant impact on the market by 1981, when other companies ('E', Manitou, Sambron) were designing their products, these companies must have been influenced by their designs. This, probably, explains the clustering of so many of the features and the narrow range of the majority of vehicle weights, loads, lifts and reaches. This suggests that producers are manufacturing generally around one basic specification. This clustering, though, could be explained by consistent (good) market research, although, on the evidence of this author's research this seems unlikely. The split in the two markets, between agriculture and construction, occurred four years after the first model was introduced for the construction market, when an agriculture version was shown by R.W.C. at the Smithfield Show, December 1978. This has been the main growth area and most design has been directed towards providing a product better suited for the agriculture market, which, probably, takes over 60% of telescopic handlers. But, from around February 1986, the reduction in farm subsidies and an upturn in the construction industry, has meant that the construction share of the market is increasing and the agriculture market declining. There is no detectable change in the emphasis in design, but 'E' are attempting to improve their sales effectiveness in the construction industry.

In spite of some companies derating the maximum load to reach the full lift, there is a general relationship between maximum height of lift to vehicle weight for telescopic handlers. Mono-boom machines fall below this figure. Even more surprising was a relationship between maximum reach and unladen weight, surprising, as again, load was not considered.

Although the market had been rising quite quickly since 1982, the number of manufacturers joining the market also grew rapidly, mainly with larger companies and it is considered by this author that the market is now saturated. As telescopic handlers now take over half the rough terrain lift market, all R.T.F.L. manufacturers need a telescopic handler in their product range. Late entries have pitched their models in the range 2-2.5 tonne, 6-7m lift. The more established manufacturers are exploring the fringes of the market. Manitou, with their very powerful machine, which, as yet, has not been a success, R.W.C. with their small, very high power to weight machine for agriculture. 'H' experimented with smaller engines, but have ceased this unsuccessful change. J.C.B. and 'H', with their high lift machines and 'E', with their hinged chasses, are other examples.

Like the car industry smaller companies are combining to achieve economies of scale. It also became apparent, in the interviews, that the smaller companies were also seeking a market niche, to survive against the large competition, who could produce at lower prices. Also what can be seen is that, as a product stays static for a period of time, all manufacturers concentrate more on providing products for various market niches. This has led to a much greater total number of telescopic handler models. Niche marketing is, therefore, a static discipline.

Using components from other products as much as possible in their telescopic designs has helped to shape the design and limit its flexibility. They also tended to use their existing skids where possible. The design process, therefore, ensured a static design.

The input to the current designs appears to come from three directions:-

1) Looking at the fringes of the market (market niches).

2) Looking at the competition.

3) Rationalisation using components from their, or others, products.

Results of Parametric Analysis

The results for the parametric analysis have been divided into two types, those following design changes over time and those that compare current models. (The item numbers relate to the graphs.)

From the clustering the following features appear:

1a) The usual unladen weight falls between 5500Kg - 7250Kg.
2a) The maximum forward reach falls between 3 - 3.7m.
3a) The usual maximum lift is between 5.6 - 7m.
4a) The maximum load generally is between 2 - 3 tonnes.
5a) Engine power generally falls between 52.5 - 68Kw.
6a) Four wheel drive vehicles have a turning radius generally between 4.75 - 5.7m.
7a) Two wheel drive vehicles have a turning radius generally between 4.0 - 4.35m.
8a) Four wheel drive vehicles generally have a ground clearance 300 - 350mm.
9a) Two wheel drive vehicles generally have a ground clearance 320 - 380mm.
10a) The overall 'volume' (maximum L x B x H) is between 17 - 29m3.
11a) Vehicles generally cost between £19,500 - £25,500 for two wheel drive vehicles (June 1986).
12a) Vehicles generally cost between £22,000 - £29,000 for four wheel drive vehicles (June 1986).
13a) The maximum speed of vehicles is commonly 25 - 32 Km/hr.

Some findings from the parametric analysis do show trends over time:

1b) Engine power is increasing.
2b) Power/weight is increasing.
3b) Lift x load v. unladen weight is increasing.
4b) 'Volume' is increasing.

With current models:

1c) Maximum lift load reduces as the height of lift increases.
2c) Maximum load reduces with extended reach.
3c) Engine size increases slightly as the vehicle unladen weight reduces (surprisingly). This must be an effect of the agriculture market.
4c) Maximum lift height x load at maximum lift increases with increased vehicle unladen weight.
5c) Maximum reach x load at maximum reach increases with increased vehicle unladen weight.

6c) Reach increases slightly with an increase in vehicle unladen weight.
7c) 'Volume' increases with an increase in unladen weight (but not as much as was expected).
8c) Vehicle cost increases with an increase in unladen weight.

There is no correlation between:

1) Lift height and engine size.
2) Ground clearance and unladen weight.
3) Turn radius and unladen weight.
4) Turn radius and vehicle length.
5) Maximum load at maximum lift x maximum lift height and engine size.
6) Maximum load at maximum reach x maximum reach and engine size.
7) Engine power and maximum speed of the vehicle.
8) There is no trend in vehicle weight over time.
9) (Surprisingly) Lift height and vehicle unladen weight.

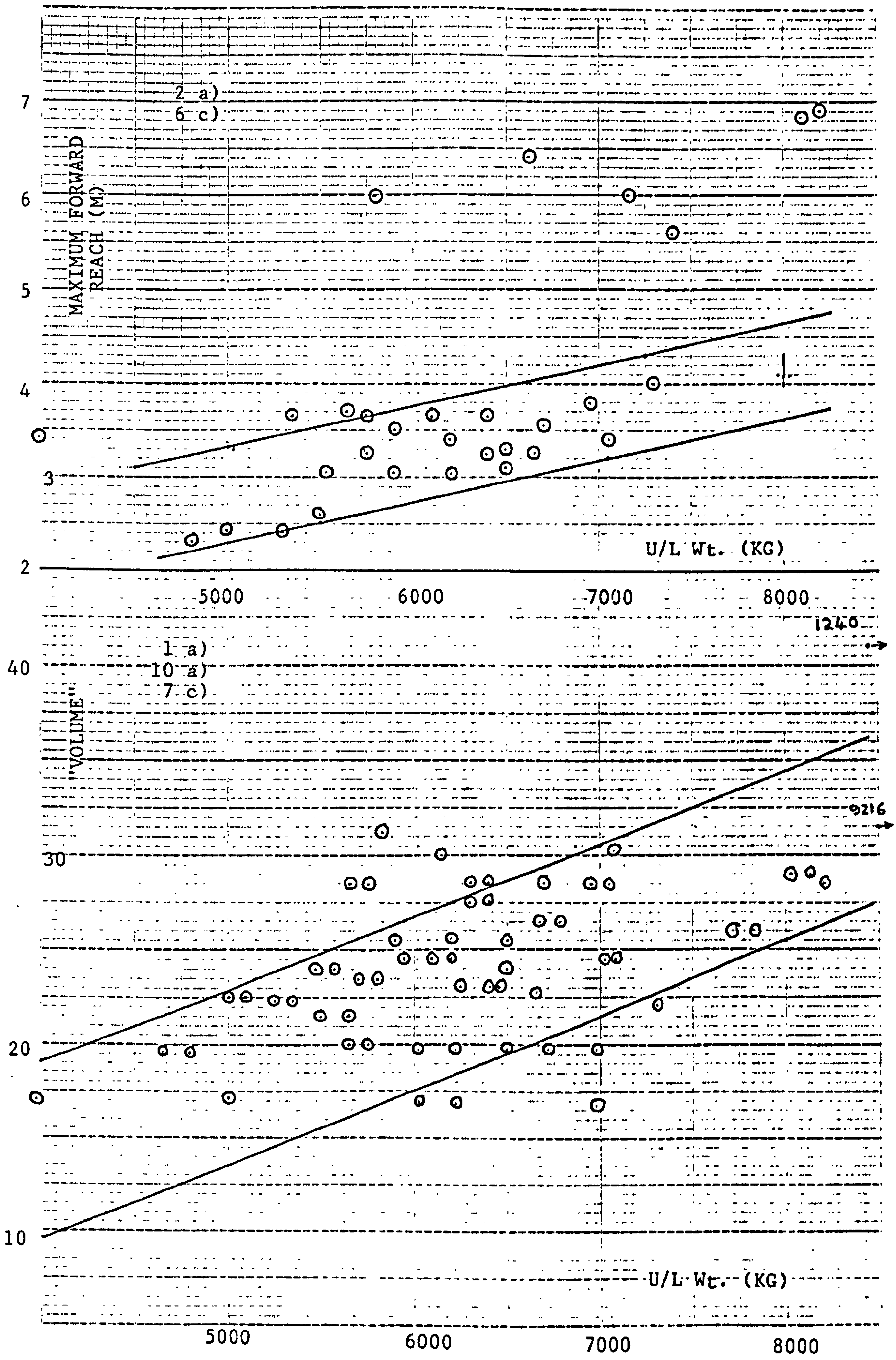
Four wheel drive costs £1,180 - £3,300 more than the equivalent two wheel drive model (June 1986).

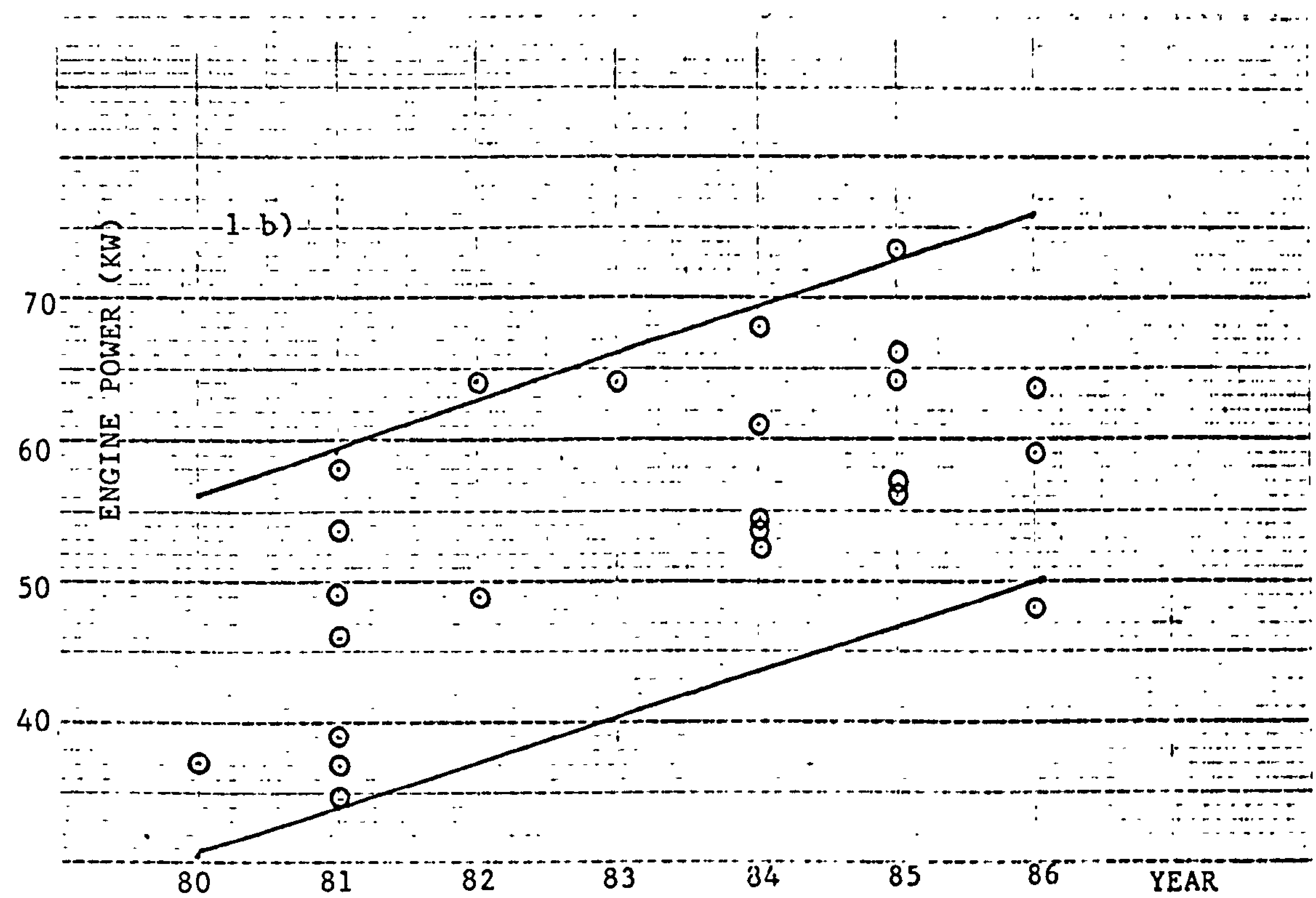
The Construction market requires higher lift, long forward reach, higher loads, better stablity.

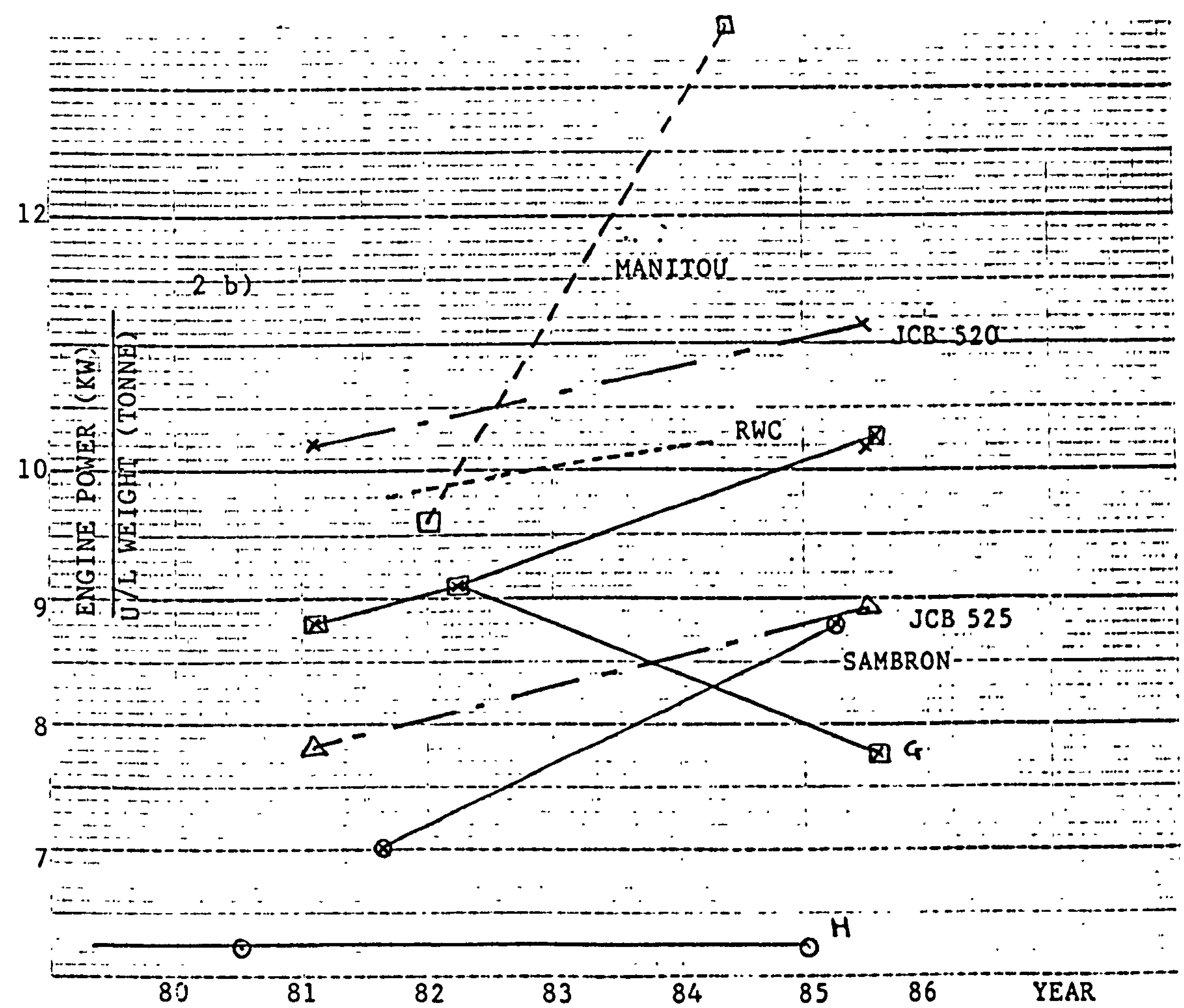
The Agriculture market requires good digging capability, operation on hilly ground, higher engine power, lower basic cost.

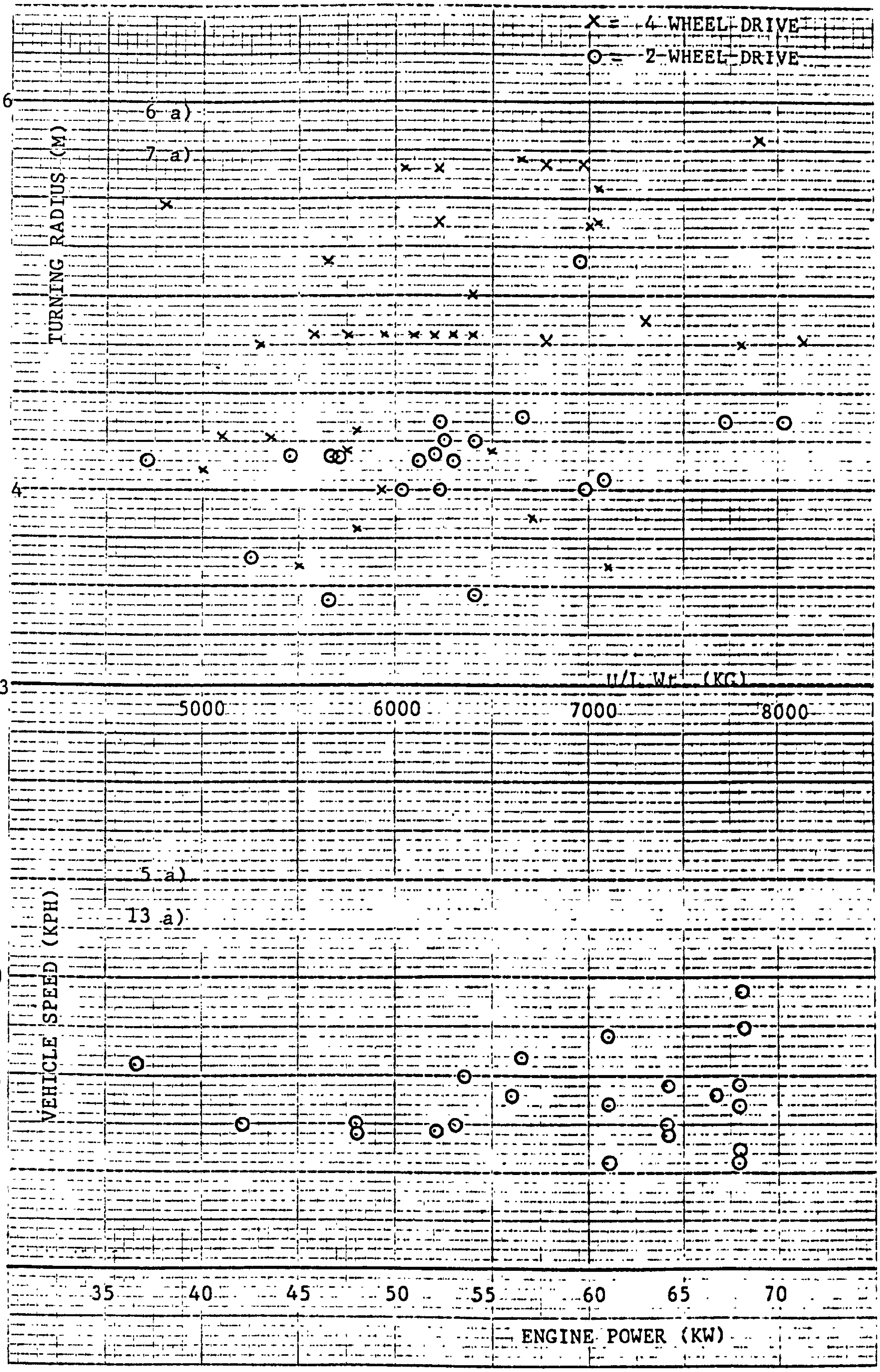
6.9 Feedback Analysis

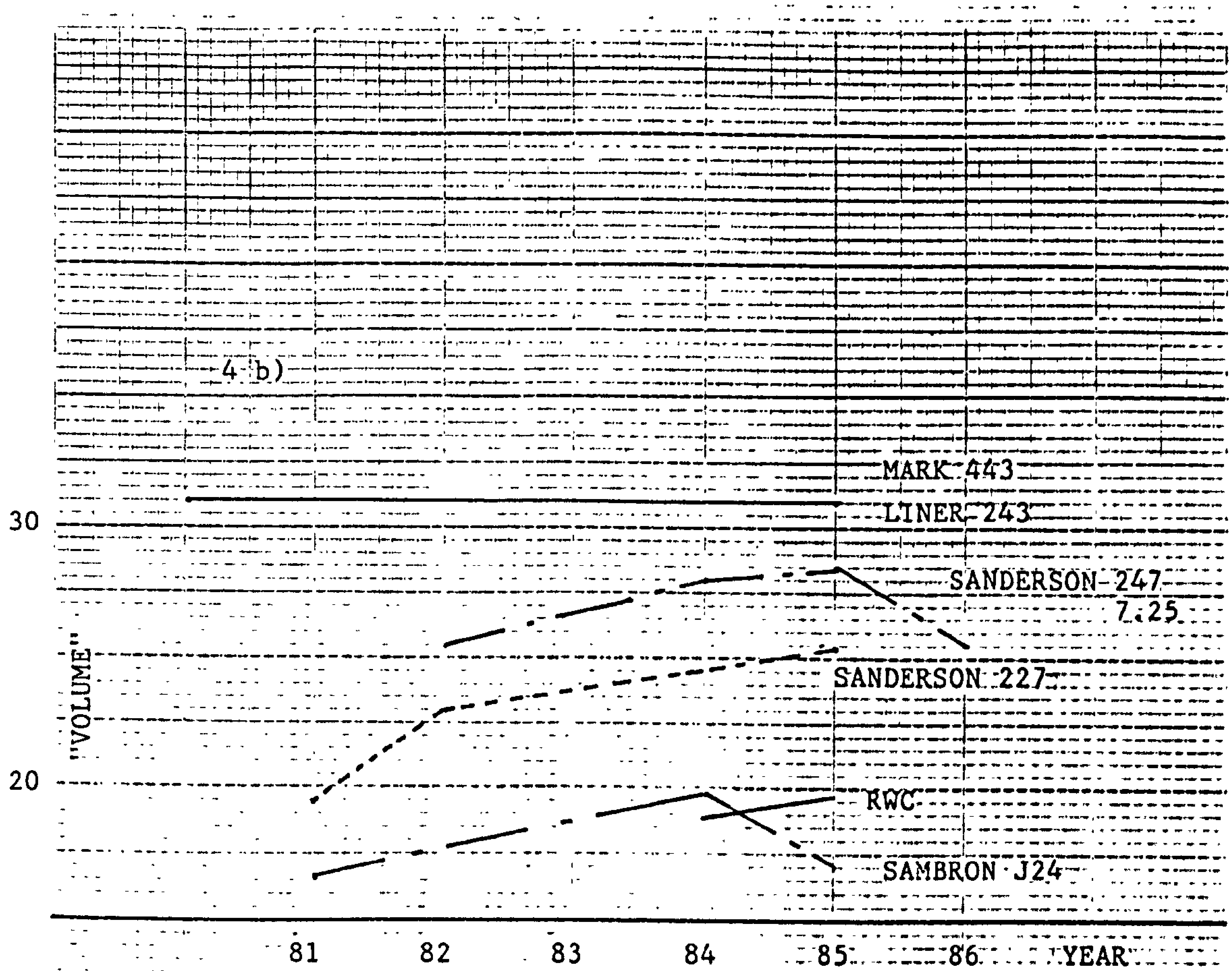
The companies in the main study were each sent a feedback questionnaire with this author's report, which was to be completed and returned. The purpose of this questionnaire was to determine whether the interview was correctly reported and also if the situation in the company was correctly assessed.

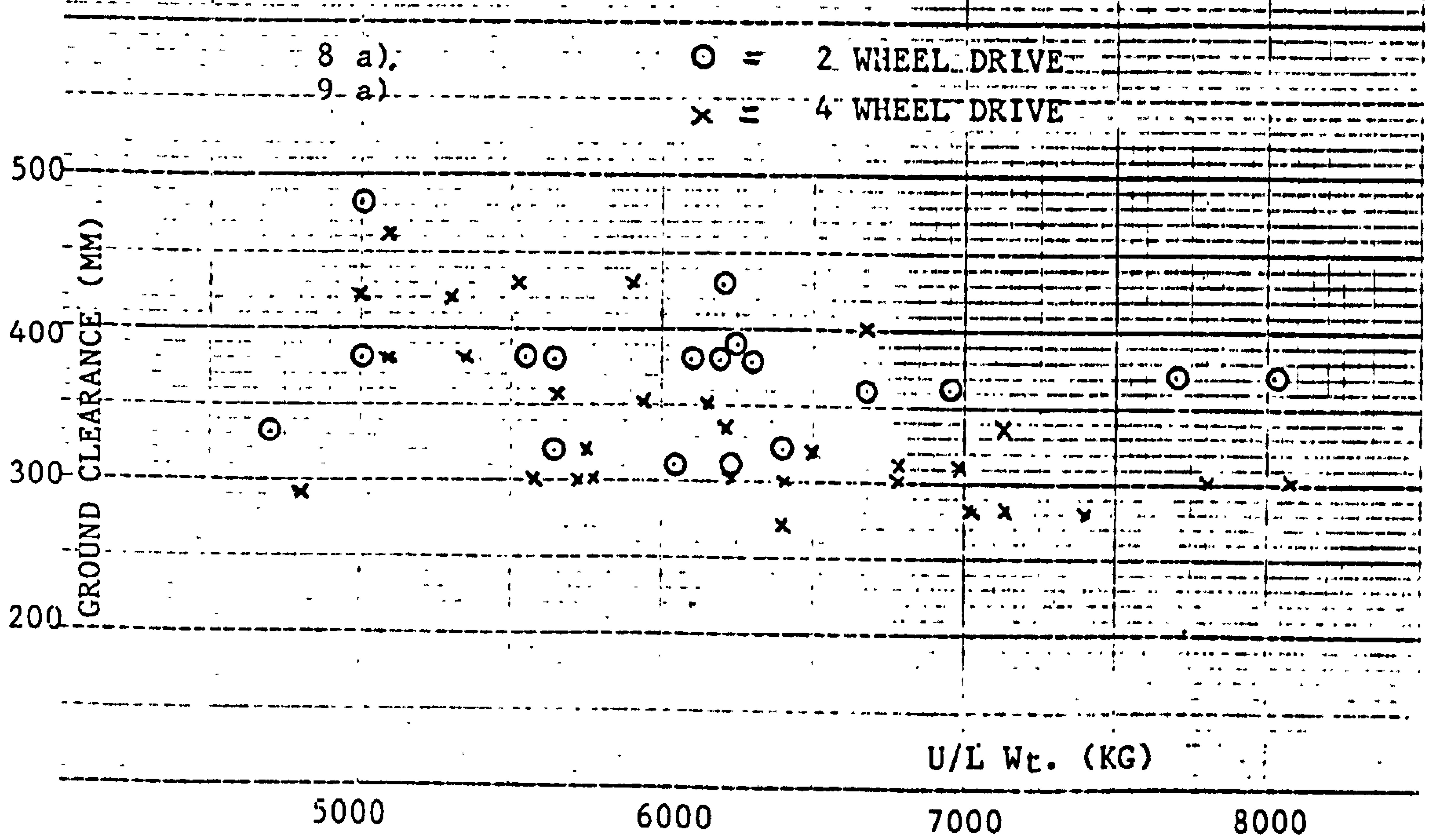

7
6
5
4
3
2
2 a)
6 c)
MAXIMUM FORWARD REACH (M)
U/L Wt. (KG)
5000
6000
7000
8000
1240
40
30
20
10
1 a)
10 a)
7 c)
"VOLUME"
9216
U/L Wt. (KG)
5000
6000
7000
8000

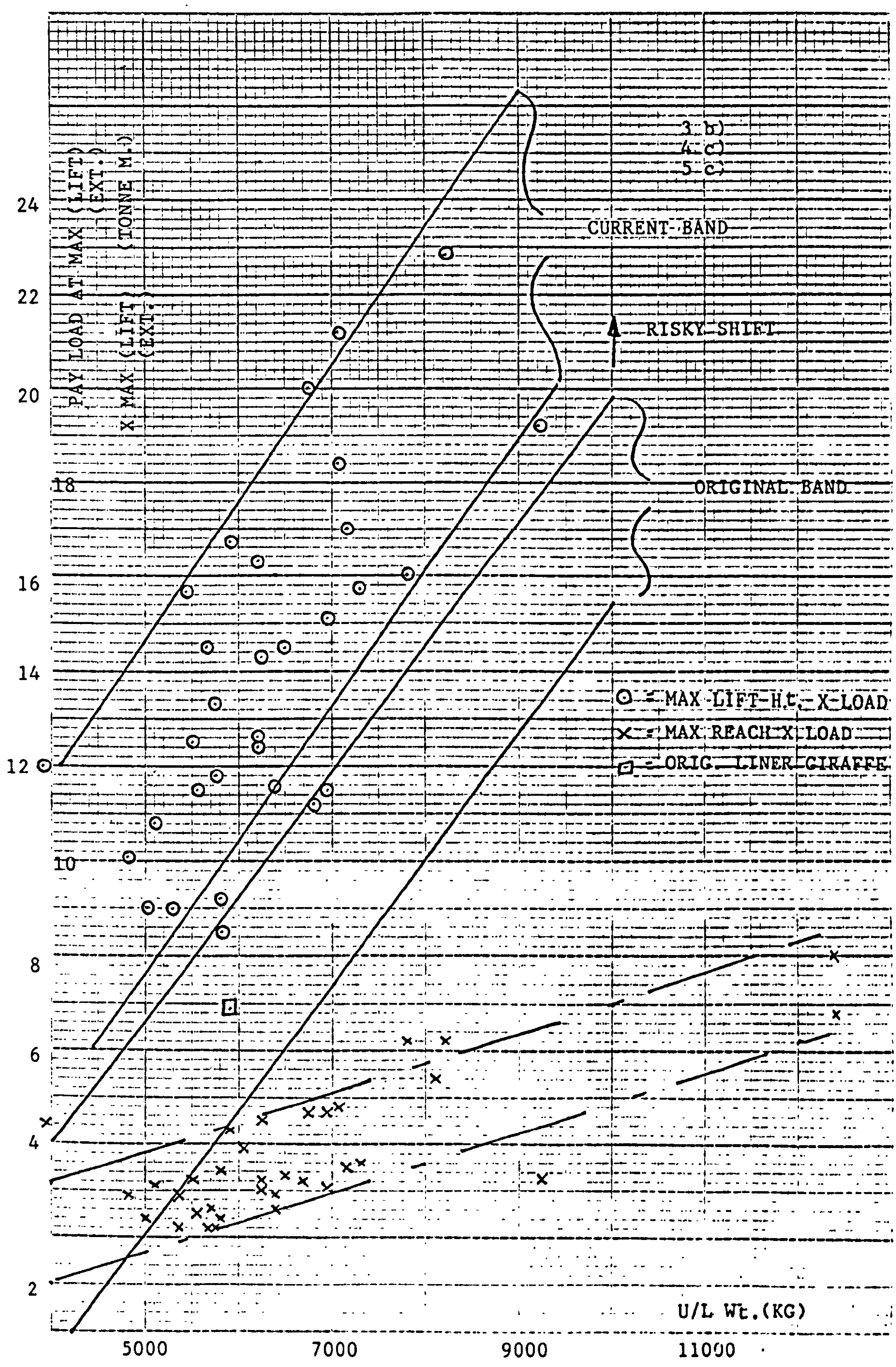

1 b)
ENGINE POWER (KW)
70
60
50
40
80
81
82
83
84
85
86
YEAR


2 b)
ENGINE POWER (KW) / U/L WEIGHT (TONNE)
12
10
9
8
7
MANITOU
JCB 520
RWC
JCB 525
SAMBRON
G
H
80
81
82
83
84
85
86
YEAR

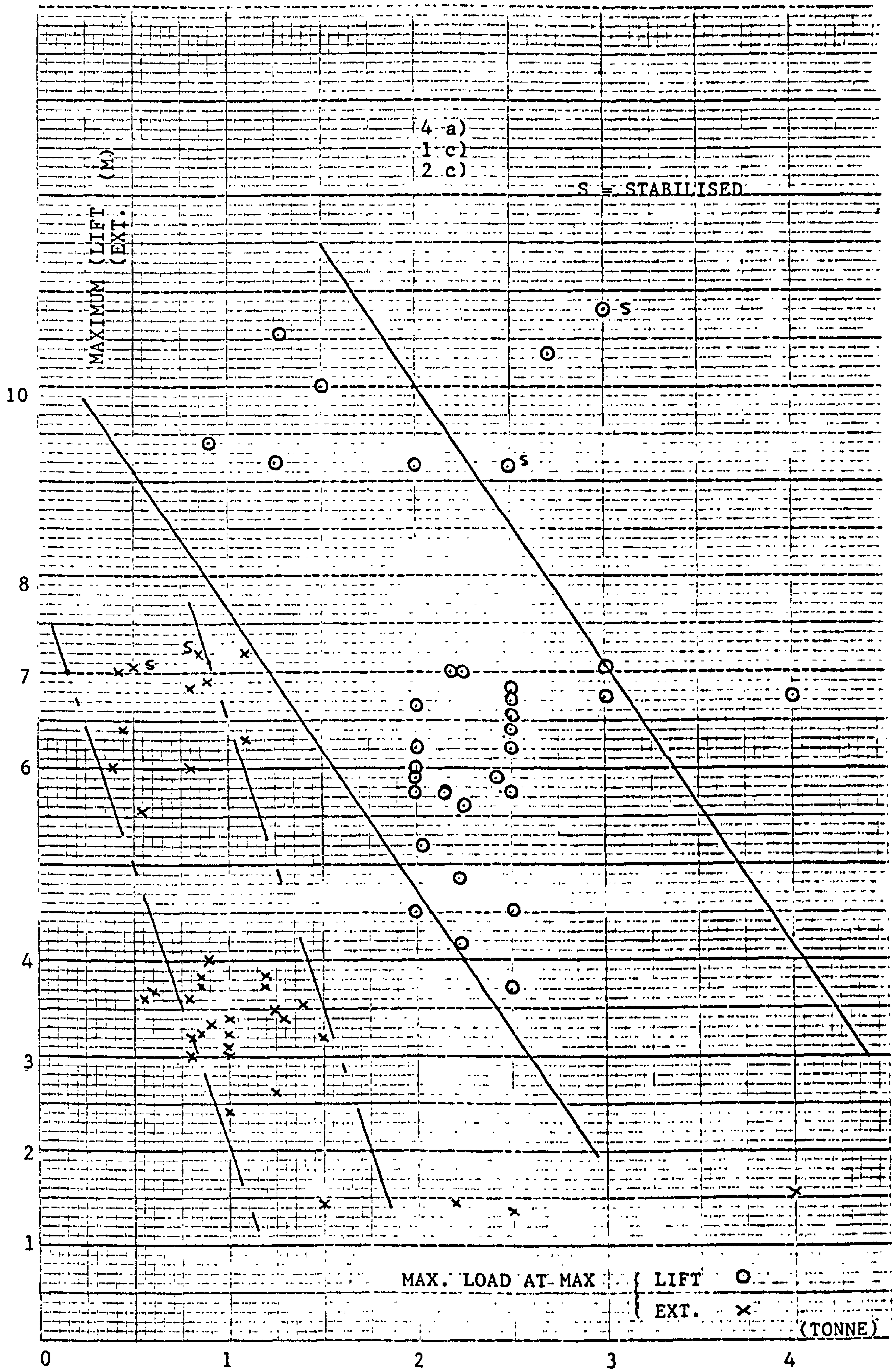

X = 4 WHEEL DRIVE
O = 2-WHEEL DRIVE
6 a)
7 a)
TURNING RADIUS (M)
6
5
4
3
U/L Wt (KG)
5000
6000
7000
8000
5 a)
13 a)
VEHICLE SPEED (KPH)
40
30
20
35
40
45
50
55
60
65
70
ENGINE POWER (KW)


4 b)
MARK 443
LINER 243
SANDERSON 247
7.25
SANDERSON 227
RWC
SAMBRON J24
30
20
"VOLUME"
81
82
83
84
85
86
YEAR

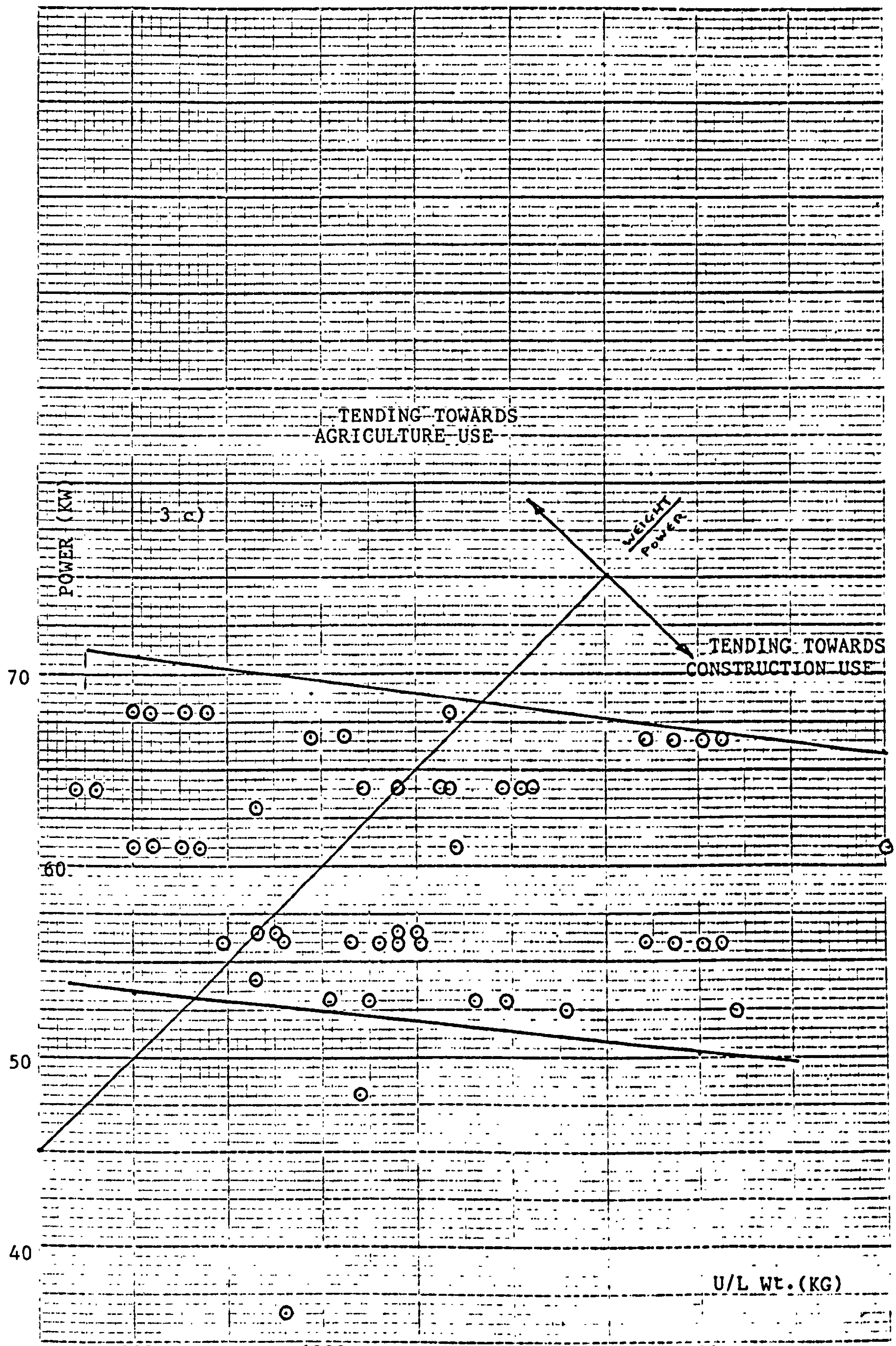

8 a)
9 a)
O = 2 WHEEL DRIVE
× = 4 WHEEL DRIVE
500
400
300
200
GROUND CLEARANCE (MM)
U/L Wt. (KG)
5000
6000
7000
8000



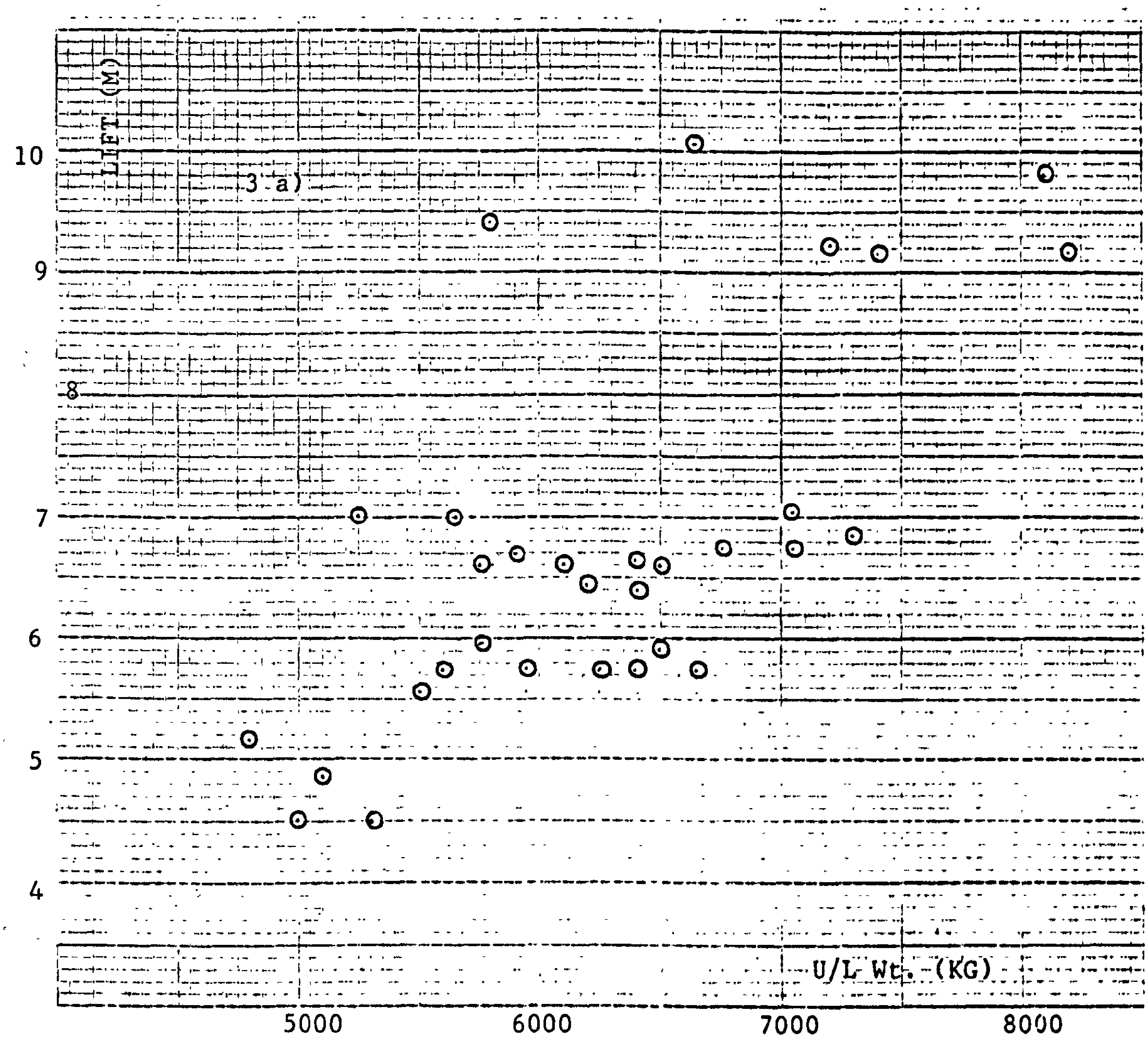
PAY LOAD AT MAX (LIFT) (EXT.)
X MAX (LIFT) (EXT.) (TONNE M.)
24
22
20
18
16
14
12
10
8
6
4
2
3 b)
4 c)
5 c)
CURRENT BAND
RISKY SHIFT
ORIGINAL BAND
⊙ - MAX LIFT H.t. X LOAD
× - MAX REACH X LOAD
▫ - ORIG. LINER GIRAFFE
U/L Wt.(KG)
5000
7000
9000
11000



MAXIMUM (LIFT (M)
(EXT.
4 a)
1 c)
2 c)
S = STABILISED
S
10
8
7
6
4
3
2
1
0
1
2
3
4
MAX. LOAD AT MAX { LIFT ʘ
EXT. ×
(TONNE)



TENDING TOWARDS
AGRICULTURE USE
POWER (KW)
3 c)
WEIGHT
POWER
TENDING TOWARDS
CONSTRUCTION USE
70
60
50
40
U/L Wt.(KG)
5000
6000
7000
8000


LIFT (M)
3 a)
10
9
8
7
6
5
4
U/L Wt. (KG)
5000
6000
7000
8000

Page numbering as original

Feedback Questionnaire

Please complete and return. Continue oversheet if necessary.

1) Was my report an accurate assessment of what you said?

10 Yes/No 0

(If 'no' please state the inaccuracy)

2) Was my report an accurate description of the situation that exists in your Company?

10 Yes/No 0

(If 'no' please state the inaccuracy)

3) Do you think the sheet 'Product Design' was accurate?

10 Yes/No 0

(If 'no' please state the inaccuracy)

4) Do you think my report was:-

Interesting? 8 Yes/No 0

Helpful? 6 Yes/No 2

5) Do you think that consideration of 'Product Status' can aid design in your company?

7 Yes/No 1

6) Can you think of any way in which I can improve the accuracy or presentation of the work I am doing on 'The Management of Design'?

7) Do you think guidelines for determining the 'status' of a product (my other area of research) would aid management of design in your company?

6 Yes/No 2

Reasons for the Questions in the Feedback Questionnaire

Question 1. To determine if the interviewer correctly wrote down what the interviewee said. To show if his statements were recorded accurately.

Question 2. To determine if the report was an accurate interpretation of what was said or implied at the interview.

Question 3. To determine if the areas of company strength and weakness were correctly determined and allow the interviewee the opportunity to disagree with the authors findings.

Question 4. If the report was neither interesting or helpful the research may not have been worthwhile.

Question 5. To determine if the area of research and it's application, as described in the report, would be useful to a potential user.

Question 6. To request assistance from the interviewee in indicating areas of the research that were unclear or, in his impression, inaccurate or wrong and how this could be improved.

Question 7. To determine if the area of the research, which was not covered in the interview or report, would be considered potentially useful to the company.

7. THE PRODUCT STATUS QUESTIONNAIRE

7.0 Introduction

The status questionnaire is probably one of the most important parts of this research as it enables those responsible for product design to identify the status of their own products.

7.1 The Input to the Questionnaires

From the pilot and main studies a series of factors that make a product static or dynamic have been determined. These have been divided into micro and macro factors. Micro factors are those existing within a company whereas macro factors are those existing outside of the control of a company and are market wide features.

By reverse synthesis these factors were compiled into two questionnaires. The macro questionnaire would determine the status of the product in the market and the micro questionnaire would show how the company were treating the product.

Although it would initially appear that the two questionnaires could be answered quickly, to be able to answer them accurately required the user to fully understand the product, company and market. It was also believed that it was unnecessary to include any additional questions and that those resulting from the research were sufficient. Subsequent users commented on the shortness of the questionnaires but none could identify or justify any additional questions.

Before showing the questionnaires to potential users the author tried them with many various products within certain time frames (e.g. with the design of the pocket calculator in 1965, work holding equipment, safety interlocks, car alternators v. dynamos, the digital watch in 1970, cars in 1980 and other products that the author was well experienced).

This caused a lot of changes of balance but none of content. After restructuring the questionnaire many times consistency of results to those known with the benefit of hindsight was achieved.

This questionnaire forms the central core of the design process. It is necessary to match the product status, as adopted by a company with a particular product, to the status in the market to optimise design effort and resources.

7.2 The Advantage of Using the Status Questionnaires

The following section demonstrates the advantage of using the status questionnaires in the design of products.

1). Having answered the questionnaire the user should know if his product is static, dynamic or about to change status and can, therefore, direct his emphasis in design.

2) As one questionnaire refers to the product environment and the other to the way it is treated within a company, it is possible to demonstrate if the company is 'in or out of phase' with the environment/market.

3) The questionnaire may be answered, if the information is known, in the manner that a competing company would and, therefore, can be used as part of competition analysis.

4) If a new product concept is being developed (a new dynamic design), by using the potential advantages of the new dynamic design when answering questions 4 to 6, on the 'macro' questionnaire (A), it provides an indication as to whether the new dynamic design is

capable of ending the existing plateau. Hence, whether it is worth pursuing the new concept or the extent to which the new concept will need to be better than the current design in order to replace it.

5) The questionnaire appears to overcome the need to define at what point a technology change should be considered static or dynamic. For example, was the introduction of a plastic bucket a dynamic design when it is still a bucket? The questionnare may be used to compare a plastic bucket with a steel bucket or a bucket with an alternative form of water carrier. The questionnaire serves both types of design change, providing that the criterion for comparison is made at the start.

6). Knowing the product status the subsequent parts of the design process uses this knowledge to direct design management to the disciplines of most benefit with regard to this product status.

Product Type Under Consideration:

Comparison with which Product:

QUESTIONNAIRE A - MACRO - PRODUCT STATUS

Place a tick in the relevant column	YES (Static)	NO (Dynamic)
1) If there hasn't been any technical advance recently that may be used to replace this product tick the 'Yes' column and go on to Question 6. If there has, name it and tick the 'No' column.		
2) Is there a large infrastructure based on the existing design that cannot be used with the new design? (e.g. fuel, sales, spares, distribution, servicing, skills, etc. Give one tick in the 'Yes' column for each, or one tick in the 'No' column if there are none.		
3) Are there any conformance standards for this product that cannot be met by the new design?		
4) Put a tick in the 'No' column for every two advantages of the technical advance that would make a customer change from the existing product (one tick for lower price*)		
5) Put one tick in the 'Yes' column for every two disadvantages that would make a customer prefer the existing product.		
6) Are a few relatively large Companies dominating this product market? (Tick the 'No' column if any technical advance mentioned in Question 1 comes from one of these Companies.		
7) Do most Companies making this product appear to copy each other?		
8) Has the product been available in its present form for more than five years?		
9) Tick the 'Yes' column if the number of your competitors is decreasing or remaining the same, tick the 'No' column if the number of your competitors has increased.		
10) Recently there may have been changes in the economic climate, legislation, or resources that make the existing product more, or less, viable to consumers. Tick the 'Yes' column if these changes have made the existing product more viable or more attractive to customers. Tick the 'No' column if these changes have made the existing product less viable or less attractive to customers. (If neither leave blank).		
TOTAL		

An equal number of ticks in both columns, or a surplus of ticks in the 'Yes' column indicates that the product status is probably static. A surplus of ticks in the 'No' column indicates that the product status is probably dynamic or potentially dynamic. Knowledge of this status can direct your emphasis in design.

Now do Questionnaire B Micro to see if your Company status is the same as the Product status.

* Think ahead. Could investment in the manufacturing process make the technical advance cheaper than the current product?.

Product Name:-

QUESTIONNAIRE B - MICRO - COMPANY STATUS

Place a tick in the relevant column	YES (Static)	NO (Dynamic)
1) Does this product interface with other products, or fit an assembly not made by your Company?		
*2) Do you/will you use much dedicated machinery or automation in the manufacture of this product?		
*3) Do you/will you use C.A.D. for the design of this product?		
*4) Does your Company have a greater market share or turnover than most of your competitors (or potential competitors)?		
†5) Is a fast design time one of the three most important considerations when embarking on a new design?		
†6) Must new designs use the existing salesforce and/or distribution networks?		
†7) Must new designs use the existing production facilities?		
†8) Must tried and proven methods be used in the design of new products?		
†9) Must new designs be an extension of the existing product range?		
10) Is this product made by assembling components the majority of which are made by other companies?		
11) Is more process design done than product design? (Design of the production method rather than the product).		
12) Has the product design specification remained significantly unaltered recently by the market research department and by your main customers?		
13) Do you use the same components from this product in several other products?		
TOTAL		

* If a 'Yes' answer is given to these questions it is in your Company's interest and advantage to seek static products.

† 'Yes' answers to these questions suggests that your Company is restricting design to static design. Is this necessary or sensible?

8 COMPILING THE IMPROVED DESIGN PROCESS

8.0 Introduction

Clausing (1986) said, "Despite the importance of the product development process it has received little attention as a structured systematic process".

Having investigated various researches into new product success and failure, R.G Cooper (1983) states, "What is missing is a shaping of the research conclusions into a managerial guide".

This section describes a design process which has been derived from this research so that a company can take full advantage of product status. This design process, being over 200 pages long, is not included in this thesis but is in the support text. The way it was compiled is included.

8.1 Layout

To make the system relatively easy to use a layered approach was chosen, in which the user should complete each layer before starting the next and this approach proved to be popular when subsequently demonstrated to potential users. Initially the process was put into six sequential layers, but it was then determined that two layers could be undertaken in parallel, without any loss in design efficiency. This means that the product design specification can be compiled whilst the correct design disciplines are being accentuated or diminished, according to status, at the same time.

The contents of each layer had been determined from the literature survey and interview results. The literature had shown that prior research identified certain disciplines and organisational practices which were important in the design of a product, but, where or when they should be included, was not usually apparent and this was determined by this author. Other disciplines that had not been considered in the literature but were still believed to be important as a result of the research findings, were included. (Fig. 8.1.A).

It was also found that certain factors that determine the status of a product were an advantage in a company designing a product with that status. This can be used to direct a company as to whether they should be seeking static or dynamic product designs. for example if a company has invested heavily in automation and C.A.D. perhaps they should concentrate their resources on designing static products. A full list is shown on Fig. 8.1.B.

This can also be used to aid competition analysis. Assess if the competition are treating their product design as static or dynamic by noting if they have these features.

Fig. 8.1.A

<u>Additional Design Disciplines</u>
<u>Product Dynamic</u> →
Non Product Related Research
Technology Push
Patents and Design Protection
Customer Training
Sub Contract Manufacture
Flexible Production

<u>Product Static 1</u>
Imitation
Low Cost Production
Group Technology
Assembly Aids
Cost Reduction Techniques
Reduction of Scrap
Effective Purchasing
Use of Standards
Maintainability
Ergonomics
Size Reduction
Use of Reputation
Fast Delivery
Effective Distribution
After Sales Service Network
Aesthetics
Fashion
Finish
Use of Different Materials in Design
Business Planning

↓

<u>Product Static 2</u>
Long Production Runs
Economies of Scale
Automation
Dedicated Machinery
Rationalisation
Niche Marketing
Specialisation
FMS/CAM/Robotics
Energy Conservation
'Just in Time'
Value Analysis
Product Static for a 'long' Period of Time
Seeking Large Market Share

Fig. 8.1.B

Factors that make a Product Static or Dynamic, which are an Advantage for a company designing products of this Status

Dynamic

1. Flexible Machinery
2. Seeking New Concepts
3. Small Producer
4. More Product Design than Process Design
5. Technolgy Push
6. Subcontract Manufacture
7. Effective Market Research
8. Open Management Requirements

↓

Static

1. Dedicated Machinery
2. Automation
3. C.A.D.
4. Large Producer
5. More Process Design than Product Design
6. Using Standards in Design
7. Using Experience in Design
8. Using Imitation in Design
9. Restricted P.D.S.
10. Rationalisation
11. Poor Market Research
12. Restricted Design
13. Assembly of Components Made by Others
14. 'Just in Time' (Kanban)

9. THE IMPROVED DESIGN PROCESS TRIED IN INDUSTRY

9.1 Companies Used in the Trial

Care was exercised in the choice of company used for testing the improved Design Process. The company had to fulfil the following requirements;

1) They had to undertake new product design and have brought new products into the market recently. This excluded such companies as Castell, that this author knew well and understood their design process but had not undertaken product design, in any organised manner, over the previous three years.

2) They had to be involved in manufacture. This was necessary as the design process made recommendations for the production of the design, and those could only be commented on by a manufacturing company. This excluded consultancies.

3) The company had to design and manufacture in the United Kingdom. This was simply for ease of being able to meet and discuss the system with the potential user.

4) The company had to already have a design process of their own currently in operation. It was felt that, for a company to already have a structured design process, they would have considered the organisation of design and would be taking product design more seriously than a company that merely 'drifted' through the various stages without following some pre-ordered pattern. It was further believed that a company, who already had a design process of their own, would be able to contrast and compare theirs with this author's,

which would lead to more effective feedback.

5) The individuals from the companies selected to assess and comment on the Design Process, would need to be involved in a senior position in design, would give due consideration to the system and would not be inflexible in their attitudes and response to new ideas.

6) The companies were not, initially, to be the ones from which the research data was obtained. This was to demonstrate that the Design Process would operate in a wide spectrum of industry.

7) And, of course, the companies concerned, had to be willing to take the time to consider and discuss the improved Design Process.

9.2 The Method of Testing

A short verbal introduction was given about this author's background, the purpose of the research and what the Design Process was hoped to achieve. This introduction was essentially kept brief, as the Design Process was written to be self explanatory and presented in a form that, it was hoped, would be easy to follow. The user was encouraged to make comments on any part which was unclear, considered wrong or unhelpful, along with overall impressions.

No contact was then made for a period of, at least, one month, although the user was asked to contact this author for any reason the user considered necessary. After the initial month the user and this author met. This generally took the form of going through the report and discussing all comments that had been made. There was also a short questionnaire, which was used to direct responses on important areas if they had not been commented on earlier. This interview was reported fully so that comments made by the user could be analysed.

In the case of Honeywell, Mr Turnbull felt that, although he was well versed with the lower end of product design, he did not deal directly with the marketing aspects, but he suggested Mr George Currie, Product Manager, who was employed in this area. The design Process was, therefore, supplied also to Mr Currie for his input and he was also interviewed, after the Design Process had been in his possession for one month.

9.3 Changes to the Design Process as a Result of the Trial

The report was, on the whole, received with some enthusiasm and there was no disagreement as to the basic content of the report or the proposals made in it. Changes, therefore, were only needed to improve it's ease of use and understanding.

The Design Process was supplied in four volumes to Honeywell, but the introduction and the system were combined for Howden and Maclarén. Four volumes appears to work better. Howden believed a more gentle introduction was needed, which may have been easier to cope with if given in a separate volume.

Howden thought that the definitions should occur right at the start and not on page 6, so that the user will understand the meaning of the terms used before they appear in the text. He also felt that a "more seductive introduction" was required. Honeywell also would like a brief summary of the entire process at the start. The start of the report was changed, with a better prescribed introduction in the preface, followed by the definitions and then the introduction.

All three users found that one of the appendices was unclear and this was the one containing matrixes, showing the most efficient sequence for the various layers of design in the process.

The improvements suggested for the Design Process, after the second visit to Howden, were shown to Mr A Mitchell of Howden in a third meeting that took place some three months after the second meeting. The changes were all considered clear, "punchy" and an improvement on the earlier versions. Between the second and third meeting the Design Process had been circulated and read by design engineers in the Design Office and it had been well received.

The idea of a design circle, incorporating product champion, was approved and the description and number of design reviews described as "good".

A difficult problem was described concerning design of several products. Each may have to vie for the same facilities at certain stages of the programme, for example, drawing office time, or short order and tool room time. This has been a problem in the past at Howden (and one experienced by this author). This had not been considered in the Design Process and must be a decision taken on merit and circumstances that exist within individual companies. A section has been added to the layer I, when, after the product has been defined, the priority of this particular design project is given in relation to other design projects (if any) that are currently being undertaken. This is a top management decision, which should be relayed to the product champion, as must any change in the relative importance of the design project in relation to other company design projects if and when they occur.

The general layout was found to be acceptable and clear. The layered approach of the system was popular and the example of system use in Appendix 4, although unreal, was found to be an aid to system understanding. The choice of the paperclip was liked, being instantly recognisable. Maclaren thought that the start of Appendix 4 was too unreal, "people don't sit around and think of an idea", however, this does help with the simplicity of the system and, therefore, has not been changed.

Both Howden and Maclaren thought the Design Process was "a bit wordy" (Howden) and "too long winded and obvious at times" (Maclaren), mainly in the appendices, but on second reading Howden realised that this was to make it unambiguous. Both of these are very experienced practitioners of design and, therefore, they probably do not need the same degree of explanation and clarification that someone new to design management may require. Maclaren said that the process would be "more useful to the less experienced".

The "obvious" parts were linked, by Maclaren, to parts where they "already do that". This would make it obvious if a person was that familiar with it. Maclaren are successful with design and, therefore, it is somewhat reassuring that they should already have found that some of the proposals decribe their work in practice.

It was agreed that financial control over a project was difficult, as a company is not likely to be in a position to accurately cost design before a set of detailed drawings become available. This author believes that, although accurate costing cannot be established early, it is often possible to detect whether or not the product looks viable against the anticipated selling price and production quantity, as supplied by the market research. The accepted difficulty of this area confirms the importance of emphasising financial control throughout the entire Design Process.

Having discussed the comments made by the design engineers with Mr Mitchell, he summed up by saying that the Design Process as supplied was "inargueably correct. A logical, systematic way of avoiding what could be a shambles".

Mr Mitchell also added that certain projects, he could mention, would have run much more smoothly had the Design Process been available at that time for them to follow.

The diagrams were generally felt to be clear and an aid to understanding ("helpful and beneficial" Honeywell).

Honeywell considered the overall report was "pushing beyond the front end of the marketing to strategic decisions and points to what is to be done". "The need is there". "The report helps them (management) to make the decisions".

The appendices were further simplified by the addition of a bibliography, which removed the title names of books from the text and placed these at the back of the report.

Mr Currie, Product Manager of Honeywell, was interviewed after he had had the Design Process in his possession for one month and had read it "three or four times". He was interviewed after the changes, proposed at previous meetings with Mr Turnbull of Honeywell and Howden, had been written and, therefore, he could comment on these changes. He thought the matrix appendix in its latest form was "much more understandable", but, as he had experienced no problems with the original preface and introduction, he expressed no need for them to be rewritten, as he felt the original and later versions were both clear. The later versions of the introduction and preface have been kept for those who are less experienced.

9.4 The Improved Design Process Retried in Industry

Having modified the design process it was decided to subject the latest version to one of the companies from the main study which conformed to the guidelines described in section 9.1. J.C.B. fulfilled the necessary requirements.

J. Moses, Product Engineering Manager, was contacted and requested to consider it for one month. This author believed it was now in a form that did not require a personal initial explanation so for this trial the design process was sent through the post. After a period of five weeks a questionnare was sent to Mr Moses and this was subsequently returned with his comments. These were favourable in all but one point, which was that he doubted "whether a company with established design procedures would use this report as a basis for altering it's outlook on design". Although he later stated that "the report will make excellent reading for new and experienced project managers".

10 CONCLUSIONS

10.1 The Results of the Research Compared with the Initial Objectives

In the Introduction (section 1.1) four objectives were given and this thesis describes the development of the research around the criteria of product status which fulfil these objectives. Discussing each objective in turn:

1). Show the existence of product status. The pilot study demonstrated that the heavy duty damper for miltary vehicles was a dynamic product design and the main study showed that the rough terrain telescopic handler was a static design at the time the research was undertaken. This was agreed by those interviewed in the study. It has been possible to identify and list the factors that make a product static and dynamic, and contribute to keeping or changing the status of a particular product. A full list is shown in section 6.5

2). Show how to determine the status of a product. The factors that make a product static or dynamic have been used in the development of two questionnaires for use by those responsible for design. Providing the user has a thorough understanding of his company, product and market the questionnaires can be quickly completed and product status easily assessed. The macro questionnaire determines the likely product status in the market, whereas the micro questionnaire determines with what status the product is being treated by the company. This shows if there is a status match or mismatch between the market environment and the product environment in the company. The micro questionnaire may also be used as part of competition analysis to judge if a competitor is also treating his product as static or dynamic. These questionnaires are shown in section 7.3.

3). Show which design disciplines should accompany a particular product status. Without a knowledge of product status it is only possible to state that a company should be proficient in all aspects of design all the time. Throughout the research various aspects of design, marketing and production were considered and from this were identified disciplines that were either necessary for all companies irrespective of the product status, more important in the design of dynamic products or more effective in static design. The disciplines most suitable for static design were divided into static 1, when the product was newly static or produced in units or batches, or static 2 which are those disciplines most effective when the production volume increases to large scale or mass production. The complete list of these disciplines is shown on the final upheld criteria, number C1 in Appendix 1. Therefore, having determined their product status, a person can then direct their actions towards more important areas thereby making product design more efficient.

4). Show product status as a method for forecasting. Product status as a guide to the treatment of product design has been shown to be more effective than either the product life cycle or S shaped curves and, therefore, can be used for forecasting and product planning. Product status estimation is most accurate when considering the present or very near into the future and the accuracy is likely to decline the further the forecast is projected into the future. Neither the PLC or S curve are generally provided with a means for product planning as product status has been. Therefore, although product status is far from perfect as a method for forecasting, it is significantly better than other systems that have been investigated. This is discussed in section 3.2.

10.2 Additional Research Findings

The research data was collected from fourteen companies with a further four subsequently testing the design process. The companies that took part in the pilot and main studies covered a significant range of successful and unsuccessful companies producing static and dynamic products. The subsequent trial and confirmation of the validity of the improved design process was undertaken in companies, and with products, very different from those where the information for the design process was originally compiled.

The research was not undertaken in isolation but built on the prior work of others as determined from the literature review. A possible shortcoming in the results obtained was the need to believe and base decisions for action, on the answers supplied at an interview. The questionnaire was so constructed that in some cases the question was asked twice or broached in different terms to check consistancy of answers. With some answers it is possible to check accuracy through magazine articles, parametric analysis and published statistics, which was done. A written declaration of confidentiality of all information meant that the interviewee had nothing to gain from providing inaccurate answers.

The structured interview was found to be effective in the pilot study and, for the main study, it did not require an alteration in structure, only in content of some questions to clarify points or make them easier to answer. Seventeen of the criteria were verified thereby upholding the principle of product status. These are shown in Appendix 1.

There has been considerable discussion, recently, in an attempt to encourage British Industry to innovate more. This study has perhaps demonstrated that some companies are better structured to undertake static design rather than dynamic design and also that dynamic design, or innovation, with some products may actually be the wrong approach to take. Innovation is important but, sometimes, and probably most often, evolutionary design would be more beneficial and appropriate to the company. This finding can save time and cost to industry as static design is generally less time consuming and less risky than dynamic design.

Even with a dynamic product, as was the case in the pilot study, a company requires static disciplines in order that the product can be produced effectively.

Also with a comprehensive list of disciplines and a knowledge of which are more or less important, the designer needs to know when they should be used. This author has not found a full and usable design process that concentrates on the front end of design and also shows what is needed in each stage of product design. Therefore, the improved design process has been written which leads the user through the various stages of design.

This research has confirmed the work of others that reliability is the single most important aspect of design. It has also been possible to rank for importance the elements in the product design specification for a particular product in a particular market. This enables a designer to know where to place the greatest emphasis in design when trying to compromise between elements in a specification (section 6.5). Four additional elements have been determined which should be considered when compiling the product design specification, (section 6.2).

This research has also shown the increasing importance of process design in relation to product design as the design becomes static, (section 2.12, 3.1)

The design circle suggests the type of organisation and people that should be involved in the design of a product at different stages of the process. It has been shown that the organic organisational structure is beneficial during most stages of design but a more mechanistic structure is likely to be more effective in the later stages of static design. This confirms the work of others but in this research the onset of the mechanistic structure is advised somewhat later than most previous writers have proposed. (section 2.6, 3.1)

Only one company in both the studies considered market share was more important than a profitable segment of that market and this company was the most successful company in the research. In every case the management provided a strong 'mantle' which constrained design or encouraged it. Strong financial control and time appear to be the main restrictions on design.

None of the companies in the pilot study were particularly successful and this was partly due to the type of product in the study. The product was chosen as the market was small and the competitors few. The companies had chosen to service a limited market which clearly restricted their growth potential. In the main study the product being static the larger companies were the most successful and these also had more static design disciplines. The smaller companies were seeking market niches, combining with other companies in mergers, manufacturing or selling agreements and some were struggling to survive. None of the companies in the main study were actively seeking a new concept to end the static plateau.

Poor market research and very poor specifications came across as the main weakness in design. The P.D.S. was markedly worse in the companies in the pilot study, but in the main study the product was static and so the market requirements were more predictable and, therefore, the P.D.S. was easier to compile. Even so the P.D.S. was inadequate in most of the companies in both studies.

Although the terms 'static' and 'dynamic', when used to describe types of product, was new to those interviewed they all quickly understood the concept and were all using the terms themselves by the end of the interview. Most appreciated the status of their own product and almost all considered that knowledge of product status would aid them in the management of design.

One interesting finding in the pilot study was that one of the companies was not even aiming to survive with their product but were maximising profit in the acceptance of their eventual decline.

In the main study, over a period of time, companies were generally drifting in the right direction with a greater emphasis on static disciplines for the static product. When the disciplines that this author considered should be emphasised were described in the report given to every company in the main study, there was very little disagreement that these recommendations appeared to be correct. Product status does highlight the strengths and weaknesses of a company.

Feedback was almost all positive stating that the report was an accurate interpretation of what had been said at the interview, was an accurate description of the company and that the recommendations appeared to be useful. Those interviewed were strongly in favour of a system that would identify areas of greater importance and show them how to undertake design management. They were also in favour of this research and the results obtained from it.

The improved design process consists of four parts, which was found to be most acceptable to subsequent users:-

1). An introduction describing it's purpose and how it should be used.

2). The procedure showing what should be considered at each stage of the design.

3). An Appendix expanding on the points made and justifying, or confirming, these with reference to the literature.

4). A worked example showing the design of a paper clip in a fictional company.

This design process was supplied to people responsible for design management in three companies who, up to that time, had not been involved in the research but were known to be actively working on the organisation of the front end of design. After a period of time these companies were visited and comments and criticisms noted through the aid of a questionnaire. Criticisms were of a minor nature involving small changes to clarify the system. There was no disagreement as to the approach, format, or content and the design process was well received, in some cases enthusiastically, being described as usable, likely to be effective as well as being in advance of their current practice. Two companies asked to retain the design process after the investigation for their use and reference.

Having made the minor changes required it was then sent to a design manager in one of the companies that was used in the main study.

All the aims of the research, as outlined, have been fulfilled and the resulting design process is both workable and effective especially through the identification and use of product status. The plan of the design process is shown on the next page on fig. 10.2.A.

The recently compiled proposed British Standard 7000 'Design Management Systems' (to be published December 1989) uses parts of this research including some of the definitions.

The design process has been developed into a book to be published by Butterworths in November 1989 which is entitled 'Successful Design: What to do and When'. In the publishers market research they have determined that there is no other book that endeavours to describe how the early stages of product design should be managed.

A paper on this research has been accepted in the proceedings of the International Conference of Engineering Design (ICED) to be held in August 1989, and several articles, resulting from this research, have appeared in design journals.

A full list, to date, of publications drawn from this research are shown in Appendix 5.


PRELIMINARY LAYER
MANAGEMENT COMMITMENT TO DESIGN
NO
YES
FINANCIAL CONTROL OVER DESIGN
NO
YES
DESIGN REQUIREMENTS
NO
DO NOT START THE DESIGN PROCESS
PROCEED TO
YES
LAYER 1 PRODUCT DEFINITION
DOES THE PRODUCT SUIT YOUR :-
1 MANAGEMENT REQUIREMENTS ?
2. PRODUCTION EQUIPMENT ?
3. SALES AND DISTRIBUTION ?
NO
NO
NO
YES
DO YOU HAVE THE EXPERIENCE, EXPERTISE AND TECHNOLOGY NEEDED FOR THIS MARKET ?
NO
IS IT WORTHWHILE ADAPTING THE COMPANY ?
NO
ABANDON THE DESIGN PROJECT
YES
PROCEED TO
YES
LAYER 2 THE STATUS SPECIFICATION
DOES THE PRODUCT STILL SUIT YOUR :-
1. MANAGEMENT REQUIREMENTS ?
2. PRODUCTION EQUIPMENT ?
3. SALES AND DISTRIBUTION ?
NO
NO
NO
YES
DO YOU STILL HAVE THE EXPERIENCE, EXPERTISE AND TECHNOLOGY NEEDED FOR THIS MARKET ?
NO
IS IT WORTHWHILE ADAPTING THE COMPANY ?
NO
ABANDON THE DESIGN PROJECT
YES
PROCEED TO
YES
LAYER 3 ASCERTAIN THE PRODUCT STATUS
COULD YOU ANSWER THE QUESTIONAIRES WITH CONFIDENCE ?
NO RETURN TO LAYER 2
YES
IS YOUR DESIGN PROPOSAL CONCEPTUALLY VULNERABLE ?
YES RETURN TO LAYER 1
NO
IS THERE A STATUS MISMATCH BETWEEN YOUR COMPANY AND THE PRODUCT ?
YES
IS IT WORTHWHILE ADAPTING THE COMPANY ?
NO
ABANDON THE DESIGN PROJECT
YES
PROCEED TO
NO
LAYERS 4
LAYER 4 A. WRITE THE PRODUCT DESIGN SPECIFICATION
LAYER 4 B. RELATE THE DESIGN DISCIPLINES TO THE PRODUCT STATUS
DYNAMIC
STATIC
GRADE ELEMENTS IN THE PRODUCT DESIGN SPECIFICATION FOR IMPORTANCE FOR YOUR PRODUCT IN YOUR MARKET
DYNAMIC STATUS DISCIPLINES
STATIC 1 STATUS DISCIPLINES
CONCEPT DESIGN (REMEMBER PRODUCT STATUS)
INCREASING VOLUME OF PRODUCTION
DETAIL DESIGN
MANUFACTURE
SELL
SELL
CAN YOU RECOUP, WITH PROFIT THE INVESTMENT NEEDED FOR THE INTRODUCTION OF DISCIPLINES OF STATIC 2 ?
NO
CONTINUE OPERATING AT THE STATIC 1 LEVEL
YES PROCEED TO
LAYER 5 STATIC 2 DISCIPLINES

Fig 1 0.2.A

10.3 The Static/Dynamic Model Upheld

In Appendix 4 the static/dynamic model is discussed in relation to the pilot and main study and it was shown that, generally, the behaviour of companies and the industry in which they operated, was as expected. The conclusions of that discussion are presented below:

1) In the main study on telescopic handlers the innovation originated from a company that was not a supplier of rough terrain fork lift trucks (R.T.F.L.), the product it partly replaced, although the innovators were in the construction market.

2) The slow rise in demand for new innovation may well have been due to the existing users familiarity with the existing R.T.F.L., which was almost in direct competition with the telescopic handler.

3) Competition increased, be it slowly at first, and the price fell relatively, partly due to this increased competition, but also because methods of manufacture improved through process design. The design became static.

4) The product became readily available.

5) The lower cost producers began to take the market from the innovator.

6) Competition continued to increase and market segmentation was employed by all producers in an attempt to reach wider markets through product variations of a basic telescopic design.

7) The larger companies began to dominate the market.

8) In order to survive, smaller companies sought a market niche and those that did not, declined. The larger companies thrive whilst the product is static.

9) Companies combined in manufacturing and selling, in an attempt

to gain economies of scale, to minimise the dominance of the larger producers with their lower cost manufacturing and better marketing.

10) The telescopic handler price reduced towards that of the R.T.F.L. Customers became familiar with the product and sales of the telescopic handler exceeded those of the R.T.F.L.

11) The 'shake out' of manufacturers then started and is continuing, as the smaller companies fail, unable to compete, as the larger companies introduce more static design disciplines to further improve the efficiency of production and marketing.

12) The only latecomer onto the market, to show a significant success, was a large company that could call upon similar parts from other products to rationalise into a product. They also have effective distribution and sales.

13) The number of manufacturers has already peaked and is now falling.

14) The market leader (the only company that considers market share is more important than a profitable segment of that market) currently do more process design than product design. They only fear competition from a lower cost producer than themselves, but, at the moment, have more static design disciplines than any existing competition.

15) The product will remain a static design for the forseeable future, as none of the companies are working on a new concept and other companies, outside the product market, are not working on a product for this market. Also it is in the interest of the larger companies to keep the product static, to retain their production and process design advantage. Therefore, regarding the telescopic

handler in the main study, the model for product status of a product that was dynamic and became static, was as expected.

In the pilot study the product, heavy duty dampers for military vehicles, was static and became dynamic:

1) The existing product was manufactured by the market leader using dedicated machinery (in a batch context) and the product had remained virtually unaltered for twenty years, except for some static design.

2) The main customer demanded an improvement in the performance of the product, which could not be met by further static design of the existing product.

3) Technical advance occurred, which enabled significant improvements to be made in the product area, which meant that the new performance specification, demanded by the customer, was achievable.

4) The product was again dynamic.

5) The innovation came from a company that previously was not in the damper market.

6) As the new product interfaced with an existing product, it took time to be accepted, as the customer held a large stock of spares and were more familiar in servicing the old design.

7) The old and new design were both available and the old design still has not been completely replaced.

8) The producer of the old design did not/could not innovate, as they neither had the skills or the desire to change from the old design and they contracted.

9) The innovators thrived when the product was dynamic, but were unable to produce effectively as they put little effort into static design.

10) The new concept had to be produced on a static plateau, with an input of static design and, therefore, the production was taken away from the innovators, who were themselves taken over by one of the producers of the new design. The product is now produced efficiently.

The research has confirmed, in the pilot study, the expected model of a static product that again becomes dynamic.

10.4 Areas For Further Research

The area of research described in this thesis proposes improved ground rules and a prescriptive process for the management of design, directed mainly at the front end of design. It is believed that it opens up several areas where future research may be useful.

Product Status

There is no certainty that the list of factors that determine whether a product is static or dynamic is complete and other factors may exist.

Development of the Design Process

The design process was written to be used in the design of manufactured products. Although the basic principles and sequence are believed to hold good for all products it would need significant adaption in it's content for use with services and in architecture. This would make a useful extension to the use of the design process.

Long Term Testing in Industry

Opinion of the design process was gauged towards the end of the research period. Although it is known that some companies are still using the process, no data has been collected on a full new product design so that the performance of its operational effectiveness can be measured. In late 1988 and 1989 some research in this area has begun and initial results are favourable. This work is continuing.

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Appendix 1

Final Upheld Criteria

Company

C1) That companies holding certain positions at or between the static and dynamic boundaries should have the features shown in figure 1.

C2) Certain companies should concentrate on static products and others on dynamic products.

C3) Some companies concentrate on static design, using the designs of others and this is an effective, successful policy and predetermined strategy.

C4) Appreciation of product status can enable a company to organise its management strategy for optimum efficiency.

C5) Design must be coupled with efficient marketing (research and sales) and production. Weakness in any one of these areas will cause a product to fail.

C6) When a product is static the larger companies are more likely to be successful. When a product is dynamic the advantages of a company being large are diminished.

Product

P1) At any point in time some product designs are static and some dynamic.

P3) The early recognition of the static plateau can, in some cases, enable a company to set standards.

P4) It is possible to create/predict the static plateau.

P5) It is possible to identify the innovations necessary to cause a static product to again become dynamic.

P6) Maximising market share must inextricably be tied up with maximising static design in order to be successful.

P8) It is possible to list in order the value, or importance, of elements in the P.D.S. for certain categories of products in certain markets.

P9) With a static product a greater emphasis on maximising static design disciplines is most likely to lead to market success.

Management

M1) Appreciation of the product status highlights strengths and weaknesses in the product design group and other areas of company operation (eg. marketing and production).

M2) Company personnel must seek and evaluate new innovations to determine if a product is again becoming dynamic.

M3) Dynamic design benefits from/requires an organic structure. Some static disciplines benefit from/require a mechanistic structure.

M4) The company structure provides a mantle in which design operates and this determines what type of design is undertaken.

Figure 1

Product Design
(Environment and Disciplines)

Criterion C1

Disciplines Necessary for All Companies

(Irrespective of Status)

Dynamic
1) Competition Analysis
2) Innovation Seeking Outside Industry
3) Market Research

Static
1) Quality and Reliability
2) Financial Control
3) Effective Sales Unit
4) Market Pull (Reactive Marketing)

Product Dynamic →

Creative Marketing
Sellers Market
Dynamic/Reiterative Planning
Uncertainty/High Risk/High Profit
High Price
Short Product Life Cycle
Short Production Runs
Changing (Unpredictable) Environment
Management Commitment to Change
Non Product Related Research
Many Competing Firms
Technology Push
Flexible Production
Large Research Effort + Costs
Innovation
Patents/Design Protection
Sub Contract Manufacture
Labour Intensive
Minor Process Design
Customer Training
Lateral Flexible Communication
Organic Design Team Structure

Static 1
Product Static
Design Evolution/Product Improvement
Business Planning
Emphasis on:-
Finish
Maintainability
Size Reduction
Assembly Aids
Low Cost Production
Use of Standards
Effective Purchasing
CAD
Imitation
Group Technology
After Sales Service Network
Good Aesthetics
Good Ergonomics
Cost Reduction
Good Reputation
Fast Delivery
Effective Distribution
Reduction of Scrap
Use of Different Materials in Design
More Process Design than Product Design
Standardisation
Capital Investment
Price Elasticity
Price Reduction
Mergers
Increased Competition
Growing Vertical Integration

↓

Static 2 continued overleaf

Static 2 Product Static Increasing
Volume, Time, or (Relatively) Large Company.

Niche Marketing
Low Risk/Low Profit
Long Product Life Cycle/Short
Model Life Cycle
Stable (Predictable) Environment
Long Production Runs/Mass
Production
Specialisation
Rationalisation
Value Analysis
Economies of Scale
Dedicated Machinery
Automation
Robotics/FMS/CAM
Energy Conservation
'Just In Time' (Kanban)
Very Low Cost Production
Seeking Large Market Share
Technology Stabilised Few
Innovations
'Model' Changes
Political Considerations
Financial Credit Systems Policy
Capital Investment
Market Saturation
Fierce Competition
Mechanistic Design Team Structure
Number of Firms Declining
High Capital Investment
Buyers Market
Impact on Society
Synergy

Appendix 2

"Those who wish to succeed must ask the right questions".

Aristotle (384-322 BC)

Revised Questionnaire

	Criterion No
A. History of the Product	
1) Who was the first company to bring this product onto the market? Were they the inventors?	P3
2) When did your company start manfacturing this product?	
3) How and why has this company changed the design?	P1,P2,P3,P7
4) What event(s) in the past have made the biggest change to your market for this product? (Or: How has the market changed since the mid '70's?)	P1,P5
B. Competition	
1) What companies do you consider are your competitors?	C1
2) How do you determine what your competitors are doing in the field of new products? (Briefing for new product search?)	C1,M2
3) Are the number of your competitors increasing or decreasing in this country and worldwide?	P6
(How many telescopic handlers did Sanderson/ J.C.B. sell last year in UK and what is their market share?)	C1,M1

4) Which of your competitors do you consider are innovative? In what way? C4,P1

5) Has the design of this product from all the competition tended to one basic design or have there been some radical changes? Why did these occur? C2,C4,P1,P3,P7

6) Is your market share for this product increasing, decreasing or remaining static? C1,C4,P2,P6,M1

7) Why do you think this is? C4,C5,C1

8) What percentage market share do you estimate you have for this product in Britain, worldwide? How many T.H.'s do you sell each week in this country? Abroad? (What is the total UK market size for this product?) P6

9) Do you consider that market share is more or or less important than securing a profitable segment of that market? P6

10) How long do you consider it will be before this product will be replaced by another product from you or your competitors? C4,P5

11) What do you think are the main threats for this product market? P1,P2,P5

C. <u>Product</u>

1) Indicate on table 1 the importance of features of this product for this market. C4,P6,P8

2) Are design changes or modifications ever made to the product on the production line? For what P7,C5

TABLE ONE PRODUCT QUESTION 1

	VERY IMPORTANT	IMPORTANT	NEITHER IMPORTANT OR UNIMPORTANT	UNIMPORTANT	VERY UNIMPORTANT
Quality and Reliability					
Low Price (Compared to Competition)					
Advanced Technical Features					
Appearance					
Ease of Use (Good Ergonomics)					
Colour					
Strength					
Maintainability					
Finish					
Long Working Life					
Safety					
Long Shelf Life					
Small Size and Weight					
Low Energy Use					
Conforming to Standards					
Fast Delivery					
Other?					

reason?

3) Which of the following are you currently actually working on with this product? Please mark with a tick on table 2. C1,P1,P2,M1,M4

4) Please mark with a cross which you have worked on in the past five years. C1,P1,P2,P8,M1, M4.

D. Production

1) Were any new machines obtained for the production of this product? C1,C3,P4,P6

2) Are some design improvements not undertaken to avoid disruption of production, catalogues, replacement parts, inter-changeability or because you do not have the machinery to produce them? P5

3) Are some of these design improvements quite fundamental or innovative? P5

E. New Product Design

1) Which departments and who from those departments decide on the designs that will be undertaken? C4,C5,M3

2) Do the designs of your competitors ever influence you? C1,C3,M3

3) With these products do you ever achieve greater success than the originators and, if so, to what do you put this down? C3,C5,P2,M3

4) What is included/considered in the pre design C5,P4,P7

TABLE TWO PRODUCT QUESTION 3 AND 4

a) Improved Reliability	
b) Seeking A New Concept	
c)	
d) Product Size Reduction	
e) Improved Aesthetics	
f) Reduction of Scrap	
g) Easier Product Use	
h) Rationalisation of the Product Range	
i) Improved Maintainability	
j) Group Technology	
*k) A Completely New Product (First on to the market)	
*l) Improved Finish	
*m) Reduced Manufacturing Costs	
n) Other?	

* Asked only in the last four interviews

specification?

5) Indicate on table 3 the elements you do not consider in your predesign product specification. C5,P4,P7

5a) When do you compile a pre design product specification?

5b) How do you determine: sales potential time scale, reliability, market constraints, customer requirements?

5c) What are the company constraints?

6) Is it a written document? If so may I see one? C5,P7

7) Who is involved in compiling this specification P7,C5

a) Design b) Sales c) Production d) Finance

e) Market Research f) Customers g) Others?

8) Do you follow a set process or model for design? M4

Could you draw this model?

9) Do you look at innovation outside your industry which you can incorporate into your products? How? C1,M2

10) Does a new product stay in the design stage until all the specification criteria are reached or is a date set for production and the product produced on that date regardless of whether the product can be further improved? P4

11) How does this company undertake market research? C3,C5,P3,P5, P7,M1,M2

F. Management

1) Indicate on table 4, with a tick, the level C1,C2,C4,C5,

TABLE THREE NEW PRODUCT DESIGN QUESTION 5

ELEMENTS OF SPECIFICATION

Sales Potential		Packing	
Materials		Weight	
Product Life Span		Market Constraints	
Politics		Manufacturing Facility	
Company Constraints		Shipping	
Safety		Size	
Testing		Processes	
Strength		Customer	
Patents		Time Scale	
Shelf Life + Storage		Product Cost	
Quality and Reliability		Performance	
Quantity		Life In Service	
Competition		Ergonomics	
Maintenance		Standard Specifications	
Selling Price		Aesthetics	
Climatic Influences		Energy Consumption	
Chemical Influences		Installation	
Other			

TABLE FOUR MANAGEMENT QUESTIONS 1 + 2

	VERY STRONG	STRONG	NEITHER STRONG NOR WEAK	WEAK	VERY WEAK
Design					
Distribution					
Purchasing					
Good Reputation with Customers					
Innovation					
After Sales Service					
Market Research					
Sales Force					
Financial Control					
Economies of Scale					
Corporate Planning					
Fast Delivery					
Assembly Aids					
Use of New Materials					
Production Flexibility					
Low Energy Use on Production					
Cost Reduction Techniques					
Automation					
Improving the Design of Others					
Technical Advance					
Customer Training					
Quality and Reliability					
Low Cost Production					
Other?					

of strength or weakness you consider on this company's performance.	M1,M4
2) Repeat, with a cross, the strength and weaknesses you consider on this company's performance five years ago.	C1,C2,C4,C5, M1,M4
3) Does formal communication (eg. design review meetings) occur between all levels of staff or only between heads of departments?	M3
4) How many people are employed in this company in a) Production b) Sales c) Finance d) Design e) in total?	M1
5) Tick as appropriate if this company has or has not the features shown on table 5.	C1,C2,C3,C4,P1, P4,P5,P6,M1
6) Please tick on table 6 the features to which a new design must comply.	C2,C3,C5,P1,P4, P5,M1,M4

TABLE FIVE MANAGEMENT QUESTION 5

DOES THIS COMPANY:-

	YES	NO
a) Protect New Designs by Patents? (P1, C1, C3)		
b) Undertake Non Product Related Research? (C4, P1, C3)		
c) Use Much Dedicated Machinery in the Production of this Product? (C1, C3, C4, P5, P6, M1)		
d) Use C.A.D.? (P1, C3)		
e) Do more Process Design than Product Design with this Product? (C1, C4, M1)		
f) Do Value Analysis? (C1, C3, C4, P6, M1)		
g) Use Standards When Designing? (c1)		

TABLE SIX MANAGEMENT QUESTION 6

NEW DESIGNS MUST:-

		TICK
a)	Use the existing distribution network	
b)	Use the existing sales force	
c)	Use the existing production facilities	
d)	Be an extension of the existing product range	
e)	Be different from the competition	
F)	Use known and tried concepts	
g)	Satisfy a known market need	
h)	Be the first product of its type on the market	
i)	Use, or improve upon, the best features of competitors designs	
j)	Create a new market	
K)	Other?	

Appendix 3

Telescopic Handlers Total Market and Company Positions in that Market

Year	1980	1981	1982	1983	1984	1985	1986 (Est)
Total Rough terrain handler Mkt.	1700	1425	1615	2090	2530	2540	2810
Number of Telescopic Handlers	170	400	695	1080	1340	1490	1690
T.H. % of Total Market	10	28	43	51	53	59	60

Company Success

Relative market positions each year for telescopic handler manufacturers (excluding Monobooms).

Nov. 1974
Liner

1975
Liner

1976
Liner

1977
J.C.B.
Liner

1978
J.C.B.
Liner
Collins(R.W.C.)

1979
J.C.B.
Liner
Collins(R.W.C.)

1980
J.C.B.
Sanderson
Liner

1981
J.C.B.
Sanderson
Liner
Manitou
Matbro
R.W.C.

1982
J.C.B.
Sanderson
Manitou
Matbro
Mark (Liner)

1983
J.C.B.
Sanderson
Manitou
Matbro
Mark (Liner)
Sambron
R.W.C.
Finlay

1984
J.C.B.
Sanderson
Matbro
Manitou
Sambron
Mark (Liner)
R.W.C.
Finlay

1985
J.C.B.
Sanderson
Matbro

Manitou
M.F. Ind.
Mark (Liner)
Sambron
R.W.C.
Finlay

1986
J.C.B.
Sanderson
Matbro/Liner
(2 Factories)

Manitou
M.F. Ind.
Climax/Henley
Sambron
Finlay
R.W.C.

1987
J.C.B.
Sanderson
Matbro/Liner
(2 Factories)

M.F. Ind.
Manitou
Sambron
R.W.C.
Finlay
Climax/Henley

1988
J.C.B.
Sanderson
Matbro

M.F. Ind.
Manitou
Sambron
R.W.C.
Finlay

Appendix 4

Is the Static/Dynamic Model Upheld?

In this section the model of a product progressing from dynamic to static and later from static to dynamic is described and then compared to the findings from the main and pilot studies.

Consider a newly innovated product introduced onto the market. The market initially will be small and, therefore, the producers will be few, probably the innovators and the method of manufacture simple (little process design). The initial market will be the professional user (if it's that type of product) and the cost will be high, due to the unsophisticated method of production and the effect of 'skimming' will occur, which is profit taking that a new product can command, where few competing producers are involved. The relatively high purchase price is also due to manufacturers recouping the cost of new product development and also they can attract customers, that some marketing literature refers to as 'innovators', people who purchase for reasons of fashion as well as improved performance, although this applies mainly to consumer products. In non-consumer products the purchasing requirements tend to be made in a more rational manner and fashion is of less importance when selecting a product which best suits their needs. Another reason for the high price may simply be a function of supply and demand. A new product may not be producable initially in quantities large enough to meet the demand.

Of course, many new innovations do not create a market and some continue with a small demand and other are discontinued.

The market may grow. This could be due to increased demand from customers, who see advantages in owning the new product, or due to a fall in price as manufacturers increase production and one or two manufacturers decide to manufacture more efficiently. The lower price will bring the product within the reach of a larger market and at this time generally the number of manufacturers increases as the product becomes newly static.

This is a crucial point in the life of a design. The relative fall in price must encourage the producers to put much greater emphasis into process design, as identified by Taguchi (1985). This may be the innovators, but often isn't. Other companies, which are often not innovative but are good at process design and low cost production appear on the market and take the market from the innovators. This process is market led, which has been shown to be the most likely path to follow for product success (Section 2.3). Certain companies (and often these have been Japanese) appear to predict the supply and demand curve and create the market by taking an innovation and, by process design, reduce the price sufficiently to create a large (often consumer) market. This practice involves risk and requires effective market research. Most Sinclair products have been based on market prediction, rather than market research and sometimes considerable process design has been undertaken and the market then failed to materialise. Process design reduces the unit cost/price, but requires a large market.

The market exists and the product is on a static plateau created when more process design was introduced and product stability was necessary. This is now the peak selling period for the product. There is now a period of 'shake out', where some manufacturers fail with the product and these are mainly due to the manufacturers lacking the static design disciplines, which may include better distribution, promotion, servicing, but, perhaps most important, lower price and product reliability. The number of manufacturers will, therefore, decline and the remainder will have a larger market share, which will enable them to introduce yet more process design to lower the price still further. They will have to, as a few large companies emerge in strong competition with each other and, if any one of them starts producing at a lower cost level, the others, by necessity, must follow or decline. This has been apparent for some years in the motor industry. This causes all the competitors to tend to produce with the same level and type of production technology.

The smaller failing companies may survive by concentrating on a small market segment, a specialist area or niche, or seek a new product or innovation. This suggests a large company tends towards a static product and a small company tends towards a dynamic product as described in sections 2.13, 3.1 and 6.5.

Regarding the product status, so much capital is tied up in the production technology, with dedicated machinery and assembly aids, that it is difficult or uneconomic to change the status from static to dynamic. The large efficient producers may be unable to innovate if the product has been static for some years and the personnel, who could innovate, may no longer be available. In the market spare parts and servicing facilities and training will have become established and there will be a reluctance to change this stability. Also certain standards will have been set, which both customers and producers will be reluctant to change.

Therefore, the larger a market grows and the longer a product has been static the greater will have to be the improvement of the new dynamic design mainly in the eyes of the customer, but also in the eyes of the producer, before a product will again become dynamic. Both time, relative size of the producers and market size are facets that weigh a design towards staying static.

Consider these points in the design of the telescopic handler. The features outlined above are not so clear cut, but there is a fair degree of similarity. The telescopic handler was introduced onto the British market by 'H' in 1974, at the Public Works Exhibition at Olympia as the result of an independent market survey amongst a cross section of contractors and their requirements for a rough terrain forklift (P.M.J. May 1983) and was followed by J.C.B. in 1977 and R.W.C. in 1978. Both J.C.B. and 'H' concentrated on the construction market, whereas R.W.C. aimed their product exclusively at the agriculture market. J.C.B.'s attempt to reach the agriculture market started in 1979, when they first exhibited their telescopic handler at December's Smithfield Show. Sambron brought out their Monoboom machine in 1974, which had a similar appearance to a telescopic handler, but did not have forward reach.

Being an industrial product purchases for reasons of fashion were probably almost nil and initial market reaction was very slow as the cost of the product was significantly above that of the rough terrain forklift truck, a less versatile machine competing for a similar market. Collins of R.W.C. designed the telescopic handler for 'G' and this came into production in December 1979. 'H' have stated that in 1980 they were already losing market share to both J.C.B. and 'G', who had lower cost machines (albeit of a less sophisticated design). The telescopic handler market penetration into the rough terrain handler market was probably only ten percent in 1980, but customers were beginning to see the advantages of this type of machine and other companies were also realising that the telescopic handler was a threat or opportunity and the number of manufacturers increased over the next four years.

In 1980 J.C.B. introduced four wheel drive as an option and Manitou, the largest producer of rough terrain forklift trucks in Europe, joined the telescopic handler manufacturers in order to survive in the British market with their Manireach. 'E' started manufacturing telescopic handlers in July 1981 and Sambron, who had persevered some years with a scissor type forward reach handler, modified their Monoboom into a telescopic handler, which was introduced in June 1983. Their Monoboom machine had sold 2,000 by December 1982. of which 95% were to farmers (P.M.J.).

The market then began to rise steadily, as customers became acquainted with the product and accelerated in 1981 and 1982, "last year over 40% of all rough terrain forklifts sold in the UK . . . were the telscopic type". The telescopic handler market "took off in the last year", 'G', May 1982, P.M.J. September 1982, but sales from 'H' and R.W.C. remained static and R.W.C. concentrated on a segment of the agriculture market with a small, twin boom, high power to weight vehicle. 'H', who continued with their vehicle, aimed at the heavy end of the construction market, expanded exports to America but lost ground on the home market. The lower cost producers were beginning to take over the market and, as the price of the telescopic handler moved downwards, nearer to that of the rough terrain forklift market, acceptance continued to grow. ("The price difference is wide but narrowing between telescopic handlers and rigid machines"). P.M.J. May 1983.

The larger manufacturers, who could use components from their other products, took a greater share of the expanding market. By the end of 1984 over 50% of the rough terrain handler market was telescopic handlers. J.C.B. had emerged the clear market leader with a claimed 45% of the market followed by 'G' claiming 30%, then 'E' claiming 23% and Manitou a similar amount. It must be noted that company claims can be seen to be exaggerated, but their relative importance in the market is probably accurate. Actual market penetration and share is shown in Appendix 3. The largest producers each put a great emphasis on low cost production.

Several other companies have since entered the market (Appendix 3) and the large producers have increased their product range to reach a wider market, without changing the design significantly. Finlay have entered the market with products better aimed at the construction market. They are small and it is not clear how they will survive in the market now that the product is static.

Lansing Henley and 'B' continued to market a telescopic handler manufactured by 'B', but when 'B' was taken over Lansing Henley did not renew the sales agreement. M.F. Industrial use their tractor skid currently used on several of their products and have the telescopic handler parts fitted by 'E'. 'H' have been taken over by 'E', who initially marketed the products produced in the Gateshead factory, but have now moved production into 'E's' factories and 'E' have a marketing agreement to supply telescopic handlers to 'K' in the United States.

R.W.C. have been taken over by Bensons and continue to manufacture for their narrow market niche. M.F. Industrial, with their marketing strengths, have grown since entering the market in 1985.

The above demonstrates that the large companies are thriving now that the product is static and the smaller companies are seeking marketing or manufacturing agreements with other companies, to enable them to gain economies of scale and allow them to introduce process design for lower cost production. The larger companies have also benefited from their superior sales and distribution set ups and larger advertising budgets.

Since 1982, the only notable design change has been the twin boom handlers first design by R.W.C. and later copied by 'B'. The market has segmented into construction and agriculture with telescopic handlers in 1986, taking 59% of the total rough terrain handler market and, probably, 72% of the agriculture market segment. None of the companies are working on a new concept for this market, they are treating it as static and do not see the concept being replaced in the near future. This being the case the larger manufacturers will continue to dominate the market through low cost production and through rationalisation of components with their other products, the smaller companies will combine or seek market niches, or decline as is already apparent.

J.C.B. and Manitou both stated that they considered the main threat to their telescopic handler market would come from a lower priced Japanese machine (although none then existed), confirming the theory that when a product is static the lowest cost producer will win the market. The Japanese have a reputation for winning markets through low pricing, made possible with process design. J.C.B. are currently investing heavily in computer integrated manufacture to take production costs even lower than the competition.

The general feeling amongst those interviewed was that J.C.B. "made the market". They were early to see the potential and had the skills to produce and market effectively and they are market leaders as a result. Most R.T.F.L. manufacturers have realised that they need a telescopic handler in their product line up, but most have arrived too late to make any significant market penetration. Only those who can call upon similar parts to rationalise into a telescopic handler to allow low cost production, or have significant marketing strength, can hope for success.

It is suggested by this author that the market is now saturated and, like the car market, a period of "shaking out" is underway. Finlay and R.W.C. look vulnerable, 'H' have already failed and 'B' and Lansing Henley have left the market. Sambron are large, but their success with this product depends on a healthy home market, which has yet to materialise. Manitou are less vulnerable in this respect, but up to a point the same applies. J.C.B. are firmly established as market leader.

All the main producers manufacture to the same level of technology, although J.C.B. are making a significant move to a higher level. It is perhaps significant that in the pilot and main studies only J.C.B. stated that they considered market share more important.

The static/dynamic principle does appear to hold up for the telescopic handler.

Consider now a static product that again becomes dynamic. When a product has been on the market for some period of time, say, in excess of five years, then a new product concept appears, which is a significant advance and an improvement on the existing design. Initially there will be a period where the new design is priced higher than before (as described previously). Over a period of time the cost of the new design will fall and both the old and the new design will be produced in parallel as some customers may prefer the older concept or require it to fit in with an existing product - such as, Betamax tapes for an existing Sony Video. The old design, will become less available and will eventually be replaced by the new concept if both the products serve identical markets, (except for spares replacement) or, if the product is still dynamic, by a later concept.

The manufacture of the new concept will follow the pattern already described, but manufacturers who have not started to produce the latest concept have one of three courses of action open to them. To buy into the new technology, which often is possible as the established manufacturers will generally be larger than the innovators of the new concept. They could try to develop the next new technology, if the product is still dynamic, to "leap frog" over the competition. The third option is to stick to their existing product and continue to treat the product as static and accept a reduction of their market and an eventual decline of this product area. This third option may be forced on a company, which may have a large amount of capital tied up in dedicated machinery, to produce the existing design, which may be unsuitable for manufacturing the changing product concept.

Further, the skills required to innovate may not be available in a company, which may be rich in experience with the existing concept that is not applicable to any new concept. The company may still have an advantage in the selling and distribution system, if this is still applicable, as it was in the case of videos sold by traditional electrical retailers, but was not in the case of digital watches, which were not generally sold in jewellers' shops, as were their predecessors, the clockwork watch.

In the pilot study the product had again become dynamic, after a period of some twenty years of being static. When a product again becomes dynamic the advantages of a company being large are reduced. Newton and Bennett, at that time, were the market leader, but they could not, or would not, adapt to the changing status of heavy duty dampers for military vehicles. Although, they were the country's leading suppliers for some twenty years, they have taken a firm decision not to innovate, maximising profit as the product declined. 'D' also failed to innovate beyond the concept of a telescopic damper, where their experience lay. Their decline in this product area was not as planned as Newton and Bennett, but their inability to innovate was part of the reason for their decline.

Laser thrived when the product became dynamic, being flexible, subcontracting manufacture and were structured almost entirely for innovation. But they were not efficient at treating the product as static for production and were too weak in the disciplines associated with the static design.

Horstman appeared to strike the right balance, innovating, but, then fixing the design. They then introduced an input of static design disciplines to produce efficiently a reliable product. They appeared in the pilot study to be the company best organised for their product status and, subsequently, they have been the most successful with a large order for dampers from G.K.N. Laser, on the other hand, have had to have much of their product manufactured by R.O.F. Leeds (Vickers), an unhappy arrangement.

In the main study, the telescopic handler is static, but the concept it partly replaced is still manufactured. The rough terrain forklift was first manufactured in 1948 and had no rivals in it's market until the introduction of the telescopic handler in 1974, there remains a difference in price and some difference in application, which has resulted in the continuing market for the rough terrain forklift. Over time, though, the cost difference between the two products has reduced, with the market of the telescopic handler growing at the expense of the rough terrain forklift truck.

This research, therefore, does indeed appear to have confirmed the static and dynamic principle in both the pilot and main studies.

Appendix 5

List of Publications Resulting from this Research

The following list of publications have appeared, or will be published, as a result of this research.

Product Status and the Management of Design. Engineering Designer vol.14 no.4 July/August 1988.

Innovation Managed. Eureka vol.9 nos.1-12. Jan.- Dec. 1989

Titles; Who needs it?
What is it?
Where to direct your effort.
The market.
Write it down.
Any Ideas?
Innovation: is it necessary?
Design Disciplines 1.
Design Disciplines 2.
Product Status. So What?
Who does it?
Putting it all together.

Successful Design: What to do and When. (Co author S.Pugh) Butterworths, book to be published Nov.1989.

The Product Status and the Management of Product Design. What to do and When. Proc. International Conference on Engineering Design. Harrogate August 1989.

Paper currently being prepared for I.MECH.E publication.

Seminars given on the findings of the research given at:

The Institution of Engineering Designers Feb. 1989.
Hatfield Polytechnic Sept.1988.
Queen Mary College, Univ. of London. Jan. 1989.
Humberside Business School Oct 1988.
Poly. of Central London. Nov. 1988.
Kingston Polytechnic July 1988.
Hawksmere Seminar Nov. 1989