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The Role of Performance Measurement during Product Design & Development in a Manufacturing Environment

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CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

SYNOPSIS

Effectively managing and measuring the product development process is widely seen as a means of ensuring business survival through reduced time to market, increased quality and reduced costs. This thesis explores the research question of: "How do companies know that they are making effective use of their product design and development function?"

A review of the literature in this area revealed that there is a distinct lack of detail available on how measurement of product development should be approached. Where articles do exist, it was found that most report on isolated projects or jump from problem solving straight through to results, without explaining the methodology used. Additionally, both in the literature and in practice, many applications of performance measures to date have been incomplete - without due consideration being given to monitoring and controlling the whole design and development process. For example one tool or technique has been introduced in isolation or schemes have been introduced without evidence of the benefits gained.

This thesis documents the development of an implementation framework and a tool (usable in the form of a workbook) to enable a Project Manager, Concurrent Engineering or Process Improvement Champion to use performance measures to improve decision-making during the product development process. The investigative part of the research was carried out by following a longitudinal case study approach with sustained participation in the organisation. This was supplemented by a series of follow-up cases, together with results from surveys to academics and industrialists both in the UK and overseas. Through interpreting the literature and triangulating the results from the data collection and analysis, a number of principles surrounding performance measurement in this area were identified. These were then grouped into system-related and metrics-related principles. Opinions of European managers were gained throughout to ensure direct applicability.

The resulting Performance Measurement for Product Development (PMPD) Methodology, consisting of an implementation framework and accompanying practical paper-based workbook (with software extensions), was tested in two companies to determine its usability.

These testbeds yielded encouraging results and provided opportunities for further refinement and improvement. The next step will be further testing and refinement in a wider range of applications.

It is believed that the research outputs of the international survey results, generic PMPD Implementation Framework, Workbook and Training Guidelines have together made a positive contribution to understanding and measuring the product development process in manufacturing organisations.

> "If you can measure what you are speaking about and express it in numbers, you know something about it. But when you cannot, your knowledge is of a meagre and unsatisfactory kind."
>
> Lord Kelvin

PUBLICATIONS

1. Driva H and Pawar K S, 'Overview of PACE - from Conceptual Model to Implementation Methodology', Proceedings of the 2nd European PACE Workshop, Weber F (ed.), Marinha Grande, Portugal, May 1997, pp. 10-22.
2. Driva H and K S Pawar, 'Performance Measurement for Product Design & Development in a Manufacturing Environment', Proceedings of the International Conference on Production Research (ICPR), Osaka, Japan, August 1997.
3. Pawar K S, H Driva and F Omar, 'Electronic Commerce and its Implications on Re-engineering the Supply Chain', Proceedings of the 3rd International Symposium on Logistics, Venice, Italy, 9-10 July 1997.
4. Driva H, Literature Review on Performance Measurement, included in Chapter 3 of The Change Process: An Operations Management Perspective, Gilgeous V, Pitman Publishing, forthcoming July1997.
5. Driva H, 'Management PhDs - What's it all about?', Institute of Management, Management Tomorrow, Issue 2, March 1997, p6.
6. Pawar K S and H Driva, 'The Development of a Generic Framework for the Implementation of Concurrent Engineering', International Journal of Computer Applications in Technology, v9, n4, September 1996, pp. 165-173.
7. Pawar K S and H Driva, 'Implementation Methodology - A Stepwise Practical Approach to the Implementation of Concurrent Engineering', Proceedings of the European PACE Workshop, Thoben K-D and F Weber (eds.), Bremen, Germany, September 1996, pp. 17-34.
8. Driva H and K S Pawar, 'The Role of Design Performance Measures in a Concurrent Engineering Environment', Proceedings of the European Operations Management Association conference (EuROMA), London Business School, UK, June 3-4, 1996, pp. 207-212.
9. Driva H and K S Pawar, 'The Development of a Generic Framework for the Implementation of Concurrent Engineering', Proceedings of the Flexible Automation and Intelligent Manufacturing (FAIM) conference, Georgia Institute of Technology, Atlanta, USA, 9-11 May 1996, pp. 478-487.
10. Driva H, K S Pawar K and U Reetz, 'An Implementation Methodology for Concurrent Engineering' (d81a), The PACE Consortium, Brite-EuRam II, Europe, September 1995.
11. Gilmour P, H Driva and R A Hunt, 'Strategic Planning Using Quality Policy Deployment: Texas Instruments (Singapore)', Focus on Change Management: Cases in Business Process Engineering, Issue 16, July/August 1995, pp. 5-10.
12. Driva H and K S Pawar, 'The Process of Developing a Conceptual Model for Concurrent Engineering', Proceedings of the International Association for the Management of Technology conference (IAMOT), Aston University, Birmingham, UK, July 1995, pp. 503-510.

13. Gilmour P, H Driva and R A Hunt, 'Future Direction for Logistics in Australia', International Journal of Physical Distribution and Logistics Management, MCB Press, v25, n3, March 1995, pp. 24-32.

14. Gilmour P and R A Hunt (with 11 case studies written by H Driva), 'Total Quality Management: Integrating Quality into Design, Operations and Strategy', Longman Cheshire, Melbourne, Australia, February 1995.

15. Gilmour P and H Driva, 'The Impact of Winning the Australian Quality Awards', The Quality Magazine, (published by the Australian Quality Council), v3, n4, December 1994, pp. 18-21.

16. Pawar K S, H Driva, et al, 'A Conceptual Model for the Concurrent Engineering Domain' (d11a), The PACE Consortium, Brite EuRam II, Europe, December 1994.

17. Driva H and R A Hunt, 'Quality Drive Brings Dividends' (an article on the premier Australian automobile association - the NRMA), Sydney Morning Herald newspaper, Sydney, Australia, 29 March 1994, p22.

18. Driva H and K S Pawar, 'A Guide to British Computing Services Firms on Exporting to Germany', European Business Review, v92, n4, June 1992, pp. 35-43.

19. Driva H and K S Pawar, 'The Design of Service Operations', Proceedings of the Operations Management Association conference (OMA), UMIST, Manchester, UK, June 1992, pp. 195-203.

During my time at Nottingham University, I have been a member of:

- the European Operations Management Association (EurOMA)
- the Institute of Management
- the Product Development and Management Association (PDMA) and;
- the Concurrent Engineering Research Forum[1]

[1] Hosted and chaired a CERF meeting of at the Department of Manufacturing Engineering and Operations Management, University of Nottingham, 21 September 1995.

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CHAPTER 1

1. INTRODUCTION

This chapter explains the background to the research that has been carried out. It then defines the problem, discusses the need for performance measures, sets out the hypothesis for the work and states the research aims and objectives. It concludes with a description of the structure of the thesis and a summary of the research findings.

Research Question:

> "How do companies know that they are making effective use of their product design and development capabilities?"[1]

1.1 Problem Definition - Why Research This Area?

A product development environment is very demanding as it requires a mixture of overlapping activities, controlled costs, reduced time to market, increased quality and increased flexibility to be effective. A literature search quickly revealed that there was a lack of performance measures to assist with product development (including [Hart96a] and [Greg93]). This is largely because of the difficulties associated with developing and implementing appropriate measures. Changing the existing performance measurement system in a company can be a difficult task as it is often a well-established source of stability (eliciting defensive comments such as 'we've always done it like that' when questioned). However, change is essential in order to move away from - what is in most cases - a finance-dominated measurement system, towards a more holistic system encompassing product development activities in particular. Making the change, in terms of access to information, is easier than ever before with communication and reporting techniques such as groupware, email and videoconferencing becoming more affordable. This facilitates the use of a diverse range of measures. As a result, there is an increasing amount of interest from both industry and academics on how product development can be better controlled, spurred on by the growing need for world class manufacturing and best practices.

[1] The purpose of the research question is to act as a directive that leads the researcher immediately to examine a specific performance, the site(s) where events are occurring, documents, behaviour or informants to interview [Stra90].

My work towards this thesis stems from a much larger project - the Brite EuRam funded research - A Practical Approach to Concurrent Engineering[2]. The initial ideas came from a deliverable concerned with formulating an implementation methodology for Concurrent Engineering (CE). Through interviews with managers in the participating companies, the lack of available performance measures to achieve CE was identified as a problem area and, hence, a potential area for further work. The original idea has been extended, with added emphasis being placed on the post concept (i.e. specification decided) to pre-production stage - including detailed design. This was due to the recognition that it would be useful to have a tool for assessing effectiveness during product development projects. The global, strategic PACE goals have been translated into operational-level actions. Although individual tools that measure aspects of the product development process exist (e.g. project scheduling packages), there are very few integrated tools to measure performance during product development, taking into account the special demands of Concurrent Engineering (i.e. overlapping activities, cross functional teams, goal sharing, time compression, continuous process improvement and customer focus).[3]

Despite the interest in performance measures and the numerous articles on the value of implementing them, there are few (if any) worked examples of how this was achieved. It was therefore felt that research into this area would make a valuable contribution to industry.

1.1.1 THE NEED FOR MEASURES

> In a survey report published by the Institute of Mechanical Engineers' Design Council [Cull96], 70% of design & development managers claimed they had previously or were currently using some metrics for internal performance measures.

Measurement is an essential part of management. Few would argue that management basically comprises of deciding what to do, how to do it, evaluating performance and using results to ensure that activities can be kept on track.[4] Many studies have identified

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[2] see [Driv95a] and [Thob95]

[3] The Hewlett Packard 'Return Map' [Hous91] is one of the few commercially available tools to include CE aspects. Here they focus on time to market.

[4] For a good overview of the need for measures see 'Performance Measurement Manifesto' [Eccl91].

a correlation between superior performance and the development and use of measurement capabilities. For example, in a study carried out in 1985, A T Kearney Consultants noted that firms engaging in comprehensive performance measurement realised improvements in overall productivity in the range of 14 to 22 percent [Bowe96]. Leading edge firms are particularly committed to performance measurement, with executives often ranking the use of a comprehensive set of measures among their top objectives in the business press[5].

Poor use of measurement can often be perceived as threatening. People dislike being tracked and writing time-consuming reports on their activities and output. This is partly because of the fear that close scrutiny of resources will result in loss of autonomy and power. On closer inspection, it becomes clear that the measurement system itself is not the root of the problem. Instead it is the management style and the culture of the organisation that needs addressing. Often it is the conflict of roles that the performance measurement system has that needs unraveling. A system must both evaluate activities (control) and appraise them in terms of effectiveness and opportunities for improvement (management). These roles should be made distinct in order to avoid confusion and mistrust by employees. This approach was advocated by Deming for over half a century but has still to be adopted in many organisations. A performance measurement system should be a cohesive collection of measures, not an attempt to achieve a magic single figure to represent all activities. Much of the controversy and lack of acceptance surrounding measures stems from attempts to make a complex situation appear too simple. When implemented properly, measurement systems are very useful (and in fact necessary) in terms of decision making, forecasting, cost estimating, problem solving, planning, continuous improvement, feedback and motivation. There are several clear reasons for using measures - primarily:

a) To reach objectives and ensure that goals are met

- ♦ you can't manage without measuring
- ♦ no measures means that decision making is guesswork

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[5] For one example see Management Today [Blai97].

b) To identify improvement areas

- to identify bottlenecks
- to optimise resource allocation

c) To benchmark for people to monitor their own performance

- can be a motivation booster
- people like to know how they are progressing and being praised

d) To set a standard for establishing comparison

- You need to know the operations you are measuring well and have high internal standards before external benchmarking can begin.

There are many 'paradigms' surrounding measures in organisations. Some of these can be misleading and become obstacles to their use. For example, in their book on measuring performance, Sink & Tuttle [Sink89] state that several paradigms commonly exist in organisations. Namely;

1. *Precision is essential to useful measurement* - Management-related performance issues do not lend themselves to the level of precision associated with laboratory measurement. The basic purpose of performance measurement is to tell the organisaton whether or not it is headed in the right direction.

2. *Standards operate as ceilings on performance.* This is only the case if the organisational culture causes it to be. Measures should be treated as updatable benchmarks not absolute values.

3. *Overemphasis on labour productivity.* Measurement schemes in the past - particularly work study and old cost accounting methods - have highlighted the costs of labour. This is changing as companies realise the value of multi-factor measurement.

4. *Subjective measures are sloppy.* As the measurement focus shifts to 'knowledge work' there is an increasing need to measure 'softer' dimensions of performance. These are typically connected with morale and customer perceptions. There is a tendency to equate soft with sloppy. However, techniques to measure attitude are well developed and can lead to reliable and valid measures.

5. *There must be a single indicator focus.* Performance of complex organisations cannot be adequately encapsulated by a single indicator. This misconception has been

partly caused by the misuse of statistical computing power capable of aggregating and reducing multiple inputs into one macro output.

1.1.2 WHERE AND HOW CAN MEASURES BE USED?

The argument for measures is very strong but in order for them be effective and make a positive contribution, they need to be applied in the right number and in the right places. On a basic level, objectives for developing and implementing performance measures in any organisational area can be divided into three categories: monitoring, controlling and directing operations. Monitoring involves tracking historical performance for reporting to management and customers. Controlling measures track ongoing performance and are used to refine and 'tune' current processes. Directing measures are more concerned with the human aspect and are designed to motivate personnel [Bowe96]. The appropriate blending of these three types of measures typically constitute a balanced performance measurement system.

Poolton [Pool94] looked at performance measures from a Concurrent Engineering perspective. She considered that; 'performance indicators provide one means of assessing the success of CE implementation efforts'. She explained that these indicators can be of a commercial nature (e.g. percentage sales captured by new products during a pre-defined time span) or an operational nature (e.g. by assessing development expenditure and/or production costs using an activity-based costing scheme). She added that while 'post mortem studies' provide a valuable means of feeding back into the new product development process directly, in practice this type of feedback is very limited owing to difficulties in reforming the CE team in the post implementation phase.

Time and cost estimates for projects can often be well far of the mark due to a combination of bad planning, inadequate forecasting and vested interests. Problems with product development have been reported for many years. As an example, a drug industry study [Mans71] found that actual cost and project duration exceeded estimates in over 80 percent of the projects. Recent advances in computer software have assisted in increasing accuracy but this alone is not enough. Certain aspects of projects - such as human resources, communication and unforeseen changes to specification of outputs - cannot be easily quantified and these may be of critical importance. For this reason, the implementation framework for a measurement tool, described in this thesis, includes both 'hard' and 'soft' aspects.

More recently, in 1991, Arthur D Little reported that 87% of Japanese respondents to a survey experienced a lack of systems and guidelines for product development and 90% felt not enough attention was paid to product specifications to meet customer requirements. Over 70% said a compartmentalized, sequential process was an obstacle to improving product innovation [Hart96a]. In a survey report published by the Institute of Mechanical Engineers [Cull96], operational managers in design and development felt that there were several key issues that constrained them from making improvements in projects. These included; late specification changes by the customer, inadequate product databases, relevant cost data not available and lack of computer-based support tools. It also revealed that reducing costs, improving product performance and reducing number of parts were among the highest priorities for design improvements. Nearly all respondents (over 95%) considered a 50% reduction in product cost and a reduction in design changes by 50% to be either 'desirable' or 'important' for future business strategy in order to remain competitive. These figures alone highlight the need for better performance measures.

A practical example of the reason for introducing meaningful performance measurement systems is as follows: A company is in a situation where the sales team consistently sell last minute rush orders on variants of new products which cause headaches for Design, Production Planning and Tooling. The Production Engineering Department's performance is measured by the timely output of the production line. Therefore, their performance is pulled down by these rush orders because of the lost changeover time for the batch of the rush order rather than the preferred long runs. If the cost of changeover were to be reassigned to Sales every time they submit a rush order, then the Sales Manager would think twice about doing this and will push his/her team harder to sell on the basis of existing lead times. This means that the decision maker (here the Sales Manager) has to consider the consequences of their decision on the rest of the organisation, as this will directly affect them rather than the next person downstream.

Companies need to be very careful about the types of measures made and how they are used. Measures quoted in published company financial accounts only reflect the external state of a company and do not necessarily reveal the root cause of any problems. For example, to know that Company X invests twice as much money into R&D as a percentage of revenue compared to Company Y is interesting but it does not help identify or improve weaknesses within the company. Selected measurements must be fully planned (both strategically and operationally) and explained before they are introduced into a company to minimise the danger of misinterpretation. According to a 1993 study by the Design Council on benchmarking in the UK; 'the most relevant information is not the actual number of things done, but the qualitative information on how things are done and in what order. It is the operational measures that provide the most valuable information' [Nich93].

It seems that the main problem in this field is lack of focus on the measures that are really needed. As long as users of performance measurement systems (including senior management) understand that there are limitations to even the best designed system and that results must not be followed blindly, the introduction of such a system is likely to be successful. The implementation framework and paper-based tool proposed in this thesis, to assist with the management of performance measurement activities, must be treated as an aid (not a panacea) for reducing uncertainty and for providing a basis for disciplined decision-making. This is much more than a simple 'shopping list' imposed on the organisation. It is generic in nature at the top level, with sector and company-specific needs being built in by those customising the system and performing the measures.

1.2 Hypothesis

At the beginning of this research, the initial hypothesis was stated as:

> The consistent[6] application of performance measures during design and development in a manufacturing environment will improve the product development process.

It was further asserted that:-

[6] i.e. applied on a regular basis as opposed to in an 'ad hoc' fashion.

a) Lack of usage of performance measures adversely affects the product development process.

b) More effective management through the use of performance measures will support Concurrent Engineering principles.

c) Reallocation of resources resulting from use of performance measures will reduce the cost and time required for decision-making.

d) Use of performance measures during product design & development aids decision making.

As this research is based on management issues, these statements were then incorporated into the data collection through the questionnaire design and tested through practical fieldwork with companies. Following triangulation of the data, at the analysis stage, it is now considered that a more appropriate hypothesis is:

> When used on a consistent basis, the formulation and implementation of appropriate performance measures for design and development projects in a manufacturing environment will improve the product development process.

1.3 Research Aims and Objectives

This research seeks to determine:

1) Which performance measures are currently in use in UK industry to assist with the design and development of products.

2) How widespread the use of performance measures is during product design and development in a manufacturing environment[7].

3) Which performance measures academics would like to see used.

4) The overlap between measures recommended by academics and those used in practice.

5) Which additional performance measures could be used to enable product development projects to run more smoothly.

[7] This excludes external development factors such as licensing, technological buyouts and subcontracting which are out of the scope of this research.

There are two main outputs from this research:

I) ***A theoretical output*** - a methodology to assess the performance of product development (with particular relevance to a Concurrent Engineering environment[8]). As one of its main functions it will focus on identifying problem areas within the development process and suggesting ways (using tools and techniques) to tackle them.

II) ***A practical output*** - a framework and a paper-based tool to assist with the management of product development projects. The tool will be presented in the form of a workbook together with training guidelines, showing how to implement performance measures for product design and development without the aid of a consultant. This will be tested and refined in a real life environment and expanded later for wider application. The resulting tool will facilitate the implementation of performance measures for product design and development on both a project and organisational level. It will also make provision for monitoring the effect of any changes on a consistent basis.

It is intended that this management tool should be flexible enough to enable it to contribute to an integrated performance measurement system for the whole organisation, as it is recognized that over-emphasis on one area is an unhealthy way to manage. The fit with organisational objectives and strategy is also an important consideration. Measures for other areas of the business have not been considered (as it is beyond the scope of this thesis) but background information and references are provided in the literature review.

1.4 Terminology

The meanings of the main terms used throughout this thesis are described below to avoid confusion.

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[8] i.e. based on projects using cross functional teams and a variety of tools & techniques that assist with achieving Concurrent Engineering objectives (see Section 1.4 for a definition of CE)

Design & Development Performance:

Monitoring performance during the product development process is an important input into an organisational performance measurement system. As performance is multi-dimensional, it is doubtful that one overall measure will suffice for design and development performance. Therefore, the aim for researchers and practitioners is to find a set of workable measures that capture most of the performance dimensions thought to be important over both the long and short term. To be truly effective, these measures need to encompass both the 'hard' and 'soft' elements of the product development process. As with many disciplines, the hard elements such as time to project completion are typically impersonal, reasonably accurate and easy to administer and collect. Softer elements such as efficiency of communication within the project team and between the team and others are much more difficult to quantify.

1.4.3 Definition of Concurrent Engineering

The most enduring and widely accepted definition (CE) is that by Pennell and Winner [Penn89]:

> Concurrent Engineering is a systematic approach to the integrated, concurrent design of products and their related processes including manufacture and support. This approach is intended to cause the developers from the outset to consider all elements of the product life cycle from conception through to disposal, including quality, cost schedule and user requirements.

Most research groups formulate their own interpretation of what CE means. The PACE interpretation, written with the help of all the project partners is:

> Concurrent Engineering is a structured and controlled way of managing product or service development with respect to integrating resources and calendar time, sharing common goals and accurate information throughout.[9]

For the purpose of this thesis, CE is categorized as a philosophy. CE is often defined in terms of software tools but this is clearly not the whole story. Increasingly, CE is thought of as a loose collection of tools and techniques that together facilitate

[9] This definition acted as a starting point for the development of a conceptual model for the CE domain, based on the rules of Rumbaugh's Object Modelling Technique (see [Driv95a]).

significant improvements in lead time, cycle time for product development, teamworking, etc. It is these attributes that differentiate CE from the traditional, sequential engineering still commonly used in industry today. The concurrency of activities makes planning much more complex and cross functional integration essential. As defined above, these considerations need to be made 'from the outset' to ensure achievement of the results reported in the many success stories of CE. As with other recent philosophies, it is lack of commitment that leads to failure and labeling as another fad.

As a guide to the terms used throughout this thesis, a glossary associated with product development, Concurrent Engineering and performance measurement has been developed and collated by the author (see Appendix I).

1.5 Research Design

The framework for the research was clear from the outset: The investigations would be company-driven with leading academics and experts in the field - together with published literature - providing theoretical support and knowledge. Two questionnaires were formulated; one for practitioners and one for academics. These were compiled from information in the literature (both on case studies and existing theoretical frameworks), experiences, observation, formal interviews and discussions with practitioners. Different questionnaires were formulated for both groups to reflect their expertise, however, a core of questions was common to both to allow for direct comparisons to be made. These were then piloted on a number of academics and industrialists (both in the UK and abroad), amended and launched by post. Ten follow-up cases were carried out with selected respondents from the company survey. This allowed for further exploration and clarification of answers across a range of industries.

An in-depth, longitudinal case study was carried out over a period of 18 months with a manufacturing organisation that carries out its own product development activities. Following consolidation of the results from the literature, questionnaires and applied case study, an implementation framework and a paper-based tool to assist in formulating company-specific performance measures in design and development were devised. The framework was then tested and subsequently refined using two product development projects as test-beds. The methodology is described in detail in Chapter 3.

1.6 Structure of the Thesis

A brief overview of chapter contents is as follows:

- This chapter presents the reasoning behind the research and introduces the reader to the subject of performance measurement during product design and development in a manufacturing environment.
- Chapter Two follows on with an in-depth literature review of relevant work to date in this area and identifies how this thesis can contribute.
- Chapter Three details the research methodology adopted and explains the practical approach taken, including data collection techniques and analysis.
- Chapter Four reports on the results and implications from an initial NPD study with the PACE project partners and the two international postal questionnaires.
- Chapter Five is concerned with the analysis and implications of the ten selected follow-up cases.
- Chapter Six discusses the outcome from the eighteen-month longitudinal case study with a manufacturing organisation on how to plan for performance measurement. This includes tracking the progress towards implementation of a set of design and development measures for a domestic appliances project.
- Chapter Seven describes and discusses the research output. It presents the resulting PMPD Methodology, including the Implementation Framework, accompanying Workbook and Training Guidelines.
- Chapter Eight concludes by discussing the outcome of the research, the extent to which the aims and objectives were met, the contribution to knowledge and areas for future research.

1.7 Summary of Research Findings

This research began at an interesting time as awareness of performance measures for product development was growing. This is due to increased competition on a global scale and the need for companies to control costs in all areas to remain competitive. Owing to its nebulous nature in the past, product development was one of the last areas to be tackled. The literature review quickly revealed that much had been written about performance measures in general and measures for manufacturing processes and finance, but that little work had been carried out specifically in product design and development. The review also highlighted that variations in definitions and data collection techniques make it difficult to compare performance measures between one organisation and another.

The positive response to the long distance questionnaires allowed for comparison between academics and practitioners encompassing world-wide views. They revealed that views were fairly closely aligned (unlike in previous similar studies in the area of NPD [Grif93 and Grif96]) and that although companies were not currently using a balanced set of measures (as recommended by academics), the vast majority had plans to expand their systems in future. Results of note included; 85% of company respondents believed that no unnecessary performance measures were made, 21% believed that all performance measures in their company were understood and only 3% claimed that they were very satisfied with the current performance measures used during product design and development. Furthermore, many of the management tools and techniques available to assist with assessing performance were not known, much less used. The follow-up cases with ten companies provided an opportunity to investigate how companies currently calculated their product development measures, how this fitted in with organisational measurement systems and how they hoped to develop them in future. In many cases, measures arose out of ISO 9000 requirements for tracking the product development process. Managers quickly saw the advantage of having access to this kind of information and encouraged the establishment of further measures.

The in-depth longitudinal case study with Domestic Appliances Ltd. provided an on-line opportunity to evaluate the company's needs and expectations of measurement of product development performance. This provided valuable insights into the problems and opportunities associated with implementing measures in a large company. It was found that much of the data required was already being collected but not in a suitable form for further analysis. A set of initial performance measures were chosen through interviews and discussions with managers team members and a spreadsheet program was written to assist with managing the measures.

The subsequent PMPD Methodology worked well when tested out at Domestic Appliances Ltd. and Plastico Ltd. Both companies found that defining performance measures that were generic enough to provide benchmarks across products and divisions within the company, yet specific enough to provide meaningful results on individual projects, was difficult (but not impossible). Thus the use of a generic system implementation workbook as a guide to setting-up the system and producing a company-specific project workbook was advocated. The main advantage it offered was considered to be that it presented many options and measures that were available at each stage of the product development process, without overly constraining the flow of action.

Outputs from tools - be they software or paper-based - are best used as indicators rather than absolute 'decision makers' as they are inherently subject to bias (garbage in garbage out). Attempting to make them completely objective is an almost impossible task. When used with this in mind, tools such as this are especially useful in setting goal posts within which to base future actions. Specific initial drawbacks reported by the test-bed companies were; not being fully aware of what could be achieved in this area, the time (and money) required to understand the use of the tool and therefore not knowing what would be beneficial to try. Further training on the effects and benefits of measurement would assist in overcoming this hurdle. Refinements and future work could concentrate on adding further options at each stage of the implementation framework, together with refining and improving the usability of the accompanying workbook.

CHAPTER 2

2. LITERATURE REVIEW

This chapter discusses the background and starting point for the work described in this thesis. It focuses on management accounting origins to measurement, performance measurement systems, success and failure factors in product development, manufacturing performance measures, quality systems and other performance measurement tools available. Various data sources were used to form this review ranging from product development journals to management journals, Concurrent Engineering journals, books, newspaper articles, conference proceedings, seminars, workshops, other academics, email newsgroups, CD ROM searches, theses and Internet web sites. The literature review also extended to research methods including questionnaire design, case studies, quantitative and qualitative analysis, statistics, scaling, factor analysis, data validation and action research. These aspects are discussed in the methodology and results chapters.

2.1 Management Accounting Origins

> 'It seems that managers talk more and more like accountants the higher they are in the organisation'. [Dixo90]

Performance measurement has been around for many years but up until recently, the only measures consistently made were for financial records (e.g. inventory valuation, shareholder value, profitability and cost of sales determination). Traditional accounting methods such as Return on Investment (ROI), Discounted Cash Flow (DCF) and break-even time were (and in some cases still are) the backbone of most accounting systems. Return on Capital Employed (ROCE)[1] is a traditional measure that is still a popular way to gauge performance at a business level. It is generally employed on a monthly and quarterly basis rather than for long term strategic planning. In Management Today, ROCE is described as 'a key measure of how hard the business is making its money work' [Oliv96a]. It is essentially a shareholder-oriented measure, with good use of

[1] Return is calculated on the basis of profits rather than cash flow.

capital being rewarded on the stock market rating. This policy can of course have adverse long term effects. For example, project managers will be encouraged to use old depreciated capital equipment, instead of investing in new machinery as this will yield higher returns in the short term.

These measures, although widely used, are calculated in a fairly simple and inflexible way and have difficulty dealing with the many variables in modern complex projects. In other words, use of cost accounting information alone is inadequate to map process performance. It is generally agreed that financial performance measures are most useful at higher levels of management where they can reflect the success of strategies. According to Johnson [John92], relevance was lost between the 1950s and 1980s when management used cost accounting to drive marketing strategies and control operations. He goes on to state that 'it is inconceivable that accounting systems ever can help to control operating processes in a customer-focused global enterprise'. This view is backed up by Dixon who considers that 'cost-based measures are inconsistent with the new emphasis on quality, JIT and using manufacturing as a competitive weapon' [Dixo90]. Many measures generated by cost accounting systems divert managers away from focusing on what is most important in manufacturing organisations. Peter Drucker, one of the most respected experts in management, warned of the dangers of using product cost accounting information as a basis for marketing and management decisions. Additional information on cost and management accounting methods can be found in [Size85] and [Trox90].

Activity Based Costing (ABC), a so-called 'new' accounting methods came to prominence in the early 1980s. As its name implies, it breaks costs down to the individual activity level. Although initially hailed as the answer to all the problems of accounting systems, it is now widely agreed that ABC should be used as a tool for decision making (in improving the accuracy of product cost allocation) rather than as a replacement for an existing cost accounting system [John92]. Furthermore, although ABC gives companies a more accurate picture of their overhead costs it does not go deep enough to change fundamental views on how to organise work to become a continuously improving and globally competitive organisation. Additionally, ABC on its own does not identify or remove bottlenecks, it is merely a step in the right direction.

Financial measures[2] have been criticised for their backward-looking perspective, with calculations and forecasts being made on information that can be months old. For this reason, risk-taking is not encouraged because results (and hence feedback) take time. As investment decisions are based on 1 to 2 year payback periods, this can make change difficult to justify. Financial measures alone do not adequately reflect factors such as quality, customer satisfaction and employee motivation. By linking development, operational and financial measures more meaningful - and directly useful - results can be obtained. For example, improved quality or reduced time to market only benefits the company when it is translated into improved sales, market share and reduced operating expenses [Kapl92]. To date, little work has been done on linking these measures, with most performance measurement systems being initiated and controlled by finance managers. This clearly has to change.

2.2 Manufacturing Performance Measures

In his widely quoted book on performance measures for world class manufacturing [Mask91], Maskell justifies the need for manufacturing measures as opposed to narrow financial measures. He outlines measurement methods for direct manufacturing, with particular emphasis on continuous improvement principles and strategy. He asserts that in order for a manufacturing organisation to become world class they need at least one senior manager to be designated a change champion. He continues that companies must use the results in a positive way (however bad) to encourage problem-solving and innovation towards continuous improvement.

Other work in this area has been carried out by Hall et al. In their book 'Measure Up' [Hall91] they emphasize the importance of measures to achieve manufacturing excellence. They focus on three broad areas of people, process and quality with particular focus on goals for continuous improvement. The book concludes with how to measure up, and discusses the accuracy and inaccuracy of the measurement process and performance indicators.

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[2] An additional problem for researchers is the confidential nature of financial data. This makes firms reluctant to release details to outsiders, which in turn makes comparisons between organisations very difficult.

Performance measurement and benchmarking - specifically in manufacturing planning and control systems - has been extensively researched at UMIST [Koch94] and [Kenn96]. They have specifically looked at ways of linking manufacturing planning (including materials, machines, processes, people and suppliers) with overall strategic measures. They found that (at the manufacturing planning level) performance measurement 'tends not to be' directly or explicitly related to practices, and is often not linked to the strategic objectives of the organisation. Findings from these projects provide some pointers for product development but manufacturing and strategic considerations are the main focus.

2.3 Performance Measurement Systems

Activity in the area of Concurrent Engineering and performance measurement has increased enormously in the last five years both in the UK and worldwide. Notable work considered here includes that by Gregory [Greg93], Crawford [Craw88], Hronec [Hron93], Globerson [Glob85] and Sink & Tuttle [Sink89].

Perhaps the longest running research on performance measurement systems is that by the Boston University Manufacturing Roundtable. Over a period of more than ten years they have watched the evolution of performance measurement systems in the USA, Europe and Japan [Mill88]. This has revealed a shift away from focusing on production and inventory control systems towards new product introduction and quality management. This reflects the increased strategic importance of these two issues.

The Manufacturing Engineering Group at Cambridge University has worked extensively on performance measurement design systems [Greg93] [Neel95a], what makes a good performance measure [Neel95b] and strategy issues [Neel94]. They have carried out a thorough review of literature in the field, covering everything from financial, quality and manufacturing methods used today through to flexibility measures and others that are emerging. Results from a pilot study carried out by Gregory revealed that all functions in the company were strongly aware of the importance of new product development and 'clearly felt that the performance measurement system did not reflect this concern' [Greg93]. The Cambridge researchers highlight the need for predictive performance measures (in the same vein as SPC[3] for quality control). A performance measurement record sheet, for use in both industry and academia, was introduced as a means of analysis and a checksheet that can be used to make theoretically appealing performance measures practical. This forms part of the group's wider aim of developing a comprehensive performance measurement system. The most recent project carried by the group in 1996 involves a benchmarking study of design and development processes in the UK electronics industry [Oliv96b]. Initial results showed that measures used were at a fairly unsophisticated level i.e. total number of components, percentage of new parts, percentage late against plan, number of change notes and actual versus forecast sales. Benchmarking across the companies proved difficult owing to different recording systems, terminology and project stages. The next phase of the project seeks to benchmark measures against companies in Japan and the US.

A collaborative project involving Liverpool, Strathclyde and Loughborough Universities is investigating integrated performance measurement systems for manufacturing organisations[4]. The objective of the research is to provide industry with a comprehensive set of tools, techniques and procedures to allow self-audit of existing performance measurement systems against a reference model and consequently continuously improve the system. Researchers at the Industrial Studies Department of Liverpool University are investigating the role of management strategy. Strathclyde University is specifically investigating the use of tools and techniques (such as customer focus, process modelling, cause/effect analysis and QFD) for designing integrated performance measurement systems. The researchers at Loughborough, meanwhile, are looking at the IT requirements. This research is similar to the work at Cambridge in that they are attempting to devise a comprehensive measurement system, with emphasis on strategy rather than specific processes or stages of development.

During work towards her PhD on performance measurement systems, Crawford analysed six manufacturing companies (specifically focusing on JIT aspects). Her results included the following findings [Craw88]:

[3] Statistical Process Control

[4] EPSRC-funded, duration 1994-1997

- Few criteria are required to detect improving and worsening performance
- Performance criteria must be measured in ways that are easily understood by those whose performance is being evaluated.
- Performance data should be collected, where possible, by those whose performance is being evaluated.
- Specific numeric standards are not required [for inventory and quality criteria]: improving trends are needed.
- Performance to schedule criteria must evaluate group, not individual, work.
- Graphs should be the primary method of reporting performance data.
- Performance data should be available for constant review.
- The reporting system must not replace frequently held performance review meetings.

Hronec [Hron93] introduces the 'quantum leap model of performance' in companies. He discusses the need for vertical (strategic, top-down) cascade of measures and horizontal - process based - measures. Within this framework, Hronec advocates a six step implementation procedure for introducing a performance measurement system into the company.

Sink & Tuttle [Sink89], in their book on planning and measurement in organisations of the future, describe a performance improvement planning process. This includes organisational systems analysis (for strategic vision and analysis); creation of planning assumptions upon which plan will be based (to raise awareness of expectations of the result); development of tactical objectives (translating strategy into achievable action items); formation of action teams and development of plan of action; continued development and management of the evaluation system. They then propose a general measurement methodology to implement this. This includes many of the general principles of management such as continuous improvement, project management, etc. but is captured in a practical, appealing way that made it popular.

The Malcolm Baldrige Quality Award, developed in the USA (with variants across the world), provides a quality management framework to carry out self-assessment audits to encourage a formalised approach to process improvement in all areas of business.

The award deals with the overall performance of the organisation rather than concentrating on processes or products but can be tailored to meet specific needs. It is divided into seven categories - leadership, information & analysis, strategic quality planning, human resource development & management, management of process quality, quality & operational results and customer focus & satisfaction - with varying weights according to importance. Supporters consider the audits to be a very effective way of analysing strengths and weaknesses in the current mode of operation and hence highlight where to deploy resources for maximum effect. Critics argue that audits are cumbersome, too bureaucratic and that they slow down improvement initiatives and sap enthusiasm. Perhaps more crucially, it could be argued that audits indicate rather than explain performance. Chiesa et al [Chie96] consider that if innovation and/or development performance measures are to be effective, innovation capability and the processes involved in development need to be understood. Previous attempts at a systems approach to document proceedings have been made, most famously by ISO9000. Within the last ten years, it has become a universal standard and even a prerequisite for business. It is undoubtedly a step forward but does have limitations in that people quickly began to concentrate on 'conforming' and following the system to the letter, rather than looking for improvements. Owing to ISO9000's systematic structured approach, it is useful as a guide to companies who don't know how to approach measuring their activities. In fact, it is widely agreed that its major value is as an auditing system rather than as a basis for improvement.

Other work in this area has been carried out by Zairi [Zair94] and Globerson [Glob85]. Zairi explored the connection between performance measurement systems and TQM. Globerson compiled a useful 'do's and don'ts' list in the design and development of an effective performance measurement system. He states that the main objective is as a decision support system that provides information. He considers a closed management loop to be a major ingredient with 'realisation of potential improvement depending on the existence of a feedback system that provides performance information'. He recommends that for measures to be successful, they must be derived from strategy and relate to specific and realistic goals. Furthermore they should be based on quantities that can be influenced by the user and/or the user in conjunction with others. The preferred form of data collection is using data that is automatically collected as part of a process, with ratios rather than absolute numbers being the best guides.

Most of the work described above highlights the need for a clear connection between measurement systems and strategy. In other words, as company strategy changes, so must the performance measures, be they finance, manufacturing or development-oriented.

2.4 Product Development and Concurrent Engineering

One of the most comprehensive global investigations of product development and management practices has been in the automobile industry, which was considered to be the most global industry. The conclusions recorded by Clark & Fujimoto [Clar91] and later by Womack, Jones & Roos [Woma90] stated that the auto industry example has far-reaching implications that will touch all R&D manufacturing organisations. They asserted that as product development is very complex and that detail is important, top management cannot know everything that goes on in the implementation of a new product development process. 'Consequently, everyone involved in new product development must share an understanding of the overall pattern of development the organisation seeks' [Clar91]. They go on to say that these firms will be close to customers and integrate understanding of customer experience with the product into details of design. Engineering and manufacturing will work together closely achieving a significant overlap in time. Clark & Fujimoto concluded that in order for Western firms to remain competitive on the world market (and reverse the effects of the decline suffered in the 1970s and 1980s), manufacturing must be regarded as a strategic function and that urgent attention must be paid to improving product development practices. However, they stop short of proposing a system of performance measures for this.

An earlier notable study in this area was carried out by Hayes, Wheelwright and Clark. In Dynamic Manufacturing [Haye88], they compared US practices with those in Japan. The main point of the research was to determine why US firms have not responded more aggressively to the erosion of their world markets. The book focuses on management strategy and ways in which firms could respond to achieve sustainable advantage are suggested. It is suggested that Japan is moving ahead rapidly in product and process innovation because of their greater understanding of management strategy. They concluded that there are four unifying themes that together form a positive response to increased competition. These are;

1. management makes the difference,
2. a holistic perspective is essential,
3. customer value and competitive advantage should be relentlessly pursued and that
4. continual learning and improvement is the organisations objective.

Of special interest to this thesis are the areas on product and process development. A sample of product development projects was studied and the main problem appeared to be the lack of integration between functions. A framework - the 'Development Funnel' - to ensure successful development projects is then proposed [Haye88][5]. Within this, methods of measuring an organisation's development performance, emphasizing the importance of development time are outlined. However, no details on how to implement them are included.

One of the first studies to focus specifically on new product development was carried out in Canada by Richardson & Gordon [Rich80]. They surveyed 15 manufacturing firms, following up with interviews and a study of case literature in manufacturing policy. From this they reported that the traditional performance measures used by these firms inhibit innovation, with the measures focusing on the plant as a whole rather than individual products. Furthermore, they found that no measures were made specifically at the NPD stage of the product life cycle or when new processes were introduced in the firms. No suggestions were made on exactly what improvements could be made or how these measures could be systematically recorded. However, it did indicate that there was a need for further work in this area.

The pre-concept stage of product design typically represents a high percentage of the overall development time. This is often not adequately documented as illustrated by conversations with Electro-Tools Inc.[6]. One manager commented that 'all the attention

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[5] Earlier work in this area was carried out by Pugh [Pugh81] who expressed the funnelling of ideas as 'controlled convergance'.

[6] Project partner on PACE.

is placed on reducing time to market once the concept is ready. However, in reality, the vast majority of development time on a typical new product is spent on finalising the concept (up to two thirds of time in some cases). If this could somehow be managed, development time could be vastly reduced'. One book that offers some guidance is by Ulrich & Eppinger [Ulri95]. They propose that in order to control the concept generation stage of new product development, a five step methodology is required. This involves clarifying the problem, searching externally and internally for guidance and ideas, exploring systematically and reflecting on the solutions and the process. It could be argued that this approach is somewhat simplistic, as it assumes that the product is well-defined by customer needs within the bounds of the 'product mission statement'. Additionally, clear target specifications are required; 'the process begins with a set of customer needs and target specifications and results in a set of product concepts from which the team will make a final selection. In most cases, an effective development team will generate hundreds of concepts, of which five to twenty will merit serious consideration during the concept selection stage'.

A project at Liverpool University was aimed at assisting firms in improving their new product development performance through the selection and implementation of appropriate improvement techniques. It hopes to establish an evaluation method whereby companies can more closely define which new product development improvement methods would be most suited to their type of business. The outputs will be a benchmarking tool to allow companies to assess their NPD performance and management techniques against best practice companies. This will be accompanied by a directory of NPD best practice, an implementation strategy and performance measures to assess implementation. The 'complexity' of the NPD process in terms of people, process and object systems is highlighted as an important factor and one of the group's main activities is developing a methodology for measuring this complexity. Ten UK firms are involved with the project and they will be used as testbeds for the framework. One of the first stages was to carry out a readiness assessment for Concurrent Engineering and in the initial stages, particular attention was paid to the CERC RACE model. Later stages of the research will involve the development of a number of performance measures to assess the implementation of an improvement strategy. While new product development forms a major part of this project, there is relatively little emphasis on developing a set of measures or an integrated tool for the development stage.

The SIMPLOFI Project at Loughborough University is looking at firms who have 'successfully' implemented Concurrent Engineering. The aim of the project is to determine a methodology to assist managers in manufacturing to implement the version of CE most appropriate to their organisation. It intends to help companies plan structural changes. It will generate 'what if..' scenarios regarding proposed changes by using a computerised tool. The resulting tool will help to work out the consequences for the organisational structure, jobs, and reskilling requirements. It will not be industry-specific. At the end of the project (late 1997), methods of changing the organisational structure, developing an appropriate business process flowchart and introducing performance measures will be provided. The first stage was to define what is meant by 'success'. Participating companies were then be grouped according to extent of implementation and success. This project is focusing on organisational issues surrounding use of the Product Introduction Process (PIP). One of the group's first outputs was the development of congruent Concurrent Engineering heuristics to validate the PIP. The work is at this stage still largely theoretical. It will be interesting to see the results of the practical application.

Professor Paul Coughlan at Trinity College, Dublin has concentrated on understanding performance-limiting practices common in today's organisations and how this adversely affects product development. The research also aimed to indicate to participating firms that the use of Concurrent Engineering could help to overcome barriers in the management of new product development projects [Coug95]. The conclusion from preliminary results was that the participating companies saw the value of a systematic self-assessment approach to focus on where they are at present in attaining goals for improved new product development processes. However, no indication was given on how this could be conceptualised or indeed on the future direction of the research.

A UK Product Development survey of 512 companies was carried out by the Design Council in 1993 [Nich93]. It aimed to measure product development performance of

UK manufacturing companies[7] and explore the key factors that determined product development ability. Ten major measures that companies should consider for benchmarking in product development were identified. These were:

1) Product development costs
2) Product development time
3) Manufacturing ramp-up time
4) Average time to process and implement engineering changes
5) Percentage of engineering changes occurring after release to manufacture
6) Total effort to develop the product
7) Number of parts within the product
8) Percentage of design effort subcontracted out to third parties
9) Design realisation - percentage of designs which get released to manufacture
10) Time to recover previous quality levels

This list is quite comprehensive but no more information is given and there appears to be no further investigation into their meaning. No clue is given as to how this list was compiled i.e. from users, academics, the Design Council, consultants, etc. Unfortunately for researchers, the original questionnaire is not included in the results.

The survey revealed some interesting statistics: Less than 30% of companies deliver more than half of their products to market within the development budget. UK companies are over-running their product design costs by an average of 19%.[8] The survey also revealed that a massive 50% of all products are late to market and that this figure remains fairly constant across all industry sectors. Furthermore, these projects typically overrun by 27% of their development time. On average UK companies require some 20% more development time to get the product right for manufacture after design release. Additionally most organisations in the survey experienced between 10 and 20% of their engineering changes after design release. Only 33% of firms has some form of product data management system and among those who do have it, only 45% of product data is being managed in a consistent manner, even though the information is

[7] included aircraft, computers, white goods, defence, vehicle components and telecommunications industries

[8] 'Where these products were also late to market, they will not reach break-even and will fail to provide a profitable return over the product life cycle.'

available in electronic form (due mainly to poor data integration and common standards). One would hope that this figure has improved since then due to an improved understanding and use of networked computers. Interestingly for this research, the survey revealed that a 'comparison of those companies which use process improvement methods (such as QFD and DFMA) shows that there is a general pattern of improvement in their ability to better predict the cost and time to market of a new product'. Across all sectors, the improvement in cost predictability shifted from 19% to 48%. Similarly, time predictability increased from 23% to 37%.

They concluded, somewhat depressingly, that very few of the best UK companies are in the same league as the best players in the world. Steady improvement is not enough for many engineering companies if they are to remain competitive; a radical breakthrough is needed.

2.4.1 SUCCESS AND FAILURE FACTORS IN PRODUCT DEVELOPMENT

Identifying factors that determine success and failure is a topic that fascinates many academics in the product development area. A UK-based study by Ughanwa & Baker [Ugha89] found that the most important factor stimulating international competitiveness and hence success are design-driven. Identifying common success factors that can be applied on a large scale is of interest to both academics and practitioners and is therefore a very active area. Professor Abbie Griffin of the University of Chicago has worked extensively in the area of performance measurement [Grif93]. One of her latest projects was concerned with how to measure success and failure during the product development process [Grif96]. From case studies conducted in the US, she found that there is currently little overlap between measures used by academics and those used by industry and that the measures used in practice are not those that managers would like to see used. She also found that the main reasons for not measuring were that there were no systems in place for measurement, company culture did not support it, no-one is held accountable for results, short-termism, 'can't wait for results' and even not understanding the development process. She made several conclusions from this:

- Multiple measures are required for success - no one measure is useful for all projects nor across all firms;

- The types of measures used should change according to changes in strategy and product characteristics and finally,
- Data for many measures recommended by academics and consultants are currently not available in firms.

Additionally, she stated that appropriate performance measures very much depend on the type of product development project being undertaken, together with the type of innovation strategy which the firm pursues. She added, however, that there is still value in agreeing on certain measures so that results can be compared across a broader base of industries and experiences.[9]

Several projects on success in new product development and innovation have been carried out by Professor Susan Hart at Stirling University[10]. An examination of the strength of relationship between innovation and continued market prosperity was one of her most recent projects [Hart96a]. She reported that NPD success is often derived from overall company performance, which can be misleading. A thorough review and evaluation of financial and non-financial measures is included. Of particular interest was the grouping of non-financial measures of success (that should be used to assess the importance of NPD) into five sub-headings; design, activity, market, technological and commercial. She reports that few of these measures are empirically derived and notes that 'given that the objective set by the person responsible should be the guiding criterion, it is surprising that there is a dearth of information regarding how managers themselves would define success in terms other than financial'. In addition, their relationship with financial measures has not been explored. The most commonly used NPD financial measures are overall company profit and sales growth. However, generally either sales growth or profits are used leaving the relationship between the two unspecified. Along the same lines, the relationship between overall company performance and direct measures of new product performance is also vague. The research examined these issues using questionnaires and interviews with British managers. She found that in the sample used, new product development is a

[9] Other works by Griffin have focused on the role of QFD in product development, cycle time reduction and innovation management.

[10] Johne and Snelson have carried out earlier work in this area [John88] and [John90].

'replacement' rather than a 'growth' activity and that sales and profits measures are very different (leading to opposite views of how successful a company is). The main conclusions were:

a) There is no significant relationship between sales growth and average profits over a five-year period.
b) Indirect measures are a more fruitful way of accessing data (owing to sensitivity of financial data).
c) The dimensions of success - as specified by companies - contained customer focused statements with regard to technology, cost, price and time to market.

She adds that owing to the multiple dimensions of 'success', it is vital to determine what types of product development strategies and processes will result in what types of success, in order for the research to have a meaningful impact on innovation.

A second study by Hart focused on new product development models and their impact on success and failure [Hart96b]. This proposed the use of a multiple convergent process to map new product development more accurately, taking into account all inputs and outputs from affected personnel and placing product development firmly at the centre of business analysis within innovative organisations. The authors suggest that this type of representation allows for a more accurate insight into the decision making process that affects success and failure. They state that mapping shows how the development of successful new products is basically dependent on cross-functional information, management and decision making. This research is ongoing and aims to assist firms in the way that they develop new products from ideas to final commercialization.

Professor Gloria Barczak [Barc95] investigated new product strategy, structure, process and performance in the telecommunications industry. She challenged the attitude toward the 'fuzzy front end' mentality of design. Central to the research was an examination of the relationship between strategy and new product development. The short shelf life makes time to market particularly vital in this industry. She found that no single strategy stands out as the best and stressed that success (in terms of product performance) is more dependent on the presence of a competent development team and a product champion who is involved with the strategy for introducing products. She added that staying in touch with the markets through customer prototype testing and concept testing was also a contributing factor to success.

2.4.2 R&D MANAGEMENT

Gupta & Wilemon [Gupt96] carried out an extensive survey of 120 R&D directors in technology-based organisations[11] in the USA to assess the current environment of R&D management. They found that many changes were afoot in the way that it is carried out. These included; increased emphasis on cross functional teamwork, R&D's contribution to short- and long-term business results and R&D's capability to quickly bring new products to market (especially those that customers value). Nearly 20% of respondents did not use any computer-based tools - such as CAD, simulation tools and other software - to make their product development process more efficient[12]. Perhaps more significantly, they found that only 25% were using primary management tools and techniques such as TQM, benchmarking, QFD, DFM, email, teleconferencing and rapid prototyping.

There was a sharp shift towards short term results but whether this will have a negative effect on long term investment for R&D and hence business competitiveness 'remains to be seen'. This short term focus was making it 'less difficult to measure R&D performance'. Whether these are the right measures to improve performance is unclear as yet. No details were given on the types of measures that they had in mind - other than they were time and cost-related. Somewhat cryptically, the article stated that increasingly 'return on R&D investment is being measured by its impact on improving business performance'. Exactly what is meant by business performance is not explained. However, the increasing importance of performance measures is mentioned in the statement that measuring R&D performance was the second most important issues to the R&D directors (monitoring market developments was the top concern). They concluded that as commercial pressures are increasing, efforts are being concentrated on high impact, customer-focused projects rather than 'blue sky' projects. In other

[11] primarily in chemical, instrumentation, telecommunication, computer software, electronics and industrial equipment industries

[12] Many who do not, may of course not engage in any engineering drawing activities.

words; 'R&D's focus is shifting from 'R' to 'D' and hence towards applied product development'.

A study carried out in 1996 by Twente University focused on current practice in R&D performance measurement in Dutch companies [Kers96]. The authors stated that 'although managers still acknowledge that R&D processes have several characteristics that make them different from other more repetitive processes, they no longer accept that this should mean they are unmanageable'. This has meant that there is growing acceptance of the need to measure R&D performance. They consider that there are five major parameters for R&D measurement systems; the Measures of Performance (MOPs), the measurement system structure, standards to measure performance against, measurement techniques and the frequency of measurement and reporting. Their subsequent survey, on the design of measurement systems for R&D, was answered by 48 companies[13], with 10 of these being interviewed about their experiences. Over half of the respondents (54%) used measures to report team performance, while 57% measured individual performance and 27% measured department performance. The way that measures are reported within these three groups is shown in Table 2.1.

	Teams	Individuals	Department
Subjective assessment by superior	32	84	44
Assessment by independent third party	26	5	11
Questionnaires/verbal feedback by internal and/or external customers	21	-	44
Objective score on quantitative criteria	47	53	67

Table 2.1: Kerssens R&D Study: Reporting of Performance Measures (figures in %)

The main reasons for measurement across all organisational levels was as an aid to decision-making and assignment of resources. One interviewee pointed out a danger of performance measurement figures by stating that 'R&D team performance was perceived by the company as being too low, because unfavourable and changing internal and external conditions were not taken into account'. Exactly how these conditions could be 'factored-in' in a fair way is not explored. Types of measures used by respondents were categorised using the Balanced Scorecard (see section 2.5.1). They

[13] primarily chemical, pharmaceuticals, electronics, instrumentation and construction industries

found that hardly any respondents used a balanced set of measures from all four perspectives[14]. Individual and departmental performance was measured on a yearly basis, whereas team performance was measured at every 'milestone' in a product development process or at project meetings. They argue that it is difficult to evaluate the value of R&D measurement procedures by their contribution to company performance as it cannot be objectively broken down into that level of detail. This was a preliminary study that did not detail why the scorecard measures were used in R&D. However, it provided interesting comparisons and pointers for more in-depth work in this area.

2.5 Performance Measurement Tools and Techniques

One of the few surveys of tools, methods and 'models' used for measuring new product development was carried out by Mahajan & Wind [Maha92]. The main aim of this research was to determine the role of new product 'models' in supporting and improving the new product development process. Marketing activities before and after product development (i.e. detailed market study for market identification, positioning and strategy, pre-market volume forecast, market launch planning, etc.) are the main focus. However, the study revealed that there was a low usage of 'models' and methods (including focus groups, conjoint analysis, Delphi, QFD and product life cycle models) among the respondents. Where methods were used, their main purpose was to assist in new product idea generation, new product screening and consumer tests of products. They also found that the major shortcomings of currently available techniques was that they were too time-consuming and that they were incapable of capturing the full complexity of the market. Their strengths, meanwhile, were that they improve the success rate and identify problems with new products. Improvement suggestions included the need for more formal and quantitative approaches, a reduction in the time required ('simplify'), and more involvement of top management and customers.

Several tools and techniques currently available on the market (in software, paper-based and workbook form) that aid performance measurement are considered below. They are

[14] financial, customer, innovation & learning and internal business perspective

the Balanced Scorecard, the Diagnostic Tool, the RACE model, PACE tool, project management tools, DFx tools, QFD and Pugh's Product Design Specification.

2.5.1 THE BALANCED SCORECARD

Following a study of 12 leading US companies in the early 1990s, Kaplan and Norton developed a set of measures that they suggested represent a 'Balanced Scorecard' for a company performance measurement system [Kapl92]. The resulting paper-based tool provides a framework for the high level visualisation of strategic, operational and financial performance and has four sections:

1) *Customer perspective* - how customers see the firm
2) *Internal perspective* - what firms must excel at
3) *Innovation & learning perspective* - how the firm can contribute to improve & create value
4) *Financial perspective* - how the shareholders see the firm.

The emphasis placed on each quadrant is entirely up to the company involved i.e. it does not have to be equal. The 'balance' refers to the fact that factors other than financial considerations are considered. Thus, a firm that wants to focus on improving for NPD can specify relevant goals and measures in each quadrant. While the framework offers top management a visual way of representing performance requirements, it does not provide a structure for going below the macro scorecard level. This is needed in order to deliver the detailed rather than aggregated measures. It is also a 'one-off' rather than dynamic approach as no feedback loop is provided.

The scorecard is usually administered by a consultant, with the main objective being to focus the strategic vision. A detailed example of how to introduce the scorecard into a company appeared in the Harvard Business Review in 1993 [Kapl93]. It has since become one of the best known tools for performance measurement systems (not a difficult task as there are few alternatives) and has since been computerised by the Nolan Norton consultancy[15].

[15] For the latest developments on the Balanced Scorecard, see the Internet site http://www.rens.com/wp-tbs.htm

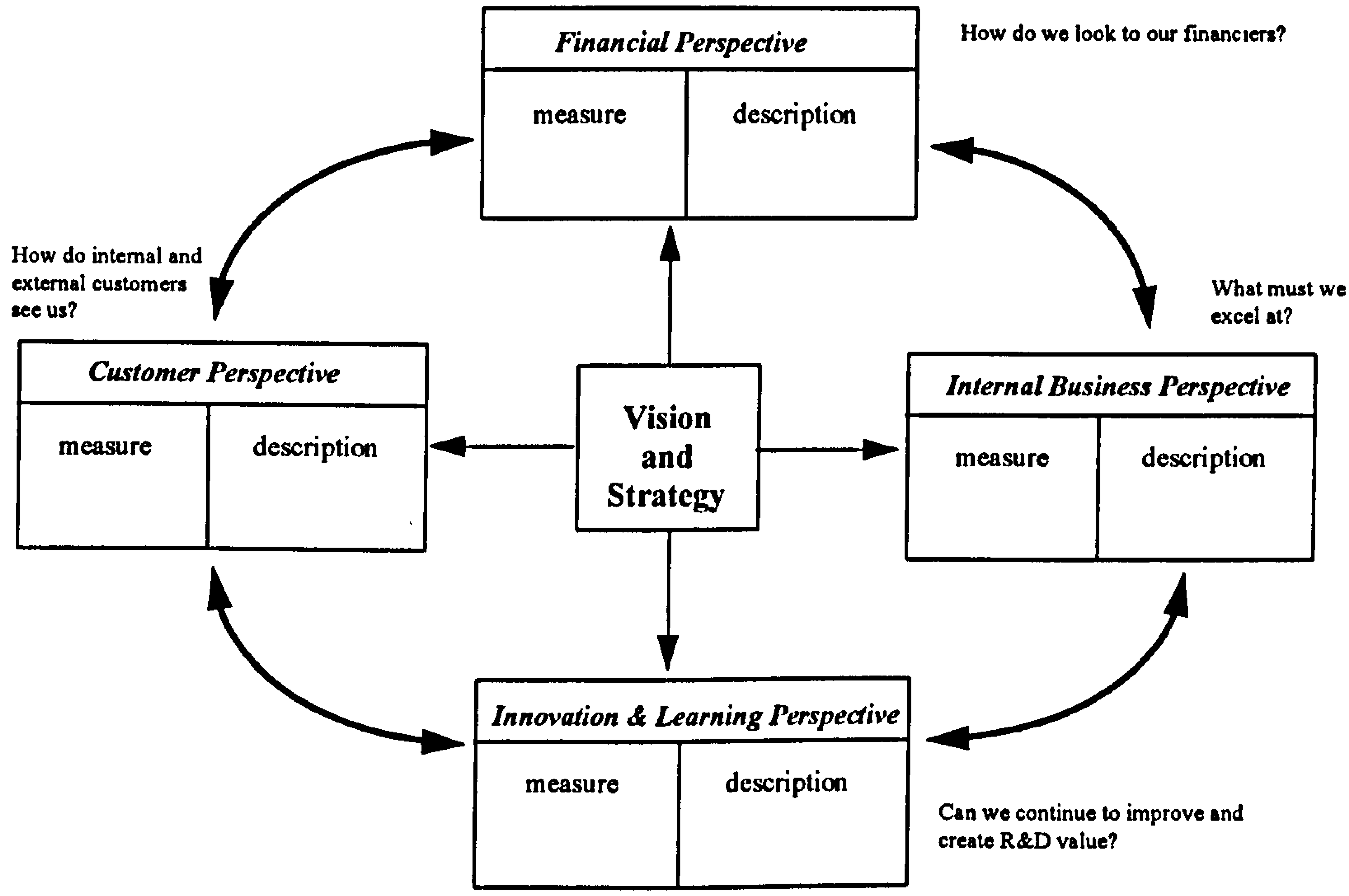

Figure 2.1: The Balanced Scorecard [Kapl92]

2.5.2 Strategic Diagnostic Tools

The Performance Measurement Questionnaire, developed in the late 1980s by Dixon, Nanni and Vollmann at Boston University, is an integrated diagnostic tool designed to check consistency between strategic objectives and performance measurement. It has since become one of the most highly-regarded surveys covering performance measurement systems. The lengthy diagnostic questionnaire is used to ascertain the status of and need for performance measures across the whole organisation. An extract is shown in Table 2.2.

Of how much importance is this performance factor?	Performance Measurement Questionnaire PERFORMANCE FACTORS	How much emphasis is currently placed on measuring factor?
None>>>>>>>>Great		None>>>>>>>>Great
1 2 3 4 5 6 7	Sales growth rate: per account	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Quality of monthly reports	1 2 3 4 5 6 7

Table 2.2: Performance Measurement Questionnaire Extract [Dixo90]

Detailed examples of the questionnaire's use in practice are included in 'The New Performance Challenge' [Dixo90]. These show how the results from the gap analysis were used by top management to achieve congruence and set the long term company strategy. The methodology described revolves around three inter-connected areas for change (strategy, actions and measures) and contains three stages of data collection. In stage 1 general data about the respondent and the company is collected. In stage 2, the respondent identifies important areas for long term improvement and determines whether or not the current performance measurement system supports this. Finally, in stage 3 the respondent compares and contrasts what is currently most important for the firm with what the existing performance measurement system emphasizes. Gaps are then analysed through the use of simple bar charts and the extent of the match between the company's strategies, actions and measures is identified. As with other existing work, this study focuses on strategic rather than operational problems, stressing implications on the organisation as a whole. Additionally, it is very 'table-oriented' with very little graphical output. However, the detailed case studies provide a useful insight into the way performance measures are implemented.

Another tool that links strategy and company objectives to measurement is the General Motors Performance Measurement & Feedback Scheme [Greg93]. 'Process Measures' and 'Results Measures' were differentiated and their position within the corporate vision was identified. Process measures in this context involve quality, responsiveness, cost and customer satisfaction, whereas results measures are those involved with determining how well strategies are being implemented. This is very much a top level view of measures, embracing the whole organisation from corporate down to departmental and cell level. The measures adopted focus on six areas; shareholder satisfaction, retail customer satisfaction, marketing and service, operations, product initiation and people development. Within this, measures specifically concerned with new product development represents only a small percentage (less than 20%) of the total of 62. As with the balanced scorecard, no feedback loop is provided to make the assessment on-going.

2.5.3 RACE

During the early 1990s, the Concurrent Engineering Research Center at West Virginia University in the USA developed a Readiness Assessment for CE (RACE) model [Kara92]. Its origins are in the defence industry and this was used as its test-bed. RACE evolved from the software capability maturity model [Hump89] and several variations exist, including those by Carter [Cart91] and Charney [Char91]. It contains an amalgamation of organisational issues. There is a comprehensive set of questions (with yes/no tick boxes) of 'process' and 'technology' elements. Some of these are useful for product development and team formation. The answers are then mapped (see Figure 2.2 for an example) and a gap analysis is carried out. RACE essentially shows a snapshot of where a company is on the road to CE by asking questions on where the company presently is, as opposed to where it wants to be.

The advantages of this form of representation are that lots of information is displayed, the analysis can be process or product oriented and it is a useful evaluation tool to determine 'where we are now'. However, as a holistic conceptual model, it does have some drawbacks. Namely, it is not a dynamic model and produces a very 'static picture' of the organisation. It is complicated for the end user to use and requires a consultant to administer it. The use of a prescribed set of questions is restrictive. In addition, the split between 'process' and 'technology' is questionable. Its validity is also questionable as the development was carried out exclusively in the defence industry. Who is it aimed at and at which level in the company should it be employed? A RACE Meter in the form of a software tool was proposed by the research team as a further development. This was intended to enable companies to take ownership and update the results themselves, making the output more dynamic. However, funding for this was not granted.

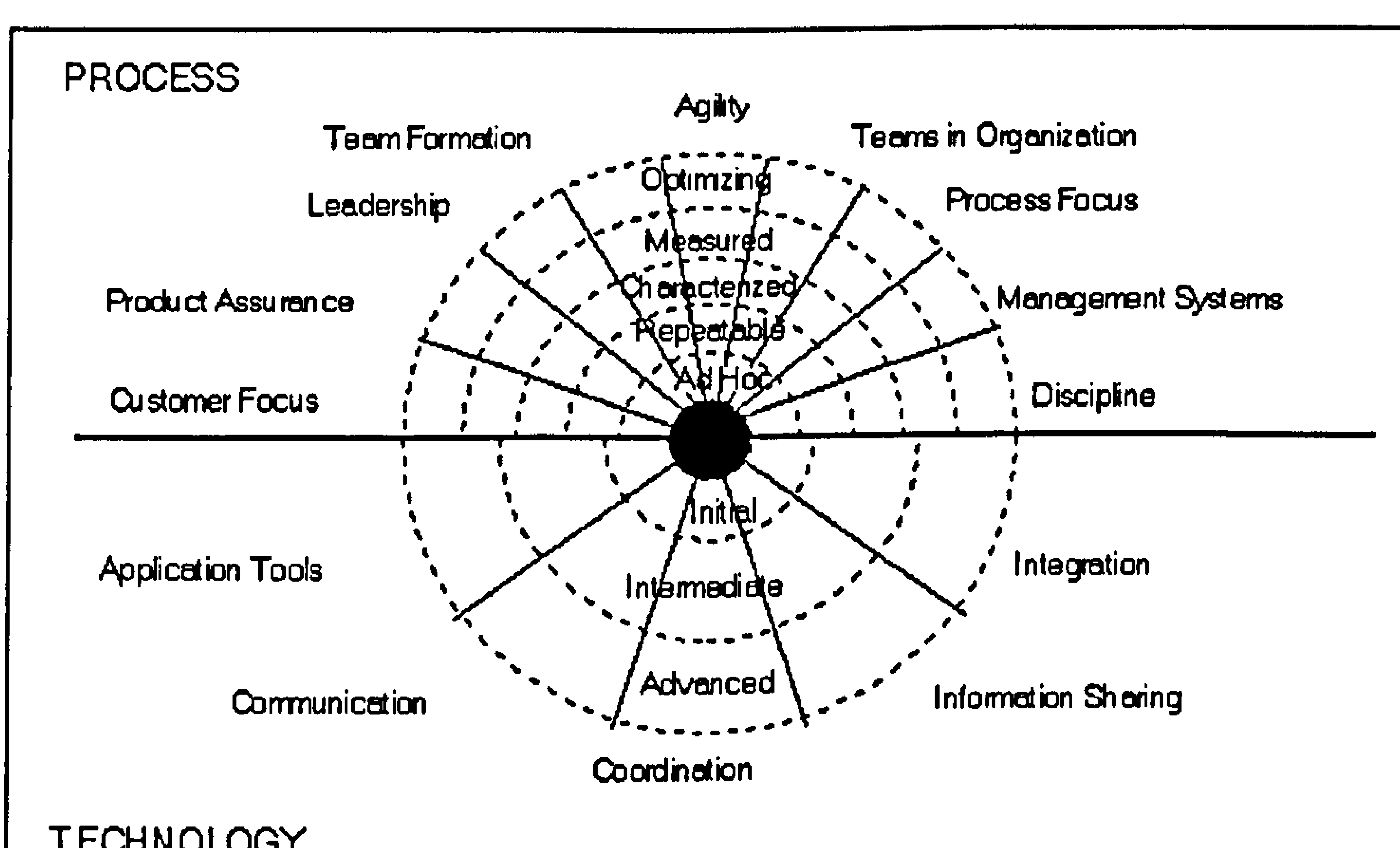

Figure 2.2: RACE Diagram

A development of the RACE model is currently being tested by Robert de Graaf [deGr94] at Eindhoven University in the Netherlands[16]. This is using a five point scale in preference to the yes/no answers of the first RACE questionnaire and, when completed, will be useful as a guide to CE implementation in the European context. The ideas contained in this assessment tool could be adapted to focus more specifically on the management of product development.

2.5.4 PACE TOOL

Developed as part of the PACE Project [Driv95a], this tool provides a 'metamodel' for performance metrics definition that enables companies to initiate and develop their own measurement programmes. It is based on the ideas of the Goal/Question/Metric (GQM) paradigm developed by Basili at the University of Maryland [Basi88]. GQM is a mechanism used in the planning phase of the 'Quality Improvement Paradigm' for defining and evaluating a set of operational goals using measurement. It takes a broad approach to integrating goals with models of processes and products, according to specific needs of the project and the organisation.

The tool has applied the GQM framework to the Concurrent Engineering goals defined as part of PACE [Thob96]. The record sheet, at the centre of the framework lists the details of the elements to be recorded. Elements include name, purpose, company type and formula for calculating the output. The record sheet is intended to be introduced as the start-point of action and is therefore very much at the macro level, dealing with strategy and issues affecting the organisation as a whole. However, ideas from this have been expanded and used as an input to the more development-centric tool advocated in this thesis.

2.5.5 OTHER PRODUCT DEVELOPMENT TOOLS

Other tools and techniques currently available which make a contribution in the product development process include HP's Return Map, Quality Function Deployment, Product Design Specification, Design for 'x', project management tools and benchmarking.

[16] See http://www.tue.nl/tm/race/ for the RACE II Homepage.

The Return Map - by Hewlett Packard is a practical tool for assessing and improving time to market performance. This requires taking measures across the organisation including; number of customer visits, product failure rates, performance to schedule commitment, manufacturing cost variance and money spent on systems, marketing, customer support. It also involves 'people issues' such as percentage of engineering time spent in training, attrition by rank and even a multi-level management survey. These measures are applied consistently and allow for a comparison between current break-even time and the original. This is a company-specific system that is tuned to the needs of Hewlett Packard. These measures relate to detailed management of the process rather than focusing on NPD. The emphasis is very much focused on monitoring break even time which is particularly critical in their industry [Hous91].

Quality Function Deployment (QFD) - is an idea generation and team focusing tool/method designed to get close to the (internal and external) customer and produce a solid product, with all contingencies being argued out. Customer needs are ranked and listed along one side of a matrix (the 'House of Quality') with the corresponding means to achieve these needs listed along the other. The plotted results should then help to identify concepts and flag up possible conflicts and from this further focused matrices are generated. This continues until the idea has been suitably refined into a workable plan [Haus88].

Product Design Specification (PDS) - is a concept design tool by Stuart Pugh [Pugh81]. The PDS consists of details on the product performance and its basic parameters; competition, current model, design intent and world class target. Once the specification has been formulated, it acts as a framework for all stages in the design process ('the design core'). Solutions then have to be generated, using a concept evaluation matrix to meet the PDS. Here, concepts are compared with PDS criteria with weights being given according to importance. Ideas are then argued out on a (more) rational basis until they converge into a feasible concept. In this respect, the technique is not too dissimilar to QFD.

Design For 'x' - These methods ensure that the product is systematically evaluated taking into account all design features to provide the best mix in terms of ease of design and manufacture. The most well known of these are design for assembly and design for manufacture; both of which were popularized by the Lucas group of companies. The variety of DFx tools is increasing all the time and now includes design for servicability, maintainability and testability to name but a few. As environmental legislation toughens, design for the life cycle of the product is becoming an especially important consideration for designers.

Project Management tools - are useful in monitoring and predicting outcomes during projects and hence could form the basis of a performance measurement tool applied to any part of the business. Simple flowcharts of activities and processes can help highlight where bottlenecks occur. An example of a flowcharting package is ABC Flowcharter by Micrografix. An example of workflow software is Workflow Automation by Staffware, which tracks documentation (i.e. acts as an electronic progress chaser) and automates procedures in departments. Another widely-used project management tool is the Gantt chart. It is a straightforward scheduling method for displaying project activities in a bar-chart format. It is particularly useful for small projects and those where activities are not highly interrelated. However, it does not show dependencies between tasks. Example software is MS Project. Program Evaluation Review Technique and its close relation the Critical Path Method are network-based project scheduling methods which can be applied at any stage in product development, through to manufacturing. They rely on a network to represent dependencies between activities/tasks. Time estimates for each activity are required and using these estimates, a probability of project completion by a specified date can be calculated. Any delays on the critical path (i.e. shortest completion time) will incur a delay for the whole project. Time/cost trade-offs can also be calculated.

Benchmarking - can be an important activity for companies that are implementing or updating their performance measures. In this context benchmarking is defined as 'evaluating products and processes inside the company with those elsewhere to identify best practice targets and areas for improvement'. Its popularisation in the 1980s (along with world's best practices) highlighted the need for quantitative performance measurement tools and techniques. Initially it focused on measuring business and product performance but it has since expanded to include management activities and business processes. Setting benchmarks against best in field or against current performance can help companies focus on their primary strategic and operational measures. However, benchmarking has its critics. Hammer & Champy [Hamm93] in their book on business process reengineering argue that 'benchmarking is a tool for catching up rather than jumping ahead' and that it puts companies in mimic mode. The main practical problem is that of direct comparison. Unless company situation's are very closely aligned, you end up comparing apples with pears, which can be at best misleading and at worst damaging. Confidentiality of information can also be a problem, especially in an area as crucial as product development. For these reasons, internal measures are most commonly used because management understands the sources of information and it is relatively easy to collect it on a consistent basis. Nevertheless, one could argue that the concept has popularised and communicated the development of non-financially based performance measurement (through case studies, management seminars, success stories, etc.). Zairi [Zair94] considers that the best way to explain the connection between performance measurement and benchmarking is that the former is a mechanism which ensures that the objectives can be achieved whilst the latter decides which measures should be used in the first place.

Aspects of all the above were applied when developing the methodology that forms the practical output of this research.

2.6 Summary of Existing Work and How This Thesis Fills the Gaps

As the literature review[17] has shown, performance measurement research to date has been largely confined to financial [Kapl92], [Size85] and more recently manufacturing [Koch94] [Koch96], [Mask91] & [Hall91] metrics and organisational measurement systems [Greg93], [Craw88], [Glob85] & [Zair94]. Some research has been carried out in product development but this has focused on complexity, success & failure aspects [Grif96], [Hart96a] and strategy [Barc95]. R&D management was examined in two recent surveys [Gupt96] and [Kers96] which offered some insight into the way R&D is being measured. However, both were preliminary studies, requiring follow up information to show how these performance measures are being implemented. To date

[17] A wider literature search on case studies in Concurrent Engineering implementation is included in Appendix II.

there has been little interest in the measurements necessary to manage the product development process. Existing measurement tools focus very much on the macro/ strategic level with minimal involvement from the designers and developers of the products. Furthermore, there was very little evidence of work that examines performance in the context of product design and development. This is significant. Many of those that do consider design and development do so only as one input into a performance measurement system. One or two questions only on this crucial area is clearly inadequate and cannot hope to represent requirements fully.

There is also an anomaly in the literature on product development in that most of it discusses *new* product development and the success factors associated with it. However, in reality companies only rarely launch absolutely new products (i.e. starting from scratch). The vast majority of work is involved with developing and relaunching existing products. Very few references were found on performance measurement specifically in the Concurrent Engineering context in which product development plays a central role. Even here detailed information on the measures themselves is not given [Hous88] and [Pool94].

Several assessment, development and project management tools are currently on the market, which together help to organise individual projects and aid designers in some aspects of their work. However, there appears to be no common thread to pull them together. In addition, they do not offer a sufficiently detailed framework focusing on product development. Writers on conceptual design and innovation [Duma94] offer some clues on how to reduce the time required to generate ideas but it seems that little thought has gone into tackling the whole development phase.

In summary, the literature review revealed that:

♦ There appears to be no cohesive methodology presently available (to the author's knowledge) for assessing performance during product development using Concurrent Engineering principles (applied on a consistent rather, than an ad-hoc basis)

♦ Use of currently available tools and techniques to assist in controlling product development activities (such as QFD, balanced scorecard, diagnostic tool, RACE tool) is fragmented and only used on some parts of the product development process[18].

- There has been an unclear distinction between 'hard' and 'soft' measures of performance or the implications of using them.
- The product development process can benefit from more formal and quantitative approaches.
- Measures of performance in product design and development are primarily internal measures that focus on comparing activities and processes to previous operations and targets. Owing to the diverse nature of products, processes and customers, external benchmarking in this area is often inappropriate[19].
- Shortcomings of measurement approaches are centered around the fact that they are time-consuming and fail to capture all factors [Maha92].
- Some surveys were not backed up by case studies (e.g. [Gupt96] and [Nich93]) which prevented follow through of the findings into practical situations.
- The way that methodologies were developed and/or rationale behind them was not always transparent [Rich80].
- There is no one set of measures that will remain definitive over time. Performance measures, as with the organisation itself, should be flexible to change.

Therefore, the research described in this thesis is new. These results form a basis for the experimentation carried out for this thesis. The methodology described in the next section seeks to test out the original hypothesis that the consistent application of performance measures during design and development in a manufacturing environment will improve the product development process.

[18] Their limited use was later confirmed in the company questionnaire results.

[19] Benchmarking across companies in a group may be an exception.

CHAPTER 3

3. RESEARCH METHODOLOGY

> 'Consultants need a considerable number of facts to have a clear picture of the situation, arrive at precise problem definition and relate their proposals to reality. Facts may be difficult to obtain and in some cases fact finding may be the most tiring phase of the consultant's work, but there is no alternative.'
>
> [Kubr84]

This chapter discusses applied management research methods and describes the research framework adopted for this thesis. Within this, it details the major parts of the methodology; the rationale, the data collection (questionnaires, the follow-up cases and the longitudinal case study) and the evaluation.

The methodology described below seeks to answer the hypotheses of this thesis and fill in the 'gaps' identified in the literature review. The work stemmed from a strong theoretical base (in the form of an extensive literature review) and was followed up with a qualitative action research approach to data collection, based on the close co-operation between the researcher and the participating companies in the follow-up cases and the longitudinal case study. It is important to note at this stage that the approach taken has focused primarily on time, quality and cost measures rather than other aspects such as success and failure factors (see [Grif93], [Hart96a] and [Barc95]).

3.1 Rationale behind the Research Approach Adopted

Management-based research is quite different from experimentally-based science projects which are focused around a series of laboratory tests. True experiments cannot be used because it is almost impossible for a management researcher not to affect a subject's responses in some way. There will always be a certain willingness to please or project an image and this will be reflected in responses. As stated in Gill & Johnson [Gill91]; 'the extreme complexity of managerial problems means that attempts to apply scientific methodology to real-world social problems have been responsible for the limited success of management science'. Although this use of applied methods is just as valid as scientific research, many management researchers are made to feel that their work is inferior. However, the real-time situation that management researchers are placed in during interviews and meetings makes it much more dynamic (requiring on the spot reactions) than sequential processes adopted by scientific research.

Many methodologies have been used by management researchers over the years. A few of the many examples across the range include postal questionnaires; Ughanwa & Baker [Ugha89] of 100 Queens Award winners, Trygg [Tryg92] of 109 Swedish machinery companies; semi-structured interview questionnaires; Hart & Baker [Hart89] snapshot view of 20 Scottish engineering firms; and case studies; Pawar [Pawa85] longitudinal study of 20 manufacturing firms and their innovation cycle. However it remains true that there is no single method of research that that is suitable for generating and assessing information in management-related research projects. Any method used on its own is subject to bias. For example, long distance questionnaires carry with them the risk of subjective interpretation of responses and snapshot interviews are restricted to the views of the interviewee. Case studies when used alone have limited use as they cannot be generalised to a wider applicability. For this reason, data collection was based on *triangulation*[1] of information from historical information (published literature and meetings with academics in the area), questionnaires (with follow-up cases) and a longitudinal case study (involving discussions, meetings, observation and contents analysis of documents at the participating company's site).

The case study follows an action research approach[2], which acknowledges the effect of a researcher on a subject or situation. In fact, the researchers intervention was an intrinsic part of the research design, with intervention being analogous to the independent variable of true experiments and the consequences - or outcomes - being the dependent variable. Action research depends largely on qualitative methods, although use of some quantitative methods also make an important contribution. This research is very much collaborative in that it synthesizes contributions from the researcher and the industrial participants to solve problems. One day per week (on average) was spent in the company over a period of 18 months. The researcher's role was to introduce academic knowledge and theories about performance measurement

[1] This involves the use of multiple but independent data sources.

[2] Action research is defined as 'participant observation with active intervention' [Gumm91]. It aims to solve a problem for the client and contribute to the chosen field of academic research.

into the company, discuss how the principles could be applied to suit their needs and apply the results. This included the assisted implementation of a measurement tool from the PACE Project. It could be argued that the researcher acted as a catalyst[3] for action within the company. However, this is not strictly true, as personal development of abilities and an understanding and appreciation of the processes within the company was gained. An effective action research project involves mutual learning (and dissemination of that learning) by the company and the researcher.

Reviewing the literature on management research methodologies revealed that several criteria have been identified to ensure that quality applied research is carried out [Gumm91]:

1. A research project should be conducted in a manner that allows the readers to draw their own conclusions.
2. Researchers should present their paradigm i.e. the values of the system under analysis and personal values together with a clarification of how these have developed or changed in the course of the research.
3. The research should possess credibility i.e. correct data with any interpretation being supported by data. In addition, the researcher should select methods that are appropriate to the problem.
4. The researcher should have adequate access to the processes under study.
5. A statement should be made regarding the validity of the research - to whom do the results apply and does the research confirm the findings of the researcher's studies?
6. The research should make a contribution to increased knowledge and be of value to both the company/participant and the wider academic community.
7. The researcher should have commitment and integrity - to be deeply involved in the project but at the same time remain objective.

Ensuring validity of data is a very important aspect of the research. As stated by Easterby-Smith et al [East91]; 'validity is a question of how far we can be sure that a test or instrument measures the attribute which it is supposed to measure. This is not too easy to ascertain, because if one already had a better way of measuring the

[3] In scientific terms, a substance that influences a process without being changed by it.

attribute, there would be no need for a new instrument'. In other words, validity is the capacity of a test to tell us what we already know. Reliability is also important. For example - is the instrument (in this case the questionnaire) stable? Will it yield the same or similar results when used on different occasions with new respondents?

3.2 Evaluating Performance

Deciding on how to evaluate performance can be a very difficult task for the researcher. The questionnaire must be designed so as to yield the results required to answer the research question, as well as provide an impression of how the respondent's company operates. The particular difficulty with the concept of 'performance' is ensuring everyone has the same understanding of what it means in that particular research context.

In his work on R&D organisations, Packer [Pack83] considers that as R&D output is multi-dimensional, ideally all aspects of output should be examined (in order to determine the overall performance). However fitting a large number of variables into a meaningful output is extremely difficult. The same problem is apparent in evaluating performance. Here, a combination of subjective and objective measures could be used when an assessment of the situation (of the needs of performance measurement for product development) is made by managers. This balances the analysis to enable the output to reflect the reality of the business situation. Achieving a good balance between raw and aggregate measures can be hard to achieve. The appropriate level needs to be decided by the company itself - depending on the scale of product development activities.

There are many measures available for evaluating individual performance (management appraisals, peer rating, self-assessment checklists, etc.) but these are not considered here as a teamworking environment is the focus.

3.3 The Research Framework

The hypothesis states that 'the consistent application of performance measures during design and development will improve the product development process'. The experimentation to prove this was designed with the industrial setting in mind. Constant access to the principal companies was available through the PACE Project and frequent visits to sites were made to carry out interviews, document studies (to collect historical information such as procedures, correspondence, etc.) and administer questionnaires. An overview of the major steps towards achieving the stated aims and objectives of this research are listed below.

3.3.1 DESIGN OF INFORMATION CAPTURE METHODS

The first stage was to review current guidelines, methodologies and tools available to assist with performance measurement in product development. This highlighted where there was a need for further work and narrowed down the area of what was to be investigated.

A research method to ask the 'right' questions regarding information capture for industry needs was conceptualised. This sought to identify which elements of existing tools and techniques can be developed and integrated to support assessment. It also sought to identify how to close the gap i.e. which aspects of the existing guidelines, methodologies and tools are useful. A combination of qualitative and quantitative methods were required to allow for large scale and in-depth information to be collected. The aim was to reveal what is currently missing in these approaches, what to add and what is required to measure the product development process on a consistent basis. This information was then used to formulate a tool to assist with implementing performance measures for product design and development.

3.3.2 DATA COLLECTION

The data collection phase had three main aspects. It used a combination of historical information (a literature review, document analysis and meetings with academics in this area), structured questioning (through postal questionnaires and interviews to academics and companies) and in-depth case studies (including observation, sitting in on meetings and content analysis of documents at the participating company sites). The initial data came directly from the PACE Project through face-to-face structured interviews with middle and senior management on the issues and challenges of implementing Concurrent Engineering. Within this, one section dealt with issues surrounding product development and performance measurement. Responses indicated that there was a need for more work in this area. This information was a valuable source of narrowing down the research focus. From this, two independent postal questionnaires (one to academics and one to industrialists) were developed based on the results from these interviews and an extensive literature review. Secondly, ten follow-up cases and an in-depth longitudinal case study were carried out to clarify specific needs and problems in performance measurement. The research process was then rounded off by formulating a framework and testing a performance measurement tool to aid product design and development.

3.3.3 *DATA ANALYSIS*

Data collected for both the academic and company questionnaires was largely categorial (i.e. non parametric nominal data). Where direct comparisons between the two groups were made, simple tests were used to determine the strength of the relationship (see Chapter 4, Section 2 for more information). Questionnaire results were analysed and compared using the statistical spreadsheet package SPSS. Both questionnaires were compared and contrasted to identify any gaps and overlaps in what was recommended by academics and experts and what is used in practice. In addition, results from the longitudinal case study and the follow-up cases were included to indicate any areas of resistance, problems and special opportunities that may be encountered when using the proposed performance measures in a practical situation. Summaries were then sent to all respondents who had requested feedback.

3.3.4 DEVELOPMENT OF AN IMPLEMENTATION FRAMEWORK

A framework to assist firms in implementing performance measures for design and development in a manufacturing environment was then devised. This framework encapsulated the themes brought out by the data analysis. Industrial consultation on the applicability of proposed framework was a central part of the process. The framework was presented to the participating companies who analysed it and discussed how it could be used in practice in a project team environment. This allowed for an assessment to be made of the framework's effectiveness and usefulness and also identified opportunities for improvement.

3.3.5 Refinement to a Specification for a Tool

Results from the fieldwork[4] and use of the implementation framework in the participating companies were used to operationalise the framework into an initial specification for a paper-based tool to assist with product design & development. The output was a workbook with accompanying software (spreadsheet template and database templates). The practical step-by-step workbook is intended to guide people through the implementation methodology. It is primarily based around checklists, tables and charts and included questions for analysing product development activities, a gap analysis to establish current and desired status, a specification sheet for measurement definition and a 'basket of measures' from which the company can select relevant metrics. Training guidelines were written to support the use of the tool without the aid of a consultant.

Two trial runs were carried out to test out the viability of the workbook by running it through activities on a real product development project. Actual project scenarios were used to test out the benefits and identify any possible drawbacks. The subsequent feedback was used to refine the workbook and accompanying training guidelines.

A flowchart graphically outlining the methodology is shown in Figure 3.1. Further information on the data collection techniques is given in the subsequent sections.

[4] including relevant comments from the questionnaires, follow-up cases and longitudinal case study

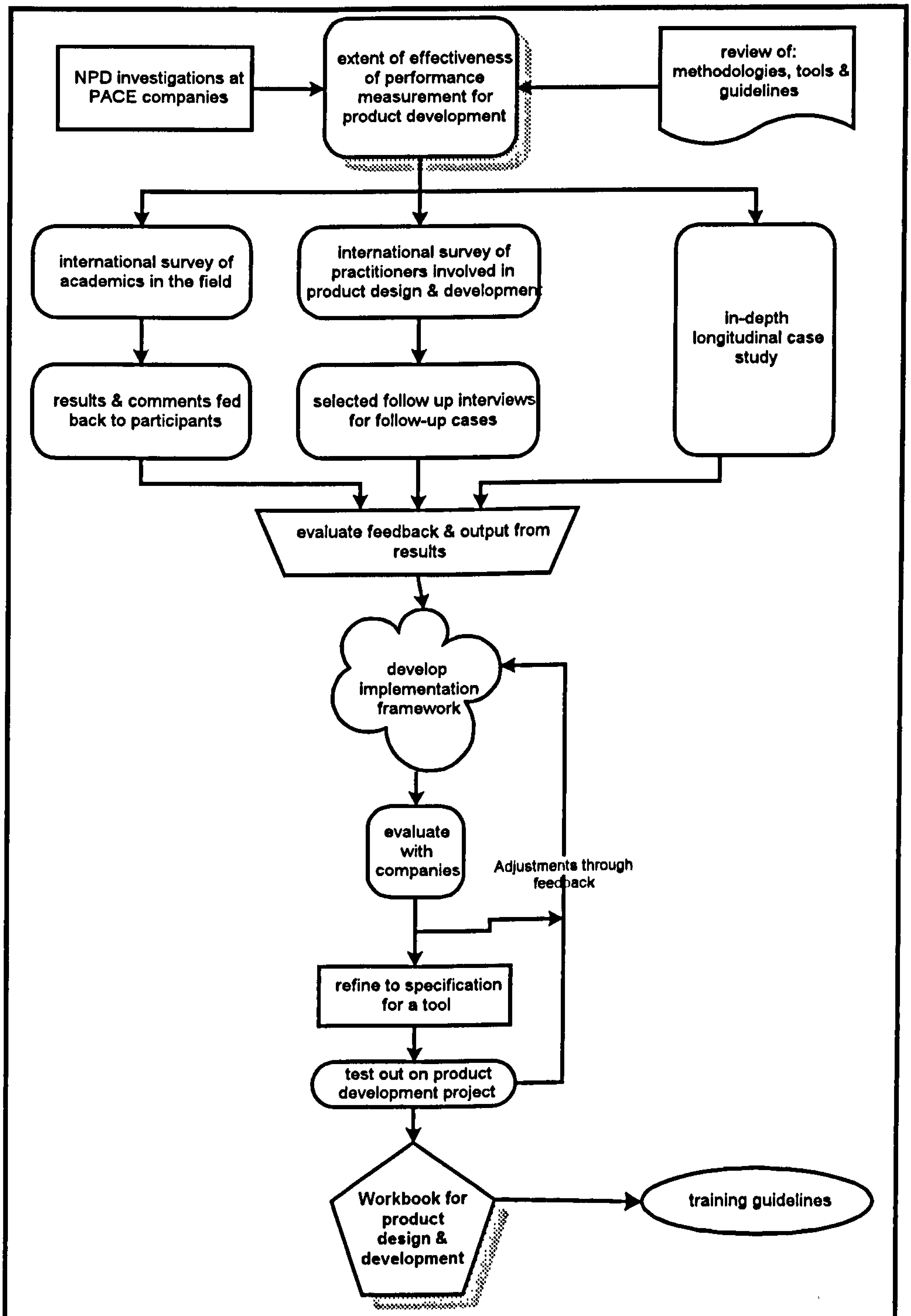

Figure 3.1: Macro Flowchart of Research Methodology

3.4 Data Collection Techniques

This section discusses the data collection procedure including document analysis, the rationale behind the questionnaire contents and case study and interview procedures.

3.4.1 *Observation and Document Analysis*

Throughout the project, the researcher was given free access to documents and invited to sit in on team meetings. The type of documents studied were the new product development process documents, minutes from meetings, emails, faxes, new initiative directives, checklists and procedures. Documents provide valuable facts but can also misrepresent events owing to selective survival and the perspective of the author. Direct observation on the other hand, gives access to group processes and can reveal differences in what is said and actually done [Karl96]. However, the discussion and the outcome is highly dependent on who is involved. Therefore, on their own, these data sources only provide part of the picture.

3.4.2 *Input from Initial Fieldwork*

The results from the PACE Concurrent Engineering questionnaire and follow up interviews (carried out as part of one of the deliverables on implementation issues for CE) gave the author an appreciation of the issues and processes surrounding product development. This information spanned a variety of manufacturing environments (instrumentation equipment, power tools, domestic appliances and injection moulding equipment) in six countries. In particular it helped to identify the specification to pre-production stages as those which would be investigated for this research[5].

3.4.3 *Questionnaire Procedure*

Two types of questionnaire surveys were carried out - one aimed at practitioners and one at academics, in order to gauge the current climate and assess what is required in the future. This approach was taken because both groups have different but equally valuable perspectives. The practitioners questionnaire focused on respondents experiences in product development and attempted to elicit their opinion on the failure

[5] As stated in Chapter 1, these stages were chosen because pre-specification deals with creativity issues (out of the scope of this research) and manufacturing measures are dealt with elsewhere.

points and their needs for improvement. The most important guideline for writing the questions was to ensure that they were phrased in such a way that all the answers were useful as input into the tool. In order to gain the best results, both questionnaires were designed to be short, objective and have non-leading questions. Additionally the questionnaires were sent to external printers to achieve a professional appearance.

For the academic survey, opinions of leading experts in the field from across the world were sought on the present use and future potential of performance measures. The postal questionnaire was five pages in length and aimed to determine key measures (from a list of 65) to discover those measures that are useful now and those that will be useful in the future[6]. The company survey, on the other hand, sought to determine industry's needs for performance measurement (during design and development) and reveal which measures are currently used, which are needed and where improvements can be made. The questionnaires were directed towards and hence addressed to Technical Director and/or Senior Management level. As both were long distance questionnaires, it was of paramount importance to make every effort to ensure that the questions were short, unambiguous and objective.

Questionnaire Design

Getting the right information from respondents was a crucial task, so questionnaire design was very important. This includes not only content but also styling, wording, and length. A breakdown of the two questionnaires follows.

Company Questionnaire:

The company questionnaire sought to establish the current usage and future intentions of use of performance measures to aid product design and development. It had two sections; general and product development information (including company size, activities, organisation, communication and teamwork) and performance measures (including types of measures, frequency and management). Additionally:

- Respondents were categorized according to volume of production i.e. (one-of-a-kind/job, batch or mass).

[6] It was initially intended to do a Delphi-style analysis on this survey, however, as the first responses were a long time in coming (and not as comprehensive as anticipated), it was decided not to follow this track. More information on Delphi is given later in this Section.

- A combination of open and closed questions were used.
- The questionnaire opened with factual questions, moving on later to opinions and values. Questions mainly requested ticks in boxes, with some Likert scales and comment sections also being included.
- Respondents were encouraged to be as honest as possible - aided by the option to remain anonymous.
- The final question provided an opportunity to voice any concerns or general opinions through an open-ended comments section.
- Trials through pilot testing indicated the questionnaire took approximately 20 minutes to complete.

Academic Questionnaire:

The academic questionnaire sought to establish what academics and experts in the product development area considered to be important aspects of measurement systems. It had two sections; recommended measures and management of the measures.

- Section 1 presented a list of 65 measures for product design and development, with respondents being asked to indicate the degree of usefulness of each measure, both now and in the future on a five point Likert scale.
- The measures were listed in groups according to the Concurrent Engineering principles of time, cost and quality, together with management and customer-related measures.
- Space was also provided to add to the list, the aim being to ensure that no important measures were excluded.
- Section 2 overlapped with questions in the company questionnaire and was concerned with issues such as who should introduce measures, how they should be managed, etc.
- Respondents were asked to declare their area of expertise in terms of industry sector.
- This format allowed for quick completion - requiring approximately 20 minutes.

The Delphi Technique Option

Initially it was proposed that the academic survey could be augmented by using elements of the Delphi Technique. Delphi attempts to systematically evaluate expert judgment on movement in the direction of agreement (consensus of opinion) by these experts [Lins75]. It enables a degree of consensus about the overall priorities of importance of these issues by using a ranking system. It is particularly suited to situations where decisions must be based on informed judgment rather than on analytic solutions. This makes it well-suited for management studies where hard data is unavailable [Scot80]. Delphi provides an anonymous, systematic way of focusing opinions of experts. For the purposes of this research, it would have assisted with formulating a structured model of opinion on the types of performance measures that the academics want to see used.

It should be noted however that certain conditions need to be met for this technique to work. Firstly, there must be a common understanding of the issues in order for the experts to reach complete agreement. This was thought to be difficult in this case owing to cultural differences and problems with wording, understanding, etc. Secondly, several Delphi iterations should ideally be carried out until consensus is reached. As it can take up to two months to receive replies to surveys, the reaction time did not fit in with the time frame for this study. Other issues include coping with the dropout rate after Round 1 (a very large initial sample size is advisable), deciding when to eliminate extremes and how to deal with bias (which is inevitably introduced to a degree because of the limited scope of the sources used for selecting participants[7]). It was therefore, reluctantly decided not to make a Delphi analysis part of this research.

See Appendices III and IV for copies of the original questionnaires.

Scaling

The scaling results is important to allow for quantitative analysis to be carried out. Various types of scaling are available to the researcher. Likert scales are the most widely used in management research and social sciences. Likert scales consist of set of items to which the subject responds with degrees of agreement or disagreement[8]. They

[7] Subconscious investigator bias can also result from question phrasing, response selection, interpretation and collation.

[8] See [Kidd86] for more information.

were used for this research on the final question in both questionnaires, to yield opinions on the usefulness and value of product development-focused performance measurement.

Scaling is not without problems. For example, the researcher needs to bear in mind the 'halo bias' that can occur when the respondent is filling in the answers - i.e. he/she may want to give a good impression of his/her department. In addition, it is important to bear in mind that research proves people tend to place items with which they disagree in a more extreme category than items with which they agree. Simple mistakes can also occur through fatigue or misunderstanding. Keeping questions and questionnaire length succinct is therefore important.

Identification and Selection of Participants

Great care was taken to select participants from a variety of sources in order to ensure a mixture of responses. Mailing lists from conferences, such as the International Symposium on Logistics and the Flexible Automation and Intelligent Manufacturing (FAIM) conference, were selected, as were members of professional institutions such as the European Society of Concurrent Engineering (ESoCE), the Institute of Management, the Product Development and Management Association (PDMA) and the European Operations Management Association (EurOMA). In addition, personal contacts in both industry and academia were invited to participate.

Relevant manufacturing organisations for the companies mailshot were chosen from personal contacts, respondents to previous surveys carried out in the department, PDMA membership, FAIM attendees and the FAME (Financial Analysis Made Easy)[9] database. Only those companies carrying out their own design and development were selected (where type of business was obvious). This list was then scanned through and inappropriate ones i.e. those that do not carry out their own research and development were discounted wherever possible. In over half of the cases, the mailshots were personally addressed in an attempt to ensure a better response. As the company survey

[9] All those chosen had Standard Industrial Classification (SIC) codes prefixed by 3 i.e. engineering organisations.

was sent to contacts collected from a variety of sources, it is thought that a fairly *representative* postal questionnaire sample of 580 companies was achieved.

One important factor that needs to be considered is that statistical bias can be produced by non-response. Those companies that use measures or are interested in performance measures are much more likely to respond thus biasing the overall response towards the impression that performance measures are quite common. One way this can be overcome is to follow up non-respondents, asking them why.

Pilot Testing

A pilot study of both the industrial and academic questionnaires was carried out before the mass launch. This is a very important step in the research process to validate the contents. Firstly, 10 of each were sent to impartial practitioners and experts to evaluate in terms of clarity, length, ambiguity and applicability. Following this first feedback, initial refinements were made and a dummy run to a further 25 companies (selected randomly from the a list of company names in the FAME database and partners on the PACE Project) and 15 academics was carried out. The latter involved academics from Aston, Birmingham, California Polytechnic, Cranfield, Macquarie (Sydney) and Nottingham.

The response was encouraging; the company pilot yielded 8 out of 25 replies and the academic pilot yielded 11 out of 15 replies. These results were not included in the final analysis. In addition, a dummy run (using dummy data) of both questionnaires was performed to test the method of analysis. This thorough pilot study allowed for fine-tuning prior to release as it resulted in constructive suggestions and hints on improvements.

Mass Release

Both questionnaires were launched by post during August and September 1996, following the results from the pilot studies. However, in total 550 questionnaires were sent to academics in the UK (30%), USA (25%), Europe and rest of the world (55%). The distribution of the company questionnaire was slightly different; this was sent to 580 managers in the UK (70%), Europe (15%) and the US (15%).

The Electronic Distribution Option

The initial intention was to send out both types of questionnaire electronically over the Internet (both through email and the world wide web). The technology exists to send attachments to email messages that can be decoded and downloaded onto the recipients PC and to submit completed forms posted on Web homepages. This would not only have saved paper but also allowed for easier data input. Distributing questionnaires electronically is an increasingly popular option available to researchers. Participants complete the questionnaire on-screen and mail it back to the researcher either in paper format or via a computer network. Interpretation of the results is then very straightforward as they can be processed straight into a worksheet and a graphics package[10]. This approach was considered by the author but then rejected for a number of reasons. Firstly, not all managers have a personal email address. Secondly, not all managers are totally comfortable with using email or the Internet. This is a problem for the current release of some software packages, which require files to be downloaded onto the hard disk in order to read and complete the questionnaire. After speaking to a number of managers and academics about this, it was felt that they weren't quite ready for this level of technology. Thirdly, once an email has been opened, it then resides in the main folder on the users computer system and may be forgotten more easily than a paper-version on the recipient's desk. In addition to this, concentrating on a screen for a long period of time is uncomfortable, making the validity of responses on computer questionable. Finally and perhaps most importantly, due to the proliferation of surveys on the Net, most tend to be ignored with the click of a button, leading to very low response rates. As technology improves and businesses become more used to working with the Internet, electronic questionnaires are likely to become a much more viable option. Therefore, paper copies were posted.

In both cases, measures were taken to encourage participation. Recipients of the academic questionnaires were sent emails prior to release and follow up telephone calls were made to a sample of 50 (of those who had not yet responded), two weeks after posting. Follow up telephone calls were made to 30 non-respondents in the company survey and reminder letters were sent to a further 100, one month after release.

[10] A software application called Pinpoint by Longman Logotron is one useful way of carrying out a large-scale survey.

Questionnaire Analysis

The questionnaire was designed so that analysis could be carried out using the statistics package SPSS. This enabled easy ranking, comparative analysis and construction of graphs. The most common method of output was descriptive frequencies i.e. how results of measurement are fed back, who brought in measures to product design/development, etc. Likert-type scales were used to determine opinions on the sub hypotheses statements i.e.:-

Statement	*Score* *Strongly Agree*				*Strongly Disagree*
a) Lack of usage of performance measures adversely affects the product development process.	1	2	3	4	5

Figure 3.2: Driva Questionnaire Extract

To reduce the danger of transcription errors in SPSS, limits were placed on input variables to reject impossible values.

3.4.4 FOLLOW-UP CASES

Ten of the most interesting responses from firms who use performance measures now were selected as case sites. These respondents had either included many comments in their answers and/or their replies had formed an interesting picture of their organisation's measurement activities. Interviews were set up with the respondents to expand on the answers. A one-off visit was then arranged, based around the questionnaire response. Discussions typically lasted 2 to 3 hours. The most important factors from the survey analysis were identified as measures used now and reasons for not using measures. These follow-up cases - carried out between October and December 1996 - enabled further clarification on how measures are carried out and what tangible benefits are accrued. The visits took the form of semi-structured interviews based around (but not limited to) the questionnaire responses. Interviews allowed for the 'how' dimension to be explored which is difficult to reach in questionnaires. This extra dimension made an important contribution to the research findings.

Use of Interviews

Semi-structured and unstructured interviews were used in several places as part of this study; for gaining background information in the field from academics, as follow-ons to questionnaire responses (to gain fuller answers) and as part of the longitudinal case study. Much work has been carried out in this area. One study by Easterby-Smith, et al [East91] explains the use of interviews in management research. They consider that one aim of the interview is to develop an understanding of the respondent's world so that the researcher might influence it, either independently or collaboratively (as with action research). They state that interviews are appropriate when:

a) The step by step logic of a situation is not clear.

b) The subject matter is highly confidential or commercially sensitive.

c) The interviewee may be reluctant to be truthful about this issue other than confidentially in a one-to-one situation.

As interviewing is subjective by its very nature, accuracy of information can be questionable. Although some of this cannot be avoided owing to the interviewees bias, accuracy can be increased if the interviewer avoids stating her own views, phrases questions impartially and appears equally accepting of any answer. In addition, answers can be backed up by cross-referencing information from as many sources as possible.

Procedure for Interviews

From a total of 150 responses, 10 were chosen for further investigation. The reasons for selection were a combination of fullness and quality of response, respondents' knowledge of the subject area, geographical location, and industrial sector. Respondents were contacted by telephone to see if they would like to participate in the interviews. Only 2 out of a total of 12 contacted refused. On average, interviews lasted 2 to 3 hours. Notes were taken and draft copies were given to participants to correct. The starting point was an overview of their background and organisational context and a recap of their questionnaire responses. A semi-structured interview followed, expanding on their previous responses and determining their three most important measures now and in the future.

Analysis of Follow-up Case Information

As the information from the cases was mainly qualitative in nature, the analysis was carried out using comparison tables. The main benefit was to develop one sentence answers and to achieve a greater appreciation of the problems and challenges involved in the implementation of performance measures in a manufacturing environment. This was invaluable input both for the longitudinal case study and the formulation of the implementation framework for a tool.

3.4.5 Longitudinal Case Study

An in-depth case study over a period of 18 months was carried out in close cooperation with the primary partner on the PACE Project; Domestic Appliances Ltd. The researcher visited the company on a weekly basis throughout this period. The research involved two main activities; investigating the current state of performance measurement throughout the company - focusing on design and development measures - and deciding on which measures to develop to assist with a 'live' new product development project. This meant that the researcher played two roles during her time at the company; on the one hand as an observer (sitting in on meetings, collecting information, etc.) and on the other as a participant observer (in formulating appropriate performance measures with the managers and team members). As part of this analysis, a focused questionnaire, very similar to the large-scale company survey, was carried out. This was directed towards those people who are involved with product development to determine their understanding of the problem, their needs and wishes. The primary aims were to find out how product development is documented and tracked, why (any) persistent bottlenecks[11] occur and why rescheduling takes place. The results were followed through with face-to-face interviews. The extent and consistency of use of performance measures by the industrial partner was determined and the extent to which techniques were ingrained into the company, together with how they are measured was investigated. This generated both qualitative and quantitative data. The major output was a practical set of measures, detailing how they would be administered on future product development projects. The performance measures were to be added to the new

[11] i.e. stoppages (especially time-related) that hinder progress

product development procedures and networked around the company using a spreadsheet template. DA Ltd. was also used as a test bed for the implementation framework and the tool.

The use of case studies as a focus for research is now a widely accepted approach in management-related areas. Since the pioneering work of Glaser & Strauss in the 1960s [Eise89], the case study has progressed to be recognized as 'a research strategy which focuses on understanding the dynamics present within single settings'. Yin [Yin84] identified three types of case study research; exploratory, descriptive and explanatory. As with most researchers in management subjects, an exploratory approach to the case has been used here. This involves carrying out a pilot study that can be used as a basis for formulating more precise questions or testable hypotheses. When carrying out a case study, it is vital to have a clear research focus (in this case understanding the current status and 'to be' future possibilities for measures of performance in design and development). Otherwise the researcher is in danger of being snowed under by data and unable to see a clear path through.

As stated previously, in this research one in-depth longitudinal case study[12] was used to allow the researcher to test out her ideas in a real life situation. Although focusing on one case study alone has its dangers (i.e. lack of applicability in a wider context and hence difficulty in generalisation), it was felt that this limitation was counterbalanced by the depth and insight that was achieved through being involved with one company over a period of time. This long term relationship between the company and the researcher allowed for a deeper appreciation of the complexities of the organisation than is usually achieved with shorter case studies. Most important of all, it allowed for better access to information that would not normally be available (e.g. project documents, minutes from meetings and cost statements). Indeed, access to companies can be a major problem for researchers. It has even been stated that 'satisfactory access to a company is a necessary condition for the development of understanding and hence for meaningful results' [Gumm91]. This single case study approach has been used to effect in previous long-term research projects such as [Karl96] and [Clar95].

[12] Previous longitudinal case studies by Pawar & Riedel [Ried91] show support for this approach.

DA Ltd. carry out their own product development and manufacturing on-site. Projects range from minor facelifts to totally new products. The company has successfully implemented aspects of Concurrent Engineering, especially team colocation and use of CE-tools (see Appendix VII). The researcher took part in a new product development project as a participant observer (as required by the action research approach). Throughout the course of the research, all levels of the organisation were consulted, including engineers, design managers, technical director, marketing and shop floor. The case study information gathering techniques were a mixture of both qualitative and quantitative evidence which can be summarised as follows:

- Documental information was collected throughout the research. This included the product development process, meeting minutes, training information, quality procedures (ISO 9000 and safety standards) and results from a 'six sigma' exercise.
- An applied questionnaire that closely overlapped with the postal questionnaire was administered across the company. In addition, both the project team and management participated in the initial company questionnaire (see Appendix III). Ideas were then framed around, but not limited to, the questionnaire responses. These results were then used as a starting point for discussion to follow up personal interviews, to obtain a fuller picture of product development measurement situation and requirements through the eyes of engineers and middle/senior managers. Where permitted, tape recordings were made. These interviews were mainly semi-structured i.e. the course of questioning was started off by the researcher but the flow of the subsequent conversation was governed by the experiences and views of the manager.
- Frequent interviews and discussions (often on an ad-hoc basis) during the days spent on the company's premises gave a more objective and balanced view of activities. However, the effects of the interviewer being present were also borne in mind.
- The interviews were documented by initially noting down as much of the conversation as possible, then reviewing the notes and extracting the important comments pertinent to the research question. This method was chosen over the option of preserving interviews in their original format without editing or comment, as it was felt that verbatim transcripts (although avoiding interpretation errors) do not tell the whole story. They overlook some important intangible elements such as

emphasis, body language and non-verbal communication. In addition, pages of unedited script have a danger of including irrelevancies and hence clouding the issue.

- All interviews were followed up at a later date (either by telephone or more usually further meetings) to clarify information received. Frequent follow-up phone calls increased detail and validity of data.
- Transcripts of interviews were shown to interviewees (where possible) to verify they were a true account.

The triangulation of data in this way provided for a well-rounded, holistic view of the company's activities in the area of product design & development.

This in-depth involvement with a development project was a very important part of the research, in that it allowed for a real feeling of the needs and the potential for change to be gained. As proposals for the performance measurement tool were evaluated by managers on a regular basis, feedback on the problems, opportunities and barriers to change was gained.

3.4.6 Testing of the Implementation Framework

To further develop the conclusions from the data analysis, the resulting implementation framework was tested on data from two product development projects at two sites (DA Ltd. and Plastico). Two full-day sessions were arranged with the participating project managers and team members. Firstly, the framework was introduced by the researcher and then the groups went through the six stages. The applicability and usability of the framework was then discussed by relating it to previous product development projects. The testing is further explained in Chapter 7.

3.5 Evaluation of Research Approach

It could be argued that research results almost inevitably have situation-bias built into them. With the increased popularity of questionnaires and case studies over the last few years, there is a danger that 'conditioned' answers that do not reflect how respondents would normally react or manage are recorded. It can be very difficult (if not impossible) to filter out the bias this causes. The researcher can, however, be aware of this when carrying out the in-depth analysis. Although steps were taken to ensure that balanced data was collected, as with any approach, the data collection techniques adopted have their own pros and cons. These are discussed below, with limitations first followed by counterbalances to address these problems.

3.5.1 LIMITATIONS

Document Study:

A document study cannot contain all facts and is open to incorrect interpretation if used on its own.

Questionnaires:

- Lack of understanding of questions not always detected - fear of ignorance.
- Questionnaire respondents give answers they think you want.
- Those who respond may not be representative of the sample frame - what motivated them to respond and others to ignore the questionnaire?[13]
- Respondents may take the opportunity to enhance the impression of the company.
- Time constraints: brief answers are given with no (or inadequate) explanation.
- Testing validity of results is difficult, especially if only one response is received per company.
- Owing to space constraints, questions can be phrased in an unnatural way compared with face-to-face situations. This can lead to misinterpretation.
- Questionnaires do not always reveal root causes - product development may not run smoothly because of low morale due to recent redundancy program resulting in bad communication, etc. even though processes are in place.

The classic problems associated with questionnaires were counterbalanced with the in-depth case study. These risks can also be minimized by follow-up telephone calls if respondents give their permission to be contacted. Owing to the large sample size, this could only be applied to a limited number. Even case studies have certain limitations that the researcher should be aware of.

[13] This problem was addressed by telephoning 20 non-respondents, selected at random from the ample, to determine their reason for non-response (see the questionnaire results in Chapter 4).

Case studies:

- The possibility of interviewee bias and the ability to interpret a particular set of events in a realistic manner. This bias can be reduced by speaking to as many people as possible across the company.
- There can be a danger of drawing general conclusions from a case study; generalisations cannot easily be made on this basis.
- Case studies used on their own, lack statistical validity.
- Case studies can be used to generate hypotheses but not to test them.
- Lack of objectivity of the researcher.
- The whole truth may not be reported owing to fears of exposure of the company's (and employees) identity.
- Given the large volume of data typically involved in a case study, there is a danger of losing focus in the final interpretation and building a theory that tries to capture everything.

These limitations have been overcome by the use of triangulation of data collection techniques which avoids over-reliance on one data source and helps present the most realistic, balanced picture possible.

3.5.2 COUNTERBALANCES

It is believed that the mix of data collection techniques used for this research provides for balanced results. More specifically:-

Document Study:
The document analysis gave a relatively unbiased account of factual information (assuming that the facts were recorded).

Use of snapshot interviews allowed for enriched information from expansion on questionnaire responses.

Questionnaires:

- Questionnaires are quick to administer and replicate.
- They are useful in that they allow a large number of people to be surveyed and reduce effect of any researcher bias (compared to interviewing alone).
- They are relatively easy to code and hence interpret.
- Ticked boxes reduce potential bias from the researcher.

Case studies:

- A holistic view of the process under study can be gained.
- Historical roots to problems e.g. processes that have led up to the company's present condition, can be identified through document searches.
- The longitudinal nature of the case study allowed for the effects of change (including behaviour and attitudes) to be experience over a period of time.
- Multiple visits allowed for clarification on previously discussed issues.
- Results from case study research is likely to have important strengths such as novelty, testability and empirical validity which arise from the intimate linkage with empirical evidence [Eise89].
- Case studies are useful for testing theory and hypotheses in areas where little or no work has been done previously.
- Cases are good for reporting and presenting current practices to managers (from an impartial viewpoint) who can then choose to implement findings.
- Issues are explored more deeply than with questionnaires alone.
- The interviewer can follow up unexpected answers.
- Reasons for differences in opinions can be established and validity of answers checked (where clarification is required).
- It is easier to telephone the contact whenever clarification is required.
- Fuller explanation of questions can be given than with other methods.

3.6 Conclusions to Methodology

Validity of the results was a very important consideration when deciding on the research approach. Validity is seen as a continuous process that is integrated with theory and that requires the researcher to continuously assess his/her assumptions, revise results, re-test theories and models and reappraise the given limitations that have been set for the study [Gumm91]. Section 2 of both questionnaires discussed management of the performance measures. This was made as similar as possible to allow for direct comparisons to be made between the academics' and industrialists' opinions. Furthermore, all case study interviews were carried out in a semi-structured manner, i.e. the researcher had a list of questions to be answered. This allowed for contrasts and comparisons to be made between firms. Owing to the constant contact with a range of companies throughout the research period, it is believed that the findings have high external validity[14].

Care was taken from the outset to ensure a well-balanced approach to this research was achieved. Many options and alternative methodologies were considered before deciding on the chosen route. The combination of an action research approach, together with triangulation of information from the case study, the surveys and the literature.

In summary, it is felt that the methodology provides a sound base for testing the hypothesis that the consistent application of performance measures during design and development in a manufacturing environment will improve the product development process. Chapters 4 to 6 present the subsequent results.

[14] This term refers to the extent to which the theory behind the research findings can be generalised beyond the immediate research sample or setting.

CHAPTER 4

4. MEASURING PERFORMANCE DURING PRODUCT DEVELOPMENT: QUESTIONNAIRE RESULTS

80% of respondents to the company survey indicated that their organisation would benefit from increased use of performance measures during design and development.

The work reported in this chapter presents the field work results from the questionnaires to both academics and industry. The questionnaires had two main aims: Firstly, they sought to investigate the current usage of performance measures for design and development and planned future use. Secondly they sought to establish whether any major difference of opinion existed between the two groups. Section 2 of both questionnaires were structured along similar lines to allow for easy comparison of views[1]. The chapter begins by relating the results from an early pilot study with the four PACE Project partners on product development, with special emphasis on their use of performance measures. It then continues by presenting the analysis, grouped into four main themes; organisation of product development, use of performance measures, management of the measures and suggestions for improvement. The chapter concludes by discussing implications from the results. Space does not permit presentation of the full analysis but all major results are included.

4.1 Findings from the Initial Fieldwork

This section discusses information gained from questionnaires, company documents, visits and interviews with the industrial partners on the PACE Project. The main focus here was the new product development processes and supporting activities, covering:

- Milestones at Electro-Tools Inc., Germany - a custom-written, world-wide system for product development[2] projects.
- The product introduction plan at Instrumentation Ltd., Denmark - includes changes proposed by engineering consultants.

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[1] allowing for differences according to perspective and situation

[2] includes formation of virtual teams within Europe

- New Product Introduction & Project Management at Domestic Appliances Ltd., UK - follows the product development process template advocated by head office.
- The Product Development Process at Plastic Mouldings Inc., Portugal - part of a larger company on the same site.

Questionnaires were given to a range of senior managers, middle managers and team members involved in product development, some of whom took part in the discussions. This information was an important first step in the research process. Evaluation of this mass of data gave the researcher an understanding of the variety of product development processes that exist and acted as a filter to focus on the more specific topic of measuring the performance of the product development process. Deliverable d81a of the PACE Project [Driv95b] contains the full details of this task, which culminated in formulating an implementation methodology for Concurrent Engineering. Some of the questions in this survey were used or adapted for the main performance measurement questionnaires. See Appendix V for the survey results. A brief synopsis of the product development processes at the four participating companies is as follows:

4.1.1 MILESTONES AT ELECTRO-TOOLS INC.

The Milestone Product Development Process was developed by the company to ensure the timely development and production of new products critical to maintaining the company's market position. The Milestone System is grouped into eight overlapping phases, controlled by the Programme Team. The structure is such that it allows for related activities to be performed as concurrently as possible instead of sequentially. The process starts with the pre-project planning process which provides the strategy and forward plans. Detailed product plans are available for all product groups, which assists with planning future projects. Documentation consists of a pro forma sign off sheet, which is a summary of the current status and any other supporting documentation required for clarification by the team. The Milestone system is based on the premise that any action can be started or completed without having to wait for a milestone review, provided the team have the information to start that action, and that the risk of starting is acceptable. The process starts with a 'Product Vision', which is the strategic direction leading to a rolling product plan. This document summarises the product group strategic direction in the form of product life cycles and key market place deliverables. The eight Milestone Phases are; strategy, proposal, definition, design, tooling, production, market sales and post audit phase. The Design Centre has ownership of the process but works closely with the manufacturing site in Southern Europe which takes responsibility for the production-related issues. The key documentation in this process comprises;

- Trigger Document which clearly defines the project start date, the opportunity and the resulting product which will meet an end user or business need.
- Product Proposal which communicates the organisation the product (or product range) in detail as it has evolved from the original Trigger Document and preliminary Marketing specifications.
- Product Definition which is a precise document defining the product that is designed to satisfy the end users' need and meet the financial objectives of the company.

It will take a long time for the mind-set of Milestones to become embedded into the company culture and even when this happens, Electro-Tools Inc. must be prepared to progress to the next iteration of improvement.

4.1.2 THE PRODUCT INTRODUCTION PROCESS AT INSTRUMENTATION LTD.

During the mid 1980's Instrumentation Ltd. realised that they were not fully capable of controlling their product introduction process. Time to market had grown to between two to five years longer than the market would accept and development costs had increased dramatically. In addition, product quality and reliability was unsatisfactory due to the increasing complexity of software and hardware in their products. An analysis of the product development process in 1991 showed that during a normal product development project there was a minimum of 250 changes of responsibility, up to 34 departments were involved and the lead time was 3-10 years (with an average of 5 years). The product introduction plan consisted of 7 phases; pre-project, requirements specification, specification, design and development, transfer to production, production start and completion.

Engineering consultants were brought in to help carry out a business development programme. This involved examining the product introduction process and applying Concurrent Engineering principles to Instrumentation Ltd.'s culture. The engineering consultants' approach at Instrumentation Ltd. was that in order to make an organisation more effective, all the business processes needed to be mapped out to help identify what adds value. This was their first step towards increasing visibility and implementing a systemised approach. As stated by one employee; 'the product introduction process should be standardised and well-defined - this stops you worrying about the quality of the process each time a new project starts and means you can spend more time on the product'. The recommendations from the consultants - together with the team - were:

1. Adopt a streamlined new product introduction process. The 7 phases became 5; opportunity evaluation, concept design, design & development, implementation and transition to operations.
2. Increase teamwork including participation from all areas of the business, customers and suppliers.
3. Re-organise Business Units and the Production Division to balance development and operational focus.
4. Institute 'heavyweight' programme management.
5. Adopt a formal project and programme management system (risk and resource) including a formal hazard escalation mechanism.
6. Recruit to address core skill deficiencies in project and programme managers, production/process engineers and sourcing professionals.
7. Increase competitor and customer understanding at the product level.
8. Ensure the focus remains on core technologies.

The project closed in Autumn 1994 at the detailed design stage - before the full implementation had taken place. It was felt that although the partnership had been useful, the programme was becoming very 'resource-hungry' and that the remainder of the work could be completed in-house. The majority of the ideas for the NPI were eventually adopted, with slight adaptations to better suit Instrumentation Ltd.

4.1.3 NPI AND PROJECT MANAGEMENT AT DOMESTIC APPLIANCES LTD.

A project management and resource management structure is now in place at most of the holding group's companies, including Domestic Appliances Ltd. The structure recognises that there are two key roles in product development; the project manager who is accountable for efficiently utilising and controlling resources to achieve the defined objective; and the resource manager who is accountable for supplying resources (people and facilities) of appropriate quality and cost at agreed times to project managers. Project managers are accountable for the success or failure of the project and are given freedom to run the project as they choose (within the company procedures). Part of the project manager's job is to secure the resources that are needed, when they are needed and at a cost that matches the budget. They match the time pattern of skills that are available to what is demanded, either by sharing multi-skilled people with other resource managers, or by encouraging project managers to re-plan their projects to match the available resources more closely. The resource managers are in a good position to monitor the efficiency of resource utilisation by the project managers and feed back the information to senior management. This is basically a matrix management system with employees (and teams) having two bosses. Their new product introduction process, using the principles of this organisation, follows a standard path from feasibility to design and development, implementation, handover to production, a 90 day review and a 120 day review.

An example of the successful use of this NPI system within Domestic Appliances Ltd. is in the reduction of development time for a cooking product. Most significantly, the time to market was reduced from 18 months to 12. Additionally, the total number of parts was reduced by 27% (compared with the previous model), with resulting improvements in cost, reliability and production (the target production rate was achieved by the second week of manufacture).

4.1.4 The Product Development Process at Plastic Mouldings Inc.

Plastic Mouldings Inc. (PM Inc.) specialises in designing and developing products for a wide range of manufacturing industries. Their system revolves around 3D CAD/CAM techniques which are used throughout all stages of the design process. Their way of operating has drawn on experience from visits to Japan. They especially admired the close and lasting relationships that Japanese manufacturers build with small, highly-specialised suppliers. This arrangement means that manufacturers can rely on suppliers to respond quickly and efficiently to their requirements without complex processes of negotiation and consultation. PM Inc. found that by handling information more efficiently throughout the product development cycle they could significantly speed up the process as well as improve reliability. The two main areas in mouldmaking where time was being lost were; insufficient or inadequate specifications from manufacturers, often discovered when two-dimensional designs were translated into solid mould forms; and the frequent need to remake or alter moulds after the first samples were produced. The product development process at Plastic Mouldings Inc. is as follows:

1. Clients conceive their new products in three dimensions. Plastic Mouldings Inc. provides assistance if the company does not have the facilities for 3D design.
2. From the 3D model, individual detailed product and component drawings are made.
3. Solid marketing and engineering prototypes are then produced that use components rigorously identical to the parts that will be manufactured from the moulds.
4. Prototypes are then made using CNC machining, stereo-lithography and mouldmaking techniques - but without the need for producing a mould.
5. At the same time, tests are carried out using analysis of plastic flow and cooling to ensure that quality and safety standards are achieved.

These processes are carried out in collaboration with the end-product manufacturer who defines, verifies and approves the specifications along with the execution of the project at all stages. Production can then begin three to six weeks before engineering prototypes are completed. This makes it possible for alterations to be made in product design (based on tests made with the prototypes) before the moulds are produced.

4.1.5 Summary of the NPD Study

The NPD study covered four companies in four different countries and four industries. This wide coverage gave the researcher an insight into a range of situations presenting technical, managerial and cultural problems. All companies dealt with customers and suppliers from overseas but in the case of E-T Inc., their products are designed in one country and manufactured in another.

A 49% response rate (17 out of 35) to the questionnaires was received. The data was used to represent the current situation within the industrial partners and identify problem areas in implementing Concurrent Engineering. Interpretation was carried out using radar diagrams, direct comparisons, percentiles and tables. Factors such as details of the new product development process, resources, supplier relations and communication mechanisms were analysed. The main findings were:

- Cross functional teams was the most widely recognised aspect of CE (all respondents indicated that it was part of CE), with most of the tools and techniques being recognised.
- Marketing was primarily involved at the concept and feasibility stages, whereas Design, Development, Production and Finance were involved throughout; and Logistics and Service at the later stages of the development cycle.
- The average product development time varied according to the type of project and the complexity of the product. For example, at E-T Inc. it takes up to 25 months to launch a new product to a new market, whereas facelifts take on average 6 months. Across the four companies, new products to new markets took an average of 20 months, new products to existing markets 15 months, restyles to new markets 9 months and restyles to existing markets 6 months.
- A wide variety of bottlenecks to the NPD were experienced across all companies. This question produced a very high response (94%), with most respondents citing multiple reasons and DA Ltd. managers listing 12 reasons between them; marketing decisions, bureaucracy, tooling, development time, long lead times, lack of resource, lack of information/communication, production drawing office, design freeze, purchasing delays, human resource availability, product specification, manufacturing, scheduling, transfer to operations and software. These were almost evenly spread. Interestingly, no-one considered product specification to be a bottleneck.
- Responsibility for the product development process was evenly split between Marketing, Design, Development and Production Engineering across the four companies.
- Product development teams were very cross functional, with Marketing being on the team in all companies. Tooling, Quality, Production Engineering, Development, Design and R&D were also heavily featured. Two out of the four indicated that external suppliers are involved where necessary.

These results agree with information on product development and Concurrent Engineering found in the literature. In particular, most references indicate that cross functional teams are a central part of CE (including [Pars93], [Take90] and [Winn88]).

These references (along with many others) indicate that teams are typically made up of full and part time members. They further state that design and development usually form part of the core members of the team. These were all clear finding from the NPD study. Additionally reductions in time were experienced by the study group once CE had been introduced. This is another well-documented effect of using CE (particularly by [Smit91] and [Clar91]).

4.1.5.1 Performance Measures

Of particular interest to this thesis are the results which addressed performance measurement. Figure 4.1 indicates which metrics are currently used by the industrial partners during the product development process. The way it should be read can be illustrated by an example; 40% of respondents at Electro-Tools Inc. calculate the total cost of NPD. This question highlighted a weakness with all partners in the recording of performance measures for all aspects of product development, rather than just the 'traditional' financial measures. If the companies made greater use of performance measures, they could use them to help overcome some of the bottlenecks they experienced during product development. The question also included a section on 'value now' and 'target value' but insufficient answers were received to provide a useful analysis.

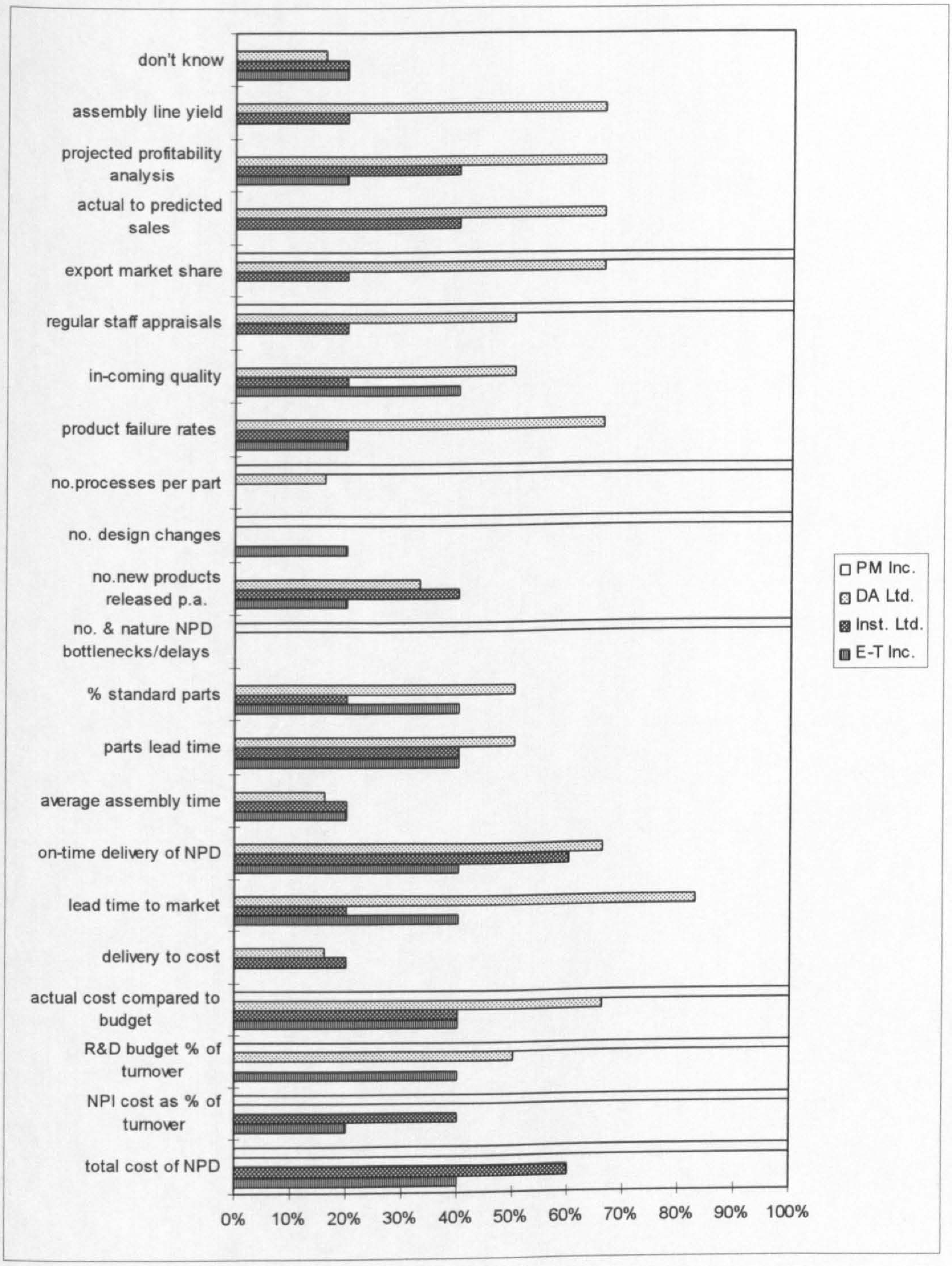

Figure 4.1: Use of Performance Measurement for Product Development by Industrial Partners[3]

[3] N.B: Respondents from PM Inc. answered as a group

4.2 Performance Measurement Surveys Analysis Procedure

The questionnaires yielded a large amount of information, for which a number of analyses (including means, modes, frequencies and correlations) were carried out. Throughout the data interpretation process, it was important to keep the primary objectives of the research in mind - i.e. to determine the extent of use of performance measures, identify future needs and directions and areas for improvement.

A variety of statistical tests are available to aid data evaluation. The purpose of a statistical test is to confirm the characteristics of a data set. In other words, the researcher wants to be able to say that a characteristic of the data has not arisen by chance and is *robust*. Both questionnaires designed for this study were quasi-experimental in nature, which meant that the data presented was largely non-parametric, being either nominal or ordinal. In other words, taking an example from the academic questionnaire, it is fair to say that there is not necessarily an equal gap between those measures that are useful now and those useful for the future. This means that attempting to fit the data into a suitable form for parametric tests, such as ANOVA, would be tenuous. This therefore narrowed down the choice of suitable tests and meant data interpretation was kept on a straightforward level. Qualitative data, in the form of comments has been grouped and/or highlighted as quotes.

In some cases, results from questions were compared using cross tabulation of data to provide more interesting output than can be seen by eye. For example, company responses on barriers to introducing performance measures were compared to those indicated by academics.

When examining the results of both questionnaires, it is important to note that not all the questions were answered by each respondent and some sections were left blank. In addition, for multiple choice questions, the total response will exceed 100%. For single choice options, a total response below 100% indicates that some respondents have not chosen to select any available options. To avoid the problem of missing data in the spreadsheet when no response was given, the value nine was assigned.

Analysis was carried out by computer using SPSS v7 for Windows 95 and MS Excel v5. Further information on the questionnaire design and analysis is given in the Research Methodology (Chapter 3).

4.3 Survey Results

What follows is an overview of the data collected from both surveys. Information on response rate is followed by profiles of respondents, organisation of product development, analysis of the types of measures used and management of the measures. It is important to note that on some questions, more than one answer was possible.

4.3.1 Response Rate

	Academic	Company
Total no. of questionnaires mailed	550	580
Total no. of respondents	84	150
Total no. analysed	63	137
Overall response rate	15.3%	25.8%
Analysed response rate	11.5%	23.6%

Table 4.1: Questionnaire Response Rates

a) Companies

The total number of responses to the company survey was 150 (out of 580). This yielded an overall response rate of **25.8%.** Following elimination of unusable replies, i.e. those that arrived late (after the data interpretation stage), those that had not been filled in correctly, or those that had replied but were unable to take part (owing to time constraints, lack of expertise, etc.), the response rate was 23.6%. Approximately 70% of useable replies were from the UK, with the rest being from Europe and the USA. The averaged responses for each question are calculated on 137 valid cases. Where data is missing, then only valid percentages have been calculated and an indication of the sample size is given. This is an above-average response rate for postal questionnaires and is thought to reflect the interest in this area. Reasons for non-response were sought where possible. Twenty firms were called to find why they had not answered. The reasons included; too busy, questionnaire too long, information not to hand, company policy discourages divulging information of this kind, original contact had left or (most commonly) the fact that they do not carry out design and development on their site. As shown in Table 4.2, over 70% of questionnaires were mailed within the UK and 30% across Europe and other countries. Surprisingly, responses received were in the same proportion, with 74% being received from the UK and 26% overseas. The lowest response rate was from the USA which yielded only a 17% return.

country	No. of responses	% of total responses	No. mailed	Response rate per country (%)
UK	98	71.5	425	23
USA	15	10.9	90	17
Japan	3	2.2	5	60
Germany	3	2.2	5	60
Denmark, Norway, Finland	4	2.9	12	33
Portugal, France, Italy	7	5.1	17	41
Netherlands	5	3.6	6	83
others[4]	2	1.4	21	0.1
Total	137	100	580	-

Table 4.2: Company Questionnaire Response by Country

Nearly all respondents were very interested in the research, with 92% wishing to receive a summary of the results. A big effort was made to personally address as many questionnaires as possible. This meant that less than 30% were sent to a company without a name[5]. This effort was justified as personalised letters yielded over 95% of the total replies.

b) Academics

The response rate from academics was not as high (15.3%). This is perhaps partly because the questions were more difficult to answer from an academic point of view. Ideally respondents should be actively involved with industry and/or have recent project examples in mind when answering the questionnaire. Approximately 41% of useable replies were from the UK, with the rest being from Europe (27%), the USA (24%) and others[6] (5%). The averaged responses for each question are calculated on 63 valid cases. Where data is missing, then only valid percentages have been calculated. Where this has occurred, as with the company responses, an indication of the sample size is given.

[4] Belgium, India, Ireland, Singapore, Spain and Sweden

[5] All of these were within the UK.

[6] Japan, India, Hong Kong and Israel

4.3.2 RESPONDENT PROFILES

a) Companies

The type of respondent ranged from Departmental Manager (40.1%), through to Technical Director (21.9%), Managing Director (10.2%), Project Manager (15.3%), Design/Development Manager (6.6%) and Team Leader (1.5%). To determine whether or not the respondents position in the organisation had an effect on their perspective, differences between levels were highlighted in some of the key questions.

Nature of production (136 responses); batch (41%), mass (37%) and project/one of a kind (22%). There was a fairly even split between but batch production had the lions share, reflecting the types of industries involved.

Sector of Business; over 70% of respondents were from either the mechanical, electrical, electronic or automotive engineering industries. This reflects the SIC codes targeted and fits in well with the engineering orientation to the questions asked.

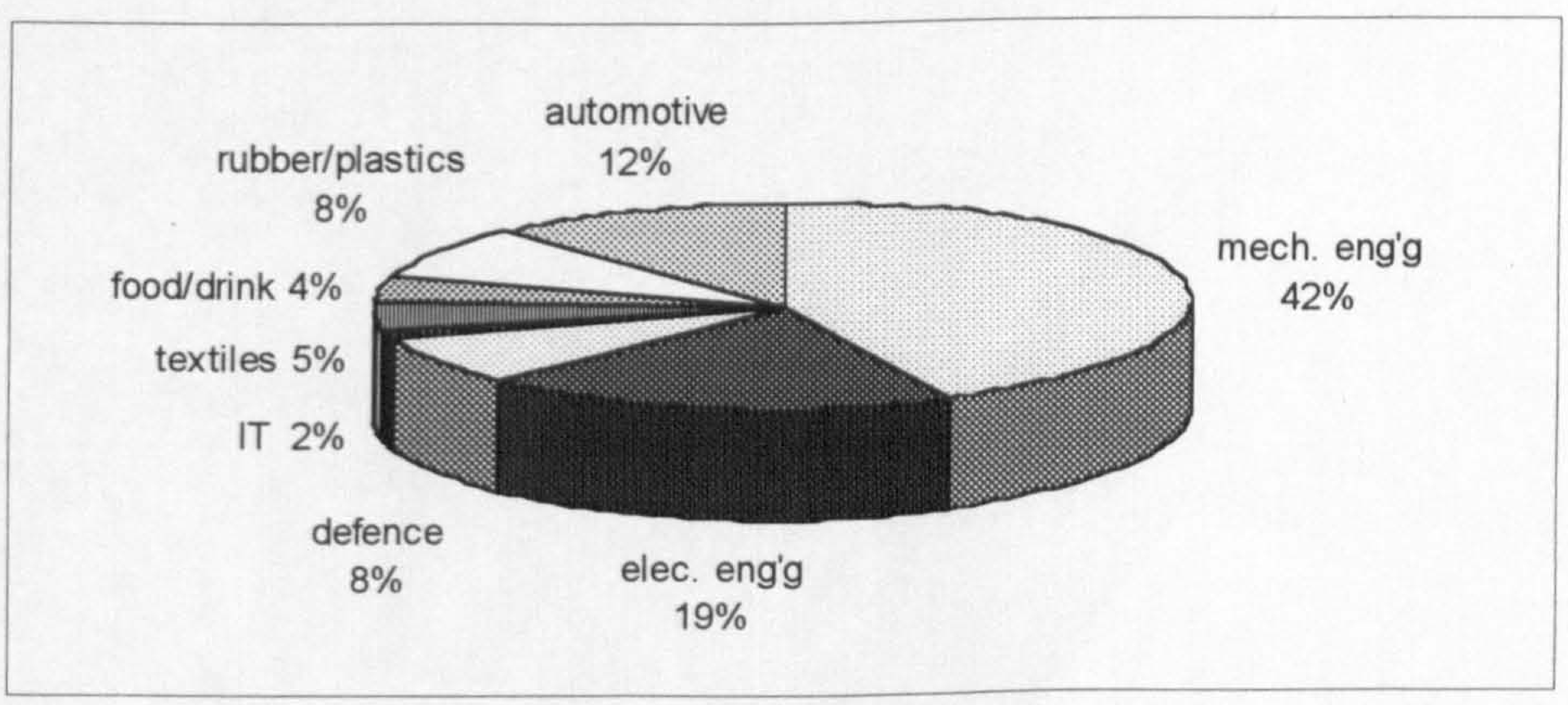

Figure 4.2: Company Sectors

As shown in Figure 4.3, a good distribution of sizes of companies was achieved, with the modal group being less than 250 employees. As would be expected, larger companies had more resources dedicated to design and development.

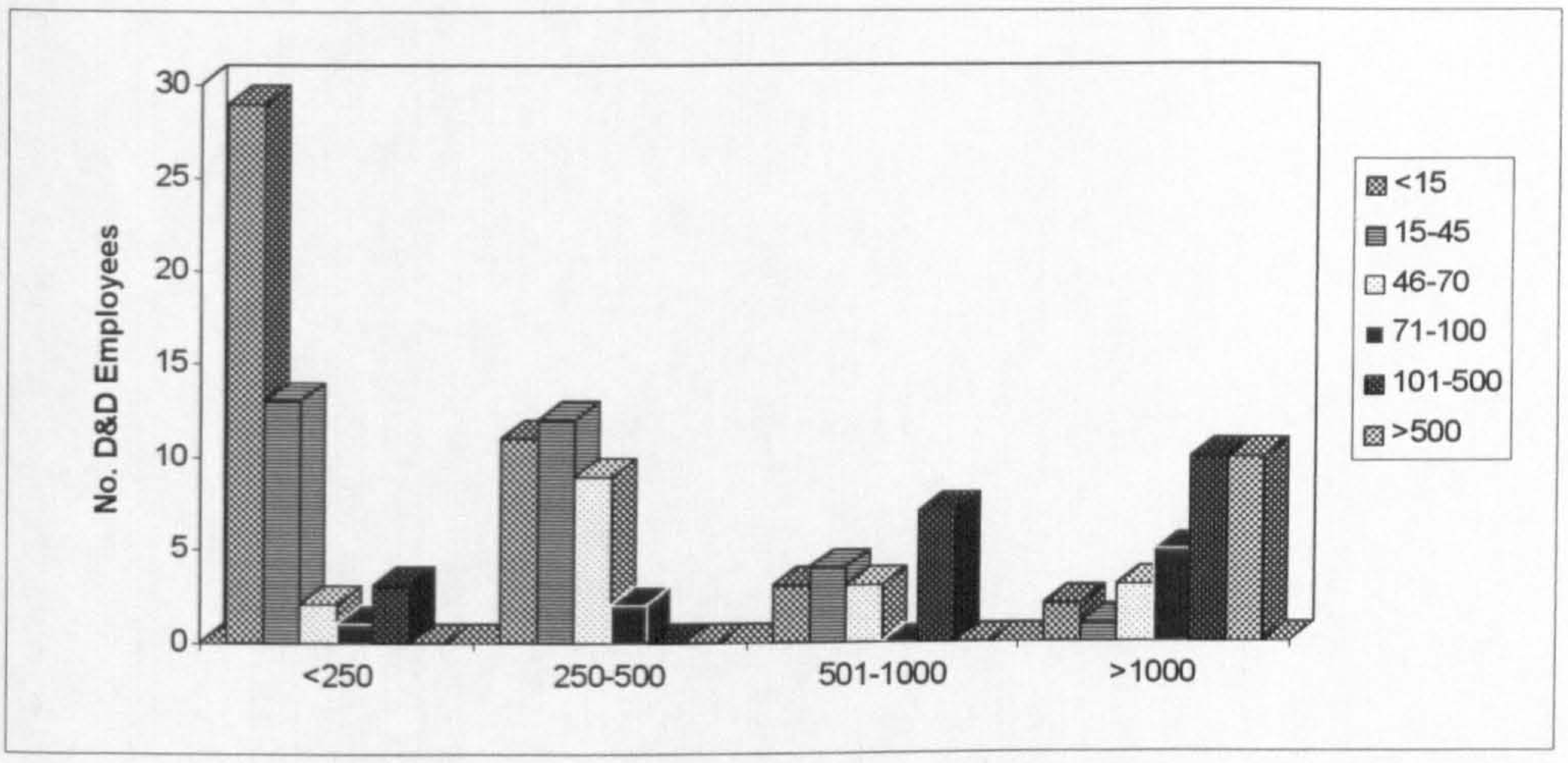

Figure 4.3: No. of Design & Development Employees against Total No. of Employees

b) Academics

As would be expected, the range of industries that the academics based their answers and experiences on was wider than with the company responses (see Figure 4.4). Many drew their experiences from a variety of industries (mainly based around mechanical engineering companies). The 'other' category included industries such as pharmaceuticals, polymer engineering, shipbuilding and construction.

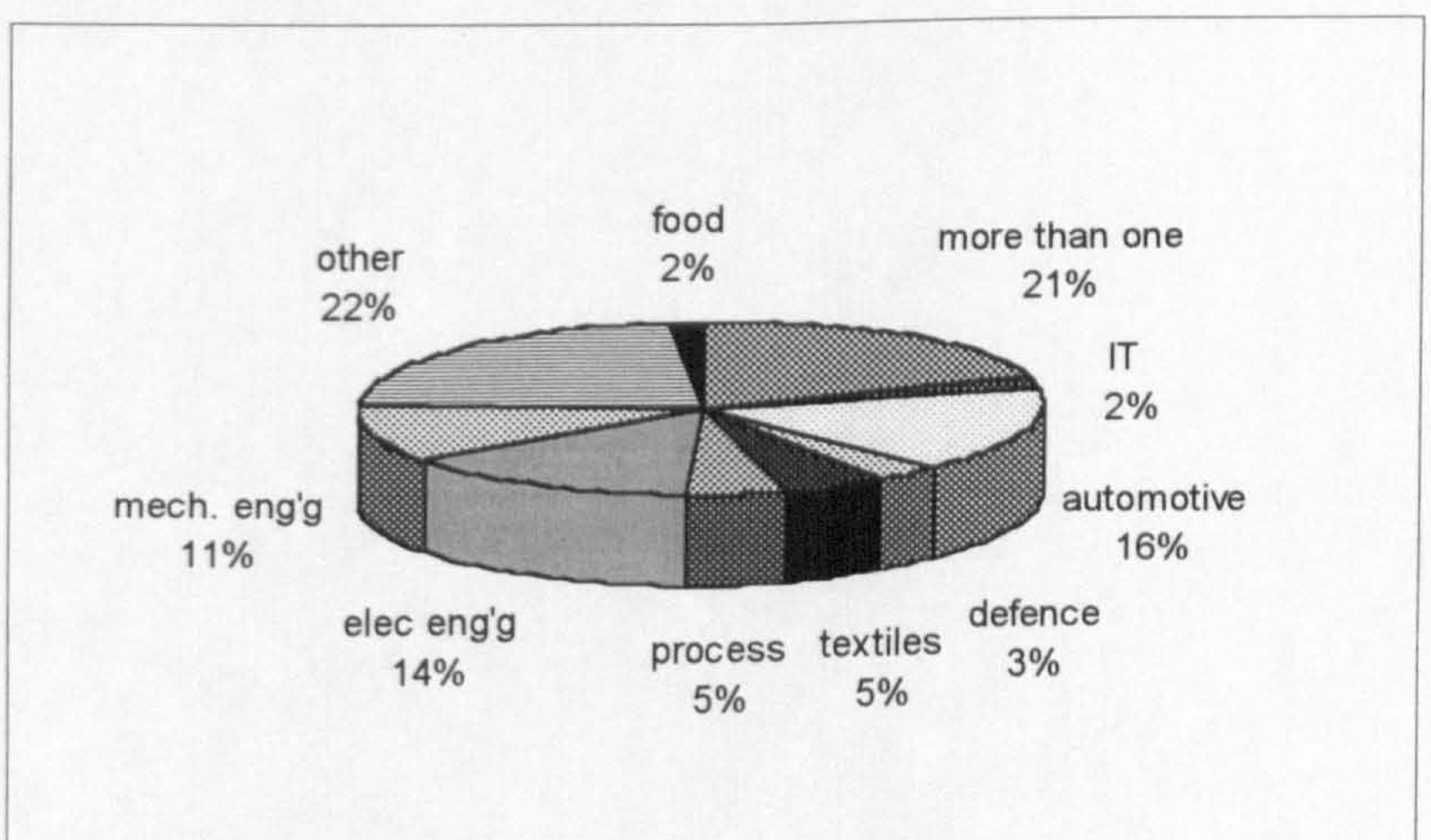

Figure 4.4: Academics' Industry Sector

4.3.3 ORGANISATION OF PRODUCT DEVELOPMENT[7]

Over 60% of respondents designed and developed products on the same site as manufacturing (134 responses). The fact that nearly 40% have split the two reflects a growing trend in the globalisation of companies. With increased use of technology such as email, data file transfer (including CAD, word-processing and spreadsheets), and videoconferencing, product development can now be successfully carried out remotely from manufacturing. This allows companies to captitalise on skills and costs. Such a situation occurs at E-T Inc. (see section 4.1.1) where development projects are split between two countries. Overall, the figure is still fairly high at 60% and it will be interesting to see what happens in five years time.

Almost 97% designed and developed their own products. Of these, 16% had 'partial' responsibility, sharing the task with customers and clients. Most of these were in one of a kind projects where close customer involvement was required throughout.

In 75% of cases, less than 20 product development projects were run at any one time, the largest group being 1 to 10 projects (129 cases). Only 6% carried out more than 50 projects. Over 60% designed new products for existing markets as their main category of product development project, with less than 6% specifically targeting new markets as their main category. The average length of product development time was very project- and industry-specific but the modal group was 6 to 12 months (36%).

As shown in Figure 4.5, computer aided techniques, cross functional teams and brainstorming were the most widely used tools and techniques amongst the respondents. Surprisingly, Quality Function Deployment was the least used with only a 27% coverage. In terms of future use, companies are most keen to make more use of design for manufacturing and assembly tools, rapid prototyping and indeed QFD. An additional question revealed that almost 90% of respondents used cross functional teams either some of the time (45%) or all of the time (45%) on product development projects.

[7] This section involved responses only from the company questionnaires.

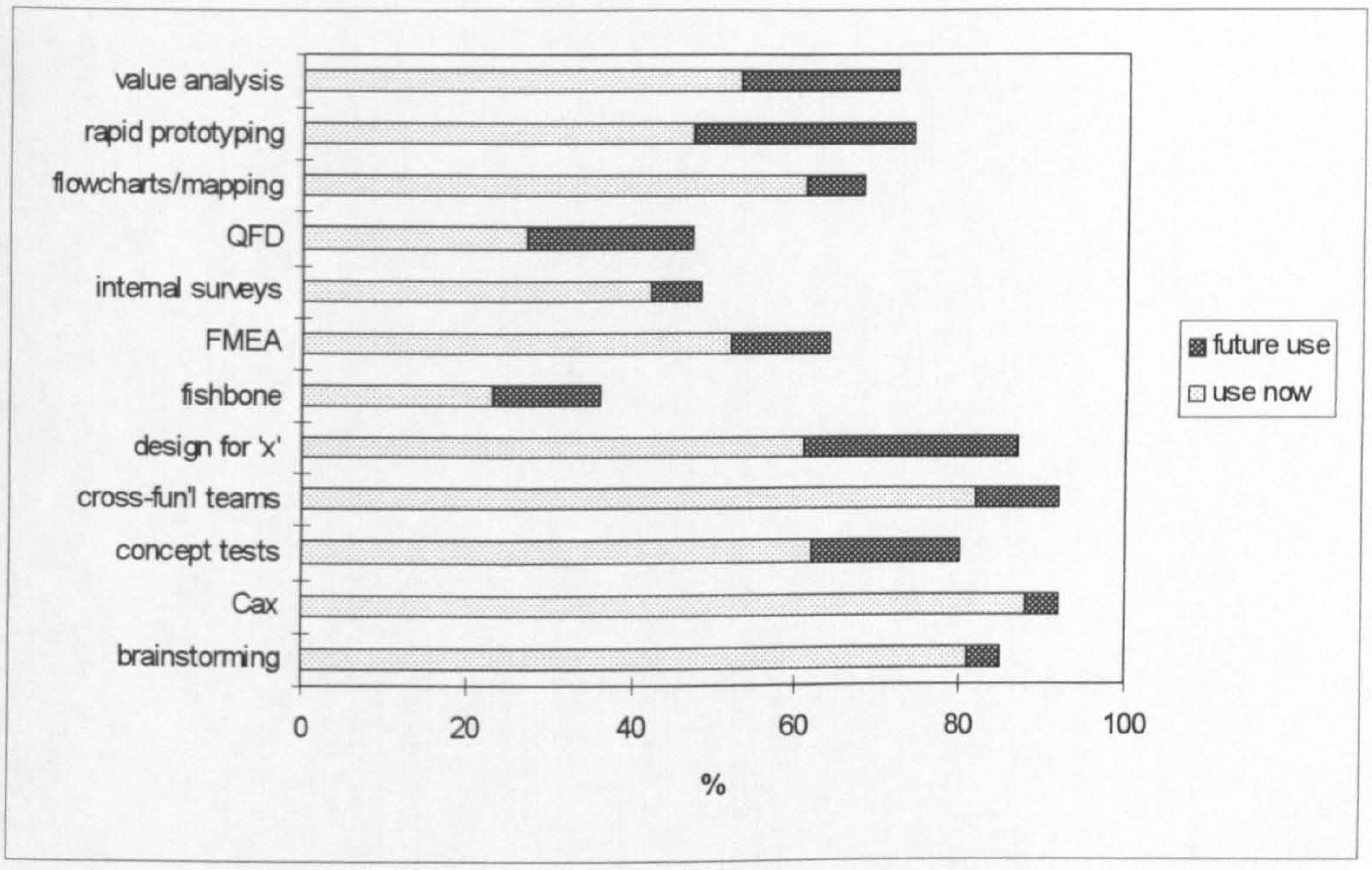

Figure 4.5: Use of Tools and Techniques

A variety of bottlenecks were identified at each of the main stages of the product development process. Communication was the top problem throughout (except for the Tooling stage), which is surprising considering the prevalence of cross functional teams among the respondents (89.8%). Communication was particularly problematic at the Specification stage, with 30% reporting problems (one manager stated that 'communication is the root cause of why the problem wasn't avoided in the first place'). 'Lack of resources' came a close second, with an approximate value of 20% across all stages. This was not listed as a choice (as it was considered too broad) but was added under the others category by a large proportion of respondents. In the Prototyping and Tooling stages, IT and more specifically provision and availability of computer equipment was the main problem (20%).

4.3.4 Use of Performance Measures

'We are still learning about measures - it's a new process to us. Management still fear that information is being used for a personal agenda'.

UK Technical Director

There were 130 company responses concerning measures currently used and 125 for frequency of use. They are listed below in order of current popularity.

Measure	*% who use now*	*% who want to use in future*	*Most common frequency of reporting*[8]
Total cost of project	71	15	m
On-time delivery of development project	61	12	pp.
Actual project cost compared to budget	60	17	m
Actual vs. target time for project completion	58	13	m
Lead time to market	57	14	pp.
Field trials prior to production	54	7	pp.
Projected profitability analysis	51	18	pp.
Product failure rates	50	7	m
Supplier lead time	49	7	m
Reasons for failures on the market	46	15	pp.
Product prototype passed safety tests	45	5	pp.
R&D budget as % of turnover	43	10	m/pp.
Time spent on each stage of product development	42	18	m
Product met quality guidelines	39	10	pp.
Actual to predicted profit on products	35	16	pp.
No. new products released per annum	33	10	m
No. projects completed per annum	31	9	m
No. design changes to specification	31	23	m
Product development cost as % of turnover	28	18	pp.
No. parts per product	28	14	pp.
No. and nature of bottlenecks	23	24	m
% tooling cost against total project cost	23	10	pp.
No. design defects detected at development stages	22	22	pp.
Development costs of products that don't get to market	18	18	pp.
Personnel turnover in Design & Development	15	15	m
% time for tooling vs. total project time	13	13	m
No. design awards achieved	12	6	m
% project time spent in meetings	8	20	m

Table 4.3: Performance Measures Used by Companies

As one would expect, the most widely used measure is the total cost of the project. However, it seems that almost 30% of respondents are still not using this basic measure and only half of these intend to introduce it in future. Further analysis revealed that it was mainly the smaller companies (250 employees) who were in this group. The five

[8] pp. = per project, m = monthly

measures that companies most want to introduce in future are; number and nature of bottlenecks (24%), number of design changes to specification (23%), number of design defects detected at design & development stages (22%), percent of project time spent in meetings[9] (20%) and development costs of products that don't get to market (18%). It is interesting to note that all five of these are 'negative' performance measures rather than those focusing on achievements and successes.

Recommended use of Performance Measures by Academics

'The front end of the design process is particularly important and presently poorly supported. The setting of targets which provide designers with goals is very important.'

Academic, Sheffield University.

The measures selected by academics are listed in order of their mean score in Table 4.4. The first 28 (out of 65) are listed to provide a direct comparison with the company selection. Scores were based on a Likert-type scale where 1 = very useful now.. 5 = not useful now.

Overall, the two groups do not differ substantially in the types of measures currently being used and those which are considered important by academics. Measures that appear in both lists include; target time for project completion, total cost of project, time to market, reasons for failures of products on the market and number and nature of bottlenecks[10]. However, some notable differences remain. The academics placed greater emphasis on customer satisfaction whereas the companies concentrated on time and costs. In particular, performance measures that were not highly rated by academics but appear in the company list are; actual project cost compared to budget, field trials prior to production, development costs of products that never get to market and personnel turnover in design & development. Some of these may be accounted for by the fact that companies want to introduce more sophisticated measures (such as those associated with customer satisfaction) but don't know how to approach them.

[9] currently one of the least used measures (8%), mainly owing to the difficulty in data collection and recording

[10] The length and reason for delay at each bottleneck was considered by an Indian academic to be 'the most important performance measure in the Indian context.'

Rank	Measure	Mean	Mode[11]	SD[12]
1	Total time to market (from concept through to launch)	1.79	1	1.10
2	Accuracy of prediction of customer requirements	1.85	1	1.03
3	Accuracy of interpretation of customer requirements	1.97	1	1.16
4	Total product development time	1.98	2	1.02
5	Actual vs. target time for project completion	2.07	1	1.02
6	Actual product quality performance vs. predicted	2.13	2	0.99
7	% on-time delivery of specification to manufacturing	2.16	2	1.11
8	No. of customer-detected design faults	2.20	2	1.13
9	Total cost of each product development project	2.22	1	1.25
10	Response time to customer requests for specials[13]	2.24	2	1.10
11	Ability to use a common design platform	2.25	2	1.10
12	Reasons for failures of previously released products	2.27	2	1.06
13	Delivery of product to cost (as quoted)	2.28	2	1.18
14	Rate of successful product development projects[14]	2.31	2	1.25
15	Time spent on changes to original product specification	2.33	2	1.12
16	Ease of manufacture of product	2.34	2	1.23
17	Impact of customer deadlines on project management	2.35	2	1.33
18	No. of changes to original product specification	2.41	2	1.22
19	No. of early failures of product on the market	2.43	1	1.28
20	No. of warranty claims (after product launch)	2.46	2	1.44
21	Engineering change costs	2.48	2	1.18
22	Product met sales volume targets	2.50	2	1.23
23	No. of projects completed on schedule over total no. of projects	2.53	2	1.17
24	% of products that met all stated objectives	2.54	3	1.07
25	Length and reason for delay at each bottleneck	2.62	2	1.23
26	No. of design faults detected at development stage	2.63	1	1.33
27	Customer satisfaction with length of product life	2.63	1	1.34
28	% standard parts[15]	2.63	2	1.19

Table 4.4: Performance Measures Recommended by Academics

Opinions on the future use of each performance measure listed was also requested but over two thirds of respondents did not answer this part of the questionnaire. As a result, no analysis has been carried out on the few results received.

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[11] scale of 1 to 5 where 1 = very useful now...5=not useful now
[12] standard deviation
[13] measure of design flexibility
[14] i.e. those that become products that reach the market
[15] appropriate if product is part of a range

Additional Measures

Respondents were asked to list any other measures they used (or recommended to be used) across the product development process. They largely fell into the main groups of time, cost, quality and customer satisfaction and are shown in Table 4.5.

Companies	Academics
Cost Related	
% hours billable; New product sales; Product cost prediction against accuracy; Repair and guarantee costs; Tooling/investment cost to budget; Impact of product cost vs. estimate; Redundant/obsolete material costs	New product added value as % of product cost; Any environmental implications (standards, recyclability requirements, pollution effects, etc.)
Time Related	
Meets customer deadlines; Tasks completed against tasks planned; Time spent before project has started	Competitor time to market; Development time as a % of product life cycle
Quality Related	
6 Sigma scorecard; FEA analysis; Customer perception of quality	Ease of manufacture; Legal liability to the customer
Customer Satisfaction	
Consumer test data results; No. of repeat clients; Press coverage received	Establishment of true customer requirements[16]
Other	
Product range complexity; Effect of new product on competitors; Effect of new product on others in the range; Design for assembly score; Design change requests[17]; Design change cause analysis - identifies where problems arise	Competitor market share by product line and country

Table 4.5: Additional Performance Measures Suggested by Respondents

[16] This comment came from a Japanese academic who considers that establishment and recognition of 'true' customer requirements is of utmost importance.

[17] monitors department performance on routine (i.e. non-project) work

It is interesting to note that many of the suggestions by academics centre around benchmarking issues such as comparison with competitors. Both groups suggested a number of qualitative measures, which are almost by definition difficult to monitor on a consistent basis. These measures were simply listed, with no clue given as to how they were measured and/or reported.

4.3.5 Management of the Measures

Understanding: Only 21% believed that all the performance measures used in their company were understood.

Top management (MD plus corporate directives) accounted for over 60% of introductions of performance measurement systems in companies - see Figure 4.6. This concurs with the widely-held opinion that this top support is needed to ensure success.

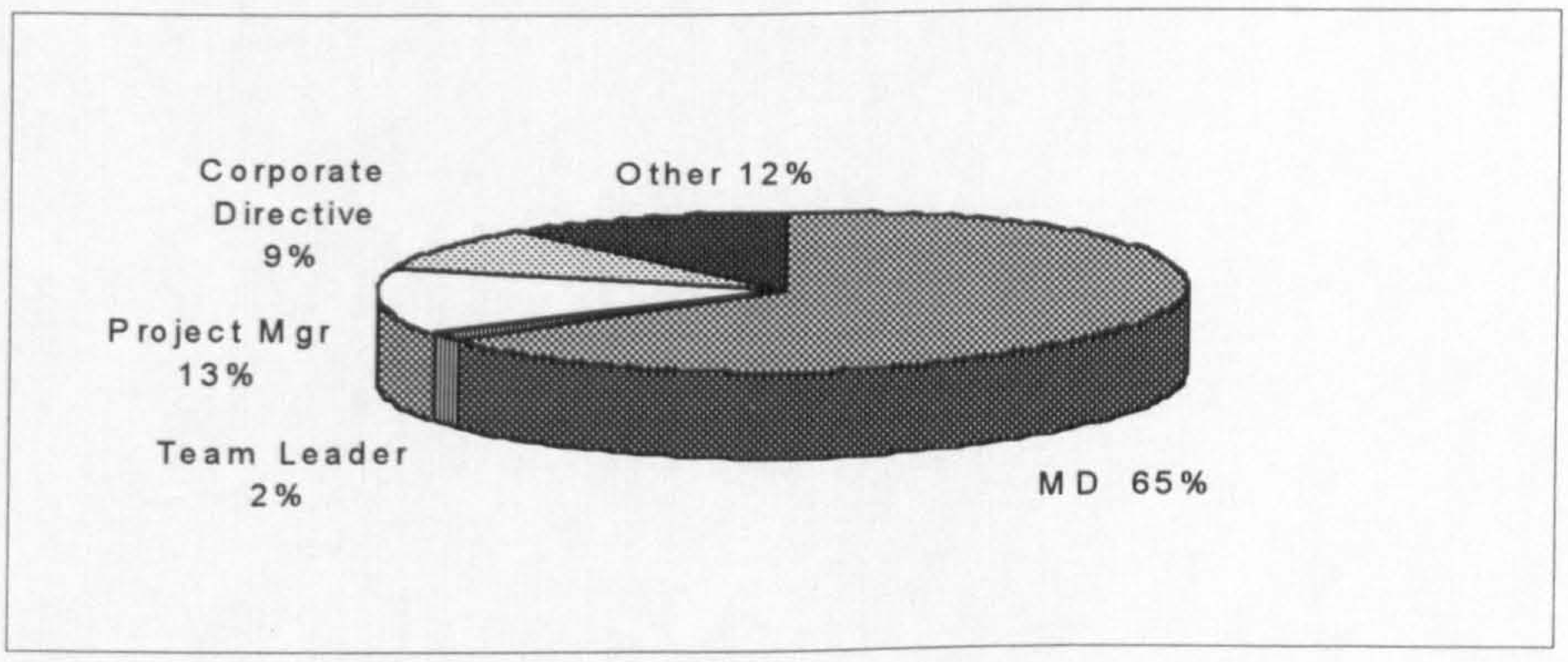

Figure 4.6: Who Introduced Measures into Companies (130 cases)

The academic view here was quite different. Although some thought that the MD should lead the way (10%), most considered that a team involving a combination of the MD/directors and project managers is the best mix (47%). Almost 7% considered that 'all' should be involved, whereas 3% chose departmental heads, 23% project managers and 10% team leaders ('Team leaders are the closest to the project and have direct knowledge and accountability for any problems'). The academics appeared to have strong feelings on this topic and a variety of comments were received. One academic at Cranfield University commented that 'senior management and team leaders should facilitate people to develop their own measures'. Another from Cambridge stated that 'top management commitment is essential but project managers are in the best position to implement measures'. A European academic, with experience in heavy engineering, warned that 'performance measures should not be brought in by an outsider'.

Collection, Reporting, Feedback and Visibility of Performance Measures

In 12% of respondent companies (115 cases), data for measuring performance was collected automatically as part of the existing system for reporting information, a further 22% spent time collecting the data, while the remaining 66% used a combination of the two.

The most popular way to report measures in companies is on a project team basis (41% of 115 responses). This mirrored what academics would like to see as 48% chose the same category (by far the most popular choice). Individual-based measurement systems were quite rare (4%), as were finance-based systems (5%)[18]. A Textiles professor from the US stated that 'all those who work on projects should have an input into the performance measurement system'. The most popular (formal) way of reporting the measures is through team meetings (35%) and reports (43%). Electronic media such as email/groupware (16%) and videoconferencing (3%) are currently used in a minority of cases.

Who sees the measures? In most cases (118 responses), measures are widely reported across the organisation; being visible to senior management (87%), all project managers (64%), CEO/MD (64%), the project team (75%) and accountants/finance (50%). This was little different to what the academics would like to see; they were merely less keen on the accountants being involved (23%).

Barriers

'There is a reluctance to spend time collecting data by participants in the process as there is little understanding of the purpose or relevancy'.

Departmental Manager, Mechanical Engineering Co. UK

A wide variety of barriers were listed which hindered introduction or increased use of performance measures (58 company and 63 academic respondents). As shown in Figure 4.7, the two groups broadly agreed on most aspects but companies placed greater emphasis on the somewhat loose term 'lack of resources', while academics considered inaccuracy of results (the biggest disparity), culture, time constraints and the danger that no-one is accountable for results to be greater barriers than did the companies.

[18] One UK academic candidly considered this approach to be 'death' to performance measurement!

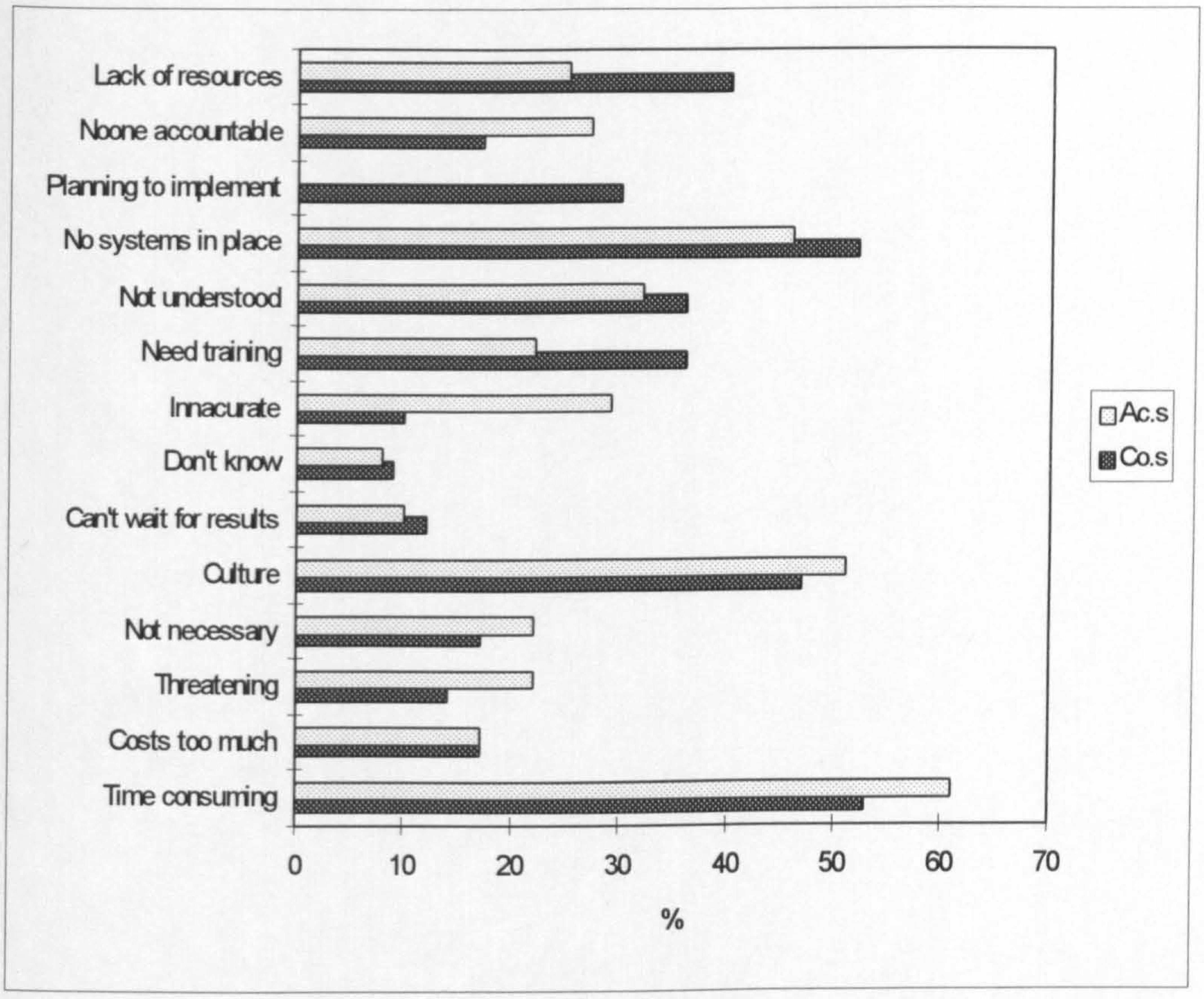

Figure 4.7: Barriers to Use of Performance Measurement

One UK academic considered that the key difficulty lies in knowing exactly what to measure to achieve improvements. Another stated that 'the main problem occurs when measures are not owned by the project team', while a third stated that 'the main barrier to measurement is the fact that in many cases results would not be used'. A US academic cited the 'subjectivity' and 'lack of credibility' of many existing measurement systems as the major barrier.

4.3.6 Opinions on Measurement, Additional Comparisons and Suggestions for Improvement

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'Since the introduction of performance measures they (*the engineers*) have become more aware of the importance of time to market and are hence motivated to improve in this (and other) areas'.

UK Manufacturing Manager

'Most performance measures currently used are the wrong ones'.

UK Company Director and Academic

Level of satisfaction with number and frequency of measurement: Only 3% of respondents were very satisfied with the number of measures currently made in their organisation. More significantly, 50% were not satisfied. In terms of frequency of measurement, it was a similar story with only 6% very satisfied and 41% not satisfied. One respondent typified the accompanying comments by stating; 'it's not the measures that are important - rather how the information gained is used'. Other comments included:

- 'The problem tends to be lack of reaction to measures rather than lack of measures'.
- 'Our most important measures focus on past performance. We currently measure more performance indicators than we feed back - which is basically lost data'.
- 'I would prefer to find metrics which somehow measure the effectiveness of the product development process and will drive improved performance in this activity'.

One manager commented; 'we measure a lot - maybe too much'. Unfortunately, no further explanation was given.

Unnecessary measurement: 85% believed that no unnecessary measures were made. Clearly, measurement has not yet reached saturation point in the vast majority of the companies[19].

Where additional measures would be most useful: The two groups differed quite substantially here as shown in Figure 4.8. Company respondents considered the Specification stage (33%) to be most in need of additional measures, while the academics want to see more measures throughout the whole product development process (37%).

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[19] The only comments received on unnecessary measures were; 'monetary measures (when used in isolation) can undervalue hours spent on training and marketing development' and 'those that overlap with finance and human resource measures'.

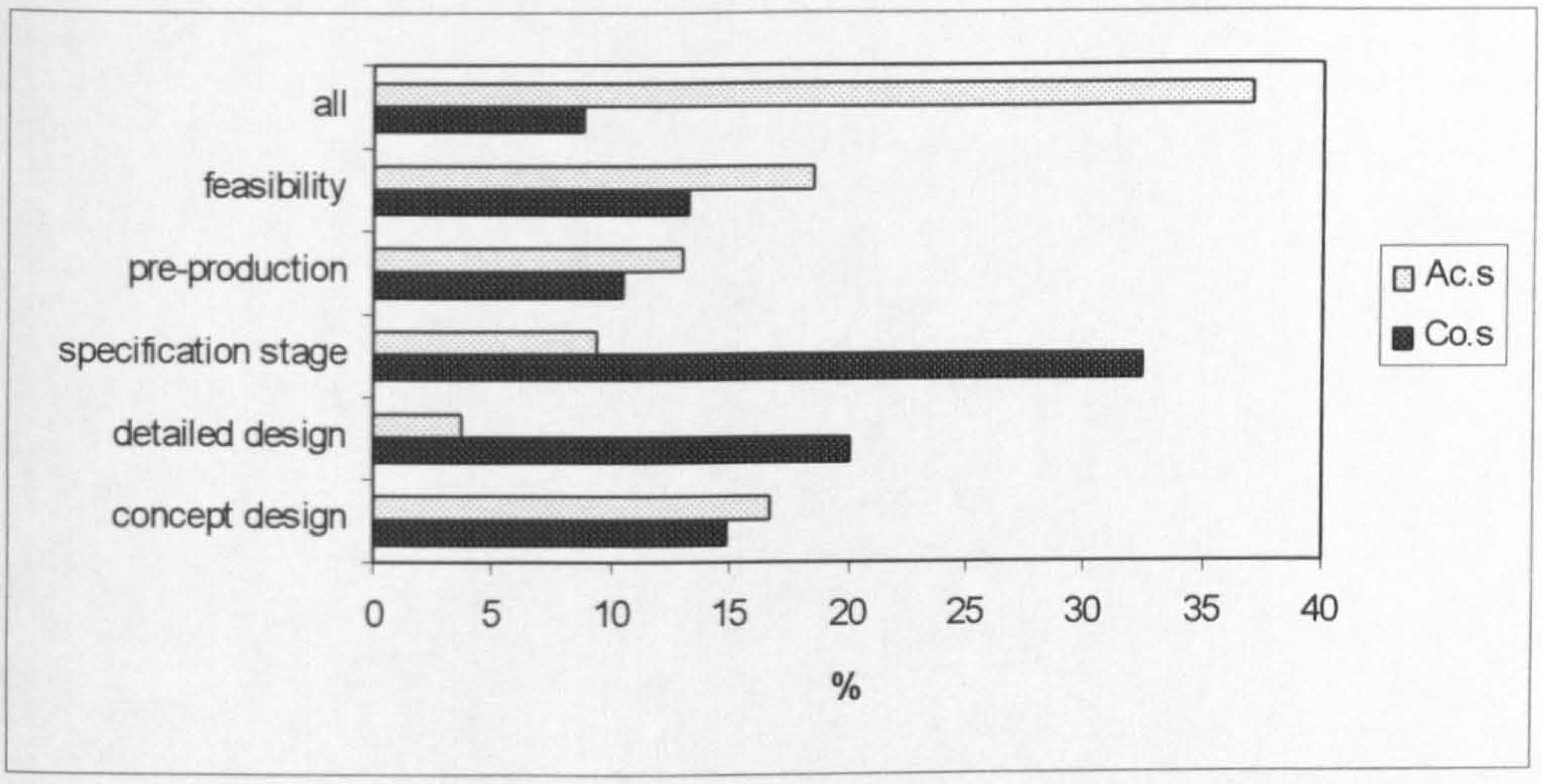

Figure 4.8: Where Additional Measures would be most useful

'Appropriate performance measures keep projects on track and focused. Without them, project members can get too easily distracted'.

American Professor of Product Development

Initial Hypothesis Statements

These statements (part of the research hypothesis stated in Chapter 1) were included in both questionnaires in an attempt to establish whether any differences in opinion existed on basic issues of performance measurement for design and development between academics and industrialists. Scoring was on a five point Likert-type scale, with respondents circling the most appropriate number (from 1 = strongly agree to 5 = strongly disagree).

	Statement	Mean Score		Mode Score		Standard Deviation		% Strongly agree/agree		% Strongly disagree	
		Co.s	Ac.s	Co.s	Ac.s	Co.s	Ac.s	Co.s	Ac.s	Co.s	Ac.s[20]
a)	Lack of usage of performance measures adversely affects the product development process	2.01	1.92	2	1	0.98	1.08	74.2	80.6	0.8	4.8
b)	More effective management through the use of performance measures will support Concurrent Engineering principles	2.03	2.16	2	2	0.99	1.04	71.7	66.1	2.3	3.2
c)	Reallocation of resources resulting from using performance measures reduces the cost & time required for product development projects	2.15	2.43	2	3	0.95	0.96	66.7	52.4	1.5	1.6
d)	Use of performance measures during design & development aids decision making	1.76	1.74	1	1	0.83	0.93	84.8	81.9	0.8	1.6

Table 4.6: Degree of Agreement with Hypothesis Statements

[20] Co.s = companies and Ac.s = academics

Table 4.6 shows that the mean scores for both groups on both questions was low, as were the modal scores indicating a high degree of agreement. This was reinforced with the low standard deviations. As an extra check, the percentage that strongly agreed/agreed and those who strongly disagreed were extracted. These also confirm the positive result.

Respondents were also requested to add any comments to the scoring of the statements. Sample comments were:

a) 'In the apparel industry, many costs and failures are hidden. Formal performance measures can help overcome this if implemented appropriately'.

b) 'Where performance indicators show lead time reductions, CE principles may be applied'.

c) 'Early warning prevents work'.

d) 'Performance measures correctly calculated are essential for decision making'.

A scatterplot of the degree of agreement[21] with the hypothesis statements - shown in Figure 4.9 - graphically shows the opinions of the two groups across all four statements. In general; the companies tended to agree with the statements more than the academics (apart from a)), opinions between the two groups were not significantly different and the biggest disparity was in statement c).

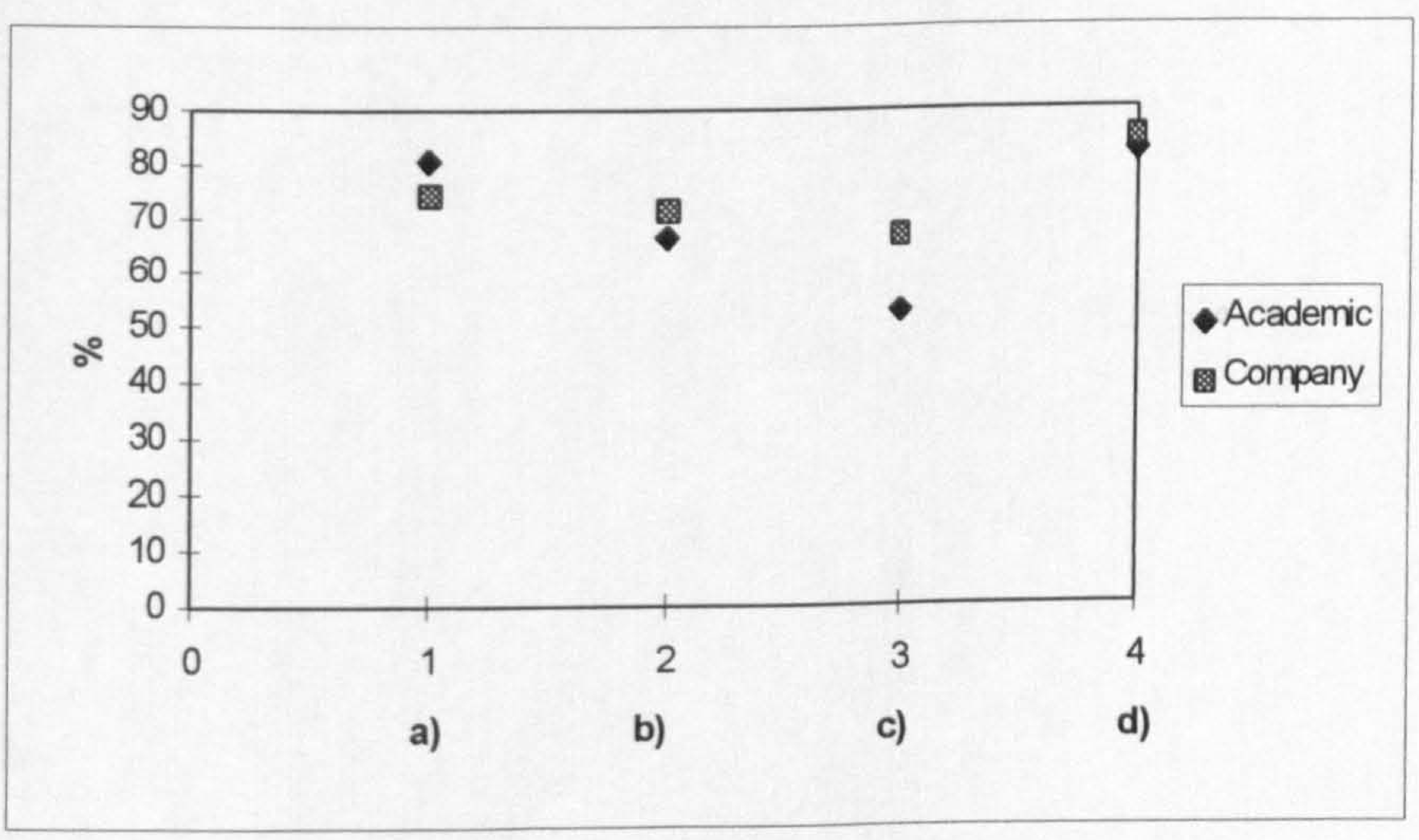

Figure 4.9: Scatterplot of Statement Responses

[21] i.e. the percentage of respondents from each group who either 'agreed' or 'strongly agreed' with the statements.

These results show strong support for the sub-hypotheses stated at the beginning of the research (see Chapter 1).

Comparison Between Sectors, Management Level and Countries

While the main emphasis of this study has been to compare industry with academia, the comparison between sectors, management level and countries was also briefly explored. Notable results are described below:

- UK managers made greater use of tools and techniques than the sample as a whole, e.g. scoring 93% for brainstorming, 73% for concept testing and 58% for rapid prototyping; but less use of cross functional teams (39% use all of the time against the 45% overall average). Additionally 'use of field trials prior to production' was considered the second most important measure (after total cost of project), with 59% of respondents currently using it.

- 33% of Senior Managers (i.e. Technical & non Technical Directors and Managing Directors) considered that all measures were understood compared with 22% among the other respondents (Departmental Managers, Project Managers and Team Leaders). 47% were not satisfied with the number of measures used, against 53% among the others. Surprisingly, 25% of them thought that some unnecessary measures were made, compared with 10% among the other respondents.

- Taking the two largest industrial sectors, mechanical engineering and electrical/ electronic engineering, both groups agreed that additional measures were most needed in the specification stage but the emphasis was slightly different (mech. eng. 33%, elec. eng. 37%). Senior management (86%) and the project team (83%) are top recipients of the measures in mechanical engineering, whereas senior management (82%) and the CEO/MD (68%) are in electrical/electronic engineering.

Although firm conclusions are difficult to establish owing to fairly small sample size, these preliminary results can be used as a basis for further investigation.

4.4 Summary of Questionnaire Results

Two separate (but overlapping) questionnaires were designed and launched to investigate theory and practice surrounding performance measurement for design and development. The nominal and ordinal data yielded was analysed and presented in a straightforward manner, allowing for easy duplication by researchers in the future and understanding by the respondents (who received summaries of results where requested). The study had an international perspective, with participants from 15 countries. A good response rate to both questionnaires was achieved, which reflected the current high level of interest in this area.

With an international long distance survey of this nature, ambiguity of terms can be a problem. When designing questionnaires, the author must aim to make the right balance between defining everything and keeping the length of the survey short and succinct. The questionnaires used for this research were 7 (industrial) and 6 (academic) pages long, which allowed for a certain amount of explanation, without exceeding tolerance levels. Pilot studies confirmed that the length was acceptable. With a sample of this size, the danger of sampling bias cannot be ruled out. The only way to test this is to carry out an additional follow-up survey, using entirely different contacts.

The initial NPD study highlighted the immaturity of performance measures for product design and development among the PACE Project partners. Although some measures were being used to manage product development activities, there was much scope for improvement. This was later confirmed in the wider company questionnaire results, where 80% of respondents stated that they would benefit from greater use of performance measures. Some of these companies were more advanced but many still had weaknesses in the core measurement areas of lead time to market calculations, monitoring design changes and total cost of product development.

The questionnaire results revealed many interesting and some surprising issues. Most company respondents had already established a set of manufacturing and financial measures and were now looking for ways of improving performance measures in design and development (hence the interest in the survey). What came out strongly from both questionnaires was that the measures were very much dependent on the stage of development and the projects' major objectives. Some measures such as 'scheduled time against actual' are useful throughout a project, whereas others such as product failure rates are one-off measures that need to be registered once in the project. Most companies were still developing their performance measurement systems, with many using only the basic indicators of time, cost and quality. The exact mix depended on a number of factors including, size, industry and globalisation.

Specific points of interest from the questionnaire results include; only 25% of respondents felt that all measures used were currently understood, the Specification stage of product development was most in need of additional measures and that only one third report measures on a project/team basis.

A surprisingly high number of respondents (58%) considered that their organisation did not use performance measures to quantify the efficiency and effectiveness of product development. On closer inspection however, they did appear to use some measures as they indicated that several of the measures listed were used on a regular basis[22]. This begs the question, is the concept of performance measurement currently understood or is it just an exercise carried out to satisfy head office and/or shareholders, rather than to effect improvement?

Communication was identified as the top bottleneck problem, despite the fact that 90% of respondents use cross functional teams. Does this perhaps indicate that teams are not working as they should or are there other reasons? Lack of resources was also a problem prevalent across all stages. Admittedly, 'communication' and 'lack of resources' are somewhat broad terms but the figures indicate that problems do exist in these areas.

The additional list of performance measures (Table 4.5), while interesting for its more industry-specific perspective, did not substantially add to the list provided. This indicated that most of the important measures were covered by the questionnaires.

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[22] In almost all cases, these respondents indicated that they would benefit from additional use of performance measures.

The results from this survey has some common strands with previous studies found in the literature. For example, in her work on R&D organisations, Kerssens [Kers96][23] found that over half of the study's respondents used measures to report on team performance. Their main function was as an aid to decision making and assignment of resources. As with this study, they found that the main way to report measures was via project meetings.

The differences of opinion between academics and industrialists found in this study reflect the findings of Griffin in her study on success in product development [Grif96]. She also found that the performance measures currently being used are not the ones that managers would necessarily choose to use or academics would like to see used (see Chapter 2). Additionally, the main barriers to performance measures cited in her study were lack of systems in place, company culture and lack of accountability for results, all of which were corroborated here. The types of measures should change according to strategy and product characteristics. Many comments to this effect were received from both academics and companies in this survey.

The company emphasis on time and cost was reinforced in the longitudinal case study where nearly three quarters of the initial 30 performance measures (identified by managers and project team members) and half of those selected for the first phase of implementation focused on these areas.

Differences between responses by academics and those in industry were not as substantial as expected. This was especially true in degree of agreement with the sub-hypothesis statements. Both groups gave them strong backing, especially the statement that 'use of performance measures during product design and development aids decision making' (average 83% support)[24]. However, differences do remain. In particular, academics consider customer-related measures to be most important, while

[23] This study is described in Chapter 2.

[24] Statement c) - 'reallocation of resources resulting from using performance measures reduces the cost and time required for product development projects' - received the lowest level of support. Looking back, it is perhaps not surprising that this statement was not highly backed as the link between the two is not easy to prove.

industrialists prefer to focus on the more basic requirements of cost and time[25]. These results may reflect the difference in the ideal situation that academics have gathered from their macro-viewpoint and the more focused, practical applications that managers deal with.

In summary, this two-fold internationally-flavoured investigation has yielded some valuable information on the current and future situations for performance measurement for product design and development. It has shown that attempts are being made to improve in this area. It has also helped to identify specific differences across industries and between industry and academia. However, due to the fairly small sample size, evidence is not sufficient to determine whether or not these differences are significant or to pinpoint the reasons for them. An additional study is currently being carried out by an undergraduate student in this department using many of the same questions posed here. Results are as yet unavailable[26] but should later provide an opportunity for comparison.

Additionally, there is scope for further analysis of the SPSS data generated from both questionnaires. The data has been carefully recorded to allow future researchers to reanalyse the data from another perspective and/or examine it with another research hypothesis in mind.

As long distance surveys preclude in-depth questions about how and why these measurement systems are used, company respondents to this survey were selected for follow-up cases. These cases are described in the next chapter.

4.4.1 VALUE OF THE QUESTIONNAIRE RESULTS

A. As far as the author is aware, this is the first in-depth analysis of performance measures for product design and development. What makes it especially valuable is that it encompasses both academic and industrial viewpoints. The data collected from the questionnaires identified the extent of use of these

[25] There are of course exceptions to this. A discussion with Dr Stephen Evans of Cranfield University revealed that the telecommunications company Nortel have only two performance measures; customer satisfaction and employee satisfaction.

[26] project completion date - May 1997

performance measures and indicated which measures academics would like to see used.

B. The questionnaires provided an insight into the current level of measurement system in UK (and overseas) manufacturing organisations. The high response rate (25%) proved that this is an area of concern.

C. Many comments on performance measures from both groups were received, covering a wide variety of industries and situations.

D. Most respondents gave their name, which allowed for follow up interviews to be held with selected companies. This formed the basis for the ten follow-up cases that allowed for further investigation of significant questions. These include; how the top three measures in design and development were selected, why they were selected, how they are calculated and plans for the future.[27]

E. The questionnaire results provided pointers for the in-depth longitudinal case study. They showed the variety of approaches available and highlighted some of the pitfalls to introducing performance measures.

F. The top performance measures currently used and recommended were used to form the Basket of Measures for the Implementation Framework (Chapter 7).

G. These results provided the foundations for the Implementation Framework and accompanying workbook designed to assist with managing product development projects in manufacturing organisations.

[27] These results are presented in Chapter 5.

CHAPTER 5

5. CURRENT PRACTICE AND FUTURE PLANS IN PERFORMANCE MEASUREMENT: FOLLOW-UP CASE RESULTS

This chapter presents the results from follow-up cases with ten respondents of the company questionnaire. The same format was followed for all; semi-structured interviews based on the questionnaire responses, supplemented with a discussion on the types of performance measures currently in use in their organisation and plans for the future. The respondents were selected on the strength of their replies and the range of industries they represented. An example case is highlighted in the company profiles and an analysis of the responses is then shown. This is followed by a comparison between the cases and the wider company questionnaire responses. Finally, the implications of the case findings are discussed, along with their contribution to the research.

5.1 Company Profiles

Long distance questionnaires, while being a valuable source of information, can be open to ambiguous interpretation. In order to gain a deeper insight into answers given, a representative sample of the respondents were selected for interview. These interviews provided an opportunity to ask open questions and follow interesting 'leads' arising from questionnaire replies. An important note to add at this stage is that all ten companies are part of multinational corporations. A profile of the interviewed companies is shown in Table 5.1:

A two to three hour semi-structured interview was carried out in each of the ten companies. All interviewees were the same person that responded to the questionnaire and all were middle to senior-level managers. Owing to resource constraints it was not possible to question multiple people at different levels throughout these organisations. This was however achieved in the longitudinal case study (Chapter 6) where over 40 people both throughout DA Ltd and across the group were consulted. Interviews were based around questionnaire responses but also explored their company's experiences with performance measures for product design and development and their plans for the future. One case is included in full in this chapter, with the remaining nine being in

Appendix VI (to allow the reader to concentrate on the output rather than the detailed data). All followed the same format; background and overview, measures currently used and future improvements. Relevant comments from all cases are included as part of the analysis in this chapter.

Ref No.	Sector	No. of employees		No. of NPD projects run[1]	Interviewee Position	Nature of Production
		site wide	D&D			
1	Chemicals	200	100	70	R&D Manager	Mass
2	Engineering	48000	2500	500	Project Manager	Project/Batch
3	Food	300	30	8	Technical Director	Mass
4	Clothing	240	7	40-50	Technical Director	Batch
5	Ventilation	300	12	10-20	Technical Director	Mass
6	Automotive	185	145	255	Program Manager	Mass
7	Adhesives	90	12	10	Technical Manager	Batch
8	Brewing	>300	80	30+	Technical Manager	Batch
9	Instrumentation	200	20	4	Industrial Engineer	Batch/Mass
10	Sports Equipment	400	12	100s	Project Manager	Batch/Mass

Table 5.1: Profiles of Follow-up Case Companies

It is worth noting that the researcher found it difficult to determine the extent to which the performance measures discussed were used in the management of the product development process. Additionally, the importance of the measures to the company and the consistency of their implementation (i.e. all projects or just major projects, cross functional team projects, etc.) was also questionable. Although the researcher did ask questions about these issues, the one visit format precluded an in-depth, independent investigation. To a certain extent, the interviewees' answers had to be taken on trust.

The data was collected on the understanding that it is confidential and would be used only for research purposes.

5.1.1 Auto Systems Inc.

Auto Systems Inc. (AS) designs and manufactures the full range of braking systems for many of the world's automobile manufacturers. It is part of a global engineering group, with manufacturing sites across the world. The company operates under a matrix structure, with 'heavy-weight' cross functional teams assigned to work on projects for different customers. The Program Manager at AS's UK design centre explained how projects are organised; 'we have two types of teams, those working on a particular product type (e.g. brake discs) and those working with one customer'.

The performance measurement system at AS Inc. was designed and implemented by the Program Manager. He firmly believes that 'measures of performance are a blunt tool' and that it is essential measurements are applied only to the areas of performance they are likely to improve. 'Basically they need to be valid to your business, otherwise it is likely that improvements will be made against areas that are not core to the problem and which may in fact cause deterioration in other areas of operation'.

'When we first started looking at measures, we posed the question "what are the important activities that need to be measured in order to ensure that improvements against measures of performance give significant improvement in engineering performance?" We decided that there were three main criteria for this. Firstly, there needed to be a significant amount of resource utilised, secondly there are significant bottlenecks in time and; thirdly the equipment overhead rate is expensive. An additional consideration was that in order to be measured, activities require to have a certain amount of repetitiveness, where the order of magnitude of the tasks and their complexity is largely the same'.

Weekly meetings were held over a period of 6 months to generate and refine a list of performance measures that were relevant and workable for AS Inc.[2]. Initially four were selected but after short term trials, one of them - concerned with measuring the number of change notes over a period - was rejected as being too prone to interpretation. The remaining 3 are listed below.

The 3 most important performance measures they use are:-

- Actual vs. target time for project completion - i.e. schedule adherence where progress is monitored monthly on all projects.

[1] at any one time

[2] One of the primary drivers for formalising the measures of performance was for ISO 9000. However; 'most people had been using measures informally for years before they became a 'buzzword'.'

- Product cost - monitored monthly during design & development. This includes shop floor labour costs and material costs. 'Variance directly affects profit margin as once the contract has been tendered, we have to stick to that price. There are two ways of costing time; use the functional budget for engineering (current practice) or on a project basis. We want to move towards the project basis as it is a more accurate reflection of our activities'.
- Total cost of project - monitored monthly. This includes engineers hours, any purchases and sub-contractor's hours. Otherwise project costs may spiral out of control and affect the potential profitability of the project.

These measures have been used on all projects for the last three years and the system is completely computerised[3]. The Program Manager explained; 'through consistent use of these three measures we now have a controlled view on the product costs, project costs and schedule adherence. All of these are important to us and our customers'. He added; 'continual monitoring of project progress ensures that they are kept under control and there are no surprises'. Interestingly, there is no mention of quality aspects among the top three measures.

Projects are measured by the overall performance of the project team[4] and not by the performance of an individual or function: 'There is no point using measures against people. On the individual level, measures need to be made non-threatening by encouraging investigation of the team member's role to search for improvements'.

There are three levels for AS Inc.'s measures of performance. Firstly, there are the three major measures listed above that are reported through the engineering function and across the organisation via monthly meetings and reports. Getting the message across can sometimes be a difficult process; 'I don't believe anyone does feedback reviews as well as they should, despite the fact that if you don't feed actions into a project it dies'. Secondly, there are additional localised measures used by project team members to monitor their own performance. These are generally only used within the team and don't go beyond project manager level. There are no ideal figures set for these

[3] All that the project manager has to do, is insert the figures.

[4] monitored by the project manager and communicated through monthly team meetings

measures. According to the Program Manager; 'they are primarily useful as indicators to monitor abnormal change or as benchmarks to set targets for future performance'. Thirdly, there are external measures of performance that are based upon interactions with external customers. The exact nature of these depends on the customer and the type of project.

What they want to use in future:-

The issue of measuring performance has been close to the Program Manager's heart for the last few years. Even so he is still cautious about their value: 'As soon as you start measuring, you have to be prepared for unusual peaks in performance as people try to impress. This may be achieved through short term increases in performance or masking of the real figures (e.g. five engineering change notes may be saved up and processed as one - hence the rejection of this measures from the selected list). Either way you get misleading skewed results. The figures but not the business will improve and that is not our aim. Realistically, all that can be done is to treat figures with caution and make their use accepted and understood throughout the company'.

'We are always open to ways of improving the system and in the near future I would like to dovetail the figures from all projects into a coherent system. In terms of additional measures, if I had to choose an area in the product development process where new measures would be most useful, it would probably be the detailed design stage'.

Benchmarking performance against other companies is an area that AS Inc. has looked at in the past. However, they have decided not to pursue this at the moment: 'Benchmarking against other companies can be misleading because the figures can be subjective. For example "what does a three star rating mean?" No matter how close their business is to ours, their processes will never be identical making direct comparison impossible. The only way that it can be done is to normalise measures to reduce bias and manipulation of questions and input them onto a computer'.

On the subject of softer measures such as communication, the Project Manager had this to say: 'Measures of performance must be something you can physically get in your hand. "Communication" is not solid enough - even if you have a feeling about what is happening, it's hard to prove. For example how do you assess the cost of failure if it is attributed to communication? More importantly, communication is the cause rather than the effect so if anything it should feed into other measures'.

The Program Manager concluded by stating; 'estimating things such as total project cost and engineering hours spent on each project are very difficult. In fact, resource management is perhaps the most difficult region of project management and very few businesses are able to achieve it successfully. Take reallocation of resources for example. This is like moving water between buckets: You can change the levels in the buckets but the overall amount of water is the same. Bringing in measures - how ever approximate - can provide knowledge of the process and decisions taken with the support of knowledge are less likely to be incorrect. Once measurements are started, then estimating slowly gets better and better'.

5.2 Comparison with Company Questionnaires Results

To allow the reader to gain an overview of the data collected, summary tables and graphs have been compiled. The reference numbers correspond to the reference number listed in Table 5.1 at the beginning of this chapter. This data is discussed and compared with the findings of the long distance company questionnaires[5].

5.2.1 TOOLS AND COMMUNICATION

The types of tools and techniques used within the companies to assist with product development is shown in Table 5.2.

[5] See Appendix III for a copy of the company questionnaire.

	1	2	3	4	5	6	7	8	9	10	total
Brainstorming	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
CAD, CAM, CAE	✓	✓	✓		✓	✓		✓	✓	✓	8
Concept testing with customers			✓	✓		✓	✓	✓		✓	6
Design for 'x'[6]	✓	✓		✓	✓	✓		✓			6
Fishbone analysis	✓	✓				✓			✓		4
FMEA		✓			✓	✓					3
Internal surveys			✓						✓	✓	3
QFD		✓		✓		✓					3
Process mapping/flowcharting		✓	✓	✓		✓		✓	✓	✓	7
Value analysis	✓	✓			✓	✓	✓			✓	6

Table 5.2: Use of Tools & Techniques

This highlights the popularity of brainstorming, CAD and process mapping. An interesting finding was that despite academics' enthusiasm for QFD, it is not widely used. Within the case study companies, only 3 had used it 'to some extent'. This was backed up in the wider questionnaire with only *25%* of respondents having used it. Another surprise was the lack of use of internal surveys to gauge staff opinion. This is a useful and relatively easy way to investigate a whole range of issues (including current policy and practices, change management, ideas for improvement, etc.). With the advent of electronic intranets, this task has been made even simpler. Internal feedback currently seems to be collected on an ad hoc and/or informal basis, regardless of the size of the companies. Increasingly, firms are using process mapping and/or flowcharting to visibly depict how they operate. This was often introduced as part of ISO 9000 and/or as a directive from head office. In terms of the product development process, process mapping is especially useful to identify where bottlenecks occur and hence where performance measures can help.

The way that the measures are communicated is shown pictorially in Figure 5.1. E-mail is becoming a standard way to communicate - replacing the function of paper memos. Videoconferencing is still somewhat of a rarity, with only 20% of the case participants and *8%* of questionnaire respondents using it to communicate the product development process. Reports and team meetings are the most popular way to communicate

[6] includes assembly, disassembly, manufacture, service, sustainability, etc.

performance measures for design and development and are often discussed at project meetings in conjunction with updates on the product development process.

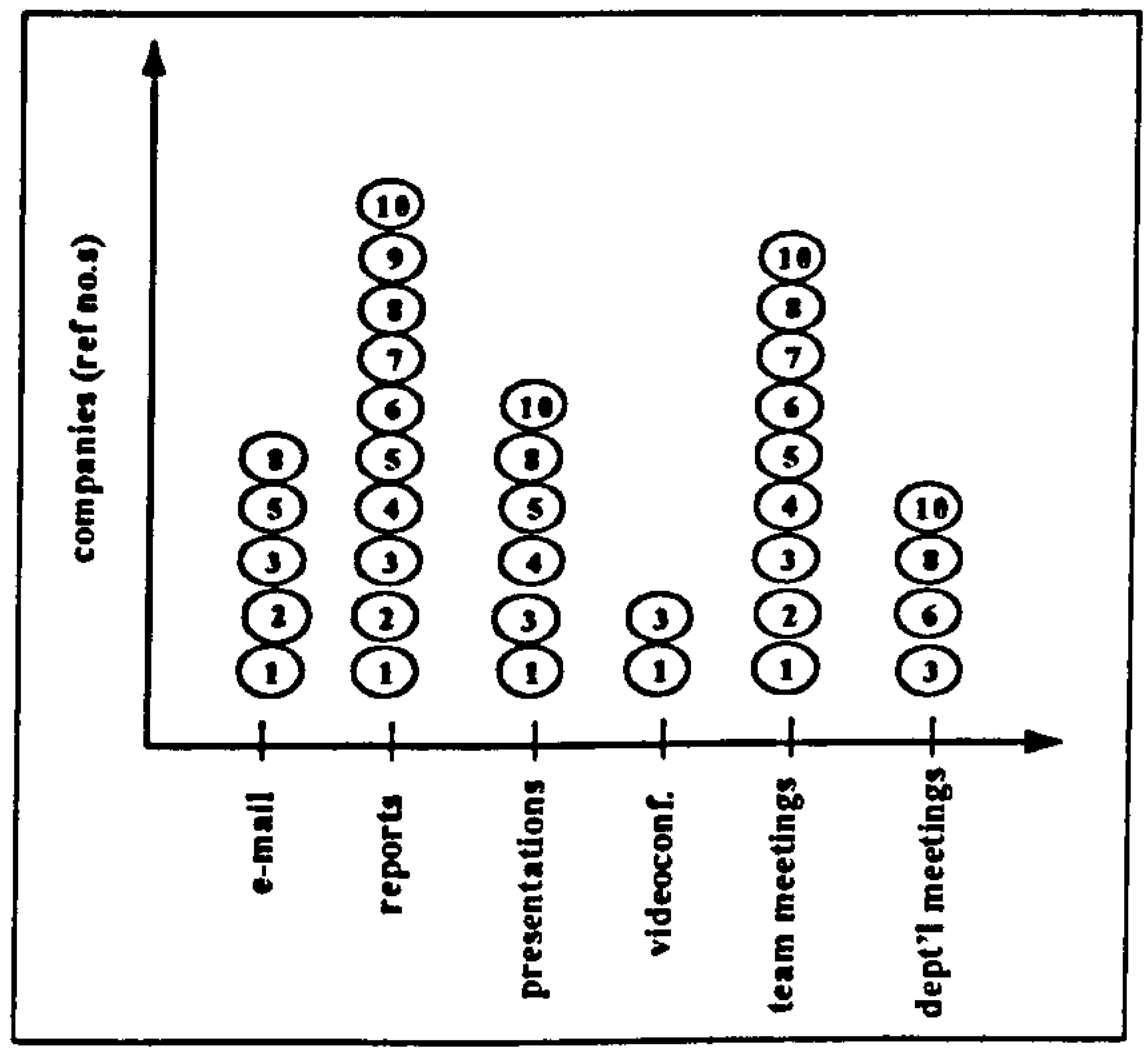

Figure 5.1: Communicating Performance Measures

5.2.2 *MANAGEMENT OF THE MEASURES*

The way that the measures are managed, including who brought in performance measures, who reports and deals with them is summarised in Table 5.3. All respondents used cross functional teams to varying extents and 8 were ISO 9000 accredited. Senior management accounted for nearly all introductions of performance measurement (90%). This was greater than for the questionnaire results (75%). With the exception of 2 (out of 10), measures were collected through a combination of automatically generated information (e.g. as part of the accounting system, ISO 9000 procedures, etc.) and specially generated for design and development. This was also higher than the questionnaire average (66%). A variety of people were responsible for reporting the measures ranging from Finance, IT and individual departments but with project teams taking responsibility in the majority of cases (60%). Again this was higher than the questionnaires (41%). Where they did differ from general opinion was in the introduction of more performance measures. Virtually all stages were mentioned by follow-up case respondents but their most popular answer was to introduce additional measures at the feasibility stage (40%). This contrasts with the questionnaire respondents who considered that the specification stage was where they were most needed.

Ref No.	Co. Name	Who brought in performance measures?	How are measures are collected?[7]	Who is responsible for reporting measures?	Who they are visible to (i.e. who sees them)	NPD stage where more measures would be most useful	ISO 9000?[8]	Cross functional teams?
1	Plastico	Division IT manager	specially formulated	centrally managed by IT	all senior and project managers	feasibility	no	some of the time
2	Global Eng. Co.	Company-wide task force	mixture	project/team based	CEO, team, senior management	all stages	yes	some of the time
3	Petproducts Ltd.	Corporate-led directive as part of ISO 9000	mixture	department/finance based	CEO, finance, senior management	specification	yes	all of the time
4	Seasonswear Plc	Technical Director	mixture	project/team based	team, senior management, finance	prototyping and tooling	yes	some of the time
5	Airvent Ltd.	MD	mixture	project/team based	all; 'anyone who asks'	specification	yes	some of the time
6	Autosystems Inc.	MD	specially formulated	project/team based	all	detailed design	yes	all of the time
7	Glueco	MD	mixture	department based	project team and project managers	feasibility	yes	some of the time
8	Brewmasters UK	MD	mixture	project/team and department based (depending on project)	all	concept design	9002	all of the time
9	Weighdex	MD	mixture	department based	CEO and senior management	feasibility	yes	some of the time
10	Sportsco.	Project Manager	mixture	project/team based	all managers	feasibility	no	some of the time

Table 5.3: Management of the Measures

[7] i.e. some measures were automatically generated from existing reporting information and some were specially formulated, with time spent collecting them

[8] i.e. is the organisation ISO 9000 accredited

5.2.3 TYPES OF PERFORMANCE MEASURES USED

The questionnaire responses revealed that the most widespread measures among the ten companies were the monitoring of the number of projects completed per annum (80%), the number of field trials prior to production (80%), the actual versus target time for project completion (70%) and the number of new products released per annum (70%). The preferred frequency of reporting was almost evenly split between monthly and per project. Scores of those measures used now are plotted along with those that will be used in future in Figures 5.1-5.4. They have been grouped into four categories; cost based (Fig. 5.2), time based (Fig. 5.3), quality/reliability based (Fig. 5.4) and general measures (Fig. 5.5) to aid presentation.

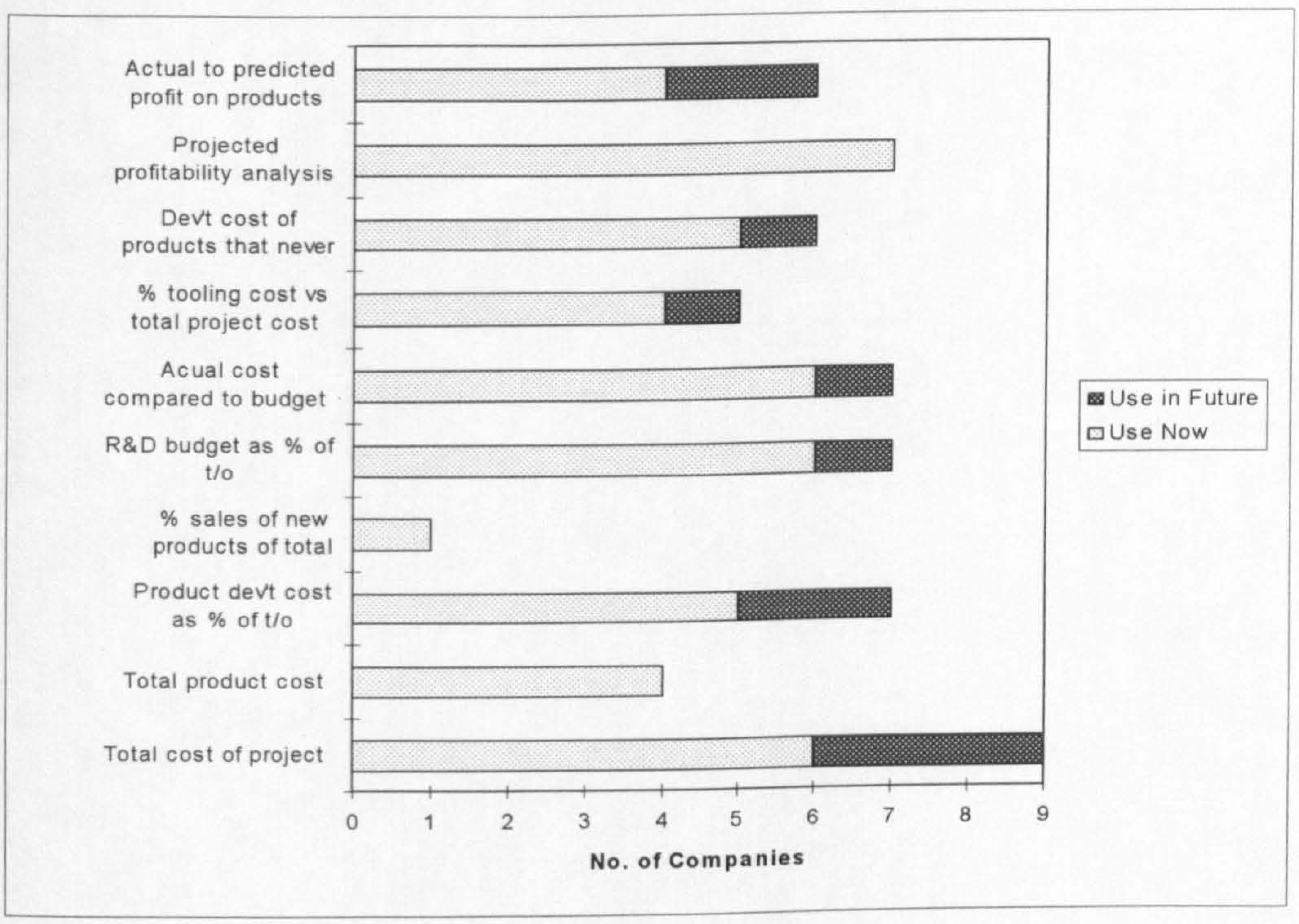

Figure 5.2: Cost Measures

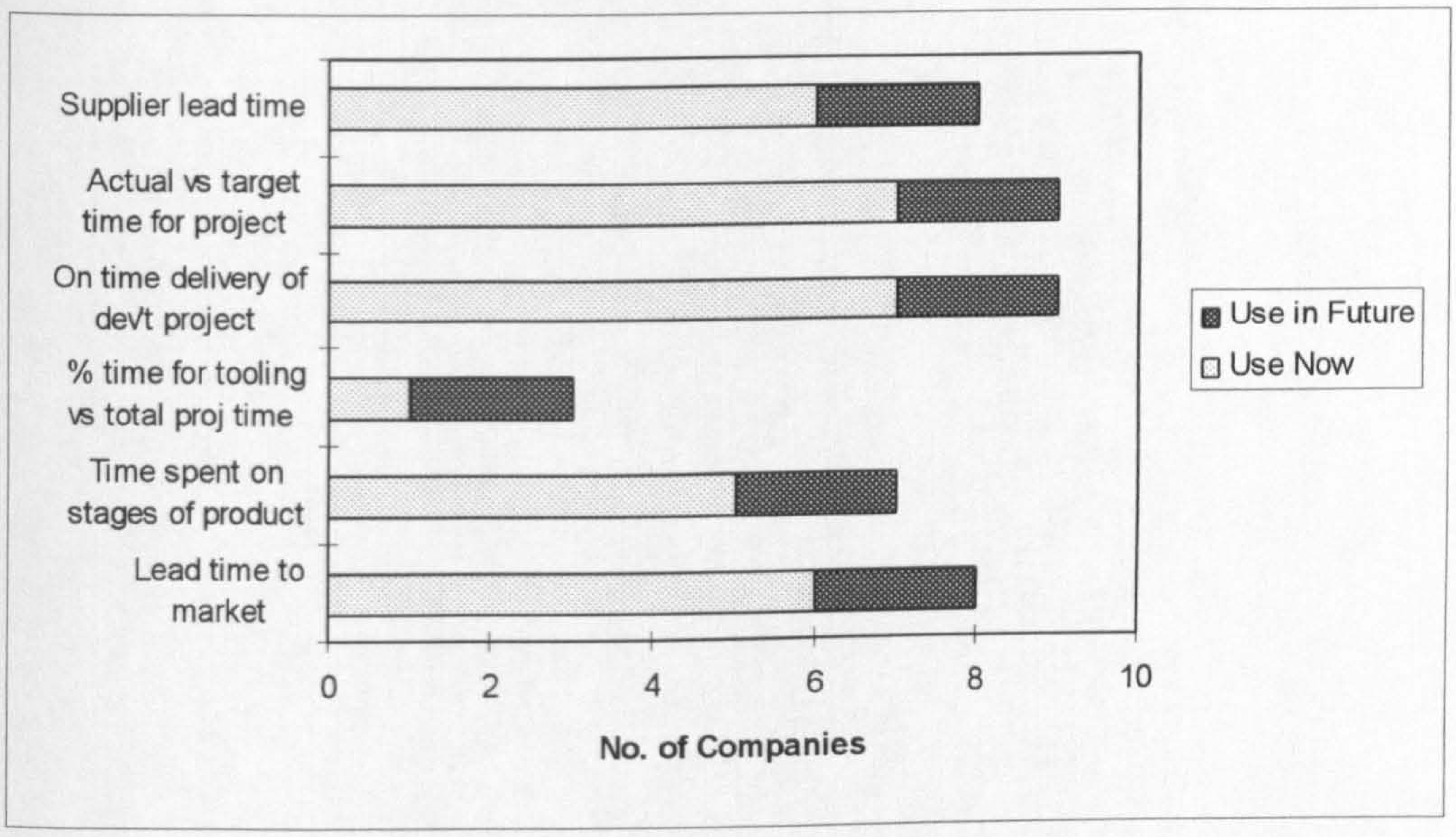

Figure 5.3 Time Measures

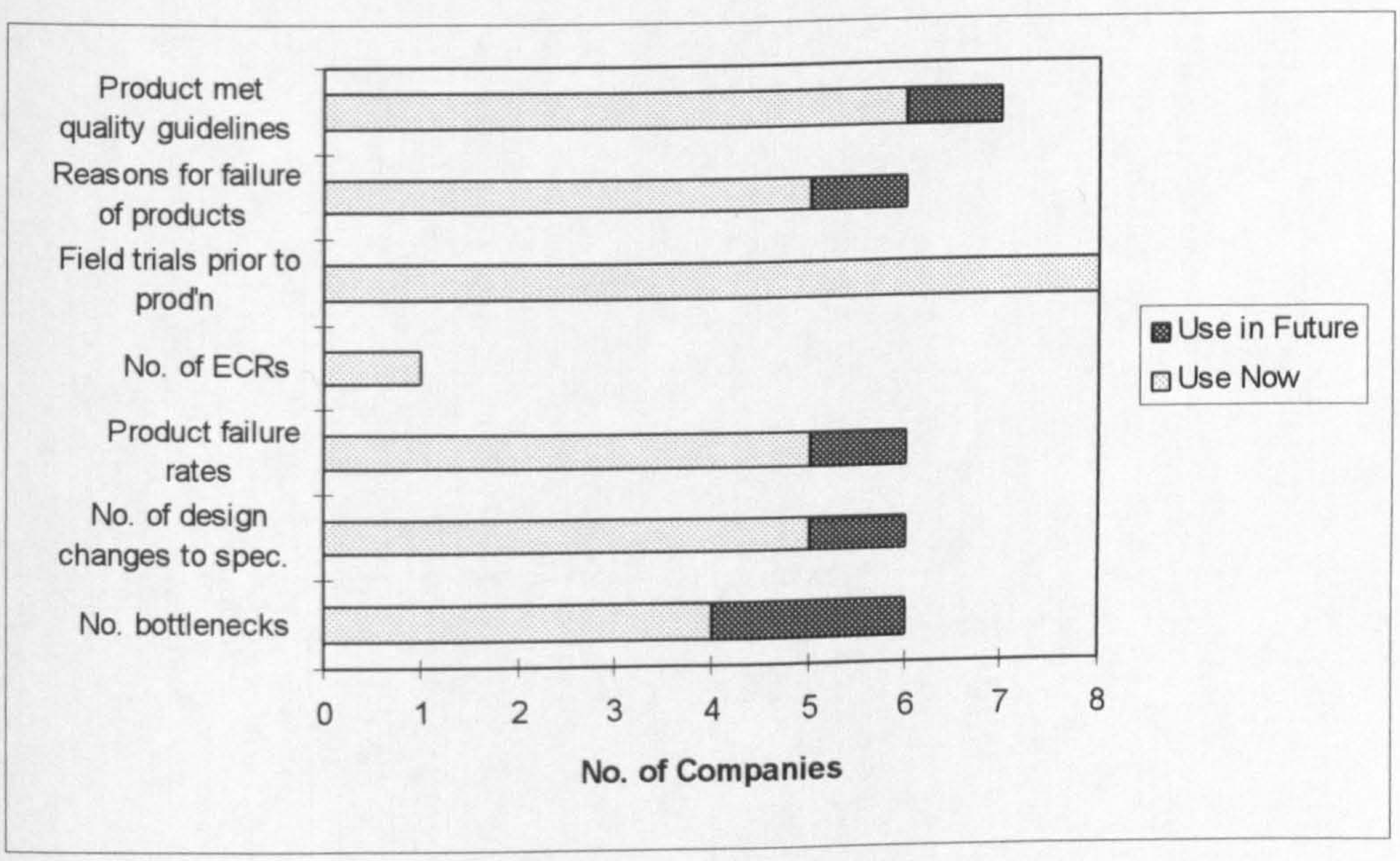

Figure 5.4 Quality Measures

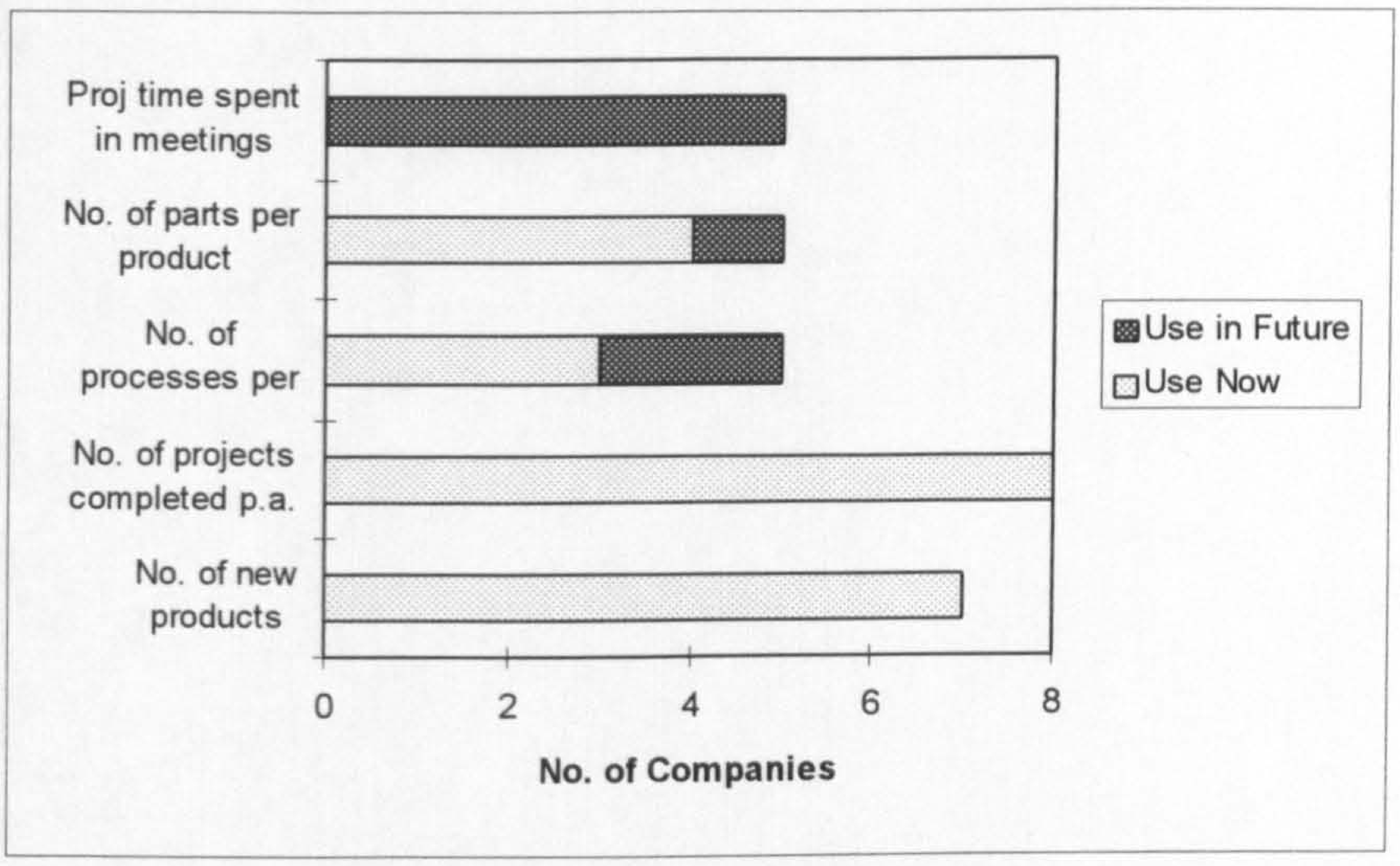

Figure 5.5: General Measures

The follow-up cases allowed the researcher to determine the three most important measures that are currently being used in companies (Table 5.4) and those they would most like to introduce in the future (section 5.2.4)[9].

Time:	**No. of Co.s**
Average time to market	2
On-time delivery of PDP	3
Schedule adherence	3
Cost:	
Total project cost against budget	4
Profitability analysis - performance against objectives	2
Product cost	1
Actual to predicted profit on products	1
Product development cost as % of turnover	1
Margin analysis	1
Quality & Customer:	
No. and nature of ECR's per project	1
Adherence to original product specification	1
Field trials	1
General:	
% sales from new products vs. total sales	1
No. of (new) products released p.a.	3
No. of successful dev't projects vs. total no. of projects	2
Money generated by new products over first 2 years vs. total sales value	1
No. of products taken up (from project portfolio) vs. total no. available	1

Table 5.4: Three Most Important Performance Measures Used

[9] As this data is of a very qualitative nature, it was decided to present it as it was described, rather than forcing it into categories.

This list clearly shows that time and cost are the most important measures - as would be expected. What is surprising though is the lack of quality measures in the top three. Is this because quality-related issues are too difficult to measure or that the companies in this survey leave quality measures to the Quality department or is there perhaps some other reason? This could provide an interesting start point for further research.

5.2.4 *FUTURE USE OF PERFORMANCE MEASURES*

As with current usage of performance measures, differences existed in what was required for future measures across the ten companies. At Plastico, where they have only recently introduced formal performance measurement, the Technical Manager stated; 'we currently have an ad-hoc system, where people monitor their own project time but realistically the results are questionable. Basically, we would like to be able to manage this area more effectively'. He added, 'idea generation is another area that they would like to improve on. It would be very useful if we could track the number of ideas logged in new product development and compare it to the actual percentage realisation of projects...I suppose what we are really looking for is long term innovation measures. Most importantly we need to ensure that long term innovation is not adversely affected by short term results from our existing performance measures. I think this is a real danger. It would be very beneficial to have a macro view of the progress of all projects in terms of schedule, performance, etc., on one screen. We want to learn from the customer and train people in the right skills to understand customers and get customers to express their needs more accurately'.

At Global Engineering Co. they are more advanced, with performance measures being integrated into the new product introduction process. However, according to the Project Manager, there is still room for improvement: 'There's no hunger from top management to receive measures but at the same time, the team may get asked to show them. Their use is more reactive than proactive at the moment'. He added; 'we are not satisfied with the number of measures currently used, we need more measures of performance to address efficiency of the process and ones to give early warning of potential problems, etc. They may vary by stage of the process. The major barrier to this is the lack of systems in place to support more measurement. The company is increasingly aiming to automate data collection because, as the number of projects increases, the cost of data collection becomes more significant'.

At Petproducts Ltd., the Technical Director sees performance measures continuing to play an important role; 'our main measure has been and always will be (for the foreseeable future) growth. The key for us over the last 5 years has been to define additional critical measurements and find ways of assessing this performance in a pragmatic manner. I believe we have achieved this. However, as to whether we need *more* measures, I'm not sure. If they were obvious, we would implement them tomorrow'. If Petproducts were to introduce any additional measures, he considers they would be most useful in the specification stage of product development. He added; 'unlike defence contracts, etc., where you can relatively easily define hard measures of performance, we have some difficulty setting appropriate values for some of the aesthetics and other features to be incorporated into the design specifications. What we are therefore trying to do is to compile a list of projects that have proved to be useful in terms of specification and use these as a pro forma for future specifications. As the designs evolve we then assess our ability to deliver designs against these specifications as part of the ISO procedural reviews'.

At Seasonswear Plc, the Technical Director explained that; 'there are currently no strategic level measures to compare the company divisions globally but I feel it is only a matter of time before this happens'. He added; 'we would very much like to use a computer package that is capable of visually mapping times (planned against actual) of all our projects on one sheet. We have looked around but there doesn't seem to be any off-the-shelf packages available that are able to do this. We may eventually write a bespoke package in-house but this could take some time. We would especially like a 'what-if' scenario to help us schedule activities to avoid bottlenecks around the constrained activities'.

At Airvent Ltd., there are several improvements that the Technical Director wants to make to the measurement system in future; 'we are a very engineering-led company. While we want to retain this focus, we need to increase our consideration of the marketing aspects. This will be built in to the 'contract' (product specification document). The contract also needs more information on product development cost (including revenue spend, capital cost and labour) against turnover. In addition; handling and transmitting data is a big issue - improving the way we do this is a high priority area....In terms of additional measures, if I had to choose one stage, new performance measures would be most useful at the specification stage.' The most visible change that the Director has already started working on is to introduce checksheets into all stages of the product development; 'I believe that checklists are central to project control and what we are currently aiming to do is integrate them into the ISO 9000 procedures to make them more workable. This will enable the monitoring of design change controls to be formalised, which in turn will help us to complete projects more quickly'.

At Glueco, the Technical Manager wanted to focus on *seemingly basic* goals; 'the costing of projects is extremely difficult (especially for projects of indeterminate duration) but we really need to get a better approximation - its currently very much based on gut feeling. Costing includes purchase of equipment (e.g. laboratory and measuring equipment) but the vast majority of the cost is the time of the development chemists. We are currently trialing the use of time sheets to establish how many hours are spent on each project. However we are encountering the usual problems of people feeling like they are being tested and tracked and others complaining that it's a waste of time or simply forgetting to fill out the sheets'. He added, 'another performance measure that we would like to introduce in future is the number of new products released per annum against the increased sales generated. This can be difficult to implement in some cases. For example, a new grade of the same adhesive is given a different number - but is it a new product? We don't currently review projects once they are finished - teams disband and move on to the next project. I want to remedy that as you can learn a lot from previous experiences. In future, we plan to build feedback into the ISO 9000 procedures. Statistical analysis of reject material needs to be carried out on a regular basis with the results being fed-back into the design phase. In the past we have very much worked on an informal communication basis. This is becoming harder since we have expanded across the world. We are basically learning to become a multinational company, starting with the use of cross functional teams on joint development projects. At the moment this involves lots of communication by fax. Obviously in future we would like to expand our computer network to encompass all activities and introduce videoconferencing to assist with projects. This will have an impact on the measures we use for product development but at the moment we are not entirely sure how to approach this.'

At Brewmasters, the Engineering Project Manager had many ideas for future improvements. He stated; 'we need to find a way of using our resources more effectively. I would like to formalise suggestions for future improvements (that could be fed back into the procedures)'. He added; 'if possible, I would like to see review stages on all projects. This may not be realistic, owing to the very tight schedules but the lack of reference points makes it difficult to verify what happened when'. They currently don't do in-depth analysis on all parts of all projects as 'it doesn't warrant the time'. There is more of an emphasis on financial reviews rather than engineering but the introduction of post-project reviews 'could be very beneficial'. He added, 'Brewmasters does not currently have a framework that pulls all the measures, in all areas together i.e. R&D, product development, manufacturing, marketing, etc. If this information were available, it would be a very powerful strategic tool'. He concluded by stating; 'basically, we want to introduce more effective measures but they must be the right ones. Any new measures must have a proven payback'. The Director of Research had a slightly different perspective. He stated that the biggest improvement would be in more meaningful consumer information: 'Consumer testing is *the* measure for us but it is also the weak link in the chain. Deriving information from consumers which can be used for product development and improvement is critical for all FMCG companies. Research is currently done externally to minimise the risk of biased responses. However, there is still room for improvement'. He reinforced what the Project Manager had earlier said by stating; 'we would only introduce more measures that would make a direct, positive contribution to decision making and the product development process'.

At Weighdex, the Industrial Engineer had many ideas about improvement: 'There is definitely room for improvement in the way we use measures. Currently, we don't look at the 'big picture' when designing and developing projects. We don't know the true cost of product development. At our level, the figures are shrouded in mystery and I'm not convinced that the figures are accurate even at Director level'. He added; 'the main thing holding us back is deciding on the best way to proceed. Commercial time pressures always mean that you need to complete the next project before you can start looking at improvements and of course this often means that changes get delayed'. 'Measures at the feasibility and concept design stages of projects would be very helpful. This could include; parts count comparison of new design against old, the degree of commonality with other products in the range (to encourage a reduction in variability of parts) and ease of manufacture. I am fairly sure that we have the information to do this but we do not currently link it together. I don't think we need fancy software tools to improve. For a start, we should spend more time at the end of projects reviewing mistakes to prevent problems reoccurring. On a more basic level, we need to gather as many people as possible into a room with a large piece of paper and brainstorm what we would like to see happening'. As Weighdex has grown, the systems and procedures have struggled to keep pace. The company has changed from an almost 'family environment' into a medium sized business in the space of a few years.

In terms of future improvements, the NPD Manager at Sportsco had this to say; 'I would like to see more performance measures at the feasibility stage of product development. Better market information would be the biggest improvement to input into the product specification. Of course this is very difficult to achieve. Market research by an external company is very expensive and often too late. In addition, as we are a global company, what they find in one country may not hold true elsewhere. We know what is selling through sales figures and customer reaction to our products through field trials, but this alone is not enough'.

In general, the follow-up case companies were more advanced in their awareness of and use of performance measures for design and development than the questionnaire companies as a whole. This is perhaps to be expected, as those who agree to participate in studies of this nature have already taken the first step to improvement.

5.3 Summary and Implications of Follow-up Cases

The follow-up cases provided a very rich area of data collection. Of the ten participants, eight had been directly involved in establishing the performance measures in their organisation. This greatly assisted the researcher in appreciating the range of challenges and problems associated with designing and implementing a system that covered situation-specific circumstances. While the emphasis remained in an engineering environment, an appreciation across a range of industries was obtained. This encompassed the food, textiles, chemicals and a variety of engineering industries.

Without exception, all companies want to improve on their use of performance measures. The message that came across loud and clear was "we are not satisfied with our current performance measurement for design and development but we don't know how to improve without incurring major costs and spending time setting up a system." The cases also revealed the increasing importance and impact of globalisation on companies; all ten were parts of multinational organisations. This 'world view' presents new problems and challenges when attempting to set appropriate and meaningful measures across the company. Issues that will need to be addressed include language (one common language or translations), culture (what is the extent and implications of culture on training material, procedures, communication, etc.) and interpretation (will existing terms and practices be misunderstood, is there a common understanding of the organisation's goals, etc.).

As would be expected, the level of sophistication and progress in implementing performance measures varied across the sample. Some are currently operating with a fairly basic set of measures that monitor the overall picture of time, cost and quality (e.g. Glueco and Weighdex) whereas others (such as Petproducts and Autosystems) have a more comprehensive set of measures. There was a varying emphasis on the type of measures used according to the industry and the marketplace. For example cost is insignificant compared to time to market in the case of Brewmasters. If they hit on a winning formula, the returns far outweigh the investment but they need to be first to market to gain maximum market share. Similarly, with Glueco the emphasis is on time to market. In the case of Petproducts, however, new innovations are of lesser importance. Here, ensuring that the new product adds to the company's overall profitability is the most important measurement as continued growth is a prime business directive.

It appears that the ideal mix was a combination of hard and soft measures. Hard measures (i.e. quantitative values) were supplemented with a corresponding set of soft measures using techniques such as mail surveys (using e-mails and memos) or telephone conversations. The particular value of soft measures lies in identifying problems. They are also useful as benchmarks to replace hard measures where they are not comparable between one organisation (or division) and another because of differences in, for example, product development stages or processes. They can be used to gauge opinions or obtain an overview of the situation only. 'Soft' questions such as 'are you satisfied with the product development process on a scale of 1-5' can be used to compare across organisations and industries. As should be the case with all performance measures, results should be treated as decision making aids rather than absolute answers owing to differences in product, process or market complexity. Even so, within a company, soft measures give managers the opportunity to assess the climate among employees and customers on a non-personal level. Soft measures were being used to varying degrees at Seasonswear, Brewmasters, Global Engineering Co. and Autosystems.

This leads on to the associated assertion that tools and techniques are not as important as getting the message across. This may seem obvious but companies have fallen into the trap of introducing software systems (such as videoconferencing or 3D CAD) or a technique (such as QFD) and expected to see swift tangible improvement in product development results. Even when adequate training is given, these tools and techniques are unlikely to make a significant difference unless the project team has a shared understanding of the meaning of the final output and/or a common goal. As stated by the Industrial Engineer at Weighdex; 'I don't think we need fancy software tools to improve...we need to brainstorm what we would like to see happening'.

Some of the companies are affected by strategic measures from corporate headquarters e.g. Economic Value Added (EVA) and other 'shareholder-friendly' measures (Global Engineering Co.). EVA in particular is a classic case of a compound measure that aggregates data to provide an overview for senior management and executives. These measures may be out of step with the operational measures advocated by designers and engineers (owing to their exclusion of non-financial factors) but somehow have to be accommodated.

One of the most difficult but important measures is the time taken for product development. Measuring engineers' and designers' time using time sheets for each project is an unsatisfactory but commonly-used method. It gives a 'ball park' figure as an indication of how many hours are spent on a project but it is unpopular and can be misleading and open to interpretation. Some performance measures were monitored throughout the process; e.g. the cost of project, the lead time to market (including any slippage), whereas others were needed at specific stages e.g. field trials and product failure rates.

What was perhaps surprising was the lack of consistency in the application of measures, together with the fact that in some cases results are not fed-back to Design and Development (even though managers want this to happen). Most of the companies had formal written information on performance measures available but it was either dispersed across several departments (and data formats) or held on one manager's computer. One major challenge will be to unite all such data onto a central (networked) database to allow for greater visibility.

During this investigation, it was not possible to determine how all of the measures used were calculated. However, this is clearly an important issue and could be the subject of a follow up study as part of further research in this area. Other opportunities for further research are discussed in Chapter 8.

In terms of future measures a common theme runs throughout in that the companies are now looking for ways to systemise performance measures. Most are finding that although measures are now established, they need to be fully accepted and systemised to work at their best. This will involve both extending consistent use of existing measures across all projects (and all divisions) and introducing additional complementary measures.

5.3.1 *VALUE OF THE FOLLOW-UP CASES*

A. The main value of the follow-up cases lay in the extra detail that they provided and their ability to surface issues that a questionnaire cannot elicit. The questionnaire responses were used as a basis for a deeper exploration of the issues and a discussion of their hopes for the future and the restrictions that are hindering implementing the measures they would like to use.

B. The cases provided the opportunity to discuss the use of performance measures in practice and across a range of industries. This included factors such as design and marketing constraints, communication problems and supplier relations.

C. The researcher was able to determine why certain measures were used through meeting the people who established performance measurement systems in their companies.

D. The cases allowed for a comparison to be drawn with the questionnaires and longitudinal case study, hence forming triangulation of the data.

E. The cases provided an input to the 'Basket of Measures' for the Implementation Framework (see Chapter 7).

F. Discussions with the companies revealed that there were opportunities for further research in this and related areas.

CHAPTER 6

6. PLANNING FOR PERFORMANCE MEASUREMENT: A LONGITUDINAL CASE STUDY

> 'To be competitive today requires continuous improvement in quality at the same time as reducing manufacturing costs and purchased material costs. This has necessitated radical changes to our designs and our design and development process. There have been many detailed changes but the most significant in reducing project time scales was the move towards Concurrent Engineering. We have recognised for some time that we need to measure our progress, especially in the early stages, if we are serious about benchmarking improvement.'
>
> Senior Technical Manager of Domestic Appliances Ltd.

This chapter takes the reader through some of the experiences in the Design and Development departments at Domestic Appliances Ltd. over an 18 month period. The case study led to the formulation of a set of performance measures to assist with design and development projects. Throughout the project, working space was provided in a colocated team area and we[1] had the full backing of top management. During this time, the researcher played the role of a *partial participant observer* i.e. gave advice on the use of performance measures where appropriate but largely observed the workings of the project team. The data collection approach was through questionnaires, semi-structured interviews, observation and document searches. Two other subsidiaries of the same group were also contacted, together with the group head office in the United States, to identify areas of overlap and evaluate opportunities for synergies. The way that product development projects are organised is outlined, as are opportunities for improvement in the way that product development is organised. The development of the a set of performance measures for DA Ltd. is then described. The chapter culminates with an illustration of the accompanying spreadsheet to manage the measures.

A colocated product development project formed the main focus of the case study; its main objectives being:

- To understand the way in which product development is carried out at DA Ltd.;

[1] Myself and two other researchers from Nottingham University; Badr Haque and Hamid Riahi.

- To determine which measures are currently used during design & development and frequency of their use;
- To identify areas for improvements (to be carried out by the project team and researcher) for use on subsequent projects;
- to identify any areas of potential conflict in introducing the new measures and attempt to address these;
- to implement the new measures and analyse their impact on subsequent projects;
- to test out the implementation framework and workbook to assist with measures for product design and development (see Chapter 7).

6.1 Company Overview

DA Ltd. is part of an international engineering group. Three of these companies, including group head office, were visited and are briefly described below. Aspects of their product development activities, team working and performance measurement are described, with key attributes summarised in the following table:

	Use QFD	Colocation	ISO9000	D&D PMs[2]	Email	Intranet
DA Ltd.	✓	✓	✓	✗	✓	soon
Southern Works	✓	✗	✗	✗	✓ (some)	✗
Complementary Apps	✓	✓	✓	some	✓	✓
Group Head Office	✓	✓	✗	some	✓	soon

Table 6.1: The Case Study Group Compared

6.1.1 Domestic Appliances Ltd.

Domestic Appliances Ltd. is a medium sized company that designs and manufactures a range of 'White Goods'. The company enjoys a healthy market share in the UK and is currently coming to terms with new opportunities and threats from the European Market (i.e. a larger, more diverse market but with the threat of cheap imports). There has been a company-wide training programme in Concurrent Engineering, mainly focusing on colocated, cross functional teams used on major product development projects. They have also used tools & techniques such as teambuilding activities, Design

[2] Design & Development Performance Measures

for Assembly and QFD; and people are generally familiar with the term 'Concurrent Engineering'. Synergies across the group include shared technology and training materials.

Understanding the complexities of the product development process (or the New Product Introduction process as it is known at DA Ltd.) was central to this research. It is based on six steps; feasibility, design & development, implementation, production, a 90 day review and a 12 month review. Specific points of interest in the product development process are mentioned below.

- The feasibility stage has in the past been the role of Marketing only. On major new developments, 'what-if' studies are carried out by an independent market research company. Feedback is given to Marketing who then write the market specification. On smaller projects, Marketing use their own product knowledge to write the specification. They then pass this on to the product development teams.
- The length of the New Product Introduction (NPI) varies between 6-18 months depending on the complexity of the project.
- Product costing is carried out at stage 1 by Production Engineering. However, although parts represent a significant percentage, this is only one element of the total project cost. Other areas such as Design and Development are currently not costed as 'people won't be tracked'.
- Designers do not currently have much direct customer contact as they are more likely to deal with the retailer rather than the end customer. Customer feedback can also come via the Home Economist.
- Design & Development feel that full commitment to NPI projects by other departments is often lacking.
- 3D CAD was introduced in late 1996. This allowed designers' drawings to be translated directly into CAM instructions by Tooling for the first time.
- The three performance measures that are used on development projects are; on-time delivery of the project, supplier lead time and actual to predicted profit.

Chapter 4 (Section 4.1) contains additional information about DA Ltd.'s product development process.

6.1.2 SOUTHERN WORKS LTD.

Southern Works Ltd. (SW Ltd.) manufacture the designs that DA Ltd. sends them. The Plant Manger stated that 'being a satellite plant can be a problem in terms of communication and coordination'. Closer contact has been achieved in the last couple of years through the introduction of communication via email and regular videoconferencing sessions. Price is one of the most important issues for SW Ltd. because of the highly competitive nature of the White Goods market. As stated by the Manufacturing Manager; 'we are a low cost manufacturer, so ensuring that costs are kept to a minimum is of prime importance'. Total product cost (including tooling, plant & equipment) and monitoring of costs is estimated by Manufacturing but all others are calculated at DA Ltd.

Time is also a very important factor in the production environment. Any delays in the schedule can place a squeeze on pre-production time, as launch dates are usually 'cast in stone'. Owing to tight schedules and resource constraints, project planning has been a source of tension between Design and Manufacturing in the past. The Plant Manager stated; 'front-ends of projects have been under-resourced but they then get a beer belly about 3 months before production starts'.

The Plant Manager feels that the increasingly cut-throat nature of the market is being achieved to the detriment of quality. He stated; 'some new entrants are going for the lowest end of the market. They sell basic units that do not even have the European quality approval mark directly to DIY stores. It is almost impossible to compete with their prices'. He continued 'to make a fast buck, you don't need to worry too much about quality or satisfy the customer, only lasting long term concerns such as ourselves do that'. He wants to ensure that their quality continues to be consistently better than most of the competition and welcomes the greater use of performance measures to help achieve this. He added; 'we listen to our workforce because they are also part of the market'.

6.1.3 COMPLEMENTARY APPLIANCES LTD.

The situation at Complementary Appliances Ltd. (CA Ltd.) was outlined by a Senior Project Manager who had worked in design and development for 15 years. The company designs, develops & manufactures White Goods that complete the range for the group. Some designs are shared with DA Ltd. and positioned not to be in opposition to them. They have faced similar challenges through the opening up of the European Market and are now starting to make inroads especially to Southern Europe. They too have embraced the principles of Concurrent Engineering, which is now a well known term throughout the company and operate product development projects using colocated teams. Full scale colocation would be 'desirable' but resource constraints have precluded that option for the moment.

Training has been carried out in QFD but they prefer to use Quick Market Intelligence meetings which form a similar function. This ensures that feedback is gained from executives, retailers (customers), shop floor and middle managers. This technique has worked well for them. Large scale parts standardisation has been carried out and tools such as DFA have been looked at but the Project Manager considers that; 'we have problems applying them consistently and still need to learn more about them'.

Current performance measures used consistently by product development teams are;

a) achievement to schedule,

b) achievement to product cost and

c) achievement of the target for reduction of service calls (typical figure would be to reduce by 5%)

The project manager would like to add to this list and felt that 'we spend too much time on setting schedules and not enough on working towards them'.

CA Ltd. have significantly reduced time to market for new products after a major push over the last 3 years. The major contributors to this have been; eliminating the model build stage (through better visualisation using 3D CAD and rapid prototyping models) and reducing the number of sign-off signatures at each stage of the product development process (from 14 to 2). Tooling time scales have also been dramatically reduced through closer working with the supplier and bringing forward the design freeze.

Engineering time (in terms of time spent in design and development) is not costed 'as this would incur a high administration cost'. Additionally, designers can be working on several projects at any given time, making time sheets very difficult to complete. CA

Ltd. is currently considering an investigation into determining the value of a new design to the business in terms of increased market share. This will then be used as justification for future projects.

Project feedback on an informal and formal basis is carried out after every project. At the formal debrief to executives, issues and challenges faced are presented by each manager under common headings and discussed. Significant results are then fed back into the existing product development process.

6.1.4 Group Head Office

A two day visit was made in Summer 1996 to the Group Head Office in the United States. The site, which designs and manufactures complementary White Goods, is very large with almost 1000 people working in Design & Development alone. They are the market leaders in their field (with many products sold under store brand names) and keep the price of their products low in an effort to keep out new entrants[3]. Over 100 new models were launched in 1996, with many more variants[4]. The Engineering Department has overall responsibility for product development and two representatives (one senior and one middle manager) involved in product development were interviewed during the visit.

Colocation has been in place now for four years and according to the Senior Engineering Manager, 'it took one full year to establish'. Owing to the large plant size, considerable time was wasted in organising meetings with the old dispersed departmental structure. This resulted in the CEO calling for open offices. Walls were pulled down, a matrix structure was put in place and colocation began. The manager continued; 'so what we have now is total colocation - not just project-wise. This allows for a totally flexible environment'. One by-product of this matrix structure is an increase in finance personnel to manage the individual cost centres. The average core team size is 12-14 members. The Senior Manager explained that the way a project works is that

[3] The price of their appliances in the US market are exactly the same as they were 10 years ago.

[4] Customer service is quite extensive. Marketing surveys are carried out 'very regularly'. Additionally a special answering centre operates 24 hours a day with calls available on a freecall 800 number. Up to 60,000 calls per week are received and weekly reports are generated from this. Engineers and designers periodically listen in on calls.

the team 'huddle together for coordination and go out for expertise. They act like a self-managing neighbourhood association'. Up to 500 product development projects can be running at one time (including variants and facelifts). Many benefits such as; faster decisions[5], better quality decisions, focused effort, team ownership and reduced functional barriers have already been gained. This has reduced the cycle time by 10-15%. They have also experienced some down sides such as diversification of standards; 'certain things such as CAD drawing versions are more difficult to control now', procedures are not always followed and core technical skills have 'dipped a little'. To overcome the versioning problem, documents are being transferred to electronic format and in future will be managed using groupware software. The Middle Manager had a less rosy picture of colocation; 'it's a huge bureaucracy. Colocated teams don't transcend divisions as they do on paper and basically there is resistance all round'.

The main bottleneck experienced in product development is at the feasibility stage, specifically with 'firming up the marketing concepts and finalising the design freeze'. Late design changes also still occur. Both managers agreed that specification change and lack of communication were the main causes for delay in bringing new products to market. They used to have sign-offs by senior managers which acted as tollgates at each stage of the NPI process but they 'blew them all away because they are too time-consuming'.

The NPI process used across the group originated at Group Head Office. At this site alone, over 2000 people have gone through NPI training. The Middle Manager was somewhat skeptical of the importance of the procedures and commented; 'do we really have a design process? We are going to introduce design record books in the near future to firm up project activities'.

Joint development documents for projects are currently formulated in isolation from their sister companies and little design synergy takes place. In fact, at present there is little overlap between the organisations in the group. The owners decided to take a 'hands-off approach' to management, with the budgets and strategic direction being the main areas of interest. The Senior Manager stated that 'the main contact we have is

[5] The manager said; 'I spend 2 to 8 hours per day on email. We are light years ahead of other parts of the group'.

through technology transfers rather than strategic or operational collaboration'. At the beginning of 1996, a Global Technology Manager was appointed to ensure a smooth interface with affiliate companies (for CAD systems, data transfer, email, videoconferencing, etc.) Training is the one of the few areas that is carried out on a worldwide basis, with training material being sent out from the head office.

Interestingly, some of the design work for new products is now being carried out in India 'because it is much more cost effective for us. We have a very good relationship with the guys down there and regard them as an extension of our design office'. This contrasts with the trend of many large organisations to subcontract manufacturing to more cost effective areas of the world but retain the design element.

They have used QFD 'for years' but it has never been fully accepted or used to its full potential because 'frankly it is too complicated and not worth the effort'. BPR and Quality Circles have also been used, together with Taguchi, FMEA, DFx, Value Analysis, and finite element analysis. The Senior Manager added; 'we did BPR two years ago - as far as I'm concerned, it is closely related to NPI'. They have ISO 9000 accreditation and are involved with six sigma: 'We are aiming for 3.4 defects per million by the year 2000'. The CEO personally endorsed six sigma and brought it is as a company directive that all employees receive training. This directive has since been extended to all European subsidiaries.

In terms of performance measures, the Senior Manager is more than happy; 'we measure well - we live and die by the numbers'. Measures include cash turnover, scrap, rework, lost sales, number of failed projects, change volume 'number of new parts' and total part count. These are all carried out on a monthly basis. No details were provided on how these were calculated[6].

6.1.5 PERFORMANCE MEASUREMENT ACROSS THE GROUP

Use of performance measures varies considerably across the group but there appears to be no pooling mechanism to communicate successful and not so successful trials at the individual sites. CA Ltd. appears to be the most advanced of the four in terms of the consistent use of a set of product development-related performance measures. The only

[6] As the senior manager's time was limited, it was not possible to probe each answer.

areas where the group seem to follow the same procedures is in the basics of the NPI process and training information.

6.2 Colocation

Colocation has been used at DA Ltd. since 1993. Initially it was seen as synonymous with Concurrent Engineering and the first full time colocated project was set up as an example of putting CE principles into practice. Top management support and major resources were assigned and new space created in the Design and Development area. It was a major project, lasting 18 months and looked at developing 20 products in a family. The specific aims of the project were to;

- achieve a batch size of 1, quick testing and flexible lines,
- minimise parts/fixings,
- maximise features and minimise costs,
- use Design for Manufacture,
- use standard components,
- achieve late differentiation (through use of a standard platform) and
- use supplier knowledge and improve quality aspects of product development.

One team member commented; 'we have shortened project time scales and broken down barriers by using Concurrent Engineering'. One of the main successes of Colocation 1 was that the team reduced part variability for the product by 62%, yielding significant cost savings. By the end of the project, the team had managed to save over £2m over the whole product range.

6.2.1 COLOCATION 2

The Colocation 2 project[7] was the main focus of the case study. The team was formed in April 1996 and contained representatives from the main departments involved in the NPI process i.e. Design, Development, Tooling, Quality, Production Engineering and Purchasing. They were provided with some team building training and briefed on the

[7] So named because it followed on directly from the first full time colocated team.

design requirements and written specifications, with initial industrial design drawings being available for discussion[8]. The major targets of the project were to;

- improve the quality of product construction,
- reduce costs and gain productivity improvements to product construction and
- reduce current NPI process time.

There were several subsidiary objectives of the project: Firstly, to design a product range that will reduce the cost of manufacturing compared to the previous generation, with specific targets for component costs and labour assembly. The second consideration was to eliminate any field reliability or production quality problems found on the existing range. Thirdly, it is a requirement to design for ease of disassembly in anticipation of future legislation with respect to disposal of products and possible 'product take back'. Finally, the ergonomics of the design to provide ease of use for the customer. Listed below are the major project activities:

1.	Team Selection
2.	Write Project Brief and detailed Marketing Specification
4.	Brief team on project (and collaboration with Nottingham University)
5.	Teambuilding training
6.	Specific design tools training
7.	Arrange team facilities and communications
8.	Arrange regular team progress meetings
10.	Conduct cost benefit analysis
11.	Record data for performance metrics
13.	Design Reviews
14.	Detail drawings and schedules
15.	Tooling
17.	Pre-production evaluation
18.	Production

Table 6.2: Colocation 2 Project Activities

The area of major interest for this thesis was the introduction and implementation of performance measures to help manage the project through the design and development stages. This is described in section 6.3.

6.2.1.1 Colocation 2 Achievements

The Colocation 2 team achieved its main objectives of reducing the number of parts and product cost. A breakdown of their savings over a previous model were as follows:

[8] The team were also provided with detailed training from the University of Nottingham on CE.

	number	cost
BOF parts[9]	14%	34%
Factory parts (pressings, etc.)	57%	25%
Fixings	28%	0.5%
New model vs. old	21% less parts	39% cheaper

Table 6.3: Colocation 2 Savings

See Appendix VII for opinions on the effects of colocation at DA Ltd. (in terms of communication, problems and achievements).

6.2.2 General Issues with Colocation

Several issues have arisen since colocation was started at DA Ltd.:

- It was important to gain top management commitment through on-going interest and support throughout the project. The team leader felt that the problem lay in commitment from department heads - 'the team members are being torn both ways and input from them now is crucial for our project'.
- The Colocation 2 team decided at a very early stage not to have regular formal meetings. Everyone agreed that these were often unproductive. Instead, members were asked to visit the colocation area on a regular basis to keep up-to-date on latest events and to be available when called on the telephone.
- The Project Manager from Colocation 1 felt that designers should be encouraged to build up their own schedules as 'this takes a potential error out of the chain'. The software now exists to co-ordinate schedules at several different sites.
- The Quality Manager felt that quality procedures need to be updated to fit in with Concurrent Engineering. He remarked that 'Colocation 2 should review the procedures to see what changes need to be made to make them more project based rather than purely functional'.

6.3 Formalisation of Performance Measurement

DA Ltd. were interested in increasing their use of performance measures, particularly in design & development. Measures have been used in the past but on a fairly ad hoc basis.

[9] bought out of the factory parts

One manager stated; 'we currently have enough data for measuring product feasibility and new product performance, however there is nobody to collate and formalize the data. Measures of the manufacturing process have been in place for ten years but we are just beginning for product development'. The Technical Director is not satisfied with the current level of performance measurement, both in terms of the number of measures and the frequency. He stated 'we need better visibility of total project loading and resource capability'.

6.3.1 *Justification for Introducing Formal Performance Measures*

There are currently several issues that can impede product development projects at DA Ltd. A useful way of structuring these is as follows:

1. Hindrances in the product development process

There were problems with getting all members of the colocated team involved in project activities. This was due to a combination of lack of time and lack of full commitment. A quote that illustrates this came from Purchasing: 'Design wanted full time participation by Purchasing but we simply didn't have the time. If top management had seen it as necessary, then resources should have been created, to enable us to manage both the project work and our daily work'.

Crossed wires in communication also created problems. For example, the marketing specification arrived without being explained by the person who had prepared it. It became quickly apparent that the specification was in places ambiguous. No-one from Marketing was available to discuss the specification at the next team meeting. The same format for the specification is used on every project as a standard (as part of ISO9000). All team members agreed that this could be improved to make it more transparent. In addition, the designers were asked to do something that was technically very difficult to achieve using the proposed components. When quizzed about this, the Marketing Manager explained that it was what the competition did and what the customer wanted. These sorts of communication problems are by no means unique to DA Ltd., as illustrated in this quote from a manager in an electronics company[10]: 'Marketing should

[10] from the company survey

learn more about how to develop products. They gave us the specification and had someone involved briefly in the beginning but we've hardly seen him since then'.

Other comments from Colocation 2 team members included:

- 'We accept lateness too much - we should have penalty points for each day late. I would do this if I were project manager'.
- 'We are offering too many 'specials' to our customers (care of Marketing). We need to rationalise - at the moment we are introducing a new product every three hours!'

2. Lack of awareness of the values of time, cost and quality of projects

When questioned, most were vague about which performance measures were currently used during the NPI process and it soon transpired that different versions existed about the total cost of projects. Furthermore, there is some resistance to introducing total project costs. As one manager commented; 'people don't want to be tracked'. Even though some measures are made (such as number of design changes to specification, lead time to market and number of new products released per year), availability and consistency of the data varies according to the project manager. One Development Engineer went so far as to say; 'we do make some measurements but I'm not sure we always act upon the results'. Another manager added that he wasn't happy either with the frequency or number of measures because there is not enough action from the results. It is also felt that some measures are made simply to complete the NPI documentation and fulfill ISO 9000 documentation rather than for adding value.

3. Data that was not being communicated

Several instances of this were found across DA Ltd. A selection is listed below:

- Lessons from Colocation 1: A feedback session was given but no formal action was taken to prevent reoccurrence of problems.
- Individual initiatives across the organisation - and there are many - are not coordinated. For example, there are several separate databases storing project information (e.g. Purchasing, Quality and data from sister companies carrying out similar work) but the results are not always communicated or made available. The Quality Manager stated: 'There is a scatter-gun approach to strategy at the moment

in this company. We have too many initiatives and training programmes in different areas that are not being coordinated'.

- One project manager has abandoned using project plans as 'the teams didn't consulted them'. He stated; 'I have gone back to using minutes from meetings to monitor progress'.
- Quality: There was lots of work within DA Ltd. (and the group) on six sigma[11]. Training was given across the organisation but as yet few long term follow-up projects have been carried out.
- Reliability data: Regular monthly figures on reasons for service call-outs and breakdowns are collected on a central database. This information does not reach Design as they do not always attend the meetings where feedback is given and no access is currently available to the information electronically via the computer network. A message from colocation team leader to the Reliability Manager highlights the communication problem: 'As you know, one of the measures we have been trying to look at putting in place is the access to reliability information on existing components in the field. Extracting this information for any designer or development engineer is not easy to say the least. From a design point of view I find the system of attending monthly meetings to find out about problems in our area too cumbersome. Plus the information does not go into detail about specific components but instead generalises problems to certain areas. An ideal tool for us would be a database into which we could key in a component that we are considering using in a new design and have the reliability information displayed or at least a rating of some kind, so that we can compare one component against another and have a measure of its performance. Maybe this information is already available to yourselves via the current system? Thinking ahead, Quality and Purchasing could also add their ratings or comments against individual components, etc.'.
- There is (currently) no common platform to communicate information e.g. groupware or other company-wide product data management systems[12].

[11] Six sigma theory proposes that strong relationships exist between product defects and product yield, reliability, cycle time, costs, etc. As the number of defects increase, the number of sigmas decrease i.e. higher sigma equals better quality.

[12] This is likely to change soon subject to budget approval.

In comparison to the potential gains, relatively little effort would be needed to make some of this valuable information available in the place that it is needed (specifically the designers) to input into the next generation of products.

6.3.2 Current Practices in Product Development that Aid Performance Measurement

There are many good practices that together will assist in the introduction of a more formal type of performance measurement system. Some of these points are listed below.

1. New Technology

The introduction of 3D CAD for design and tooling has 'slimlined' the design and development process, avoiding paper drawings and redrawing by Tooling into suitable format. Initial problems with the system occurred in that it was difficult to exactly emulate the curved surfaces specified by Industrial Design. In the near future they intend to buy PC-based NT platforms for the 3D CAD terminals (instead of UNIX) which will mean the PC will be more flexible for all applications (including networking and MS Office).

DA Ltd. currently hold a license for a Product Data Management (PDM) system. It is a groupware tool which enables effective document management across the organisation via the computer network. Present usage is restricted to versioning management of drawings[13]. However, many more modules are available that can handle office documents, parts management (part requests, numbering and status), configuration management (interacts with MRP system), business process mapping and reporting (cost of change, on-line status reports and audit trail checks). This is currently being evaluated and will provide a common platform and user interface to bring together data and databases from all parts of the company, making data more accessible.

2. Quality Management Targets

Regular training for both staff and shopfloor is carried out, most notably in the area of 'six sigma'. This is being championed by the Quality Manager who considers measurement across all processes in the organisation to be essential. The Head Office

[13] It is UNIX based but PC compatible.

vision from the CEO is to achieve six sigma performance for all subsidiary companies by the year 2000. This is based on the idea that high quality equals a low cost organisation. In a recent communication he stated; 'an appreciation of the variability within all processes is the main aim from the outset. At the moment support is lacking to promote this process mindset'.

DA Ltd. is currently introducing design checklists to cover areas such as the marketing specification[14], the quality and reliability specifications and checklists for suppliers. This will be managed by the project managers and fed into the product specification. The main aim is to firm up tolerancing and build up a database to hold all drawing tolerances for easy access and cross referencing. This will then feed into DFM calculations. Figures will be normalised by factoring out the complexity of the product so that cross comparisons can be made. Monthly progress reports have been requested by Head Office.

In the Spring of 1997, the Quality Department recently carried out a capability study to identify and isolate critical design dimensions. The aim is to keep number of critical dimensions to a minimum as each one needs to be measured individually (by the supplier and/or the production operative). The intention is to build up a 'Capability Database' of this information and introduce this across the company.

Design review checklists are being implemented at various stages in the NPI process in an effort to ensure that all factors are considered at the earliest opportunity. These revolve around suppliers, marketing and quality & reliability issues. The only foreseeable problem with this is the additional administration time it poses to project managers who have to complete the checklists.

A Specification Review is being added to the NPI documentation to assist with formal discussions and agreements on the details of the product specification. It identifies aspects that are critical to the customer. The Quality Manager is also looking into setting up a 'Design Concerns' database to identify past problems and design tips for future projects.

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[14] This should help overcome the problem mentioned in section 6.3.1 (pages 134-5)

3. People

The success of Colocation 1 brought acceptance to the concept of multifunctional team working which is now integrated into the company culture as is learning new skills[15].

Designers are encouraged to go out to local retail parks to meet the customers and carry out measurements, comparisons, etc. On one recent trip, the sales staff commented that if DA Ltd. designed something that was *different*, it would definitely get displayed as most products look almost identical. These trips don't yet happen on a regular basis across the group.

The Domestic Appliances industry is now fiercely competitive and there is an overall willingness to change and introduce more measures to help beat the competition[16]. One manager stated; 'we need better visibility of total project loading and resource capability to ensure that targets are met every time'.

6.3.3 Observations

Many observations were made during the course of the investigations for this research. Some of these are mentioned below:

- Concurrent Engineering is known but not fully appreciated beyond the concept of teams. More time and training needs to be spent on gaining a wider understanding of CE for it to realise its full potential. For example, tools such as brainstorming, QFD and fishbone analysis have been used to varying degrees but greater, more consistent use on projects could be beneficial.
- Although overlapping of phases takes place, traditional milestones and sign-offs can still be a sticking point, causing delays and paper chases.
- The project teams need an increased 'process perspective'. According to the Quality Manager, this concept is not currently widely understood.
- Throughout September 1996 a video presentation introducing the new Managing Director and other new senior managers was presented to all the workforce through a series of screenings in the works canteen. A panel of three of these managers was

[15] Appendix VII illustrates this acceptance.

[16] There has been a severe drop in market share over the last 3 years (1993-1996).

available to answer questions afterwards. The main message of the video was 'we've been through a rough time during the last couple of years but we are now in good shape and ready to take on the European market as well as continue to be market leaders at home'. Much of the video outlined the strategy of how this was going to be achieved, communicated the latest activities and involved interviewing the senior managers.

6.4 Selection and Implementation of Performance Measures

Interviews were carried out with ten managers across the organisation who were in some way involved with design & development, with the aim of determining their needs for performance measurement. This initial enquiry resulted in the identification of 30 possible measures. A set of six workable measures were then selected by the team, based around the project mission statement. The Senior Project Manager explained the selection process: 'We have nominated one member in the colocation team to be the expert on performance measurement but all members of the team will be involved in collecting the data. We have been establishing a set of data about the current range including production costs, quality issues in the various manufacturing and assembly areas, plus reliability statistics out in the field. We have a particular interest in reducing the time it takes to purchase and process material so we have examined the parts and suppliers currently being used to target possible improvements in cycle times'.

The 6 measures identified were divided into 5 categories:

Time:	Actual time for sub-tasks against plan
Cost:	Part count comparisons (between models)
	Product cost estimates to targets
Quality:	Reliability lessons; internal failure rates and failures from the market
Flexibility:	Number of unique parts compared to previous designs and compared to other products in the range
Management:	Benefits of colocation as a way to organise projects

The Technical Director was very aware that 'on-time delivery of products is vital' and that 'being late is the biggest drain on profits'. This meant that the time-related measures were the most important from his point of view. The initial set of specific performance measures that were selected to aid design and development projects were:

Time

1. Actual time for sub-tasks against plan: This involves analysing the weekly project plan and reporting percentage differences e.g. percentage delay, time ahead of plan, new projected estimates, etc. This is a useful, clear measure that can be shown to senior management.

Cost

2. Part count comparison of new design versus old. This is a straightforward measure to collect, display and monitor.
3. Product cost estimates to target; focusing on percentage accuracy and including past history. This information can be obtained from Purchasing.

Quality

4. Reliability; including reasons for failure on the market and right first time rates. For example, has new product overcome old problems and failures from the market such as distortion of pressings, batch failures and faulty controls? This information is currently stored on a database administered at DA Ltd. by the Senior Reliability Engineer. The field service data, recorded by the service 'engineers' is collected and inputted onto the database at Complementary Appliances Ltd.[17]. Monthly meetings take place to feed back reliability and quality problems. Paper minutes are later distributed. The short term action taken was to ensure a team member from Colocation 2 attended these meetings. Long term action needed to ensure that the figures are available for the designers to access when required.

Flexibility

5. Part standardisation/rationalisation across the product range: Flexibility is an important issue as standardisation with other products in the range reduces part variation (and hence cost). This will involve monitoring the number of unique parts for each product and comparing with the previous model. A figure showing

[17] A 'buddy' system operates at CA Ltd. to support field engineers with QA advice and to ensure accurate information is written onto the service cards that are fed into the database. This in turn enables more accurate interpretation of the root causes of problems.

percentage common versus percentage unique parts can then be obtained. The percentage standard parts is especially appropriate if the product is part of a range.

Management

6. Evaluation of the benefits of colocation: This can be shown by recording the experiences of Colocation 1 through two sets of short internal surveys; one filled in by the team themselves and the other by people outside the team who contributed to the project. This balance was thought to provide a realistic picture. A follow up survey with the same questions could be completed by Colocation 2 at a later stage in the project. This will allow for comparisons (in terms of improvements & persistent problems) to be identified.

Appendix VII shows the results of a short feedback survey on the effects of colocation. This was designed by the author with contributions from the Team Leader and was distributed in January 1997. Of the 30 sent, 14 were returned. The result showed positive support for colocation, with all but one respondents indicating that colocation was the way forward for DA Ltd. in organising NPI projects. The main problems seemed to occur between the team and others with query response time being the main concern (53%). Product specification errors (50%) and interest in their work (32%). Within the team, accuracy of drawings was identified as the major problem (38%), with prioritisation of tasks also being an area of concern (30%). The major communication problems teams experienced was with Marketing (80%), Tooling (52%) and Design (25%). This feedback clearly highlighted problem areas and was used to show senior management where the strengths and weaknesses lay.

6.4.1 DEVELOPMENT OF THE PERFORMANCE MEASUREMENT SPREADSHEET

An MS Excel spreadsheet was chosen to be used as the basis for entering and displaying these performance measures, as this software is commonly available on all networked computers and is well understood by most employees. A user-friendly front-end was written by the researcher to assist with data entry. This involves accessing a control page which;

a) displays a brief introduction and background,

b) allows direct access to the graphical output for the selected measures,

c) gives the user the opportunity to add the latest figures and/or new variables to the database,

d) provides direct access to a computerised, more user-friendly version of product reliability information (written in MS Access by the researcher[18]),

e) links up with the design specification review (recently computerised and part of the NPI procedures for ISO 9000) and

f) informs the user who to go to for further information.

The program was placed on the internal company network, with provision being made for read-only sectors of data to some users to protect the validity of the data. This spreadsheet is seen by the management as a temporary solution until a more comprehensive product data management system is implemented throughout the organisation. This is likely to take some time, so the spreadsheet is a useful temporary control. The Excel control sheet, Access reliability database and data entry sheet are shown in Figures 6.1 to 6.3.

[18] The advantage of this database is that the designer can key in a word such as 'glass' and find all the entries associated with it, without searching through the meeting minutes or grouped codes in the existing DOS-based system.

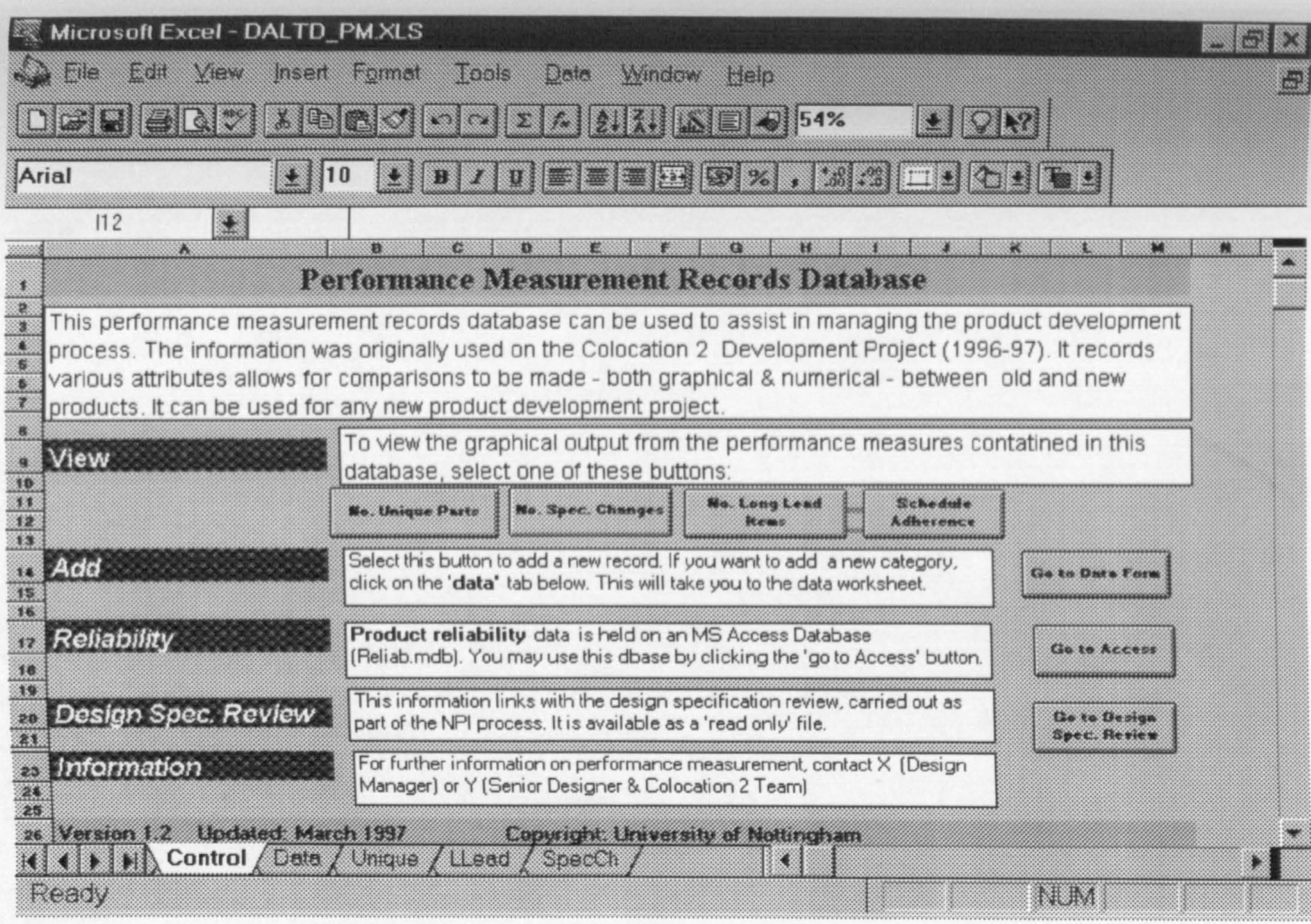

Figure 6.1: Control Sheet for Performance Measurement Database

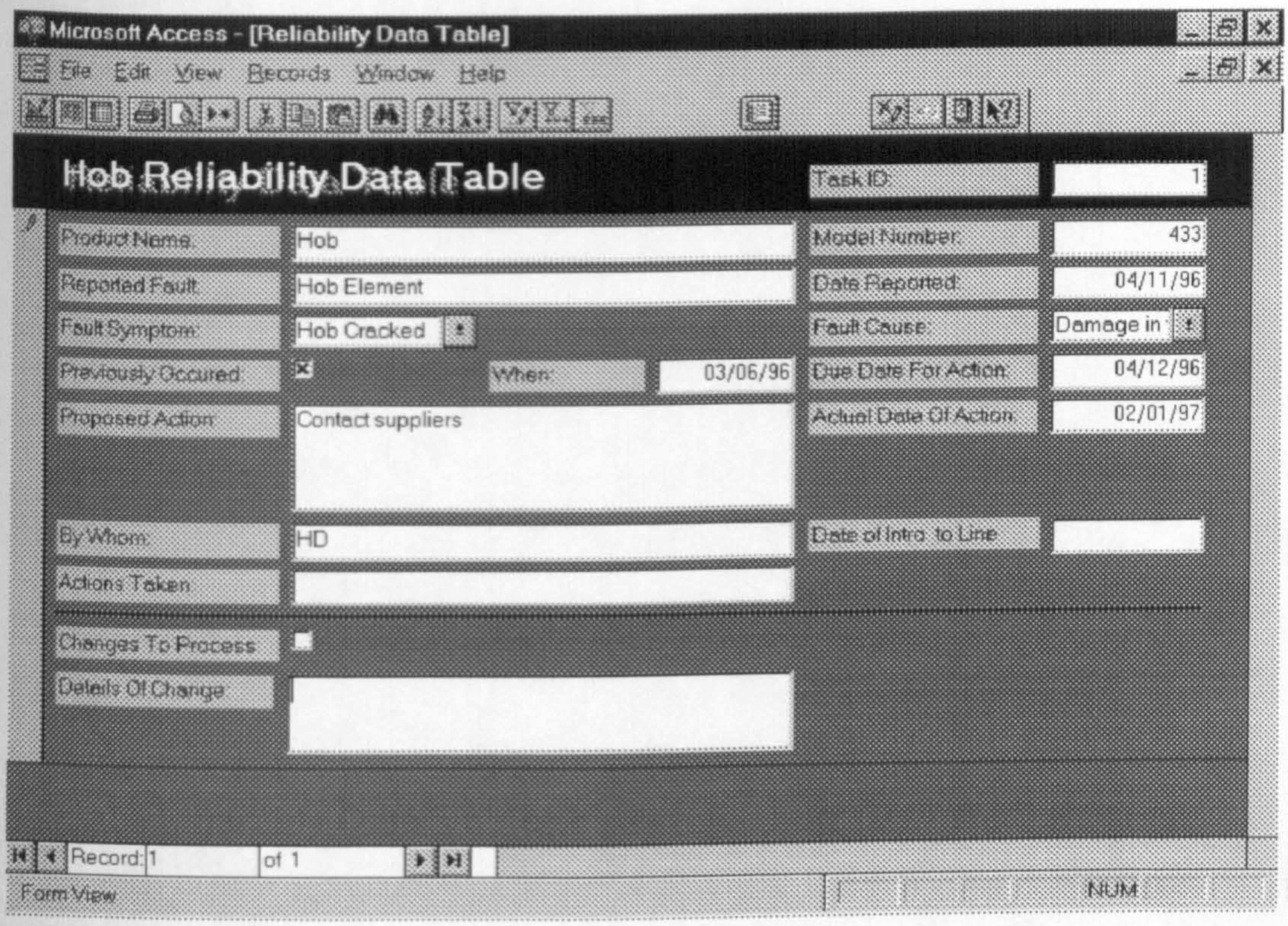

Figure 6.2: Reliability Database

Model No. & description	Date Launched	No. of Unique Parts	No. of long lead items	% cost saving over previous model	No. changes to product specification[19]	Stage of NPD Process that change was made	Who made changes and why?	Product failure rate

Figure 6.3: Data Sheet for Performance Measurement Database

Links were made to enable direct access to complementary information held in MS Project (the project plan) and MS Access (the reliability database). Additionally, information held by Purchasing on supplier performance could also be fed into the basic template if so desired.

[19] post design and pre-production

6.4.1.1 *Input to PMPD Tool*

This work at DA Ltd. provided valuable input into the spreadsheet, RACE-style assessment questionnaire and the 'Experiences in Performance Measurement' database which is used as part of the PMPD Tool (see Chapter 7).

6.5 Summary of the Longitudinal Case Study

Analysing the large volume of data collected during case study investigations, filtering it and bringing it together to form a coherent output is one of the most difficult aspects of applied research. However, the longitudinal approach to investigating DA Ltd. proved very rewarding and revealing.

The longitudinal case study was carried out at the same time as the questionnaires and follow-up cases. Results from these two other areas of data collection were very important to ensure that the research output was balanced and not overly-biased towards one company's needs. DA Ltd.'s situation was similar to that of some of the follow-up cases in that they were 'finding their way' with performance measures and were very much in the learning phase. As with the other companies in that situation, the first measures they applied were the basic ones based around time, cost and quality. Furthermore, the measures chosen contained a mixture of failure measures (e.g. reliability) and improvement measures (e.g. benefits of colocation).

Not all of the value of being involved with DA Ltd. during this project can be summarised into a tangible output. Suffice it to say that this longitudinal case study has been very valuable to the researcher as it provided rich information, direct 'live' feedback for ideas and a good test bed for the implementation framework and the first version of the PMPD tool. It is believed that the benefits were mutual, as the researcher gave the company access to the latest ideas, methods & models and an independent view of their current practices.

6.5.1 *Value of the Longitudinal Case Study*

> 'The process of defining necessary measures for design and development has been a real learning experience for us. It made us sit back and think about our product development process.'
>
> Team Leader of Colocation 2

The experiences from working with DA Ltd. (backed up by visits to the sister companies) on the options available for implementing performance measurement into the design and development function can be summarised into several points:

A. Questions posed by the researcher during the course of this research have alerted both senior managers and team leaders to the improvement opportunities available through performance measurement.

B. A workable set of initial performance measures has been formulated and tested. It is important to realise that once these measures have been fully implemented, they should not be regarded as the answer. Instead they need to be continually reviewed and refined. As suggested by Karlsson among others; the company culture needs to continuously change so that 'old ways are unlearnt' [Karl96] .

C. A unified approach to process improvement needs to be achieved to focus the separate initiatives (including databases). These do not necessarily need to be merged, rather coordinated from one point. As discussed, this could be via a groupware platform.

D. DA Ltd. have just survived a lean period where much 'rationalisation' occurred (both in terms of sites and resources/manpower). However, they clearly still have the talent and enthusiasm to make these improvements to continue competing successfully. It is hoped that the momentum gained from this and other improvement projects will be maintained.

E. This work at DA Ltd. provided important input into the paper-based tool that formed the practical output of this research.

F. There was a positive response to the MS Excel performance measurement spreadsheet. It was thought to be user-friendly and clear. Although it was not implemented at the time of writing (outside of Colocation 2), the Senior Project Manager was keen to further refine it and make it part of the Design Specification Review and hence formally part of the NPI process.

CHAPTER 7

7. RESEARCH OUTPUT AND DISCUSSION

'I try to encourage people to take ownership of measurement and intuitively review performance as part of their job, rather than carrying out formal reviews. Ideally, they should develop their own measures to achieve internal standards, rather than someone imposing measures onto them. This is not always possible, but it can be very powerful.'

Director of Research, Brewmasters UK

This chapter deals with the practical outputs from the research findings. A set of principles associated with performance measurement for product development is presented, resulting from the findings of this research. The input from the PACE Project is then discussed, followed by the Performance Measurement for Product Development (PMPD) Implementation Framework, the paper-based tool (usable in the form of a workbook) and training information. Results and feedback from initial trials are presented, along with suggestions for improvement.

Findings from previous chapters highlighted that there was a need for assistance in implementing performance measures in product design and development. In particular, results from the questionnaires showed that more assistance was required with managing and controlling the product development process, especially at the product specification and detailed design stages (see Chapter 4). Further investigations with the follow-up cases reinforced this view and indicated that although some measurements are being made on a consistent basis, these aren't always necessarily the right ones or the ones that project managers want to use (see Chapters 5 and 6). These findings, together with comments and suggestions from a wide variety of companies were incorporated into the design of the PMPD Methodology. This advocates a step by step way of implementing performance measures; providing question sheets, checklists and a database to add comments, experiences and any relevant information found in the literature. It builds on previous work in this area by using aspects of established methodologies (e.g. RACE [Kara92]) and encouraging use of already proven development tools (e.g. Gantt charts, QFD and brainstorming). The generic way that it has been structured means companies can, and should, tailor the tool's use, according to their specific needs.

7.1 Principles of Performance Measurement for Product Development

As has been shown throughout this thesis, there are many considerations when designing performance measures for product development. Through interpreting the literature and triangulating the results from the data collection and analysis, it appears that there are several principles surrounding performance measurement. These can be divided into system-related and metrics-related principles.

System-Related Principles

1) Start with simple achievable measures that will provide tangible results on the first project and progress to more demanding ones later. Most importantly, the purpose of all measures used must be clear and unambiguous to all those on the project team who use them. Additionally, the unit of analysis must be clear otherwise it can cause frustration which may ultimately lead to failure of a measurement system.

2) Avoid simply transposing any existing measures within the organisation to be applicable to product development. More is not better and adding to the number of measures usually serves to confuse and inhibits 'ownership'. A clean sheet is a far clearer way of forming a coherent system. Where possible, the project teams should be responsible for formulating and/or adapting at least some of the performance measures they use. This will encourage ownership.

3) Any proposed measurement system should contain a combination of mandatory and key measures. This will allow for easy comparison between projects, while maintaining a project-specific relevance.

4) If a company is new to measurement, no more than five measures should be selected and implemented in the first place. Somewhere between 1 and 5[1] is the recommended number to ensure that the associated administration involved does not become unmanageable.

5) Frequency of reporting depends very much on the type of project being undertaken e.g. facelift or new and the corresponding level of investment. Too much reporting is time-consuming and a distraction to the team while too little can make the results irrelevant and/or that measurement is a waste of time.

6) Try to ensure a high degree of both macro and micro visibility:

   a) Performance measures should be directly related to strategic goals to gain top management support and to ensure high visibility of results ('macro visibility').

   b) Within the team, high visibility of results is essential to ensure that everyone knows what is happening ('micro visibility').

7) Data should be easy to collect, record and access by the project team once the system is in place. If appropriate, consider setting up a central access point on a computer network. Keep the user interface at a straightforward level without jargon and abbreviations.

8) Although metrics that record negative aspects such as reliability problems, bottlenecks and costs are important, a balanced system should incorporate success measures such as improvements and achievements.

Metrics-Related Principles

9) In a product development team environment, individually-based measures are inappropriate. Team performance is what matters.

10) Don't let project teams become discouraged because they are unsure of how to measure a new variable accurately. This doesn't matter as long as it is measured consistently it can provide trend data. Over time, this can be fine-tuned. Once firmly established, metrics should allow for comparison across time, location and organisation.

11) To ensure that metrics are being recorded on a consistent basis, each one needs a standard. Two approaches can be taken to do this. Firstly, the static approach which fixes a standard at a certain level of performance and stays unchanged until a 'new analysis' is performed. Secondly, the dynamic approach which expresses the standard as a rate of expected improvement. This incorporates opportunities for continuous improvement but requires more effort and understanding to work.

12) A combination of hard and soft measures are required to assist with measuring product development projects. Hard measures (such as time to market and costs)

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[1] According to findings from the follow-up cases and information from the literature.

typically form the 'core' measures as they are relatively easy to collect and allow for comparisons but soft measures should complement them by providing pointers for the unknown or intangible, but equally important aspects such as customer perceptions, communication and opinion.

13) If possible, avoid or minimise the use of compound[2] measures on product development projects. Although they are useful as a quick overview for senior management and easy cross project comparisons, they can hide underlying reasons and can lead to false conclusions being drawn without the full information to hand. Additionally, avoid cumulative measures that incorporate knock-on effects from others as this can lead to a conflict of reporting interest between projects.

14) Ensure the measurement system monitors performance at specific stages as well as assessing overall project performance. Within this, a mixture of product (e.g. component cost and design defects) and process measures (e.g. time to market) is useful.

These primary principles[3] contributed directly to the formulation of the PMPD methodology.

7.2 PACE Project Input

As part of the PACE Project, preliminary investigations were made into existing types of assessment tools and techniques to evaluate company performance with respect to Concurrent Engineering. This involved clarifying the difference between assessment and benchmarking[4] and reviewing assessment models available in the literature. Overall, assessments were seen as more appropriate than benchmarking as a technique in supporting practical improvements in an organisation. These results were useful to this

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[2] Measures providing multiple inputs e.g. weighted combinations of time, quality and design productivity can be used to produce the 'total product development performance' score.

[3] As these principles are of a general nature, they should be considered as a start-point rather than a definitive list, if used directly to assist with projects.

[4] Benchmarking is a way to collect information about a company or competitors in a structured way to support positioning against major competitors and definition of targets. It is an external view on internal activities/processes to identify goals for improvement. Benchmarking is often over-estimated as a technique to implement change, as it does not answer detailed questions of the implementation process.

research as inputs to the PMPD Implementation Framework and tool. In particular, they contributed to the decision to use a RACE-style analysis in the system development stage.

7.2.1 Comparison of Available Assessment Models

Assessments allow information to be collected in a structured way to compare the current company profile against a defined target profile. They can be seen as a specific set of questions to fulfil a defined need. Based on identified deviations between current and target profiles, priorities can be defined. Assessments must enable tracking and controlling during an implementation and/or change process through regular measurements. Four established company assessment models were evaluated[5]. The evaluation focused on a number of key issues, including identification of the models' current strengths and weaknesses. Table 7.1 contains a condensed comparison of the results.

[5] see Chapter 2 for information on others

	Comparison of Available Assessment Models			
	CMM	RACE	Charney	Carter
Purpose	Analyses the maturity of software development environment	Evaluates the readiness for CE	Self study on current performance in relation to a book	Self study on current performance in relation to a book
Major area of application	Software Development	Mechanical Engineering	Mechanical Engineering & technical companies	Electronic development & Mechanical Engineering
Structure	Complex, heavily linked to a software maturity model	Two major sections divided into ten areas	Questions after every chapter of the book	Single structured questionnaire linked closely to chapters of book
Scoring	Yes / No	Yes / No/ No opinion/don't know	from 1 - 5	Yes / No
Evaluation of results	Classification into five maturity levels	Scoring, displayed as graphics, normally done by consultancies	Five scores from poor to excellent	Uses radar graph to present the current company profile
No. of questions	~ 180	150	109	83
Self use possible	No - only when properly trained	No - consultancies recommended	Yes	Yes
Usability	Highly complex	Complicated	Easy	Easy
Advantages	- Very detailed - Good integration into the software maturity concept - Some questions are too abstract - Focus is on software development - Clear concept for an improvement process	- V. comprehensive questionnaire which is integrated into a good assessment tool - Most of the questions are helpful to analyse the readiness for CE.	- Good questions in several areas - Charney focuses on people, human factors - Good because manufacturing is part of the CE approach	- Good questions in several areas - Carter focuses on technologies - Good granularity on scoring
Weaknesses	- 180 questions is excessive - Questions are too theoretical -No clear focus on CE - Only usable for soft-ware development -Whole CMM Concept documentation approx. 600 pages	- 150 questions is excessive - Questions are too theoretical - The focus is more on technologies not techniques - Questions ask whether tools are available, but not if they are used	- Not a real assessment tool - Charney focuses on people, human factors only - Often too broad to get the required information - Questionnaire directly related to the book	- Not a real assessment tool - Carter focuses only on technologies - Often too broad to get the required information - Questionnaire directly related to the book

Table 7.1: Assessment Tool Comparison

As result of the comparison, it was concluded that most of the models focused on areas which did not match with the PACE requirements. The structure either follows the environment described in the related book as is the case with the Charney assessment model [Char91] and the Mentor Graphics assessment tool [Cart92], or they are dedicated towards only one type of development as with the Capability Maturity Model (CMM) [Hump89] and RACE [Kara92]. All models are static rather than dynamic (when used alone) and lack direct links with any wider change implementation processes. Of the four, the RACE questionnaire proved the most useful as a start point for a front-end for the implementation framework for product design and development performance measures.

7.3 The Performance Measurement for Product Development (PMPD) Methodology

Taking into account the results from the data collected earlier on in the research process a methodology (comprising an implementation framework and two practical workbooks[6]) to assist with managing performance measures for product development activities was developed.

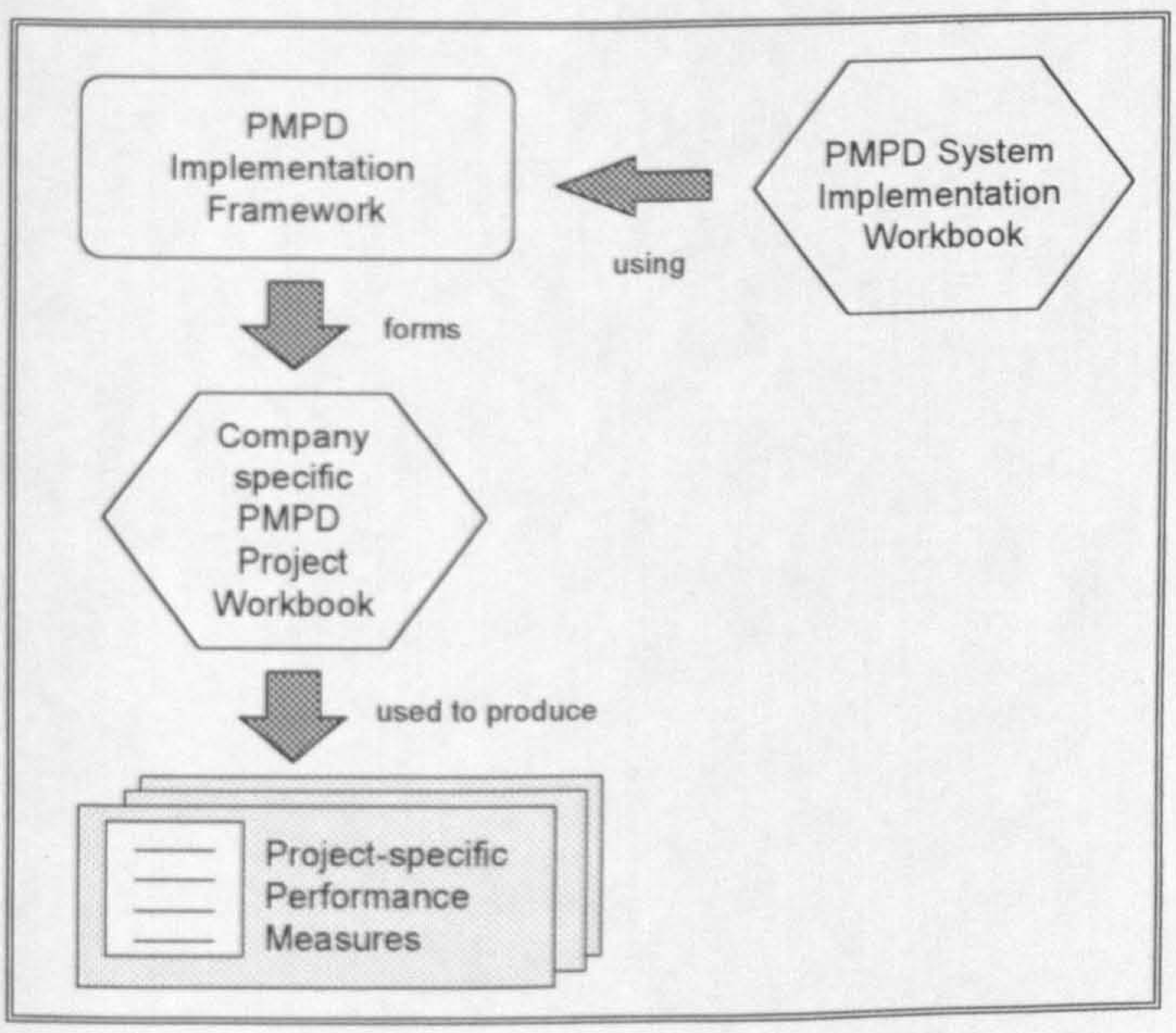

Figure 7.1: PMPD Methodology

[6] The exact form of the PMPD Project Workbook is decided upon by the companies, following their specific PMPD System Implementation Workbook.

In brief, the idea is based on identifying needs by understanding the stages of the product development process, the philosophy being that the type of measures needed at different stages and in different industries, varies. An overview is shown in Figure 7.1.

- The PMPD ***Implementation Framework*** focuses on product development activities and describes the major steps that the company needs to go through when introducing and managing a performance measurement system
- The PMPD ***Workbooks*** include the operational steps that the managers and team members take when:-
  - a) implementing (PMPD System Implementation Workbook) and;
  - b) running the system on a day-to-day basis (PMPD Project Workbook).

The PMPD Implementation Framework is aimed at assisting with implementation of product development-oriented performance measures in 'ordinary' companies i.e. not restricted to those that have resources to commit to exploratory projects. This is achieved through appointing a 'Task Force' (comprised of a cross-functional group closely involved with product design and development) and following the six stages of the framework. The stages should not be regarded as a blueprint, but rather a basic template upon which to build. The tools, techniques and checklists of the PMPD System Implementation Workbook are then selected and adapted to suit the company-specific situation. This procedure leads to a company-specific PMPD Project Workbook, that is intended to act as a template to be used by product development project teams.

7.4 PMPD Implementation Framework

The way that the implementation framework operates is outlined through a description of the six stages of; need evaluation, status analysis, action plan, change awareness, system implementation and monitoring and refinement. Tools and techniques included in the accompanying PMPD System Implementation Workbook have been highlighted in italics[7].

[7] Established existing tools & techniques such as QFD and Gantt charts have been referenced rather than fully explained.

1. *Need Evaluation*

Establish if there is a need for performance measures in product design and development.

a) Assign a Task Force: This should involve a series of meetings between senior management and those heavily involved with product development activities (from managers to team members). From this, a cross functional (and if appropriate, cross-divisional) Task Force should be selected to carry out the full need evaluation.

- Team selection should be based on factors such as knowledge, experience, location, availability and 'closeness' to product development activities.
- Choose good communicators who will be able to drive enthusiasm about the performance measurement system.
- Carry out team building activities to form bonds between the team.

⇒ There are many books and methodologies available to assist with teambuilding. They include those by Belbin [Belb93], Katzenbach & Smith [Katz93] and Woodcock [Wood89].

b) Analyse how product development can help achieve strategic business objectives:

- Focus on long- and short-term objectives and identify the role of product development.
- Examine business trends based on information from customers, specialists, market analysts, benchmarking reports and other relevant sources and discuss their impact on product development activities.

c) Where applicable, consider the impact that Concurrent Engineering and/or streamlined business processes has on product development projects.

⇒ Useful references include; [Cart91], [Clar91], [Hamm93], [Take90] and [Ulri95].

d) Brainstorming could be used to establish where problems and blockages commonly occur in product development. By way of assistance, a *Suggested*

Question Sheet for Analysing Product Development Activities is provided to frame the discussion around and spark off debate.

e) Once a need has been established, the Task Force will go on to be responsible for developing and testing out the performance measurement system.

2. *Status Analysis & Target Setting*

The next step is for the Task Force to re-examine the results from the needs analysis, set targets and determine the current status of performance measurement throughout the organisation.

a) The *PMPD Cause-Effect Analysis* is helpful at this stage. These diagrams[8] were originally used to establish a relationship between a particular quality characteristic (the effect) and the factors which impact it (the causes). Here it has been adapted to address product development issues and problems by helping to identify where in the process that performance measures would be useful. An example and blank template are included in the Workbook.

- This is a group exercise that is best carried out using a flipchart or whiteboard.
- It is important that the start-point problem is not too large, otherwise it quickly becomes too complicated to map.
- It will result in a prioritisable list of target areas, open to refinement once a full analysis of the current status of performance measures within the organisation has been carried out.

➡ For more information see [Gilm95].

b) Consider use of a QFD-style analysis to examine areas highlighted by the need evaluation and the Cause-Effect Analysis. Here the Task Force should bring in representatives from all areas of the business who are affected by design and development. This should include suppliers and customers if possible. The pros and cons of the suggested actions for implementing the measurement system can then be discussed in a systematic manner. In this

[8] also known as a fishbone diagram or an Ishikawa diagram after its inventor

way, the important needs and wants can be separated and prioritised from the trivial many so that effort is not wasted on 'nice to have' features.

- This process design version of QFD based around an action programme for achieving a specific goal is known as Quality Policy Deployment [Gilm95].
- QFD also allows the opportunity to benchmark against competitors[9].
- To be used effectively, a high level of understanding of QFD needs to be achieved by the group before the analysis is attempted.

➡ For information on QFD see [Haus88].

c) Customise and administer *a PMPD Gap Analysis* questionnaire across the organisation to determine the current opinion on, understanding of and use of performance measures during product development projects. This 'as-is' will identify the gap away from the 'to-be' (target) situation.

- This assessment is based on the approach used in the Readiness Assessment for Concurrent Engineering (RACE) Questionnaire [Kara92]. Basically it is a self assessment gap analysis technique that has been identified as being specifically advantageous in team environments.
- The template categories for questions are; product development process, communication, organisation, supply chain and strategy. This is included in the PMPD Workbook.
- Results will assist with deciding on what will be required from the PMPD System and for formulating the contents of the Project Workbook.

d) Carry out the project management timeplan for developing the system, using a Gantt chart and/or project management software.

[9] However, reliable information on the use of performance measures may be difficult to come by.

3. *System Development*

Discuss implications of the Status Analysis findings and the implications they have on the design of the PMPD system. This is a very important stage of the process, as the output forms the basis of the measurement system. Therefore, it may require anything up to several months until the initial system is finalised and ready for implementation.

a) Read through and discuss the *PMPD Development Guidelines* to learn more about considerations when designing a measurement system.

b) Customise the *PMPD Basket of Measures* to suit the company-specific stages of the product development process.

- This technique recognises that some measures will be useful across the process (e.g. total project time and cost), whereas others are useful at specific stages.
- A list of commonly used measures in the areas of time, cost, quality, customer service and other general areas is provided as a starting point.
- The output from the basket of measures exercise will guide product development project managers on the types of measures that are available.
- The Task Force may want to distinguish between key measures and optional measures. The key measures will be mandatory and used on all projects throughout the organisation as a common benchmark. The optional measures will be used on a project basis to assist with the project management.

c) Customise the *Individual Metric Checksheet*[10] for each measure;

- This checksheet is designed to ensure that all the appropriate measurement parameters are recorded. The template provided offers categories that include purpose of the measure, tools required,

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[10] Checksheets are widely-used in industry. As stated by the Technical Director of Airvent Ltd.; 'I believe that checksheets are central to project control - they help us complete projects more quickly and more efficiently.'

frequency of measurement, format for reporting the measures, level of detail reported, communication methods and who sees the results. This will be customised and used in the Project Workbook.

d) Ensure data management considerations have been addressed. For example:

- How the information is captured (automatically as part of existing reporting methods, specially collected or a mixture),
- processed (any changes required to make this data suitable for product development use),
- stored (electronic or paper-based format) and
- retrieved (including data access preferences such as 'read only').

e) Customise the *PMPD System Definition Checksheet* to ensure that all areas have been addressed. The suggestions include management, reporting, cost and training considerations. The customised checksheet will then be used in the Project Workbook.

f) A simple *SWOT*[11] *Analysis* will assist with evaluating the proposed measurement system by focusing the Task Force discussion on the strengths and weaknesses, together with opportunities and any threats.

- This should help to ensure that the system will work in practice.
- Examples can be found in any Marketing textbook.

g) If the system is to be made available in a software format, consider customising the *PMPD Spreadsheet Template* to record and manage information.

h) Produce 'Version 1' of the Company *PMPD Project Workbook*.

- Suggestions for stages are offered to assist the Task Force with structuring the Project Workbook.
- The Project Workbook should be flexible and not overly prescriptive to enable easy adaptation to suit the needs of all company product development projects. It should assist project managers with introducing and managing performance measures, without causing excessive administration.

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[11] Strengths, Weaknesses, Opportunities and Threats

- Consider any link with NPD and/or ISO 9000. What changes will need to be made to company procedures. Who will do this?
- Encourage the MD/CEO to add a preface to the workbook.
- Consider computerisation;
    - networking and versioning implications
    - check on system constraints with computer systems experts.

4. *Change Awareness Program*

Carry out a series of training and education sessions to raise awareness and familiarise the organisation with using performance measures for product development.

a) Use the *PMPD Training Information* as a template upon which to build the company-specific training programme.

- The choice will depend on existing methods used and culture of the site where the training is being given.

b) The Task Force will return to their own areas and communicate the message of PMPD using the customised training information. This will typically involve a combination of;

- presentations,
- informal discussions,
- 'hands-on' use of the workbook,
- a case study to show how the workbook can be applied,
- panel discussions with experts/specialists to provide question and answer sessions.

c) A series of sessions should then be carried out around the rest of the organisation (if appropriate).

- Consider local and global videoconferencing sessions to ensure cultural, language and local market issues have been addressed in the proposed system.

d) Keep a *Training Record* to document progress (e.g. type of training given, trainer, who attended, etc.).

e) Apply the training:

- Ensure that all those trained get chance to participate in a team that uses the PMPD Project Workbook before interest is lost.

➡ For more information on training see [Bent92] and [Good90].

5. *Implement the System*

How the performance measurement system is implemented will determine its success. The details are very organisation-specific but general guidelines can be applied. A *PMPD Implementation Strategy Checksheet* could include the following:

a) Use of relevant feedback from the Change Awareness Program to refine the measurement system and 'Version 1' of the Project Workbook.

b) Scale of implementation:

- Will it be organisation-wide, at site/division level or at project level?
- Will there be trials on selected projects or full scale organisation-wide coverage?
- Set percentage targets for project improvements.

c) Issue the new version of the *PMPD Project Workbook* to the product development teams, project managers and senior management.

- Make the master copy available on the computer network (if appropriate).

d) Install a feedback loop to ensure that the change process is stable and that benefits are visible.

- Pool results at regular meetings to identify possible areas of overlap and synergy in implementation experiences.

6. *Monitoring and Refinement*

Once the measurement system has been implemented, it needs to be monitored and refined to ensure on-going success. This stage is mainly concerned with ensuring that progress is monitored problems are solved and suggestions for improvement taken on board.

a) Customise the *Performance Measurement Database* Template to record project experiences and information. This could include; any teething problems experienced and how to overcome them, suggested improvements, what has been tried in the past and data to carry out 'what-if' analyses.

b) Disseminate results on a regular basis:

   - The company must choose a preferred routes for communication e.g. email, reports or periodic PMPD meetings.

c) Establish a support network where members of the Task Force can be available to answer queries.

d) Top management must continue to support the PMPD system in a visible way to ensure success.

   - Decide on how this will be achieved.

e) Contingency funding:

   - Provision should be made in the budget to cater for any unexpected expenses (e.g. technology, resources, personnel) that may be encountered when designing and implementing the performance measurement system.

A flowchart of this implementation framework is shown in Figure 7.2.

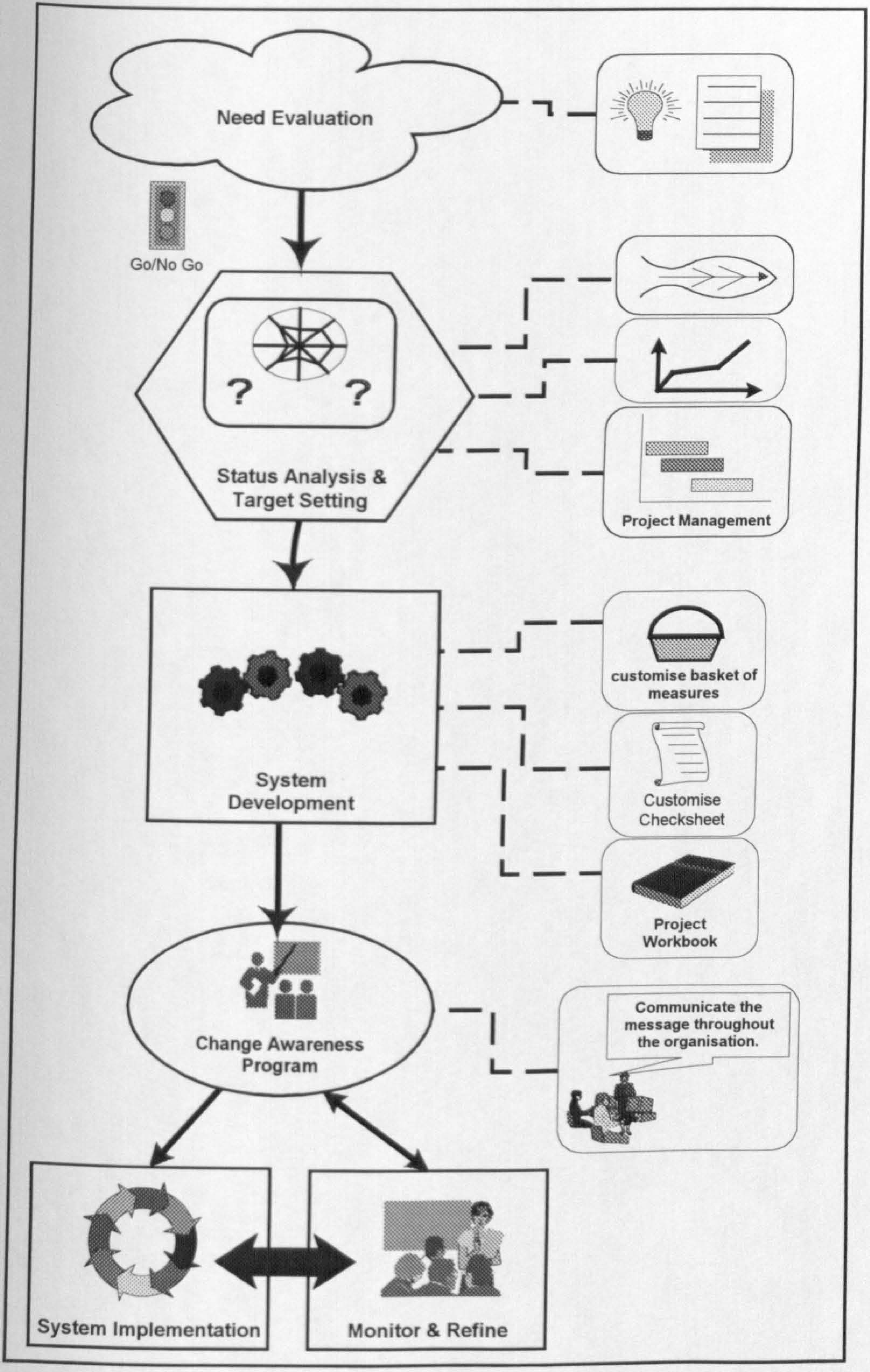

Figure 7.2: Flowchart of Implementation Framework for Performance Measurement for Product Design & Development

7.5 PMPD System Implementation Workbook

This workbook is structured according to the Implementation Framework to provide step by step information on how to implement performance measurement for product development projects. The full workbook is available from the Department of Manufacturing Engineering at the University of Nottingham [Driv97]. By way of example, some of the central tools and checklists are included in this section in order to illustrate and explain their use.

- a section from the Question Sheet for Product Development Activities (Stage 1),
- procedure for using the Cause Effect Analysis (Stage 2),
- an excerpt from the PMPD Gap Analysis Questionnaire (Stage 2),
- the Basket of Measures (Stage 3),
- the Individual Metrics Spreadsheet (Stage 3),
- the System Definition Checksheet (Stage 3),
- the suggested inputs for the PMPD Project Workbook (Stage 3),
- an excerpt from the PMPD Training Information (Stage 4) and
- the Performance Measurement Feedback Database Template (Stage 6).

These elements are available in software format and can be provided to the Task Force with the workbook on a disk.

7.5.1 *QUESTION SHEET FOR ANALYSING PRODUCT DEVELOPMENT ACTIVITIES*

All of the relevant questions in the list (shown in Table 7.2) should be considered prior to embarking on a project in product development. Some will not be applicable to the company's situation but they should be considered before being discarded, as they may trigger other questions and issues. The questions are divided into sections but are not listed in any order of importance. The list is not intended to be exhaustive and customisation is strongly advised.

Exiting Measures, Time and Budget
1. What existing measures are used? Both in product development and across the organisational performance measures. Frequency?
2. How widespread are they?
3. Are they the right measures? How do we know?
4. Why are they used (history, required by head office, etc.)? Evaluate and classify existing measures as either 'useful' or 'a waste of time'.
5. Identify any compound i.e. aggregated/macro measures - who are these aimed at? Are they understandable or useful?
6. How do we currently achieve project targets? On average, what is the success rate? What needs to be done?
7. Who is responsible for managing the budget? Is this the right way to manage our projects?
Resources and Bottlenecks
8. Is there a database of past and current project attributes e.g. timescales, contacts, sticking points or successes?
9. What are the areas where bottlenecks occur during design and development? Why?
10. What extra measures can we use to overcome these bottlenecks?
11. Are compatible formats of communication used by project team members and internal and external customers e.g. data files and documents?
12. Who typically captures and records project information? How is this done?

Table 7.2: Suggested Question Sheet for Analysing Product Development Activities

7.5.2 Cause Effect Analysis

Procedure for use:

1. Choose a common problem with product development projects e.g. failure to meet deadlines, goes over budget, early failures on the market. This is the 'effect' which is placed along the stem of the diagram

2. Brainstorming should quickly generate the main causes for this e.g. hold-ups downstream in the process (specify), supplier performance, identifying customer needs, etc. These are then attached to the stem.

3. By examining each of these causes in turn, the way that performance measures will help prevent these factors may be identified.

    - These suggestions are often written on adhesive notes and attached to the main diagram to allow for easy portability in the dynamic brainstorming environment.

➡ By starting with a blank 'fishbone' and identifying key problem areas in your product development projects, design a template for use in your company.

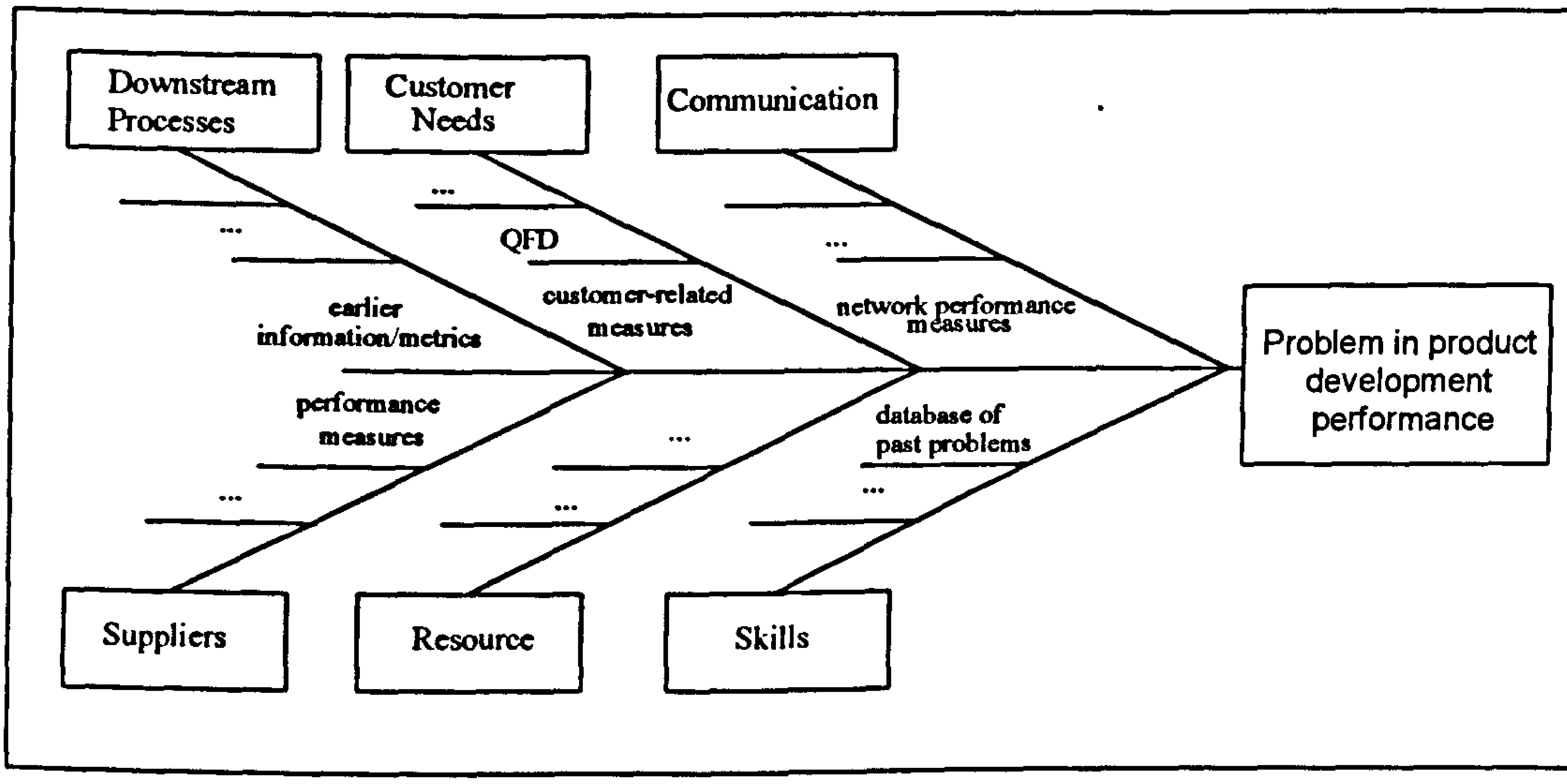

Figure 7.3: Cause-Effect Analysis Template (with examples)[12]

7.5.3 PMPD GAP ANALYSIS

The gap analysis questionnaire contains a series of questions relating to current product development activities. This is answered by people regularly involved with product development from across the organisation. The basic template found in the workbook focuses on five key areas; the Product Development Process, communication, the supply chain, strategy and organisation. Results will assist with deciding on what will be required from the PMPD System and for formulating the contents of the Project Workbook.

A number of statements are made beneath each area to which the participants register their degree of agreement on a scale of 1 to 5[13]. An extract from the product development process questions is shown in Table 7.3:

[12] A blank template is also provided in the workbook.

[13] This scale used in the RACE II trials [deGr94].

Product Development Process	*Strongly disagree*				*Strongly agree*
Our product development procedures take into account performance measures	1	2	3	4	5
We make full use of previous project information & experiences	1	2	3	4	5

Table 7.3: Extract from the PMPD Gap Analysis Questionnaire

Scores from the individuals are averaged to form a snapshot picture of where the company is in terms of product development. If required, the questions can also be answered from the point of view of a leading competitor to enable direct comparisons to be made.

The PMPD Task Force answers the same questions from the 'to be' or target situation. The time frame for the desired state should focus on the next 1 to 2 years. The two are compared to identify the 'gap' and highlight where the greatest discrepancies lie. Hence, targets can be set. A sample radar diagram of the 'as is' against the 'to be' situation in 'Company X' (shown in Figure 7.3) illustrates the visual impact of this technique.

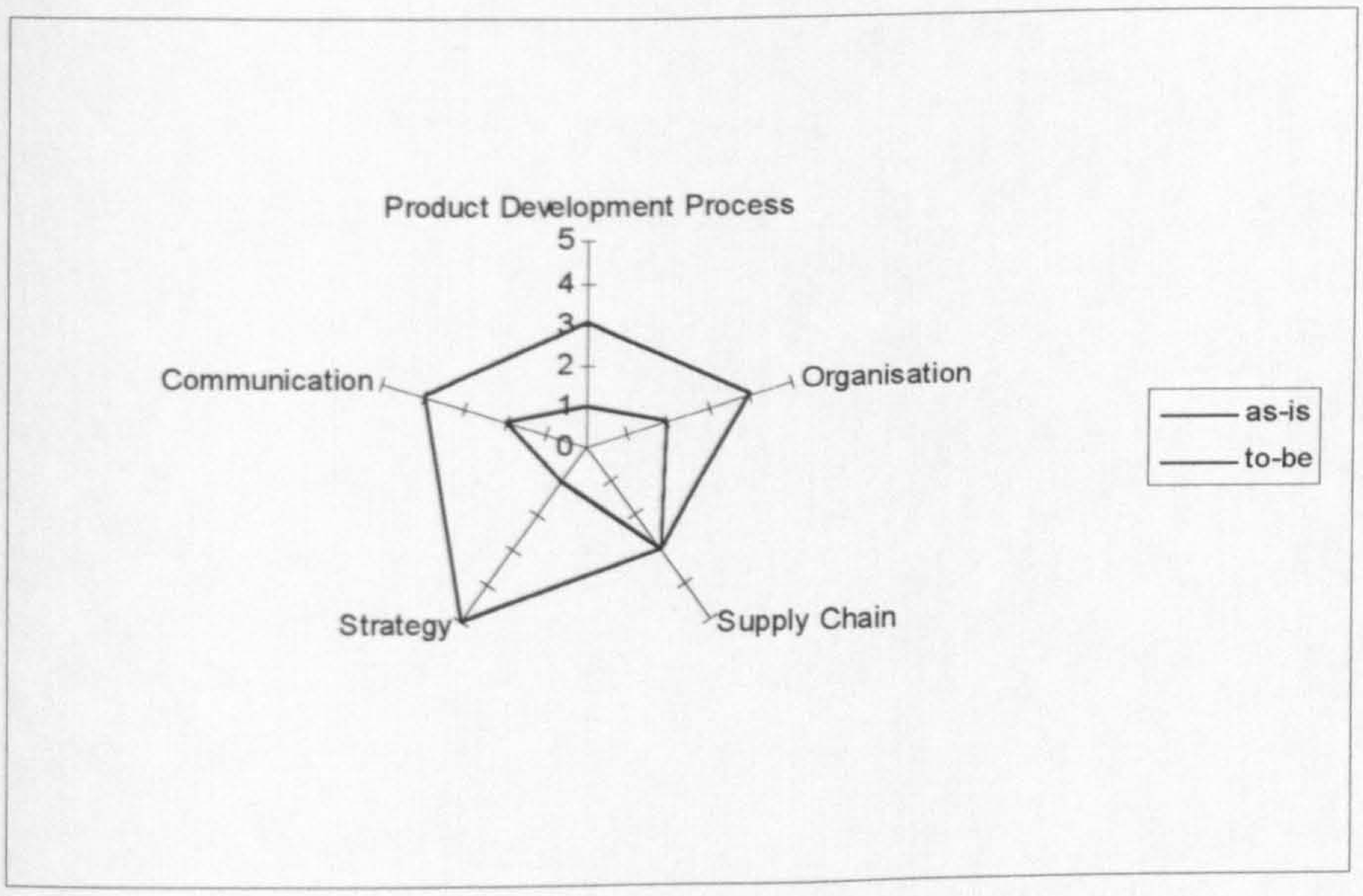

Figure 7.4: Sample PMPD Gap Analysis

7.5.4 Basket of Measures

The PMPD Basket of Measures (shown in Figure 7.4) should be customised by the Task Force to suit the company-specific stages of the product development process. This technique recognises that some measures will be useful across the process whereas others are useful at specific stages. It is intended to enable the project manager and his/her team to examine the measures that are available from a general pool or 'basket' and select those that are most appropriate. This basket is then carried along the process and the contents changed as the requirements change.

A pool of performance measures derived from the questionnaire responses (Chapter 4) was used as the input for the basket contents. As with the questionnaire, the measures are divided into the categories of time, cost, quality, customer service and general measures.

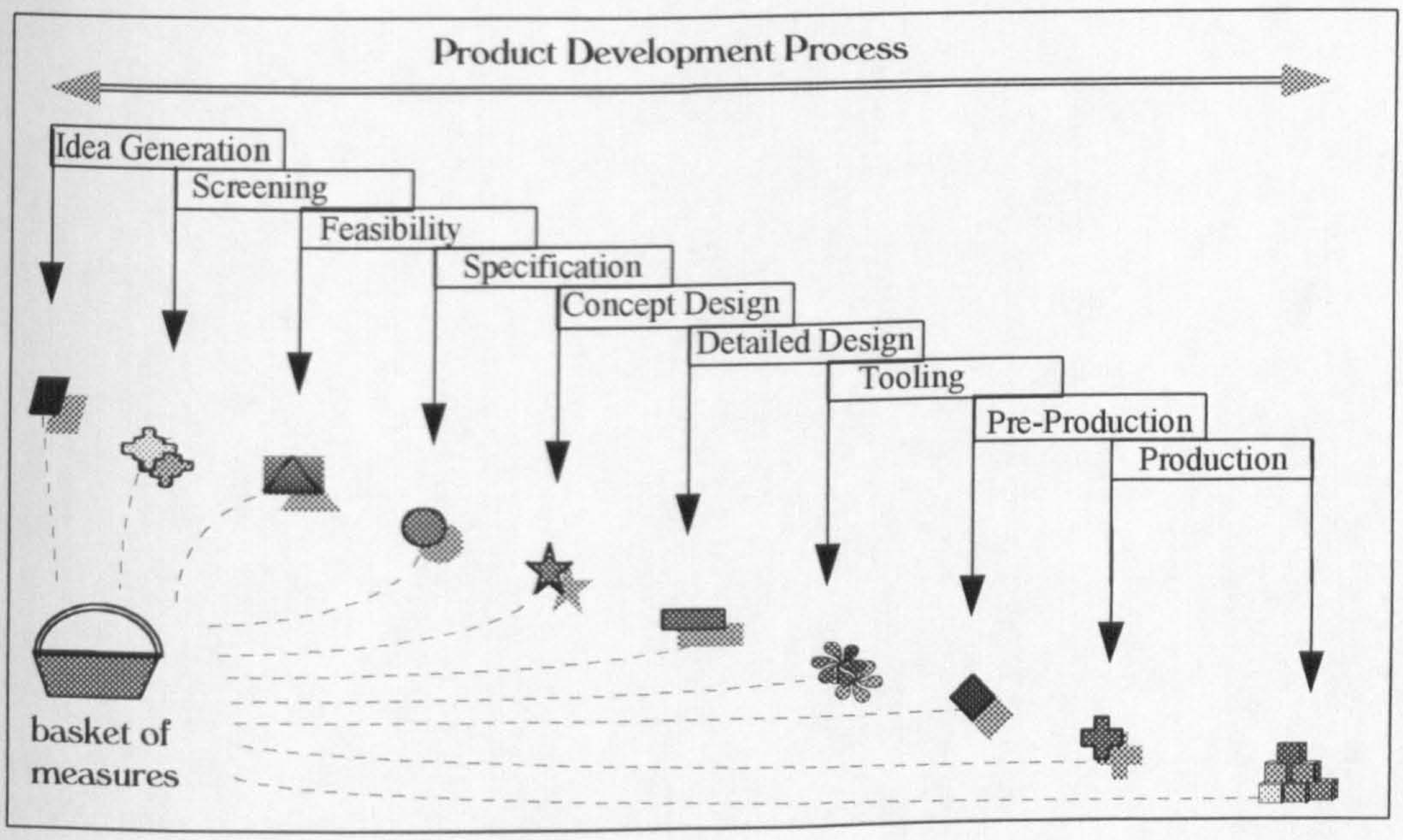

Figure 7.5: Basket of Measures for the Product Development Process

At this stage, the company may want to select a small number[14] of key measures that are mandatory for all projects to enable comparison across all divisions. These will be highlighted in the list. A selection - compiled from the data collection results - has been included by way of illustration in Table 7.4.

Measure	*Useful (✓)*	*PDP Stage*	*Key measure?*
Time			
Total product development time	☐		☐
On-time delivery of development project	☐		☐
Lead time to market	☐		☐
Actual vs. target time for project completion	☐		☐
No. of projects completed on schedule over total no. of projects	☐		☐
Cost			
Actual project cost compared to budget	☐		☐
Total cost of each product development project	☐		☐
Development costs of products that don't get to market	☐		☐
Product development cost as % of turnover	☐		☐
Engineering change costs	☐		☐
Quality			
Reasons for failures of products on the market	☐		☐
No. of early failures of product on the market	☐		☐
Product failure rates	☐		☐
Product prototype passed safety tests	☐		☐
No. of design faults detected at development stage	☐		☐
Customer			
Accuracy of interpretation of customer requirements	☐		☐
Customer satisfaction with length of product life	☐		☐
No. of customer-detected design faults	☐		☐
Response time to customer requests for specials[15]	☐		☐
General/Other			
No. of projects completed per annum	☐		☐
No. of changes to original product specification	☐		☐
No. and nature of 'bottlenecks'	☐		☐
Ability to use a common design platform	☐		☐
% standard parts[16]	☐		☐
% of products that met all stated objectives	☐		☐

Table 7.4: Selection of Product Development Performance Measures (by Type)

[14]Somewhere between 1 and 5 is the recommended number to ensure that the associated administration involved does not become unmanageable.

[15] measure of design flexibility

[16] appropriate if product is part of a range

7.5.5 *INDIVIDUAL METRICS CHECKSHEET*

The checksheet in Table 7.5 lists options that may be appropriate when defining the individual profile for each product development measure.

	Description			
Name	*Name of the metric; preferably reflecting its use.*			
Purpose/goal	*e.g. to focus total product cost or to reduce cost by X%*			
Individual Responsible	*Who is recording and reporting it*			
Date Introduced	/ /			
Stage in Product Development Process	Feasibility Concept Design Detailed Design Specification	☐ ☐ ☐ ☐	Tooling Pre-production Production All	☐ ☐ ☐ ☐
Measurement Frequency: a) Recording b) Reporting	**a) Recording:** daily weekly monthly per project quarterly	 ☐ ☐ ☐ ☐	**b) Reporting:** daily weekly monthly per project quarterly	 ☐ ☐ ☐ ☐
Method of Reporting	emails memos reports	☐ ☐ ☐	presentations team meetings dept'l meetings	☐ ☐ ☐
Visible to:	MD/CEO All project managers Some project managers	☐ ☐ ☐	Organisation-wide All project team ....(*Details*)	☐ ☐
Calculation	*The formula to calculate values to be recorded*			
Useful Tools/Techniques	*Any tools required to perform the calculation and/or use the metric*			
Costs	£ *Cost implications of its use (if known)*			
Benefits	*e.g. reduced cost of process*			
Changes in performance	*Improvements/problems noted since the measure was introduced*			
Current Use of Metric	Unique to this Project Organisation-wide	☐ ☐	Used previously ....*(Details)*	☐
Format on which metric is held	Software Paper-based	☐ ☐	*Details; filename, location*	
Notes	*Comments on experiences and use to date*			

Table 7.5: Individual Performance Metric Specification Sheet

7.5.6 SYSTEM DEFINITION CHECKSHEET

A system definition checksheet such as the one in Table 7.6 is important to ensure that all areas of the system have been considered.

The measures specified will directly contribute towards achieving the strategic goals of product development	☐ Yes ☐ No
Measurement areas that have been addressed:	
Time	☐
Cost	☐
Quality	☐
Customer Satisfaction	☐
...	☐
Views of the following departments have been considered:	
Development	☐
Marketing	☐
Manufacturing	☐
...	☐
For global implementation, the following have been consulted:	
USA Division	☐
...	☐
Across the organisation consideration has been give to:	
cultural issues	☐
language issues	☐
standards/procedures	☐
...	☐
The PMPD system has been checked for compatibility with existing computer systems on the network	☐
The PMPD system fits in with other performance measurement programs in the organisation	☐
A regular reporting period for the measures has been set	☐ *frequency*
A regular review period for the measurement system has been set	☐ *frequency*
Comments from the PMPD database will be reviewed by:	☐ *frequency*
A training program has been organised	☐
Representatives have been identified to carry out training	☐
The system will be incorporated into the ISO 9000 procedures	☐
Master copy is held by:	
Financial implications of the system Approved by:	£
Date:	/ /

Table 7.6: PMPD System Definition Checksheet

7.5.7 SUGGESTED INPUTS TO THE PMPD PROJECT WORKBOOK

The format of this template is purposefully flexible to enable the framework set by the Task Force to be adapted to suit the needs of the project teams (on a project-by-project basis). Ensure that all team members have undergone training on the PMPD System as defined in the System Implementation Workbook. This will not only have familiarised the team with the measurement concept but also provided them with training on the associated tools and techniques (e.g. Gap Analysis, Basket of Measures and the PMPD Feedback Database Template).

Once the training has been given (preferably by an internal manager), participants work through the stages of the book, completing appropriate sections from their viewpoint. This is intended as a suggestion for the start point of the first version of the Workbook and is primarily paper-based. In future versions, the information could be wholly computerised and networked.

Base Project Workbook Stages

It is anticipated that a project team will already have been formed before the workbook is used. Once the procedure for using the workbook has been used a few times, not all steps will be required[17]. Base stages could include:

1. Introduction:
    - The rationale behind using performance measures and a preface by the MD, Technical Director and/or other suitable senior manager.
2. Outline of workbook stages with brief explanations.
3. Project objectives:
    - Include project mission statement and targets
    - List team members (leader, core and part time team)
4. Plan and prioritise what to measure and which tools/techniques to use.
    - Project PMPD Gap analysis:
        - Questions will have been adapted by the Task Force to suit the company products and processes.

[17] apart from for new project team members

- Use the template finalised as part of the System Workbook.

- The PMPD Cause-Effect Analysis used at the project level.
  - For example a company may have a problem with high cost in-house components - this effect is based along the stem of the diagram. Brainstorming will quickly generate the main causes for this. These are then attached to the stem. By examining each of these causes in turn the types of performance measures that will help prevent these factors may be identified. These suggestions are often written on adhesive notes and attached to the main diagram to allow for easy portability in the dynamic brainstorming environment.

- Examine the Basket of Measures (which will already have been adapted to the company product development process) to identify which measures to use at which stage and which will be used throughout.
  - The project manager and his/her team can examine the measures that are available from a general pool or 'basket' and select those that are most appropriate for their project. These will then be recorded alongside any key measures identified in the Basket of Measures template.
  - If resource is a problem, prioritise in terms of importance and/or urgency. Those not initially included can be added on the next iteration.

- Complete an Individual Metric Specification Sheet for each performance measure that has been identified from the above steps. Here, the exact parameters for each measure need to be decided upon.

- Collate and use a Project Checksheet to ensure that all areas have been addressed.

5. Management of the Measures:

   - Assign Responsibility among the project team for carrying out the measurement, monitoring and reporting and recording feedback.

6. Carry out and Record Measures for chosen project performance parameters:

    - ♦ Collate and analyse all specification sheets onto a spreadsheet (preferably computerised) and enter data to produce graphs, tables and reports showing predicted progress against actual.
    - ♦ Could use the template provided in the System Implementation Workbook.
    - ♦ Make use of the PMPD Database Feedback Template.

7.5.8 PMPD Training Information

What follows is a template that can be used to build a company-specific training programme.

The training information is aimed at all those who will be involved in using PMPD. The purpose is to introduce the project team members to performance measurement and to show how it will enhance the operation of their projects. The preferred format for this will be a half or one day course either on or off site. It will be a presentation-led course could cover the following topics:-

1. ***Introduction to Performance Measurement.***
    - The definition and meaning of performance measurement
2. ***Why is Performance Measurement useful?***
    - The reasons for using PMPD (inc. message from the CEO/MD)
    - Characteristics of the company product development process
    - Benefits performance measurement can offer
    - Tables showing the improvements made after example implementations
    - What areas of the company performance measurement affects
3. ***What is PMPD?***
    - A short explanation of the need for performance measurement for product development (markets, competition, standards, timescales, etc.)
    - The objectives and initial targets
    - Who was involved in formulating the PMPD system

4. ***How does PMPD help us carry out product development?***
    - What this means in practical terms
    - An overview of the stages and tasks involved in the Project Workbook
    - Expanded components of the worksheets
    - What are the tools & techniques involved
    - Customisation
    - How PMPD will fit in with other organisational measures
    - The costs and benefits
    - How it will change as the company changes
    - Who to go to for advice
    - Summary
5. ***Case study to show how PMPD can help the company.*** Gather relevant sector, market and company-specific information.
    - Use relevant experiences from sister-companies in the group, trade federation company information, published case studies, etc.
    - The training could be networked on PCs in a training room or videoconferencing session; or given using overhead projector slides.
6. ***A workshop and/or panel discussion for the team members;*** to allow project teams to evaluate where they feel that PMPD will be useful to their work. The panel should consist of members of the Task Force as well as senior management. These sessions should help team members to fully understand the material presented and allow them to develop their own ideas.
7. Additional training may be given in specific tools and techniques as appropriate.

7.5.9 Performance Measurement Feedback Database Template

Establishing a feedback mechanism is an important aspect of any control/feedback system. Adjustments arising from comments and experiences keep the system alive. This basic template in Figure 7.5 for the PMPD System provides a start point.

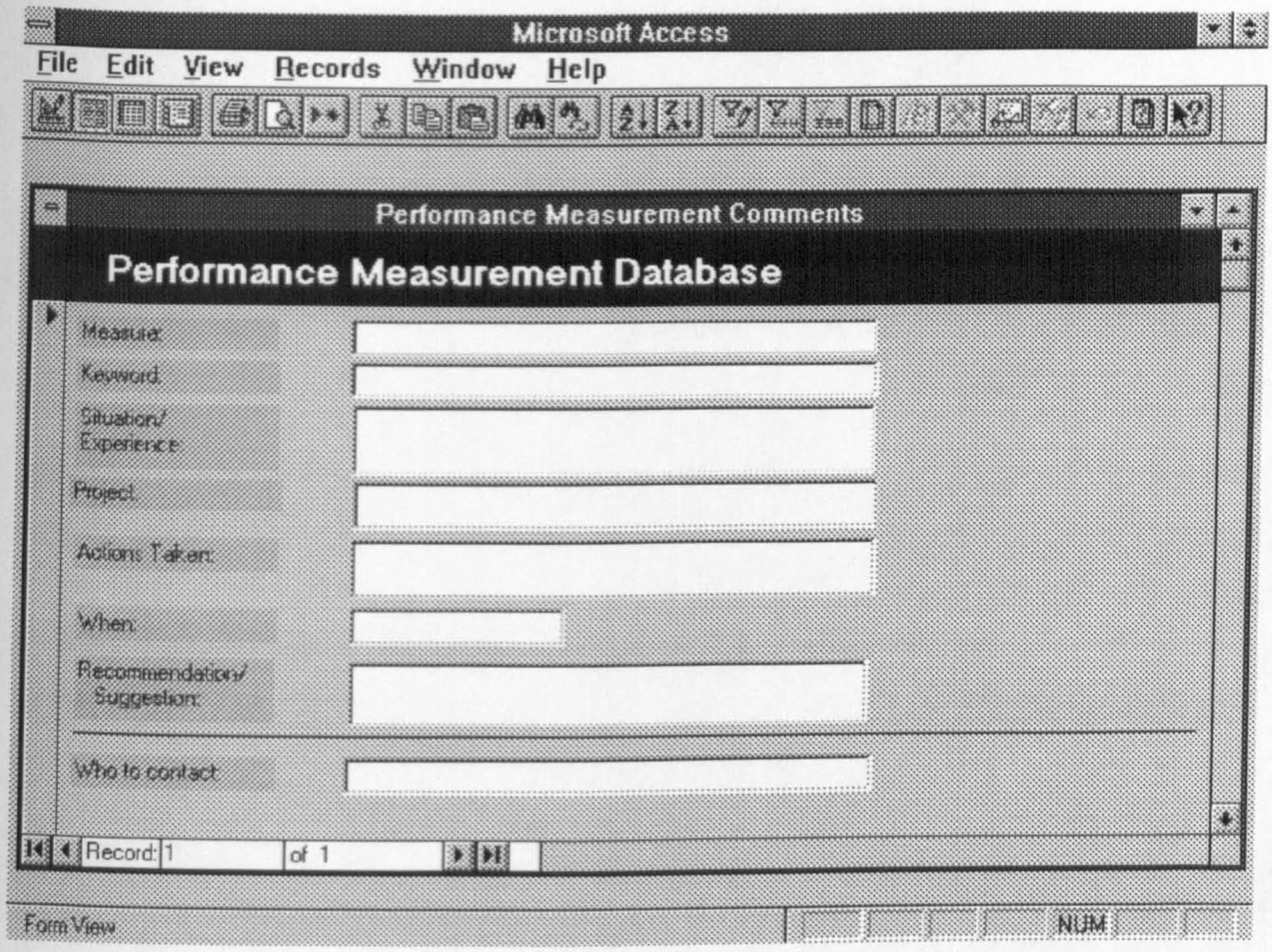

Figure 7.6: Performance Measurement Feedback Database

7.6 Initial Testing

In the Spring of 1997 the proposed PMPD Methodology was tested at two companies; Domestic Appliances Ltd. and Plastico Ltd. This gave the author a valuable indication of its usefulness, user-friendliness and clarity. The researcher outlined the methodology and then answered questions as the participants (mainly senior managers and project team members) read the PMPD Implementation Framework and went through the stages of the PMPD System Implementation Workbook. The researcher stayed out of the discussions as much as possible, only becoming involved to clarify terms or instructions. A group discussion rounded off the sessions by concluding on the framework's usefulness and offering suggestions for improvement. This included an analysis of the proposed training material. The feedback was backed up with a formal evaluation (shown in Table 7.7). The information presented in this chapter was produced following refinements based on their suggestions.

7.6.1 DA Ltd.

Employees of DA Ltd. were consulted throughout the course of this research for their input to the development of the PMPD Methodology. Throughout this time, they allowed full access, administered questionnaires across the organisation and gave feedback on ideas. This long term relationship put them in a good position to be used as a test-bed, as criticism would not be held back.

The Senior Project Manager and members from the Colocation 2 team took part in the test. Once the procedure for use had been outlined, the Senior Project Manager went through the stages of the PMPD Implementation Framework and System Implementation Workbook with his team. They felt that an overview of the framework was necessary in the introduction to the workbook to allow the 'process champion' to demonstrate the 'big picture' to his team. They also wanted to see a fuller explanation about each of the tools and techniques involved. They particularly liked the Gap Analysis but recommended adding a provision to investigate why the gap exists between the 'as-is' and 'to-be' situation.

7.6.2 Plastico

As Plastico are in a totally different situation to DA Ltd. - being a mass producer in the chemicals industry - they had an alternative perspective to offer on what they required from a measurement system. Measuring performance during product design and development is still a relatively new activity for them, which meant that they were keen to make the most of the evaluation session. The meeting was attended by the IT Manager (who coordinates product development projects) and a Project Manager (who is responsible for administering and recording performance measures).

Availability of resource is the biggest problem that Plastico face in developing their performance measurement system. For this reason, they liked the system viewpoint with its structured step by step approach. The Project Manager commented; 'this approach will give us an opportunity to step back and evaluate what is required which we haven't done before. In the past, we have recognised the need for measures but have always identified what we need amongst ourselves and launched it on the rest of the organisation, without the full consultation or training'. He added that 'this is just what could be needed to 'win over' the project managers' (without whom nothing would get done). The IT Manager agreed by commenting that the 'whole workbook approach is much more participative than what we are doing now'.

As Plastico is a multinational company, they want to be able to compare measures on a global basis. They communicates via groupware which meant that they were very keen on the computerisation option in the methodology: 'We want people to be able to manage their own measures rather than us acting as 'brokers' which tends to happen at the moment. The spreadsheet and database template offer possibilities for this'.

However, they felt that there was 'a lot to take in' and 'too many stages' to the first version of the PMPD Methodology. They also thought that the Gap Analysis and Cause-Effect Analysis required clarification before they would be of practical use.

7.6.3 EVALUATION

The evaluation form in Table 7.7 was given to all participants at the end of the day. Average scores were based on five completed forms. Obviously this small sample has limited validity when taken at face value. However, the figures do not reflect the real more intangible value of the trials. This came from testing ideas in a real company environment with managers who were faced every day with product development problems.

Overall the response was very positive. The high scores show that participants supported the PMPD Methodology. Of the tools and techniques used, they particularly liked the Training Information, the Basket of Measures and the Feedback Database. Both companies liked the systems approach which enabled them to devise a more detailed plan of action than time would normally allow for.

	Ave. Score[18]
The PMPD Methodology supports the introduction and implementation of performance measures for product design & development	4.2
The purpose of the tool is clear	4.0
Customisation to our company situation will be easy	3.2
The PMPD Implementation Framework is easy to follow	3.5
The PMPD System Workbook can be used without the aid of a consultant	3.0
The PMPD System Workbook is comprehensive	3.8
The PMPD System Workbook should be more detailed	2.0
The checksheets are clearly worded	4.3
The Question Sheet for Analysing Product Development Activities is helpful	3.8
The PMPD Gap Analysis is useful	3.6
The Basket of Measures is useful	4.4
The PMPD Development Guidelines are useful	3.8
The Training Information Template is useful	4.6
The Performance Measurement Feedback Database Template is useful	4.4

Table 7.7: Initial PMPD Methodology Evaluation

7.6.4 Subsequent Refinements

The positive response by both companies meant that the essence of the Framework remained the same. However, the concern over length was addressed by reducing the number of stages from 8 to 6 by combining some exercises. Additionally, instructions on the PMPD System Implementation Workbook were clarified and personalised. An overview of the Framework was also included in the introduction to the Workbook to provide the Task Force members with a visual progress map. Finally, relevant adjustments were also made to the individual tools to make them more user-friendly.

[18] from a scale of 1 to 5 where 1 = strongly disagree and 5 = strongly agree

While testing the tool in the participating companies, a number of costs and benefits were identified. As with any change, costs are incurred before benefits can be realised. Below are listed the typical costs and benefits that the companies expected from implementing the PMPD System.

a) Costs:

- New equipment purchase as software and hardware purchases may be required.
- Running costs e.g. collecting, analysing, recording, interpreting and reporting data.
- Introduction costs incurred from changing the system.
- Training costs e.g. training days, printing material costs, advertising and communicating the change.

b) Benefits:

- Aids decision making by providing facts at managers' fingertips.
- Encourages Concurrent Engineering principles; use of teamwork, tools and techniques to produce faster, for less cost and improved quality.
- The systematic approach advocated should catch problems and/or mistakes earlier rather than later.
- Improved visibility of actions should increase internal and external customer satisfaction.

7.7 Summary of Research Output

This chapter has described the development of the PMPD Methodology to assist with implementing and managing performance measurement for product design and development activities. These outputs drew on both previous work in this area and the findings from this research (distilled to become the principles of PMPD).

Results from the fieldwork were directly used to formulate the System Implementation Workbook contents. These included tangible items such as the list for the basket of measures, visibility and reporting options, etc. and intangible items such as advice and comments made by managers. The PMPD System Workbook is paper-based with software extensions (such as the Performance Measurement Feedback Database), as it is believed that this format is the most flexible option available. In this way, the methodology is highly portable and more-group-work friendly than a solely software-packaged format[19].

The trials indicated the methodology had several specific strengths. These were; ease of use, ease of monitoring at all stages of projects and ease of control (through the checksheets). Overall the companies felt that the PMPD Methodology would indeed assist them with implementing performance measures.

7.7.1 SCALE OF IMPLEMENTATION

A major challenge encountered during the practical stages of this research was finding a way to fully test the PMPD Methodology. For this to be achieved, the company needed to have involvement from both top management and team level on a new project. In addition, the timing had to be right so that a new project was being started during the research period. This required a lot of commitment in terms of time and resources and proved to be a difficult task. However, the initial tests allowed for problems to be identified and refinements to be made to the original version.

7.7.2 IMPROVEMENT OPPORTUNITIES

Although the testbeds provided useful information this is only a starting point for making the tool fully operational. Full testing in a real-time environment over the natural duration of a product development project would be the most obvious next step.

One option with the System Implementation Workbook would be to carry out full-scale computerisation from a paper-based to a software-based format. Although the author advocates a combination of paper-based and software tools, computerisation may be more suitable for some companies. Information could be made available on a company's network, making it more compatible with the software packages recommended as part of the implementation framework. This would require questions on ownership of and access to the master versions to be addressed.

It was initially hoped that time would permit the testing of the PMPD Methodology without the use of a consultant. Although the researcher is not a consultant, it would be

[19] A common complaint with management software tools is that they can be too constrained, literal and difficult to adapt.

true to say that a fair amount of guidance was given when the field trials were held. However, these trials indicated that the tool was user-friendly and it is hoped that unaided use of the tool will be an area for further research in this area.

Further testing is strongly recommended to corroborate the results from the initial tests. Suggestions for further research work are included in Chapter 8.

CHAPTER 8

8. CONCLUSIONS

This chapter summarises the findings that have arisen from this research. Implications of the research findings are discussed, together with the extent to which the original objectives have been achieved. The contribution to knowledge in the area of management research is assessed and finally pointers for further research are given.

"If you want to manage it, you have to measure it". So goes the old management adage. It is an oft-quoted phrase that is sometimes used as a weapon rather than as a tool to effect performance improvement. Measurements for product design and development are, in some cases, used as approximations to enable comparisons between projects or between divisions. Another point of view is that they are essentially indirect attempts to measure intangible elements. The problem that managers have to face is that as soon as something is part of a measurement system, figures can be disguised, aggregated or generally altered to provide a rosier picture than is actually the case. However, a well-designed measurement system is able to overcome some of these problems. In the case of product design and development, where consistent and comprehensive measures are still in their infancy, the attitude has been to start measuring to get an approximation of 'where we are now' and then fine tune. Invariably, once things start to be measured, they improve.

The task of performance measurement is made particularly difficult owing to the inherent variability of design and development processes. The argument to date has been that it is very difficult to assign costs, especially on so-called 'blue sky' projects. Hence, there has been a certain amount of unwillingness in the past to report measures in this area. A typical comment would be 'you can't track development - it's a creative process'. As has been shown throughout this thesis, this view is now being challenged as both domestic and global competition becomes ever more intense.

The main outcome of this research has been to establish a methodology for implementing a performance measurement system for product development in manufacturing organisations. Instead of replacing existing ideas in performance measurement (e.g. [Dixo90], [Grif93] and [Kers96]), the research has built on them to form one of the few international analyses focusing on product design and development.

It was quickly realised that the formulation of a comprehensive set of measures that would be applicable to all manufacturing organisations or even to all firms in one sector was unrealistic, if not impossible. Mahajan & Wind [Maha92] stated that 'shortcomings of measurement approaches are centred around the fact that they are time-consuming and fail to capture all factors'. This may be true but time and effort is required to initiate and manage any change. Additionally, designing a tool that aims to 'capture all factors' (in all situations) is rather ambitious given the vast range of requirements of modern organisations. The approach taken for this research has therefore been to provide a framework with guidelines and pointers to enable companies to consider alternatives, rather than attempting to meet specific criteria. A company looking at implementing product development measures cannot be expected to get all considerations right first time as change is, after all, an iterative process.

The message from the research is that measures for product design and development have been neglected in the past. However, as competition increases and other areas such as quality management, organisational re-structuring and manufacturing process control have been addressed, organisations are turning to product design and development to gain a new competitive edge. The high response to the company survey suggested that there was considerable interest in this area and the follow up interviews with managers and directors confirmed this. The company questionnaire revealed that the consistent use of performance measurement in design and development - both in the UK and global manufacturing organisations - is still very limited[1]. To the author's knowledge this is the first time that such a large scale study has been carried out in this area. The comparison with academic opinion revealed that a gap does exist between the measures recommended by the academics and those used in practice, but that the difference was not as great as anticipated. The main difference lay in the fact that companies are using basic time, cost and quality measures, whereas academics would like to see increased use of customer-related measures at the design and development stages.

[1] although companies are keen to improve in this area

The 'optimal' set of performance measures is very situation-dependent, relying on their purpose and role within the company applying them. It is, however, fair to say that a balanced system will typically include a combination of hard and soft measures (e.g. time to market and reasons for delays). Some of these will be used long term throughout all stages of the process and/or on a large number of projects, whereas others will be more project-specific. The notion of a 'recipe instruction book' for applying performance measures that will solve product development problems in a company is misjudged. An interesting quote from one manager sums up the work in this field: 'When dealing with performance measures, it is important to remember that the measures are not an end in themselves and that on their own, they don't give you direct benefits'.

As described in Chapter 7 as part of the explanation of the Implementation Framework, appropriate measures are very company-specific. The Director of Research at one follow-up case company illustrated this point by stating:

> 'We do not have a template of detailed measures that must be used on each project - we leave it to the individual project managers and teams to decide on what is appropriate. Flexibility is vitally important as management is a dynamic activity. The best approach is to review your system on a regular basis and ensure that what you are measuring is both useful and accurate. It is important to remember that you can easily measure the wrong thing e.g. head count. One extra person costs virtually nothing compared to implications of a late project. For each project we need to weigh up the impact of being late against the deployment of extra resources. These aspects cannot be written into hard and fast rules, that is why flexibility is important.'

The number and frequency of measures is an important issue for success of a performance measurement system. The company questionnaire revealed that 35% of respondents were not satisfied with the number of measures and 43% were not satisfied with the frequency of measures being made in their company. This is not to say that more is necessarily better: Comments from the cases illustrated the point that measures should not be applied everywhere without due thought; 'we would only introduce more measures that would make a direct, positive contribution to decision making and the product development process'. Another manager reinforced this view by stating; 'basically, we want to introduce more effective measures but they must be the right ones. Any new measures must be proven to be useful and worth the effort i.e. they must have a proved payback'.

It seems that when implementing a performance measurement system, crude intermediate measures may be introduced as a yardstick for future action. These should subsequently be dropped and replaced as the performance measures become more fine-tuned and measurement becomes part of the company culture. It is a common mistake for companies to add to the list of measures they are using without discarding obsolete measures. As the number of measures increases, the system becomes increasingly cumbersome and unworkable.

Another important consideration is having a clear system and supporting procedures for managing the measures. This came out in both the questionnaires and the follow-up cases. In the case of the company questionnaire, 52%[2] stated that one of the main barriers to introducing performance measures was that there was no system in place. In the follow-up cases, a project manager at Global Engineering Co. Stated that; 'we are not satisfied with the number of measures currently used. We need more measures of performance to address efficiency of the process and ones to give early warning of potential problems. They may vary by stage of the process. The major barrier to this is the lack of systems in place to support more measurement'. This was reinforced by another manager who separately stated; 'Brewmasters does not currently have a framework that pulls all the measures in all areas together. If this information were available, it would be a very powerful strategic tool'.

Without exception, all companies were keen to improve in their management of design and development through measurement but were unsure of exactly how to achieve this. Almost all case study companies (8 out of 10) admitted that there was room for improvement in current systems. For example one Project Manager stated; 'there's no hunger from top management to receive performance measures but at the same time, the team may get asked to show them. Their use is more reactive than proactive at the

[2] of those that answered the question regarding barriers (58)

moment. We are aware that better measurement will produce better end results with our products but I'm not sure exactly what types of measures they should be'.

As access to and familiarity with computers improves, ever more companies are buying increasingly complicated tools and techniques to assist with management. Through talking to managers it seems that complicated tools may not be the answer. This comment by the Industrial Engineer at Weighdex typifies this opinion; 'I don't think we need fancy software tools to improve'. The tool produced here has attempted to keep the core requirements on a basic level, allowing for as much or as little added complexity as required.

The PMPD Methodology brought all the research findings together into one coherent output. Several well-known tools and techniques were adapted for use in a product-development context and other new tools were introduced. The in-depth longitudinal case study and initial testing of the research ideas with the participating companies showed that at a general level the PMPD Implementation Framework is useful in focusing both top management and team efforts on the importance of product development activities. At a more specific level, it proved a valuable means of problem identification and clarification that provided assistance with one company's move towards greater use of Concurrent Engineering (i.e. DA Ltd.). Trials indicated that the System Implementation Workbook is a practical and useful tool that will assist with introducing and managing performance measures for product development into an organisation. It achieved the flexibility desired in the output objectives (Chapter 1) as both the case study and initial tests indicated that it is possible to integrate the information into an organisation-wide performance measurement system.

The aims of the research presented in this thesis were to determine:

1) Which performance measures are currently in use in industry to assist with the design and development of products.
2) How widespread the use of performance measures is during product design and development.
3) Which performance measures academics would like to see used.
4) The overlap between measures recommended by academics and those used in practice.

5) Which additional performance measures could be used to enable product development projects to run more smoothly.

It is considered that all the research objectives have been met. Point 1 was covered in the literature review and questionnaires, while points 2 to 5 were covered through the questionnaires, follow-up cases and longitudinal case study. These data sources also lend support to the hypothesis[3] that 'when used on a consistent basis, the formulation and implementation of appropriate performance measures for design and development projects in a manufacturing environment will improve the product development process'. In particular, there was strong agreement with the sub hypotheses shown by the industrial and academic participants with an average agreement of 74% and 70% respectively across all four statements.

Once the right system is adopted, performance measurement for product design and development can make an important contribution to assisting with the management of Concurrent Engineering projects[4]. It must be realised, however, that this is an iterative, continuous process, which requires consistent time and effort to implement successfully. As highlighted in the literature review - and reinforced through meetings with academics and practitioners - performance measurement has in the past been very much restricted to financial measures, with manufacturing measures recently receiving more attention. It also showed that measurements during the design and development stage are currently still scarce. It is therefore felt that the proposed PMPD Methodology will be beneficial to companies as a way of systemising measures to improve the product development process and hence support Concurrent Engineering principles.

In summary, considering these conclusions in relation to the research question of 'how do companies know that they are making effective use of their product design and development function?' it appears that in most cases they currently do not but that they are striving to find out. An advantage of this research is that the output - the PMPD Methodology - was tested in a real environment, although more testing would have been desirable. However, as companies are reluctant to take on full scale real time testing (owing to the amount of time and commitment of resources required)

[3] for this sample

[4] The same could also be said for TQM and BPR projects.

preliminary tests were the most that could be achieved under these circumstances. It is, therefore, felt that the results from the two test beds used provide an adequate and reasonable basis for further work and that the investigation as a whole has made a positive contribution to the area of management research.

8.1 Contributions to Knowledge

This research has contributed to the existing body of knowledge on performance measures for product design and development in several ways:

Overall Contribution

1) The principles of the research outcomes (see Chapter 7) provided recommendations for implementing product development for performance measurement in manufacturing organisations.

2) To the author's knowledge, this is the first time that a practical methodology for performance measurement (with an implementation framework and workbook) specifically aimed at product development projects has been developed.

3) The information gained from the detailed research methodology (see Chapter 3) is thought to be unique. This methodology was carefully designed to be repeatable and provides a pre-tested starting point for future research in this area.

Fieldwork Findings

4) Visibility of data is a problem in companies that currently monitor performance measurement. Data for measures often exists in one form or another but is not always extracted by those who could benefit from the information (see longitudinal case and follow-up case results for details).

5) The results from the international company survey provide an insight into the current use of and future intentions of the implementation of performance measurement for product design and development. It is believed that this is the first time that such an in-depth survey has been carried out in this specific area.

6) Key results from the questionnaire data include:

◊ The survey companies indicated that additional measures are most needed at the specification stage of product development.

◊ Almost all the measures used by companies focused on failure aspects rather than success.

◊ Quality and customer satisfaction appear not to be as significant as others (specifically time and cost). This may be because they are more difficult to measure accurately, owing to their 'softer' nature. Academics would especially like to see greater use of customer satisfaction measures.

◊ There is currently a low usage of internal surveys[5]. This indicates that employee opinion is not sought on a systematic basis (excluding informal discussions) by the majority of companies.

7) The follow-up cases provided a more detailed account of the needs and intentions for product development performance measurement in 10 firms. In particular, the description of their top three measures, together with their intended future use of measures assisted in formulating the PMPD Methodology.

8) The longitudinal case study illustrated some of the issues and challenges involved in introducing measures for product development and described one way in which it was done.

PMPD Methodology Contribution

9) The PMPD Methodology with its six step implementation framework and accompanying practical workbook is believed to assist with formulating and implementing performance measures for product design and development. It was tested at two companies where it was positively received. Subsequent comments and feedback led to a refined, more 'user-friendly' framework. It is purposefully non-sector specific to make it adaptable to fit with a wide range of industries.

10) The PMPD System Implementation Workbook that operationalised the framework, was designed to be used directly by companies without the need for

[5] The company questionnaire indicated that 42% use them now and only 6% intend to use them in future. The follow-up cases backed this up with only 3 out of the 10 using internal surveys.

an external consultant. Within this, a number of tools and techniques were developed:

- ◊ A PMPD Gap Analysis to assess the current situation and future measurement needs for product design and development.
- ◊ A 'Basket of Measures' template to identify what measures are useful at which stage of a product development process.
- ◊ Product-development oriented checksheets to assist with the PMPD system development.
- ◊ A product-development specific Cause-Effect Analysis to isolate how measures can be used to achieve project goals.
- ◊ A Performance Measurement Feedback Database template to record experiences while using the measurement system.

In addition, feedback was given to participating companies in the form of summaries of questionnaire data and write-ups of follow-up cases, enabling respondents to learn from the experience of taking part in this research.

8.1.1 GENERALIZABILITY

Ensuring that the research methodology that underpins the results presented here can be applied across a wider sample was an important consideration. Full scale testing in multiple settings is obviously the best way to achieve this but as described previously this is not always possible. Taking into account the constraints placed on the research setting, results were tested in two different industries. This means that, strictly speaking, the results can only be generalized to companies in these sectors. However, the tools and techniques employed are considered sufficiently non-sector specific to indicate that the methodology could be used outside of this context. For example, the original RACE questionnaire has been used in a variety of industries, as have project management tools, database interfaces and system checksheets. Having said that, additional testing of both the research methodology and the PMPD Methodology is of course strongly recommended.

8.1.2 LIMITATIONS

As discussed in the research methodology (Chapter 3), all research approaches have their own strengths and weaknesses. A weakness of questionnaire-based research is that data collected is based on people's perceptions rather than actual observation of their behaviour. With a large sample size this is difficult to avoid. However, in this study the effects are offset by the use of follow-up cases and an in-depth longitudinal case study. The information included here has been collected and analysed from a wide variety of sources in an effort to ensure that a holistic view was gained. This approach has the advantage of maximising external validity but minimising the opportunity for making a repeat comparative study (with the same sample)[6].

One could argue that the study is not definitive in that the sample-size of both the surveys were fairly small (200 responses in all), making extrapolation of results dangerous. For this reason and owing to time constraints, the results were not analysed from a highly statistical perspective. This data could, however, be used in future for further cross comparisons. One possibility for the future would be to analyse the data from a sector-specific perspective. The research method was such that the sample came from those involved with and therefore interested in product development activities. This clearly has both positive and negative aspects. It is an almost unavoidable research problem but results are still valid as long as these conditions are declared and borne in mind.

Additional longitudinal case studies would have been preferable to one-off follow up cases as the information yielded would have been much broader and richer. However, this would have demanded a heavier commitment from the participating companies, which would, in some cases, have required considerable negotiation owing to the commercially sensitive nature of product development.

[6] Reliability (in terms of repeatability of 'experimental conditions') is almost impossible in management-oriented research.

8.2 Potential for Further Research

The findings from the research contained in this thesis have indicated that further work would be beneficial in this area. This could either involve extending the theme of this research or investigating related areas. More specifically:

1) Additional analysis of the company and academic questionnaire results and the longitudinal case study could be carried out. The data has been carefully recorded to allow future researchers to reanalyse it from another perspective and/or examine it with another research hypothesis in mind.

2) Further triangulation of the follow-up case data would allow for comparisons to be made between (say) management layers, company size and/or geographical locations in terms of opinions on and hopes for performance measurement.

   ◊ This could lead to an investigation of the implications of globalisation on the use of performance measures. As product development projects are increasingly being divided between design centres and manufacturing sites in different countries, how can appropriate performance measures be administered to provide a common understanding?

   ◊ Additionally, an investigation into the effect of electronic communication on performance measurement for product development could prove both interesting and useful. This may lead to a methodology and/or tool that focuses on ways of uniting disparate data sources.

3) This research revealed the types of measures currently used in a range of companies (Chapters 4 and 5). Further work could explore the reasons for their use in more detail and describe the exact calculations involved. This would allow for more detailed cross comparisons to be made.

   ◊ This could lead to determining why companies largely focus on negative-oriented measures (such as bottlenecks and defect rates) and how the use of more positive performance measures could be encouraged.

4) Academics indicated that they would like to see more customer satisfaction-oriented measures. A study could be carried out to determine what this should

involve and how such measures could be developed, calculated and implemented.

5) Companies stated that calculating the time (and hence cost) required for product development projects was a difficult task. This was due to a combination of accurately measuring designers' and engineers' time (timesheets were unsatisfactory) and controlling bottlenecks. Further work could focus on this area.

6) A high percentage of respondents used cross functional teams (approx. 90%). This research did not explore the relationship between these teams and the use of performance measurement systems for design and development projects. Further work could do so and determine how this connection could be improved to produce better results.

7) Conduct a follow up survey on worldwide use of performance measurement in design and development in approximately five years time. This would provide a valuable insight into progress in this field and could report on successes and failures encountered.

8) Further testing of the implementation framework and tool in a real-time environment in different industries[7] (across a range of sectors and for different volumes of production). This would provide a number of benefits. Firstly additional validation for the results, secondly a test of the principles of PMPD (Chapter 7) and thirdly it would enable the tool to be enhanced and fine-tuned to make it more widely applicable (in particular to ensure that it can be used without the aid of a consultant or advisor).

9) Make a full software version of the tool: The tool could also be easily converted into a fully computerised format, using a point and click interface with pull down menus and hypertext links to jump to related topics and further detail. A proposal for an EPSRC project is currently being prepared to develop this.

[7] One follow up survey, specifically focusing on the domestic appliance industry is currently (academic year 96/97) being carried out at the University of Nottingham by an undergraduate student.

10) The PMPD Methodology could also be extended to other areas of the business. It could be adapted or broadened to include areas such as Logistics or Purchasing. Alternatively, these could be added as separate modules to constitute an overall performance measurement system.

◊ It would also be interesting to investigate the possibility of service applicability; could the methodology - adapted or otherwise - be used in service industries?

Finally, it is believed that this thesis has made a positive contribution to the understanding of the needs of manufacturing firms using performance measures for product development projects. It is sincerely hoped that the results are used to assist with further research[8] in this area and perhaps act as a stimulus for other ideas in related areas.

[8] One research proposal has already been submitted to further develop the framework.

REFERENCES

[Barc91] Barclay I & Benson M, Success in New Product Development: Lessons from the Past, Leadership and Organisation Development Jnl, v11, n6, 1991.

[Barc95] Barczak B, New Product Strategy, Structure, Process and Performance in the Telecommunications Industry, Jnl of Product Innovation Management, v12, n3, June 1995, pp. 224-234.

[Basi88] Basili V & Rombach H, The TAME Project: Towards Improvement-Oriented Software Environments, IEEE Transactions on Software Engineering, June 1988.

[Belb93] Belbin M, Team Roles at Work, Butterworth Heinemann, Oxford, UK, 1993.

[Bent92] Bentley T, Training to Meet the Technology Challenge, McGraw Hill, UK, 1992.

[Blai97] Blair A, Watching the New Metrics, Management Today, April, 1997, pp. 48-50.

[Bowe96] Bowersox DJ & Closs DJ, Logistical Management: The Integrated Supply Chain Process, McGraw Hill, NY, USA, 1996.

[Camp89] Camp R C, Benchmarking: The Search for Industry Best Practices, ASQC Press, Wisconsin, USA, 1989.

[Capl94] Caplice C & Sheffi Y, A Review and Evaluation of Logistics Metrics, Intl. Jnl of Logistics Management, v5, n2, 1994, pp11-28.

[Cart91] Carter DE & Baker BS, 'Concurrent Engineering: The Product Development Environment for the 1990's, Mentor Graphics Corporation, USA, 1991.

[Char91] Charney C, Time to Market - Reducing Product Lead Time, Society of Manufacturing Engineers, USA, 1991.

[Chie96] Chiesa V, Coughlan P & Voss CA, Development of a Technical Innovation Audit, Jnl of Product Innovation Management, v13, n2, March 1996, pp. 105-136.

[Chow94] Chow G, Heaver TD & Henriksson LE, Logistics Performance: Definition & Measurement, Intl. Jnl of Physical Distribution & Logistics Management, v24, n1, 1994, pp. 17-28.

[Clar91] Clark KB & Fujimoto T, Product Development Performance: Strategy, Organization and Management in the World Auto Industry, Harvard Business School Press, Boston, USA, 1991.

[Clar95] Clark J, Managing Innovation and Change: People, Technology and Strategy, Sage Publications, London, 1995.

[Coat91] Coats J, Davis E, et al, Objectives, Missions and Performance Metrics in Multinationals, European Management Jnl, v9, n4, Dec. 1991, pp.444-453.

[Coug92] Coughlan P, Voss C & Fuggles W, A Review of Practice and Issues in Simultaneous Engineering in the UK, Procs. of the EIASM Intl. Product Development conf., Brussels, Belgium, May 18-19, 1992.

[Coug95] Coughlan P & Brady E, Understanding Performance Limiting Practices in Product Development, Procs of the 2nd EurOMA conf., Twente, Holland, May 1995, pp. 71-80.

[Craw88] Crawford KM, An Analysis of Performance Measurement Systems in Selected Just-In-Time Operations, University of Georgia, USA, Ph.D. thesis, Order Number 8812059, 1988.

[Cull96] Culley S J, Own GW & Pugh P, Current Issues in Design Survey 1995-96, IMechE, University of Bath, UK, 1996.

[deGr94] de Graaf R & Sol EJ, 'Assessing Europe's Readiness for Concurrent Engineering', Procs of Concurrent Engineering: Research and Applications conf., Pittsburgh, PA, USA, Aug. 1994, pp.77-82.

[Dixo90] Dixon JR, Nanni AJ & Vollmann TE, The New Performance Challenge, Business One Irwin, Illinois, USA, 1990.

[Driv95a] Driva H & Pawar KS, 'The Development of A Conceptual Model for Concurrent Engineering', Procs of the IAMOT conf., Aston, UK, July 1995, pp.503-510.

[Driv95b] Driva H, Pawar KS and Reetz U, An Implementation Methodology for Concurrent Engineering, d81a: Brite EuRam PACE Project BE-8037-93, 1995.

[Driv96] Driva H and Pawar KS, 'The Role of Design Performance Measures in a Concurrent Engineering Environment', Procs of the 3rd EurOMA conf., London Business School, London, 3-4 June 1996, pp. 207-212.

[Driv97] Driva H, PMPD System Implementation Workbook, Department of Manufacturing Engineering and Operations Management, University of Nottingham, Order Ref. KSP PMPD-1, 1997.

[Duma94] Dumas A, Building Totems: Metaphor Making in Product Development, Design Manufacturing Jnl, v5, n1, 1994, pp.71-82.

[East91] Easterby-Smith M, et al, Management Research - An Introduction, Sage Publications, London, 1991.

[Eccl91] Eccles R, The Performance Measurement Manifesto, Harvard Business Review, Jan-Feb. 1991, pp.131-137.

[Eise89] Eisenhardt KM, Building Theories from Case Study Research, Academy of Management Review, v14, n4, 1989, pp. 532-550.

[Evan93] Evans S, Concurrent Engineering Implementation: Common Failure Modes and Success Factors, Chap. 3, in Concurrent Engineering: Contemporary Issues and Modern Design Tools, Parsaei H R & Sullivan W G (eds.), Chapman & Hall, London, 1993.

[Garv91] Garvin DA, How the Baldrige Award Really Works, Harvard Business Review, Nov-Dec. 1991, pp.80-93.

[Gill91] Gill J & Johnson P, Research Methods for Managers, Paul Chapman Publishing, London, 1991.

[Gilm95] Gilmour P & Hunt RA, Total Quality Management: Integrating Quality into Design, Operations and Strategy, Longman Cheshire, Melbourne, Australia, 1995.

[Glob85] Globerson S, Developing a Performance Criteria System, Intl. Jnl of Production Research, v23, n4, 1985, pp. 639-646.

[Good90] Goodlad S, Speaking Technically, Ventura, Surrey, 1990.

[Greg93] Gregory MJ, Integrated Performance Measurement, Intl. Jnl of Production Economics, v30-31, 1993, pp. 281-296.

[Grif93] Griffin A & Page AL, An Interim Report on Measuring Product Development Success & Failure, Jnl of Product Innovation Management, v10, n4, Sept 1993, pp.291-308.

[Grif96] Griffin A & Page AL, The PDMA Success Measurement Project: Recommended Measures for Product Development Success and Failure, Jnl of Product Innovation Management, v13, n6, Nov 1996, pp.478-496.

[Gumm91] Gummesson E, Qualitative Methods in Management Research, Thousand Oaks, Sage Publications, CA, USA, 1991.

[Gupt96] Gupta AK & Wilemon D, Changing Patterns in Industrial R&D Management, Jnl of Product Innovation Management, v13, n6, Nov 1996, pp.497-511.

[Hall91] Hall RW & Turney PB, Measuring Up: Charting Pathways to Manufacturing Excellence, Business One, Irwin, Homewood, IL, USA, 1991.

[Hamm93] Hammer M & Champy J, Reengineering the Corporation: A Manifesto for Business Revolution, Nicholas Brearley Publishing, London, 1993.

[Hart89] Hart SJ, Service LM & Baker MJ, Design Orientation & Market Success, Design Studies, v10, n2, 1989, pp. 103-111.

[Hart96a] Hart S, Dimensions of Success in New Product Development: An Exploratory Investigation, Chap. 4, New Product Development - A Reader, Dryden Press, London, 1996.

[Hart96b] Hart S & Baker M J, The Multiple Convergent Processing of NPD: Chap 9, New Product Development - A Reader, Dryden Press, London, 1996.

[Haus88] Hauser JR & Clausing D, The House of Quality, Harvard Business Review, v66, n3, May-June 1988, pp. 63-73

[Haye88] Hayes RH, Wheelwright SC & Clark KB, Dynamic Manufacturing: Creating the Learning Organisation, The Free Press, NY, USA,1988.

[Hous91] House C H & Price R L, The Return Map: Tracking Product Teams, Harvard Business Review, Jan-Feb. 1991, pp.92-100.

[Hron93] Hronec S, Vital Signs: Using Quality, Time and Cost Performance Measurement to Chart your Company's Future, Amacom, NY, USA,1993.

[Hump89] Humphrey WS, Managing the Software Process, Addison-Wesley, Reading, Mass, USA, 1989.

[John88] Johne A & Snelson P, Success Factors in Product Innovation: A Selective Look at the Literature, Jnl of Product Innovation Management, 5, 1988, pp.114-128

[John90] Johne A & Snelson P, Successful Product Innovation in UK and US Firms, European Jnl of Marketing, v24, n12, 1990, pp.7-21.

[John92] Johnson HT, Relevance Regained, Free Press, New York, USA, 1992.

[Kapl92] Kaplan RS & Norton DP, The Balanced Scorecard - Measures that Drive Performance, Harvard Business Review, Jan-Feb. 1992, pp.71-79.

[Kapl93] Kaplan RS & Norton DP, Putting the Balanced Scorecard to Work, HBR, Sept.- Oct. 1993, pp. 134-147.

[Kara92] Karandikar HM, et al, Process and Technology Readiness Assessment for Implementing Concurrent Engineering, CERC Technical Report CERC-TR-TM-92-004, West Virginia, 1992.

[Karl96] Karlsson C & Ahlström P, The Difficult Path to Lean Product Development, Jnl of Product Innovation Management, v13, n4, July 1996, pp. 283-296.

[Katz93] Katzenbach J R & Smith DK, The Wisdom of Teams: Creating the High Performance Organization, Harvard Business School, Boston, MA, USA, 1993.

[Kenn96] Kennerley M, Davies A & Kochhar AK, Manufacturing Strategy, Performance and Best Practices, Procs of the 3rd EurOMA conf., London Business School, London, UK, 3-4 June 1996, pp. 363-368.

[Kers96] Kerssens-van Drongelen I, Bilderbeek J, R&D Performance Measurement in Dutch Large and Medium-Sized Companies, Procs of PDMA conf., Florida, USA, 1996, pp. 94-104.

[Kidd86] Kidder L & Judd C, Research Methods in Social Relations, 8th Ed, CBS Publishing, USA, 1986.

[Koch94] Kochhar AK, Kennerley M & Davies A, A Framework for Performance Indicators in Manufacturing Control Systems in Operations Strategy and Performance, Procs of 1st EurOMA conf., Cambridge, UK, 27-29 June 1994, pp.85-93.

[Kubr83] Kubr M, (ed.) Management Consulting, International Labour Office, Geneva, Switzerland, 1983.

[Lins75] Linstone HA & Turoff M, The Delphi Method: Techniques and Applications, Addison-Wesley, USA, 1975.

[Maha92] Mahajan V & Wind J, New Product Models: Practice, Shortcomings and Desired Improvements, Jnl of Product Innovation Management, v9, 1992, pp. 128-139.

[Mask91] Maskell B, Performance for World Class Manufacturing, Productivity Press, Cambridge MA, USA, 1991.

[Mans71] Mansfield E et al, Research and Innovation in the Modern Corporation, Norton, NY, USA, 1971.

[Mill88] Miller JG & Roth AV, Manufacturing Strategies, Boston University Manufacturing Roundtable, Boston, USA, 1988.

[Mock79] Mock TJ & Grove HD, Management, Accounting and Organizational Information, John Wiley & Sons, NY, USA, 1979.

[Muff94] Muffatto M & Panizzolo R, New Product Development Process: The Case of the Motorcycle Industry, Procs. of EIASM conf. on New Product Development, Gothenburg, Sweden, May 1994, pp.482-493.

[Neel94] Neely A, Mills J et al, Realizing Strategy Through Measurement, Intl. Jnl of Production Management, v4, n3, 1994, pp. 140-152.

[Neel95a] Neely A, Gregory M & Platts K, Performance Measurement System Design, Intl. Jnl of Production Management, v15, n4, 1995, pp. 80-116.

[Neel95b] Neely A, Richards H, Mills J & Platts K, What Makes a Good Performance Measure?, Procs of the 2nd EurOMA conf., Twente, Holland, June 995, pp. 362-371.

[Nich93] Nichols K, Pye A & Mynott C, UK Product Development: A Benchmarking Survey, The Design Council, Gower Publishing Ltd., Hampshire, UK, 1994.

[Oliv96a] Oliver J, Which Numbers Count, Management Today, Nov. 1996, pp. 106-108.

[Oliv96b] Oliver N, Design and Development Benchmarking, Procs of the 3rd EurOMA conf., London Business School, London, UK, 3-4 June 1996, pp. 501-506.

[Pack83] Packer M B, Analyzing Productivity in R&D Organisations, Research Management, Jan-Feb 1983, pp.13-20.

[Pars93] Parsaei H R & Sullivan W G (eds.), Concurrent Engineering: Contemporary Issues and Modern Design Tools, Chapman & Hall, London, UK, 1993.

[Pawa85] Pawar K S, An Investigation of the Nature of the Working Relationship between Product Design and Production Functions in Manufacturing Companies, Ph.D. Thesis, University of Aston, Birmingham, UK, 1985.

[Penn89] Pennell JP & Winner RI, et. al, Practices and Prospects, IEEE, CH2682-3/89/0000-0647, 1989, pp. 18.5.1-18.5.9.

[Pool94] Poolton J, Concurrent Engineering Establishment: A Framework Proposal, Liverpool University, 1994, Thesis No. DX192121.

[Pugh81] Pugh S, Concept Selection - A Method that Works, Procs. of the Intl. Conference on Engineering Design (ICED), Rome, Italy, 9-13th March 1981, pp. 497-506.

[Rhod94] Rhodes E & Wield D, Implementing New Technologies; Innovation and the Management of Technology, 2nd Ed, NCC Blackwell, Oxford, UK, 1994.

[Rich80] Richardson PR & Gordon JRM, Measuring Total Manufacturing Performance, Sloan Management Review, Winter, 1980, pp. 47-58.

[Ried91] Riedel JCKH & Pawar KS, The Strategic Choice of Simultaneous Versus Sequential Engineering for the Introduction of New Products, Intl. Jnl of Technology Management, Special Issue on Manufacturing Strategy, 1991, pp. 321-335.

[Scot80] Scott GM & Troberg P, 88 International Accounting Problems in Rank Order of Importance: A DELPHI Evaluation, American Accounting Association, 1980, pp. 6-8.

[Sink84] Sink DS, Tuttle TC & deVries SJ, Productivity Measurement and Evaluation, National Productivity Review, v4, n3, 1984, pp.265-287.

[Sink89] Sink D S & Tuttle TC, Planning and Measurement in your Organisation of the Future, Industrial Engineering Press, Norcross, Georgia, USA, 1989.

[Size85] Sizer J, An Insight into Management Accounting, Penguin Books, Middlesex, UK, 2nd Edition, 1985.

[Smit91] Smith P G & Reinertsen D G, Developing Products in Half the Time, Van Nostrand Reinhold, NY, USA, 1989.

[Stra90] Strauss A & Corbin J, Basics of Qualitative Research, Sage Publications, USA, 1990.

[Take90] Takeuchi H & Nonaka I, The New New Product Development Game, Harvard Business Review, Jan-Feb. 1986.

[Thob95] Thoben K-D, Oehlmann R & Pawar KS, Supporting Companies in the Self Organisational Implications of Concurren Engineering, Procs of the Intl. Conference on Engineering Design (ICED), Praha, 1995, pp. 190-196.

[Trox90] Troxel RB & Weber MG, The Evolution of Activity-based Costing, Jnl of Cost Management, Spring 1990, pp.14-22.

[Twig92] Twigg D & Voss CA, Managing Integration in CAD/CAM and Simultaneous Engineering: A Workbook, Chapman & Hall, UK, 1992.

[Ugha89] Ughanwa DO & Baker MJ, The Role of Design in International Competitiveness, Routledge, London, UK, 1989.

[Ulri95] Ulrich KT & Eppinger S D, Product Design and Development, McGraw-Hill, International Edition, 1995.

[Wats93] Watson GH, Strategic Benchmarking, John Wiley & Sons, NY, USA, 1993.

[Winn88] Winner RI, Pennell JP et al, The Role of CE in Weapons Systems Acquisition, Institute of Defense Analyses Report R-338, Dec. 1988.

[Whee92] Wheelwright SC & Clark KB, Creating Project Plans to Focus Product Development, Harvard Business Review, April 1992, pp.70-82.

[Woma90] Womack JP, Jones DT & Roos D, The Machine That Changed The World, Macmillan, NY, USA, 1990.

[Wood89] Woodcock M, Team Development Manual (2nd Ed), Gower, Hants, UK, 1989.

[Yin84] Yin R, Case Study Research, Sage Publications, Beverly Hills, USA, 1984.

[Zair94] Zairi M, Measuring Performance for Business Results, Chapman & Hall, London, 1994.

Appendix I

Glossary of Terms for Concurrent Engineering and Product Development

Benchmarking	The measurement of business performance against the best through a continuous effort of constantly reviewing processes, practices and methods.[1] The search for best industry practices that will lead to superior performance.[2]
Bottleneck	In a project management context, a bottleneck is a build-up of information and/or activities that primarily causes time (and consequently cost) delays.
BPR	Business Process Reengineering: The fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed.[3] BPR is the means by which an organization can achieve radical change in performance as measured by cost, cycle time, service, and quality, by the application of a variety of tools and techniques that focus on the business as a set of related customer-oriented core business processes rather than a set of organizational functions.[4]
Brainstorming	A creativity improvement method which is used to develop ideas on a distinct topic in a team session. Any evaluation or criticism of ideas is not acceptable during the brainstorming session.
CAD	Computer Aided Design is a software tool used for all aspects of design. It usually covers geometry creation, manipulation and the production of plotted drawings.[5] 3D CAD specifically the design of products in their spatial three dimensions in one drawing.
CAE	Computer Aided Engineering provides automated support for design decisions using computerised tools for CAD, CAM and process planning.
CAM	Computer Aided Manufacture is the application of CAD system geometry to automate the programming of numerically controlled machine tools.[5]
CAx	A generalised notation for all forms of computer-aided tools.
CERC	Concurrent Engineering Research Center established in West Virginia USA. A government-funded body to initially intended to investigate the uses of concurrent engineering in the defense industry and promote knowledge of CE. Its horizons were later broadened to include the health industry.
CIM	Computer Integrated Manufacture is a means of achieving highly flexible and integrated production environments through computer automation.[6] A full CIM system provides centralised control of the manufacturing environment.[7]
Colocation	Locating of teams in one physical place to allow for ease of communication.

Company vision	Future (usually long term) goals for the organisation to aim at.
Conceptual Model	A set of concepts used to represent or describe (but not explain) an event, object or process.[8]
Concurrent Engineering	A systematic approach to the integrated, concurrent design of products and their related processes including manufacture and support. This approach is intended to cause the developers from the outset to consider all elements of the product life cycle from conception through to disposal, including quality, cost schedule and user requirements.[9] Concurrent Engineering is a structured and controlled way of managing product or service development with respect to integrating resources and calendar time, sharing common goals and accurate information throughout.[10]
Configuration Management	An engineering discipline that provides direction and monitoring of configuration (i.e. arranged) items. CM responsibilities include: to identify, document and control changes to the functional and physical characteristics, to document change processing and implementation status, and verify compliance with specified requirements.[11] Configuration management is ultimately concerned with the control of change and the effective management of that process.[12]
Data exchange standards	Standardised formats for data interchange for example between different computer aided applications (CAx).
DBMS	A Data Base Management System is a computer program that is designed to provide general purpose functionality for storing, retrieving and controlling access to permanent data. It is an effective way to manage large amounts of information including CAD data and design catalogues.
Design Concept	Developed by Pugh, uses a matrix with a datum to aid concept selection during design.[13]
Design for Assembly	Systematic method for simplifying a design by reducing the number of parts and ensuring that the remaining parts are easy to assemble.[14]
DFx	A generalised notation for all forms of 'design for' methods. The most well known of these are design for manufacture and assembly. These involve systematic procedures that aim to help companies make the fullest use of the manufacturing processes that exist and keep the number of parts in an assembly to a minimum.[15] Others include design for serviceability, testability, reliability and maintainability.
EDI	Electronic data interchange is the exchange of structured data from one computer application to another by telecommunications.[16]
Empowerment	Concerns the level of decision making an employee or team can take (in terms of financial decisions and working priorities) to improve the performance of their work.

Expert systems	Expert systems are a subset of artificial intelligence that attempts to produce expert levels of performance in solving problems within a very specific area.[17]
External Customer	Suppliers and end-customers.
FEA	Finite Element Analysis is used for testing at the design stage. It enables three dimensional modelling of properties of the design e.g. thermal analysis. It also enables automatic creation of a complete meshed model of a design and performs theoretical calculations to analyse static and dynamic behaviour components using boundary conditions, together with the physical and chemical properties of the material.
FMEA	Failure Mode and Effect Analysis is a methodical way of studying the cause and effects of failures before the design is finalized.[14] The systematic analysis of products or processes to identify and minimise potential failures and their effects on the customer.[18]
Formal Methods	A diversity of methods (either paper-based or computer-based) which facilitate a structured, scientific approach to problem solving. They can be used to solve detailed problems by cutting across functional barriers. Examples include QFD, DFA and Taguchi Design of Experiments.
Groupware	Systems that support the collaboration of several people in a team-like setting by means of computers. A closely aligned term is CSCW - computer supported cooperative work.
Integration	Integration is the most important CE principle. It can be defined as 'to make into a whole; to amalgamate or mix with an existing community. In the CE context it could be described as the readiness to improve the participation of the employees. This includes the joining of their special knowledge as far as possible, as well as motivational (goal sharing) and reward aspects (benefit sharing). Other facets are the integration of tools, standards, data/information /knowledge, communication and organisations.
Internal Customer	Employees in different divisions, functions, departments, etc. within an organisation, who are working on the same task/project.
Method	A procedure which is described by a set of rules, which can (but does not have to be) based on a principle.
Model	A simplified representation or abstraction of reality.[19]
Multidiscipline Teams	Groups formed transcending functional barriers with the aim of solving a specific problem (s)or work on a particular project.
Multi-skilling	Training the workforce to enable individuals to carry out a broader range of tasks.
Multi-tasking	Enables execution of two or more processes on a computer in such a way that the user has the impression of simultaneous execution of the processes.

Object-Oriented Approach	Modelling based on the notion of objects as encapsulated units of data and corresponding functions, relationships and inheritance.
OMT	Object Modeling Technique is an object-oriented development methodology that uses object, dynamic, and functional models throughout the development life cycle.
Performance Measurement	Performance measurement can be defined as the process of quantifying the efficiency and effectiveness of action[20]. A measurement (or metric) can also be defined as an assignment process where numbers are assigned to represent some attribute of an object or event of interest for the decision maker[21].
Poka-Yoke	A technique to avoid simple human error and aiming for zero defects at all levels of work. Japanese for foolproofing. [18]
Process	A collection of activities which take one or more kinds of input and create output of value to the customer. [3] A method of doing or producing something.
Quality	The totality of features and characteristics of a product or service that bear upon its ability to satisfy given needs.[22]
QFD	Quality Function Deployment is a system for designing a product or service and the processes that go into its production based on customer needs and expectations, and involving all members of the producer or supplier organisation that have an effect on it. It provides a means for all people involved in the process of designing, supplying raw materials, producing, distributing and servicing the product or service to meaningfully contribute their expertise and experience so that the whole process leads to satisfaction of the customers' and other stakeholders' needs and expectations.[23]
Rapid Prototyping	RP enables the flexible and highly automated fabrication of complex physical models directly from 3D CAD data in a variety of materials.[24] Methods include stereolithography, selective laser sintering, 3-D welding and fused deposition modelling.
Robust	A product or manufacturing process design is robust if it is relatively insensitive to noise factors which are present i.e. exhibits small variation.
SPC	Statistical Process Control is the use of statistical monitoring and control techniques to achieve desired outgoing quality in products. [14]
STEP	Standard for the Exchange of Product model data is an international standard for representing digital product databases, including shape/size data and three-dimensional CAD geometry and tolerances, materials, assemblies, and configurations. [32]
SWOT	Strengths, Weaknesses, Opportunities and Threats analysis. This is a widely used Marketing tool.
Taguchi Methods	The development of robust designs through design of experiments. The main elements are tolerance, parameter, process design.

Team	A team is a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable. An organised collection of people working together on a project.
TQM	The seeking of continuous improvement in the quality of performance of all processes, products and services of the organisation. This philosophy emphasizes the understanding of variation, the importance of measurement, the role of the customer and the involvement of employees at all levels of an organisation in the pursuit of such improvement.[25]
Transparency	Easy to see through, understand or recognise. The purpose is to underlie that it is advantageous to state explicitly and explain the hierarchies, responsibilities, duties and rights inside a company to the people involved. This facilitates the understanding of the directives and self-assessment of the employees and may be seen as one prerequisite for goal sharing.
Value Chain	Developed by Porter as a means of exploring potential sources of competitive advantage.[26]
Value Engineering	Systematic application of recognized techniques which identify function, establish value for the function and provide the necessary function at the lowest overall cost.[21]
Variability	The measurable effects of noise on products and processes.[36]
Video-conferencing	A means for communication between remote participants in a discussion applying audio-visual devices.
Virtual Reality	A synthetic computer-generated (and hence virtual) environment within which a person can navigate and interact with the virtual objects as the person would in the real world (reality).[27]
Virtual Teams	Teams that operate by using electronic communication.
World Class Manufacturing	Although poorly defined, the expression connotes global competitive standing and a position many companies are striving to attain. 'World class' can be defined as those companies that continuously outperform the industry's global best practices and that intimately they know their customers and suppliers, their competitor's performance capabilities and their own strengths and weaknesses. All of which form a basis of - continually changing - competitive strategies and performance objectives.[28]

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1 Zairi M, Competitive Benchmarking: An Executive Guide, Technical Communications Publishing,, Hertfordshire, 1992.

2 Camp R C, Benchmarking, ASQC Press, Wisconsin, USA, 1989.

3 Hammer M & Champy J, Reengineering the Corporation: A Manifesto for Business Revolution, Nicholas Brearly publishers, USA, 1993.

4 Johansson H, McHugh P, et. al., Business Process Reengineering: Breakpoint Strategies for Market Dominance, Wiley & Sons, USA, 1993.

5 Howe D, EDS Unigraphics, PDM Glossary, UK, 1995.

[6] Lu S C-Y, Knowledge Processing for Concurrent Engineering: An Evolving Challenge in CIM Research, Robotics & Computer Integrated Manufacturing, Vol. 7, No. 3/4, 1990.

[7] Hazony Y, Design for Manufacturing, Handbook of Design, Manufacturing and Automation (Eds. Dorf & Kusiak), Wiley Inter-Science, NY, USA, 1994.

[8] Meredith, J, Theory Building through Conceptual Methods, IJOPM, no. 5, 1993.

[9] Winner, Pennell, et al, The Role of CE in Weapons Systems Acquisition, Institute of Defense Analyses Report R-338, Dec. 1988.

[10] PACE consortium, BRITE EuRAM PACE Project, 1994.

[11] Carter D & Baker B, CE - The Product Development Environment for the 1990s, Addison-Wesley, USA, 1992.

[12] Fowler A, Models & Applications of Configuration Management', Omega, vol. 21, iss. 4, Aug. 1994.

[13] Pugh S, Concept Selection - A method that works, Procs. of ICED conference, Rome, Italy, 1981.

[14] Ettlie J E & Stoll H W, Managing the Design-Manufacturing Process, McGraw Hill, NY, USA, 1990.

[15] Boothroyd G, Simplifying the Process, Manufacturing Breakthrough, Mar/Apr. 1992.

[16] Hartley J & Mortimer J, EDI - The Route to Lean Production, Industrial Newsletters, UK, 1991.

[17] Leonard-Barton D & Sviokla, Expert Systems, (1981) in Parsaei H & Sullivan W, Concurrent Engineering, Chapman & Hall, USA, 1993.

[18] Ranky P G, Concurrent/Simultaneous Engineering, CIMware Ltd., UK, 1994.

[19] Turban E & Meredith J, Fundamentals of Management Science, 5th ed. Irwin, IL, USA, 1991.

[20] Neely A et al, Performance Measurement System Design, Intl. Jnl of Production Management, v15, n4, 1995, pp. 80-116.

[21] Mock TJ & Grove HD, Management, Accounting and Organizational Information, John Wiley & Sons, NY, USA, 1979.

[22] American Society for Quality Control (ASQC), Glossary and Tables for Statistical Quality Control, Milwaukee, USA, 1983.

[23] Gilmour P & Hunt R, The Management of Technology, Longman Cheshire, Australia, 1993.

[24] Casteel K, CE: Thinking fast, free-form and in virtual reality, World Mining Equipment, Jan/Feb 1995, pp.35-37.

[25] Thompson K, The Trouble With TQM, The Quality Magazine, Dec. 1994, pp.89-94.

[26] Porter M, Competitive Advantage: Creating and Sustaining Superior Performance, Free Press, NY, USA, 1985.

[27] Dani T H, et. al, Covirds: An Architecture for a Conceptual Virtual Design System, Procs. of the ASME conf. on Design for Manufacturability (ed. Mason), Illinois, DE-Vol. 67, March 1994.

[28] Greene A, Plant-Wide Systems: A World Class Perspective, Production and Inventory Management, July, vol. 11, issue 7, 1991.

Appendix II

Case Studies and Experiences on Concurrent Engineering Implementation

There are many cases in the literature outlining company approaches to CE implementation. These show that the approach taken very much depends on (among other things), industry, sector, company size, market climate. Interesting cases that have implemented various aspects of CE include: [Barc92], [Clar91], [Gate94], [Geha92], [Muff94], [Pars93], [Shin94], [Turi92], [Woma90] and [Wool94]. Space limitations preclude detailing the individual methodologies so instead selected comments on findings and what has been learnt from these case studies are listed.

1 Aspects for Success

Success factors are a common theme in articles on CE. Listed below are sections from those articles that seek to explain where the improvements come from.

On communication...

From [Turi92]: 'New CAE and networking tools can often be used to help overcome physical location barriers, but existing methods - including phone calls, faxes and personal meetings - can be used to implement concurrent engineering without the requirement for large capital expenditures for new tools. Everyone in the organisation must, however, be fully trained in Concurrent Engineering, speaking the same language and pursuing a common set of goals that they have agreed to'.

On organisation...

From [Barc92]: A survey of companies practicing Simultaneous Engineering was carried out in 1992. 189 replies from manufacturing organisations were analysed.
'There existed within the companies three types of organisations for the development process. Each of these is listed below, together with their percentage occurrence and major comments made by the respondents:

- matrix (45%): The major criticisms were its centralised focus, unclear responsibilities, fragmentation and dual reporting. The suggested remedy was the giving of more responsibility to the programme leaders to help diffuse conflicting loyalties.
- project (32%): The major criticism here was the possibility of duplication of effort between teams.
- functional (23%): The major problem here was the poor and uncoordinated communication. The answer to this seems to be a more business, as opposed to functional, focus.

There is a clear emphasis here on teams'.

On teams...

From an article describing the development of the Boeing 777 [Wool94]: 'Boeing brought customers and suppliers onto the design team to learn valuable lessons on what things cost. ..The [core] design team argued endlessly about inanities such as the shade of white for the cabin, when all passengers do is get on the plane, read or work, eat or got to sleep. They [customers] need to join with us to reduce variability'.

On expectations...

From [Barc92] (from the same study): 'When asked whether SE had lived up to the company's expectations, 57 companies replied that it had. The main reasons given for this were the reduction in cycle times, improvement of teamwork and early problem identification. Several of the companies said that SE had been beneficial but that it was too early to defined how exactly'.

On best practices...

From a message on the Internet responding to best practice companies [Hoop95]: 'Winners of the Malcolm Baldrige National Quality Award (US based) tend to be excellent sources of information about best practices in a variety of areas, not only because these companies are among the best of the best, but also because they are obliged upon receiving the award to share information regarding how they do things with anyone who wants to know. Many of these companies have innovative ways of dealing with both *information management* and *customer relationship management* (both of which are among the Award's criteria)'.

On processes...

From [Shin94]: The key processes to enhance the concurrent product creation process (on the basis of the case studies in the book) are:

1. Phased review process - this should be the primary vehicle for project management. Specific phases are identified in the product development process, with each phase being a collection of task completions. The project team should plan each phase and milestone carefully, with shorter time between the later milestones. The process should be used as the primary vehicle to update the management and project teams with the current status of the project.
2. Quality advocacy and the quality systems review - this procedure is used to assure that the quality system is effective in achieving Total Quality and customer satisfaction. There should be great emphasis on company-wide adoption of TQM and it should have a process rather than a product focus.
3. Manufacturability assessment - to evaluate new products for ease of manufacturing, to ensure a high level of quality and to maintain lower production costs using tools/techniques such as DFA, DFM, DFS, etc.

Extracts from the case studies (*written by practitioners*) themselves in [Shin94]:

On using QFD....

'Although QFD was applied well after the start of the development work, many benefits were derived. The team recommends strongly, however, that QFD be used from the very beginning in future projects. ..For maximum effectiveness, QFD requires a support structure formed by tools, project team member skills, and company processes and systems. A TQM-oriented company culture and philosophy form the foundation for sustained success with QFD'.

On participation...

'The employee involvement survey and research readings all point to workers wanting a genuine participatory role in decision making which can improve the way things get done. Corporate strategies elicit lofty visions, but these visions will not turn into effective competitive weapons without the full cooperation of all employees...The corporation must offer enhanced skills training and then encourage educated risk taking with decisions. People must believe that they have real control, or this will not promote innovative thinking'.

On customer involvement...

'In retrospect, the area of customer feedback was critical to the manufacturing line in this study and efforts are under way to improve their incoming product measurements. This mutual exchange of information was one of the most beneficial aspects that returned value to the corporation. The customer site benefited from the expertise provided form other areas within the corporation and the manufacturing site developed the feedback necessary to focus o improvements most valued by the customer'.

On payback...

'The payoff of time and energy on this project cannot be measured accurately in a monetary manner, but rather in the efficiency of both companies when dealing with paperwork'.

On employee participation...

From [Mask91]: 'In the past, problems were solved by middle managers, engineers and specialists. In a world class manufacturing [and CE] plant, the entire work force is involved in one or more projects aimed at continually improving products, processes, and services. These programs have found spectacular success in many companies because an atmosphere of team involvement and common cause has enabled people who previously had very little opportunity to contribute to become innovative and resourceful problem-solvers. In addition, the people involved in these efforts enjoy their work more because they have a wider variety of tasks and because their ideas are treated with respect'.

2 Reasons for Failure

In order for CE to succeed, full commitment in all aspects of the business is required from an organisation. The following excerpts list the most common reasons for failure of CE in practice.

On common reasons for failure of CE...

From research carried out by Dr. Stephen Evans at Cranfield University [Pars93][1]:

Cost: Costs are difficult to predict. The ongoing nature of a CE implementation means that costs continue *ad infinitum*. The return on investment of team training, awareness and management training are more difficult to calculate than, say, a CAD system, and are prone to easy cost cutting.

CE champion: Middle management can never support a full implementation. ..cross functional changes will require cooperation at the highest level if CE is not to remain an engineering project. A senior champion must be recruited early.

Poor vision: It is acceptable to motivate people by saying 'we want to be number one' but it is unacceptable to use that as a direction setter (number one what?). The group needs to be told their change boundaries - in terms of market, product range new product plans, structure and design methods.

No CE experience: In the early phases of CE implementation there is no CE experience within the organisation. The size of the task ahead and the number of unknowns can make it impossible to generate sufficient confidence to progress. A typical symptom of this problem is constant searching of conferences, workshops, etc. - without obvious progress. To overcome this, plan well and recognise how valuable your experiences are going to be and plan to maximise their effect by including a learning system into the plan.

Culture: Many advocates of CE suggest that the best, or only, way to have an effective team is to find a team leader with almost supernatural qualities. What is more important (and more realistic) is a culture change to understand why the change is needed and to make sure all individuals do the right thing in all circumstances.

High Technology: Though hi-tech tools can and often do deliver improved performance, their return on investment is poorer than many of the cheaper (lo-tech) tools and their implementation is longer.

In addition, over-emphasis - and over-hype - on a pilot project using a team of highly motivated employees, with a huge budget, can make future goals unrealistic.

AT&T see things slightly differently...

Here is an extract from their Technical Journal [Gate94]:

'Is it necessary to go to the head of your Business Unit to make something happen [if you are interested in implementing CE]?. The answer is clearly no! At some point the support of top management becomes critical but is possible to start locally and still show success.

- Network - share this article with your colleagues to build local interest. Ally yourself with others in your organisation who have similar interests and goals.
- Train - acquire a basic set of relevant skills and knowledge by taking courses or attending conferences. Learning about methods and tools can help you in your CE implementation efforts.

[1] Chapter 3 by Evans - 'Implementation: Common Failure Modes and Success Factors'.

- Get involved - if a related activity is under way in your organisation, ask to work on a project that is using, or trying to use, the concepts of CE. If CE is not being used, commit to use CE on your project. Build a project team including as many functions as possible'.

Case studies say...

From [Barc92] (the same study cited in the success section):

- '18 companies said that SE had not lived up to their expectations. The main reasons for this were resource constraints (lack of capital investment in new technology), organisational constraints (especially functional resistance) and lack of commitment from all parties'.

From a case study on Hewlett Packard [Whee91]:

On part-time team members: 'One of the difficult things about applying CE to small projects is ensuring that part-time team members are productive on other projects when the team does not require their services but that they are immediately available when their services are needed...A problem can occur if the project manager fails to recognise the need for the part-timers' help at the appropriate time or if the part-timers are not fully aware of the latest issues then they are called on for help. There is a danger too that they may become engrossed in certain projects, to the neglect of others.

REFERENCES

[Barc92] Barclay I & Taft J, Trends in New Product Development and the Introduction of Simultaneous Engineering, Procs. from PDMA conf. on Managing Product Development, Chicago, USA, 1992, pp. 66-76.

[Clar91] Clark KB & Fujimoto T, Product Development Performance: Strategy, Organization and Management in the World Auto Industry, Harvard Business School Press, Boston, USA, 1991.

[Gate94] Gatenby DA, Lee PM, et al, CE: An Enabler for Fast, High Quality Product Realisation, AT&T Technical Jnl, Jan/Feb. 1994, pp. 34-46.

[Geha92] Gehani R, Concurrent Product Development for Fast Track Corporations, Long Range Planning, v25, n6, 1992, pp. 40-47.

[Hoop95] Hooper D, Quality Catalyst at SSDS Inc., Denver, USA, BPR-Mailbase Message, 23 June 1995.

[Mask91] Maskell B, Performance for World Class Manufacturing, Productivity Press, Cambridge MA, USA, 1991.

[Muff94] Muffatto M & Panizzolo R, New Product Development Process: The Case of the Motorcycle Industry, Procs. of EIASM conf. on New Product Development, Gothenburg, May 1994, pp. 482-493.

[Pars93] Parsaei H & Sullivan WG, CE: Contemporary Issues and Modern Design Tools, Chapman & Hall, London, 1993.

[Shin94] Shina S (Ed.), Successful Implementation of CE Products & Processes, Van Nostrand Reinhold, NY, USA, 1994.

[Turi92] Turino J, Managing CE: Buying Time to Market, Van Nostrand Reinhold, USA, 1992.

[Woma90] Womack JP, Jones TD & Roos D, The Machine that Changed the World, Macmillan, USA, 1990.

[Wool94] Woolsey JP, Air Transport World, 4, 1994, pp. 22-31.

Appendix III
Company Questionnaire

<u>MEASURING PERFORMANCE DURING PRODUCT DEVELOPMENT ACTIVITIES</u>

The purpose of this survey is to provide insight into how management at a variety of companies, both in the UK and abroad, view the existing product development process at their manufacturing and/or development sites. The questions cover a range of issues associated with product development to establish the 'as is' situation and provide pointers for the 'to be' and/or desired situation in the future. I have focused on *organisation* and *enabling tools* rather than the people aspects (as the main interest is what is required, more than how to implement). Your answers will only be used for the purposes of research and will contribute towards providing a specification for a tool to assist in managing product development. Your help is very much appreciated. The questionnaire is divided into two sections:

A. General information & overview of development
B. Performance measures

Summaries of the results, will be circulated back to you if you are interested. You are given the opportunity to indicate your interest in the participant details box (below).

Instructions

The questionnaire is presented in a straightforward format, with responses requiring a tick or a short sentence. Please answer from *your own point of view* - which may not necessarily be the same as 'the company view'. If you feel that you cannot answer a question, simply put a line through it or write 'don't know'. In total the questionnaire should take about 20 minutes to complete. If you have any general comments, please feel free to write on the back of the page.

Confidentiality - The results are for research purposes only and answers will remain confidential.

Please return the questionnaire, even if some parts remain unanswered to:
Helen Driva, Research Associate,
Dept. of Manufacturing Engineering & Ops. Management,
University of Nottingham, University Park, NOTTINGHAM, NG7 2RD, UK
Tel: +44 115 9514 020 Fax: +44 115 9514 000 E: epzpace@epn1.maneng.nott.ac.uk

Participant Details

Company:..

Address:..

Name: (optional)...Tel:.......................................

Position:	Technical Director	☐	Departmental Manager	☐
	Project Manager	☐	Team member	☐
	Team leader	☐	Design Engineer	☐
	Other..			

SECTION A - GENERAL OVERVIEW

1. Please indicate which sector of business your company is in:

Mechanical engineering	☐	Textiles/clothing industry	☐
Electrical/electronic engineering	☐	Food industry	☐
Information Technology	☐	Rubber & plastics industry	☐
Defence industry	☐	Automotive industry	☐

Other (please specify) ______________________________ ☐

2a) No. of employees on the site: _____ b) No. in product design/development dep'ts: _____

3. Nature of production: Project/One-of-a-kind ☐ Batch ☐ Mass ☐

4. Is your design and development on the same site as manufacturing? Y ☐ N ☐

5. Does your company design and develop the products it makes? Y ☐ N ☐ Partly ☐

If partly, please explain______________________________

6a) Which category of ***product development projects*** is most common in your company?

New products to new markets	☐	New products to existing markets	☐
Product restyles to new markets	☐	Product restyles to existing markets	☐

b) What is the average length of development time (i.e. from post specification to pre-production) ***in months*** for a project in this category?

1-6 ☐ 6-12 ☐ 13-18 ☐ 19-24 ☐ 25-36 ☐ >36 ☐

7. Which tools & techniques are currently used to assist in your company's product development activities and which would you like to use in the future?

tool/technique	*use now*	*would like to use*
Brainstorming sessions	☐	☐
CAD/CAM, CAE	☐	☐
Concept testing with customers	☐	☐
Cross-functional teams	☐	☐
Design for manufacture/assembly	☐	☐
Fishbone analysis	☐	☐
FMEA (Failure Mode Effect Analysis)	☐	☐
Internal surveys	☐	☐
QFD (Quality Function Deployment)	☐	☐
Process flowcharts/mapping	☐	☐
Rapid Prototyping	☐	☐
Value analysis/value engineering	☐	☐
Others (please specify)______________________	☐	☐

8. Typically, how many product development projects are run at any one time?__________

9. In terms of your product development projects, do you use cross functional teams:

All the time	☐
Some of the time	☐
None but intend to in future	☐
None - we organise differently (specify)	☐

____

____

10. Would you benefit from greater use of performance measurement during product development i.e. quantifying the efficiency and effectiveness? (See question 15 for examples)

Yes ☐ No ☐ Don't Know ☐

11. Indicate where & why *bottlenecks* in your development process occur.Tick the *main reason only* for each.

WHY / *WHERE*	communication	IT tools/ equipment	training/ understanding	other reason *(specify)*	
Feasibility stage	☐	☐	☐	☐	________
Concept design	☐	☐	☐	☐	________
Drawing up spec.	☐	☐	☐	☐	________
Detailed design	☐	☐	☐	☐	________
Prototyping/tooling	☐	☐	☐	☐	________
Pre-production/ pilot run	☐	☐	☐	☐	________
Handover to production	☐	☐	☐	☐	________

Other (please specify)____

12. Which of the following aspects does the *product specification* cover ? Tick as many as applicable.

Functional requirements	☐	Maintenance and support	☐
Detailed design (CAD drawings)	☐	Styling/appearance	☐
Product cost	☐	Development costs	☐
Payback period	☐	Production processes	☐
Capital costs	☐	Tooling	☐
Labour requirements	☐	Compatibility with existing products	☐
Materials	☐	Disposal	☐
Environmental Requirements	☐	Effect of competition	☐

Others (specify)____ ☐

13. Do you use any performance measures to quantify the efficiency & effectiveness of product development in your organisation? Y ☐ N ☐ Don't Know ☐

14. What communication methods are used to;

a) complete the ***product development process*** and

b) report ***performance measures*** (such as those in question 15)?

	a) *product development process*	b) *performance measures*
e-mail	☐	☐
reports	☐	☐
presentations	☐	☐
videoconferencing	☐	☐
team meetings	☐	☐
departmental meetings	☐	☐
informal discussions	☐	☐
other (please specify)	☐	☐

SECTION B - PERFORMANCE MEASURES

15. Tick the following measures you currently use during product development and which would you like to use in future. Of those used, indicate how often you measure them.

			Frequency of reporting		
use now	*future use*		*daily/ weekly*	*monthly*	*per project*
☐	☐	Total cost of project	☐	☐	☐
☐	☐	Product development cost as % of turnover	☐	☐	☐
☐	☐	R&D budget as % of turnover	☐	☐	☐
☐	☐	Actual project cost compared to budget	☐	☐	☐
☐	☐	% tooling cost against total project cost	☐	☐	☐
☐	☐	Dev't cost of products that never get to market	☐	☐	☐
☐	☐	Projected profitability analysis	☐	☐	☐
☐	☐	Actual to predicted profit on products	☐	☐	☐
☐	☐	Lead time to market	☐	☐	☐
☐	☐	Time spent on each stage of product dev't	☐	☐	☐
☐	☐	% of project time spent in meetings	☐	☐	☐
☐	☐	% time for tooling against total project time	☐	☐	☐
☐	☐	On-time delivery of development project	☐	☐	☐
☐	☐	Actual vs. target time for project completion	☐	☐	☐
☐	☐	Supplier lead time	☐	☐	☐
☐	☐	Number and nature of bottlenecks e.g. delays	☐	☐	☐
☐	☐	No. of new products released p.a.	☐	☐	☐
☐	☐	No. of projects completed p.a.	☐	☐	☐
☐	☐	No. of design changes to specification	☐	☐	☐
☐	☐	No. of processes per part	☐	☐	☐
☐	☐	No. of parts per product	☐	☐	☐

use now	future use		Frequency of reporting: daily/ weekly	monthly	per project
☐	☐	Personnel turnover in design/development	☐	☐	☐
☐	☐	Product prototype passed safety tests	☐	☐	☐
☐	☐	Field trials prior to production	☐	☐	☐
☐	☐	Reasons for failures of previously released products	☐	☐	☐
☐	☐	No. of design defects detected at development stage	☐	☐	☐
☐	☐	No. of design awards and commendations achieved	☐	☐	☐
☐	☐	Product failure rates	☐	☐	☐
☐	☐	Product met quality guidelines	☐	☐	☐
☐	☐	Risk analysis	☐	☐	☐
		Others *(specify)*			
☐	☐	______________________	☐	☐	☐
☐	☐	______________________	☐	☐	☐
☐	☐	______________________	☐	☐	☐
☐	☐	______________________	☐	☐	☐

15b) Please pick out the most important ***3 measures*** and state why you use them.

- ______________________________
- ______________________________
- ______________________________

➡ *If you do not currently use performance measures, go to question 23*

16a) Overall, how satisfied are you with the number & frequency of measures that you currently use? Circle the most appropriate number.

	Very satisfied	*Satisfied*	*Not satisfied*
Number of measures used	1	2	3
Frequency of measures used	1	2	3

b) Reasons?______________________________

____

17. In terms of ***data collection***, are the measures:

Automatically generated from existing reporting information *or*	☐
Specially formulated i.e. time is spent collecting the data *or*	☐
Mixture	☐

18. Who *brought in* performance measurement to product design/development?

MD/department head	☐	Project manager	☐
Team leader	☐	Other (specify)________________	☐

19. Are the measures currently used well understood?

All ☐ Some ☐ None ☐

Comments____

____

20. Do you feel any unnecessary or unreasonable measures are made?

Yes ☐ No ☐

If yes, where?____

21. Is the reporting and feedback of results of measurement:

Individual	☐	Project/ team based	☐
Department based	☐	Managed centrally by Finance	☐
Other (specify)________________________________			☐

22. Who are the results of the performance measures *visible* to i.e. who sees them? Tick as many as appropriate.

CEO/MD	☐	Senior management	☐
The project team	☐	All project managers	☐
Accounts/Finance	☐	Other (specify)________________	☐

23. If measures are not used, why not? Tick as many as appropriate.

Time consuming	☐	Not necessary for our type of business	☐
Costs too much	☐	Co. culture doesn't support their use	☐
Threatening	☐	Not understood/ complicated	☐
Inaccurate	☐	No systems in place for measurement	☐
Need training	☐	Planning to implement in future	☐
Can't wait for results	☐	No-one is accountable for results	☐
Don't Know	☐	Lack of resources	☐
Other (specify)________________________________			☐

24. Where in the product development process would new measures be most useful? Choose the most important one from the list.

Feasibility stage	☐	Concept design	☐
Specification stage	☐	Detailed design	☐
Pre-production/ pilot run	☐	Other (specify)________________	☐

25. Please address the following statements and indicate your agreement with each one, by circling a number on the scale . Look at the statements from a ***project*** and ***process*** perspective.

	Statement	*Strongly Agree*		*Score*		*Strongly Disagree*
a)	Lack of usage of performance measures adversely affects the product development process.	1	2	3	4	5
b)	More effective management through the use of performance measures will support Concurrent Engineering principles.	1	2	3	4	5
c)	Reallocation of resources resulting from use of performance measures reduces the cost & time required for product development projects.	1	2	3	4	5
d)	Use of performance measures during design & development aids decision making.	1	2	3	4	5

State the reasons for your answers:

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

Thank you very much for taking the time to help with this research.

Please return the questionnaire, even if some parts remain unanswered to:
Helen Driva, Research Associate, Dept. of Manufacturing Engineering & Ops. Management, University of Nottingham, University Park, NOTTINGHAM, NG7 2RD Fax: +44 115 9514 000

Appendix IV
Academic Questionnaire

ACADEMIC SURVEY ON PRODUCT DEVELOPMENT PERFORMANCE MEASURES

Participant Details (optional)

Organisation: ....

Address: ....

Name:...Tel:.. E:...

Section 1 - List of Performance Measures

Below is a list of measures associated with product development. Please evaluate each of them in terms of their usefulness in managing the product development process now and in the future. One important connection between all the measurement categories is that they encapsulate concurrent engineering principles. The section is divided into five categories of measures, covering various aspects of product development. For each measure within the categories, indicate your opinion on a scale of 1 to 5 of how useful you consider the measure to be and in addition indicate whether or not you think the measure will be useful in the future. We are interested in a 'macro view', so the details of context and business situation are not important. Please answer all questions from the viewpoint of the industry you are most familiar with. You will find that some measures listed will be not appropriate for your industry - just leave these blank. After each category, a request is made for suggestions on other measures you consider useful. Comments and explanations on your answers are also very valuable.

1.1 Which sector of industry are you most familiar with (please tick)?

Automotive	☐	Textiles/clothing industry	☐
Telecommunications	☐	Food industry	☐
Aeronautical	☐	Information Technology	☐
Pharmaceuticals	☐	Paper industry	☐
Instrumentation	☐	Process industry	☐
Heavy engineering	☐	Electronic components	☐
Defence industry	☐	Domestic appliances	☐

Other (please specify) ____ ☐

1.2 General Measures

	Currently (*very useful* … *not useful*)	*Future* *will be useful*
Total no. of products released per year	1 2 3 4 5	☐
No. of projects completed per year	1 2 3 4 5	☐
No. of 'new' products released per year	1 2 3 4 5	☐
No. of parts per product	1 2 3 4 5	☐
No. of changes to original product specification	1 2 3 4 5	☐
Ease of manufacture of product	1 2 3 4 5	☐
% in-house against % contracted design & development work	1 2 3 4 5	☐
Ratio of % of sales from new products over total sales	1 2 3 4 5	☐

	Currently: very useful				Currently: not useful	Future will be useful
Rate of successful[1] product development projects	1	2	3	4	5	☐
Ratio of $ invested in R&D p.a. over net sales revenue p.a.	1	2	3	4	5	☐
Ratio of $ invested in R&D per annum over total profit p.a.	1	2	3	4	5	☐
Ability to use a common design platform (with other products)	1	2	3	4	5	☐
No. of design awards achieved	1	2	3	4	5	☐
Competitor market share	1	2	3	4	5	☐
% standard parts (appropriate, if product is part of a range)	1	2	3	4	5	☐
Others (specify) ______________________	1	2	3	4	5	☐
______________________	1	2	3	4	5	☐
______________________	1	2	3	4	5	☐

Comments____

1.3 Time Related Measures

	Currently: very useful				Currently: not useful	Future will be useful
Total time to market (from concept through to product launch)	1	2	3	4	5	☐
% changes in time to market from project to project	1	2	3	4	5	☐
% on-time delivery of specification to manufacturing	1	2	3	4	5	☐
Total product development time[2]	1	2	3	4	5	☐
Time elapsed between concept generation & product spec.	1	2	3	4	5	☐
% products launched late onto the market	1	2	3	4	5	☐
No. of development hours spent per new part designed	1	2	3	4	5	☐
No. of projects completed on schedule over total no. of projects	1	2	3	4	5	☐
Time spent on changes to original product specification	1	2	3	4	5	☐
Actual versus target time for project completion	1	2	3	4	5	☐
No. of bottlenecks (i.e. stoppages) during product development	1	2	3	4	5	☐
Length of & reason for delay at each bottleneck	1	2	3	4	5	☐
Others (specify) ______________________	1	2	3	4	5	☐
______________________	1	2	3	4	5	☐
______________________	1	2	3	4	5	☐

Comments____

[1] i.e. those that become products that reach the market
[2] i.e. time from concept to handover to production

1.4 Cost Related Measures

	Currently very useful				*not useful*	*Future will be useful*
Total cost of each product development project	1	2	3	4	5	☐
Actual project cost compared to budget	1	2	3	4	5	☐
Delivery of product to cost (as quoted)	1	2	3	4	5	☐
% change in product cost from previous model	1	2	3	4	5	☐
R&D budget as a % of turnover	1	2	3	4	5	☐
Ratio of product development cost over total revenue	1	2	3	4	5	☐
% capital equipment cost against total project cost	1	2	3	4	5	☐
% cost of tooling against total project cost	1	2	3	4	5	☐
Engineering change costs	1	2	3	4	5	☐
Development cost of products that never get to market	1	2	3	4	5	☐
Design & development labour cost as a % of project cost	1	2	3	4	5	☐
Others (specify) ______________________	1	2	3	4	5	☐
______________________	1	2	3	4	5	☐
______________________	1	2	3	4	5	☐

Comments____

1.5 Quality & Reliability Related Measures

	Currently very useful				*not useful*	*Future will be useful*
Product development process followed quality procedures	1	2	3	4	5	☐
Actual product quality performance against predicted	1	2	3	4	5	☐
Product prototype passed safety tests first time	1	2	3	4	5	☐
No. of early failures of products on the market	1	2	3	4	5	☐
Reasons for failures of previously released products	1	2	3	4	5	☐
Accuracy of interpretation of customer requirements	1	2	3	4	5	☐
% change in internal failure rate (detected through pre-release tests)	1	2	3	4	5	☐
No. of engineering change notes issued	1	2	3	4	5	☐
No. of design faults detected at development stage	1	2	3	4	5	☐
No. of warranty claims (after product launch)	1	2	3	4	5	☐
Model to model improvement targets met	1	2	3	4	5	☐
Others (specify) ______________________	1	2	3	4	5	☐
______________________	1	2	3	4	5	☐
______________________	1	2	3	4	5	☐

Comments____

1.6 Project Management Related Measures

	Currently very useful				not useful	*Future* will be useful
% of projects that met all stated objectives	1	2	3	4	5	☐
% of projects that partially met stated objectives	1	2	3	4	5	☐
Availability of choice personnel for project	1	2	3	4	5	☐
Frequency & duration of project team meetings	1	2	3	4	5	☐
Value of output from project team meetings	1	2	3	4	5	☐
Project team motivation (measured through attitude surveys)	1	2	3	4	5	☐
Personnel turnover in design & development	1	2	3	4	5	☐
Value of staff appraisals	1	2	3	4	5	☐
Impact of deadlines of other projects	1	2	3	4	5	☐
Impact of customer deadlines on the project management	1	2	3	4	5	☐
Others (specify) ____________________	1	2	3	4	5	☐
____________________	1	2	3	4	5	☐
____________________	1	2	3	4	5	☐

Comments____________________

1.7 Customer Related Measures

	Currently very useful				not useful	*Future* will be useful
Product met sales volume targets	1	2	3	4	5	☐
Accuracy of prediction of customer requirements	1	2	3	4	5	☐
Response time to customer requests for 'specials'[3]	1	2	3	4	5	☐
No. of customer-detected design faults	1	2	3	4	5	☐
No. of faults in first 12 months of product release per customer	1	2	3	4	5	☐
No. of customer returns in a given time period	1	2	3	4	5	☐
Level of customer input to product through QFD[4]	1	2	3	4	5	☐
Results from returned customer report cards	1	2	3	4	5	☐
Customer satisfaction with length of product life	1	2	3	4	5	☐
Others (specify) ____________________	1	2	3	4	5	☐
____________________	1	2	3	4	5	☐
____________________	1	2	3	4	5	☐

Comments____________________

[3] this is a measure of design flexibility
[4] Quality Function Deployment

Section 2 - Management of the Measures

This section is concerned with the management issues surrounding performance measurement. Unless otherwise specified, tick as many choices as appropriate.

2.1 Should the reporting and feedback of results of measurement be:

Individual	☐	Project based	☐
Department based	☐	Managed centrally by Finance	☐

Other (please specify) ____________________ ☐

2.2a) Who should bring in performance measures to product design & development?

MD/corporate directive	☐	Project management	☐
Department head	☐	Team leader	☐
Other (specify)__________	☐		

2.2b) Please give reasons ____________________

____

2.3 Where measures are not used, what are the main reasons?

Time consuming	☐	Not necessary for our type of business	☐
Costs too much	☐	Co. culture doesn't support their use	☐
Threatening	☐	Not understood/ complicated	☐
Inaccurate	☐	No systems in place for measurement	☐
Need training	☐	Planning to implement in future	☐
Can't wait for results	☐	No-one is accountable for results	☐
Don't Know	☐	Lack of resources	☐

Other (specify)____________________ ☐

2.4 Who should the results of performance measures be visible to i.e. who should see them?

CEO/MD	☐	All senior management	☐
The project team	☐	All project managers	☐
Accounts/Finance	☐	Other (specify)__________	☐

2.5 Where in the product development process would new measures be most useful? Choose the most important one from the list.

Feasibility stage	☐	Concept design	☐
Specification stage	☐	Detailed design	☐
Pre-production/ pilot run	☐	Other (specify)__________	☐

2.6 Do you know of any performance measurement tool/system that specifically addresses product development? Y ☐ N ☐

If yes, please give details____________________

____

____

____

2.7 Have you acted as consultants or conducted any research in this and/or published in related areas? If yes, please give details. Y ☐ N ☐

____

____

____

2.8 Indicate your agreement with each of the following statements by circling a number on the scale . Look at them from a ***project/process*** perspective.

	Statement	*Score* *Strongly Agree*				*Strongly Disagree*
a)	Lack of usage of performance measures adversely affects the product development process.	1	2	3	4	5
b)	More effective management through the use of performance measures will support Concurrent Engineering principles.	1	2	3	4	5
c)	Reallocation of resources resulting from use of performance measures reduces the cost & time required for product development projects.	1	2	3	4	5
d)	Use of performance measures during design & development aids decision making.	1	2	3	4	5

State the reasons for your answers:

a) ____

b) ____

c) ____

d) ____

2.9 Any general comments or comments about additional measures that may not have been covered by this questionnaire?

____

____

Thank you very much for taking the time to help with this research.

Please return the questionnaire, even if some parts remain unanswered to:

Helen Driva, Research Associate,
Dept. of Manufacturing Engineering & Ops. Management,
University of Nottingham, University Park,
Nottingham, NG7 2RD, UK
Tel: +44 115 9514 020 Fax: +44 115 9514 000
Email: epzpace@epn1.maneng.nott.ac.uk

Appendix V

Initial PACE Survey Results

In total, 35 questionnaires were given out and 17 were analysed, yielding a response rate of 49%. This first section of the questionnaire analysis covers a cross company comparison of the responses. It should be noted that a certain amount of variation in the answers is due to the fact that respondents came from various divisions in the organisations. The questionnaire is divided into four parts; a general overview of new product development, performance measures (covered in Chapter 4), teamwork and organisation. All percentages are worked out according to the number of people who answered that particular question. These responses led to the formulation of the performance measurement questionnaires.

1. Results by Section

General Overview of NPD

1.1. Department which has overall responsibility for NPD

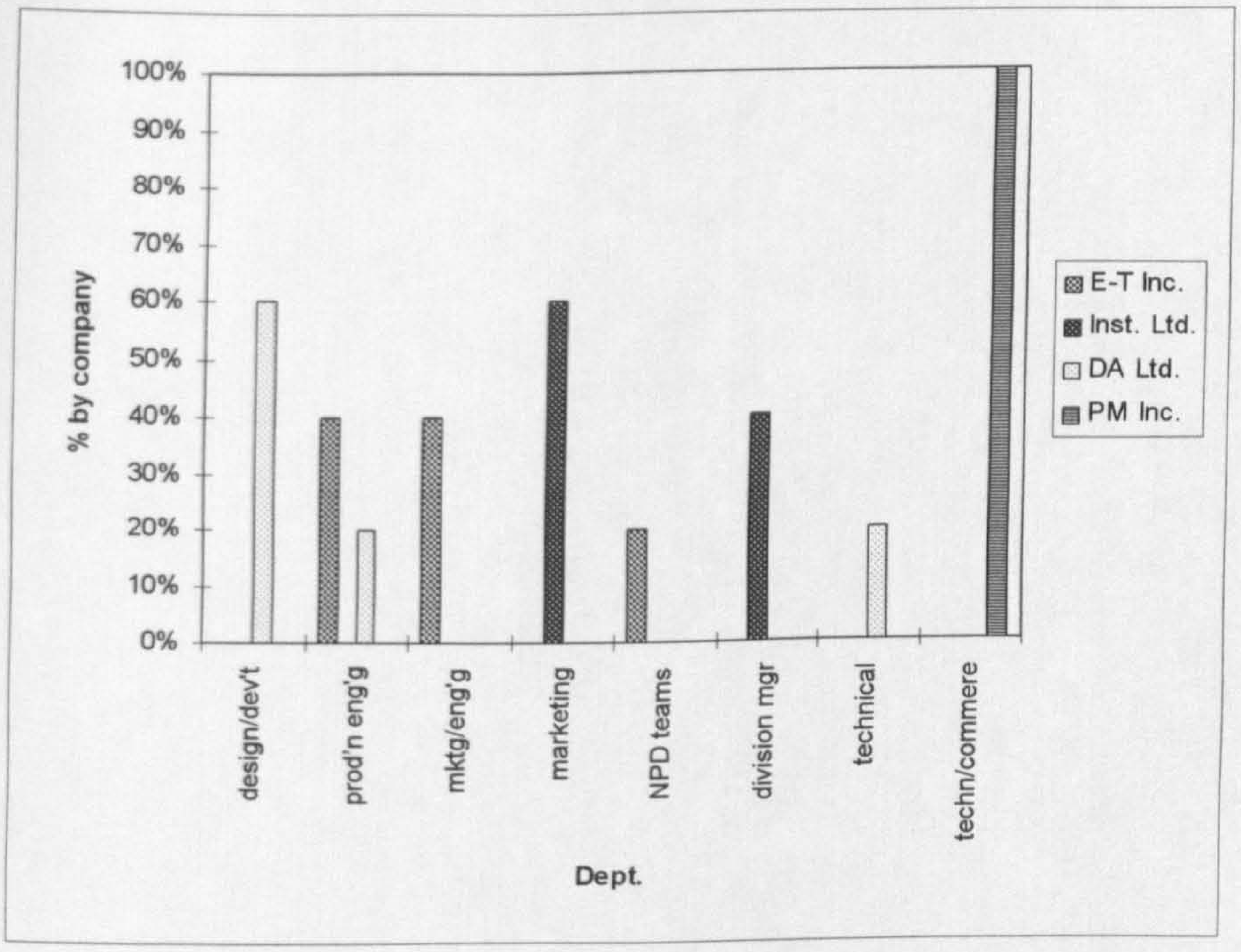

Figure V-1: Department responsible for NPD

There was quite a variation in responses within the companies (as well as between them) as to which department had overall responsibility for product development. Inst. Ltd. respondents were divided between marketing and the division manager, whereas there was a three way split in E-T Inc. and DA Ltd., depending on who responded.

1.2. Departments involved in New Product Development/CE activities

From these results, Marketing was primarily involved at the concept/feasibility stage, while Design & Development and Finance were involved throughout. Logistics and Service were involved later in the product development cycle.

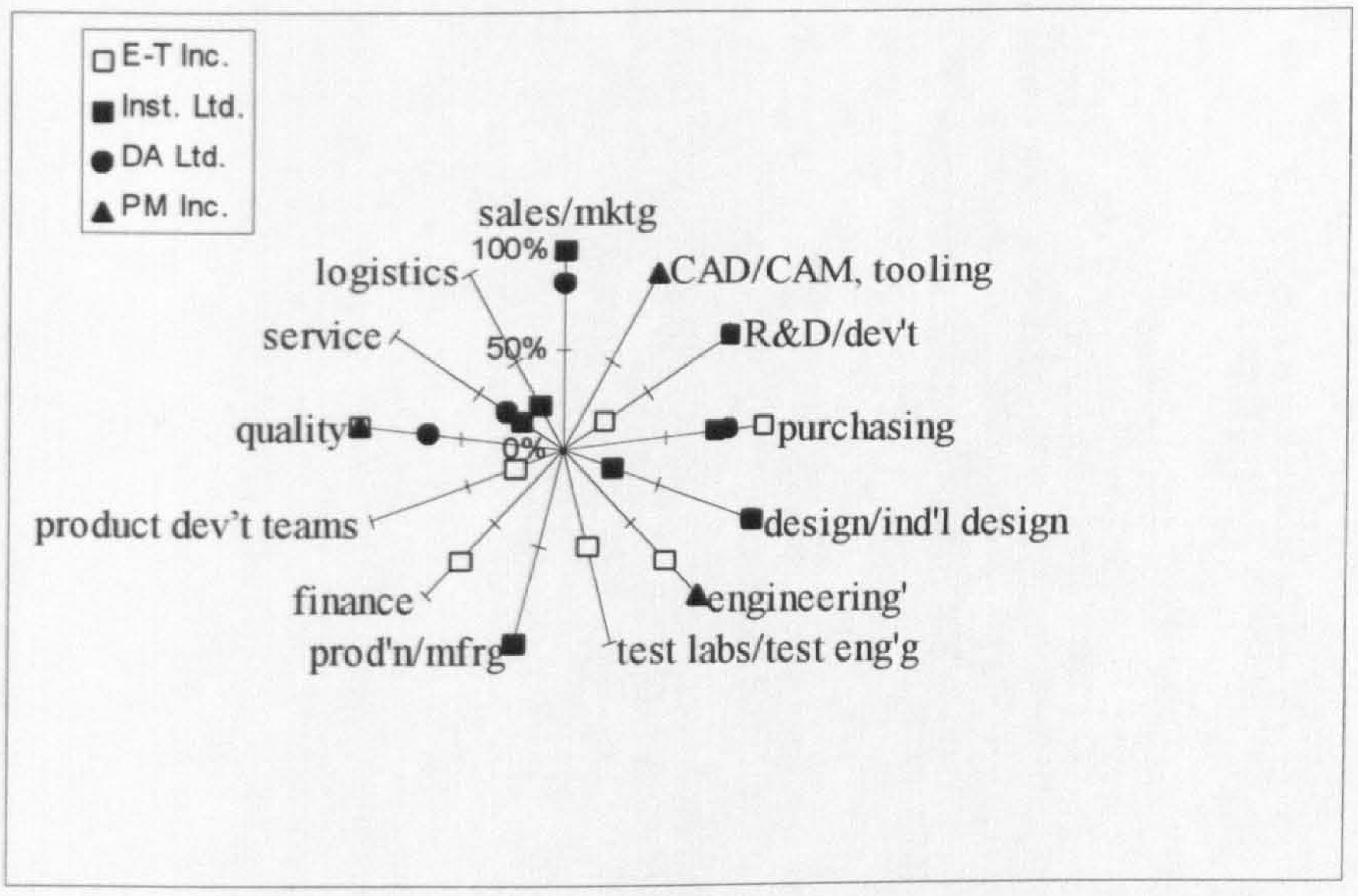

Figure V-2: Departments involved with NPD/CE

1.3. Average product development time for products (in months)

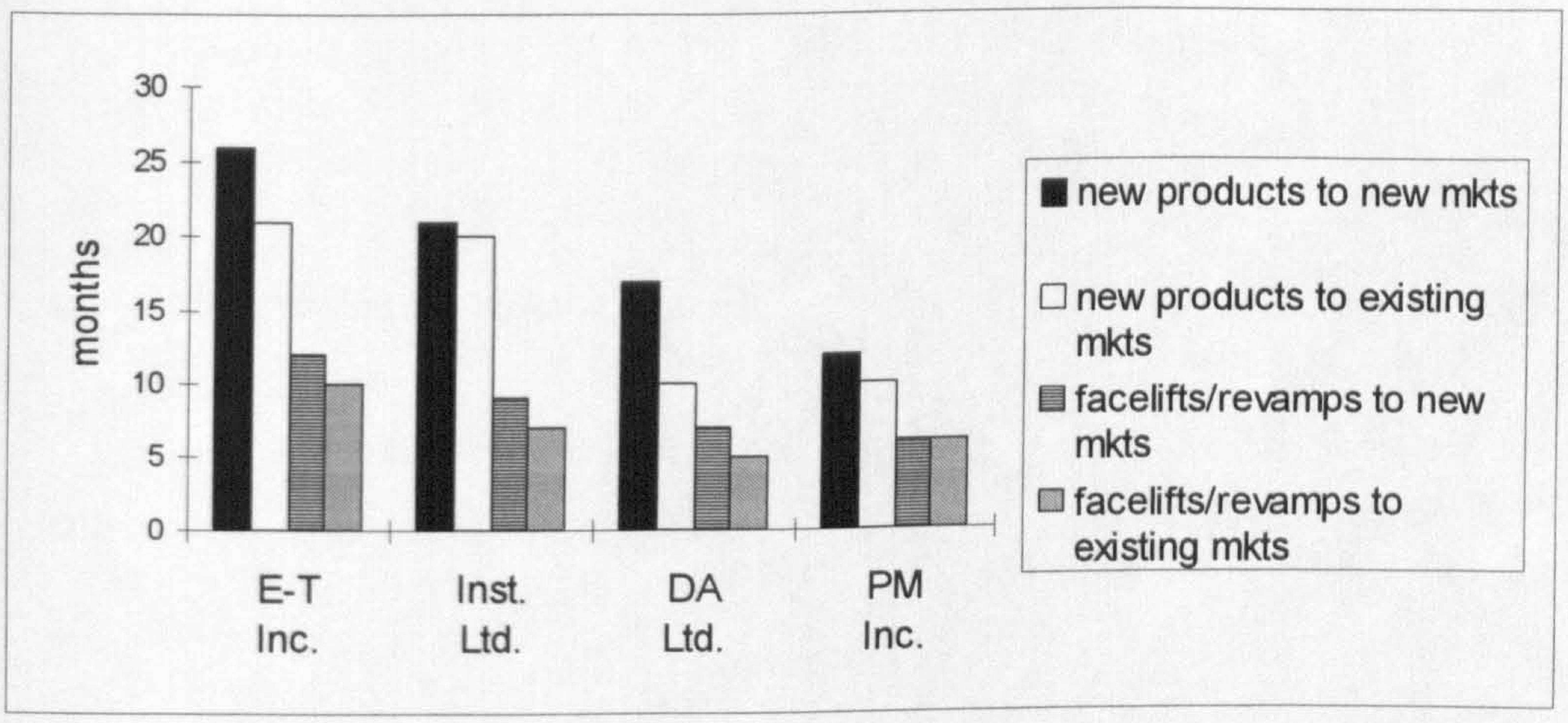

Figure V-3: Product Development Time

The time required for product development depends heavily on the type of product being launched. As expected, the time required to launch new products to new markets was the longest for each company, with Electro-Tools Inc. requiring the longest overall time for all types of development.

1.4. Number of projects run concurrently (at any one time)

The number of projects varied quite widely, especially in Electro-Tools Inc.. Some managers reported that 4-6 projects were running while another reported over 50. PM Inc. was involved in the least number of projects owing to its smaller size and closer focus.

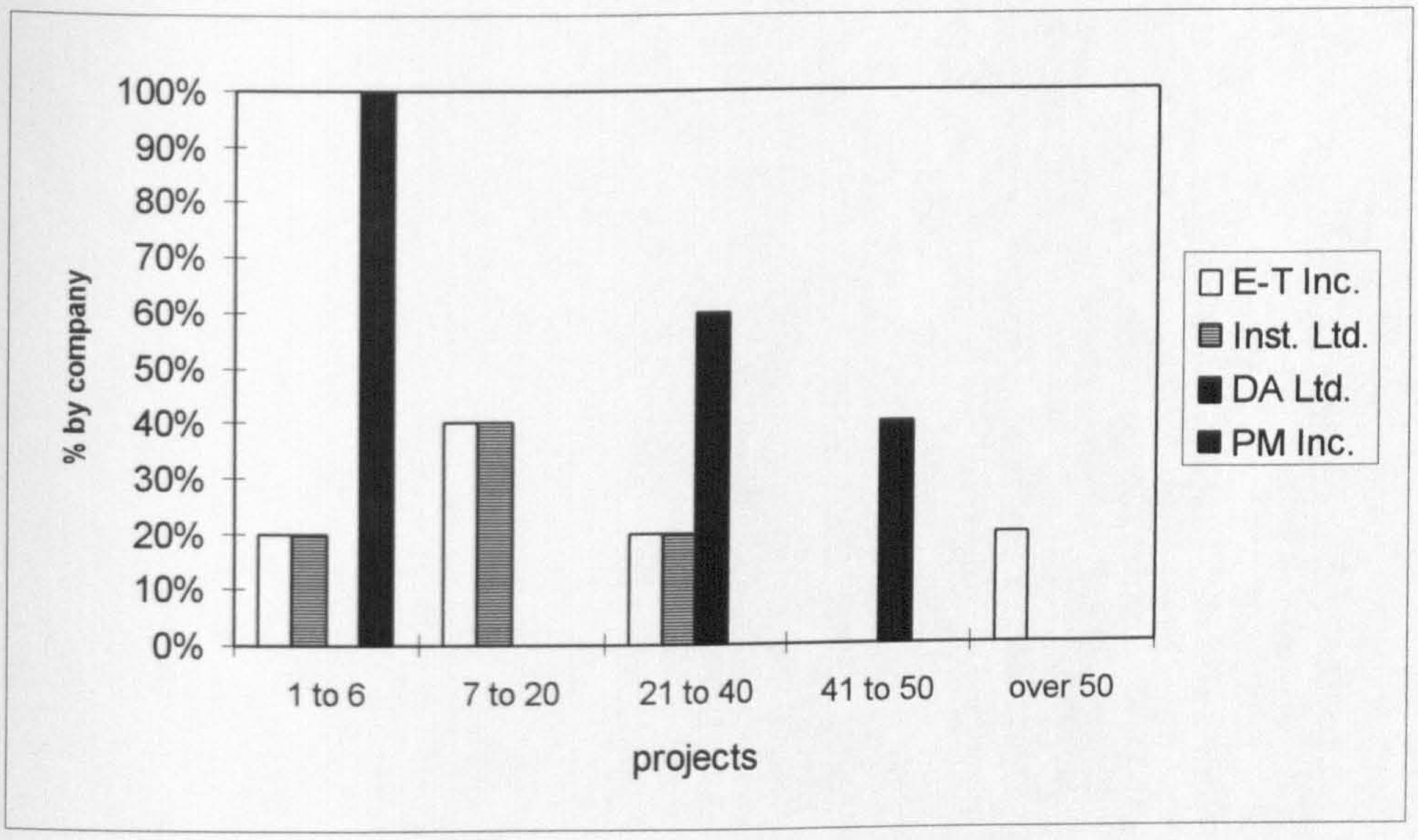

Figure V-4: No. of Concurrent Projects

1.5. How NPD time is calculated

Five options were presented on how the time to complete the NPD process was calculated:

a) concept to first shipment
b) concept to first production
c) milestones
d) first expenditure to first shipment
e) project start to full production

Managers from the individual companies had different ideas as to how the time taken for the total development is calculated. Managers from E-T Inc. differed in opinion, with some considering it to be a), b) and c), managers at DA Ltd. were also evenly split between b) and e), whereas everyone from Inst. Ltd. cited project start to full production and PM Inc. considered it to be the time between 'project start and full production'.

1.6. Main bottlenecks in the process

Multiple answers were given here. There was a fairly even spread of reasons for bottlenecks. This question produced a very high response (94%), with most respondents citing multiple reasons and DA Ltd. managers listing 12 reasons between them; marketing decisions, bureaucracy, tooling, development time, long lead times, lack of resource, lack of information/communication, production drawing office, design freeze, purchasing delays, human resource availability, product specification, manufacturing, scheduling, transfer to operations and software. These were almost evenly spread. Interestingly, no-one considered product specification to be a bottleneck.

1.7. No. of products released to the market in the last 12 months

The responses from Inst. Inc. varied quite widely here (according to division). Quite a few of the managers questioned did not know how many products were released. It would be interesting to find out how product information is disseminated. DA Ltd. released the largest number of products, mainly due to its large number of varieties and add-ons for the same basic model.

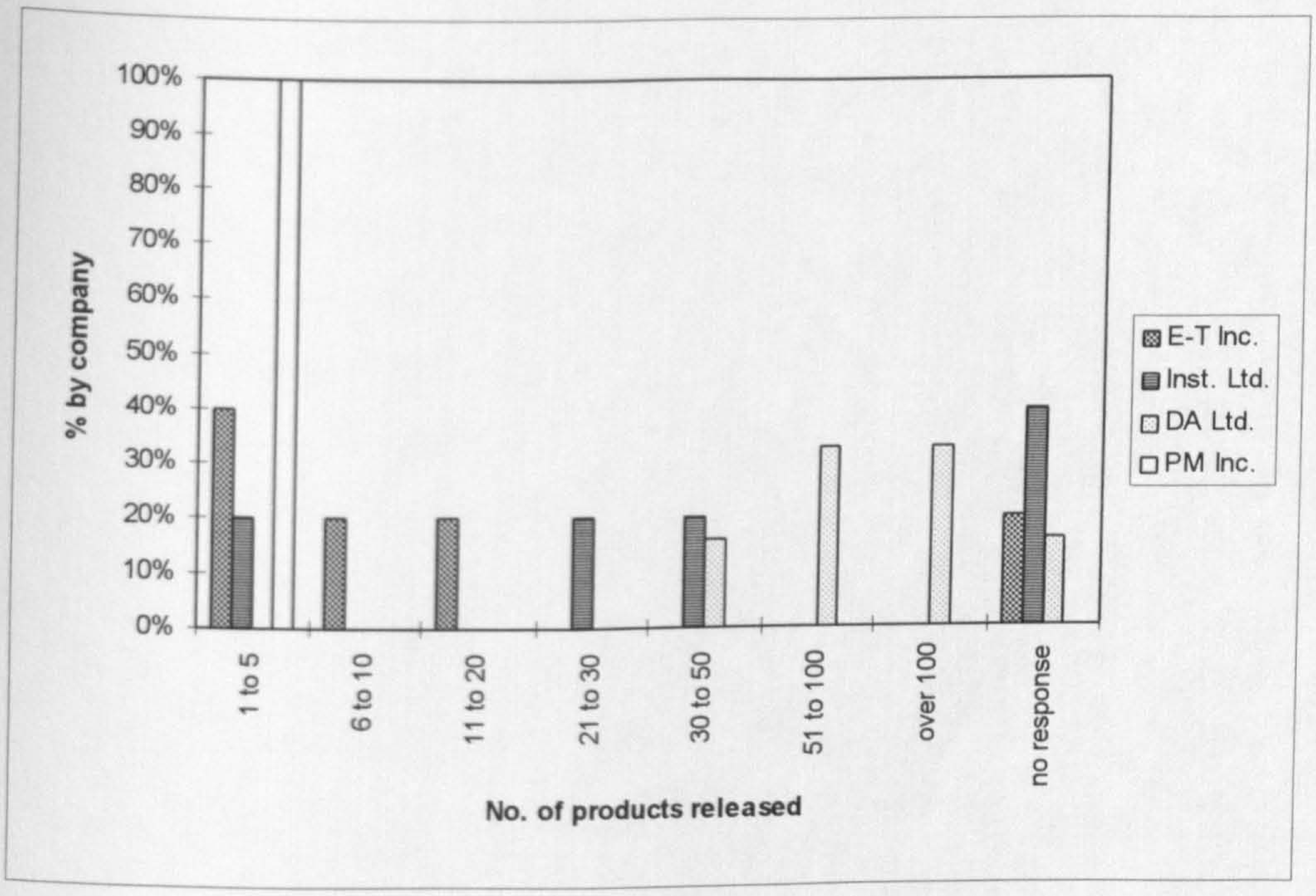

Figure V-5: No. of Products Released in Last 12 Months

Teamwork

1.8. What is the typical makeup of a product development team?

The answers indicate that teams in all the industrial partners are very cross functional, with marketing being on the team in all companies. Tooling, quality, production engineering, development, design and R&D were also heavily featured in all the companies. Comments from respondents included: 'external suppliers will be involved where necessary', 'it is fully documented in the milestones process'.

1.9. Communication methods used

All use telephone, team meetings, fax, internal post, departmental meetings and informal discussions; all use e-mail apart from PM Inc.; Inst. Ltd. and DA Ltd. use newsletters; E-T Inc. and DA Ltd. use videoconferencing; and Inst. Ltd. and DA Ltd. use notice boards.

1.10. Benefits from teams

Most respondents indicated that all the listed benefits had been realised i.e. reduced time to market, increased cost control, increased product quality, increased motivation, reduced departmental barriers, increased use of new techniques, increased use of new technology and increased skill base.

Organisation

1.11. Most important training areas

The most important areas were considered to be TQM, teambuilding, CAD/CAM/CAE and time management. Comments included: 'TQM training is on-going and needs to be regularly reinforced', 'flexibility using new technologies is important'. 'Company vocational qualifications are mainly targeted at the shopfloor and are financially supported by the Government.' Quality and timely delivery were seen as the two most valued qualities of the company's products and services.

1.12. Project feedback is carried out by

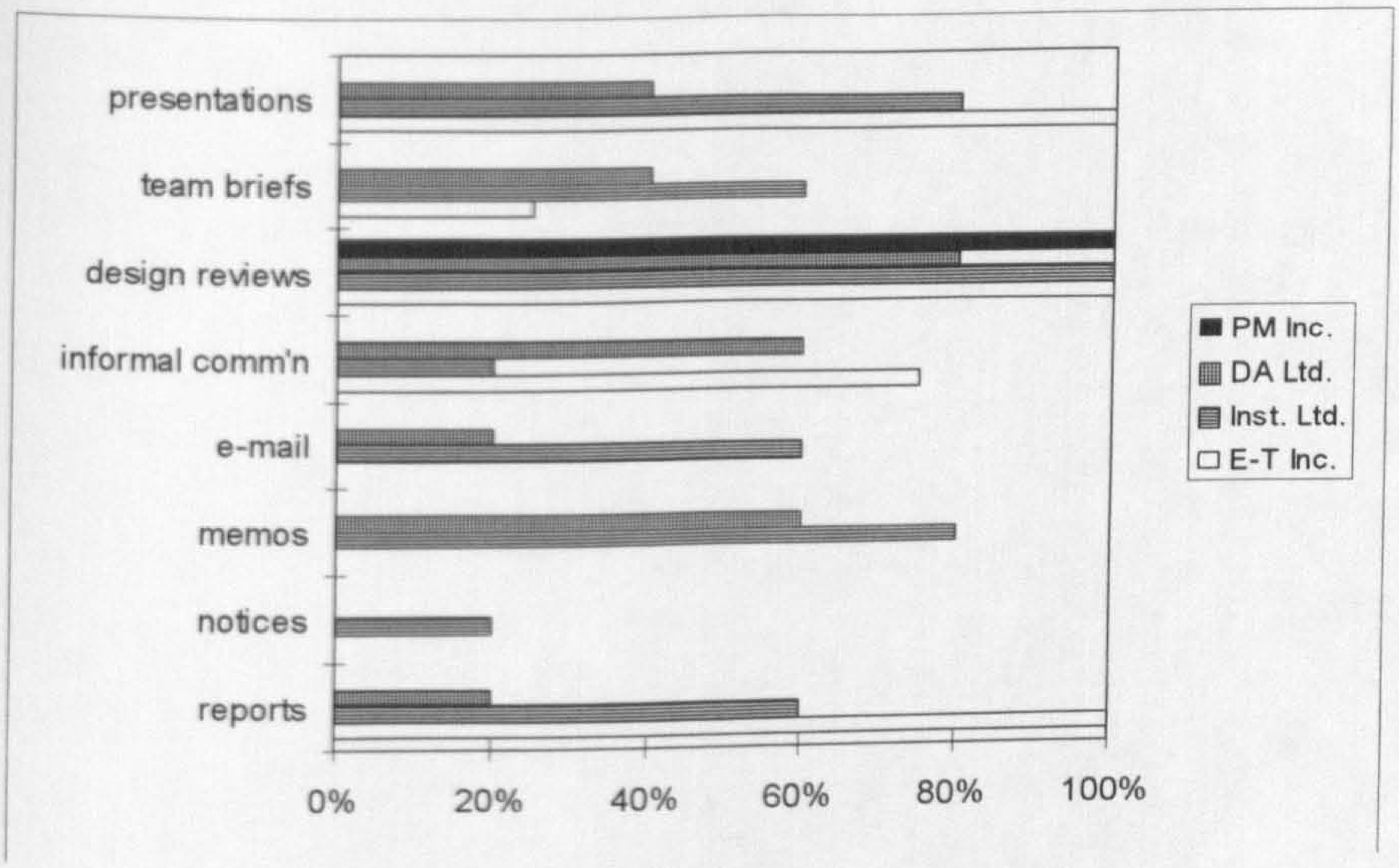

Figure V-6: Methods of Project Feedback

Multiple answers were given by many of the respondents here. Comments included; 'this is an area where awareness could be improved, especially in view of the fact that departments are geographically dispersed', 'we have a monthly management letter with short reports on all projects'. Other were; 'the highest priorities will remain unchanged for the foreseeable future i.e. increasing profit margin, increasing number of new products and customer service', 'increasing export sales will also be an important factor', 'improving quality and customer contact needs to be the main focus', 'time to market and training will become the most dominant factors'.

1.13. What (if anything) hinders you from making improvements?

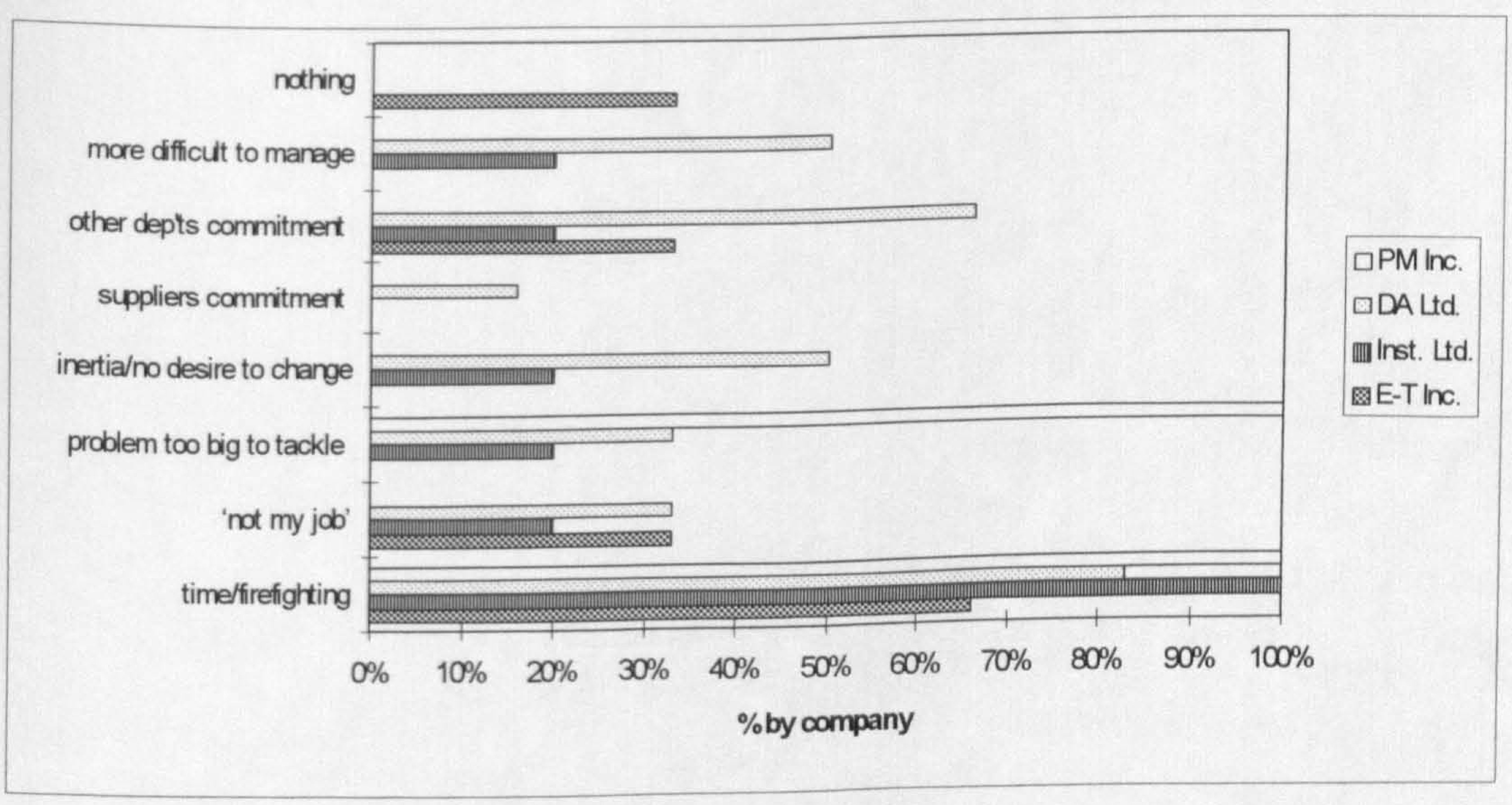

Figure V-7: Improvement Hindrances

1.14. Terms Associated with Concurrent Engineering

Cross functional teams was the most widely recognised aspect of CE, with most of the tools and techniques being recognised. Perhaps surprisingly no-one had heard of the CALS (Computer-Aided Acquisition and Logistics Support) information-flow management initiative or at least did not recognise it as part of CE. No-one considered CE to be associated with high costs or that it was just a passing fad or another 'buzzword'.

1.15. Does the company have ISO9000 accreditation?

E-T Inc.	Inst. LTD.	DA Ltd.	PM Inc.
✗	✓	✓	✗

1.16. What other quality related programs are you currently using?

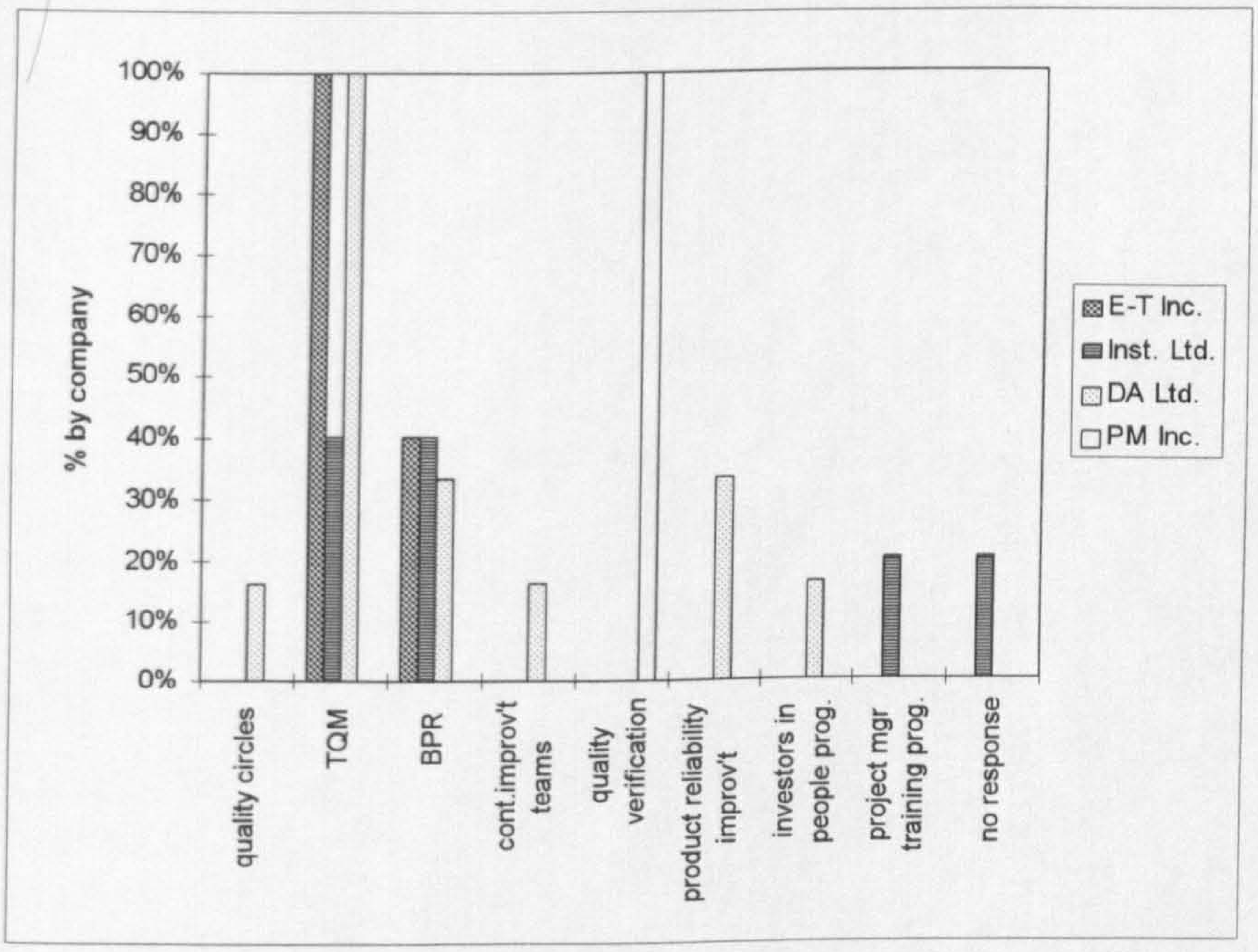

Figure V-8: Quality-Related Programs

Multiple answers were given here. TQM was the most widely used method, with BPR being introduced in parts of DA Ltd., Instrumentation Inc. and Electro-Tools Inc.. DA Ltd. had the most number of programs, with some such as 'Investors in People' being developed specifically within their group of companies.

2. General Comments

The response to the questionnaire was almost 50%, owing to the close cooperation with the partners. It has provided a basic ideas of the partners' involvement with concurrent engineering and allowed for an insight into the way that new product development is carried out. These results were also a useful starting point for the more in-depth and focused questions on performance measurement.

Appendix VI

Follow-up Cases

This appendix contains summaries of the follow-up cases that were selected from the questionnaire results.

1. Plastico. - Profile:

Plastico is part of a large chemicals multinational that produces plastic film for use on foodstuffs, floppy disks and a range of other commercial and consumer applications. It is a truly global company with manufacturing sites and export markets all over the world. In Plastico's division alone there are 70 projects globally. It therefore comes as no surprise to learn that it is common practice for design and development to be carried out using virtual teams that communicate via videoconferencing. Communication by groupware (Lotus Notes) across a computer network is also a fact of life throughout the company. This includes macro documents such as safety manuals and company policy documents; and more localised documents such as product development process stages and lists of new projects at different sites.

The manager who took part in the research has the dual role of managing information technology and monitoring & tracking the product development process[1]. He has been working for the chemical company for thirty years and at the Plastico division for seven years. Plastico is very committed to research and part of the manager's job is to investigate management research techniques. He explained that the company primarily uses informal techniques[2] such as brainstorming to reach a consensus of how to move forward.

Two years ago, the manager was assigned the task of developing measures for the Plastico division. This has not been easy: 'In our industry, the product development process is not as clear cut as in engineering organisations. This makes formulating effective and meaningful measures very difficult'. He added; 'we are five years ahead of the questionnaire situation - we have already assessed what measures we need and are now in the process of trying to implement them'. In terms of the intended use of measures within the organisation, he stated; 'we have used measures in the past. In particular, a study was made looking at the financial aspects of the Balanced Scorecard i.e. ROI, cash flow, etc. On a wider scale, the divisional structure of our company demands internal benchmarking to allow for comparisons worldwide. This was a major impetus for us to expand our use of measures in design and development'.

The manager added that performance measures have never been driven from accounting: 'Once we analysed what we wanted, we found that it was better and quicker to generate the information again ourselves (in development). We are pushing the accountants for more information on development and marketing. The main problem is the very high cost of collecting measures as nothing was generated automatically. We have a particular problem in the process industry just trying to get figures. The differences recorded can also appear small, making it difficult to justify the result'.

'We initially had a bad experience with measurement. We started by getting managers to rank measures that they wanted to use. Collating the data quickly became an over-complicated and boring chore. Charts were shown at presentations but the differences in results in the short terms were very small. I saw people's eyes glaze over when the charts were shown'.

---

[1] He was also responsible for re-designing the product development process. He stated; 'our current product development process inspired Robert Cooper's star-gate system - I would even go so far as to say that he took some of our ideas!'

[2] rather than the more formal QFD-style approach

The major aim in developing the measures further is to get project managers to take ownership of measures they require at each stage of the product development process: 'At the moment, there are too many 'black holes' in projects; within stages information is unclear. Realistically this will take another few years as the culture doesn't currently support it. I feel that we need broader measures but there is the high cost of generating these to consider. Justification of the budget is an important consideration when attempting to implement any new measures'.

The 3 most important performance measures they use are:-

- % sales from new products[3] against total sales - 'this is the bottom line.'
- Average time to market of product lines - 'this is all about speed.'
- On-time delivery of product development projects to the customer.

The % sales figure signifies the % sales of each product line (e.g. plastic film for overhead projectors) against total sales. This is calculated once per quarter and is especially useful as 'a basic business metric'. The manager added; 'for most of our standard products, we know even in the development stage how much we have sold. Marketing start to sell as soon as the specification has been finalised. Targets are set for each product line'.

Time to market is currently calculated from the time an idea is registered in the stage gate database (gate 1) to the time it is available for sale i.e. passes the development to scale up stage (gate 3). The manager commented; 'this system is based on the premise that faster is better - but this is of course not always the case. It also relies on the accurate and consistent use of the stage gate process'. He added; 'for this to be a reliable measure that can be used for benchmarking, we need to ensure that we have a global agreement on the exact meaning of time to market. As we are in the chemicals industry, the early exploratory stages can in some cases represent the vast majority of the total time. Some projects are in the system for a long time and we need to find a way of monitoring them more closely and concentrate on accelerating them. With simple changes to existing formulae, the picture is quite different'.

On-time delivery basically describes schedule adherence. It reports on how often the planned date has changed up to final delivery of the product. The manager stated; 'sometimes we have problems with project slippage'.

What they want to use in future:-

As the use of performance measurement is still at an early stage in Plastico, there are many areas in which the system could be extended. These come under the broad headings of people, innovation, project tracking and global measurement.

Human resource is the biggest variable in the development of products. The manager explained; 'I feel that owing to commercial pressures, we are too thinly spread on some projects, resulting in people being stretched too far. We currently have an ad-hoc system in manufacturing process development, where people monitor their own project time but realistically the results are questionable. As a first step, we need to carry out more training and awareness on the value of metrics... Basically, we would like to be able to manage this area more effectively'.

Idea generation is another area that Plastico would like to get a better handle on: 'It would be very useful if we could track the number of ideas logged in new product development and compare it to the actual percentage realisation of projects...I suppose what we are really looking for is long term innovation measures. Most importantly we need to ensure that long term innovation is not adversely affected by short term results from our existing performance measures. I think this is a real danger'.

---

[3] A new product is defined as anything with a new code number.

'It would be very beneficial to have a macro view of the progress of all projects in terms of schedule, performance, etc., on one screen. This is clearly a possibility but organising the data and administering the system for all our projects globally is an extremely big task'.

'We are increasingly setting more market-oriented goals as marketing has been a problem in the past. We want to re-organise and learn from these failures. In particular, we want to learn from the customer and train people in the right skills to understand customers and get customers to express their needs more accurately'.

Perhaps surprisingly there are currently no global measures of performance that are reported across of the whole organisation. The manager stated; 'Personally I am a little dubious about the added value of using performance measures - we don't really know what effect the measures have that we currently use. However, top management are very keen to introduce them wherever possible. We are still very much on the learning curve both in terms of the scope and the value of measures available but I'm sure that global measures will almost certainly be with us in the near future'.

2. Global Engineering Co. - Profile:

Global Engineering Co. is a worldwide group that designs and manufactures systems and products to mechanical/electrical engineering markets. Performance measures were brought in as a company-wide initiative[4] and were part of a wider program aimed at reshaping the product introduction process. The incentive for this change was to achieve considerable reductions in product cost, project cost and time to market in order to retain the company's globally competitive position. The large number of sites offered little commonality in the way products were developed or in the associated project management. The four year-long change program aimed to change this and touched all parts of the organisation. This resulted in a generic model for the product introduction process, with provision for local site variations. According to the Project Manager who took part in the survey; 'different markets and territories pose different problems in product development so local input is essential'. Use of tools & techniques including QFD, design of experiments, DFA and FMEA were promoted wherever possible and project management goals were set for each stage of the process. The Project Manager stated that the major value of measures of performance is; 'that they are useful for auditing stages (through phase reviews) of the product introduction process'. Each phase review has an accompanying checklist which includes ensuring that the relevant performance measures have been recorded. The manager added that these phase reviews are not 'tollgates' as such, as the company practices Concurrent Engineering: 'They act more as warning flags saying proceed at known risk'.

The 3 most important performance measures they use are:-

- TIME: Schedule adherence - monitored using their in-house developed project management software.
- QUALITY: Number and nature of Engineering Change Requests per project - monitored by project managers. The aim is not to point the finger but to spot trends on a site-wide level.
- COST: Total project cost vs. budget.

Total project cost is a compound measure which is calculated by considering all costs directly attributable to the project activities and is defined as the cost of bringing the product to market. In other words, it shows how much it costs to bring the product range to production. This

[4] implementation began May 1993

includes; capital expenditure[5] (engineering & factory), labour (full time & part time team members), supplier tooling, sub-contracting costs, materials, prototypes (purchases & production) and expenses & travel.

Total product cost is also a central measure. It includes recurring costs for production such as materials, factory overheads, labour and other associated overheads.

The rationale behind using these measures is simple. As the Project Manager explained; 'time, cost and quality has proved to be a powerful combination because if you flex one it impacts on at least one of the others. It is always going to be a tradeoff situation'. He also stressed that as each project is different, 'measures are used as a ball park figure only, as direct comparisons are meaningless.....Strictly speaking it is difficult to say from looking at the measures whether we have improved or not because the products (and hence projects) have become more complex, but some measures are better than no measures'. A variety of other measures (including number and nature of bottlenecks, number of design changes to specification and field trials prior to production) are also used informally, depending on the needs of the project and the project manager.

On a more macro-measure level, the company newsletter states that Global Engineering Co. is an EVA company. 'EVA stands for Economic Value Added and is what remains of operating profit after deducting the cost of the money used to produce that profit. It is the way a company's real performance and profitability is measured and is hence the basis of our entire business approach'. It is designed to appeal to shareholders and aims to highlight the efficiency of the organisation. Some project managers are against introducing this measure as they think it will have an adverse impact on innovation. The emphasis on cost reduction could make investment in new equipment more difficult to justify. EVA has yet to be implemented, so a certain amount of time is required for it to get bedded-in to the company culture before an assessment of its success can be made.

What they want to use in future:-

Global Engineering Co. has increased its use of performance measures through the implementation of the new product introduction and project management process. However, there is still room for improvement: 'There's no hunger from top management to receive measures but at the same time, the team may get asked to show them. Their use is more reactive than proactive at the moment'. The Project Manager added; 'we are not satisfied with the number of measures currently used, we need more measures of performance to address efficiency of the process and ones to give early warning of potential problems, etc. They may vary by stage of process'. The major barrier to this is the lack of systems in place to support more measurement. The company is increasingly aiming to automate data collection because, as the number of projects increases, the cost of data collection becomes more significant. For example; 'cost estimating is still a major bottleneck, as estimators are needed for business case developments, on-going monitoring of product cost during project and then the subsequent "cost down" initiatives through the product life. The problem is we typically only have one estimator per major site, so we need to find a way of using his/her skills more effectively by automating and communicating their work'.

The Project Manager doesn't consider that any unnecessary measures are made; 'we have been through a long process of refinement and 'binned' those measures that weren't contributing. I think we need measures all through the process but right now, I'm not sure exactly what they will be'. He concluded by stating that 'when dealing with performance measures, it is important

[5] Project costs excluding capital expenditure are written off in the year incurred.

to remember that the measures are not an end in themselves and that on their own, they don't give you direct benefits'.

3. Petproducts Ltd. - Profile:

Petproducts Ltd. design and manufacture pet care products primarily for Europe[6], with new world-wide markets being a growth area. The product range includes dog and cat biscuits, fish food, meat treats, toys, grooming items and healthcare products. Since the purpose-built site was opened in 1986, the product range has increased from just 7 to almost 100. Despite this immense growth, the number of staff has remained constant. The company is part of a large food multinational and it shares the manufacture of food products but sub-contracts non-food items to independent manufacturers outside of the group.

According to the Technical Director who has worked for the group for over 20 years and at the new Petproducts site since it was built, one of the most important aspects in product development is understanding the customer: 'We are a consumer-driven business and are always designing directly for the consumer'. He added; 'pet owners can't always express exactly what they want in a new product so the approach we take is to ask them questions about their behaviour patterns that involve their pet. So for example, they may feel guilty, when leaving the house, about abandoning their pet. They may assuage this guilt by providing something to occupy the pet while they are away. We would take this sort of information as a start point for developing a chew-item'.

In terms of taste tests, as they can't ask the animal which food it prefers, they monitor things such as relative preference, the amount eaten from the bowl and eating curves over a period of time. Textural properties such as hardness, strength, lasting time and tactile properties such as stickiness are very important in products which will be hand fed to the pets.

The other main product development activity within R&D is technology development (covering materials and processes). Perhaps surprisingly to outsiders, this is a very active area in pet products. All R&D staff have either scientific or engineering backgrounds. The Technical Director explained a recent project: 'While most of our products start life in the kitchen, they will ultimately be mass produced using the principles and techniques of chemical engineering. So the aesthetics of product design sit side by side with computational fluid dynamics. One of our recent innovations was to successfully adapt some injection moulding equipment (used within the group) to be used with food ingredients to produce hard, long lasting chewy pet snacks'.

At the design brief stage, the consumer understanding and the technology development meet and the resulting propositions are tested and trialed with customers and their pets. 'This is the stage where we would use a QFD-style analysis on the available options (if appropriate)'.

The Technical Director considers that resource management 'is less about allocation than optimum use. The key to this is communication which allows all members of the team to contribute their expertise across the whole range of projects although they only have direct responsibility for their own portfolio. This is a company-wide philosophy, hence colocation, flat structure, open plan office, etc. which allows a business of our size to seem small'.

The company is ISO-certified and has a well-defined product development process, with checklists at every milestone. At each major milestone (i.e. timing plan, letter of intent and capital expenditure request), the project is evaluated by 'the business' which basically consists of senior managers in R&D, Marketing and Operations.

[6] Germany alone currently represents almost 50% of the market.

On a basic level, they see performance in a very straightforward way: 'We have two priorities: things we are doing and things that we are not doing and we base our planning on this. Hence, our future actions are the consequence of this planning'.

Formal new product development performance measurement has been around since mid 1994[7]. It originated from a simple question posed to the Technical Director by an employee; "how do you know that the new product programme is successful?" He explained that 'in writing the response to this, we defined measures'.

The 3 most important performance measures they use are:-

- On-time delivery - a trade and market requirement.
- No. of new products p.a. - defines R&D resource.
- Profitability analysis - measures performance versus strategic hurdles.

Guidelines and targets for these measures are set by 'the business' (senior management) on a quarterly basis. The project managers then assess initial profitability and routes to achieve these targets as the market matures. For example; 'we are currently aiming for 25% of turnover to come from products launched in the last 5 years and for 6 new products to be launched per annum. Profit targets on individual projects are set by the project managers. New products are given up to 3 years to achieve these set targets'.

Timing is a very important aspect of business for Petproducts: 'Basically for the vast majority of new products we need to aim for a launch date of 1st January. This is forced upon us by European trade restrictions. Indeed because the trade want everything to go from this date in store we need to have all aspects fixed including price point preparation, bar coding, language labelling[8] and packaging. This requires two to three months preparation. Brand competitiveness is great so we need to maintain a strong position at all times[9]. We would much rather spread the launch dates out but you only get one chance per year in this business. We only commit to launch dates when we are confident we can deliver. Therefore, on-time delivery is a critical measurement for us'.

Profitability analysis has always been a key business indicator for Petproducts and the group as a whole. The Technical Director stated; 'we sell through our sister companies in the markets. This is what allows us to distribute the profit between our site and the market as we choose. We can't be too profitable because we need to remain competitive'. Profit is expressed in terms of 'margin after conversion'. Conversion costs are the development costs of bringing the product to market (inc. design, manufacture, labour, factory fixed costs, packaging and distribution) but not the selling costs (i.e. marketing and advertising). Therefore, margin after conversion equals sales value minus conversion costs. Constant large volume is their key to on-going profitability.

An internal measure, used for leverage of corporate resources, is "spend per pet analysis". The Technical Director explained how this was used: 'It is an excellent way of showing our current market penetration and can thus be used to indicate potential if each market was as good as the best. We can then use the figures to increase our share of marketing personnel and the sales force among the group'.

A high percentage of business growth comes from innovation: 'In the past, when the market wasn't so open to accepting new products, our emphasis was on reissuing and repackaging existing products to appeal to wider markets or to extend product life. We then moved more into

[7] Measurement of other business indicators were introduced prior to this.

[8] European branding is used wherever possible, but as up to 12 languages are used, separate labels need to be issued.

[9] Approximately 10% of profits go directly back into supporting the brand.

innovations and ended up investigating all aspects of pet care products. What we have now decided to do is focus on large volume products to support further growth[10], which is our prime business directive. We have found that it costs just as much to launch small products so these have been squeezed out'.

A business review, including the three indicators of on-time delivery, number of products released and profitability analysis for each project is published internally on a monthly basis. This is augmented by a thrice-yearly business performance review - that adds sales value and margin on all products - to discuss major points.

What they want to use in future:-

The Technical Director sees performance measures continuing to play an important role in Petproducts Ltd.: 'Our main measure has been and always will be (for the foreseeable future) growth. The key for us over the last 5 years has been to define additional critical measurements and find ways of assessing this performance in a pragmatic manner. I believe we have achieved this. However, as to whether we need more measures, I'm not sure. If they were obvious, we would implement them tomorrow'.

'We don't need to benchmark against our competitors - we lead and the rest follow. We believe that we shouldn't spend time analysing the competition and its performance but rather that we should focus our efforts on staying out in front'. Benchmarking is carried out internally across the group and for wider issues such as pay surveys.

If Petproducts were to introduce any additional measures, the Technical Director considers they would be most useful in the specification stage of product development. 'Unlike defence contracts, etc., where you can relatively easily define hard measures of performance, we have some difficulty setting appropriate values for some of the aesthetics and other features to be incorporated into the design specifications. What we are therefore trying to do is to compile a list of projects that have proved to be useful in terms of specification and use these as a pro forma for future specifications. As the designs evolve we then assess our ability to deliver designs against these specifications as part of the ISO procedural reviews'.

'We are an innovation-led company and are constantly looking for new product ideas. One of the recent innovations has been oral hygiene for pets. The idea came from the group's central research centre, following cooperation with vets and attendance of veterinary conferences. When we presented the idea to consumers, they loved it. Things like this are hard to measure in absolute terms but ultimately some idea can be gained in terms of sales and return on investment'.

4. Seasonswear Plc - Profile:

'Development is our future and we take it very seriously' was the reply of Seasonswear's Technical Director when asked about the role of design and development measures in his organisation. Seasonswear Plc supply leisurewear, underwear and lingerie to retail outlets in Europe and across the world. They are part of a large industrial multinational based in the UK. New designs are produced every season to fit in with the fashion calendar and are shown at all major shows around Europe[11]. They are a major supplier to a large chainstore group in Europe and 70% of the mens' underwear sold at the chainstore's shops passes through Seasonswear's

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[10] Senior management at Petproducts Ltd. set a growth-rate target of 20% p.a.

[11] Designs need to be planned almost two years in advance.

East Midlands factory[12]. Owing to this close relationship, customer contact is very important. They are a high volume batch producer, with approximately 55 tons of fabric passing through the factory every week.

In terms of business strategy, they are very much a technology-led organisation. The Technical Director commented; 'we are the main innovator of underwear in Europe. We use chemistry to try out combinations of different finishes and new fibres. New projects involving properties of fabrics (stretchability, fineness, warmth, etc.) and dyes (colour stability and colour fastness) are very important to our on-going success. These are all tested in our laboratory'.

Broadly speaking, the company has two types of development projects; customer or designer-led, and 'blue sky'-led. Customer-led is fairly self-explanatory; customers suggest products or concepts which are then developed with marketing personnel. Ideas from designer-led projects are shown to the customer and management. Blue sky projects are a little different. This class of project is run by the company's technicians (i.e. the chemists). Design and Marketing only get involved once the new formula has been fully tested and approved[13]. Realisation can be a long process, as sometimes it takes up to two years for new products to be taken up by designers. The project then follows the standard path for development from idea acceptance, through to trials in the lab, knitting review, scheduling and production. The product development process is documented in the company's ISO 9000 procedures. As there are many variables and unknowns involved with blue-sky projects, there is no specific time limit imposed.

All new proposals must satisfy three basic questions before they progress into commercial briefs[14] and hence new projects. The Technical Director explained what these are; 'do we have the kit to make it, what is the technology required and what are the cost implications?' He added that a project may not get off the ground simply because the re-needling costs are too high. Re-needling is equivalent to tooling in a typical engineering company and can represent a large percentage of the project cost and time. Cross functional meetings are held once per week to report progress on all current projects. These meetings are generally attended by the Production Manager, the Marketing Manager, Technical Director, the yarn sourcer, and a designer. Development cards are used as the main tracking document for each project. As the project progresses through the stages from initiation to production, the card goes with it (in a similar fashion to the Kanban system used in production). Information from all projects is summarised onto an Excel spreadsheet by the Development Engineer. This helps to avoid bottlenecks such as those that can occur in constrained areas such as the knitting machines, the dyehouse machines and finishing department (especially where special processes are required).

Performance measures - covering all activities from design through to production - were introduced by the Technical Director in 1993.

The 3 most important performance measures they use are:-

- No. of development projects that were successful (i.e. realised into products) against total number of projects.
- Money generated by new products over the first one and two years against total value of sales.
- No. of products taken up and sold against the total no. available (from project portfolio).

[12] They also have a 30% share of the womens' underwear and lingerie sales.
[13] i.e. has passed safety, washing, colour run tests, etc.
[14] The commercial brief contains details of volume, colours and who is responsible for the various stages of product development.

What they want to use in future:-

'There are currently no strategic level measures to compare the company divisions globally but I feel it is only a matter of time before this happens'.

'We would very much like to use a computer package that is capable of visually mapping times (planned against actual) of all our projects on one sheet. We have looked around but there doesn't seem to be any off-the-shelf packages available that are able to do this. We may eventually write a bespoke package in-house but this could take some time'.

We would like a 'what-if' scenario to help us schedule activities to avoid bottlenecks around the constrained activities (mentioned above).

5. Airvent Ltd. - Profile:

Airvent Ltd. is a UK company (but part of an international engineering group) that designs and manufactures world class ventilation equipment. They are primarily a mass producer, with design and development being located on the same site as manufacturing. Product development projects are mainly for new products to existing markets, with an average development time of 6-12 months. A variety of tools and techniques are used to assist with PDPs including design for manufacture, FMEA, rapid prototyping and cross functional teams (which are used on some but not all projects). The company uses 3D CAD on selected projects and is aiming to increase this to all projects in future.

The Technical Director was previously at another of the group's sites and moved into his new role in February 1995. He found that the only way to monitor design and development activities was through ISO 9000 procedures. However; 'no-one adhered to them and they were even used as excuses for delays. One of my first tasks was to improve these documents by making them clearer and more user-friendly'.

Although the company is a major player in the ventilation market, the exact size of market share is not known. This is because business includes retail, industrial and commercial markets. Many specials, one-off items and large orders (e.g. from the building industry) are made, which makes tracking the total market size difficult. As with many UK manufacturing organisations, they have suffered from the effects of cheap Far Eastern imports. The Technical Director stated; 'unfortunately the CE mark has had a limited effect as now everyone seems to have acquired it. We are hoping that a new low voltage safety directive will exclude those cutting corners and not complying with standards'.

One of the major initiatives that the new Technical Director brought in was a set of simple measures to monitor product development projects. He called them the '3 Cs'; contract, calendar and cost. He added that there is also a silent fourth C of communication that underpins the other three: 'This aspect can sometimes be overlooked but is extremely important in the reporting and operation of measures'.

The 3 most important performance measures they use are:-

- Contract / specification - what the customer wants.
- Calendar i.e. schedule against actual - when he can get it.
- Costs - how much he pays for it.

Contract is basically the product specification document which consists of three major parts; market information (such as market intelligence, analysis and competitor analysis), costing (of previous models and other products in the range) and the details of the specification itself.

Calendar progress is monitored by the Project Manager who checks on a daily basis with their team. This is reported on spreadsheets or simple graph paper at the monthly product planning meetings to other project managers and the Technical Director.

Cost is made up of capital expenditure (tooling and factory facilities) and product cost (materials, components, labour and overheads).

These measures are set at the start of a project and Project Managers report progress at monthly product planning meetings. These meetings are cross functional and typically involve Sales, Marketing, Export, Finance, the Technical Director and the Managing Director. In addition to this monthly meeting, the Technical Director also likes to be kept up to date on an informal basis if anything important changes on projects. 'I want to move away from the 'placing blame approach' and encourage people to report what is happening without fear of reprisals. Basically I don't want surprises - I want to know when things go wrong'. Feedback of performance measures is a combination of formal and informal reporting. The Technical Director stated; 'in the last year, we have reduced the number of formal meetings. We used to have meetings all day on Friday, every Friday and they were often non-productive for many people there. We have since moved away from this rigid system and now have meetings as and when necessary'. Other methods of communicating measures that are used to various degrees (depending on the nature of the project and the project manager) are email, reports, presentations and team meetings.

On the subject of colocated teams he commented 'we are simply not big enough to support this for every project. We only have 12 people in the whole of design and development so taking people away for long periods of time is not practical'.

What they want to use in future:-

There are several improvements that the Technical Director wants to make to the measurement system in future. He stated; 'we are a very engineering-led company. While we want to retain this focus, we need to increase our consideration of the marketing aspects. This will be built in to the contract (product specification document). The contract also needs more information on product development cost (including revenue spend, capital cost and labour) against turnover'. In addition; 'handling and transmitting data is a big issue - improving the way we do this is a high priority area....In terms of additional measures, if I had to choose one stage, new performance measures would be most useful at the specification stage'.

Teamworking is a targeted area for improvement; 'I want to encourage interactive communication within teams. At the moment, it is up to the Project Manager to go round the various departments, monitoring progress and picking up on problems. I want the team members to be more proactive and find out the information for themselves'.

The most visible change - that the Director has already started working on - is to introduce checksheets into all stages of the product development; 'I believe that checklists are central to project control and what we are currently aiming to do is integrate them into the ISO 9000 procedures to make them more workable'. He added; 'we will make the questions asked more direct so rather than asking 'is everything satisfactory?', we will say 'has check X been completed?' This will enable the monitoring of design change controls to be formalised, which in turn will help us to complete projects more quickly'. The Director also intents to introduce a post project review to improve the product development process.

6. Auto Systems Inc. - Profile:

See Chapter 5.

7. Glueco - Profile:

Glueco is a multinational corporation based in the UK with subsidiaries in Europe, America and Australia, and sales offices across the world. They develop and manufacture adhesives and coatings - in batches - for a wide range of applications. These include bookbinding, laminates for crisp packets, hot melt adhesives for cardboard packages (e.g. cereal packets), self seal cold adhesives (e.g. wrappers for chocolate bars) and water-based emulsion adhesives for lamination of work tops[15]. Exports represent approximately 45% of their business[16] with goods being transported by a fleet of 500 one ton trucks. They currently have no direct retail involvement, as they deal only in the bulk volume market.

The Group Technical Manager has been with the company for 30 years. He explained the company's situation; 'we are a low profile industry but have a defined niche market. We are basically all chemists and are a totally technically-led company. We have almost zero turnover of staff, with most people having been here for over ten years'. He continued; 'there's still a lot of 'feel' involved in this industry and I don't think it will ever be an exact science. For example, I can tell a lot about the glue by the way it feels. Our customers expect glue to be a certain colour or they don't feel that it's right. Sometimes we have to add colour to stop them sending the batch back. Only experience can give you these sorts of insights'.

In terms of developing the product, the Technical Manager explained; 'its all cookery. Assigning deadlines for mixing compounds is a futile task - its unpredictable. Either it works or it doesn't. We have been working on one particular project for almost five years. We haven't folded it because if we achieve the breakthrough, it will be very lucrative for us. This makes it difficult to set measures. The longer the project goes on, the worse the cost/benefit equation becomes. Setting project review dates to monitor progress and prioritising key projects by pulling out all the stops is the most you can do'.

The idea for measuring project performance originated from ISO 9000 documentation. The sections on product development were written and are monitored by the Technical Manager. He explained; 'we currently have a project monthly report that covers product development activities'. This records the customer name, the project title, the start and finish dates, priority and the status of the work (i.e. proactive - new discovery, or reactive - investigating a customer complaint)[17]. He added; 'unfortunately we do not accurately assess development costs but we want to find a way to implement this in future'.

'The only real bottlenecks encountered in the product development process are associated with training and communication. Specifically, there can sometimes be a misunderstanding between the sales people and the customer on the specification required. This is due both to the customer not really expressing what they want and the sales people not having the required technical insight. Other problems we sometimes encounter are with the handover to production of products. If the production personnel do not follow the mix to the exact specification (down to 0.1 of a percent) this can change the adherent properties of the glue, thus affecting the quality. Both of these problems can be avoided with more training and we now have an in-house training program for this purpose'.

Teamworking is very important for us - it keeps people focused and committed to the project. However, we do not use colocation as we are small enough to be able to contact everyone very quickly.

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[15] High volume, low margin market.

[16] They currently have almost 80% of the European market of self-seal cold laminates.

[17] Produced on a spreadsheet from MS Works.

The 3 most important performance measures they use are:-

- No. of new projects realised - good and simple.
- No. of projects released - good and simple.
- Field trials - essential to sales.

The number of new projects realised refers to those that complete the development against those that are abandoned part way through. Projects can originate from customer requests, internal investigation or salesman's request.

Number of projects finished refers to those that go through the stages of development and production and are subsequently released to the market.

Concept and product testing through field trials are an essential part of the product development process - in fact, development revolves around them. Long term relationships with customers have been built over the years meaning that trials are usually done at the customers' sites at their expense. The Technical Manager added; 'the personal touch is very important in this industry as much of our business is make to order'.

What they want to use in future:-

'As previously discussed, the costing of projects is extremely difficult (especially for projects of indeterminate duration) but we really need to get a better approximation - it's currently very much based on gut feeling. Costing includes purchase of equipment (e.g. laboratory and measuring equipment) but the vast majority of the cost is the time of the development chemists. We are currently trialing the use of time sheets to establish how many hours are spent on each project. However we are encountering the usual problems of people feeling like they are being tested and tracked and others complaining that it's a waste of time or simply forgetting to fill out the sheets'.

'Another performance measure that we would like to introduce in future is the number of new products released per annum against the increased sales generated. This can be difficult to implement in some cases. For example, a new grade of the same adhesive is given a different number - but is it a new product?'

'We don't currently review projects once they are finished - teams disband and move on to the next project. I want to remedy that as you can learn a lot from previous experiences. In future, we plan to build feedback into the ISO 9000 procedures'.

Statistical analysis of reject material needs to be carried out on a regular basis with the results being fed-back into the design phase.

'In the past we have very much worked on an informal communication basis. This is becoming harder since we have expanded across the world. We are basically learning to become a multinational company, starting with the use of cross functional teams on joint development projects. At the moment this involves lots of communication by fax. Obviously in future we would like to expand our computer network to encompass all activities and introduce videoconferencing to assist with projects. This will have an impact on the measures we use for product development but at the moment we are not entirely sure how to approach this'.

8. Brewmasters UK - Profile:

Brewmasters is a large UK-based brewer of alcoholic beverages. The company also owns public houses, hotels and entertainment centres They research new flavours, blends, etc. and develop new techniques, as well as designing and manufacturing their own cans, bottles and packaging. The specialist manufacturing machinery required for brewing is bought in and commissioned in-house. They have many leading brand names and export across the world. Brewmasters has ISO

9002 for their manufacturing sites but not for design procedures. There is a view in the company that full ISO accreditation would hold-back progress: 'We don't want to have to slavishly follow procedures and check boxes if there is no real benefit - it's too slow and inflexible'. The brewing business is high volume low margin, demanding high utilisation of vessels (up to 97%; 24 hours per day, 7 days per week). As they are in the food and drinks business, they need to be fully aware of any changes in European legislation (e.g. on one site a new boiler system had to be introduced in 1996 to reduce pollution levels).

The Director of Research at Brewmasters believes that use of cross functional teams is key to product development and they are now used on all major projects; 'any use of Concurrent Engineering involves overlapping and hence increases the risk of doing things wrong. This could obviously have implications on product quality and safety. There is a constant tension between speed to market and risk. Teams enable us to keep communication clear and allow us to react quickly to changing situations'. He added that 'product development is driven by Marketing Managers, as brewing is a consumer-driven business and they are closest to the customer'.

The Project Manager has been working on engineering projects with Brewmasters UK for the past 10 years. He explained the way projects begin: 'Projects start with a project origination document and they have a five year plan for implementing projects. Some are expedited on the fast track if they become urgent. Most project steering teams meet on a monthly basis but fast track meet every two weeks'.

The major bottlenecks for engineering development projects are release of design money, getting agreement on a specification (and keeping to it), short time scales for pre-production and, on occasion, unwillingness to accept responsibility on the handover to production.

Performance measures were introduced by the new MD in 1995. A small team was set up to implement them. The main targets that every development team has to achieve are that their new products must be:

- robust in filling, packaging, transport and consumer handling,
- marketable worldwide,
- easy (and low cost) to manufacture in large volumes and
- have an appropriate price tag for the market.

The Engineering Director stated; 'we are in a mature market place which means we need to be careful about the dynamics of products being introduced both in terms of their effect on competitors and our own similar products'. He added; 'the company structure and culture is receptive to introducing more measures but time and resources mean that we do not'. He added; 'the company operates in a mature market. NPD is a relatively new area for exploration and the culture is predominantly 'risk averse', with a 'cash cow' type of operation, focussed on slow growth through new presentation of products'.

The original document that starts projects contains a proposal on why the product will be successful, what alternatives (and competition) are available, the net present value over five years and the Product Standard Cost (PSC) which includes manufacturing, packaging and distribution costs. Engineering performance is based around time sheets both for in-house designers and engineers and for external draftsmen and consultants.

In R&D, all new product launch proposals go to the Board of Directors for approval. Proposals include details on technical performance, financial analysis (including volume forecasts and risk analysis), results from mini trial and extent (if any) of old product substitution. The Director of Research explained; 'a vital question at the outset is are we going to add profit from launching this product? All projects must have a proven payback before they are approved'.

Performance measures are an inherent part of Brewmasters' product development strategy. Measures are discussed at every product development meeting and are now tracked as part of a new electronic management system that is networked across the organisation. This includes details on milestones attained for all projects, Gantt charts and resource allocation.

The 3 most important performance measures they use are:-

The Engineering Project Manager explained that when commissioning new plant, the criteria of performance are simple - 'it needs to be on time, on budget and it needs to work!' The main measures they use are:

- Total cost of the project - including actual cost against estimates.
- No. of amendments (i.e. design changes) to the specification including time spent on them.
- Delivery rate of projects - percentage on-time.

Each engineering project has a set of core of performance measures (including those listed above, line efficiency, loss rate and changeover times) supplemented as necessary.

The Director of Research had a rather different set of measures that he considered important for product development:

- Consumer research information - to input into the new product specification.
- Achievement of technical objectives - in order for the product to go ahead.
- Speed to market - it's absolutely vital to achieve time scales and meet retailer deadlines.

'Consumer testing is a central measure of our success. It helps us calculate market price, margins, volumes and substitutions'.

There are technical developments in nearly all of our new products and these need to achieved on time in order for the launch dates to be met.

'Product development cost is not a major issue because if we get it right, the returns are potentially very great. Speed to market is much more important, as we need to achieve a dominant market position and maximum revenue before copycat products come on to the market'.

The Director of Research added; 'we do not have a template of detailed measures that must be used on each project - we leave it to the individual project managers and teams to decide on what is appropriate. Flexibility is vitally important - management is a dynamic thing. The best approach is to review your system on a regular basis and ensure that what you are measuring is connected to the critical path. It is important to remember that you can easily measure the wrong thing e.g. head count. One extra person costs virtually nothing compared to implications of a late project. For each project we need to weigh up the impact of being late, against the deployment of extra resources. These aspects cannot be written into hard and fast rules, that is why flexibility is important'.

'I like to encourage people to take ownership of measurement and intuitively review performance measures as part of their job, rather than carrying out formal reviews. Added to this, they should develop their own measures to achieve internal standards, rather than someone imposing measures onto them. This is not always possible, but it can be very powerful'.

What they want to use in future:-

The Engineering Project Manager had many ideas for future improvements. He stated; 'we need to find a way of using our resources more effectively ('prioritise and compromise'). We also need to consolidate our databases and find some consistent way of tapping ideas from trade journals on the latest innovations and customer requirements. I would like to formalise suggestions for future improvements (that could be fed back into the procedures)'. He added; 'if possible, I would like to see review stages on all projects - including fast track. This may not be realistic, owing to the very tight schedules but the lack of reference points makes it difficult to verify what happened when'.

'We already do actual cost against estimates to ensure good feedback to follow-on projects. We don't do in-depth analysis on all parts of all projects as it doesn't warrant the time - especially with the smaller projects. Personally, I would like to see more post-project reviews. Currently, there is more of an emphasis on financial reviews rather than engineering but the introduction of post-project reviews could be very beneficial'. He added, 'Brewmasters does not currently have a framework that pulls all the measures, in all areas i.e. R&D, product development, manufacturing, marketing, etc., together. If this information were available, it would be a very powerful strategic tool'. He concluded by stating; 'basically, we want to introduce more effective measures but they must be the right ones. Any new measures must be proven to be useful and worth the effort i.e. they must have a proved payback'.

Future measures:-
- Idea generation: no. of ideas generated; various databases checked, alternatives identified (data pooling).
- Screening: reasons for rejection - sensible, well thought out or badly presented.
- Feasibility: % estimates confirmed within x% of estimate / feasibility of ideas.
- Specification: no. of amendments / no. of follow up meetings/time required.
- Detailed design: time/ no. of referrals to designer/cost of follow up design.
- Pre-production: estimate accuracy of time/performance.
- Production: time available / final cost.
- End: efficiency of performance / time to commission, etc.

The Director of Research stated that 'the biggest improvement would be in more meaningful consumer information. Consumer testing is *the* measure for us but it is also the weak link in the chain. Deriving information from consumers which can be sued for product development and improvement is critical for all FMCG[18] companies. Research is currently done externally to minimise the risk of biased responses. However, there is still room for improvement'.

He reinforced what the Project Manager had earlier said by stating; 'we would only introduce more measures that would make a direct, positive contribution to decision making and the product development process'.

9. Weighdex - Profile:

Weighdex is a well-established, small to medium sized company that designs and manufactures a range of mechanical and electronic weighing equipment[19]. Products include bench scales, crane-weighers, counting scales and electronic weighing platforms, manufactured on a make to order basis. They are part of a larger group based in the south of England, with another sister company in the USA. The company has grown rapidly over the last 10 years and is planning to double its size again over the next 3 years. As part of this expansion, world exports, which currently represent approximately 15% of business, will be targeted as a major growth area. They primarily sell to the trade (rather than commercial or consumer markets) and are well known for designing complete weighing systems for customers. Additionally, a large part of their business comes from their reputation for after sales service. Weighing is a very much trade-led business. Conforming to safety standards and weighing and measuring legislation is a

[18] Fast Moving Consumer Goods
[19] Mechanical scales, while no longer enjoying a large market in Europe, are a growth product with an expanding market in India & Africa with room where these scales are still commonly used (e.g. in clinics for weighing babies).

vital part of the product development process. They design and manufacture on the same site and have three types of product introduction projects; designing from scratch; customising systems for clients and adapting and introducing designs from the US office for the European market. They are ISO9001 certified and have a comprehensive continuous process improvement program.

The Industrial Engineer at Weighdex is a graduate who has been with the company for two years. He is mainly concerned with the introduction of new designs (as part of a Concurrent Engineering team), factory layout, tooling, manufacturing systems and pre-production issues. He explained how projects are run; 'we have a very experienced workforce, with many people having been here for up to 20 years. Bearing this in mind, together with the fact that we are fairly small and located in one building, we use management tools and techniques on an ad hoc basis. For the same reasons, we do not feel the need for colocation but we do have cross functional teams on most projects'.

Most bottlenecks that occur during product development tend to revolve around early errors. The Engineer stated; 'basically (wrong) decisions or mistakes made at the feasibility and concept design stages manifest themselves in later stages, especially during tooling and pre-production. Of course, problems that are not spotted at the start of a project cost far more to resolve at the end. I would like to see more research done and measures taken earlier to prevent these problems occurring'.

The 3 most important performance measures they use are:-

- Actual to predicted profits on products.
- Product development cost as % of turnover.
- Projected profitability analysis.

Actual to predicted profits is managed by Marketing. At the project proposal stage, they predict how many will be sold, at what price, etc. This is then checked against actual figures once the product has been launched.

The product development cost as a percentage of turnover is a fairly straightforward measures that is based on three components; the man hours of the engineers, the tooling cost and the cost of any subcontracted engineers and designers.

Projected profitability analysis is handled by Marketing and Accounts and is based on volume sold and profit margins.

The Industrial Engineer stressed that 'the bottom line is the most important part of a project. We can measure performance but I'm not sure of the extent of the use of these measures'.

The first performance measures were introduced by the Engineering Director and they have since 'grown organically'. Performance measurement is based around the filling in of time sheets by all employees. In Design and Development, time is booked against product (i.e. project) time. This information is entered into the mainframe computer on a weekly basis and used to update all running averages. The Finance Department then deals with this information, which is initially passed on to the Managing Director and to senior management level.

Company-wide performance measures are posted around the offices and the factory and are updated monthly. These include;

- Return on Capital Employed (ROCE),
- a customer satisfaction index (based on customer returns, complaints, comments, etc.),
- cost of quality calculations (involving scrap rates, failure rates, etc.),
- a cash flow monitor,
- delivery performance (% on-time) and

- profit created per employee.

The Industrial Engineer was enthusiastic about measuring; 'performance measures can provide focus and define objectives of the project. Focusing on problems aids decision making. Good decision making on one problem will have a positive effect on other potential problems'. There is, however, a problem in the way that measures are communicated at Weighdex: 'The main problem I have with our current performance measures is that most of the results are never fed back (formally) to the operational level. Sometimes we don't even get to hear about the success of the products we developed'.

What they want to use in future:-

In terms of the future of measurement, the Industrial Engineer stated: 'There is definitely room for improvement in the way we use measures. Currently, we don't look at the 'big picture' when designing and developing projects. We don't know the true cost of product development. At our level, the figures are shrouded in mystery and I'm not convinced that the figures are accurate even at Director level'. He added; 'the main thing holding us back is deciding on the best way to proceed. Commercial time pressures always mean that you need to complete the next project before you can start looking at improvements and of course this often means that changes get delayed'.

'Measures at the feasibility and concept design stages of projects would be very helpful. This could include; parts count comparison of new design against old, the degree of commonality with other products in the range (to encourage a reduction in variability of parts) and ease of manufacture. I am fairly sure that we have the information to do this but we do not currently link it together'.

'Engineers should have more direct involvement with customers. Currently this is always done through Marketing (except in the case of systems development). The only time that we get consulted is when something goes wrong'.

'Our engineers design products to function. They don't consider other aspects such as the parts count or the bill of materials - they leave this to Manufacturing. We should encourage people to take ownership of the whole project, not just their part. Personally I would like to see us using benchmarks to target project goals. This idea could later be expanded to include comparison with competition on key factors. It would even be worthwhile recording the number and nature of ideas, together with who suggested it to get people interested and motivated'.

'I don't think we need fancy software tools to improve. For a start, we should spend more time at the end of projects reviewing mistakes to prevent problems reoccurring. On a more basic level, we need to gather as many people as possible into a room with a large piece of paper and brainstorm what we would like to see happening'.

As Weighdex has grown, the systems and procedures have struggled to keep pace. The company has changed from an almost 'family environment', into a medium sized business in the space of a few years. Some of the formalisation of information that the Industrial Engineer would like to see may soon be implemented, as new strategic and operational directives from Head Office are being rolled out.

10. Sportsco - Profile:

Sportsco is a multinational company based in the UK, with manufacturing units in the UK and overseas (mainly in the Far East). The company has two main lines: sports clothing and sports accessories. They are market leaders in their field, with a strong brand name. Whereas the sports clothing is mainly manufactured in-house, all sports accessories are bought in from suppliers and distributed and marketed by Sportsco. They operate on a make-to-order basis. To date, they have not applied for ISO 9000 certification as they view it as a hindrance to the dynamic nature of the business.

The New Product Development (NPD) Manager[20] for sports accessories has been with the company for 3 years. He is responsible - together with a colleague - for over 350 SKUs[21]. While he does not personally design the products, he is responsible for setting the brief for designers, setting the specification, approving designs and prototypes, liaising with suppliers, trailing technical innovations and testing the concept with customers. As Sportsco Accessories oversees and controls product development, while leaving the suppliers to carry out the development, maintaining close supplier relationships is very important. The NPD Manager stated; 'we are in the consumer equipment business, meaning there are strict European and World standards to which our global products need to conform. We have set agreements with suppliers and put the onus on them to meet agreed quality criteria. Periodic checks are carried out at suppliers' factories to ensure that their standards are being maintained'.

Sportsco is a very flat organisation, making direct meetings with senior managers and the Managing Director a regular occurrence. Cross functional teams are used on selected projects - depending on size and complexity - but colocation is not necessary owing to the size and nature of product development. Informal lines of communication exist because of the flatness and performance measures tend to be reported only when there is a diversion from the agreed plan.

The 3 most important performance measures they use are:-

- Margin analysis
- Calendar time
- No. of products released per annum.

Margin analysis is a vital measure as it calculates the breakdown of the product price at each stage of the product's life i.e. development, marketing, manufacture, distribution (including shipping) and sales and hence the margin left for Sportsco. This also has a direct bearing on the total cost of the project.

Meeting time scales and deadlines is critical for Sportsco. As sports accessories are mainly sold in retail outlets and affected by fashion, business is cyclical and dependent on well-defined launch dates. The NPD Manager stated; 'we set two year timelines for developing new products. A new product to us means anything that warrants a new SKU. This can mean colour variants, packaging changes, new technology improvements or a totally new concept'.

The number of products released is not an absolute measure with a pre-set value. It depends on the market and fashion of the time: 'We have a constant battle between offering total flexibility in terms of colours and sizes; and range rationalisation to achieve better economies of scale. All we can do is attempt to optimise the costs associated with launching the product against the potential gains. There is no computer programme to do this, it is dependent on market knowledge and experience'.

Product trials are carried out with professional sports people, coaches and 'ordinary consumers'. The NPD Manager explained; 'although our sports equipment is used by the professionals (and we sponsor them to maintain the brand image), they only account for a very small percentage of sales. [22] We need to be aware of what 'ordinary' consumers want'.

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[20] who also has the dual role as project manager
[21] Stock Keeping Units i.e. product lines
[22] Their biggest competitor is a top department chain store.

An overview on the progress of all projects is available through Sportsco's in-house product development tracking software. This is presented in the form of checksheets and simple process flowcharts, used to record which stage of development each product has reached. It is a useful aid to report progress to senior management and may be expanded in the future to incorporate performance measures.

What they want to use in future:-

In terms of future improvements, the NPD Manager had this to say: 'I would like to see more performance measures at the feasibility stage of product development. Better market information would be the biggest improvement to input into the product specification. Of course this is very difficult to achieve. Market research by an external company is very expensive and often too late. In addition, as we are a global company, what they find in one country may not hold true elsewhere. We know what is selling through sales figures and customer reaction to our products through field trials but this alone is not enough.

Appendix VII
Colocation Feedback Survey

This is a short survey on Colocation 1 that explores some of the benefits and problems experienced. The main aim is to provide learning opportunities for future colocated projects. It should take approximately 5 mins to complete. Responses are anonymous.

1. Which of the following, in your opinion, were achieved by Colocation 1?

Use of standardised components	❑	Batch size of 1	❑
Late stage differentiation	❑	Quick testing	❑
Closer links with suppliers	❑	Flexible lines	❑
Minimum part count	❑	Minimum costs	❑
Maximised features within budget	❑	Quality aspects satisfied	❑
Used design for manufacture	❑	Consideration of service	❑

Other (specify).. ❑

2a) With which of the following were communication problems experienced both within the team and between team and the rest of the company? Tick as appropriate.

	within the team	between the team & others
Marketing		
Tooling		
Design		
Development		
Purchasing		
Suppliers		
Production		
Quality		
Service		
other......................................		

2b) What was the nature of these problems? Tick as many as appropriate.

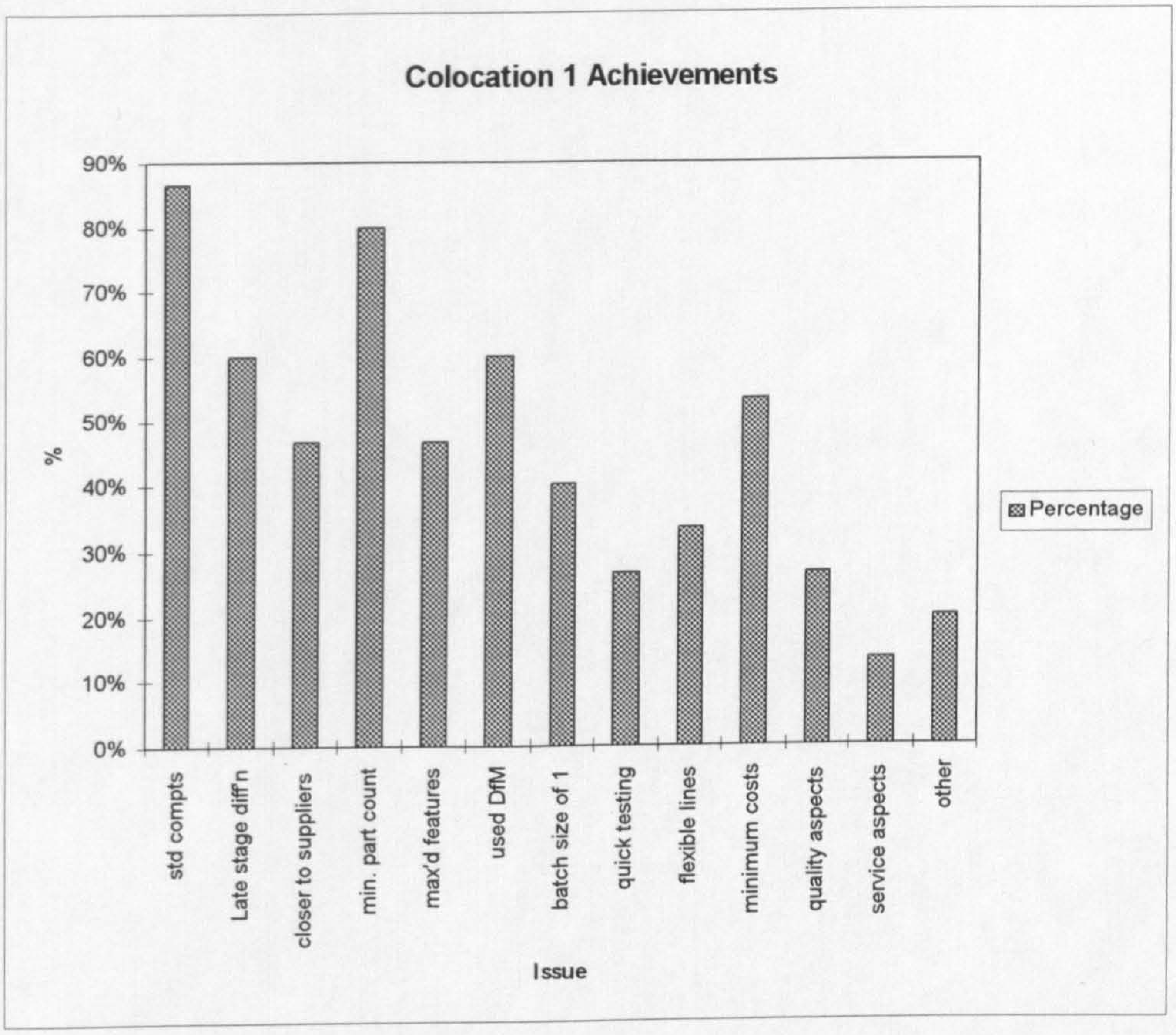
	within the team	between the team & others
Query response time		
Obtaining quotes		
Obtaining signoffs		
Product specification errors		
Accuracy of drawings		
Understanding the issues		
Prioritisation of tasks		
Interest in your work		
other...		
other...		

3. In your opinion, are colocated projects the way forward with NPI for us? ❑ Y ❑·N

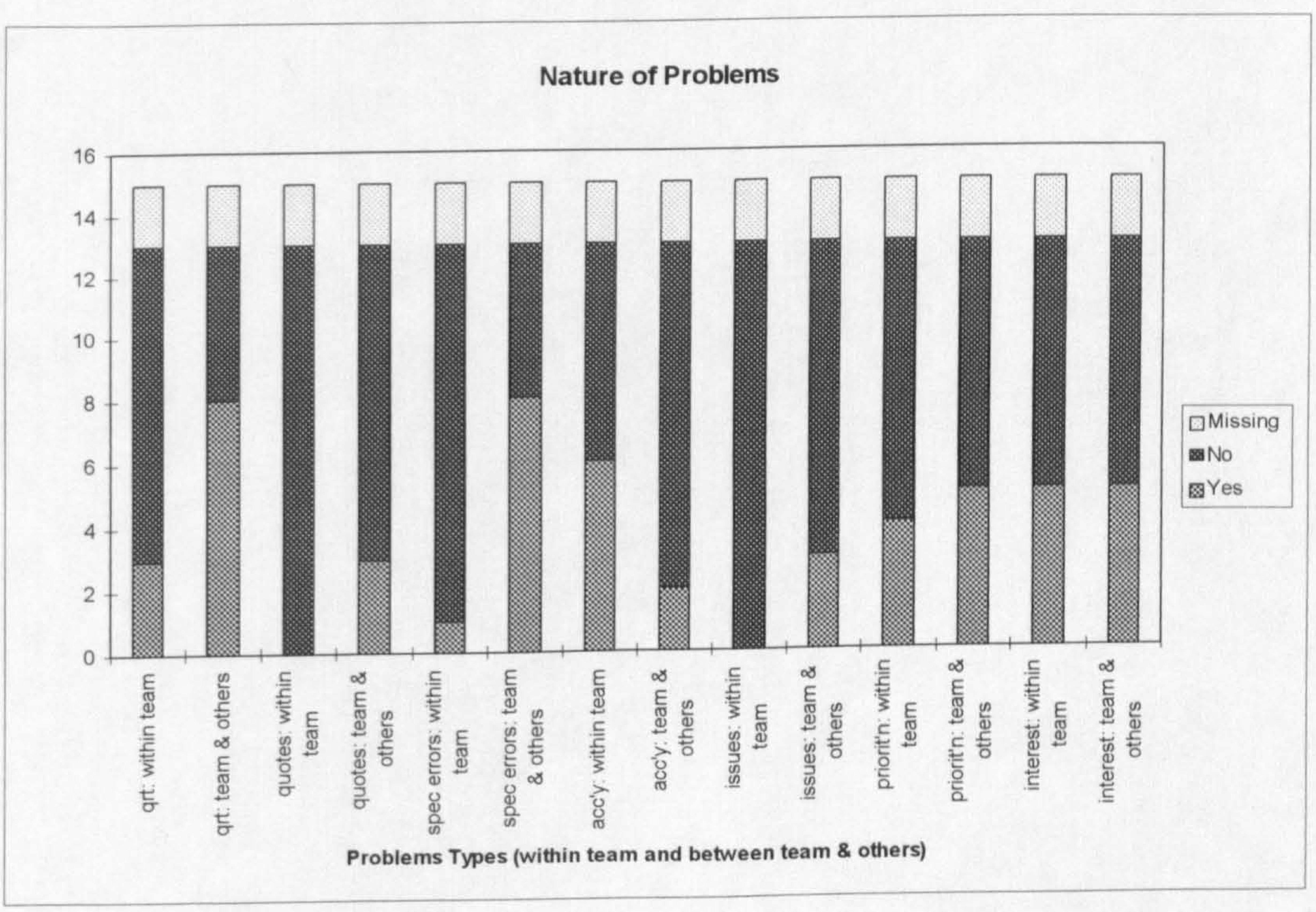
Reasons____

____

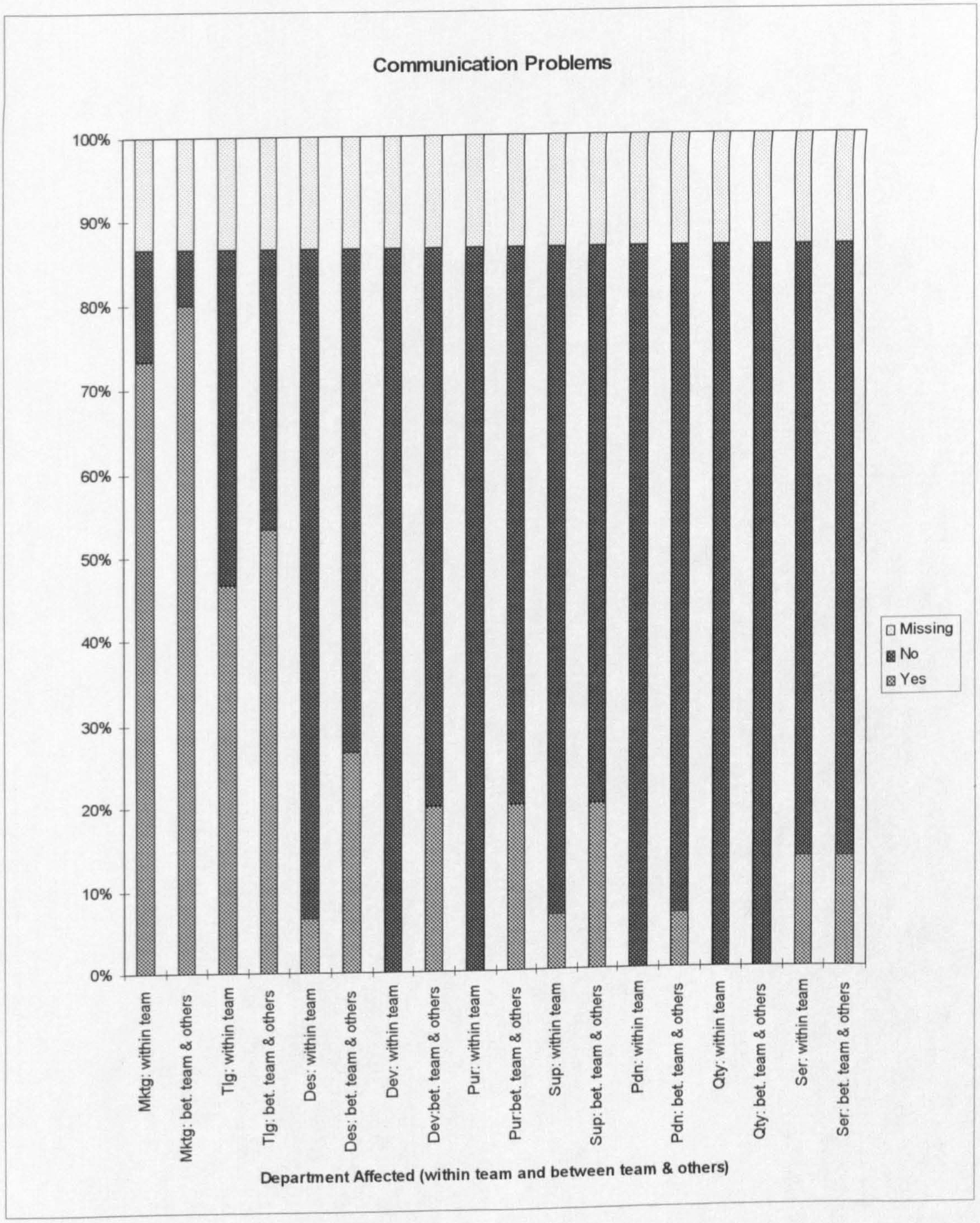
Thanks for your help. Please return completed forms to *Colocation 2.*



Colocation 1 Achievements
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
%
Percentage
std compts
Late stage diff'n
closer to suppliers
min. part count
max'd features
used DfM
batch size of 1
quick testing
flexible lines
minimum costs
quality aspects
service aspects
other
Issue



Nature of Problems
16
14
12
10
8
6
4
2
0
Missing
No
Yes
qrt: within team
qrt: team & others
quotes: within team
quotes: team & others
spec errors: within team
spec errors: team & others
acc'y: within team
acc'y: team & others
issues: within team
issues: team & others
priorit'n: within team
priorit'n: team & others
interest: within team
interest: team & others
Problems Types (within team and between team & others)


Communication Problems
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Missing
No
Yes
Mktg: within team
Mktg: bet. team & others
Tlg: within team
Tlg: bet. team & others
Des: within team
Des: bet. team & others
Dev: within team
Dev:bet. team & others
Pur: within team
Pur:bet. team & others
Sup: within team
Sup: bet. team & others
Pdn: within team
Pdn: bet. team & others
Qty: within team
Qty: bet. team & others
Ser: within team
Ser: bet. team & others
Department Affected (within team and between team & others)

Comments on Colocation	
1	For large projects they ensure commitment from all departments at early stages of the project (specification and design) avoiding changes and compromises when its too late.
2	Promotes understanding of roles within company, solves problems faster, creates ownership
3	Helps each of us understand the business better, helps the whole team to have a common goal
4	Team commitment and drive plus capacity to handle many products due to team being together all day each day, a better understanding of the project requirements.
5	Provides right environment for concurrent engineering.
6	NPI process time scales improve. Team members have ownership of the project. Departmental barriers are removed.
7	The ownership & responsibility taken on by the team creates the drive to succeed in achieving the targets of lowest cost & increased quality, etc. This allows x-functional roles & relationships: leading to increased morale & job satisfaction.
8	Improves communication/ breaks down functional boundaries/ promotes platforms
9& 10	No comments
11	Production dates, product spec. all met on time. Quick response bet. dept's improves product interest. Team created feeling of satisfaction & improved morale. All team members & departments have common aim having taken part in establishing product plan.
12	Gives a feeling of project ownership and greater commitment from colocated members.
13	Better communication and gives realistic opportunity to achieve compressed time scales
14	Benefits are obtained from having a full time team of people of different disciplines. Project lead time can be reduced.
15	I disagree with colocation because the whole design & development & testing of appliances is a total shambles when happening in parallel.