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MULTIFUNCTIONAL NEW PRODUCT DEVELOPMENT

This thesis is submitted in partial fulfilment of
the requirements for the degree of

Doctor of Philosophy

PhD

By

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Durham
University

July 2005

DECLARATION

I can confirm that this thesis is the result of my own work. No part of this thesis has been submitted for any other degree in this or any other university.

K.J. TURNBULL
July 2005

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For my wife

Lorraine

And to

James

'Whatever you do in life son, do it well and make us proud'

ABSTRACT

The New Product Development (NPD) process in manufacturing industry, together with the application of multi functional teams in the process, has been well studied in the extant literature. Tools, and techniques used to assist project teams in NPD have also been investigated in detail. However, many of the claims of the effectiveness of 'tools' such as Rapid Prototyping (RP) and techniques such as Failure Mode and Effects Analysis (FMEA) are anecdotal in nature, lacking empirical evidence, or promoted by authors with a commercial interest in the subject.

Therefore, as part of the objectives of this research to provide more empirical data, case studies were conducted over a period of 12 years in companies such as Flymo, Kenwood, and Domnick Hunter. Key Performance Indicators (KPIs) were selected for the case studies to provide a rich source of quantitative and qualitative data from which some of the root causes of NPD problems were identified. A common NPD problem identified was project delays, following late changes to the specification and the product engineering. It was clear however, that not all of the changes had a negative impact on a project, indeed some teamwork studies encourage changes to improve the product value and quality. A 'penalty weighting' model to quantify the 'impact' of changes with respect to any benefits was developed to identify the most cost effective period for teamwork studies and provide an efficiency profile for each project.

A strategic business approach for Rapid Prototyping activities was also presented together with a 'sub-group' methodology to encourage innovation and reduce 'front end' delays. Appropriate project management control documentation was developed for the NPD teams to support the control of various KPIs including product deliverables, product costs, capital spends and launch timing.

ACKNOWLEDGEMENTS

Special thanks and appreciation goes first of all to my supervisor Professor Ernie Appleton, at the University of Durham for his experience, guidance, support, humour, enthusiasm and tireless energy during the completion of this project. The importance for students to have the right university and supervisor can not be overemphasised, I believe I had the best.

I am also grateful to my employers: Flymo, Electrolux, Kenwood and Domnick Hunter who supported and sponsored the research case studies.

I shall always be grateful for the support and encouragement from my wife Lorraine, who's intellect, logic, courage, humour and competitive spirit has been inspirational in my life. Together we share the *Team Leader* role in the family.

What a Team!

Kenneth James Turnbull

July 2005

GLOSSARY

BSI	British Standards Institute
CE	Concurrent Engineering
CNC	Computer Numerical Controlled
DFD	Design Function deployment
DFM	Design For Manufacturing
DFMS	Design For Manufacturing and Servicing
DSS	Design for Six Sigma
FEA	Finite Element Analysis
FMEA	Failure Mode and Effects Analysis
GDPM	Goal-Directed Planning Methods
KPIs	Key Performance Indicators
LOM	Laminate Object Manufacturing
NPD	New Product Development
PAS	Product Acceptance Specification
PAT	Product Acceptance Tests
QFD	Quality Function Deployment
RP	Rapid Prototyping
SE	Simultaneous Engineering
SLA	Stereolithography
SLS	Selective Laser Sintering
STL	Stereolithography Translation software
StratPro	Strategic Rapid Prototyping
VE	Value Engineering

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CHAPTER ONE

MULTI-FUNCTIONAL NEW PRODUCT DEVELOPMENT

1.1 INTRODUCTION

The global objective of this research was to study the New Product Development (NPD) process in manufacturing industry, test-out the claims in the extant literature by conducting case studies, and propose improvements.

The research concentrated on NPD projects employing multifunctional teams, which, were cited in the literature as fundamental to the requirements of 'successful delivery'. How to measure 'successful delivery' was also explored and a derived model for measuring NPD performance was presented using selected Key Performance Indicators (KPI).

1.2 THE PROBLEM AREA

Most companies involved in the development of new products are interested in finding ways of reducing development *lead-times* for taking potential products from conceptual ideas, to manufacture. The subject of 'lead time' has received close attention in the literature, with books such as *'Developing Products in Half the Time'* by Smith *et al* (1991), with improved NPD methodologies such as *Stage Gate* $_{\text{TM}}$ offered by Cooper

(1993), and similar thematic publications from many other authors. However, most companies involved in developing new products, experience problems from time to time in the development process. Development problems may delay an activity or the planned launch date. A delay may originate from; poor project planning, problems with engineering, changes to the specification requirement of the new product, or inventions during the development process that may create opportunities for performance or cost improvements. The cost of delays in the NPD process may include lost revenue due to late launch and de-selection by a customer, or the extra cost of human resources for an overrun project. It is for these reasons that delays are regarded as a key problem in the NPD process, even if there are valid reasons to allow a delay to occur. Very often a company may not be able to make a calculated decision whether to accept a delay or continue the project as planned. Moreover, many companies are not able to assess the impact of a delay with respect to the other KPIs in a project. All of the above problems have been investigated in the research.

1.3 **THESIS STRUCTURE**

The research approach is depicted in Fig. 01. The thesis consists of a comprehensive review of the extant literature including; the common objectives of the NPD process, with respect to the type of product under development, how it is measured and typical problem areas encountered. The mobilisation of multi-functional teams in the NPD process will be reviewed in detail, together with examples of structural organisation and individual roles of people representing each function.

Case studies formed a key part of this research to identify the root causes of failures in the NPD process, test out claims in the literature and provide the much-needed empirical data identified in the review.

The author, due to the nature of his job, was able to conduct a number of case studies on consumer and industrial products over a period of twelve years, to provide a rich source of quantitative as well as qualitative data for analysis. This method of data gathering has been described as 'action research' (or *action science* Gummesson 1991) since it is not always possible to negate the influence of the author in the outcome of the studies. Qualitative discussions are included in each case study to qualify findings and provide a complete 'picture' of exactly how each product was introduced and identify problem areas.

One of the deliverables of the research was the derivation and presentation of a model for measuring NPD performance. The model may be used to quantify the impact of delays during the course of a project. The model provides a way of representing the 'impact' of a delay in terms of cost, with respect to 'where' the delay occurred in the project plan. The research concludes by taking the derived model for measuring the impact of delays, and reapplying it to further case studies to test out the effectiveness of 'tools', such as Rapid Prototyping, in the NPD process. The overall benefit of including Rapid Prototyping cycles in a project was explored with respect to the added cost and time needed to accommodate RP as an activity.

RESEARCH APPROACH

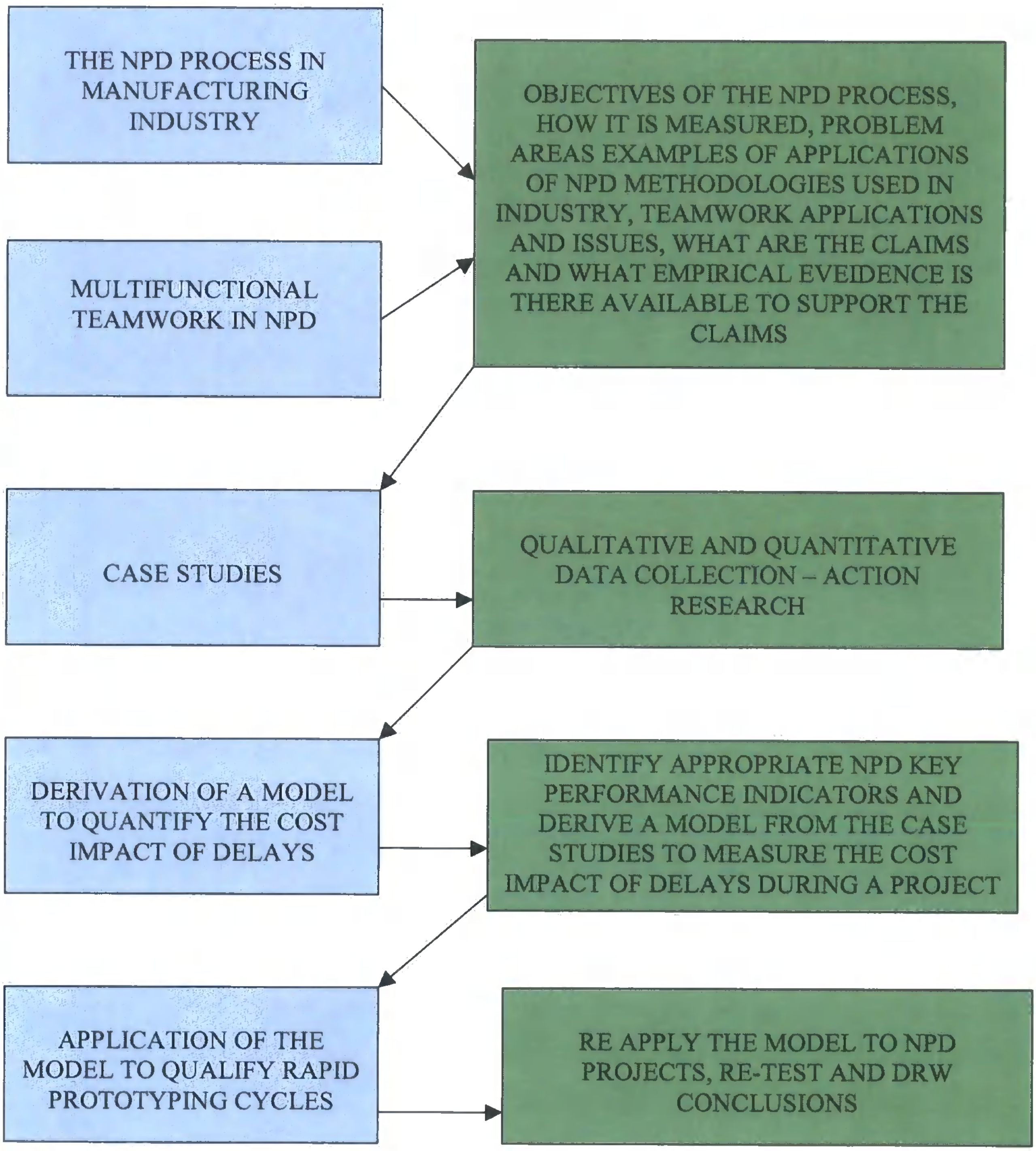


Fig. 01 Block Diagram of Research Approach

CHAPTER TWO

METHODS AND OBJECTIVES OF THIS RESEARCH

2.1 RESEARCH OBJECTIVES

This chapter describes the global objectives of the research together with a list of specific deliverables. The methods used to obtain the results will also be described in detail. According to Hasslop (1996) carrying out research involves three interrelated aspects:

"First, one needs to think about the kind of knowledge one is attempting to produce. Second, is a need to look at the theoretical issues surrounding a particular area of enquiry. Third, one needs to consider which technique is appropriate for data collection."

The initial objective of this research was to review the extant literature on the New Product Development (NPD) process in manufacturing industry, focussing on the role of multi-functional teams in the process, to identify gaps and opportunities for further contribution to existing knowledge. After the initial review case studies were conducted to test out the claims in the literature with process improvements to multifunctional NPD proposed. It was believed that this approach would contribute to both the engineering and business management disciplines, therefore the research was carried out with a bias towards an industrial base. A literature review of the NPD process was conducted to provide an academic foundation followed by empirical data gathering through case studies. Case studies were used extensively to identify problem areas in the NPD process especially delays to launch and to investigate tools and techniques for improvement through 'action research'. Both qualitative and quantitative methods were employed to provide a 'rich' source of data for analysis.

2.2 THE RESEARCH DELIVERABLES

As described above, the research focused on the New Product Development (NPD) process in manufacturing industry and the role of multi-functional teams in the process. A specific deliverable was to investigate the 'cause and effect' of delays in the NPD process, which was identified in the review as a key problem area causing late launches of projects. This involved the derivation of a model to evaluate the impact of delays in various activities during a project, and their effect on the final product launch date and project objectives. The derived model was also used to identify the most efficient stages for multi-functional team activities to take place, such as Failure Mode and Effects Analysis.

The literature review looked at a number of 'best practice models' of the NPD process by authors such as Cooper (1993), Smith (1991 and Wheelwright (1995), and practical implementation techniques used in industry including British Standard guidelines. It was intended that this work would build upon previous research and doctoral studies from authors such as Lettice (1995), who argued that:

"multifunctional teams provide the main 'vehicle' for improved product development performance, by integrating upstream and downstream functions early in the product development process."

In recommendations for further work, Lettice suggested that:

"Concurrent Engineering is still very much an emerging discipline. There is a large amount of anecdotal evidence to support and justify the use of Concurrent Engineering, but very little

empirical data to match the use of Concurrent Engineering to improve performance."

In a similar theme, Poolton (1994) argued that: 'It is implicit for managers to measure and improve their New Product Development process, however attempts to empirically measure and monitor NPD improvements, are limited'.

A deliverable of this research was therefore to provide more empirical data from case studies, of NPD projects employing multifunctional teams. The subject of multifunctional teams in the NPD process has been well covered in the extant literature however performance improvement techniques have been investigated in this research together with appropriate Key Performance Indicators (KPI) for further research. By way of example, the claimed benefits of using Rapid Prototyping in the NPD process are measured and evaluated together with suggestions how the effectiveness of RP can be optimised in a multifunctional environment.

In evaluating 'best practice models' Maffin (1996) argued that many models deal with 'generally applicable principles' but in many respects do not deal with how they should be implemented, claiming that:

"Methodologies based upon empirical studies are of particular interest being holistic in nature and applicable to 'real life' applications."

Maffin (1996) also discussed the need to 'develop a framework that provides a way of analysing and understanding the engineering and product development processes within the context of a commercial manufacturing organisation and to apply whatever elements of best practice where appropriate.' It was concluded in Maffin's research that: 'Some areas of best practice methods were found to be inappropriate in circumstances involving small companies and failure to recognise this could lead to some companies attempting to apply models that were inappropriate'.

In a similar theme Evbuomwan (1994), concluded that:

"In a modern product development environment, there is a need to integrate downstream manufacturing and use considerations into the early stages of design to - Design it Right First Time"

In opportunities for further work, Evbuoman discussed the need for a *'vehicle or methodology'* to integrate the needs of the NPD project objectives with the methods to be used in its manufacture. Therefore, within the scope of this research, it was intended to build upon existing NPD methodologies that may be easily adapted to a number of product and organisational contextual requirements.

In reviewing techniques to shorten New Product Development Project Plans Matin (1994) found that:

"Successful Concurrent Engineering New Product Development projects share certain common traits, prominent among these being:

1. *An intense, bi-directional, frequent exchange of information between various activities and business functions.*
2. *Emphasis on doing things right first time which was reflected on the project plan by the fact that the projects were heavily front loaded, with more time spent on getting the output of earlier activities right so as to reduce the duration of downstream activities.*
3. *Structured methods being used for formulating customer requirement.*
4. *Overlapping activities in the project plan."*

The author's comments on Matin's findings are as follows together with identified actions for the research: -

1. It was not exactly clear from Matin's research, how an 'intense, bi-directional, frequent exchange of information' can be organised between the 'business functions' and exactly what information should be exchanged. It is accepted that there must be an information interchange system within the NPD team, so an attempt was made in this research to define what should be included in the information interchange and how it could be efficiently exchanged.
2. There is a great deal of emphasis placed in the literature about 'time to market' and reducing NPD 'lead-times', Matin (1994) also emphasised the need to 'shorten New Product Development Project Plans'. However, if more time were spent in 'front loading' a project, the question must be asked 'how much time' can be afforded and what would be the impact of 'front loading' the project. There is clearly a need to quantify the *impact* of adding development time and activities to 'front end' stages of a project instead of making corrections at a later stage. By way of example, a key research question investigates if it would it be more efficient to include more prototyping cycles in an NPD project, before the manufacture of the 'production tools', or to accommodate any changes and corrections following inspection of the 'off-tool' parts? In order to address this research question, a derived model to quantify the 'impact' of delays with respect to where they occur in a project was included in the research deliverables.
3. Methods were also investigated in this research to help NPD teams to clarify the NPD *project* deliverables and how to verify the needs of the customer, in a timely way.
4. 'Overlapping activities' are fundamental to the philosophy of the *multifunctional* NPD process, referred to as '*Simultaneous* Engineering' or '*Concurrent* Engineering' (Hartley *et*

al 1991), however there is clearly a limit as to how much 'overlap' activities in an NPD project can be accommodated. This research shows examples of Gantt chart NPD introduction plans from the case studies including a baseline template for projects introduced by a number of consumer durable manufacturers. The templates, designed by the multifunctional teams involved in NPD projects, show practical examples of 'concurrency' and positioning of the various activities.

Following the above discussion, the key actions and deliverables of this research are summarised below: -

1. Review the extant literature and practical examples of the New Product Development Process in manufacturing industry.
2. Review Teamwork concepts in NPD.
3. Identify appropriate NPD Key Performance Indicators and conduct case studies.
4. Derive a model to quantify the effectiveness of teamwork activities in NPD from case studies.
5. Investigate, and test out, techniques for improving the effectiveness of teamwork activities in NPD.
6. Draw conclusions and identify opportunities for further research.

2. 3 THE STRATEGIC USE OF RAPID PROTOTYPING IN THE NPD PROCESS

In investigating techniques for improving the multifunctional NPD process, the claimed benefits of including Rapid Prototyping (RP) cycles were tested in the case studies. The technological development of RP falls outside of the scope of this study, however the *strategic* use of RP is investigated as a *management tool* together with measured engineering benefits.

Clark *et al* (1993) claimed that 'traditional managers have treated prototyping only as a technical tool for use by engineers'. He argued that: *'senior managers, functional heads, and project leaders do not fully utilise the power of prototyping thereby handicapping their efforts to achieve rapid and effective product development results'*. Clark *et al* (1993) also describes a role of 'prototyping cycles' as a 'management tool' to represent the development status of the new product.

From the review of previous work, *Design it Right First Time* is often referred to as an objective in an NPD project however, is not entirely clear what is meant by '*Design it Right First Time*'. Product design has been described by Clark *et al* (1993) as an *iterative* process involving a number of 'develop-prototype-test cycles', and the decision as to whether a design *is right or wrong* can only be taken given clearly defined pass/fail criteria. The literature review has also shown that the pass/fail criteria are not always clearly defined at the beginning of a project, therefore making it difficult to finalise the product design specification. The review also suggests that the accountability for achieving the pass criteria lie not only in the hands of 'design team', but the whole team including functions such as:

1. Production Engineering
2. Marketing
3. Quality

4. Materials Management
5. Design Engineering
6. The Customer

It was accepted that in order to minimise the time taken to introduce a new product, the number of design iterations should be minimised, and any design changes involving the modification of the production tooling should be avoided due to cost and time penalties. Given the iterative nature of product design, *'design right first-time'* may not always be an achievable target. In some NPD projects, for example the Flymo Garden Vac case study, even the customer was unclear what was required until presented with a conceptual model, which had in itself gone through a number of design iterations. From the above discussion a view was taken that *design right first-time* could not be a practical objective of an NPD project. Therefore this research will explore how the strategic use of Rapid Prototyping in a multifunctional environment could ensure that the product is **'Delivered right first-time'**.

Clark *et al* (1993) discussed the use of prototyping cycles in three major appliance manufacturers and suggested that: 'each company benefited from the use of prototyping cycles to enable them to deliver products on time. There were, however, clear differences in the methodologies used which influenced the total time period taken'.

Rapid Prototyping (RP) cycles in the NPD process were explored in this research, both as a technical tool, and as a ' strategic management' tool within a multifunctional team. RP in recent years (since 1990) has provided a number of distinct advantages over traditional prototyping methods according to Kidd (1996), including:

1. Faster production of complex geometry prototype components.
2. The potential for improved precision of complex geometry prototypes compared to traditional prototyping methods.

The above view was largely supported in the literature however there were also a number of potentially negative points to consider when including Rapid Prototyping in the NPD process:

1. Rapid Prototyping is still an expensive process; therefore the cost must be justified.
2. The RP materials may not always replicate the mechanical properties of the production material.
3. Rapid Prototyping activities may be required in addition to traditional prototyping methods thus potentially adding time to a project.

Much of the available literature describing the benefits of using Rapid Prototyping in product development is anecdotal in nature and is usually produced by practitioners with a commercial interest in the technology. Although a great deal has been written about the technology itself, which is not a key consideration in this work, very little evidence has been presented about the ability of Rapid Prototyping to 'add value' to a new product development programme.

A key consideration of this research was to identify a process to enable an NPD team to efficiently agree the product design objectives and deliverables, minimise the number of design iterations and provide a vehicle to verify the objectives and deliverables before the commitment of production tooling.

2.4 RESEARCH METHODOLOGIES

In order to address the key action points discussed above, it was important to choose an appropriate research methodology to obtain the most accurate and meaningful results from the case studies. The case study results were used as a basis from which potential improvements to the NPD process were identified together with opportunities for further research. Research methodologies according to Gummersson (1991) may involve the following methods, all of which will be used in this research:

1. Quantitative Methods (Scientific Methods)

   Evaluation and measurements based on quantity as opposed to quality - Oxford Dictionary.

2. Qualitative Methods

   Evaluation and measurements based on quality as opposed to quantity - Oxford Dictionary.

3. Action Research

   A process of doing or acting - Oxford Dictionary.

In order to complement previous work on the NPD process, this research was carried out from an industrial base rather than an academic base. However, a further literature review was conducted in order to understand the attributes of the above research methods used by other researchers.

Qualitative methods are described by Van Maanen (1983) as:

"An array of interpretative techniques which seek to describe or otherwise come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world."

In a similar study Pugh (1994) made the following observations about research techniques:

"There is no such thing as an unbiased observation- irrespective whether the methods are qualitative or quantitative". All scientific work of an experimental or exploratory nature starts with some expectation of the outcome. The expectation, known as a hypothesis, may be modified or discarded according to the outcome of the experiment. Hypotheses are imaginative and inspirational in character. Quantitative research involves the extraction of numerical data from an experiment for evaluation of the hypothesis. This method is favoured by the engineering and scientific research community."

Maffin (1996) described the Scientific method as: *"A systematic approach to investigations, which is founded on three central characteristics: reductionism, repeatability and refutation. The complexity of a phenomenon being investigated may be reduced in experiments whose results are validated by their repeatability, enabling hypotheses relating to a theory, or view, to be established or refuted. Typically for Engineers and scientists such experiments may take place in a laboratory or involve the construction of some quantitative model."*

Qualitative methods are described by Gummersson (1991) as a 'powerful tool' for researchers in the business and administrative domain. Gummersson stated that:

"Although both quantitative and qualitative methods are used for data collection in case studies, the latter will predominate in the study of processes where data collection, analysis, and action often take place concurrently."

Qualitative data, according to Miles *et al* (1994) is:

"Usually presented in the form of words rather than numbers. Experimental results are narrative in nature based upon the observations of an individual and his/her interpretation of the outcome of an experiment. Qualitative data therefore provides rich descriptions and explanations of a process."

In discussing a limitation with qualitative research, Soderquist (1997) argued that:

"The analysis methods are less explicit than quantitative studies. The resulting problem is that formalised statistical methods can rarely be used. This is not necessarily because of the nature of the data, but because there is a limited number of observations which do not allow statistical generalisation."

Driva (1997) claimed that Management research is 'quite different' from experimentally based science projects, which are focused around a series of laboratory tests. This is because, he argues that: 'true experiments cannot be used because it is almost impossible for a management researcher not to affect a subjects response in some way.'

This research employed both quantitative and qualitative methods to provide a complete account of all the case studies investigated. The approach involved the inclusion of a narrative description of the project, the significance of the new product to the company, how the team was organised and the issues encountered by the team. Most of the case studies in this research also involved the management influence of the author and were therefore inevitably influenced by the author, this type of research has been described as Action Science (Gummerson 1991).

Action Research, or 'Action Science', is research carried out with the *'active participation of the researcher'*, who will 'actively' intervene, with the outcome of an investigation. Action Science similar to other scientific methods involves stages of data gathering, which could involve case studies the formulation of hypothesis and a period of 'testing out' to prove a theory. However, the researcher not unlike a management consultant or 'change agent', will influence the end result of the study. The data collection process in action research can be both qualitative and quantitative in nature but is likely to be largely qualitative.

Whilst researching a framework proposal for the establishment of Concurrent Engineering in 'firms' Poolton (1994), decided to adopt a combination of both quantitative and qualitative research methods, suggesting that this approach might be considered suitable to study 'organisational behaviour'. Poolton's decision was based on a view that quantitative methods are the most popular techniques used in management research. Poolton (1994) points out that:

"If behaviour is 'seen to be socially constructed, idiosyncratic and largely holistic', then a more 'rich' and descriptive analysis is often called for. Therefore, 'qualitative' analysis, usually expressed in the form of words rather than numbers, can be a good source of information."

Poolton (1994) also acknowledged a problem with research using qualitative methods in the 'complex and time consuming nature of data gathering which can take many months or years'.

2.5 CASE STUDIES AND DATA GATHERING METHODS

In describing research methods Lettice (1995) claimed that:

"Multiple methods of data gathering tends to reduce the chances of errors. Moreover, multiple methods and sources can be used to address different but complimentary questions within a study; initial exploratory work is done using one method and subsequent exploratory work employs another. Also, multiple methods and sources can be used in complementary fashion to enhance interpretability. That is, one method or source is used to enhance the findings of another and therefore improves the quality of data, the accuracy and credibility of the findings."

As discussed previously it was decided that this research would attempt to compliment the extant literature review with empirical quantitative and qualitative data gathered from case studies. The quantitative data from a case study provides the raw data which when analysed with qualitative data will provide a complete 'picture' how the NPD project was conducted. Therefore the research consisted of the following data gathering methods:

1. Literature Review

The literature review in New Product Development is vast, involving a number of disciplines including social sciences, new technology, project management techniques and human performance and limitations, all of which were reported, in the review, to influence the outcome of a new product development programme. It was therefore necessary to reduce the scope of the research to a manageable size and define a focus.

2. Quantitative Data Gathering from Case Studies

A number of actual New Product Introduction projects were monitored by the author from conceptual stages through to manufacture. The projects were developed using a number of methodologies, technologies and cultural mixes of people and organisations. This work was carried out during work employment by the author within the collaborating manufacturing organisations. A significant amount of quantitative data was extracted from the case studies and used to derive a measurement model for the evaluation of further case studies

3. Qualitative Data Gathering from Case Studies.

A view was taken that the collection of quantitative data alone would not provide a complete 'picture' of how efficiently a project was introduced. It was decided to include qualitative information about each case study to enable meaningful conclusions to be drawn. Therefore the analysis of the Case Studies involved both quantitative and qualitative methods, since a considerable amount of numerical (physical quantities) data was produced, together with the need to qualitatively analyse the performance of people and processes in the studies. The three data gathering methods are depicted in Fig. 2.

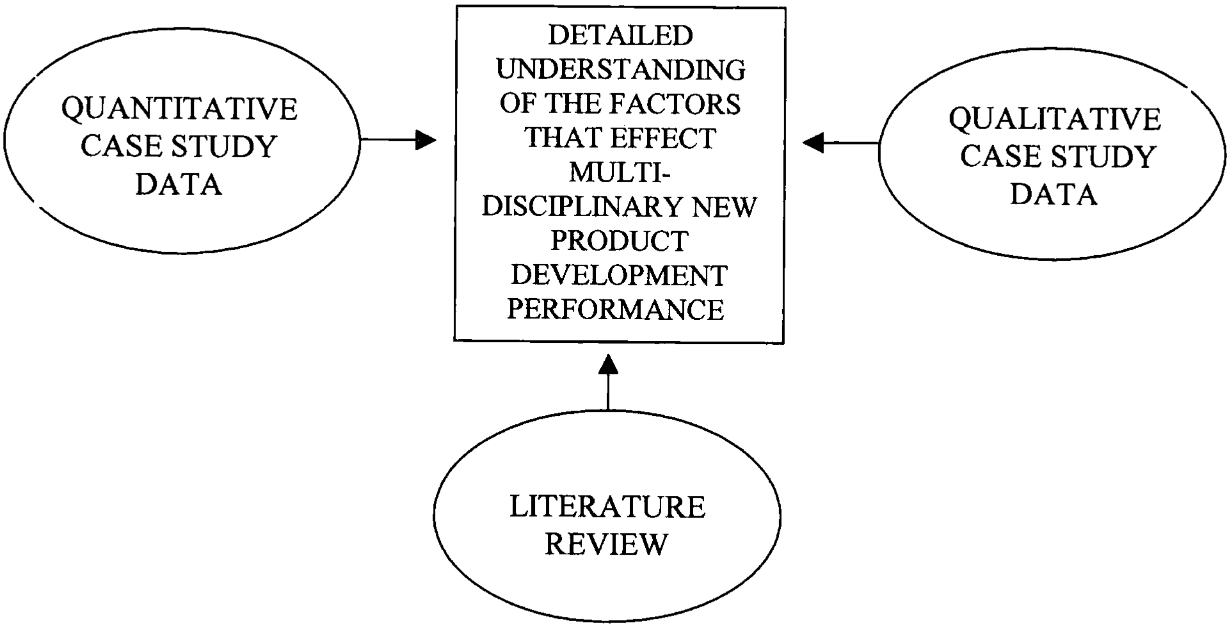


Fig. 2 Three research data gathering methods for NPD performance

2.6 SCOPE OF THE RESEARCH

With regard to research methodologies using scientific methods, Checkland (1981) argued that it is necessary to reduce the complexity and influences of many systems during an investigation in order to conduct meaningful controlled experiments. This is especially true, he argues, when studying management and social sciences which 'tend to be linked to *the real world* with many variables and ill defined structures'.

A number of factors have been identified, from the review of previous work that may influence to outcome of an NPD project. It was decided to review some of these before defining the scope of the research. Factors that may influence a project include:

1. THE SOCIAL AND CULTURAL ORGANISATION of a company.

This factor refers to the way people are organised, structured or departmentalised in an organisation and to the way they are managed. Vertical hierarchical structures emphasising a chain of command with the management acting as the supreme co-ordinating authority are typical of 'traditional' organisations. This approach has largely been superseded by the deployment of cross-functional teamwork. A great deal of previous work has been carried out in this area suggesting that the organisation of 'people' in a company has a considerable influence on the ability of that company to deliver successful new products to market.

2. NEW TECHNOLOGIES available to the company.

There are a number of technological developments that have influenced the NPD process such as:

a) Rapid Prototyping

b) Rapid Tooling

c) Digitising (Reverse Engineering)

d) CAD

3. EFFECTIVE PROJECT MANAGEMENT.

The review of previous work showed that effective project management is an essential part of the NPD process and that a project will benefit from a strategic approach with detailed project planning. This will include the application of control documentation or other communications media to clarify the project deliverables, objectives and timing.

4. HUMAN PERFORMANCE AND CAPABILITIES.

It is recognised that the New Product Development process will also be influenced by the skill levels of people and individual abilities and capabilities to carry out the tasks involved.

5. RESOURCE availability, both human and financial.

Time is usually a resource in short supply in the development of new products. In some cases more people allocated to a project will allow the project to be completed faster or, if the financial resource is available this may allow some part of the project to be sub-contracted.

It was necessary to understand the influences in the NPDS process, together with their interrelated factors. However, as discussed above, it was necessary to reduce the scope of the research to manageable size. Fig. 3 shows some of the major influences in a New Product Development project (excluding external influences) with the focus of the research highlighted in red.

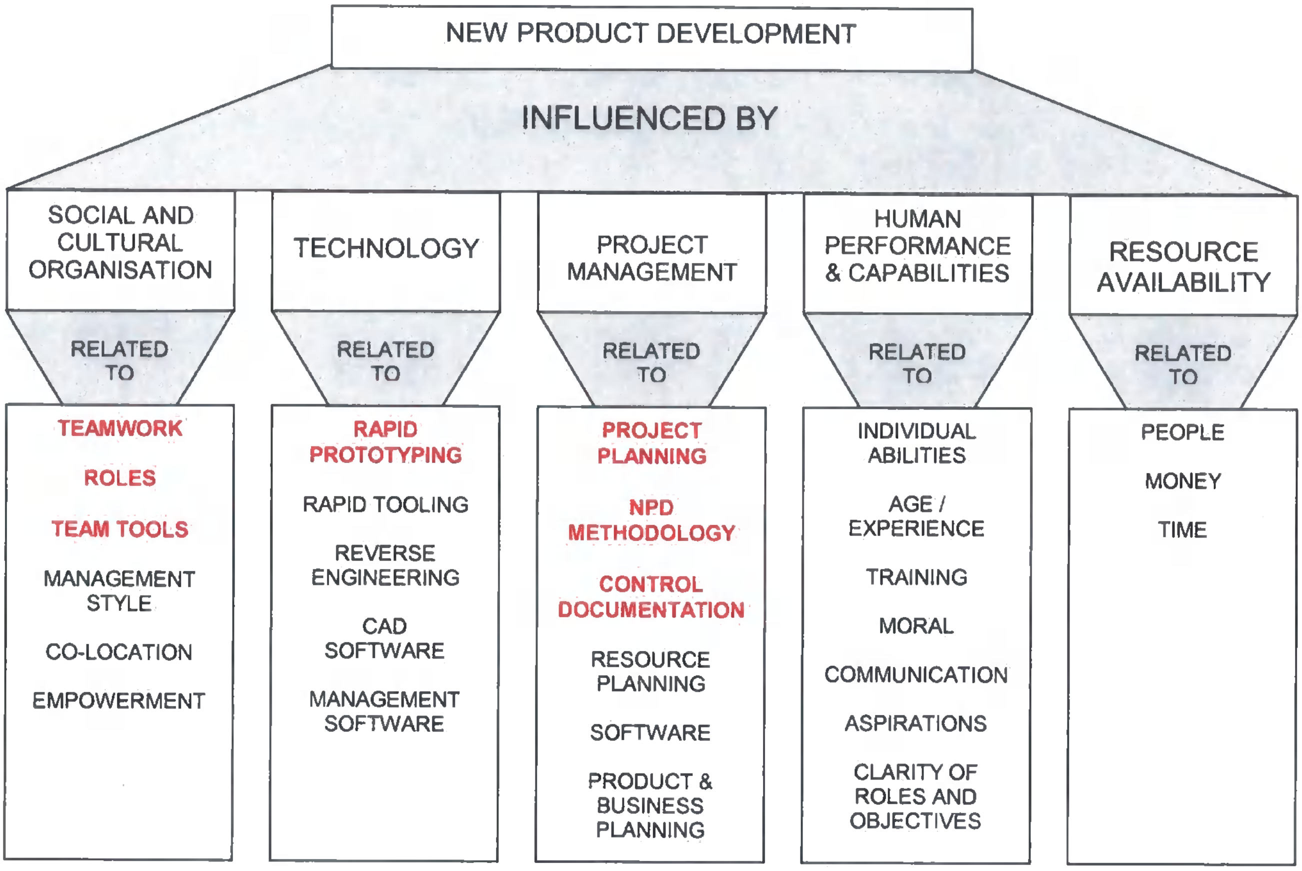


Fig 3 Scope of this Research highlighted in red with other influential factors.

2.7 CONCLUSIONS FROM THIS CHAPTER

Whilst it was important to understand all of the factors that may influence the outcome of a NPD project it was clear from the above discussion that it would be necessary to focus on specific problem areas and limit the scope of the research. It was also clear from the above discussion that, in order to find ways of improving the NPD process, it was necessary to establish appropriate Key Performance Indicators. Case studies were viewed as a useful way of testing out the claims made in the extant literature and for investigating process improvements. It was also decided that, in order to provide a complete 'picture' of how a product was introduced, both quantitative and qualitative data would be extracted from the case studies.

CHAPTER THREE

THE NEW PRODUCT DEVELOPMENT (NPD) PROCESS

3.1 OBJECTIVES OF THE NPD PROCESS

This section outlines the basic objectives of the NPD process and describes variations in the type of products typically developed in manufacturing industry, the NPD processes used and how they are measured.

Organisations involved in the manufacture of products in a competitive market place, according to Cooper (1992), are unlikely to remain competitive with the same products indefinitely and therefore need to continually develop new and better products. The process involved in developing new products or replacing an existing product with various improvements is referred to here as the New Product Development Process. Trueman *et al* (1995) argued that:

"It is not surprising to learn that companies which have a proactive and innovative approach towards the development of new products are likely to achieve a better performance than those which do not."

In further emphasising the need for continual New Product Development, Gruenwald (1992) argued that: 'A business needs new products to survive, consumers accept new products faster and reject them faster, product life cycles are shorter, except for those products that are continually infused with "newness'.

The statement by Gruenwald (1992), identifying a separate category of products *as 'continually infused with newness'* suggests that new product development projects may consist of two categories: -

1. Completely new development.
2. Improvements to existing products.

The above categories are often usefully described as *'Strangers'* and *'Repeaters'*. Companies such as Flymo and Electrolux have also used the terms 'Strangers' and 'Repeaters' in their NPD processes. A 'Stranger' or 'Repeater' may either be viewed from the perspective of the market place, or the technology. Both Flymo and Electrolux have variations in their NPD processes to develop each type of product, requiring differing strategies for marketing and engineering.

In a slightly different approach, Jobber (1995) classified new products into *four* categories:

1. **Product replacements**: These account for about 45% of all new product introductions and include revisions and improvements to existing products, repositioning (finding a new market position for the product), and cost reductions (existing products being reformulated or redesigned to cost less to produce). An example of products in this category would be the latest range of 'TC' Hover Mowers from Flymo that offer better performance at reduced costs but do not provide an incremental addition to the product range.

2. **Additions to existing lines**: these account for about 25% of new product launches, and

take the form of new products that add to a company's existing product lines. This produces greater product depth. An example of this category would be the Flymo Garden Vac, which does not replace an existing product (therefore provides incremental growth) but employs similar airflow technologies as mowers; and is sold into the same market place.

3. **New product lines**: these total around 20% of new product launches, and represent a move into a new market. An example of this type of development could be Flymo (an outdoor product manufacturer) moving into the development of refrigerators.

4. **New-to-the-world products**: these total around 10% of new product launches, and create entirely new markets. Recent examples of these types of products include the mp3 digital recorder, multifunction mobile phones and digital cameras. All of these products have created new market opportunities because of the highly valued customer benefits they provide.

As discussed above, Flymo have variations in their NPD process to develop different 'types' of product and according to Jones (1997) most companies involved in the development of new products should have NPD processes capable of introducing products in each of the above categories. Also, following the market launch of a new product for the first time, Jones (1997) described four generic groups requiring different marketing strategies: -

1. *Offensive*

Characterised by significant R&D activity, which enables manufacturers to be first to market with an innovative new product and thereby establishing a lead in the market place. These types of projects are considered 'high risk' because of the uncertainty in the market response and the levels of investment involved.

The author, whilst project managing projects in this category always ensured that there were adequate prototyping cycles in the project plan to ensure the multifunctional team and the senior management were 'comfortable' with the product proposal, and the prototype would be tested for aspects such as Safety, Performance and Reliability.

2. *Defensive*

This type of development focuses on improvements or cost reduction of existing products. This is considered less risky than 'offensive' products because of the known response to such products in the market place.

3. *Imitative*

This type of product development is similar to 'defensive' development in that it relies on the development of existing products, but without adding further innovation except possible cost reducing modifications. This takes minimal R&D and is a process described as 'cloning' or copying.

4. *Traditional*

This is again product development in an established market sector, where there is little call for change in the product specification, apart from minor change in the aesthetic appearance or Industrial Design of the product, sometimes referred to as a 'face-lift'.

The variations in the products described above not only require different marketing strategies, but may also change the priority of the KPIs during the development processes. However, the popular theme in the extant literature predominantly places 'time-to-market' as the highest priority KPI, together with the benefits of introducing *all* new products as quickly as possible. According to Smith *et al* (1991) there are three advantages in introducing a new product faster:

1. Extended sales life and increased period of revenue profit.
2. Increased market share - the earlier it appears the better are the prospects of obtaining and retaining a large share of the market.
3. Higher profit margins - if the product appears before the competition the company will enjoy more pricing freedom.

Whilst the above advantages are generally accepted, it may be argued that they are more applicable to a Stranger rather than a Repeater, since the former may provide greater incremental sales opportunities. By way of illustration, the development of the Flymo Garden Vac provided a new product category for the outdoor market place with a monopolistic opportunity for the company. Therefore time-to-market was regarded as a priority KPI in the project. The product was launched on time, and enjoyed 12 to 18 months monopoly before the competition was able to introduced their products. By this time Flymo had developed a 2nd generation product (a Repeater) with further improvements to stave off the anticipated competitive products. Pricing freedom initially existed with a 100% market share, and following the launch of the competitive products a premium pricing policy was maintained due to the addition of new features with patent protection 'locking-out' the competition.

The launch of the Garden Vac illustrated the benefits of launching new products (Strangers) as quickly as possible, with the continued improvement of such (Repeaters) to remain competitive. Also, the introduction of such a new concept created a 'generic' title for the new product. This encouraged consumers to ask for the original 'generic' product rather than a newer competitor product. Examples of this are the 'Strimmer'- lawn edge trimmer developed by Black and Decker and the 'Hoover' - floor cleaner marketed by Hoover Ltd.

The introduction of the Garden Vac was a great success selling >500K units in the first year. However, there are many examples of product development projects resulting in market failures, or failure to meet the needs of the customer. Bailetti *et al* (1995) emphasised the need to incorporate the needs of the customer in the development of new products stating that:

'There is a need for a 'frame-work' to ensure that the information produced by the product designers, result in a product that meets the needs of the customer, to avoid failure'.

The reasons why new products fail to be delivered 'on time' or meet their commercial objectives is a popular theme in the literature; Cooper (1992) cited the following sources of success or failure in NPD:

1. *Organisational Strategy*

   Unless the corporate strategy is clearly defined, based on sound data, and is accurately translated into market, design and technology strategies, NPD is likely to fail.

2. *Organisational Structure, Culture and Climate*

   Important factors for NPD success include a need for leaders of innovation, creative scientists, agents of change and multifunctional teams. Senior management support and commitment is also cited as a factor.

3. *NPD Strategy*

A NPD project cannot be undertaken successfully without considerable thought being given to the overall strategy of the company and how this is translated into an effective NPD strategy.

Further details in Cooper's publications also refer to how the team members are organised. Cooper (1992) cites the key functions involved in successful NPD, together with their key roles:

1. *Marketing* - early market recognition; reading, clarifying and defining the 'market need'; product planning; screening and product testing prior to launch.
2. *Design* - correct management of: adding innovation, preparing design briefs, budgeting and controlling external consultants.
3. *Technology* - the appropriate use of technology in terms of materials and processes is a key factor in successful NPD.
4. *Finance* - regular financial control checks are required to monitor product costs and investment capital.
5. *External Factor* - are also recognised as factors influencing the successful outcome of NPD, including economic climate, the market conditions and environmental issues.

In recommendations for further work Cooper highlighted the need for organisations to develop methodologies for diagnosing the sources of failure in the NPD process and to recognise the symptoms. This research has attempted to address this need.

Jones (1997) has described the product development process as a process in a constant state of change, requiring the involvement of many disciplines in an organisation such as: -

1. Engineering Design
2. Production Engineering
3. Marketing
4. Finance Management
5. Quality Control
6. Sales and Distribution

The above disciplines must have an involvement in the NPD process at strategic times in the process according to Cooper (1992). The Production Engineering function, for example, responsible for methods and tools in manufacture were traditionally an activity carried out after the product design process typical of 'over-the-wall engineering'. In a manufacturing environment using teamwork, the Production Engineering activities are performed with a degree of concurrency with the design process. The other activities listed above also perform their responsibilities during specific 'Phases' in the NPD process.

Companies such as Flymo, Kenwood, and the Rover Group have developed constantly evolving NPD processes that can be 'adjusted', from a generic *template*, to cope with a variety of product categories and project complexities. A generic model of the NPD process was produced by the British Standards Institute (BSI) showing the stages (Phases) and key activities illustrated in Fig.04. The B.S.I model divides the NPD process into stages similar to many consumer durable companies shown in Fig.05.

From the above discussion, the multifunctional New Product Development Process may be summarised as follows: -

'The NPD process is a business process used in manufacturing industry, which provides a baseline methodology for the development of new products. The NPD process consists of a timing schedule for the involvement of each functional activity and general guidelines for the development of products with higher added value than the competition, as quickly as possible.'

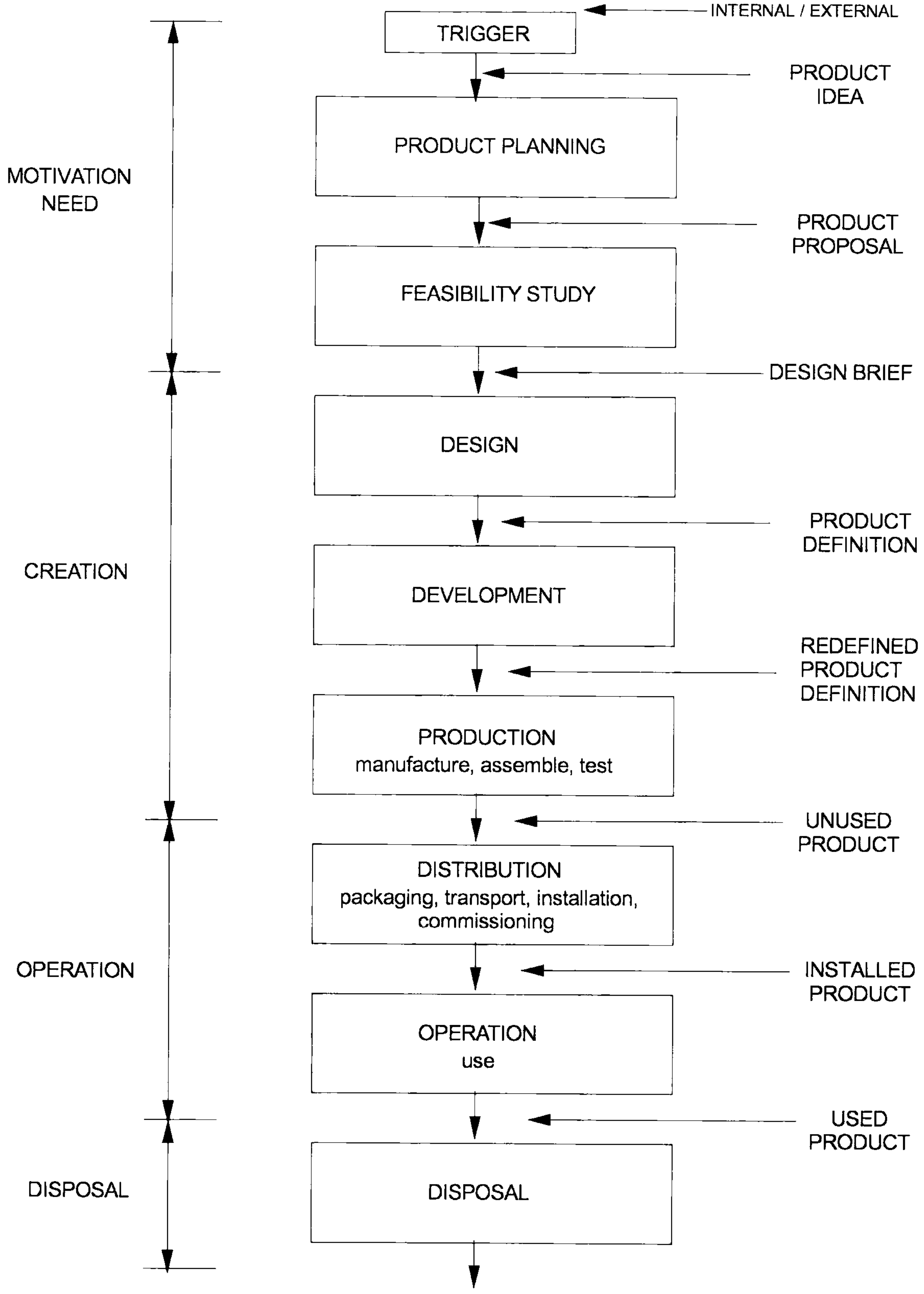


Fig.04 Generic product evolution process (British Standards Institute 1989)

Stage	BSI designation	Outdoor Products Mfr	Power Tools Mfr.	Kitchen Products Mfr	White Goods Mfr.
1	MOTIVATION	DEFINITION	DEFINE	INNOVATION	PRIMARY DEVELOPMENT
2	CREATION	DETAIL DESIGN	DESIGN	CREATION	SPECIFICATION
3	OPERATION	TOOLING	RELEASE	IMPLEMENTATION	INDUSTRIALISATION
4	DISPOSAL	REPLACEMENT	REVIEW	REVIEW	EVALUATION

Fig. 05 Stages of NPD processes from consumer durable manufacturers and BSI.

Maffin (1996) reviewed various models of the NPD process and concluded that many so-called 'best practice' techniques were found to be inappropriate for some companies. Maffin suggested the need for a framework comprising of factors that classify a company in terms of its organisation, markets, and products and select KPIs for the NPD process accordingly.

It could, however be argued that it may be more appropriate for a company to keep the same KPIs, but modify their order of priority. By way of example the priority for a 'Stranger' may be time to market whereas product cost may be more important for a 'Repeater'.

3.2 ACTIVITIES IN THE NPD PROCESS

There is considerable variation in the detail involved in NPD processes adopted by companies however, Jones (1997) claimed that there is an overall framework for NPD emerging into which most development programmes can be mapped. Jones' 'generic' NPD process is split into three distinct phases:

1. The Inception Phase - covering the pre-development activities, which are undertaken before a product concept, is even visualised.

2. The Creation Phase - which includes the core development stages associated with generating a product concept and taking it through to a working prototype.

3. The Realisation Phase - which deals with taking the final design, putting it into manufacture and launching it onto the market.

The above phases in this generic New Product Development programme in practice would contain a number of sub-tasks or activities. By way of example, Jones (1997) identified the phases and sub-tasks, which are shown in Fig.06. The BSI guide to managing the design process BS7000 part 2 (1997) also provides a baseline generic model for the NPD process Fig. 07. Within the guide, project managers are encouraged to:

'Customise the model to meet the contextual requirements of the product under development and the business needs of the organisation'.

PHASE 1 INCEPTION

MARKET RESEARCH - Marketing research and analysis of customer requirements and availability / performance of existing products.

IDENTIFY THE NEED - Identification of a new product opportunity and business planning.

PROJECT BRIEF - Documented, brief description of the new product requirement outlining product features, timing and cost objectives

IDEAS GENERATION - Innovative process of presenting possible, conceptual solutions to the Project Brief.

FEASIBILITY STUDY - Study to confirm, or otherwise, the requirements of the Project Brief can be achieved in a producible product.

PROJECT PLANNING - Business and project planning including financial and human resource requirements.

PHASE 2 CREATION

CONCEPT CREATION - The development of a physical model, sketches and / or data representing the new product.

DESIGN - The engineering function of specifying the product in technical terms for manufacture, including the creation of drawings.

DEVELOPMENT - Design iteration process to improve the performance, assembly or value of the proposed new product.

MODELLING - The production of prototype model or models representing the physical attributes of the product. e.g. performance.

TESTING - The evaluation of the prototype models to confirm suitability and fulfilment of the Project Brief

PHASE 3 REALISATION

PRODUCTION PREPARATION - Including the procurement of production jigs and fixtures, tooling and production line design.

PILOT BUILD - Initial - limited quantity, manufacturing run, usually using 'tooled' components to identify minor adjustments.

PRODUCT INTRODUCTION - Product introduced into a full-volume manufacturing process.

DISTRIBUTION - Packaging and shipment of the new products to strategic locations for delivery and LAUNCH to the customer.

OPERATION - On going development of the manufacturing process including the management of materials, costs and work-in-progress.

EVALUATION - Feedback of the response of the market or customer to the new product.

Fig.06 Generic NPD process showing 'phases' and sub-tasks. (Jones 1997)

Phase of Project	Process	Output
Concept Phase	Inception of a new or improved product. Analysis of opportunities. Formation of individual or core team. Analysis of business concepts and product identification. Formulation of the project, objectives and strategies. Preliminary evaluation and approval of project by the corporate body.	Perceived opportunities. Alliterative business and product concepts. Identification and selection of preferred business concepts and product characteristics. Preliminary definition and project proposal. Permission to proceed.
Feasibility Phase	Planning, research and feasibility studies leading to the formulation of a project proposal. Refinement of characteristics. Development of a functional specification. Development of project configuration and work programme. Evaluation and sanctioning of project by corporate body and commitment of resources.	Criteria of acceptability to the organisation. Product Design Brief. Project Plan, Resource Plan. Project Approval.
Design / Development Stage	Bringing together of a multi-disciplinary team of specialists to realise the project. Design concept development. 'Rehearsing' the customer-product experience. Outline design (embodiment design or general arrangement).	Roles and responsibilities matrix. Preferred option. Product resolution.
Implementation or realisation phase	Detailed Design. Construction and testing of pre-production design.	Specification for product. Confirmation of performance including reliability and maintainability.
Manufacturing Stage *Liability Starts*	Finalisation of the completed design ready for manufacture. Design support for manufacture. Provisions for manufacture and delivery. Product launch, introduction, promotion and on-going customer support. Selling and use. Monitoring 'in use' performance for feedback and refining the design as necessary. On-going product testing. Evaluation of the whole project and identification of areas of improvement in the design management process for the benefit of future projects.	Product package. *External to the organisation* Product availability. Fulfilment of business objectives and customer requirements. Potential improvements, product enhancements, modification and retrofits. Identified design process improvements.
Termination Phase	Termination of the project. Design support for decommissioning activities. Formal termination of the project. Disposal of the product.	Hand-over of responsibilities and redeployment of staff. Continuing liability

Fig.07 British Standards Institute guide to managing the design process BS7000 part 2

Many companies such as Flymo, Electrolux, Black & Decker, Kenwood and Domick Hunter, frequently undertake NPD programmes for *Strangers* and *Repeaters* in their range. All of the above companies have similarities in that they all produce products requiring production tooling for plastic or cast metal parts. The NPD methodologies used by these companies are also very similar with some activities included or omitted from the template plan, according to the project type. By way of example, when Kenwood appliances replaced their range of toasters in 1997 with a 'new look' range, a project plan was produced from the generic template for the redesign of the plastic parts and associated tooling activities. However, activities involving the electrical design and testing were deleted from the plan as not being required. In a similar way, Flymo developed a range of products for the United States based upon UK mouldings. Therefore only activities involving the electrical components design were included in the project plan.

From the above examples of Phases in projects, generic definitions are summarised as follows:

a) PHASE ONE: This is the early conceptual stage of the project, before the introduction team has agreed 'firm product proposal'. This is a period of consolidation of market research data and engineering development to research and provide an answer to a market requirement.

b) PHASE TWO: This phase follows the agreement of a 'firm product proposal' and project deliverables by the introduction team, but before the release of engineering drawings to commit production toolmakers. This phase involves most of the 'detail design' activities and CAD drawings. Rapid Prototype models are sometimes produced at this stage from the CAD models to verify the design proposal. The phase usually concludes with a 'design freeze', where specified components and details are defined as finalised from an engineering perspective and not subject to further changes.

c) PHASE THREE: This phase marks the release of capital funds reserved in the project budget for the manufacture of the production tooling. The tools usually consist of injection mould or casting tools from which the component parts of the new product are made. A change implemented during this phase may place planned completion dates in jeopardy as well as risking an 'overspend' in capital budgets.

d) PHASE FOUR: This phase of a project marks the completion of the production tooling but before production runs commence. Changes often occur during this phase, and perhaps should be expected, to make final 'minor' changes to the product before production begins. There may also be a need to make slight modifications to the individual components to allow the production tools to run smoother.

e) PHASE FIVE: This is the Production Launch of the product and marks the commencement of the production builds intended to be of 'saleable quality products'. The product is manufactured in volume during this stage to allow full sales and production launch. This is a Phase that is often used as a stock and distribution 'build-up' where product is released from the manufacturing unit but not necessarily to the 'end user'.

PHASE SIX: This phase is the Market Launch of the product and delivery to the customer. This frequently includes some degree of 'post launch development' of the product from feedback in the field. This is the 'acid' test of the product and any product safety issues that have not been identified during the development phases. Any issues exposed here may result in a product 're-call' from the field to execute the change, or expensive field servicing.

3.3 DEPLOYMENT OF FUNCTIONAL DISCIPLINES IN THE NPD PROCESS

It is recognised that, whilst a multifunctional team is involved in the NPD process it may not always be practical, or necessary, to involve each discipline *all* of the time. By way of example, Jones (1997) discussed the phased involvement of departmental functions (Fig. 08) where each function contributes to the project at the most efficient time. The illustration in Fig. 08 depicts a three-phase NPD process: Inception, Creation and Realisation. However an alternative view could be that the 'deployment' of the Production Engineering function should also have more involvement during the Inception phase, to avoid the apparent *over-the-wall* approach. However, the example adequately illustrates the 'phased' involvement of functional activities in a typical NPD process.

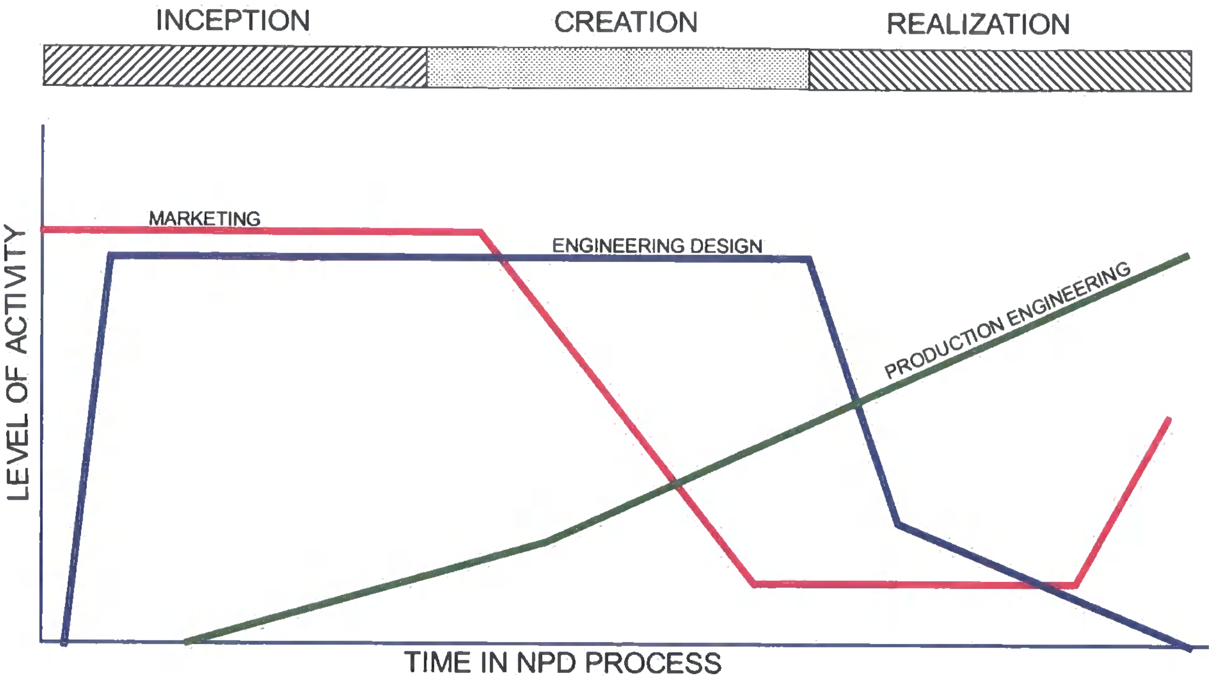


Fig. 08 deployment of functional activities in NPD Jones (1997)

The timing of each functional activity, including external suppliers, may vary according to the particular requirements of a company, the product under development, type of product and the core competencies possessed by a company according to Maffin (1996). In a similar way, Cooper (1992) recommended that the deployment of functional activities in a project is a consideration for the project manger (or Team Leader) and the team, at the planning stages of the project to ensure each departmental function is able to contribute at the most valuable stage. According to the British Standards Institute guide (1997) the timely involvement of resource (Resource Plan) in a NPD project should be determined in the 'Feasibility Phase' of the project.

3.4 INNOVATION IN THE NPD PROCESS

The term 'innovation' may be overused today and often intended to depict *invention*, differentiation or newness. It has also been used to describe a functional activity or department in a company i.e. 'The Innovation Department'. By way of example, the author's job title in Domnick Hunter Ltd. is Director of Innovation and Marketing. In contrast to the title with Kenwood as Director Of Product Engineering. Despite the unfortunate acronyms the titles produce, the job functions were very similar. To help to clarify the contextual meaning of *Innovation*, the Oxford English Dictionary provides the following formal definitions: -

Innovate: To change a thing into something new; to alter, to renew, to bring in something new for the first time to introduce as new.

Innovation: The action of innovating; the introduction of novelties the alteration of what is established by the introduction of new elements or form. A change made in the nature or fashion of anything; something newly introduced a novel practice or method etc.

The subject of Innovation in NPD process has been extensively covered in previous work and often 'required' by marketing people as part of the deliverables of a project. Jones (1997) argued that innovation is at the *core* of new product development. In a similar way, Trott (1998) claimed that: 'Innovation is at the heart of many companies activities - companies that have established themselves as technical and market leaders have shown their ability to develop successful new products. In virtually any industry from aerospace to pharmaceuticals and from motor cars to computers, the dominant companies have demonstrated an ability to innovate.'

Trott (1998) describes the different kinds of innovation:

1. Technological - improvements in technologies used in products and processes used to manufacture them.
2. Managerial and Organisational - improvements in the management and organisation in a company.

Innovation in NPD may not necessarily be a 'radical' change or improvement to a product, but may involve a collection of minor or 'incremental' improvements including cost reductions or Value Engineering which is a process of improving the 'value' of a product, without proportional increase in the manufactured costs.

Publications specifically on the subject of innovation include titles of how to 'manage the innovation process' in a company. By way of example Burns *et al* (1995) argued that: *"Technical progress and organisational development are aspects of one and the same trend in human affairs. The ability for an organisation to succeed is dependent upon the companies ability to innovate technically, in the development of new ideas and products; and in the organisational development of a company."*

Innovation is considered so important in today's manufacturing industries that a number of publishers have produced journals focusing on the subject of innovation such as:

1. The Journal of Product Innovation Management - USA MCB University Press
2. International Journal of Technology Management - Switzerland MCB Press
3. The European Journal of Innovation Management - UK

4. Product Innovation Management - Elsevier

In one journal paper that contributes to this topic Twiss (1995) discussed the importance of organisations providing opportunities for innovation and new ideas in NPD. Making the distinction between and idea invention and an innovation, claiming that the former can only be described as the later if the idea demonstrates success in the market place.

In recognition of the need for 'differentiation' in NPD, many organisations endeavour to provide opportunities for innovation in the development of new products. Zien *et al* (1997) argued for the need to involve the whole organisation in innovation and to encourage an innovative culture. However, Ahmed (1998) noted that many companies pay 'lip service' to innovation and stressed that becoming innovative requires an organisational culture, which nurtures innovation and is conducive to creativity and invention. Arguing that mechanistic organisational structures hinder innovation characterised by:

1. Rigid departmental separation and functional specialisation
2. Hierarchical
3. Bureaucratic
4. Many rules and set procedures
5. formal reporting
6. Long decision chains slow decision making
7. Little individual freedom of action
8. Communication via written word
9. Much information flow upwards; directives flow downwards

3.4.1 THE INNOVATION FORUM

The author, whilst employed at Flymo, experimented with ways of reducing *Fuzzy Front-End* (Smith *et al* 1991) delays in projects. The Innovation Forum was established to provide a meeting forum for NPD teams to collectively discuss and agree project deliverables and explore opportunities for innovation in a project. Flymo had experienced delays in previous NPD projects due to both Marketing and Engineering waiting for 'each other' to provide a clear definition of project deliverables. Misinterpretations (fuzziness) of product specifications and deliverables were common leading to a 'lack of ownership' and conflict between the two functions.

The Innovation Forum meeting started with a discussion of the 'marketing need', lead by the Marketing team member, with Engineering, R&D and other attendees asking questions. A period of 'brainstorming' followed, sometimes involving a basic QFD analysis, to identify the project deliverables and agree project targets such as launch dates and product costs. Competitor products were occasionally brought along to the Innovation Forum, for collective critique. The senior management at Flymo supported the Innovation Forum as an effective way to: -

1. Improving working relationship between R&D and Marketing, helping to break down traditional barriers by making the two functions collectively responsible for innovation.
2. The Innovation Forum also provided a solution to the common debate of 'who should write and take ownership of the Product Design Brief'. Before the introduction of the Innovation Forum, the question of 'who owned' the PDB lead to a great deal of conflict between the R&D and Marketing team members. Misunderstandings or

misinterpretations of the P.D.B. by designers were common leading to the delivery of products which fell short, in the eyes of the marketing team, or the customer's requirements. The R&D members used to frequently complain that the Marketing Brief document was nothing more than a 'wish list' containing unrealistic demands thereby creating unnecessary work and delays in a project. The Innovation Forum was introduced to *allow* the initial production of a 'wish list' from the Marketing Team for discussion in the meeting, to be concluded with a clear, unambiguous 'Design Brief' containing agreed deliverables, with joint ownership.

Other organisations have activities similar to the Innovation Forum used in Flymo with the same objectives of encouraging innovation and to reduce the time taken to agree the project objectives. Activities such as the Innovation Forum helped Flymo to address a problem highlighted by Jobber (1995) who argued that:

"One of the major causes of R&D rejecting input from marketing was the lack of quality and timely information." He emphasised that - *"Marketing should encourage R&D to be more customer aware"* also stating that: - *"...There is often personality and value differences between the two groups - more effort could be made to break own barriers by socialising, going to lunch together, and sitting with each other at seminars".*

Flymo's Innovation Forum encouraged the functions of Marketing and R&D to work together to take collective responsibility for innovation in the new product, and the construction of the design brief. Other examples of team-tools have been developed to assist the integration of functional groups in NPD such as, Quality Function Deployment (QFD), Design for Manufacture (DFM) and Failure Mode and Effects Analysis (FMEA), discussed later in this research.

The subject of NPD Key Performance Indicators was discussed in a previous chapter in which time-to-market was frequently viewed as a priority in projects. However, this raised the question of whether the continual pressure to reduce lead times may restrict the time available to innovate in the process? Cumming (1998) also raised this question and in his conclusions he stated that:

"Currently in manufacturing industry, process innovation is being applied to allow the potential conflicting KPIs of quality, cost and timing to be achieved concurrently. It can be argued that with the correct approach to development these three goals can become mutually supporting"

As part of the objectives of this research tools and techniques to assist NPD teams to addresses the goals discussed by Cumming, were investigated. The author hypothesises that if a suitable 'strategic' approach is taken, it may be possible for all of the KPI goals of quality, cost and timing to be achieved.

3.5 MEASURING N.P.D. PERFORMANCE

As discussed in the objectives of this research, it was considered important to establish a set of appropriate Key Performance Indicators (KPI's) for the NPD process in order to evaluate the effectiveness of tools and techniques to be investigated. This required a review of how NPD in manufacturing industry is currently measured.

In researching the subject of Performance Measurement in NPD, Driva (1994) posed the research question of 'How do companies know that they are making effective use of NPD process'. One of her key conclusions was that most companies 'do not know', with most organisations limiting their measurements to a 'finance dominated' system and often spending time measuring parameters that are not the 'key' to the performance of the business.

In concluding this research Driva (1994) recommended that:

"When implementing a performance measurement system, crude intermediate measures may be introduced as a yardstick for future action. Theses should be subsequently 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 the obsolete measures."

Driva (1994 p.3) listed several 'clear reasons for KPI measures':

1. You can't manage without measuring.
2. To identify improvement areas.
3. To identify bottlenecks.
4. To optimise resource allocation.
5. To benchmark people to monitor their own performance
6. Can be a motivational booster - people like to know they are progressing.
7. To enable standards for establishing comparison.

In a survey of 512 UK manufacturing organisations, Nichols *et al* (1993) looked at performance measures in some consumer durable, electronic product and aerospace manufacturers, concluding that they should consider ten KPIs for bench marking in product development:

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 a product.
8. Percentage of design effort sub-contracted out to third parties.
9. Design realisation - a measure of conceptual product design reaching manufacture.
10. Time to recover previous quality levels.

From the above discussion, it was accepted that there is a need to measure NPD performance and to provide a set of appropriate KPIs to test techniques for process improvement. It was also acknowledged, following research conducted by Maffin (1996), that it is important for an organisation to establish KPIs that are specifically relevant to that particular company and avoid the temptation of measuring parameters that may not have a significant bearing on the performance of the organisation. The KPIs proposed by Nichols, will now be discussed in the order they were presented below, together with arguments (from the author) for and against their selection as valid NPD KPIs for benchmarking companies and for their use in case studies:

1. Product development costs.

This parameter was considered to be a valid KPI since development costs are often a fundamental constraint in a project. However, development costs (which may include people costs and 'capital') may be less important than other parameters such as time-to-market. By way of example, Dumaine (1989), calculated that: 'A product 3 months late to market may cost an organisation 33% loss in profit, whereas a development budget overspent by as much as 50%, may only effect profits by 3.5%'. A tool to enable a company to evaluate relative costs of parameters such as delays to launch and overspend in the development budget is presented later.

2. Product development time.

From the review of previous work, time-to-market is the most common KPI measured in NPD projects. However, this may be a difficult parameter to define and 'benchmark' because of the following reasons:

a) It is not clear from the review how development time or time-to market is measured? There appears to be no clear, consistent, industry definition of the start point of a project, often described as the 'Fuzzy Front End'. Also, the point in the NPD process where the project is considered 'complete' may also be unclear, especially if the product is released with a number of flaws which are then the subject of a considerable amount of post-launch development changes.

b) There seems to be very little point in benchmarking 'time-to-market' as a specific measurement of one company's NPD performance, compared to another, unless they are both developing 'exactly' the same product. Also, based upon the fact that some products are by nature more difficult to develop than others.

The improvement in 'time to market' is also a KPI often used in an unqualified way to demonstrate the effect of a technique, 'tool' or methodology. By way of example, from a survey of major approaches to accelerating new product development, Murry *et al* (1992) cited the following examples:

i) Honda now turns out new models in less than 4 years from drawing board to showroom compared to 5 years for most western manufacturers.

ii) AT&T now take 1 year to design a new phone, down from previously 2 years.

iii) Honeywell, which used to take 4 years to design and build new thermostats, now takes only 12 months.

The above examples may be factual correct, but it was not clear how each project was measured or if the improvements were due to improved technology or improved NPD methodology. Very little data was provided to identify which factors influenced each NPD project. Is it possible that some companies developed 'Repeaters' following the development of a 'Stranger' and therefore have progressed up a steep learning curve with the first product, making subsequent developments simpler? A more pragmatic KPI for 'development lead time' is presented later.

3. Manufacturing 'ramp-up' time.

This may be defined as: 'the time period from the commencement of production of 'saleable-quality' product on the assembly line, in limited quantities to the stage where the assembly line is manufacturing to pre-set targets volumes.' It is not always possible for an organisation to commence full target volume production of a new product from the outset. This may be due to the time for an assembly worker to learn how to assemble the product efficiently; or the time required for adjusting assembly jigs and fixtures. The 'manufacturing ramp-up time' may be a valid parameter of team preparedness. The manufacturing ramp-up time is also an indication of how suitable a product is 'designed for assembly', or how well prepared the assembly team are to receive it. Manufacturing ramp-up time may be a valid measurement of the degree of concurrent engineering that has been successfully conducted by the team. It can be seen from the case studies that products have been launched with considerable 'post launch' development required. This is regarded as inefficient due to the potential cost and disruption.

4. Average time to process and implement engineering changes.

It is recognised that if corrections or changes need to be implemented in a product design, particularly at a late stage in the NPD process, they should be implemented as quickly as possible. However, since no two engineering changes are likely to be the same there would seem to be very little point in defining an average time for engineering changes.

5. Percentage of engineering changes occurring after release to manufacture.

One of the objectives of Concurrent Engineering according to Wheelwright (1993) is the ability of the team to identify engineering changes before the product is committed into manufacture. Therefore this parameter was accepted as a way of measuring the effectiveness of 'team performance'. However, in some cases it may be beneficial to fine-tune certain components after production tooling has been produced. For example the response of 'live hinges' in plastic components together with the tactility of clips and 'snap' fixings may result in minor changes to tooling at a late stage in a project. However, if changes of this type were required, it would be prudent to 'plan' and provide adequate time for the fine-tuning.

6. Total effort to develop the product.

How this is defined or how it could be could be measured was not clear from the literature but may be related to total man-hours used by the NPD team, which may be useful to some organisations.

7. Number of parts within a product.

It was not accepted that the number of parts within a product is always a valid measurement of NPD performance. There are case study examples in this study where components were added to a product to increase the value of the product by providing an expanded function or appeal to the user. The increased value may be perceived such as the addition of an aesthetic trim component or real, such as the addition of a flexible hinge component in a toothbrush. The author is also able to cite examples of products developed by Kenwood for manufacture in the U.K., where the parts count was kept to a minimum because of the high cost of labour in the UK. This resulted in large complex geometry plastic components containing many 'clip' features, which were expensive to tool and time consuming to design. Kenwood subsequently replaced those products with products manufactured in China containing an increased number of parts benefiting from the low cost manufacturing base compared to UK. Other benefit included simpler design for the CAD engineers and lower cost tooling. Therefore the Number of parts within a product was not accepted as a valid measurement of NPD performance.

8. Percentage of design effort sub-contracted out to third parties.

The degree of 'vertical integration' or the proportion of the product development process carried out by an organisation is dependant upon the core capabilities contained in the organisation, the resource availability and many other factors as discussed by Maffin (1996). Therefore, the percentage of design effort sub-contracted out to third parties may not be a concern to an organisation. Many organisations such as consumer durable manufacturers routinely sub-contract the Industrial Design aspects of the product to a number of agencies which provide a constant supply of 'fresh' ideas and styling variations in their products. Many other examples of design sub-contracting may be beneficial where the core competency does not reside in the organisation, or external resource can do it better, faster or cheaper such as software design or electric motor design. However, 'design sub-contracting' referred to by Nichol (1993) also refers to 'unplanned' recruitment of resource to make up for delays in the project which represents inefficiency in a project, and should be measured.

9. Design realisation - percentage of designs released to manufacture.

This was not accepted as a reliable KPI since some organisations may take the view that it is acceptable for development teams to research a number of projects for the release of one 'word-beater'. Cooper (1994) argued that it is more important for an organisation to understand 'why' some of their products fail. This is a view supported by the author. Also, according to Jobber (1995) the reasons for a product failing to reach manufacturing may include issues which may be out of the control of the organisation involved such as: -

a) The launch of a superior competitive product

b) Changes in local or global economies

10. Time to recover previous quality levels.

From an internal quality audit conducted in Flymo in 1996 (not published) the measurement of quality levels may range from:

Manufacturing 'line' quality failures such as: -

a) Production line reject levels

b) Production re-work numbers

Quality related to 'field' failures such as: -

a) Failure under Guarantee (FUG) levels of product returned from the field.

b) Product returned because of dissatisfaction by the user.

A further analysis of field failures and product returns, conducted by Flymo, concluded that a product might be returned from the field for the following reasons: -

a) The product **design** was flawed.
b) The product was **manufactured** incorrectly.
c) The product was **marketed** for an application beyond its capabilities, or 'oversold' in advertising and promotions, leading to disappointment and annoyance by the customer. An example of this was the initial failure of the 'hover mower' by Flymo shown on TV as being very easy to use and 'light as a feather' to push - which was not always the case. This lead to disappointment by the customer due to the marketing campaign creating an over-expectation of performance in the eyes of the customer.

There were a number of other NPD performance indicators identified in the literature review which were viewed as less tangible. By way of example, Wight (1993) prescribed a checklist for measuring 'operational excellence' in NPD performance: -

1. Commitment to excellence.
2. Multi functional product development teams.
3. Early team involvement.
4. Customer requirements used to develop product specifications.
5. Decrease time-to-market.
6. Preferred components, materials, and process.
7. Education and training.
8. NPD integrated with the planning and control system.
9. Controlling changes.

The Department of Trade and Industry in the United Kingdom produced a less tangible 'self-assessment' checklist for 'successful product development' - DTI (1997) suggesting that the following elements were among the key factors to the successful implementation of NPD.

1. The need for a Product Development Strategy consistent with business strategy.
2. Structured Product Development Process with clear roles and responsibilities, appraisals and adequate performance measurements.
3. Teamwork with tools such as FMEA.
4. Working in Parallel.
5. Applying appropriate Project Management techniques.

3.6 KEY PERFORMANCE INDICATORS SELECTION FOR CASE STUDIES

A key objective of this chapter was to select appropriate NPD Key Performance Indicators for use in the research case studies. It was considered important to review all of the KPIs listed above, assess their relevance to the NPD process, and then make appropriate selections. Particular attention has been given to the KPI relating to introduction 'time' since this parameter received the closest attention in the review. The priority ranking of each KPI will be discussed later according to the contextual requirements of each project. Therefore, from the above discussion the following list of KPIs was configured: -

1. Accuracy of the Launch

This parameter was chosen to show if the product was launched on time, early or was it late? The value of Accuracy of Launch is found by calculating the deviation from the 'planned' introduction period in days: -

i) Deviation (days) = Actual Introduction Period (days) – Planned Introduction Period (days)

From the above the Accuracy of the Launch can now be expressed as a ratio or percentage using the following formula: -

ii) Accuracy of the Launch = (Deviation / Planned Introduction Period) 100%

A ratio was selected in favour of an absolute value, such as lead-time, to enable direct comparisons to be made between projects. Also, a dimensionless value could be used to benchmark NPD performance capabilities between a number of different projects from the same company, or substantially different products developed by other companies. Also, by using a dimensionless value, it may be possible for a company to assess any benefits from changes they may make in NPD methodologies, people, or the effectiveness of activities such as FMEA, QFD or Rapid Prototyping. In order to calculate Accuracy of the Launch, the target launch date must be nominated and agreed at an early stage in the project after the deliverables of the project have been defined and agreed.

2. Unplanned Specification and Engineering Changes.

Unplanned Specification Changes refers to changes in the deliverables of a project by the customer or the Marketing team member in the project. This may be an indication of the effectiveness or accuracy of any market research used to establish the specification requirements of the new product, or how carefully the requirements were considered at the start of the project. Unplanned Engineering Changes refers to changes in the product's 'engineering' configuration and may be used as an indicator of the quality of the design proposal. By way of example, if product performance issues were discovered, from first production builds, the product would be subjected to engineering changes to correct the issues. Alternatively, a product may require engineering changes to improve the assembly methods, or reduce manufacturing costs.

The issue being raised here is the timing of Specification and Engineering (S&E) changes rather than the number of them. It may be argued that 'changes' form part of the development process. However, if S&E changes are implemented during the later stages of a project, i.e. after the completion of production tooling, they could be very disruptive to the progress of the project and create unplanned delays to the launch. Late (unplanned) engineering changes may also affect the Accuracy of Launch or require additional unplanned resources (human and financial) for the project to recover delays.

The number of S&E changes, and their timing, has been included in the list of KPIs since it may provide an indication of the effectiveness of Engineering and Marketing functions in the company. It may also show how well the team leader and the team communicate during the project; or the effectiveness of 'tools' used in the project such as FMEA, QFD or prototyping, to identify the changes early enough and avoid the potential of disruption and delays.

3. Product Quality.

It was accepted that it would be of little value to launch a product on time (100% accurate launch) and avoid changes, if the product failed in the field or in the manufacturing process. Therefore it was decided to include control parameters for product quality in the NPD KPI list. Most organisations are able to quantify Field Failures or failure under guarantee (FUG) after the launch, and record production line rejects during the manufacturing process. Therefore, Field Failures during the first six months after launch, and production line rejects in parts per million, were selected as valid NPD KPIs.

4. Cost Control Target

It was accepted that Product Cost Targets need to be defined during a project. The control of Product Cost Targets is a KPI that will show if the team has achieved the target.

5. Capital Cost Control

Most NPD projects require some form of monetary investment during the introduction process, referred to here as the Capital Costs. It was decided that these costs also need measuring and controlling in a similar to Product Costs. Capital Costs for a project which may include:

i) Tooling Capital Costs.

ii) Capital equipment costs for production.

iii) Capital investment for Sales and Marketing materials.

The above Capital Costs are usually established during the design process or set as a target at the start of a project. It was decided to include the control of Tooling Capital Costs as a KPI since Unplanned Specification and Engineering Changes could also influence this cost.

It was accepted that there are potentially many other KPIs that could be applied to the case studies, however, they may not always depend upon the performance of the NPD team and the methodology used to introduce the new product. Examples of other KPIs that will not be used in the case studies will now be discussed such as:

1. Profit Margin

   Profit, defined as the 'Excess revenue generated by the sale of a product after the costs for the manufacture of the product have been subtracted'. This was not selected as a KPI for the case studies since 'selling price' may not always be under the control of the NPD introduction team. A view was taken that since 'product costs control' was included in the KPI list, there would not be a need to include Profit Margin.

2. Market Share

   This may be a valid parameter to define and set as a target for the NPD team for 'post project review' discussions with the team several months after the project launch. However, market share may be subject to many influences outside the control of the introduction team such as competitor activity, and was not considered to be a useful measurement of NPD teamwork performance.

3.7 CONCLUSIONS FROM THIS CHAPTER

A number of direct conclusions were taken from this chapter:

1. Following the above review, it was concluded that the specific objectives of the NPD process are dependent upon the type of product under development and the contextual priorities of the organisation involved. Therefore NPD KPIs and their relative priorities should be selected with contextual consideration.
2. Also, for organisations employing multifunctional teams, there is a need to define clear project management procedures in the form of a NPD methodology, which may include appropriate control documentation and an introduction template plan, to ensure that each functional activity is considered and correctly scheduled.
3. It is recognised that 'Innovation' in the NPD process is an activity that also requires careful planning and consideration in order to encourage the development of high 'added-value' products. Therefore it may be beneficial for a company to include activities similar to Flymo's 'Innovation Forum' to provide every opportunity for creativity whilst minimising the time required to define the deliverables of the project.
4. It was concluded that the following KPIs will be applied to the case studies:
    i) The Accuracy of the Launch.
    ii) Uncontrolled Specification and Engineering Changes.
    iii) Field returns and production line rejects Quality.
    iv) Product Cost Control.
    v) Capital Cost Control.

CHAPTER FOUR

REVIEW OF TEAMWORK CONCEPTS IN N.P.D.

4.1 INTRODUCTION

A common theme discussed in the review of the New Product Development process in manufacturing industry, was the organisation and use of multi-functional teams. Teamwork was frequently described by many authors as a, 'pre-requisite' to improving the NPD process.

The author was privileged to be invited to present part of this research in 2005 to Lord Broers, president of the Royal Academy of Engineering and Chairman of the House of Lords Science and Technology Committee. Following a discussion after the presentation Lord Broers emphasised the 'value of collaboration in New Product Development' and endorsed teamwork in NPD.

Collaboration in product development was the subject of one of Lord Broers Reith Lectures, broadcast by the BBC (Broers 2005), where he argued that 'Most technologies are created by bringing together and evolving technologies that already exist'. Broers also emphasised the following points: 'It is rare nowadays, for an individual to posses all that is needed to develop, manufacture and take a new technology to market. Without joining with others, one simply does not have the resources to be internationally competitive.' Technological examples cited by Broers include the mobile phone and the modern GPS system, where: '...it would be extremely unlikely for any one person nowadays to posses all of the Engineering, Manufacturing and Marketing skills required to develop and launch such products.'

The 'teamwork approach' has been described as an 'enabler' (Boothroyd 1993), for a number of 'tools' such as Design For Manufacturing (D.F.M.), Failure Mode and Effects Analysis (F.M.E.A.) and Quality Function Deployment (Q.F.D.). Therefore, the subject of teamwork will be reviewed in detail in this chapter, together with the claimed benefits and implementation techniques.

In reviewing the extant literature on the multifunctional NPD process, McDonough III (2000) concluded that: '97% of a sample of companies studied used Cross-Functional teams in some NPD projects, with 33% using them for all projects.' McDonough identified the following benefits of using Cross-Functional:

1. To speed up NPD.
2. Improve quality of products.
3. Lower product costs.
4. Improve success rate.
5. Improved added value for consumer.

During the course of this research the above, typical, claimed benefits of using multifunctional teams in NPD are explored. An attempt will also be made to 'quantify' the above benefits, their relevance and how they should be measured. It was not the intention of this chapter to endorse, or otherwise, the use of teams in new product development, rather to understand their organisation in order to propose areas of improvement.

4.2 SIMULTANEOUS / CONCURRENT ENGINEERING

Concurrent Engineering was defined by Poolton (1994) as:

"A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support; intended to cause the developers from the outset, to consider all elements of the product life cycle from concept through disposal, including quality, cost, schedule, and user requirements."

From a practical implementation guide to the use of the simultaneous, or teamwork, concepts Hartley and Mortimer (1991), described Simultaneous Engineering as:

"An integrated approach to new product introduction. Using multi-functional teams or task forces, it ensures that research, design, development, manufacturing, purchasing and supply, and marketing all work in parallel from conceptual stages of the new product, through to final launch of the product into the market place. Unlike traditional (or 'over-the-wall') methods involving a process of 'sequential' events in a project"

Over the past 45 years, not only have Japanese companies made enormous gains in their share of world markets, they have impressed the West with their ability to introduce new high technology products that have astutely matched the needs of their customers. Rosenbloom and Cusumano (1987) described how the Radio Corporation of America and Ampex (in the United States) competed with JVC, Matsushita, Sony and Toshiba (in Japan) for a technological advantage to produce the VideoCassette Recorder for the mass market. Sony, JVC and Matsushita succeeded where others in the West failed, primarily because of the way they managed the development of the technology. Over a period of nearly three decades, The

Japanese repeatedly focused on more value-added opportunities in the development, and positioned their technical efforts and 'people' more efficiently in product introduction teams.

In the Simultaneous Engineering approach, according to Hartley *et al* (1991), the team has an appointed team leader, who leads the project and helps the team to 'self manage' day to day issues by 'removing any barriers to success'. The team leader ensures that each team member is *'empowered'* to represent his or her functional activity without the need for any further authorisation from *'above'*, thus improving the efficiency of the decision making process. The 'teamwork structure', illustrated in Fig.09, depicts a communication process in the team without the intervention of departmental managers. Simultaneous Engineering and the deployment of 'self managed' teams is a departure from the more 'traditional' approach described by writers such as Fayoy (1949), Mooney (1947) and Urwick (1947), who claimed that high performance came from a staffing structure which was hierarchical in nature. This approach emphasised a chain of command, clear lines of authority through which communication passed downwards, delegation of tasks and responsibilities and role specialisation. Within this approach management was seen as the supreme co-ordinating authority. The traditional structure is shown graphically in Fig.10. The illustration depicts a series of 'over-the-wall' steps where each departmental function operates almost in isolation to the next department, with the customer being involved at the end of the project. Each respective functional manager provides the 'authorisation' for each function to 'pass' the project to the next stage. The flow of information shown in the 'traditional organisation' is unidirectional, with project problems perceived as the fault of the previous player, sometimes known as 'Functional Silos'.

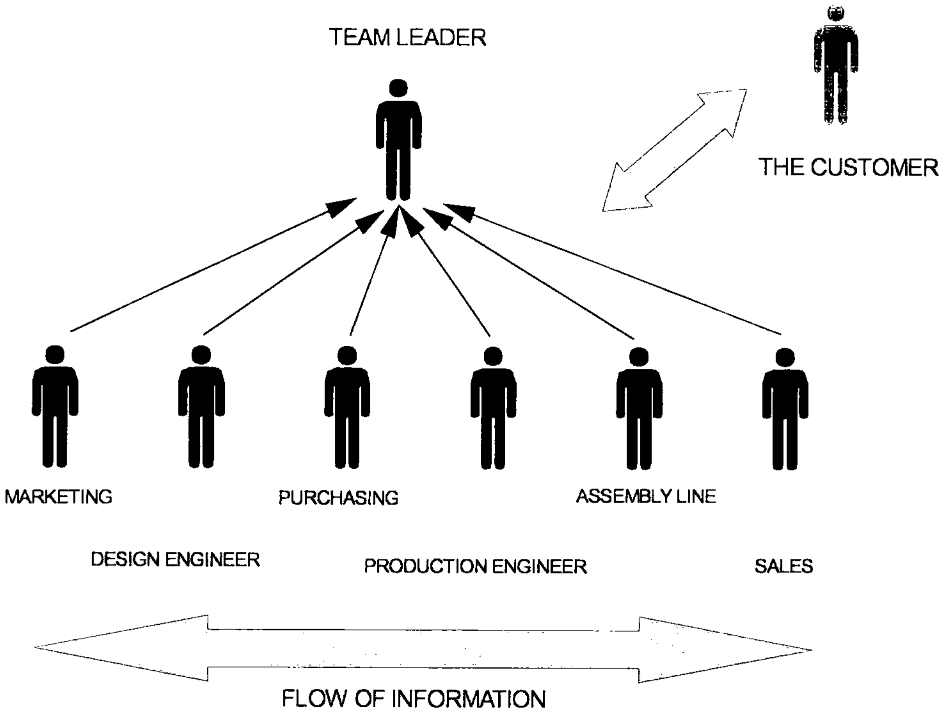


Fig.09 Teamwork structure

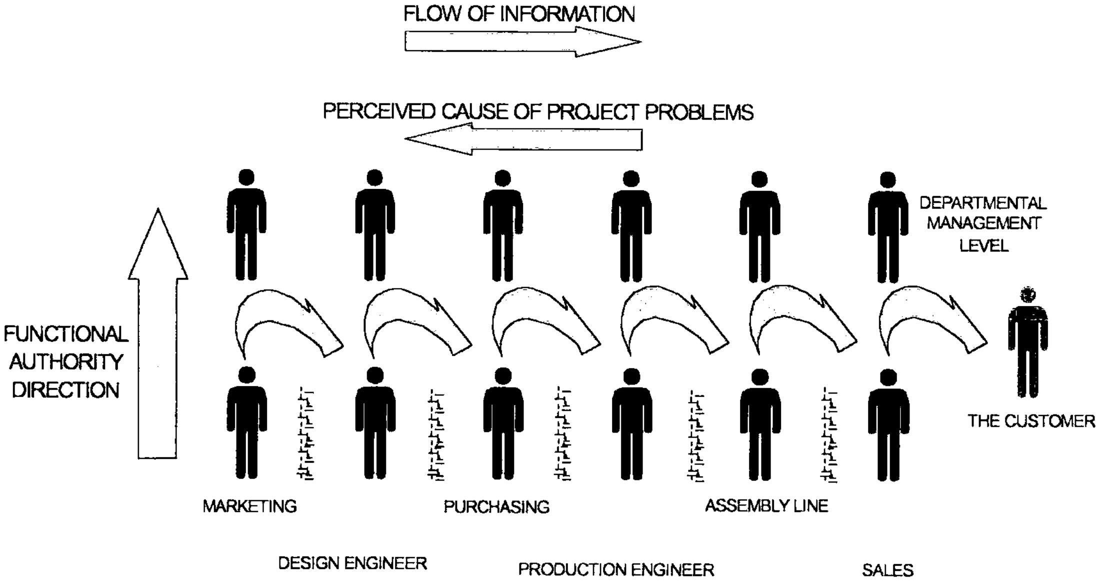


Fig.10 Traditional Hierarchical Structure

Traditional, sequential, over-the-wall, approaches were criticised in the extant literature because 'responsibility and accountability for the product is denied by all parties'. It was also noted that this approach created barriers between the functions where 'each member believes the other to be incompetent'. In support of this criticism, Smith *et al* (1991) discussed the need for the 'mobilisation' of a 'Team-work' culture in an organisation intended to reduce product lead-times claiming that: 'The resulting change in culture produces a 'flatter' structure thereby reducing the need for a 'middle manager' level.'

This was also supported by Miles *et al* (1992) who claimed that: 'traditional, functionally organised, product introduction processes are 'incapable of meeting the new requirements placed upon them' for the following reasons:

1. Sequential activity results in protracted lead times.
2. Customer requirements, product design and method of manufacture are inextricably linked with many trade-offs and they cannot be addressed independently by marketing, engineering and manufacturing functions.
3. Scarce design resources are wasted on interdepartmental communications, progress chasing and non value-added activities correcting designs that prove difficult to make or do not fully meet customers' expectations.
4. Manufacturability issues are discovered too late and are the subject of 'quick-fix' solutions.
5. All design work is pushed through a single, ill-defined activity.
6. Products are designed with an excessive number of component parts which, in addition to the cost of these parts, adds to the supply and stock control.

A number of researchers recognised the need to 'rearrange' organisational structures, such as Little (1996) who claimed that:

"Hierarchies create dependant employees and behaviours - hierarchies are too slow, and they impede the easy flow of knowledge that is key to effective decision making".

Morgan (1988) argued that a hierarchical structure in an organisation 'stifles debate' and therefore 'constructive conflict'. Morgan advocated smaller, flatter structures that are communication intensive by giving the members of a team more responsibility to progress tasks and solve problems along the way.

In a similar way, Clark *et al* (1992) endorsed the formation of teams in NPD projects, requiring team members to be appointed from each function in the organisation, lead by 'heavyweight' team leaders rather than their 'functional' managers who tend to concentrate on departmental priorities. Clark argued that:

"The team leader will not only guide the team in their objectives, but will also 'sell' the team concept to each member of the team improving integration and motivation in individuals achieving their objectives for the team. The role of senior management is to guide, support and empower the teams to solve problems within pre-defined limits."

In a guide to implementation Hartly *et al* (1991) list the following as vital elements to the simultaneous engineering process: -

1. The formation of a 'multi-disciplinary task force' or project team consisting of all the key departmental members, and external suppliers involved with the introduction of a new product.
2. Matching the product definition to the requirements of the market place with the customer. The project definition must be clear and agreed by the whole team, providing a common goal for all to achieve.
3. Parameter design to ensure the product is optimised for use and quality. This is a process of investigating potential problems in the product and solving them before they occur.
4. Include Design for Manufacture and Assembly studies in the process.
5. Simultaneous development of the product, the manufacturing process and equipment, quality control, spares, maintenance / servicing and marketing etc.
6. A formal structure for the team is necessary so that the members understand their job functions and can work together as a team, ideally in the same office.
7. Team leaders must be appointed with strong personalities also committed to achieving the common goal.
8. Senior management needs to take a 'hands-off' approach to the task force, but must make its support for the system crystal clear.
9. Directors should be ready to foster whatever changes are needed to improve the effectiveness of simultaneous engineering.

From a study of Fortune 500 manufacturing companies, Henke *et al* (1993) suggested that 'firms' realise four primary benefits through the use of cross-functional teams:

1. The shortcomings of hierarchical structures are overcome by the team's ability to cut across traditional vertical lines of authority.
2. Decision-making is decentralised.
3. Hierarchical information overload is reduced at higher levels.
4. Higher quality decisions can have a significantly greater potential of occurring than with individual decisions.

Along with the claimed benefits of using a teamwork approach to NPD, there were a number of issues identified in the literature as described by Henke *et al* (1993), who discovered that 'no single firm had implemented the team concept to the fullest extent.

Henke *et al* (1993) concluded that:

'Firms were not always including external suppliers and 'blue collar' involvement in the teams, also claming that, 'simply designing a system of teams, and then assigning a mix of functional people to them is not enough to make the system work. An individual's commitment to a team and its job must be sought by senior management as well as the suitability of individuals in a team role.'

The above recommendations were used as guidelines for the research case described later.

Concerning the involvement of external suppliers in a team, Bonaccorsi *et al* (1994) claimed that: *"The early involvement of suppliers in new product development saved time by synchronising technical development, provides more opportunities for concurrent engineering, increases profitability of both parties which leads to mutual trust and free information exchange. Nissan Motor, for example, employs the concept of guest engineers from their key technical suppliers as members of their development teams."*

The author, whilst project managing a number of new products for Flymo Ltd. and Kenwood, experienced a number of benefits of early supplier involvement, for example the injection mould and tool makers in a project gave the following advantages: -

1. Enabling designers to design components compatible to injection moulding.
2. Reduced cost of tooling by involving the chosen toolmaker in the design process.
3. Improved component finish and quality by involving the toolmaker in the design process.
4. Reduced moulding cycle times, therefore reducing piece part manufactured costs.
5. Improved tool reliability and lifecycle.

In addition to the subject of teamwork discussed in the extant literature, professional institutions and management consultants have staged a number of high profile conferences highlighting the benefits of multi-functional team working in the new product development process. One such 'international' conference staged by the IMechE (1994) entitled 'Design for Competitive Advantage' placed 'teamwork' as the pre-requisite for competitive advantage. Many presenters claimed that product development is not the result of efforts in any one department but needs the active involvement of many people, especially from Marketing, Engineering, Purchasing, Manufacturing members and key suppliers.

4.3 ORGANISATIONAL AND CUTURAL CHANGES

In order to implement a multi-functional teamwork environment, Hartley *et al* (1991) described criteria that managers need to consider; considerations such as the organisational structure of a company and the 'cultural' changes required to accommodate a cross-functional way of working. Hartley *et al* (1991) also acknowledged that it was the Japanese who first recognised that: -
"Teamwork is one of the fundamental levers which can profoundly influence the pace of change in new product development, with Japanese culture based on the need to find a consensus on a course of action. Sometimes however, contrary to the popular view, the consensus is reached only after considerable argument, but once the consensus is reached, the team involved will give their all to achieving the objectives of the project."

A common theme in the literature review about teamwork implementation, was the changing role of senior management from 'decision-makers', to enablers thereby redistributing authority down to the team players. Lettice stated that:
"It is important to have 'committed and flexible people' on the teams, as well as the correct skills mix in a team" - "Part of creating a supportive team environment, involves 'moving decision making down the organisation', if this is to work team members need to have a clear understanding of their authority and who makes what decisions must be clear".

Hasslop (1996) also supported the need to move the decision-making process 'down' to the team members and discusses the considerable 'autonomy' held by the team leader. This shift in responsibilities for some organisations can be in itself difficult to manage if some senior managers may reluctantly see their authority taken away. Hasslop's research demonstrated that in some electrical/electronics manufacturers, top management tended to 'hold on to power' and retained control of the 'strategic' dimensions of a project, whilst allowing the team leader to control the 'operational' issues. Hasslop argued that projects and company success (in terms of sales volume and turnover) could be improved if team leaders were allowed a greater degree of 'Autonomy' and more responsibility for strategic, as well as operational, tasks.

In a similar theme, Hammer *et al* (1993), described a process of 'Re-engineering the Corporation' to improve company performance based upon a total review of the business process in which the workers make the key decisions, claiming that:

"Hierarchical structures need to be 'vertically compressed', and workers empowered to make decisions. The benefits include fewer delays, lower overhead costs, better customer response, and greater empowerment."

In endorsing the use of teams in NPD projects Muhiem *et al* (1994) argued that: -

"...for an organisation to successfully meet the requirements of the customer with a 'manufacturable' product, agreement must be reached between all of the businesses functions on matters such as:

1. Performance
2. Aesthetics
3. Quality
4. Reliability
5. Quantity
6. Selling price
7. Delivery dates"

Muhiem *et al* (1994) also claimed that:

"The foundation for long term success of any organisation can be established only on the basis of synergistic relationships between Marketing, Design and Operations functions of the organisation, good integration between these groups is essential."

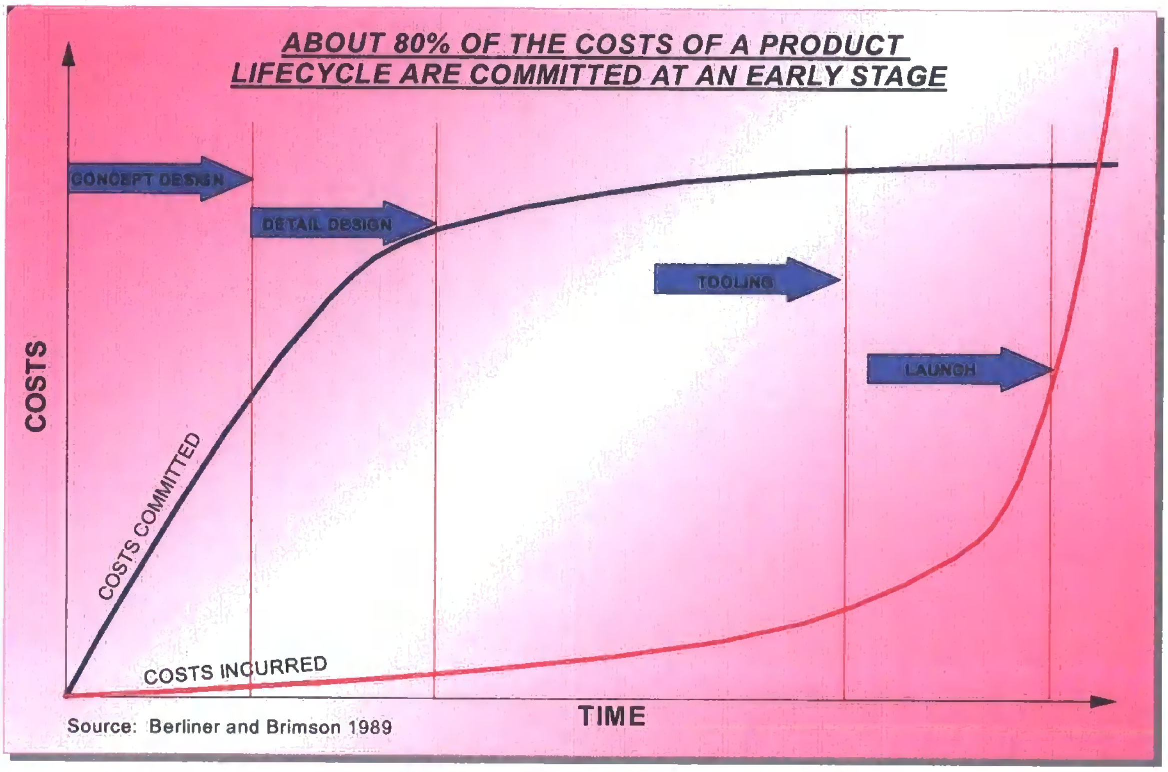
The author has also experienced delays in NPD projects due to failures between the Marketing and Design functions to reach timely agreements of the matters identified by Muhiem.

In order to save costs in manufactured product Berliner *et al* (1989) emphasised the early involvement of a team to improve the effectiveness of the team's involvement claiming that: -

"In the early stages of a project decisions are being taken that will not only dictate the product costs in terms of labour and materials, but also, distribution costs and the costs of product failures, including servicing. During the early stages, tooling investment may be committed to the project, but that money is not yet spent. It is at this time when the team's decisions are most effective at controlling the costs for the entire life cycle of the product. At a later stage in the

project it may be more difficult, and possibly prohibitively expensive to implement any changes."

Costs incurred during a product life cycle are depicted in Fig.11, which shows the rate of commitment of product costs with respect to costs incurred.



ABOUT 80% OF THE COSTS OF A PRODUCT LIFECYCLE ARE COMMITTED AT AN EARLY STAGE

Source: Berliner and Brimson 1989

Fig. 11 Costs incurred during a product life cycle (Berliner et al 1989).

The relationship between the 'timing' of a change with respect to 'costs incurred' was investigated in detail later in this research. A model was developed to quantify the 'impact' of changes in terms of cost and according to the 'phase' of implementation during a project.

Research described in a number of management journals has endorsed the benefits of adopting a teamwork approach to new product development. The most significant benefit is 'reduced time-to-market'.

McDonough (2000) claimed that a key factor in reducing development time is the implementation of cross-functional teams which has 'unfrozen' many of the problems that occurred at the departmental boundaries such as 'formal hand-overs' and resource scheduling. Also, Jaskolski (1992) described a paradigm shift in corporate culture focusing on a multi-functional approach that can help shift companies from a time-deficient 'structured' organisation to time-effective fluid teams.

In a somewhat different approach, Imai (1986) described a 'functional' system of departmental managers 'naturally' tending to place priority on their own departmental functions, arguing that: *"Cross-functional teams involved in new product development avoid 'long periods of in-fighting' and adjustments before production starts. 'Cross-functional management has been born of the need to break interdepartmental barriers, and, cross-functional goals should be determined prior to departmental goals'. Without cross-functional goals, the departments with the loudest voices tend to win interdepartmental negotiations, regardless of the impact on company-wide goals."*

4.4 SIMULTANEOUS ENGINEERING EXAMPLES IN INDUSTRY

From discussions of the evolution of the automotive industry, Womack *et al* (1990) described a complex processes requiring 'enormous efforts form a large number of people' and how 'lean production' techniques encompassed both process and industrial engineers in teams, with strong team leaders, to collectively engineer the entire vehicle. Lean Production was described as an enhancement to 'mass-production' avoiding the need for a large numbers of specialists concentrating on isolated details such as the 'door locks'. However, Womack argued that Lean Production could inhibit individual career paths. In a mass-production process, for example, a junior piston engineer may progress to a senior piston engineer by displaying '*genius*' in the engineering of a single component without regard to the engineering of the final product. Womack, *et al* (1990) described two 'key' organisational features of 'lean production' requiring the use of a cross-functional teamwork approach to evolving and building cars. Firstly, transferring the maximum number of tasks and responsibilities to the workers actually adding value to the car, and secondly, empowering the team to retrace and rectify problems and faults 'as they appear'.

Honda was one of the first automotive manufacturers to adopt the simultaneous engineering approach, introduced by the then president Kiyoshi Kawashima in the late 1970's. In the U.S. Chrysler, Ford and General Motors started using simultaneous engineering in 1984-85 and have since developed clearly defined methodologies, all based upon multi-functional teamwork. The Ford motor company claimed the following benefits for the implementation of simultaneous engineering: -

1. Reduced time-to market.
2. Improved product quality
3. Reduction in development costs
4. Reduction in product costs.
5. Increased customer satisfaction.
6. Optimised use of available resources (people and money).

The result of the traditional, 'sequential', approach experienced by Rover Group (Kelly 1993) was: time delays, because each departmental function in the process must climb up a steep 'learning curve' at each stage in the product introduction process. The traditional process also makes little or no use of opportunities to process a number of activities in parallel. The illustrative chart in Fig.12 shows a development process proceeding, apparently in isolation from the other functional activities, followed by production engineering and other key activities in the process, culminating in the manufacturing assembly functions. In contrast, the simultaneous engineering ('teamwork') approach is shown in Fig.13 where the Gantt chart shows a number of activities occurring with a significant degree of overlap. This shows activities occurring concurrently with others, hence saving time over the sequential methods. Note also the reduction in the time required for design changes due to a continual consultation process.

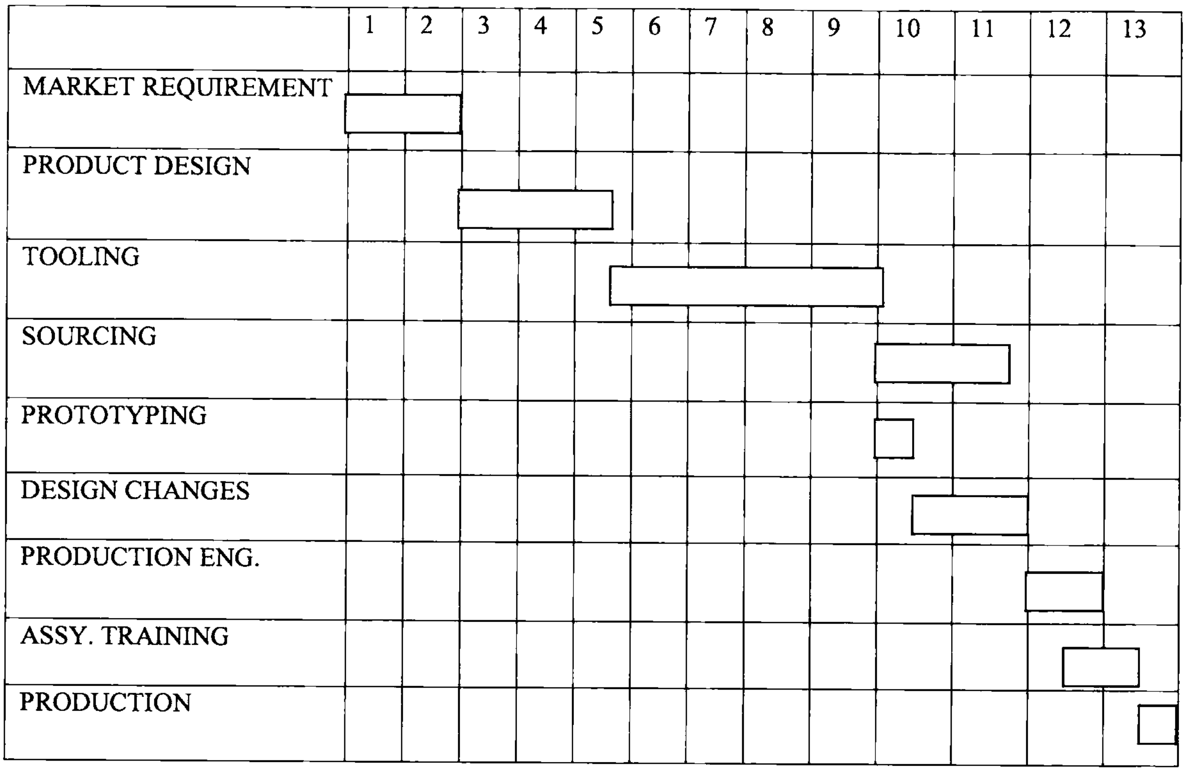


Fig.12 Sequential or 'over-the-wall' NPD plan.

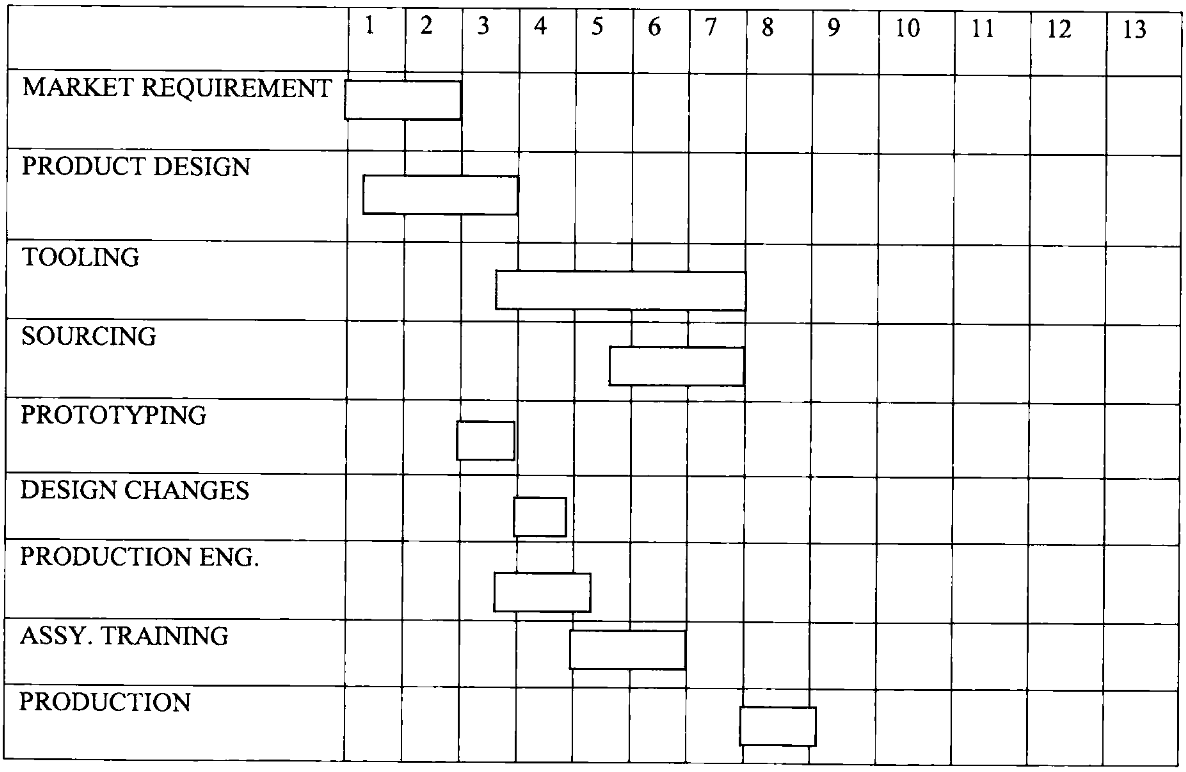


Fig.13 Simultaneous Engineering or 'teamwork' NPD plan.

4.5 BEST PRACTICE TEAMWORK IMPLEMENTATION TECHNIQUES

This section will review some examples of how 'teamwork' methods have been implemented in a number of companies manufacturing consumer durable, aerospace and automotive products.

Teamwork is often described as a 'Best Practice' technique in new product development - Matin (1994) defined 'Best Practice' as: 'The business processes used, by the best performing companies, to provide a product, or service, to their customers.'

However, Maffin's (1996) work showed that one 'best practice' technique which has provided operational benefits for one company, may be inappropriate for application by another. Maffin emphasises that it is important for an organisation to: 'Identify those features of good design and development practice, which are generic and those, which are company specific.'

It was also shown in Maffin's research that 'best practice' methods require significant effort and understanding, of the techniques, by senior management to make them work for the benefit of the organisation.'

Whilst reviewing a number of case studies in concurrent engineering practices, Poolton (1994), discussed the development of the 'K' series engine, and the Land Rover Discovery, by the Rover Group. The Land Rover Board provided the 'enabling' conditions to establish multi-disciplined NPD teams. The team had both full-time and part-time representatives who included external suppliers and various experts resulting in successful introductions. The 'K' series engine was described as an "unqualified success" and the Discovery was delivered to the market in record time, on cost, and above targets for profitability.

From another implementation of simultaneous engineering in British Aerospace Regional Aircraft, Lockwood (1995) discussed a methodology for the production of small to medium size aircraft, such as the Jetstream Commuter and the BAE 146. Lockwood described the implementation as 'wide ranging' involving every department function in the company. Starting in 1991 a business wide simultaneous engineering programme was launched to significantly improve the way the company undertook and managed projects. The first step was to identify the full extent of cross-functional engineering processes, such as new aircraft development and aircraft customisation, and to quantify the opportunity for improvement. Then an analysis was undertaken to pinpoint the fundamental problems that were resulting in wasted effort and time in the processes. The conclusion of the analysis was that significant improvement in the development and customisation of new aircraft could be achieved by 'empowering' cross-functional teams to 'challenge' the implicit management practices using 'Goal-Directed Planning' methods (GDPM) rather than traditional, activity-based planning methods. Lockwood (1995) described GDPM as: 'a results-orientated approach to project management which offered a radical departure from traditional critical-path techniques in which the project manager becomes 'sucked in' to a spiral of planning and re-planning; and focusing on what *must* be achieved.'

Lockwood (1995) also described the principle of GDPM forming a 'robust' basis for planning and control. This was achieved by involving a cross-functional group to identify milestones in a project that must be achieved, starting from the final objective and working back. In traditional planning, milestones were described by Lockwood as representing the completion of an activity rather than the accomplishment of the result.

Following a series of three day workshops at BAE on simultaneous engineering, cross-functional teamwork and GDPM, key projects were selected to pilot the implementation of simultaneous engineering with one project selected, as a control, which would still use traditional methods. The results of the pilot programme showed that the GDPM team had produced a coherent plan in just two days while the traditional teams using conventional techniques were struggling to understand the customers' request.

The above implementation of SE in projects, followed the following steps:

1. Cross-Functional consultation to understand the potential benefits of SE.
2. Identify a pilot project.
3. Identify the final Business Goal to a SE team with clearly defined roles.
4. Identification of the milestones, by the team, of 'what must be achieved'.
5. Implement the plan and project.

The benefits to BAE of the implementation of SE and GDPM was:

1. The lead time of projects was reduced by 75%
2. Significantly reduced re-work.
3. Letters of compliments from customers to BAE about improved performance.
4. Improved motivation, plan ownership and commitment from the team.
5. The Project Manager stayed focused on the accomplishment of the goals.

Following the review of the above, the author interviewed the Production Director of BAE, Tony Douglas, in February 1997. Douglas revealed that:

"The success of the above was still very dependant upon a strong-willed team of managers who, first of all, needed to convince themselves that SE would provide benefits, before 'exposing' the methodology to the work force. It then became a 'one way selling job' to the cross-functional team, for them to complete the implementation as described above."

Douglas explained the need to implement a comprehensive personal objective and appraisal scheme in the organisation, together with the re-issue of 'generic' job 'profiles' for everybody in the company to ensure that their roles were clear, what was expected of them to achieve, and how they would be measured. The job profiles of the other team players, and team leaders were available for all to review and understand. Douglas also explained that objectives were set by the individuals involved and agreed by their senior managers thus linking the company's objectives with individuals.

The above process in BAE became a corporate product development methodology, which was well documented for use in the organisation. Many other organisations also produce published procedures, often referred to as 'corporate methodologies' for use by their personnel (usually confidential and not in the public domain) as guidelines for the development of new products.

Within the Electrolux group of companies a SE implementation guide was designed in Stockholm - Sweden, for implementation by the rest of the worlds group companies in 1994. The Electrolux guide, called 'The Integrated Product Development Process', was based on research conducted by Berliner (1989). Berliner showed that a manager's ability to significantly influence the outcome of a project by the involvement of multi-functional teams in the 'primary' and 'specification' stages of the project, where up to 80% of the project costs are committed, see Fig.11.

The Electrolux methodology integrated Business, Technology and Marketing Strategies to provide an Integrated Product Development Process. The process was split into four key development phases:

1. Primary Development
2. Project Specification phase
3. Project Industrialisation phase
4. Project Evaluation

Phase One: Primary Development

This included the Project Definition activities, Ideas Generation, Selection of Project Leader, Planning, Marketing sign-up, and various creative / innovation activities. The phase was sub divided into various 'check-points' which represented a number of milestones depicting the completion of tasks such as 'Performance / Design Verification'. Two levels of Prototype models were included in the first phase of 'Primary Development' which were:

1. Prototype mock-up - this was a non-functional Industrial Design model representing the styling and aesthetic intent.

2. Functional Prototype - this was purely a working representation of the product offering for evaluation by the design and marketing team members.

Phase Two: Product Specification Phase

This phase ran with some concurrency to the Primary Development but included Business Planning, Competition Analysis, Risk Analysis, Manufacturability, and reference is made to the production of 'Representative Appearance Prototype' models which was intended to represent a 'production' unit, albeit using Rapid-Prototype components.

Phase Three: Project Industrialisation Phase

This phase also ran with some concurrency with the previous phase, but included milestones such as Design Freeze, First Trial Builds from 'off-tool' samples, Field Testing, Market Launch Plan, and Updated Financial Analysis.

Phase Four: Project Evaluation

This phase was simply an evaluation of the performance of the new product, starting with the Field Testing, detailed above, and concluding with the response of the Market Place to the new product.

The Electrolux methodology also incorporated a 'stage gate' process as described by Cooper 1993, and prescribed a 'template' for the introduction of new products. However, provided very little implementation guidance was provided for managers. The methodology was used by some Electrolux companies based in Sweden, but other group companies either totally rejected it, paid 'lip service' to its implementation, or as in the case of Flymo designed their own processes.

The author, together with a small group of senior managers in Flymo, developed a New Product Development methodology specifically for use in the Flymo organisation. The group consulted with each function in the organisation in the design of the methodology, which helped to gain the ownership of the team players and created considerable enthusiasm and commitment to make it work. The methodology included:

1. The design of an introduction 'template' split into four phases, which could be modified to suite the complexity of a particular project without changing the order of the activities.
2. The definition of the objectives of each phase, and the activities within each phase.
3. The definition of the roles of the key team players and team leader.
4. The design and definition of the control documents used to monitor the progress of a project such as the project plan - Gantt chart, the product costing sheet and the capital investment (usually for mould tooling) sheet.

Tools such as F.M.E.A., D.F.M., Q.F.D. and Value Engineering were included in the template with corresponding documentation for use by the team. The methodology and control documentation significantly reduced a number of problems experienced in the development of previous products, such as:

1. Unclear project definitions and deliverables.
2. Projects progressing without the above being agreed by the team.
3. Unclear roles of departments and individuals.

4. Products designed and introduced without optimal use of expertise in the company.
5. Products designed and introduced without optimal use of supplier's expertise.

A major consumer durable manufacturer in the U.S.A (name not published due to commercial confidentiality) designed a 'Global Product Development System' for the development of power tools and outdoor products. The system again comprised of a Gantt chart template containing a number of generic activities for the development of a 'typical' product within the organisation. The activities were grouped into several phases requiring a 'sign-off' by the management of the company, before the project could be authorised to proceed to the next phase. Before release to the next stage, evidence of phase completion would be presented by the team leader to the management - referred to in the system as a '*tollgate*'. The process followed, very closely, the '*stage gate*' process developed by Cooper (1993). The use of standardised documents were used to provide project data updates, check lists showing which activities in a particular phase had been completed by the team, and costs and investment budgets were within the target limits of the project. Other standard documents included:

1. The Design Guide - a broad product description used to guide the engineering team.
2. QFD Plan - split into customer, manufacturing process and production assembly requirements.
3. The Technical Feasibility document - produced by the engineering team in reply to the demands of the Design Guide requirements, highlighting any new technologies or processes used, together with indications of costs, and risks associated with the project.

4. Industrial Design Proposal - A series of sketches indicating the visual style of the new product.
5. Quality Review - An analysis of quality related problems with previous products in the same category, such as Failure-under-guarantee levels and line reject rates.
6. Safety Assessment - an analysis of where the new product may pose a danger to the user or the assembly operator.
7. Manufacturing Study - a report recommending manufacturing methods, equipment requirements and the 'make-or-buy' rational.
8. Materials management Plan - a plan produced by the purchasing department showing the longest 'lead-times' for component procurements, and a list of preferred suppliers for the design team to involve in the deign work.
9. Financial Appraisal - a financial review document showing the product costings, investments required and the projected profit and loss spreadsheet for the project over a period of time.
10. Serviceability review - a summary document highlighting product service and repair issues with previous products in the same category.
11. Patent Review - a document summarising new 'inventive' ideas, or highlighting risks of infringing other manufacturers patents.
12. Laboratory Test Plan - detailing the test regime required to prove functional acceptance, how the tests will be carried out and which prototype model will be used.
13. F.M.E.A. analysis - The results of the F.M.E.A. highlighting the potential failure modes of the new product, and the consequences of such a failure.

The above documents would be scheduled for completion and presentation at various *tollgates* in the project (Fig.14), and used by the management team to enable a decision to be taken whether to proceed to the next stage. The final key '*tollgate*' would be a release to the customer for use.

Tollgate 1	Tollgate 2	Tollgate 3	Tollgate 4	Tollgate 5	Tollgate 6	Tollgate 7	Tollgate 8	Tollgate 9
People Allocation	Define Project Requirements	Confirm Feasibility	Approve Design	Commence Tooling	Authorise first production build	Authorise full Production	Release product to customer	Post Project Review

Fig.14 NPD project 'Tollgate' Phases

4.5.1 THE ROLE OF THE TEAM

The team player in the NPD process, according to writers such as Poolton (1994), Hasslop (1996), Hartly (1991), and McDonough (2000) must be able to make decisions for the team, representing his/her department. They must therefore be 'empowered' by their respective departmental manager to do so.

In supporting this Wheelwright (1991) argued that if the team members are to truly represent their departmental functions then it would be reasonable to expect that representative to have a detailed knowledge of the procedures, capabilities and responsibilities of their respective department. A team representative from the purchasing department, for example, must have a detailed knowledge of sourcing tactics (order lead times and payment terms), key supplier capabilities (production volume build up and quality), and anticipated component usage on the production line. The purchasing representative can also play a useful role in Value Engineering with the design team, and to provide a link for the design department with key technical experts from suppliers.

In the development of the Garden Vac product for Flymo, the electric motor manufactures (Ciarramella, Italy) played a key role in the performance and cost development of the product. The purchasing representative in the team arranged joint visits to ensure that project objectives such as costs and timing were clarified to each component supplier.

4.5.2 THE ROLE OF THE TEAM LEADER

In describing the role of the *Team Player* Hartley *et al* (1991) described the team leader as the overall project manger, who is responsible for the successful delivery in terms of timescales, cost and specification of the new product to market. The Team Leader was also responsible for 'coaching' the team members to ensure that they interface together in the most efficient way, without allowing historical 'departmental barriers' to present obstacles in the project and assist the team to collectively resolve problems in the project.

Smith *et al* described four skills required of a Team Leader: -

1. Leadership Skills

The Team Leader must have **Leadership Skills**, and must be able to get the best from people by gaining their respect quickly. The Leader must be able to encourage, lead support and identify problems at an early stage in the project together with the solutions.

2. Vision Skills

Visionary Skills refer to an awareness of what the new product will mean to the company, the customer and the competition.

3. Technical Skills

Technical Skills with regard to the product and the technologies involved in manufacturing it are required by the team leader. Although *Engineering* personnel often make excellent team leaders, care should be taken to avoid appointing a team leader who will focus or protect the activities in one functional area.

4. Management Skills

Management Skills or as described by Smith as Project Management Skills involving the detailed planning of the project, maintenance of check lists, resources, tracking charts and reports.

A common view from the extant literature is the importance for the team leader to be aware of the need for effective communication skills both within the team and to senior management. It is therefore important for the team leader to communicate with the team in the form of regular team meetings by chairing the meetings, reviewing progress and discussing issues openly with the team. Fisher *et al* (1997) focuses on the importance of effective, bi-directional, communication in teamwork - especially between the Marketing and Engineering functions, where the project goals are established.

Lettice (1995) argued that the team leader's primary responsibility is to encourage communications with the team and the rest of the organisation, including suppliers and customers.

A view may also be taken that communication with customers and some suppliers may benefit from a degree of co-ordination within the team. For example, the responsibility for communications with key suppliers, may be better controlled, or at least overseen by the representative from the purchasing department. Co-ordination breakdown within the team may result in a number of conflicting requests to the supplier from a number of team members.

Hartley *et al* (1991) described the interface role that the team leader must adopt with the functional managers in the organisation to ensure that the resource required in the NPD project is not diverted to the 'day-to-day' tasks involved in running a department.

From a study to define the degree of autonomy granted to the team leader by the senior management in an organisation, Hasslop (1996) concluded that: management in NPD today still retain control of the strategic tasks, whilst delegating the operational tasks to the team leader. Hasslop distinguishes four key stakeholders in NPD as:

1. Senior Management
2. Steering Committee
3. Team Leader
4. The Team

Haslop identified and lists tasks of 'strategic' and 'operational' autonomy:

STRATEGIC AUTONOMY	OPERATIONAL AUTONOMY
Team Selection	Project Design
Team De-selection	Project Planning
Budget Setting	Project Scheduling
Project Selection Criteria	Project Implementation
Reward Team Success	Project Reviews
	Project Evaluation
	Project Deadlines

In discussing the selection of the team leader, Hasslop (1996) found that in over 80% of companies studied, members of the management team selected the team leaders, of which, 54% of the companies considered personal attributes, including psychometric testing, in the selection.

From the above discussion, the Team Leader's role may be described as a co-ordinating member of a new product development team. The team leader manages the timely and cost effective completion of a project within the scope of a pre-agreed product design specification. He or she is essentially a project manager and should be able to guide the team to achieve common goals and milestones in the project without bias to any one functional department. The team leader will be the spokesman for the team to keep senior managers informed of the progress of the project and to present any issues, such as resource demand, that cannot be addressed by the team. The team leader must ensure that the team is adequately resourced and represented by all functions e.g.

1. Engineering design
2. Marketing
3. Production engineering and tooling
4. Materials management, plus any key suppliers
5. Quality
6. Accounts
7. Production assembly

4.5.3 THE ROLE OF SENIOR MANAGEMENT

A company moving from a 'traditional' hierarchical management structure to a structure conducive to multifunctional empowered teams may experience some resistance to this change from the senior managers involved. Hartley *et al* (1991) discussed the need for a 'commitment to change in an organisation which 'must have its roots among the senior management of the company'. Without this commitment and 'without a cultural upheaval, simultaneous engineering has little chance of success'. Hartley *et al* (1991) also discussed the need for senior management in an organisation to play a supporting role and to act as an enabler to the team to achieve its goals. This involves creating the right environment for the team by:

1. Empowering the team to decide how best to achieve their objectives.
2. Exercising tolerance of some mistakes.

Lettice (1995) discussed the importance of creating the right 'supportive' environment for the implementation of teamwork in an organisation and to ensure that the roles of each player are understood. Lettice argued that: '...this is essentially a task for the senior management who must show commitment to the implementation of change in the organisation. Implementation often proceeds more smoothly if the company can find a "champion at the top.'

A number of authors argued that 'management' must also ensure that the team and its leader are adequately 'equipped' to carry out their tasks. By way of example, Baker (1997) highlighted the need for training for teams and team leaders, warning that the concept of self managed teams may not always be achieved overnight but if implemented correctly improvements in productivity and morale can be achieved.

4.6 'SUB GROUPS' IN THE NPD TEAM

The Sub-Group concept (team within a team) used in Flymo, expanded the role of a team player from 'departmental (functional) specific', to an 'inter-departmental (multi-functional) role, with the 'sub-group leader' gaining useful experience for possible future 'team leader' roles. Examples of typical sub-groups used by Flymo during the development of a number of new products are shown in Fig. 15. In each 'sub group' members of the team were selected by the team leader to manage various key tasks in the project and report progress to the whole team at the monthly team meetings. Sub Group leaders assisted the team leader by having other members of the team managing specific, often specialised, tasks.

The 'sub-group' principle was also described by Smith *et al* (1991) as 'Support Groups' where part-time specialists were used in a team to solve particular problems.

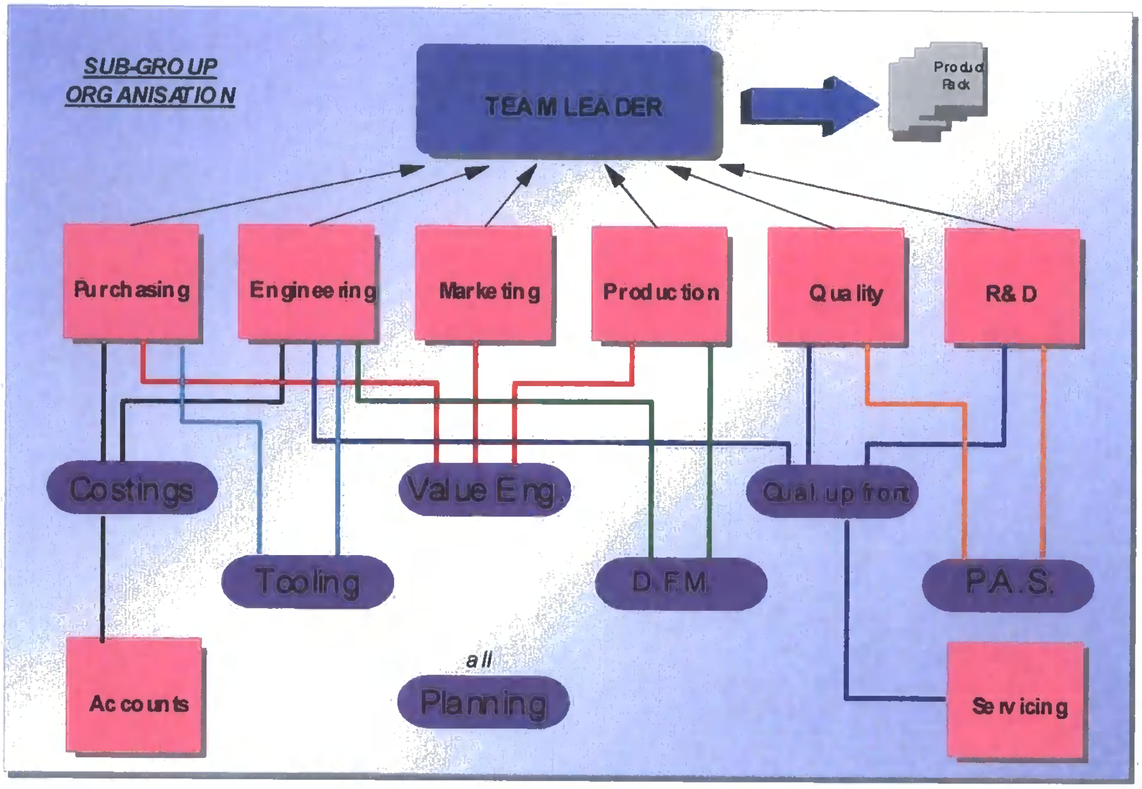


Fig.15 Sub Group organisation used in Flymo Ltd.

The 'sub groups' in Flymo operated as a small 'team within the main team' to address particular issues or tasks in the project. For example, a 'sub group' could be established within the team to ensure that the product packaging was delivered on time to an acceptable specification and cost. The design of packaging for consumer durable products was quite critical for companies like Flymo, and Kenwwood, which involved a number of functional activities, co-ordinated by a 'Sub Group Leader'. The packaging for the Kenwood 'Cuisine' Food Mixer, for example, had the following activities controlled by a Packaging Sub-Group, headed by a Sub-Group Leader from the Purchasing Department in the company:

1. Establish packaging requirements from prototypes and 'Drop Test' criteria.

   Action: Design Engineering, Marketing.

2. Establish Printing requirements and Point Of Sale messages.

   Action: Marketing, Industrial Design and Lithographic Printers.

3. Agree manufacturing methods.

   Action: Production Engineering.

4. Organise the timing for international product launches.

   Action: Sales, Translator.

All of the above activities were co-ordinated with the packaging manufacturer, with the sub-group leader responsible for the successful implementation of this portion of the overall project.

4.7 TEAMWORK IMPLEMENTATION ISSUES

As well as literature supporting the need to develop a 'teamwork culture' in the new product development process, issues associated with the change from the hierarchical structure a structure conducive to teamwork were also identified.

The literature review revealed instances of senior 'departmental' managers outwardly embracing teamwork but believing it to be the responsibility of the 'other departments' to sort out. Arther (1994) described how some traditional departmental managers often resist loosing total controlling authority of people reporting to them, in a functional sense, to a team leader. This must be recognised by the senior management when setting objectives for departmental managers.

Strong views are also portrayed in a marketing book by Jobber (1995) who whilst asserting the 'Importance of teamwork' argued that:

"The challenge is to prevent technical people developing only things that interest them professionally, and to get them to understand the realities of the market place"

In a similar way Bawdawy (1987) discussed cases where some product designers viewed the involvement of multi-functional team as 'contaminating' the product design and therefore resisted input from other functions. Bawdawy explained that: 'Designers often find the persistence of other members of the team to: reduce costs, modify the specification or remove an 'over engineered' feature as an irritation, unless the benefits are clearly explained to them by the team leader or their senior manager.'

In a similar way, Brooks (1980) discussed functional team members, as well as designers, often viewing a multi-functional intervention as an irritation. He claimed that this was a common excuse used to avoid the need to involve others, is that 'it wastes time', which may be indicative of poor understanding of the role of teams in an organisation.

Many organisations have R&D centres in different geographical locations, sometimes different countries from the assembly plants, with the sales and marketing functions in another location. By way of example, Hartley *et al* (1991) discussed problems associated with diverse geographical locations and regular team communication arguing that co-location of the team may help to improve the team's ability to work together. Alternatively, new technologies such as video conferencing are helping many organisations to keep in touch with their people around the world.

With regards to supplier involvement, Bonaccorsi *et al* (1994), claimed that key suppliers to an organisation might not be comfortable with an 'open book' teamwork relationship, without understanding and sharing in the mutual benefits. This is exacerbated if there was a mutual distrust between supplier and producer. Supplier relationships would need development, which may take time if the producer has historically dominated the supplier with demands and threats.

Perry (1997), argued that: '...some functional managers do not always empower their people which prevents the team members making decisions without consultation back to their manager, thus wasting time. Also, individuals may not want to take the responsibility for fear of regression and therefore need support and encouragement from their senior managers. Griffith also argued that one reason why teams fail is because of senior management failure to work well together. Burns *et al* (1995) also made the point that 'no concern, it is safe to say, is without political or social conflicts which generate, or contribute to, manifest inefficiencies of communication within a working organisation.'

In order to create a climate for innovation and to build an enduring company Ahamed (1998) recognised that it is vitally important for senior management to understand the 'soft side' of the organisation. Poolton (1994) also cites examples where teamwork fails in some organisations because of poor support and preparation by the senior management in a firm and their failure to recognise the 'softer' or psychological aspects of the organisation. A common problem recognised by Pooton was the interface between the Sales team members and the Design Engineering team.

Some companies have initiated programs to radically change the way in which they operate, to improve their performance. Hammer *et al* (1993) presented a methodology of Business Process Re-Engineering to maximise the efficiency of an organisation, which includes the methods used to develop new products. The methodology involved a complete 'rethink' of the stages involved in a process-, which may have evolved in an organisation over a long period, which may now be outdated. The managing director of Flymo issued copies of Hammer's book to all of the senior mangers in the organisation however few managers embraced the concept.

According to Drago *et al* (1997) Business Process Re-Engineering was 'oversold' and has failed; claiming that even Hammer has 'had a change of heart'. Drago focused on problems such as: low morale, declining performance, discrepancies in the performance across a company and threats to core competencies. Morgan *et al* (1997) stated that: 'Change is a slow process and that change needs to be sustained', concluding that: 'change leaders should constantly challenge people to test, recalibrate and improve their processes.' Perry (1997) argued that a change over to a teamwork culture is likely to meet with some resistance and that management must help the team to develop their skills to perform efficiently.

Eby *et al* (1997) asserts that there is little empirical evidence to assist practitioners in team implementation initiatives and that there is a limitation in existing research to provide practical guidance and evidence. This research will attempt to provide empirical data from case studies in teamwork NPD projects.

4.8 TOOLS TO ASSIST TEAMWORK IN NEW PRODUCT DEVELOPMENT

A number of 'tools' have been developed over the years, mainly by the Japanese, to assist multifunctional teams to carry out investigations to improve product quality and cost effectiveness of the new product. Some of the most popular will be briefly discussed in this next section.

4.8.1 QUALITY FUNCTION DEPLOYMENT (Q.F.D.)

First used in the Kobe Shipyards Japan in 1972, Quality Function Deployment is a translation of six Kanji characters (Japanese characters) Hin Shitsu Ki No Ten Kai, which describes a process of 'deploying' the voice of the customer into a new product design specification and deliverables. Yoji Akao is widely regarded as the father of QFD and his work led to its first implementation at the Mitsubishi Heavy Industries Kobe Shipyard in 1972. The interest in QFD in the West was stimulated by reports of the achievements made by Toyota through its application between 1977 and 1984. These included a reduction in product development costs by 61%, a decrease in the development cycle by one third and the virtual elimination of rust related warranty problems.

Yoji Akao defined QFD as "...a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demands into design targets and major quality assurance points to be used throughout the production phase".

It is beyond the scope of this work to provide a comprehensive tutorial for the use and implementation of QFD, which often benefits from a 'workshop' style of learning requiring a number of practical examples to fully illustrate the methodology. The main features of QFD are its focus on meeting customer needs through the use of their actual statements, termed the "Voice of the Customer". It facilitates multidisciplinary teamwork and the use of a comprehensive matrix for documenting information, perceptions and decisions. This matrix is commonly referred to as the Kawakita Jiro or the "House of Quality", and is often perceived to represent QFD in its entirety.

The QFD technique is designed to highlight the attributes of customers' requirements, and then to explore the most efficient way of 'deploying' those requirements into a new product. Today many companies use QFD in the development of new products and as a tool to improve existing products. Toyota, for example used a QFD process to help reduce a car's susceptibility to rust. Other practitioners include: The Ford Motor Company, General Motors, Nissan, BMW and Rover, together with many consumer durable manufacturers such as Electrolux, Flymo, Black & Decker and Hitachi. QFD is also used in the electronics industries and defence industries to assist the product development teams to clearly define improvement objectives for the product designers to implement.

Wight (1993) provided a checklist for industrial operational excellence, which included new product development, to help managers to constantly monitor the progress and effectiveness of NPD teams. Wight referred to team tools such as Quality Function Deployment (QFD) to, not only assist the team to derive the true requirements of the customer, but to also assist the team to *work together*. Ginn *et al* (1998) discussed the link between QFD and FMEA, which were viewed as more than just technical tools but are in practice communication tools that act as a catalyst to spark off teamwork. Ginn argued that, if QFD and FMEA were used together, they enable company wide cross-functional teams to share like-minded goals. Moreover, there is no reason why multi-disciplinary teams involved in QFD and FMEA, cannot be one and the same. Ginn claimed that it is the interaction of the two tools that supports the argument - FMEA can be used as a design and planning tool, with QFD, while QFD can be used as a problem solving tool, with FMEA.

4.8.2 FAILURE MODE AND EFFECTS ANALYSIS - F.M.E.A.

FMEA is an analytical technique to establish failure weaknesses in a product or new product proposal or process. It is a technique whereby a number of 'what-if' scenarios are presented to a team of people involved in the development of a new product or process, for further analysis. FMEA is usually conducted as a 'brainstorm' type session with the intention of highlighting all of the possible modes in which a product or process can go wrong, structurally fail or lead to disappointment and misunderstanding of the value of the product to the customer. The 'failure modes' are then assessed in terms of severity, followed by suggested corrective action. An FMEA investigation can be carried out from a number of viewpoints:

1. DESIGN FMEA - An investigation questioning the design construction and function of a complete new product.
2. COMPONENT FMEA - An Investigation questioning the suitability of the individual components comprising the complete product.
3. PROCESS FMEA - An investigation questioning the processes involved in the manufacture and build of a product.

4.8.3 DESIGN FOR MANUFACTURE - DFM

Design For Manufacturing (DFM) is a technique used in manufacturing industry to encourage a design team to consider appropriate manufacturing methods and capability of the organisation, in the development of a new product. It is a multi-disciplinary exercise where the accountability for ensuring the product can be manufactured in the most efficient manner involves manufacturing personnel involvement as well as designers. Nissan, frequently invite their suppliers (guest engineers) to DFM meetings to ensure key sub-assemblies are mutually suitable for incorporation in their new vehicles.

4.9 CONCLUSIONS FROM THIS CHAPTER

A popular theme identified in the extant literature on the New Product Development was the use of multi functional teams in the process, with the following cited as being some of the benefits:

1. Reduced Time to Market.
2. Improved product Quality.
3. Reduced development costs.

Very little evidence was provided in the literature to support the above claims with no consistent measurement methodology presented. It was identified that many tools such as FMEA and DFM, provide additional benefits when conducted within a multifunctional environment however, there was no clear method identified to quantify the benefits. It was clear that in order to provide the best environment for teamwork an organisation must review its structure carefully and clearly define roles of all of the team players, including functional managers. It was also concluded that a multifunctional teamwork implementation usually requires a complete review of the NPD methodology used in a company however, again, there was no clear method identified how to quantify the effects of changes in NPD methodologies. NPD measurement methods are addressed later in this research.

Potential issues were identified with regard to the 'cultural changes' required to accommodate a multifunctional way of working which included associated changes in the roles of functional managers. Many companies have minimised 'cultural change' issues by involving functional managers in the design of a new multifunctional NPD methodology.

CHAPTER FIVE

NPD METHODOLOGY AND PROJECT MANAGEMENT

5.1 INTRODUCTION

From the literature review, there were many reasons postulated to explain the cause of delays in NPD projects attributed to poor methodology. Traditional 'over-the-wall' techniques were identified as inefficient, with multi-functional teams or Simultaneous Engineering cited as the most efficient resource structure to minimize NPD introduction time. A great deal of literature has also been published about the claimed benefits of using 'strategic tools' in NPD such as FMEA, DFM, VE, QFD, Design for Six Sigma (see glossary for definitions) to reduce the causes of project delays and improve product quality. However, Cooper (1993) argued that NPD project teams and the 'tools' they use, must also have a suitable Project Management system in order to ensure successful delivery of a new product. Cooper (1993) therefore commercialised a project management system called *Stage Gate$_R$*, which divides a project up into a series of manageable stages defined by milestone checkpoints. Each checkpoint or *Stage Gate$_R$* is configured in a Gantt Chart plan together with control documentation to ensure that the key activities between each checkpoint are properly planned and executed before the project is allowed to progress to the next *Stage Gate$_R$*. Many consumer durable manufacturers have adopted project management systems similar to Cooper's *Stage Gate$_R$*

technique. For example Black and Decker use a system called *'Toll Gate'*, whilst Flymo call their PM system Product Introduction Control (PIC).

A popular theme from the review of previous work was that NPD projects benefit from the application of multi functional structures using various strategic 'tools', with a contextually appropriate project management system. The collective application of Human Resource Structures, Strategic Tools and Project Management techniques are referred to here, as the NPD methodology, which may be defined as:
'A business process employed to ensure the successful delivery of new products through the organisation of people using supporting tools, within the scope of a Project Management system.' (Author)

Wheelwright *et al* (1995) and Cooper (1993) have argued that teamwork, project management and supporting tools such as FMEA provide 'mutually supporting' benefits to a project. By way of example FMEA and DFM studies may benefit from the involvement of a multifunctional contribution, planned at a strategic time in a project. Alternatively, teamwork in a project may be enhanced through structured investigations such as QFD. The author has depicted the three mutually supporting members of an NPD Methodology in an NPD Collective Triangle shown graphically in Fig. 16.

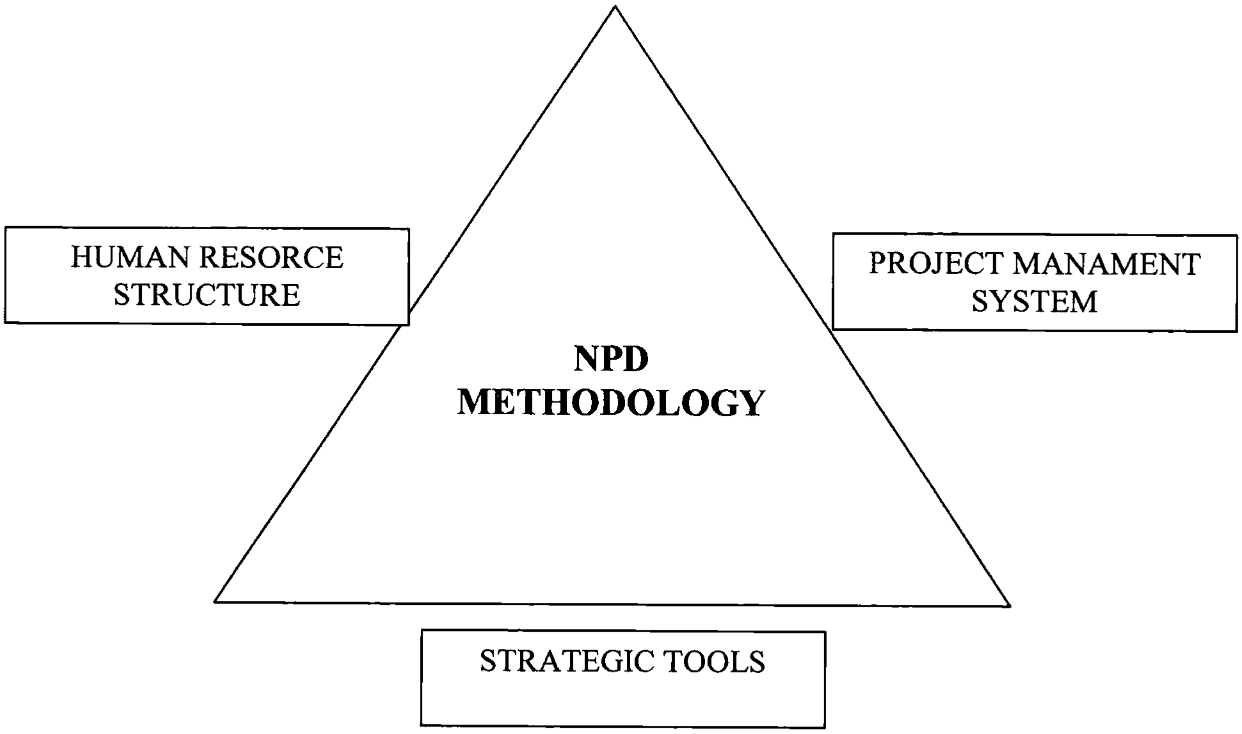


Fig.16. Mutually supporting members of the NPD collective triangle. (Author)

5.2 NPD PROJECT MANAGEMENT SYSTEM

The subject of teamwork and supporting tools have already been discussed in this research therefore the role of Project Management will now be reviewed. The definition of Project Management may be derived from the definition of a project. If a Project is defined as:

'An individual or collaborative enterprise that is carefully planned and designed to achieve a particular aim.' (Oxford Dictionary) then, Project Management may be defined as:

'The planning, design and coordination of an individual or collective enterprise to ensure that a particular aim is achieved."

This section has been included in order to identify the requirements of a *robust* Project Management System as part of a collective NPD methodology. Consistent with many authors such as Cooper (1993), Jobber (1995), Cooper (1993) and Smith *et al* (1991), a 'Project Management System is used to monitor and track the course of a project and define its deliverables. The objective is to ensure that the new product is delivered on time, to specification and within financial constraints of a pre-defined business plan.'

It is clear from the literature review that many NPD projects benefit from the use of multi-functional teams. However, according to Randolph *et al* (1992), 'Without the application of some basic project management techniques projects are likely to fail to deliver all or some of their objectives. Moreover, poor communication within the NPD team can create a misunderstanding of the deliverables and cost targets causing delays in launching a product. Therefore, a Project Management System should provide adequate communication media in the way of control documentation with regular meetings chaired by a project manager, or Team Leader, to discuss their content.' The control documentation according to Randolph *et al* (1992) may include some or all of the following: -

1. A Project Plan containing a critical path analysis.
2. Product deliverables and Specification list.
3. Product Cost status spreadsheet.
4. Capital investment status spreadsheet.
5. 'Issues and actions' document.
6. Team member list and contact details.
7. Business Plan.
8. Resource planning with appropriate management protocols must be applied.

In support of the above, Jeffrey *et al* (2003) argued that:

"Planning provides a NPD team with detailed rules and procedures to follow by specifying activities to be performed and the obstacles to be overcome. Details such as product specification, well-defined target markets and suitable technologies need to be identified and managed."

Jeffrey *et al* (2003) researched links between Project Management characteristics and New Product survival and concluded that: 'Firms can improve cross-functional integration and planning through various project management practices'. His study confirmed links in the extant literature between situational (project management) dimensions, structural dimensions and outcome dimensions of NPD.

It is interesting to see the link between 'good project management techniques' and creating an environment conducive to 'multi-functional teamwork'. This is a view supported by the author on the basis that NPD teams may differ substantially in their experience in developing new products and may benefit from the establishment of some 'ground rules' to help with the planning of the project. Maffin (1996) also supported the 'mutually supporting link' of teamwork and project management methods as part of an NPD methodology and asserted the need for companies to select a project management system 'within a contextual framework' appropriate to the organisation concerned.

In a similar way, Reinertsen (1991) stressed the importance of applying appropriate project management techniques in New Product Development projects to achieve the desired outcome. He also identified the following parameters for close control by project managers to ensure successful NPD performance: -

1. Product specifications should be written jointly between design and marketing functions.
2. There is a clear need for a project plan for the NPD project that has had the involvement of the whole team in its construction.
3. NPD projects will benefit from clear control documentation to monitor and report to senior management the status of a project.

Case studies have shown that, even when an NPD project has multi-functional participation, there is a need for clear planning and control of various aspects of the project to ensure that the product is delivered successfully. This includes the control documentation proposed by Randolph *et al* (1992) discussed above.

Many authors such as Smith (1991), Randolph (1991) and Hartley *et al* (1992) recommended that organisations develop a Gantt chart template for the introduction of new products. This is to ensure that the activities of each function are not omitted and are appropriately planned in each project undertaken without the need to plan each project from scratch.

A well-designed project management system can help to promote efficient communication within a team during a project, according to Randolph *et al* (1992) who also emphasised the need for management to:

"Set clear goals for project teams and to ensure that project deliverables are communicated to the whole team. Moreover it is also vital that the whole team are committed to project deliverables and time-scales. In order to achieve this there must be clear communications established in a NPD team supported by a robust project management system."

Cooper (1993) stressed that team participation in the planning and specification of the new product is essential to ensure joint ownership of the project objectives is established. Without the team involvement, Smith *et al* (1991) argued that it is difficult to get the team to 'sign up' to the deliverables of the project and often leads to a *'Fuzzy Front End'* with the associated risk of time delays.

In a similar theme, Jobber (1995) claimed that one of the causes of delays in NPD projects is the failure of the NPD team to clearly establish and agree the project deliverables in a timely and controlled way. However, difficulties often arise between the Engineering and the Marketing team members in deciding who is responsible for writing the 'product design specification'. In discussing this question, Jobber (1995) reports that this often leads to conflict between the two functions.

The author has also experienced some NPD projects where 'deadlock' existed between and the Engineering and the Marketing team members and the whole project was delayed in starting. Conflicts often arise and each function may take the view that it is the other one's responsibility to provide the 'product design brief'. Case studies have shown that even when the 'product design brief' document existed, the specification was changed so many times (specification changes) that it became difficult to identify the current status of the project. Many authors, such as Smith *et al* (1991) have described this as the *Fuzzy Front End* and one of the main causes of delays in NPD projects. To avoid the *Fuzzy Front End* Randolph *et al* (1992) recommended the formulation of a project management documentation system to provide a basis for control by the project manager. The control documentation may be used to define the agreed objectives, project deliverables and target costs / dates of the project.

5.3 PROJECT MANAGEMENT CONTROL DOCUMENTATION

Following the above discussion, it was decided to configure a pack of control documentation for use in case studies. The following NPD KPIs, identified earlier in this study, are listed together with an appropriate Project Management vehicle to assist their control in a project:

1. Accuracy of Launch – This KPI gives an indication of how accurately a project was launched with respect to a planned launch date. The vehicle for monitoring this parameter is a project plan. A Gantt chart project plan is also beneficial to help a Project Manager to coordinate all of the activities in the project and to identify the 'critical path' to launch. The plan may include key milestones and activities in a project and who is accountable for each activity.
2. Product Costs – The project management vehicle to monitor this parameter could be a simple spreadsheet to monitor the status of product costs during the project. The document will also show the 'make up' detail of the product costs such as materials, labour, royalties and overheads etc.
3. Capital Costs – again a simple spreadsheet may be used to monitor the status of product Capital costs during the project. As discussed earlier, this is essentially the cost for tooling but may contain other capital investments such as patent, approvals, assembly equipment and advertising.
4. The Project Deliverables - a document 'vehicle' to monitor and report the status of the project deliverables is useful to avoid misunderstandings of the objectives.

A Summary Sheet showing the key parameters from the above documents will also be included as part of the NPD product pack. The summary sheet is useful for presentations to senior managers who may only be interested in the key details when reviewing many projects at a time: -

5. NPD Summary Sheet - This is a 'single sheet' document detailing, in a very concise way, the specification deliverables of the product, costing and investment targets and key dates in the project on one sheet of paper. This sheet could be used as an 'overhead' summary of the project for the NPD team and senior management meetings showing the essential data.

The NPD Product Pack project control documents are shown in Fig.17.

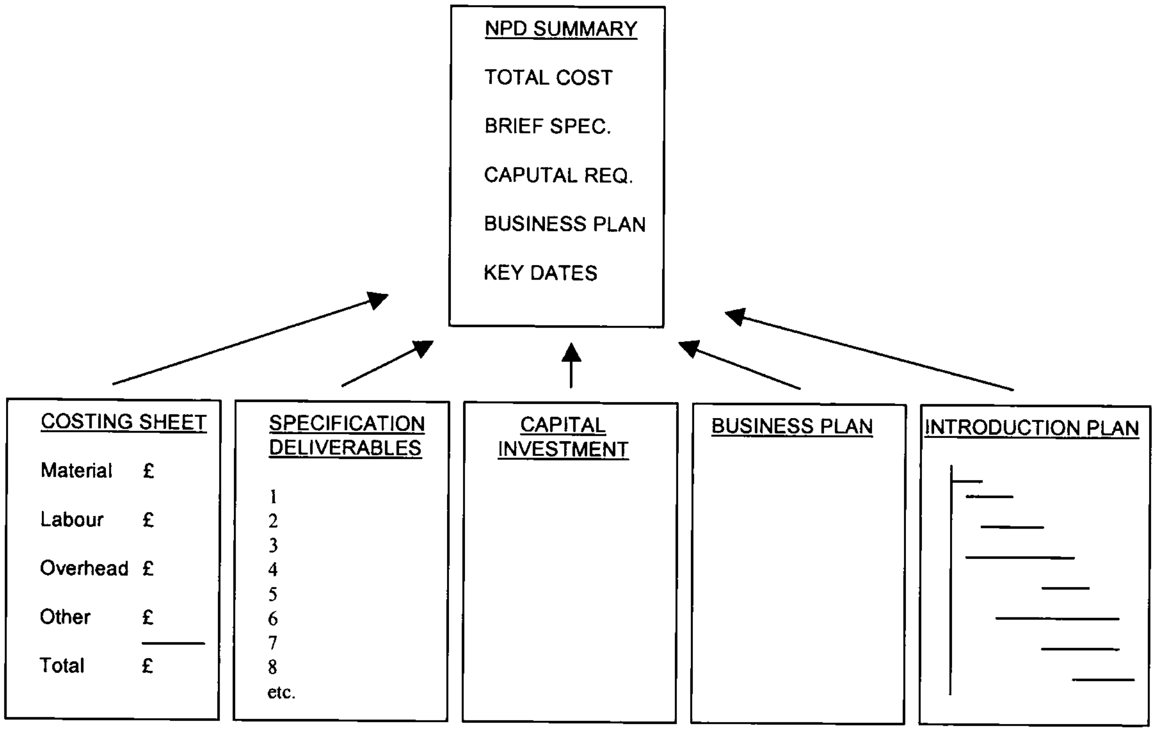
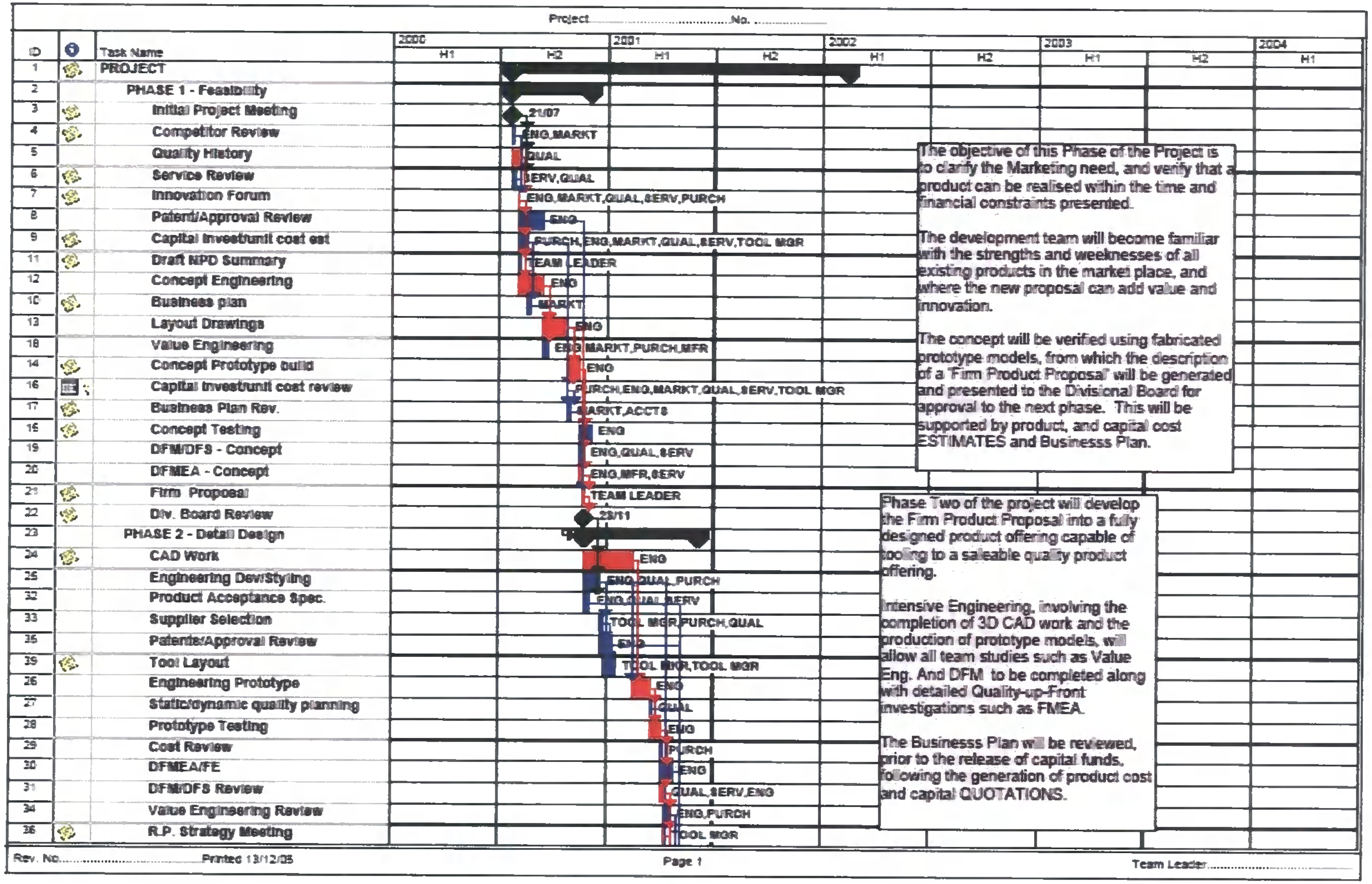


Fig.17 NPD Product Pack project control documents.

As suggested by Hartley *et al* (1992) the Project Plan may derive from a 'template' Gantt Chart identifying the critical activities for the development of the new product, including the key milestones. By way of example, the NPD project template shown in Fig.18 and Fig.19 used by a consumer durable company splits the project up into PHASES. Splitting the project into phases enables a project manager to understand and communicate to senior managers the progress of the project. In the example shown each phase has a specific objective in the project with defining notes printed for the guidance of the user.

Examples are also shown of project control documentation Fig.20 to Fig.24 from an industrial product manufacturer.

(The commercial details in the following documents have been disguised or erased for display in the public domain)



Project..No. ....

ID	Task Name	2000–2004
1	PROJECT	
2	PHASE 1 - Feasibility	
3	Initial Project Meeting	21/07
4	Competitor Review	ENG,MARKT
5	Quality History	QUAL
6	Service Review	SERV,QUAL
7	Innovation Forum	ENG,MARKT,QUAL,SERV,PURCH
8	Patent/Approval Review	ENG
9	Capital invest/unit cost est	PURCH,ENG,MARKT,QUAL,SERV,TOOL MGR
11	Draft NPD Summary	TEAM LEADER
12	Concept Engineering	ENG
10	Business plan	MARKT
13	Layout Drawings	ENG
18	Value Engineering	ENG,MARKT,PURCH,MFR
14	Concept Prototype build	ENG
16	Capital invest/unit cost review	PURCH,ENG,MARKT,QUAL,SERV,TOOL MGR
17	Business Plan Rev.	MARKT,ACCTS
15	Concept Testing	ENG
19	DFM/DFS - Concept	ENG,QUAL,SERV
20	DFMEA - Concept	ENG,MFR,SERV
21	Firm Proposal	TEAM LEADER
22	Div. Board Review	23/11
23	PHASE 2 - Detail Design	
24	CAD Work	ENG
25	Engineering Dev/Styling	ENG,QUAL,PURCH
32	Product Acceptance Spec.	ENG,QUAL,SERV
33	Supplier Selection	TOOL MGR,PURCH,QUAL
35	Patents/Approval Review	ENG
39	Tool Layout	TOOL MKR,TOOL MGR
26	Engineering Prototype	ENG
27	Static/dynamic quality planning	QUAL
28	Prototype Testing	ENG
29	Cost Review	PURCH
30	DFMEA/FE	ENG
31	DFM/DFS Review	QUAL,SERV,ENG
34	Value Engineering Review	ENG,PURCH
36	R.P. Strategy Meeting	TOOL MGR

The objective of this Phase of the Project is to clarify the Marketing need, and verify that a product can be realised within the time and financial constraints presented.

The development team will become familiar with the strengths and weeknesses of all existing products in the market place, and where the new proposal can add value and innovation.

The concept will be verified using fabricated prototype models, from which the description of a 'Firm Product Proposal' will be generated and presented to the Divisional Board for approval to the next phase. This will be supported by product, and capital cost ESTIMATES and Businesss Plan.

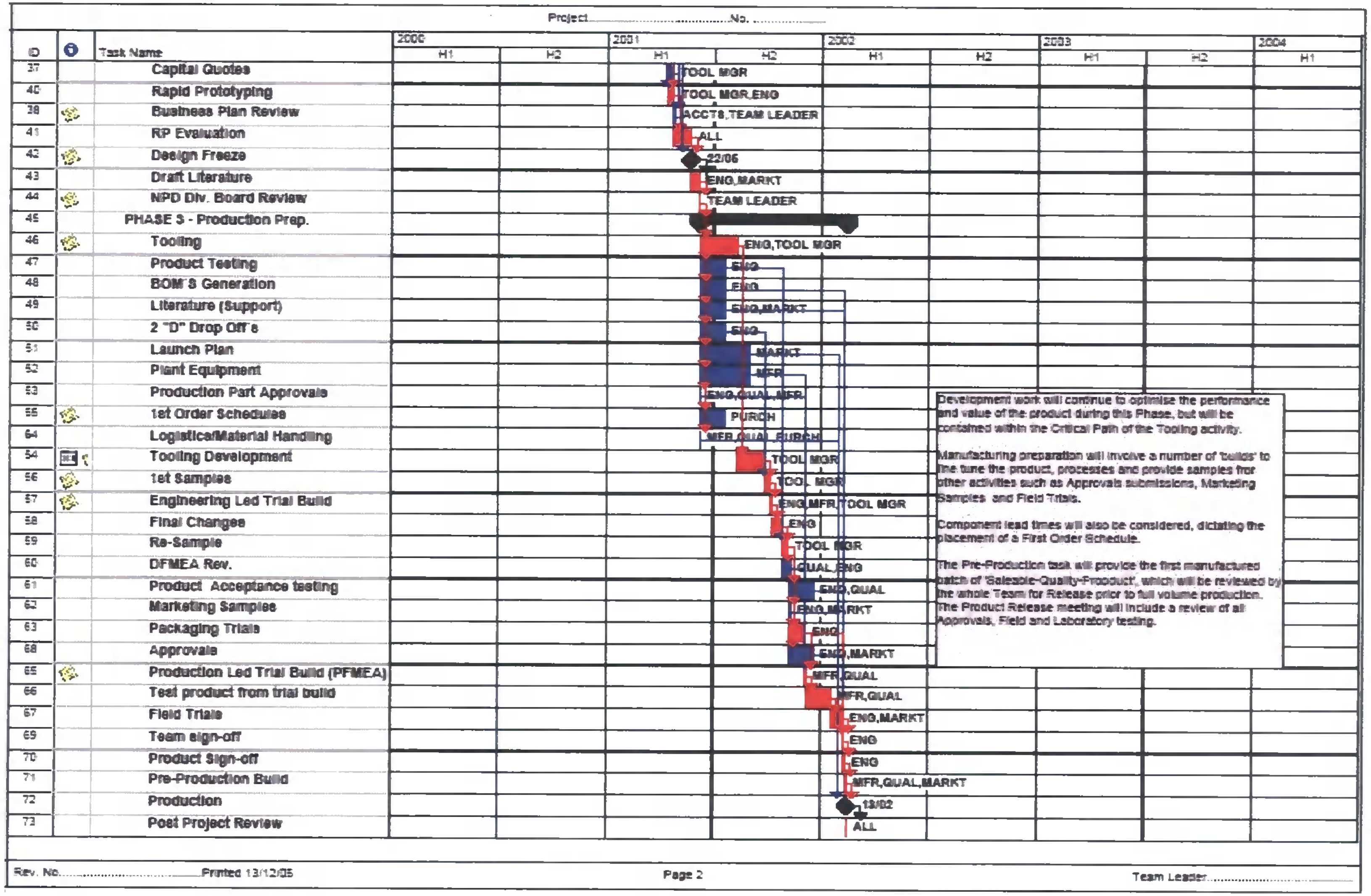
Phase Two of the project will develop the Firm Product Proposal into a fully designed product offering capable of tooling to a saleable quality product offering.

Intensive Engineering, involving the completion of 3D CAD work and the production of prototype models, will allow all team studies such as Value Eng. And DFM to be completed along with detailed Quality-up-Front investigations such as FMEA.

The Businesss Plan will be reviewed, prior to the release of capital funds, following the generation of product cost and capital QUOTATIONS.

Rev. No...Printed 13/12/05 Page 1 Team Leader..............................

Fig 18 NPD introduction Template Gantt Chart sheet one.



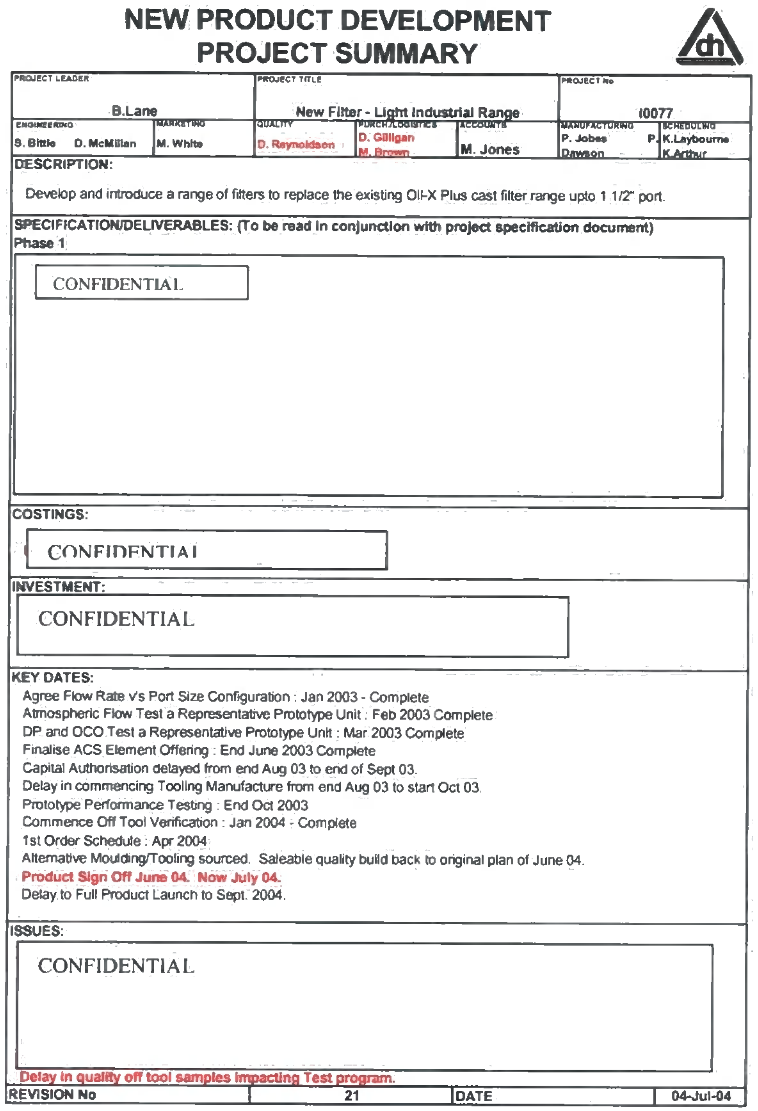
Development work will continue to optimise the performance and value of the product during this Phase, but will be contained within the Critical Path of the Tooling activity.

Manufacturing preparation will involve a number of 'builds' to fine tune the product, processes and provide samples for other activities such as Approvals submissions, Marketing Samples and Field Trials.

Component lead times will also be considered, dictating the placement of a First Order Schedule.

The Pre-Production task will provide the first manufactured batch of 'Saleable-Quality-Product', which will be reviewed by the whole Team for Release prior to full volume production. The Product Release meeting will include a review of all Approvals, Field and Laboratory testing.

Fig 19 NPD introduction Template Gantt Chart sheet two.



NEW PRODUCT DEVELOPMENT
PROJECT SUMMARY

PROJECT LEADER		PROJECT TITLE			PROJECT No	
B.Lane		New Filter - Light Industrial Range			I0077	
ENGINEERING	MARKETING	QUALITY	PURCH/LOGISTICS	ACCOUNTS	MANUFACTURING	SCHEDULING
S. Bittle D. McMillan	M. White	D. Reynoldson	D. Gilligan M. Brown	M. Jones	P. Jobes P. Dawson	K.Laybourne K.Arthur

DESCRIPTION:

Develop and introduce a range of filters to replace the existing Oil-X Plus cast filter range upto 1 1/2" port.

SPECIFICATION/DELIVERABLES: (To be read in conjunction with project specification document)

Phase 1

CONFIDENTIAL

COSTINGS:

CONFIDENTIAL

INVESTMENT:

CONFIDENTIAL

KEY DATES:

Agree Flow Rate Vs Port Size Configuration : Jan 2003 - Complete
Atmospheric Flow Test a Representative Prototype Unit : Feb 2003 Complete
DP and OCO Test a Representative Prototype Unit : Mar 2003 Complete
Finalise ACS Element Offering : End June 2003 Complete
Capital Authorisation delayed from end Aug 03 to end of Sept 03.
Delay in commencing Tooling Manufacture from end Aug 03 to start Oct 03.
Prototype Performance Testing : End Oct 2003
Commence Off Tool Verification : Jan 2004 - Complete
1st Order Schedule : Apr 2004
Alternative Moulding/Tooling sourced. Saleable quality build back to original plan of June 04.
Product Sign Off June 04. Now July 04.
Delay to Full Product Launch to Sept. 2004.

ISSUES:

CONFIDENTIAL

Delay in quality off tool samples impacting Test program.

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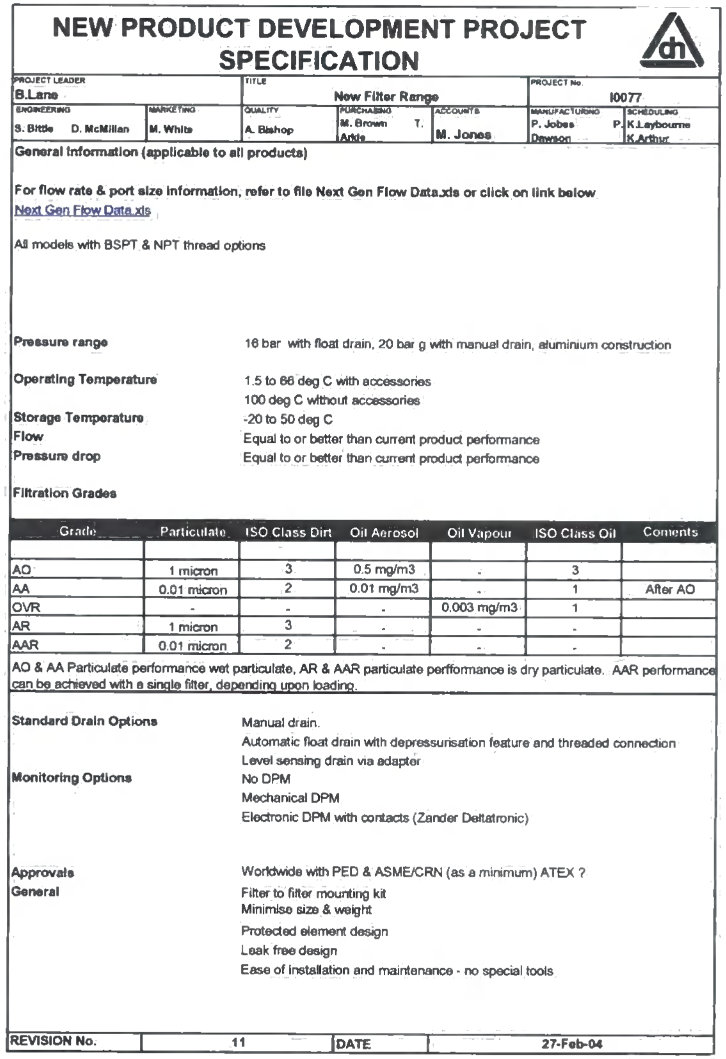
Fig. 20 NPD Summary Sheet example



NEW PRODUCT DEVELOPMENT PROJECT
SPECIFICATION

PROJECT LEADER		TITLE			PROJECT No.	
B.Lane		New Filter Range			I0077	
ENGINEERING	MARKETING	QUALITY	PURCHASING	ACCOUNTS	MANUFACTURING	SCHEDULING
S. Bittle D. McMillan	M. White	A. Bishop	M. Brown T. Arkle	M. Jones	P. Jobes P. Dawson	K.Laybourne K.Arthur

General Information (applicable to all products)

For flow rate & port size information, refer to file Next Gen Flow Data.xls or click on link below
Next Gen Flow Data.xls

All models with BSPT & NPT thread options

Pressure range	16 bar with float drain, 20 bar g with manual drain, aluminium construction
Operating Temperature	1.5 to 66 deg C with accessories 100 deg C without accessories
Storage Temperature	-20 to 50 deg C
Flow	Equal to or better than current product performance
Pressure drop	Equal to or better than current product performance

Filtration Grades

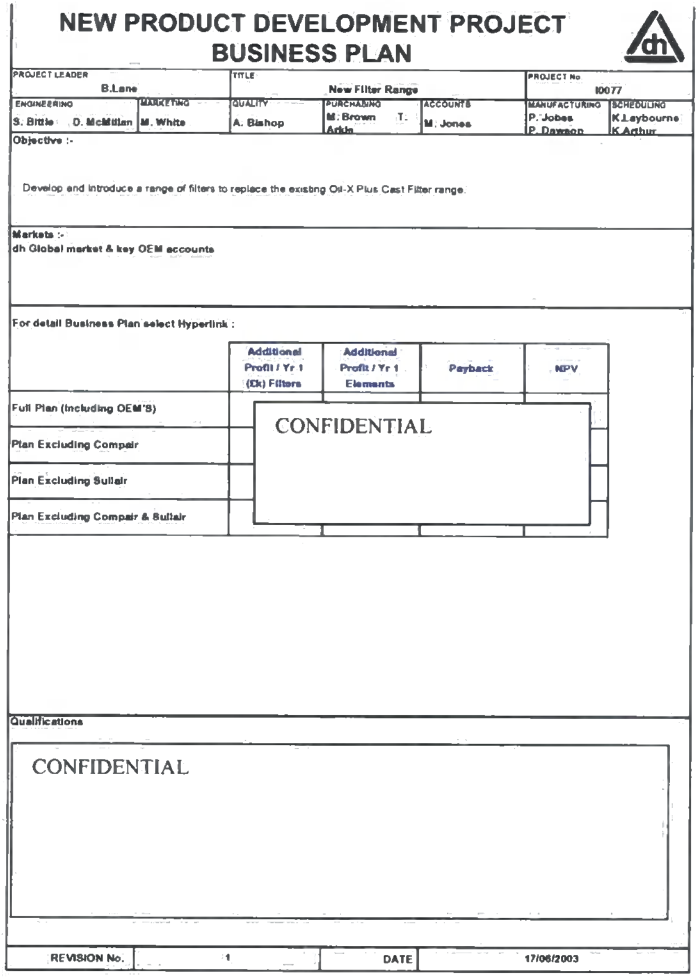
Grade	Particulate	ISO Class Dirt	Oil Aerosol	Oil Vapour	ISO Class Oil	Coments
AO	1 micron	3	0.5 mg/m3	-	3	
AA	0.01 micron	2	0.01 mg/m3	-	1	After AO
OVR	-	-	-	0.003 mg/m3	1	
AR	1 micron	3	-	-	-	
AAR	0.01 micron	2	-	-	-	

AO & AA Particulate performance wet particulate, AR & AAR particulate perfformance is dry particulate. AAR performance can be achieved with a single filter, depending upon loading.

Standard Drain Options	Manual drain. Automatic float drain with depressurisation feature and threaded connection Level sensing drain via adapter
Monitoring Options	No DPM Mechanical DPM Electronic DPM with contacts (Zander Deltatronic)
Approvals	Worldwide with PED & ASME/CRN (as a minimum) ATEX ?
General	Filter to filter mounting kit Minimise size & weight Protected element design Leak free design Ease of installation and maintenance - no special tools

REVISION No.	11	DATE	27-Feb-04

Fig.21. NPD Project Specification Sheet example



NEW PRODUCT DEVELOPMENT PROJECT BUSINESS PLAN

PROJECT LEADER B.Lane	TITLE New Filter Range		PROJECT No I0077

ENGINEERING S. Bittle D. McMillan	MARKETING M. White	QUALITY A. Bishop	PURCHASING M. Brown T. Arkle	ACCOUNTS M. Jones	MANUFACTURING P. Jobes P. Dawson	SCHEDULING K.Laybourne K.Arthur

Objective :-

Develop and introduce a range of filters to replace the existing Oil-X Plus Cast Filter range.

Markets :-
dh Global market & key OEM accounts

For detail Business Plan select Hyperlink :

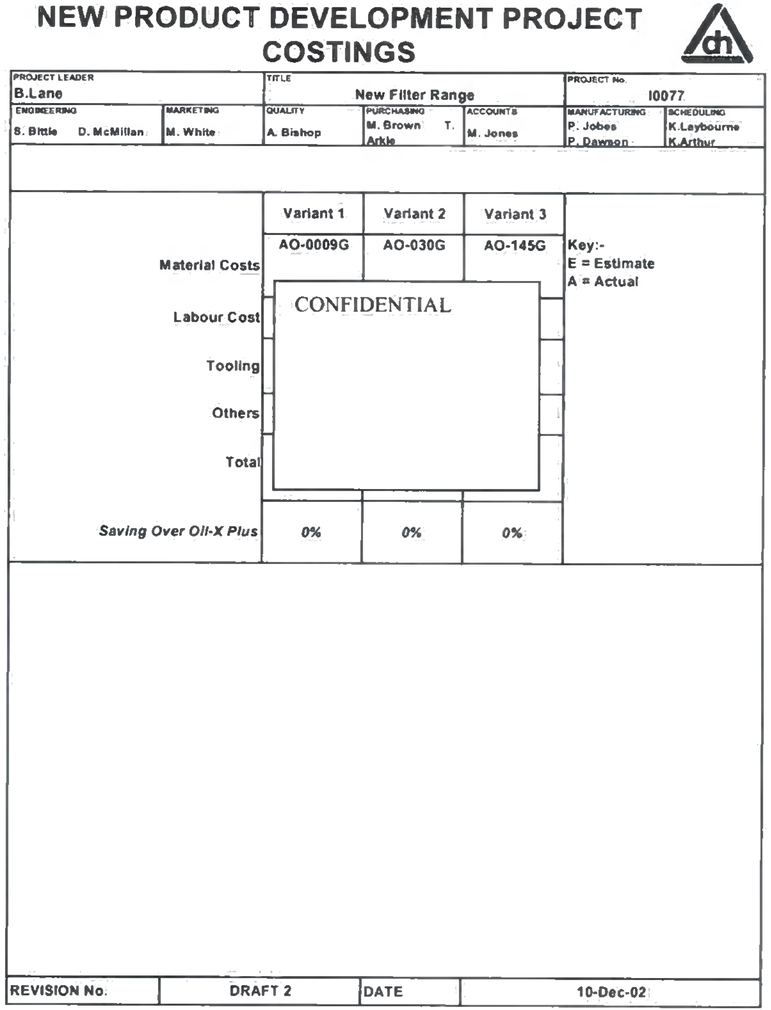
	Additional Profit / Yr 1 (£k) Filters	Additional Profit / Yr 1 Elements	Payback	NPV
Full Plan (Including OEM'S)	CONFIDENTIAL			
Plan Excluding Compair				
Plan Excluding Sullair				
Plan Excluding Compair & Sullair				

Qualifications

CONFIDENTIAL

REVISION No.	1	DATE	17/06/2003

Fig.22 NPD Business Plan Sheet example.



NEW PRODUCT DEVELOPMENT PROJECT COSTINGS

PROJECT LEADER B.Lane	TITLE New Filter Range	PROJECT No. I0077

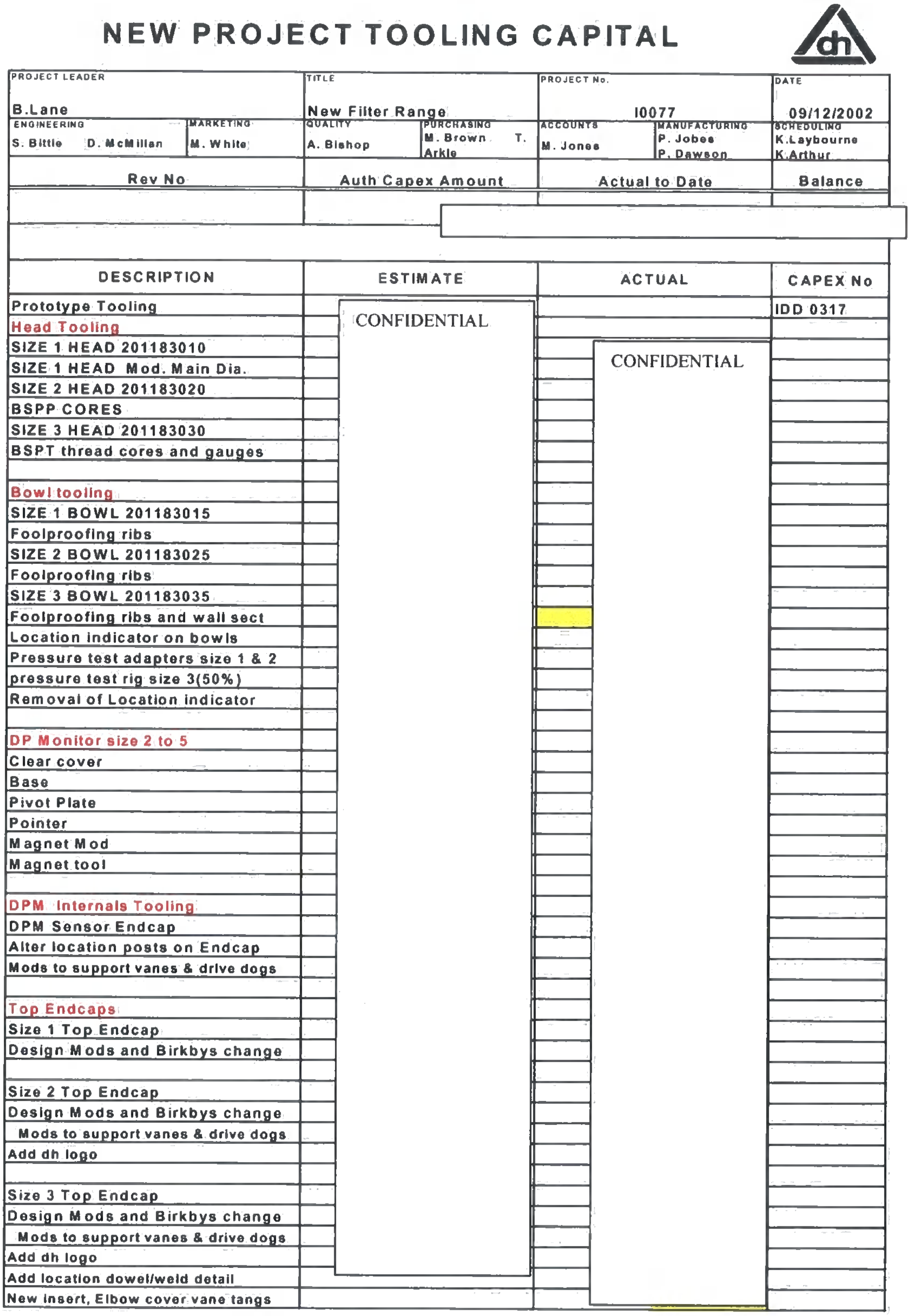
ENGINEERING S. Bittle D. McMillan	MARKETING M. White	QUALITY A. Bishop	PURCHASING M. Brown T. Arkle	ACCOUNTS M. Jones	MANUFACTURING P. Jobes P. Dawson	SCHEDULING K.Laybourne K.Arthur

	Variant 1	Variant 2	Variant 3
	AO-0009G	AO-030G	AO-145G
Material Costs	CONFIDENTIAL		
Labour Cost			
Tooling			
Others			
Total			
Saving Over Oil-X Plus	0%	0%	0%

Key:-
E = Estimate
A = Actual

REVISION No.	DRAFT 2	DATE	10-Dec-02

Fig.23 NPD Product Costing Sheet example.



NEW PROJECT TOOLING CAPITAL

PROJECT LEADER B.Lane	TITLE New Filter Range	PROJECT No. 10077	DATE 09/12/2002
ENGINEERING S. Bittle D. McMillan MARKETING M. White	QUALITY A. Bishop PURCHASING M. Brown T. Arkle	ACCOUNTS M. Jones MANUFACTURING P. Jobes P. Dawson	SCHEDULING K.Laybourne K.Arthur
Rev No	Auth Capex Amount	Actual to Date	Balance

DESCRIPTION	ESTIMATE	ACTUAL	CAPEX No
Prototype Tooling			IDD 0317
Head Tooling	CONFIDENTIAL		
SIZE 1 HEAD 201183010			
SIZE 1 HEAD Mod. Main Dia.		CONFIDENTIAL	
SIZE 2 HEAD 201183020			
BSPP CORES			
SIZE 3 HEAD 201183030			
BSPT thread cores and gauges			
Bowl tooling			
SIZE 1 BOWL 201183015			
Foolproofing ribs			
SIZE 2 BOWL 201183025			
Foolproofing ribs			
SIZE 3 BOWL 201183035			
Foolproofing ribs and wall sect			
Location indicator on bowls			
Pressure test adapters size 1 & 2			
pressure test rig size 3(50%)			
Removal of Location indicator			
DP Monitor size 2 to 5			
Clear cover			
Base			
Pivot Plate			
Pointer			
Magnet Mod			
Magnet tool			
DPM Internals Tooling			
DPM Sensor Endcap			
Alter location posts on Endcap			
Mods to support vanes & drive dogs			
Top Endcaps			
Size 1 Top Endcap			
Design Mods and Birkbys change			
Size 2 Top Endcap			
Design Mods and Birkbys change			
Mods to support vanes & drive dogs			
Add dh logo			
Size 3 Top Endcap			
Design Mods and Birkbys change			
Mods to support vanes & drive dogs			
Add dh logo			
Add location dowel/weld detail			
New insert, Elbow cover vane tangs			

Fig.24 NPD Capital Spend Sheet example

5.4 CONCLUSIONS FROM THIS CHAPTER

It was concluded from the review of the extant literature, on the NPD process, that effective Project Management techniques could provide the following benefits to a multi functional teamwork project:

1. Clarification of project objectives and deliverables to the team.
2. Agreement of project objectives and deliverables to the senior management.
3. Clarification of individual roles and timing of involvement in a project.
4. Communications of progress of a project and identification of the 'critical path' activities within the team.
5. An overall methodology for the introduction of future projects and therefore a familiarity with the NPD process.
6. Reduced introduction period due to fewer misunderstandings (Fuzzy front end) within the team and key stakeholders of the project.
7. Improved confidence, teamwork and morale in the team due to a feeling of 'being in control'.
8. Efficient use of human resource.
9. Better control of product costs during the project.
10. Better control of investment capital in a project.

It is recognised that NPD projects need to be effectively managed by suitably qualified people working to a contextually appropriate methodology. Without appropriate control and optimisation of the project plan, it would be difficult to quantify process improvements due to other initiatives. Consistent Project Management techniques provide a degree of control, in the scientific sense, for case study experiments thus enabling new techniques to be evaluated and their effects quantified. By way of example it would be difficult to measure the effectiveness, of reducing delays in a project, by employing Rapid Prototyping cycles, without establishing a consistent introduction process and KPIs.

Case studies conducted by the author also suggest that effective Project Management techniques enhance the confidence of a team, particularly when time scales are tight or difficulties occur. The enhanced confidence also leads to enhanced teamwork and cooperation within the team.

CHAPTER SIX

RAPID PROTOTYPING

6.1 PROTOYPING IN THE NPD PROCESS

Prototyping in New Product Development is an activity traditionally used to evaluate a conceptual idea through the realisation and testing of a working model. Clark *et al* (1993) discussed the benefits of prototyping in the N.P.D. process whereby machined or 'hand fabricated' representations of the finished product, or its component parts, are produced to 'verify' fit, form and function. Clark described a series of 'prototyping cycles' in the NPD process to represent the *status* of a product proposal though the various stages of development, in which the development engineer would progressively 'develop' a new product through incremental modifications to the prototype.

Traditional prototype components, relying upon 'human' interpretation of a two dimensional engineering drawing, are often time consuming to produce and may lack the accuracy of a production 'tooled' part. Also, prototype model makers (skilled machinists and craftspersons) occasionally 'mask' small errors and imperfections in the components described in the engineering drawings in order to achieve better fit, form and function. By doing so the designer may not identify the imperfections until the production 'off-tool' parts are produced.

To provide a complete set of traditional prototype parts for a consumer product such as a power tool or kitchen appliance, may be very time consuming and costly. The problem is further exacerbated with modern Industrial Design aesthetic trends, incorporating many complex intersecting ‘soft’ curves and surfaces which, whilst pleasing to the eye, are difficult to describe on two dimensional drawings required for the fabrication of prototype models. Therefore, for the reasons described above, traditional prototyping methods may not always provide a fast and accurate way for NPD teams to evaluate a product concept proposal.

Traditional prototype models, according to Wheelwright (1993), are occasionally produced to test a specific function of a product, which may be an activity confined to the engineering domain only. Case studies, conducted by the author, have shown that ‘multi-functional activities’ such as DFM, FMEA and Value Engineering studies had only been partly completed because the prototype components were not ‘fully representative' of the component described on the CAD machine. Some case studies have required FMEA investigations to be repeated from ‘off tool’ parts, or were not carried out at all because of the poor accuracy of prototype models.

Rapid Prototype (RP) components offer a solution to the problems described above. RP methods provide an opportunity to produce dimensionally accurate components, described in a three dimensional computer generated (CAD) model, within days of the completion of the geometry. RP models have therefore allowed design engineers to quickly and accurately verify ‘fit and form’ and ‘clash detection’ *before* the commitment of production tooling.

Rapid Prototyping was developed in the late 1980’s to offer a fast way of producing prototype components representing a high fidelity facsimile of a three dimensional CAD drawing, without the need for human interpretation, thus allowing potential faults in a design concept to be revealed and corrected efficiently.

According to Kidd (1996), Rapid Prototyping in recent years (since 1990) has provided a number of distinct advantages over traditional prototyping methods, including: -

1. Faster production of complex geometry prototype components.

2. The potential for improved precision of complex geometry prototypes compared to traditional prototyping methods.

Venus (1996), however identified some cautions for NPD teams to be aware of when including RP prototypes in a project, such as: -

1. Rapid Prototyping is still an expensive process.

2. The prototyping materials may not always replicate the mechanical properties of the intended production material.

3. Rapid Prototyping activities may be required in addition to traditional methods, thus adding time and cost to the project.

Much of the available literature describing the benefits of using Rapid Prototyping in product development is anecdotal in nature, produced by practitioners with a commercial interest in the technology. Although a great deal has been written about the technology itself, which is not a key consideration in this work, very little evidence has been presented about the ability of Rapid Prototyping to 'add value' and save cost in a new product development project.

6.2 BRIEF HISTORY OF RAPID PROTOTYPING

Traditional prototyping methods involve machining as a subtractive process, starting with a solid piece of material. A skilled machinist must then carefully remove material until the desired geometry is achieved. For a complex part, this is a time consuming and expensive process. Occasionally some components are so complex that they are cost prohibitive to be machined, compared to the cost of tooling the component. Rapid Prototyping is a method in which a physical component part is created using a *layer-additive* process. Using specialised software, a 3-D CAD model is divided into very thin layers or cross-sections. Then, depending on the specific method used, an automated Rapid Prototyping machine constructs the part layer by layer until a solid replica of the CAD model is generated. Material selection for the component depends upon the RP method used.

Charles Hull developed one of the first solid-imaging RP systems in 1984 in a back-room lab while working for a company in California that made ultraviolet lamps. Some of the lamps were used to treat special coatings that harden when exposed to ultraviolet light. By extending the process, Hull realised that he could make solid objects from light-cured plastics. Labouring long nights and weekends, he finally engineered a computer-guided light beam system to scan in a precise pattern on the surface of a basin containing a polymer resin. After the jittering beam solidified a thin layer of plastic, a platform just below the surface dropped a fraction of a millimeter, submerging the layer under another coat of polymer, and the procedure repeated itself. Finally with the topmost layer hardened, the platform automatically rose completely, revealing Hull's first creation: a translucent, bluish, inch-tall cup. Hull dubbed the process *stereolithography*, meaning roughly "printing in three dimensions."

When Hull unveiled his machine at a Detroit engineering show in 1987, designers from a cross section of industries realised the benefits in the design of consumer and automotive components. Compared with traditional prototyping, which required skilled craftsmen, to carve wood, sculpt clay or machine steel, stereolithography presented great time saving potential. RP systems have the capability to translate a computer model of a camshaft or a hair dyer into a three-dimensional prototype in hours rather than weeks. Soon after the discovery by Hull, designers from industry and medicine applied the technique to automotive products, consumer products, drainpipes, dentures, heart valves and military products.

Today, most consumer products are developed using prototypes produced using stereolithography (SLA) or Selective Laser Sintering (SLS) methods. These RP processes have the potential of reducing the time for Prototyping Cycles, thereby shortening the development process compared to traditional methods as described by Clark *et al* 1994. Another advantage provided by the RP software file (SLA file) is the ability to electronically transfer data from a CAD station in one location (e.g. a designer's desk), to a RP machine in another remote location. This allows a design engineer to remain at his workstation, located in his company, whilst transferring the STL file via telephone lines, to specialised RP bureaux.

6.3 EXAMPLES OF RAPID PROTOTYPING TECHNOLOGIES

6.3.1 Stereolithography (SLA)

As described briefly above *Stereolithography* employs a CAD controlled laser, which draws a cross-section of a component on the surface of a bath of photosensitive resin. The laser partially cures the resin and thus produces a thin layer of solid material. The process commences by positioning a support table just below the surface of the resin so that the first layer drawn adheres to the table. After each layer is completed, the table lowers by a small increment, exposing another thin layer of resin, which can be cured. In this way a solid model slowly builds up in the bath of resin. In order for the model to be removed from the table, the first layer consists of a fine lattice of resin. As the model develops in the resin bath, overhanging sections can present structural problems. To prevent the collapse of the structure, supports in the form of a lattice are provided for the layers and are removed from the object after the final curing. After the model is complete, it is removed from the bath, cleaned by removing excess resin, and then baked in an ultra-violet oven. Stereolithography, or SLA, therefore creates a 3-D object, or physical model, directly from a CAD drawing without the need for human interpretation of engineering data.

The end product is an exact physical model, or prototype, of the 3-D drawing providing designers, engineers, manufacturers, sales managers, marketing directors, and prospective customers the opportunity to handle the proposed new product. In this way, design flaws can be quickly identified and corrected providing companies with a quick engineering solution.

The process can be held to tolerances of +/- 0.005/inch. The resulting parts are strong enough to be snapped together, drilled and tapped, finished and painted, and built into assemblies. They can also be used as mould patterns for casting parts in a variety of materials.

6.3.2 Selective Laser Sintering (SLS)

This process employs a powder instead of a resin, which can be fused by heat. The RP model is again constructed, from a CAD model, on a platform, which is situated within a horizontal platen in a SLS machine. The platform is incrementally lowered so that a very shallow recess is formed between platform and platen. A roller then spreads the powder, the laser scans the surface, and the process is repeated. There is generally no need for additional supports to be provided for overhangs, because unfused powder fulfils this function. No other finishing process is required, and very little 'dressing' of the model is required. Currently, materials such as polycarbonate, nylon and wax powders are capable of SLS prototyping, with metal powders under development. The models can be filed, carved, painted or sprayed. The latest generation of Selective Laser Sintering (SLS) machines provide the ability to build parts in both engineering type resins as well as disposable foundry waxes.

6.3.3 Laminar Object Modeling (LOM)

The LOM Process is a technology similar to both Stereolithography and Selective Laser Sintering in that a laser is used to build an object from substrate material in thin slices. The LOM process creates a three dimensional object by using a succession of layers of a paper based substrate coated with heat activated adhesive. Each layer of the material is cut to the desired shape using an optically positioned CO2 laser. After laser cutting, the machine positions another layer of substrate on top of the cut layer and a heated roller then bonds the layers together. The new layer is cut and the process repeats until the object is completed. The laser, to facilitate removal at a later date, crosshatches excess material. Applications include concept models, packaging test models, fit verification models, prototype design models, patterns for casting processes and development test models.

The LOM process has a number of advantages over SLA and SLS in that support structures are not required. LOM uses non-toxic materials, the material does not change phase, large part fabrications are possible, post creation curing is not required, internal stresses are not present in model, no warping during creation, and uses standard STL CAD file format.

Disadvantages of LOM include; surfaces require preparation, strength varies with design and poor performance in wet or high humidity conditions, creation of internal cavities is also difficult.

A number of manufacturers and suppliers of RP equipment have claimed the following benefits over traditional prototyping techniques: -

1. Cost Saving – RP methods are usually significantly less expensive than labour intensive fabrication techniques. Rapid prototypes greatly reduce design iteration, production, & tooling costs. Having a tangible model, or physical prototype, at the time of quotes improves a quote's accuracy.
2. Time Saving – RP methods can turn an idea into a prototype overnight. What previously took months with fabrication methods takes only hours with PR, so that finding errors, making design improvements, and analysing an end product is possible in less time.
3. Test Product - RP models may be used in focus groups, engineering testing with other components for compatibility, and for product performance tests.
4. Catch Errors - Costly errors can be identified before the product goes into production with the help of RP models. The efficiency and cost-effectiveness of a RP provides an inexpensive physical and tangible model for design evaluation, form, fit and function, studies.
5. Sell Product – Prototypes, built through RP and Stereolithography, also allow a sales team to pitch new products before they are manufactured.
6. Rapid Manufacturing - Stereolithography can be used for small volume production runs.

Some applications of RP technologies include development of new product moulds and tooling. Additionally, in the medical field, the convergence of medical imaging, CAD, and RP has made it possible to quickly produce three-dimensional models of human bones and organs, to assist surgery and the manufacture of prosthesis.

6.4 THE CLAIMED BENEFITS OF RAPID PROTOTYPING BY USERS

Kidd (1997) researched ways in which Rapid Prototyping may be used to improve the competitive advantage of an organisation. In this research Kidd used case studies to explore how RP's were used by major manufactures in aerospace, consumer durables, automotive and medical markets, to improve NPD performance and innovation. He emphasised the need for 'organisational changes' to be considered to maximise the benefits of innovation improvement through RP in the NPD process.

There are also a number of journals currently available today on the subject of RP technology. Many articles in these journals reporting companies making large cost savings, between 40% and 70% and up to half lead times savings in NPD projects through the use of RP. However, many of the publishers of the journals have a commercial interest in RP technology and precise data of cost or time savings were not available.

As part of the objectives of this research, any benefits of using RP models in controlling Key Performance Indicators in NPD are studied. The study involved the exposure of RP models into a multi-functional NPD environment and the construction of a 'business case' to 'justify' the additional cost and time associated with the inclusion of RP cycles in a project. An activity called 'Strategic Rapid Prototyping' has been included in some of the case studies to provide a strategic tool for senior managers.

6.5 STRATEGIC RAPID PROTOTYPING

In an attempt to find a 'vehicle' to encourage multi-functional teamwork, Clark *et al* (1992) used prototyping 'cycles' as timely review points, for senior management, during a project. This required the participation of a cross-functional team to make 'full use' of prototype models. Clark claimed that: -

"...every function is involved in prototyping cycles, which brings together all the key players (periodically) to communicate the status of their portion of the project's tasks and to see the status of counterpart activities on the project."

In reviewing applications of prototypes, Clark *et al* (1993) argued that traditional managers treated prototyping as a *technical tool* to be used exclusively by engineers. He suggested that: 'Some senior managers, functional heads, and project leaders did not fully utilise the power of prototyping.' Asserting that this may handicap their efforts to achieve rapid, and effective product development results. Clark also described a role for prototyping, through prototyping cycles, as a management 'tool' for guiding the development of new products. Clark discussed the use of prototyping cycles in three major appliance manufacturers each of, which used a 'similar sequence of tasks'. The study suggested that each company benefited from the use of prototyping cycles to deliver products on time, although no specific details were given. Also, there were clear differences in the NPD methodologies used by each company, which may have influenced the total time period taken.

In a similar way Kidd (1997), looked at the 'business case' for organisations to purchase their own RP machines for Rapid Prototyping and argued that RP models may provide opportunities for other multi-functional investigations to be quickly and accurately carried out, such as: -

1. Design For Manufacture.
2. Failure Mode and Effects Analysis.
3. Value Engineering.
4. Injection mould and cast tooling studies.

Additional multi-functional applications may also be added to the above list: -

1. Demonstration models for senior management approval meetings.
2. Design for Servicing models.
3. Ergonomics and human interface studies.
4. Non-destructive Safety and Approvals studies.
5. User guides (manuals) construction, photography and instructions.
6. Customer demonstrations and 'hall testing'.
7. Performance verification.
8. The production of assembly 'jigs and fixtures'.
9. Packaging design.
10. Aesthetics (styling) verification.
11. Television commercials and advertising photography.
12. QFD studies.
13. EMC approvals tests for electronic products.
14. Dust and water ingress tests.

It has been discussed that RP models have the potential of saving time in a project by providing a way to complete the above activities before the availability of production parts. However, this will be at some cost for the production of the RP models. The concept of Strategic Rapid Prototyping (*StratPro)* includes the generation of a simple business planning agreement between senior managers and the NPD execution team. The business plan is used to justify the additional time and expense associated with the production of RP components, with identified benefits.

The *StratPro* concept places the accountability for the investment in RP models with the NPD team. The return on the investment, from the perspective of senior managers, may include fewer changes to off-tool parts and therefore earlier product launches. Other benefits may include reduced product costs following detailed Value Engineering and D.F.M. studies, and/or improved product quality following detailed F.M.E.A. studies with RP models. The production of RP models also allows senior managers and directors to be able to 'see' and 'sign-off' the progress of a project through various phases of development.

StratPro was developed by the author and applied to a number of NPD projects in Flymo, Kenwood and Domick Hunter. A subroutine of *StratPro* activities was included in project plans starting with a RP strategy meeting. At the RP strategy meeting, team members identified using a checklist aide memoir, where RP models could be used to save time or other KPIs such as product quality and cost. A budget sum of money was then released to fund the manufacture of the RP component parts, or derivative castings, in return for identified savings. An example of a *StratPro* business plan is shown in Fig. 25.

RAPID PROTOTYPING STRATEGY PLAN

Project.....................................

DEPT.	RP REQUIREMENTS	STUDIES	COST	RETURN
Engineering design	All proposed injection moldings to be made in SLA format	Dimensional clash detection and patterns for silicon moulds also initial verification of styling with marketing Product Manager	£18k	No tooling changes after phase 3 of project
Engineering design	6 off sets of resin castings of all moldings	Performance, approvals and design FMEA studies also VE team studies	£3.5k	Verify product costings and no tooling changes after phase 3 of project
Production Assembly	1 off set of 'top clamshell' moldings in SLS format	Motor assembly trials and jig & fixture development	£670	Completed Jig & Fixtures for pre-production trials
Production Assembly	3 off sets of resin castings of all moldings	Assembly training and development of line procedures and process FMEA studies	£1.3k	Target full production capability within first month of prod.
Marketing	3 off sets of resin castings of all moldings	Verification of aesthetics and ergonomics. Verify user guides via focus groups operating prototype models	£1.3k	No tooling changes after phase 3 of project with verified user manuals on-time
Quality	Use same parts as Production Assembly team	Design , Component and Process FMEA studies	£0	No tooling changes after phase 3 of project
After Sales	Use same parts as Production Assembly team	Service training and completion of spares and service manuals	£0	No tooling changes after phase 3 of project
Sales	3 off sets of resin castings of all moldings	Exhibition models and key-account demonstration models	£1.3k	Improved initial order intake of new product

TOTAL RP COSTS	RETURN SUMMARY
£26.07 k	No tooling changes after phase 3 of project full production capability within first month of prod. Improved initial order intake.

Project Manager/ Team Leader..Date/Issue............

Fig. 25 Rapid Prototyping Strategy Plan example for Kenwood kitchen appliance.

6.6 CONCLUSIONS FROM THIS CHAPTER

From the review Rapid Prototyping appears to offer significant benefits to a design engineer in the development of new products Fig.26. Further applications and benefits of RP models were also identified for other functions involved in NPD projects. However, it was clear that a degree of planning would be required to fully utilise the potential of RP models in a multifunctional NPD project. It was also evident that the production of RP models may involve significant cost and time for their manufacture, which may require a 'pay back' justification from the NPD team.

It was therefore concluded that a carefully planned 'strategic' approach to RP was required to maximise the potential benefits and provide a business case for the cost and time investment required. The claimed benefits of RP are tested in the case studies in this research, together with the application of RP as a strategic management tool.

Fig. 26 Rapid Prototype Components under engineering investigation

CHAPTER SEVEN

CASE STUDIES - OBJECTIVES, SCOPE AND METHODOLOGY

7.1 OBJECTIVES OF THE CASE STUDIES

Case Studies are used extensively in this research to provide the much needed empirical data, identified in the literature review and to identify some of the 'root causes' of multifunctional NPD problems. Each case study starts from conceptual stages of the project and concludes with the production launch of the product. It is recognised that the NPD process does necessarily finish at launch however, the scope of this research will be confined to evaluating the 'efficiency' of the process leading up to launch. Therefore, Key Performance Indicators such as market share and business improvement figures will not form part of the analysis. The objective of the Case Studies may be defined in two parts:

1 Provide the much need empirical data, on multifunctional NPD and evaluate the performance of multi-functional teams and 'tools' engaged in the NPD process. The Key Performance Indicators selected in previous chapters will be applied.

2 Draw conclusions from the results, identify process improvements and re-test with further case studies to provide improvements for the multi functional NPD process.

Case studies are extensively used in manufacturing industry to test the effectiveness of a process. Gummersson (1991) discussed the benefits of conducting case studies in management research, one being:

"The opportunity to develop a 'holistic' view of a process, and to provide evidence to support or refute previous 'anecdotal' explanations of how a process actually works in practice. The results of a case study can also be used as a means of implementing change in an organisation."

It was identified from the review of previous work, that the extant literature on the New Product Development process lacked empirical data. A number of researchers including: Maffin 1996, Poolton 1994, Mattin 1994, discussed the need for more evidence to be provided of the effectiveness of 'teamwork' in the NPD process. The KPI's differ according to the view of each author. Therefore, following a review of the arguments presented in the literature on NPD performance, the following KPIs were selected for the case studies:

1. The 'accuracy of the launch' with reference to pre-defined production dates.
2. The *achievement* of targeted Product Costs.
3. The control of Capital spends within pre-set budgets.
4. The achievement of product Quality Targets (line reject and field failures).
5. The timing of Specification and Engineering Changes will also be measured.

It was interesting to note however, that some of the projects studied, did not have all the above parameters clearly defined at the start of the project and many of the above targets and costs established during the course of the project. Moreover, from the review of previous work, it was not uncommon to see the project deliverables and targets changing a number of times during the course of a project. The effects of a constantly deviating specification requirement in projects were monitored in the case studies, together with the reasons why deviations occurred. In such cases, cost and time 'tracking' techniques were used to establish a measurement of 'control' in a project. This is discussed in detail in each study. Finally, conclusions were drawn from each study with recommendations made to improve the NPD methodology for future projects.

7.2 SCOPE OF THE CASE STUDIES

As discussed above one of the objectives of the Case Studies was to measure the performance of multi-functional 'teamwork' in N.P.D. projects and provide empirical data for analysis. Therefore, the scope of the studies was limited to projects involving Multi-Functional introduction teams in each project.

All of the projects studied resulted in the production of a physical product, rather than a service. This usually involved the development of 'production tooling' for plastic injection mouldings or castings, which were made to manufacture multiple production parts. The 'tooling' activity generally consumed the longest lead-time in each project and also tended to incur the highest capital investment except where TV advertising campaigns were concerned. Therefore, the control of this activity was viewed as being very important to the successful outcome of the project and a key influence on the KPIs in the NPD process. The tooling activity was measured in terms of lead-time to manufacture and commissioning the tools, as well as the control of the capital investment involved.

Only projects considered to be strategically important to the organisations involved, incurring significant investment, were included in this research. The 'value' of a project to a company, was discussed in each case study. This qualification helped to ensure that each project was adequately resourced, prioritised and had senior management support. The strategic value of each project also placed a high priority on the introduction time-scale for each project. Therefore minor 'face-lift' projects involving an introduction period of less than 2 months or projects not requiring a complete multi-functional NPD team participation were not considered in this research. The scope of the case studies may be summarised in the following classifications:

1. All of the projects studied were introduced using multi-functional teams.
2. All projects resulted in the production of a physical product.
3. Each project required the procurement of 'production tooling' for the volume manufacture of the new product, and therefore significant capital investment.
4. Each project was considered strategically important to each company.
5. Project lead times were in the order of several months from concept to launch.

7.3 CASE STUDY METHODOLOGY

Whilst supporting the need for case study research, Gummesson (1991) claimed that:
"A wide range of information gathering techniques can be used in case studies.' also *'A thorough analysis of a particular process will require the use of the researchers' personal observations that result from their presence, participation, or even intervention in the actual process to be examined."*
This technique is generally known as 'action research' and specifically referred to as 'action science' by Gummersson.

Due to the nature of the authors' employment, as a Director or senior manager in industrial product development, it was possible to 'observe' and 'intervene' in the NPD projects studied. This enabled the author to compile a rich source of qualitative and quantitative data for future analysis. As discussed above, the Case Studies were conducted to 'test out' anecdotal claims in the extant literature regarding New Product Development performance and Simultaneous Engineering (SE).

It was also viewed in the literature that generic benefits such as 'improved time-to-market' and 'improved product innovation and quality', through the use of multi functional teams (SE), needed to be qualified, and that case studies would help support or refute the claims. The case studies were conducted over a period of twelve years from 1993, whilst the author was employed in companies manufacturing consumer durable and industrial products. A number of well-known household products were included in the studies such as the *Flymo Garden Vac* and the *Flymo Turbo-Collect* grass-collecting 'air-cushion' lawnmowers. The *Flymo Garden Vac* was a tremendous success for Flymo and the *Turbo-Collect* range have been Britains best selling lawnmower since they were launched. A collection of 'food preparation' products, regarded by Kenwood as vital to the survival of the company, was also studied. Industrial products used compressed air systems were studied; again all of the products were regarded as fundamentally important to the companies concerned.

7.3.1 QUANTITATIVE DATA GATHERING

A number of quantitative parameters were selected for the case studies, which were viewed to have a direct influence on the KPIs of the project. Fig.27 shows listed the chosen Key Performance Indicators of a project in the left-hand column, followed by parameters viewed to influence the KPIs in the centre column. How the influencing parameters were measured is shown in the right hand column of the table.

Key Performance Indicator	**Parameters seen to influence K.P.I.**	**Measurement method**
Project completion timescales with reference to pre-defined target Production Launch Dates.	Time added to the project due to the implementation of *unplanned* Engineering Changes.	Time period added to implement the change plus Time to change tools.
	Time added to the project due to changes to the specification requirement.	Time period added to implement the change plus Time to change tools.
	Time added to the project due to Tooling issues.	Time to correct Tooling
	Time added to the project due to Supplier delays	Time added due to delay
	Time added to the project due to other delays	Time added due to delay
The achievement of Targeted Product Costs.	Material Costs deviations to estimated values.	Cost difference to budget
	Labour Costs deviations to estimated values.	Cost difference to budget
	Other Costs adding to targeted product costs.	Cost difference to budget
The adherence of Capital spends within pre-set budget limits.	Deviation from budget.	Cost difference to budget
The achievement of Product Quality Targets.	Quality production line rejects rate.	Line reject numbers (ppm)
	Products returned from the field.	Volume of product returns

Fig.27. The K.P.I. quantitative matrix.

7.3.2 QUALITATIVE DATA GATHERING

A view was taken that qualitative data alone, extracted from case studies would not provide a complete account of each project. Similarly, the collection of quantitative data alone would not provide a complete 'picture' of what actually happened in a project. The collection of quantitative data could provide a tangible measurement of how close each project was to achieving its KPI objectives but would not necessarily explain any outcome. Gummesson (1991) supported this view and argued that:

"Qualitative, informal, in-depth interviews and the anthropological/ethnographic methods of observation and participation are also important as part of action science".

It was therefore decided to link both types of data in each case study to common parameters seen to effect the project KPIs. The author, due to his direct involvement in the projects studied, was able to take 'qualitative notes' during the course of each project from general discussions with the team members involved.

The qualitative results from each case study are presented in the form of a 'discussion' within the 'results analysis' section of each study. Also, as part of the introduction to each study, background information was provided describing the contextual 'value' of each project to the company involved. The qualitative discussions have attempted to provide answers to the questions listed in Fig.28 under the 'qualitative explanation' column on the right hand column of Fig.28.

Key Performance Indicator	**Parameters seen to influence K.P.I.**	**Qualitative explanation**
Project completion timescales with reference to pre-defined target Production Launch Dates.	Time added to the project due to the implementation of *unplanned* Engineering Changes.	Why were unplanned changes requested in the project?
	Time added to the project due to changes to the specification requirement.	Why was the project specification changed?
	Time added to the project due to Tooling Issues	What caused the issues?
	Time added to the project due to Supplier delays	What caused the delays?
	Time added to the project due to other delays	What caused the delays?
The achievement of Targeted Product Costs.	Material Costs deviations to estimated values.	What caused the deviation?
	Labour Costs deviations to estimated values.	What caused the deviation?
	Other Costs adding to targeted product costs.	What generated the costs?
The adherence of Capital spends within pre-set budget limits.	Cost of the unplanned changes to tooling.	What caused the changes?
	Costs of additional tooling.	Why wasn't it planned?
The achievement of Product Quality Targets.	Quality production line rejects rate.	Were they preventable?
	Products returned from the field.	What caused the returns?

Fig.28. The qualitative K.P.I. matrix.

7.3.3 CASE STUDY TEMPLATE

A template was developed to provide a consistent way of presenting the findings of each case study and to assist with comparative analysis. The case study template followed the following structure:

1 Project and Case Study reference information

This includes the Project Name/ ID, Company involved and the start and completion dates of the project.

2 Project Background and Objectives

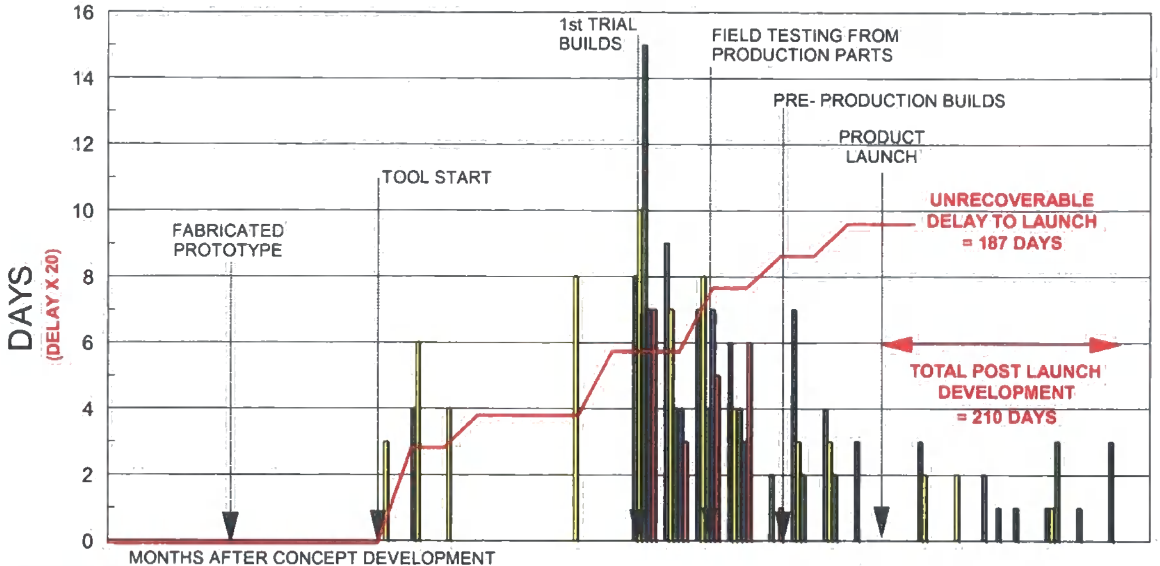
This included a brief narrative of the background history of each project including the type of product under development, the reasons for doing it together with the commercial justifications. A brief description of the objectives of the project was also discussed together with the relative priorities between time-to-market, product cost, capital investment or any product innovations.

3 Quantitative Case Study Results

Case Study Results were presented in two sections to show quantitative data, followed by associated qualitative discussion and analysis. The Quantitative case study results took the form of 'bar charts' and graphs showing the data outlined in Fig.27. The qualitative discussions attempt to explain what happened in the project and what influenced this data.

The top graph in Fig.29, shows 'Where and Why' delays occurred in a project. The lower bar graph shows project run 'Time' on the bottom axis in months. Delay time is shown on the vertical axis in days.

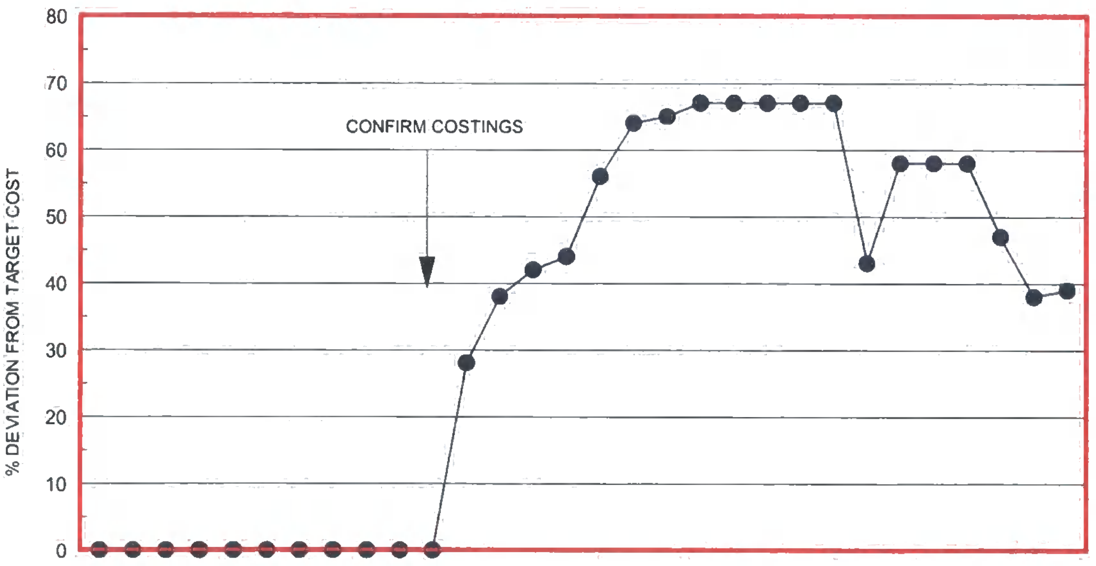
WHERE AND WHY DELAYS OCCURRED IN THE PROJECT



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Eng.Changes ■										4							8	9	7	6		7	4	3		3		2	1	1	1	3
Spec.Changes 🟨									3	6	4				8		10	7	8	4		3	3			2	2			1		
Tool Dev. 🟩																	15	4	4	4	2	2	2							3		
Supplier req. 🟦																	7	4	7	3								1				
Other 🟥																	7	3	5	6	1											

CASE STUDY 005 ***FLYMO TC350 LAWNMOWER***

PRODUCT COST TRACKING AGAINST TARGET



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	28	38	42	44	56	64	65	67	67	67	67	67	43	58	58	58	47	38	39

Fig. 29 Examples of quantitative case study data

A ‘delay’ represents an ‘overrun’ in a planned activity; e.g. the completion of a production mould tool may take 14 days longer to complete due to a change in the specification of the part. Therefore, a bar representing ‘14 days’ will be shown on the graph representing a delay due to specification changes.

As discussed in the review, any delays have the potential of adding time to the critical path of a project and thereby delaying the launch date. In some of the case studies the ‘critical path’ delays were minimised by deploying extra resource to the project, or paying toolmakers to work overtime to maintain delivery dates. However, this method of recovering lost time in a project was viewed as inefficient, costly and tended to result in a ‘fire-fighting’ approach to keep the project ‘on-time’. Therefore, every time a planned activity was delayed the delay was shown on this graph together with the reason why. The actual ‘total delay to the critical path’ to product launch was also shown on the graph. This was, as discussed, not always a total of all of the individual delays rather an indication of time added to the project that could not be recovered by other means.

The lower graph in Fig.29 shows ***Product Cost Tracking*** during a project. This graph shows any deviations from a pre defined product target cost. The base line of the chart represents a 0% variance with any increase or decrease in the costs shown as a percentage above or below this baseline.

It can be seen in this example that the project team were not able to confirm what the product costs actually were until 11 months into the project, at which point they were seen to be significantly higher than the target. The information available in these charts raises a number of interesting issues, which were discussed in each study, when taken in context with other qualitative data in the project. Similar graphs are included in each study to show: **Capital Spend Tracking** showing any variance between budgeted Capital Spend (for production tooling) and 'actual' spend during the project. From this information it can be seen when the capital funds were committed and at which point, they deviated from budgeted levels. Product **Quality Analysis** graphs show 'line reject' rates in parts per million, together with an indication of product field returns, compared to any pre-set target levels during the first six months of production.

4 Project Team Organisation

The organisation of the multi-functional team was discussed in each case study together with the role of the author in the project.

5 Qualitative Case Study Results

This was a narrative section of the case study results, which attempted to provide answers to the questions listed in Fig.28. Following discussions with the team members, this section described what happened during the project, what influenced the outcome and how the team operated.

CHAPTER EIGHT

CASE STUDY RESULTS AND BACKGROUND

8.1 OBJECTIVES OF THIS CHAPTER

The results of the case studies are presented in this chapter together with a narrative to provide a contextual framework to describe the background and business relevance of each project to each organisation involved.

As discussed earlier in this thesis, a view was taken that the presentation of *quantitative* data alone would not provide a complete account of how each product was introduced without supportive *qualitative* data. Therefore, the results are presented in both quantitative and qualitative terms. The qualitative results derive from interviews and discussions with the introduction team members who planned and developed each product, together with the personal experiences of the project by the author. The results for each case study are presented according to a common template, tracking the Key Performance Indicators outlined in previous chapters. This data was presented graphically where possible to build a complete 'picture' of how each project was developed for later detailed analysis.

8.2 CASE STUDY No. 004 - FLYMO GARDEN VACUUM CLEANER

COMPANY: FLYMO Ltd. PROJECT PERIOD: 1992 – 1993

8.2.1 PROJECT BACKGROUND AND OBJECTIVES

Flymo, an outdoor consumer durable company manufacturing lawnmowers and grass trimmer products, were by nature, a very 'seasonal' sales company. With most of the products sold during the 'grass-growing' seasons of spring and summer, the Garden Vac was seen as a counter-seasonal opportunity for the company, providing an incremental business opportunity and fewer peaks and troughs for the manufacturing operation. The original conceptual idea of the Garden Vac was offered to Flymo by an external 'inventor' who developed a way of collecting autumn leaves and other loose debris without the need for the debris to pass through a *suction* fan, thereby reducing the chance of blockages. This offered a unique 'added value' benefit to the user and a monopolistic market opportunity for the company. Following the adoption of the concept, the Directors of the company committed to the project in early 1992 and set a launch date for the autumn of 1993. This dictated an introduction period of 18 months for the development team, which presented quite a challenge given typical introduction periods of more than twice that for previous product launches by the company.

At the start of development of this product, there were a small number of 'outdoor' vacuum cleaners available to the consumer in the market. However, they all tended to suffer from blockages in the system as the collected debris passed up a collection tube in the product and through an impeller fan, before entering the waste collection bag. Blockages were difficult and messy to clear. There was also a danger to the user from accidental start-up of the fan during the cleaning process. The new concept relied upon airflow passing over an aerodynamic surface creating a low-pressure zone immediately adjacent to the surface (Bernoulli principle). Flymo protected the application of the idea with an international patent and marketed the product as an 'easy way to collect leaves and loose debris in the garden'. From an innovative perspective the product was regarded as new to the market place i.e. a Stranger.

8.2.2 QUANTITATIVE CASE STUDY RESULTS

The following tables and graphs represent the key quantitative data gathered during this case study. As described in the previous chapter, the following four graphs show in order:

1. *Fig.30 Where and Why delays occurred in case study 004*

This tracks 'changes' imposed on the intended design configuration throughout the project that may either delay the product launch date, or impact other KPIs in the project.

2. *Fig.31 Product Cost Tracking case study 004*

This tracks the 'product cost' throughout the project with reference to a targeted launch cost.

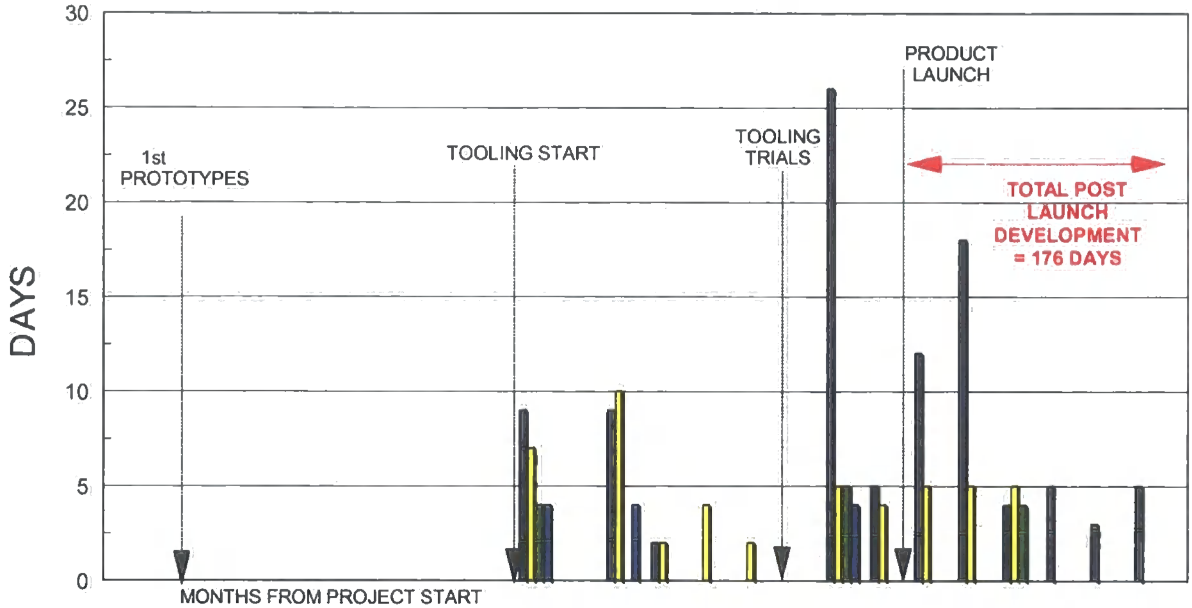
3. *Fig.32 Capital Spend Tracking case study 004*

This graph shows when the capital funds were committed and tracks any deviation to budget targets.

4. *Fig. 33 Quality Analysis case study 004*

Manufacturing 'lines reject rates' and 'product returns' from the field are shown following launch.

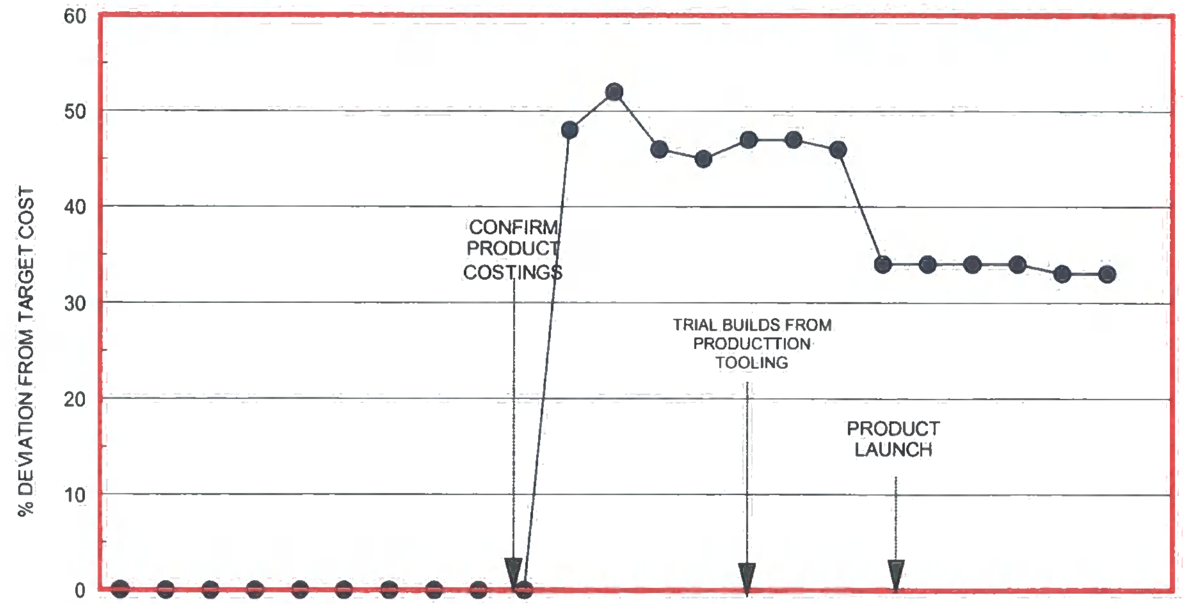
WHERE AND WHY DELAYS OCCURRED IN THE PROJECT



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ■										9		9	2				26	5	12	18	4	5	3	5
Spec.Changes 🟨										7		10	2	4	2		5	4	5	5	5			
Tool Dev. 🟩										4							5				4			
Industrial Design 🟦										4		4					4							

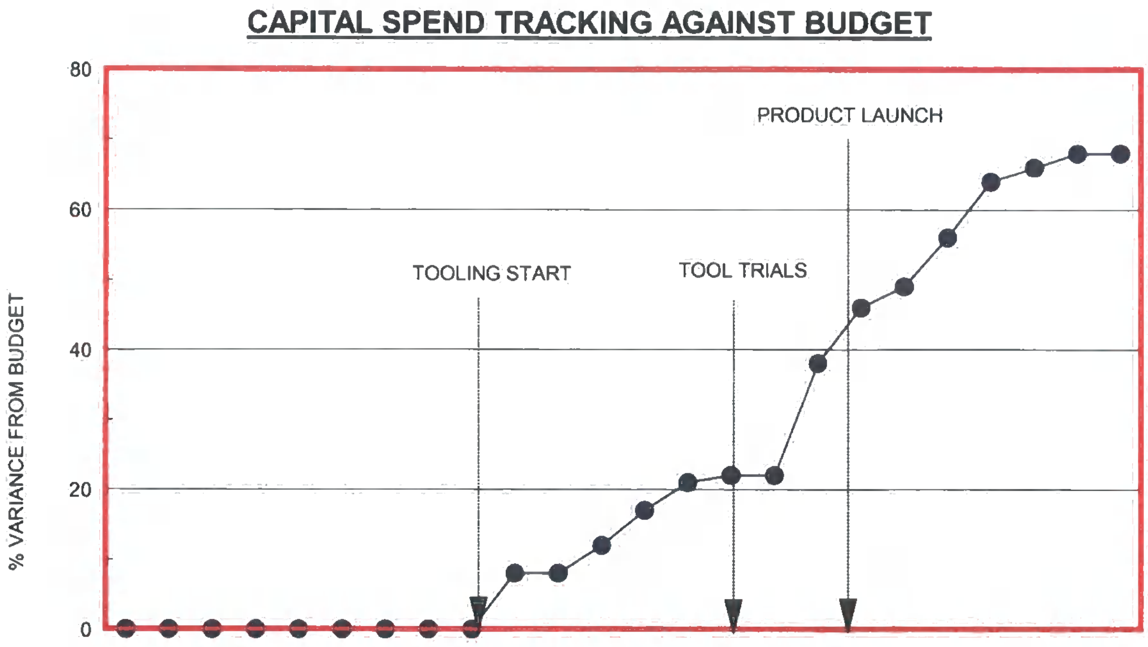
Fig.30 Where and Why delays occurred in case study 004

PRODUCT COST TRACKING AGAINST TARGET



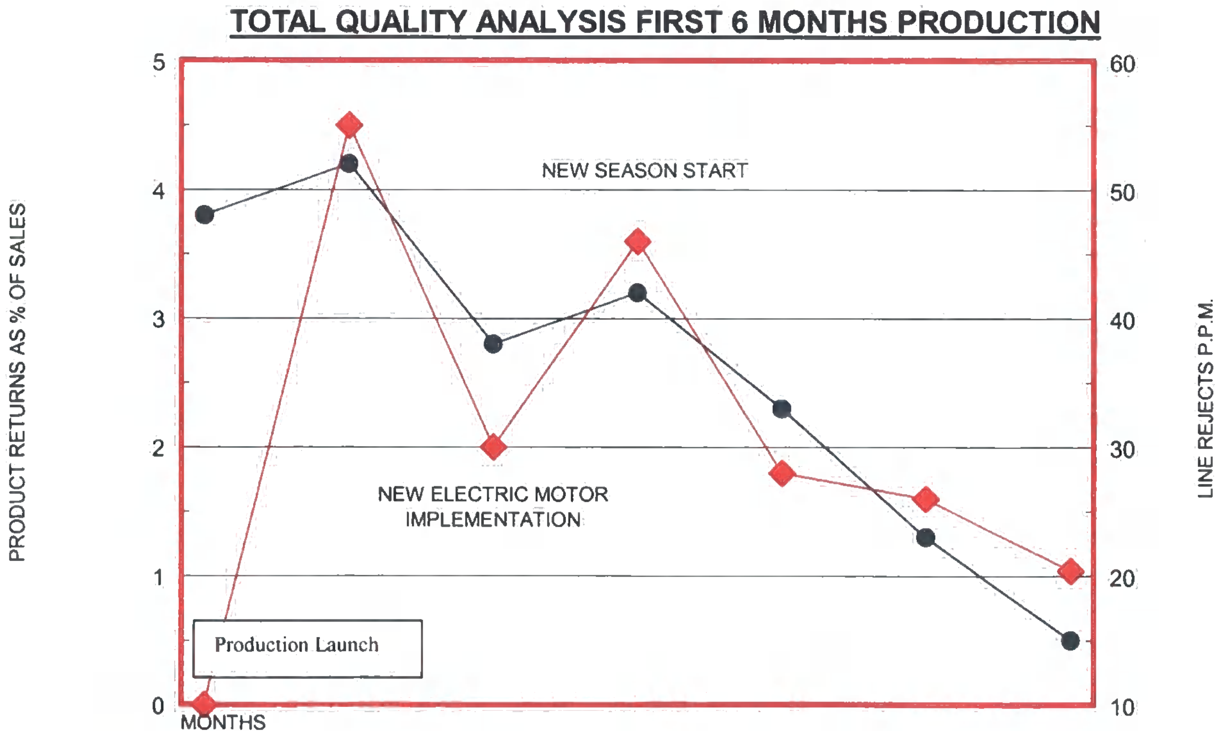
Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	0	0	0	0	0	0	0	0	0	0	48	52	46	45	47	47	46	34	34	34	34	33	33	

Fig.31 Product Cost Tracking case study 004



Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	0	0	0	0	0	0	0	0	0	8	8	12	17	21	22	22	38	46	49	56	64	66	68	68

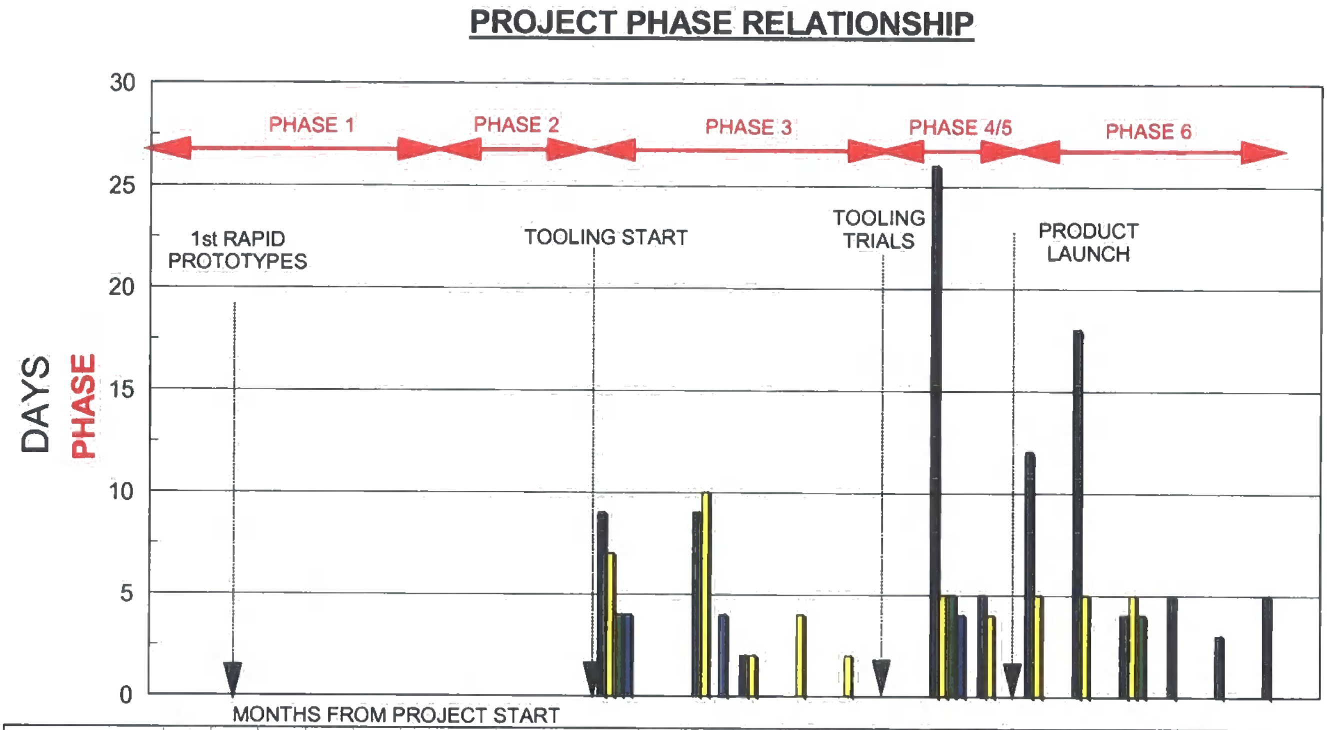
Fig.32 Capital Spend Tracking case study 004



	1	2	3	4	5	6	7
REJECTS ●	48.00	52.00	38.00	42.00	33.00	23.00	15.00
RETURNS ◆	0.00	4.50	2.00	3.60	1.80	1.60	1.04

Fig. 33 Quality Analysis case study 004

The following figure (Fig.34) shows where change requests were implemented relative to the PHASE in the project:



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ■										9		9	2				26	5	12	18	4	5	3	5
Spec.Changes 🟨										7		10	2	4	2		5	4	5	5	5			
Tool Dev. 🟩										4							5				4			
Industrial Design 🟦										4		4					4							

CASE STUDY 004 ***Flymo GARDEN VAC***

Fig.34 Case Study 004 delays according to the PHASE

8.2.3 TEAM ORGANISATION:

A multi functional team was assembled to introduce the product. The team were briefed and made clear of the project objectives, their roles and accountability. The team consisted of representatives from:

1. Research & Development
2. Purchasing
3. Marketing
4. Tooling
5. Industrial Design (External consultancy)
6. Production Engineering (Team Leader)

The team members met on a monthly basis to review progress against the Gantt chart plan. Basic FMEA studies were carried out using fabricated prototype models, which could not be disassembled. No other 'sub group' activities took place, with activities such as product costing calculations, carried out by the project design engineer.

8.2.4 QUALITATIVE CASE STUDY RESULTS

This project, being a counter-seasonal opportunity for the company and a 'new' product category, generated a great deal of urgency and enthusiasm in the team. The team was determined to hit the launch date and needed very little convincing to take whatever action was necessary to develop the product within the time scales dictated by the Managing Director of the Company. The single most expensive component in the product was the electric motor. This component was also, potentially, the component that would determine the reliability and 'life expectancy' of the product. Therefore, the electric motor was carefully specified to the motor manufacturer, and the product was designed around this vital component. Airflow rigs were constructed to 'prove' the motor/fan assembly and to develop the essential aerodynamic surfaces which were key to the performance of the product. The test rig was also used to define air-cooling paths for the motor to maximise longevity and reliability.

Prototype models were also used to enable an agreement to be reached between the marketing and R&D team members with regard to the product aesthetics. However, since this design was drawn in 2D (two-dimensional CAD), rapid prototype models were not produced for the project. Innovative team investigations did not take place until phase 3 of the project and studies such as FMEA and DFM, had limited success because it was not possible to disassemble the prototype models.

Production tooling was committed to the project based on the performance of a 'performance test' prototype. This was a fabricated model containing the selected motor with interior surfaces sculpted in ABS plastic that were glued and screwed together. The model did not fully represent a production unit from an assembly point of view. Therefore, upon completion of the production parts, the product proved difficult to manufacture, requiring design changes. A number of other issues also demanded revisions to the design and subsequent changes to tooling. Issues such as sharp corners on the handle, control shutters, to change the function from vacuum to blower, also proved difficult to use, requiring modifications. Debris bag attachment details, cable entry housings and shoulder strap locations created further changes to production tools.

The product was launched on time, but in the words of the team members, the original products were 'very shaky' and needed much further development. Post project development continued for a further six months after launch creating a vast overspend in the budgeted capital sums reserved for the project. Product costs were approximately 35% above initial targeted levels due to higher material and labour costs than initial estimations. It was not possible to recover these costs through design changes within the introduction period therefore; the product was launched at a higher price than the initial estimate. The senior management accepted this cost increase, until the competition was able to respond with a product challenge on the market.

This project consolidated Flymo's new philosophy of multi-functional teamwork NPD. Also, the senior management team was using the project to *see* if the large 'cultural' changes in the organisation, required to accommodate a multi-functional way of working, were actually working. The project was also a 'platform' (Stranger) in terms of the product application and offered a new counter-seasonal opportunity for the company, which was strategically important for the company. Therefore the priority KPI placed on the project team was:

The achievement of targeted launch dates

All other KPIs were viewed, by senior management, as being of a lesser priority since this product was seen as a monopolistic opportunity, innovative and not as 'price sensitive' as other products in the portfolio. Whilst this concession was not directly revealed to the introduction team, it can be seen from the results that senior management allowed the launch to continue even though *Product Costs* exceeded targets by over 30% at time of launch. This followed a period of intensive Value

Engineering studies using 'off-tool' samples in phase 4 and 5. The Product Costs were estimated to be 150% of targets, following studies using fabricated 'functional' prototype models. The introduction team was not able to effectively conduct the VE investigation using the prototypes because they were not fully representative of the 'tooled' product, and would not disassemble for FMEA and DFM studies.

The late modifications required to reduce product costs also resulted in a gross overspend (68%) in the capital tooling budget. The over spend was accepted by the senior management who regarded the project as a success because it achieved its primary objective and was launched on time. However, there then followed a considerable period (176 days) of post-launch development in Phase 6, to improve manufacturability, ergonomics and quality problems, which had a disruptive effect on production and contributed to the overspend in the capital tooling budget.

Fig.35 Case Study 004 the Flymo Garden Vac

8.3 CASE STUDY No. 005 - THE FLYMO TC 350 LAWNMOWER

COMPANY: FLYMO Ltd. PROJECT PERIOD: 1990 – 1994

8.3.1 PROJECT BACKGROUND AND OBJECTIVES

The TC 350 air-cushion lawnmower was a development of Flymo's patented *Nutri-Vac* grass collecting system. Flymo, at the time of this development project was enjoying a monopoly in air cushion (hovering) lawnmowers that had the added capability of collecting the grass clippings. This provided Flymo with a unique product in terms of maneuverability, ease of use together with grass collection.

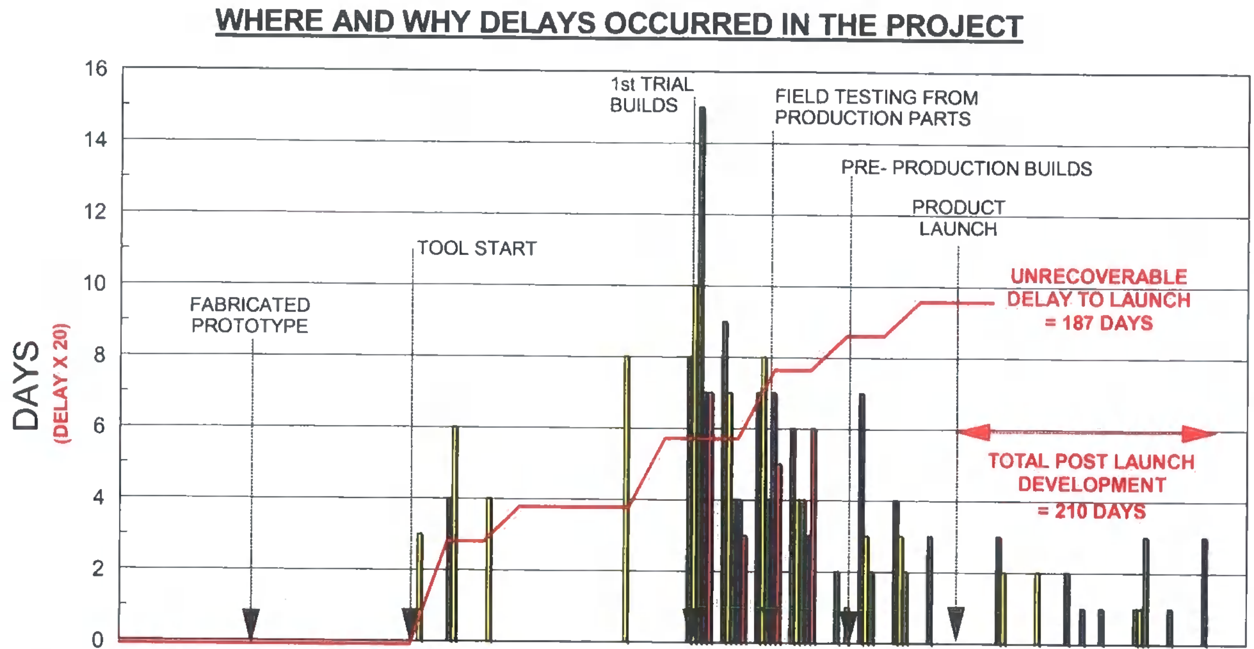
The proposed TC (Turbo Compact) range of products was developed by Flymo to address problems of collection efficiency compared with traditional 'wheeled rotary' lawnmowers; and a problem of 'balance shift' in their existing 'tandem' products where the grass box trailed behind the mower 'hood'. As the grass box filled up with grass the current products would become rear-heavy and would 'drag' at the back whilst tipping up at the front, rather like a car weighed down at the back by a heavy caravan. The result of the weight shift was loss of air pressure under the hood, spoiling the 'hover' effect, creating frictional drag and loss of grass collection efficiency. The development of the TC350 product solved the balance shift problem by locating the grass box 'on top' of the air cushion hood, thereby maintaining the center of gravity of all components during operation. This stopped the machine tilting as the grass box filled with grass therefore improving collection efficiency and ease of use.

The project was developed in two stages: Phase one; to develop the fundamental technology of the TC range took two years. R&D personnel carried out 'Phase One' of the project in isolation, with no other functions represented. 'Phase Two' introduced a multi-functional team to take the concept to a production reality. This was Flymo's first NPD project to involve a multi-functional team. The team had an appointed 'Team Leader' following a non-specific introduction methodology. 3D CAD systems were available, however the product was mainly designed using two-dimensional engineering drawings. Rapid Prototyping was not in common use, therefore all prototype models were built using traditional 'fabrication' techniques.

Since multi–functional team involvement in the TC350 project started after the fundamental concept development was completed, only the second stage of this project will be discussed in the case study. Very little information was documented during Stage one of the project and even the Managing Director of the company had little knowledge of the detail of the project at that stage of development.

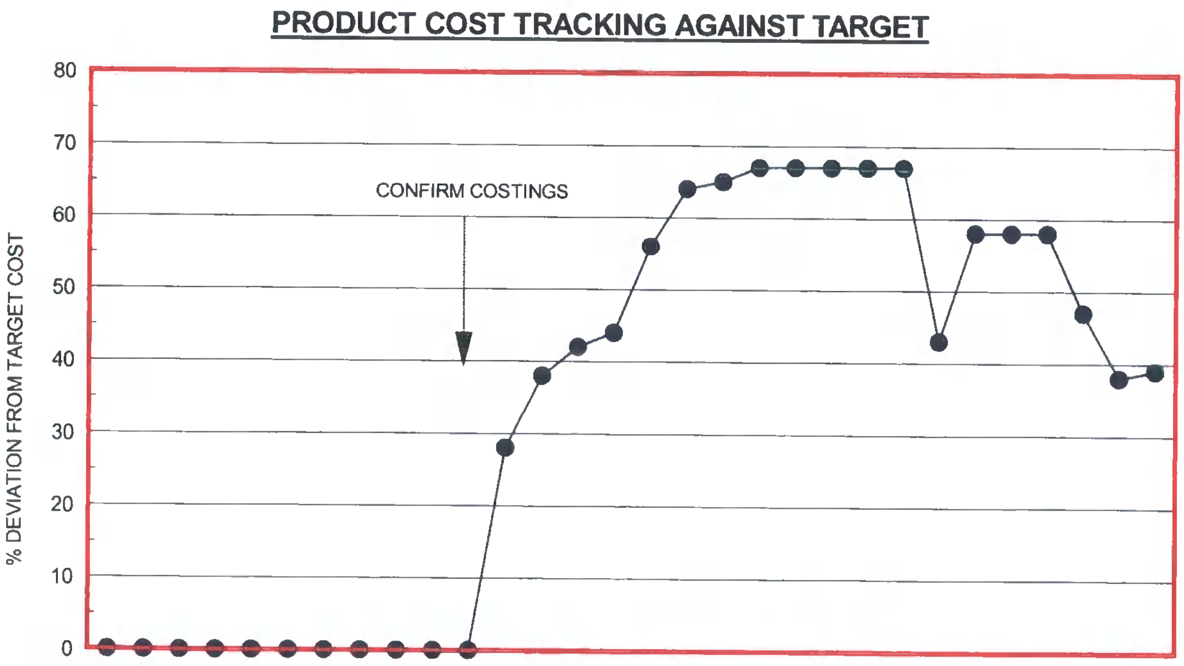
8.3.2 QUANTITATIVE CASE STUDY RESULTS

The following tables and graphs represent the key quantitative data gathered during this case study. The graphs are presented in the same sequence as previous case studies:



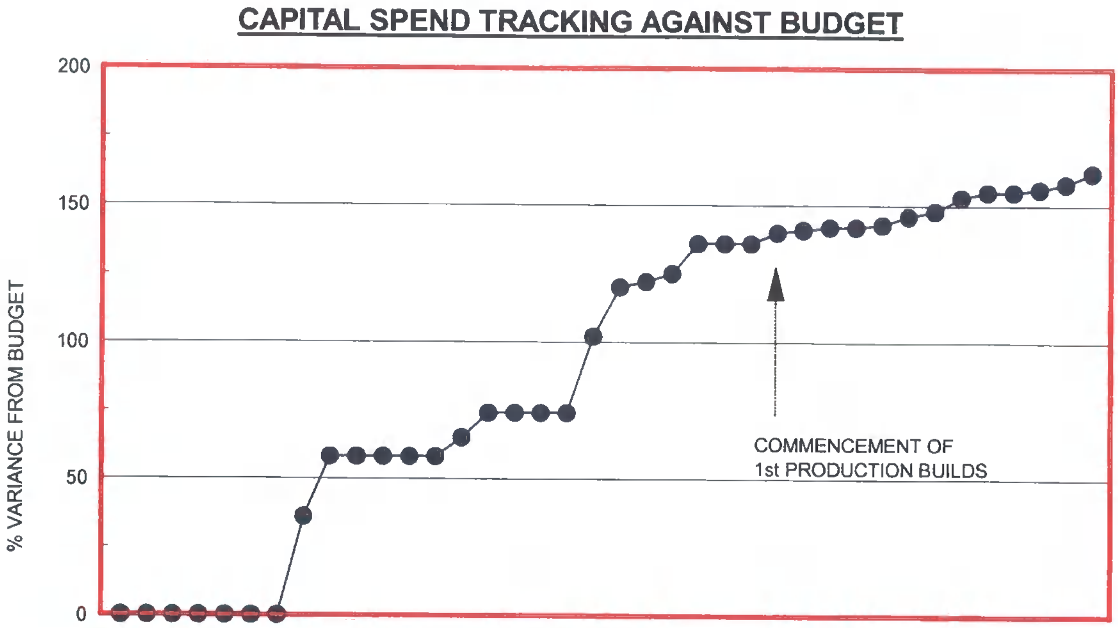
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Eng.Changes ■										4							8	9	7	6		7	4	3		3		2	1	1	1	3
Spec.Changes 🟨									3	6	4				8		10	7	8	4		3	3			2	2			1		
Tool Dev. 🟩																	15	4	4	4	2	2	2							3		
Supplier req. 🟦																	7	4	7	3								1				
Other 🟥																	7	3	5	6	1											

Fig. 36 Where and Why delays occurred in case study 005



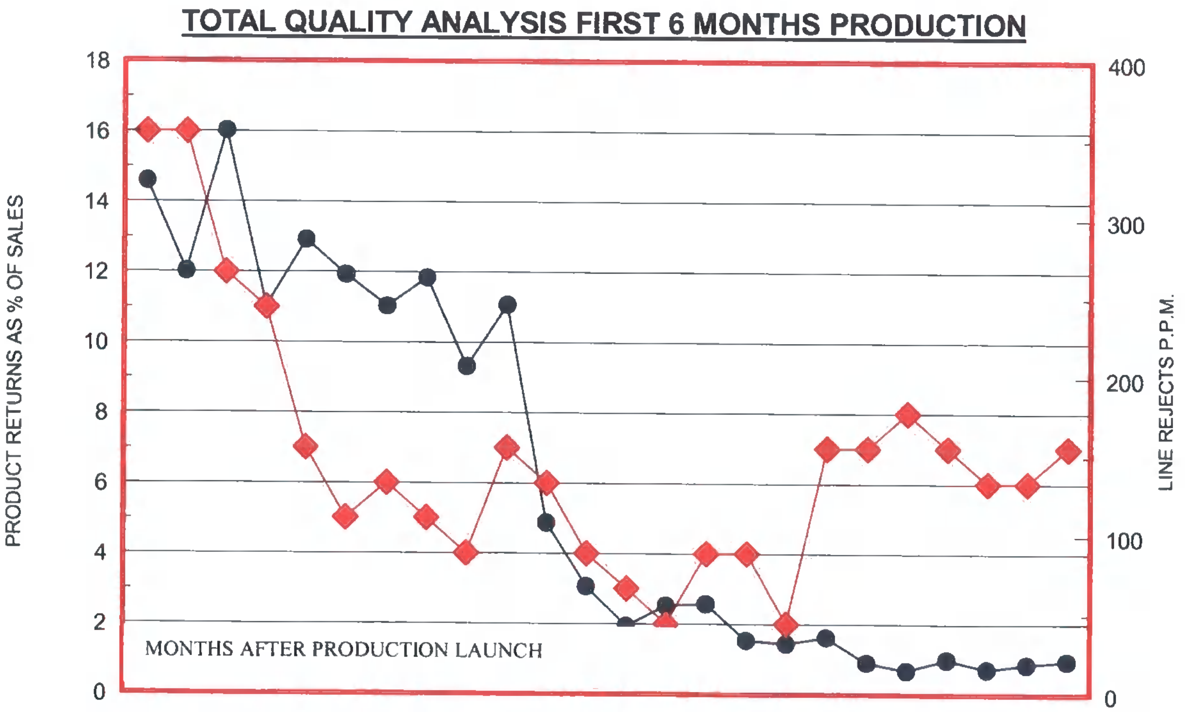
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	28	38	42	44	56	64	65	67	67	67	67	67	43	58	58	58	47	38	39

Fig. 37 Product Cost Tracking case study 005



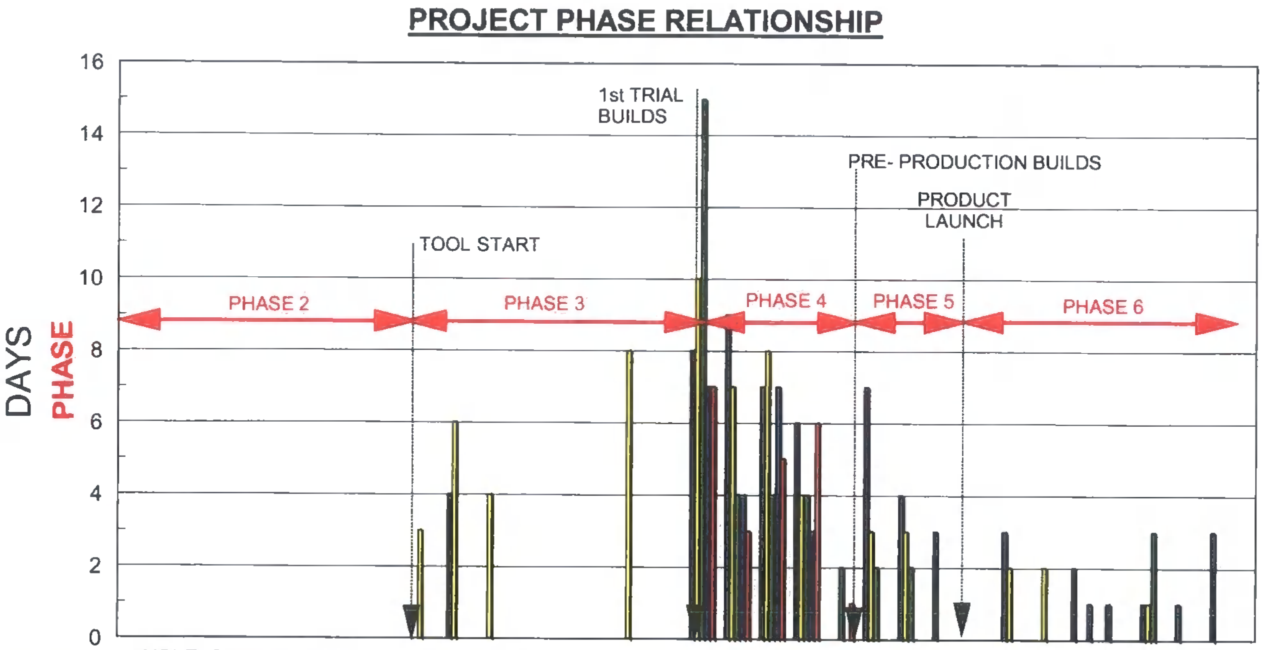
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	23	24	25	26	27	28	29	30	31	32	33	34	35	
0	0	0	0	0	0	0	36	58	58	58	58	58	65	74	74	74	74	102	120	122	125	136	136	136	140	141	142	142	143	146	148	153	155	155	156	158	162

Fig. 38 Capital Spend Tracking case study 005



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
REJECTS ●	324	267	356	245	287	265	245	263	207	246	108	68	43	56	57	34	32	36	20	15	22	16	19	21
RETURNS ◆	16	16	12	11	7	5	6	5	4	7	6	4	3	2	4	4	2	7	7	8	7	6	6	7

Fig. 39 Quality Analysis case study 005



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Eng.Changes ⬛										4							8	9	7	6		7	4	3		3		2	1	1	1	3
Spec.Changes 🟨									3	6	4				8		10	7	8	4		3	3			2	2			1		
Tool Dev. 🟩																	15	4	4	4	2	2	2							3		
Supplier req. 🟦																	7	4	7	3								1				
Other 🟥																	7	3	5	6	1											

CASE STUDY 005 ***FLYMO TC350 LAWNMOWER***

Fig.40 Case Study 005 delays according to the PHASE

8.3.3 PROJECT TEAM ORGANISATION

During concept development, the project was initially progressed in a secretive environment within the R&D department. Access to the details of the project was limited to R&D personnel with even the Managing Director of the company, excluded from the details. After the concept development a team was appointed to the project consisting of personnel from:

1. Research & Development (R&D)
2. Production Engineering (Project Team Leader)
3. Marketing
4. Purchasing
5. Tooling
6. Quality
7. Industrial Design (External Resource)

The author was the manager of the R&D design team during the final 12 months of the project and was responsible for the engineering integrity of the product, performance testing and safety approvals; as well as the management of the development budget. A senior 'Project Engineer' from the R&D design team was responsible for the design engineering of the product and was delegated to represent the R&D function in the introduction team. The team had an appointed Team Leader, from the Production Engineering Department, and the team met on a weekly basis during the project.

8.3.4 QUALITATIVE CASE STUDY RESULTS

Since the initial two years of 'conceptual development' were completed in secrecy, the analysis of this project could only take place upon appointment of the multi-functional team.

The presentation of the concept prototype to the team was greeted by initial excitement, followed by frustration. Marketing Product Managers, keen to 'stamp their mark' on the new product were very frustrated at many of the features in the product and operational characteristics, as well as total rejection of the product aesthetics. Appointed team members from the 'Production Engineering' function were tasked to, very quickly, learn and understand efficient ways to manufacture the new product. Other team members also started to complain that the project had 'progressed too far' without their involvement and initiated changes to the design. The team were also under severe pressure from the senior managers to start production tooling for the product as quickly as possible which led to this activity taking place before a 'Firm Product Proposal' was agreed in the team.

From the commencement of the production tooling, the design was subjected to numerous changes, which directly affected the targeted completion date of the production tools. Upon completion of the tools, a small quantity of products was built for further evaluation and testing. This resulted in further changes and some components being completely re-tooled. The design changes resulted in a total of 187 days delay to the critical path, to launch the product. Even after launch, changes to component parts continued in order to improve product performance, quality, ease-of-manufacture and reliability. A quantity of products was also returned from the field due to 'motor mounting plates' becoming loose during operation. This led to redesign, and re-tooling of several component parts. The tooling 'capital' budget for this project was grossly overspent due to the changes in design and subsequent production tooling.

Due to the nature of the fabricated prototype models, it was not possible for the team to carry out early, meaningful F.M.E.A., D.F.M. and Value Analysis studies. Therefore, because of the use of fabricated prototypes, these activities were regarded as ineffective and were repeated upon the completion of the Trial Builds, using 'off tool' parts. Unfortunately the findings of these studies led to further changes from each team function, many of which were too late in the project to be implemented.

The team did not use any particular NPD methodology during the project, relying on a simple Gantt chart plan as a critical path monitor. This plan changed frequently due to the changes taking place in the design, which also effected key project milestones. Therefore, the whole team was forced to meet several times each month to review the changes in order to maintain some degree of control in the project.

Many conflicts ensued between the Marketing and R&D team members, each one frustrating the other due to different opinions regarding: aesthetics, ergonomics, product performance and how to measure the grass cutting and collection efficiency. Also, since no product costing targets were identified at the start of the project, many disputes within the team were the result of differing views in component, and feature, value analysis.

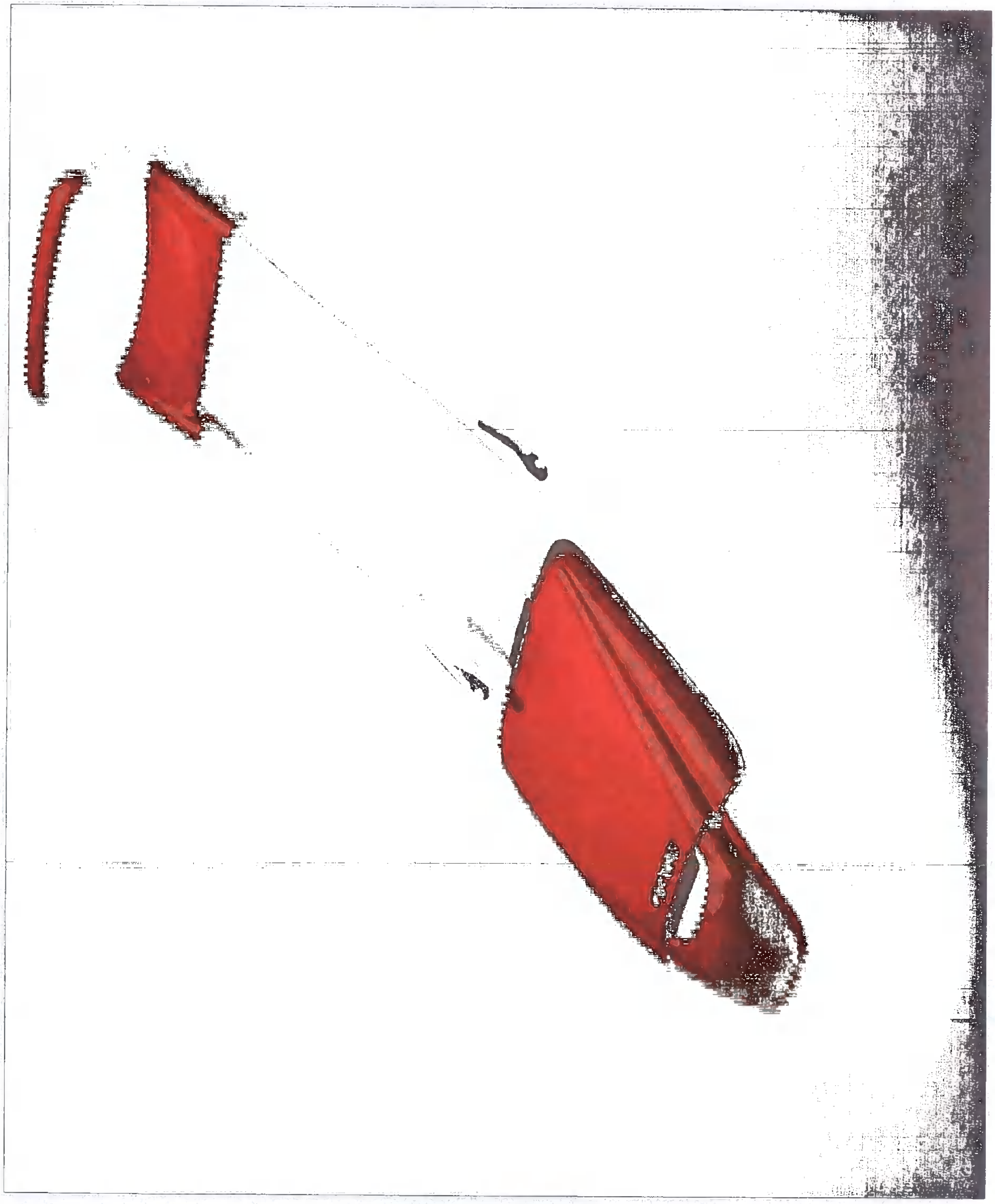


Fig. 41 Case study 005 The Flymo TC 350 Lawnmower

8.4 CASE STUDY No. 006 - THE FLYMO TC 300 LAWNMOWER

COMPANY: FLYMO Ltd. PROJECT PERIOD: 1993 – 1994

8.4.1. PROJECT BACKGROUND AND OBJECTIVES

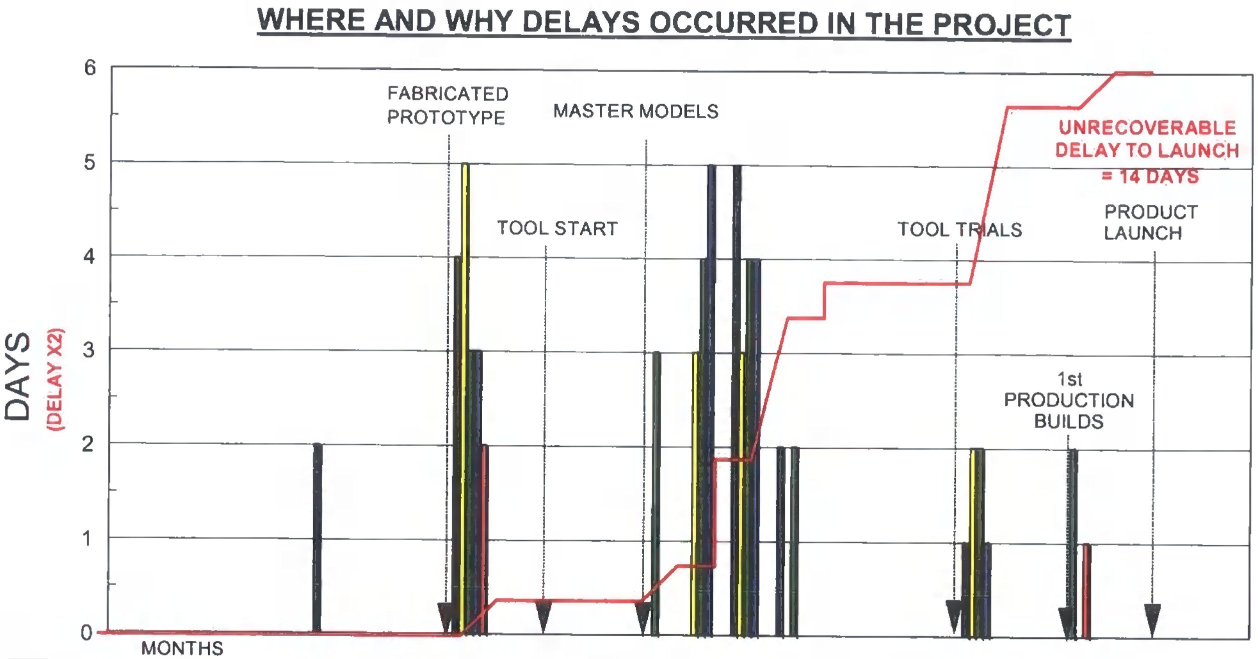
The Flymo TC300 was the second product in the range of 3rd generation 'grass collecting' air-cushion lawnmowers to supplement the TC350. The TC (Turbo Compact) range was a development of Flymo's patented Nutri-Vac system enabling grass clippings from an air-cushion (hover) mower to be collected, a feature unique to Flymo. Since its launch the TC350 – 35cm cut diameter, has been the best selling lawnmower in Britain. In operation the grass clippings are 'sucked' into a removable collection box, mounted on the top of the air cushion hood, thus maintaining the center of gravity and balance during the collection process.

During the development of the TC300, Flymo were using a New Product Development methodology, developed by managers, including the author. The methodology included all of the key elements of Simultaneous Engineering with the teamwork culture in the organisation benefiting from two years, and several products, previous experience. The team was experienced in the use of team tools such as FMEA and DFM techniques. Rapid prototyping was still in its infancy although fabricated prototypes and CNC machined components played an important role in the project. A set of 'Master Models' was produced to provide representative models to enable development testing (grass cutting trials) to be carried out. The Master Models were used as a reference platform for the team, to enable an agreement between the Marketing and R&D team members to be reached regarding the performance specification and esthetical appearance of the product.

A key objective of the TC300 project was to significantly reduce manufactured costs of the new 30cm product with respect to the larger 35cm product (TC350), and improve the grass collecting performance measured in density of grass collected per area cut. The operational performance of the product was particularly important because of the anticipated launch of a competitor product the same year. Due to this competitor activity and the seasonal nature of the business, an introduction lead time of 24 months was set by the senior management team, at the start of the project. This targeted production date coincided with the commencement of TV commercials, the publication of sales catalogues (in department stores such as Argos) and the commencement of stock build-up in the shops in preparation for the grass-growing season. Product aesthetics, performance and ergonomics were a subject of a great deal of debate and conflict between Marketing and R&D functions during the TC350 project. Poor communication between these two functions resulted in a number of specification changes with subsequent delays to product launch. It was also made clear by the senior management that the conflicts and delays experienced in the TC350 project were not to be repeated in the TC300 project.

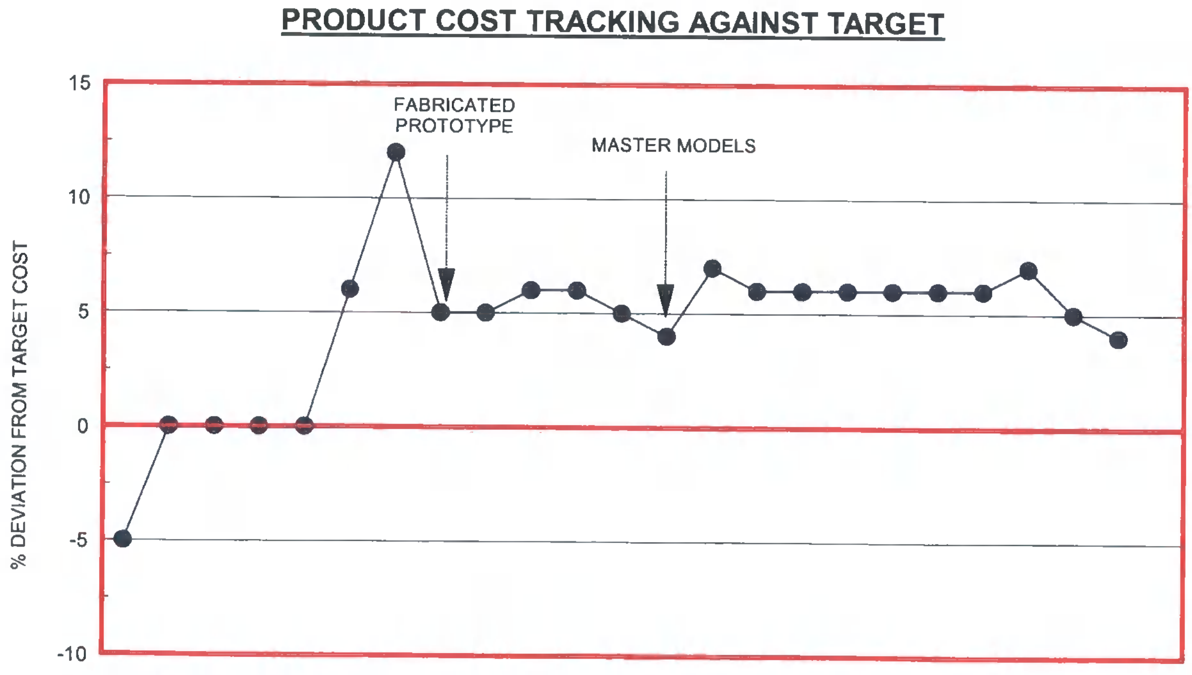
8.4.2 QUANTATATIVE CASE STUDY RESULTS

The following tables and graphs represent the key quantitative data gathered during this case study.



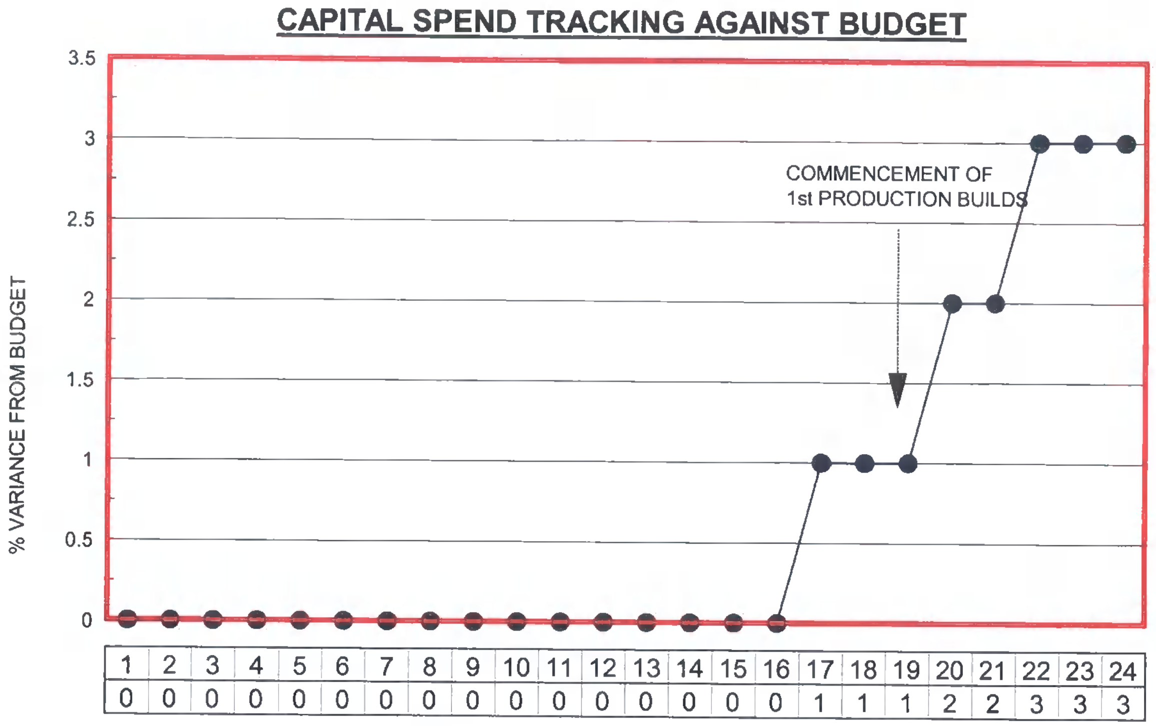
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ⬛					2			4						5	2				1					
Spec.Changes 🟨								5					3	3					2					
Tool Dev. 🟩								3				3	4	4	2				2		2			
Supplier req. 🟦								3					5	4					1					
Other 🟥								2													1			

Fig.42. Where and Why delays occurred in case study 006



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
-5	0	0	0	0	6	12	5	5	6	6	5	4	7	6	6	6	6	6	6	7	5	4	

Fig.43 Product Cost Tracking case study 006


CAPITAL SPEND TRACKING AGAINST BUDGET

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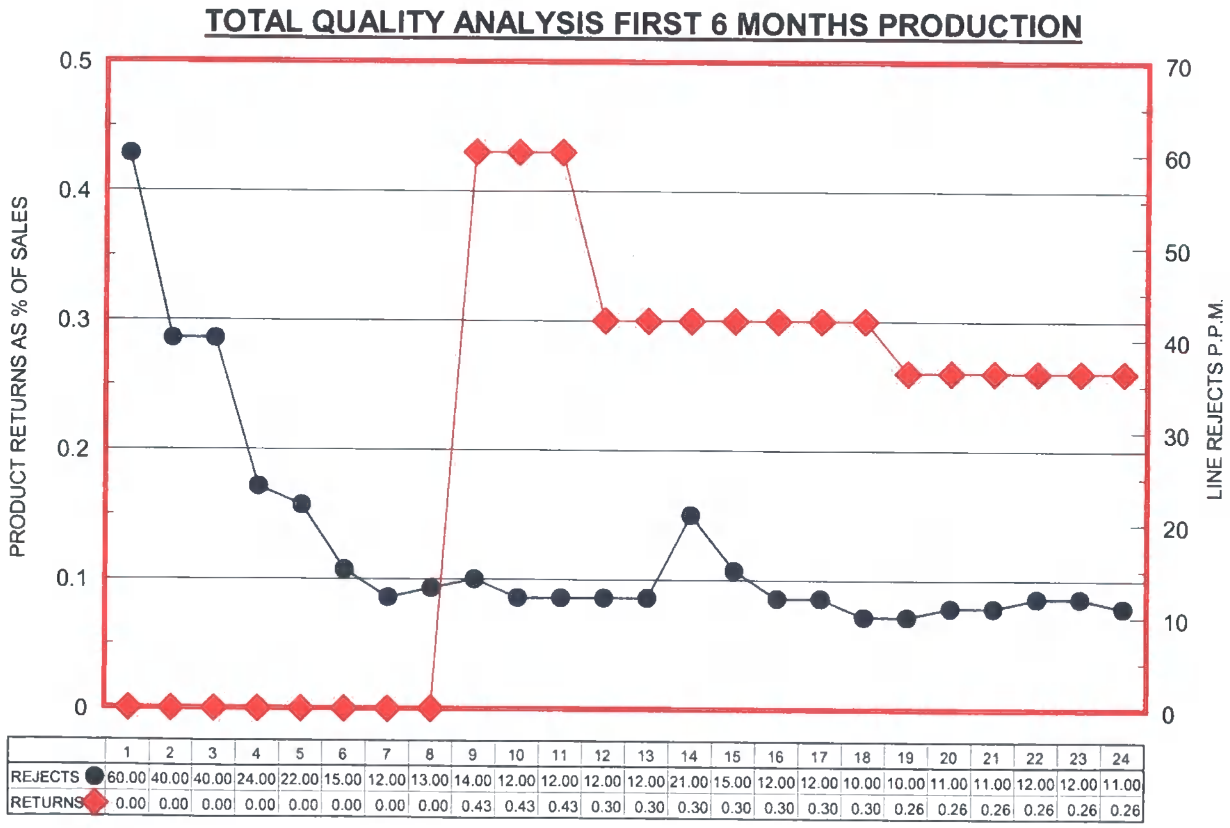
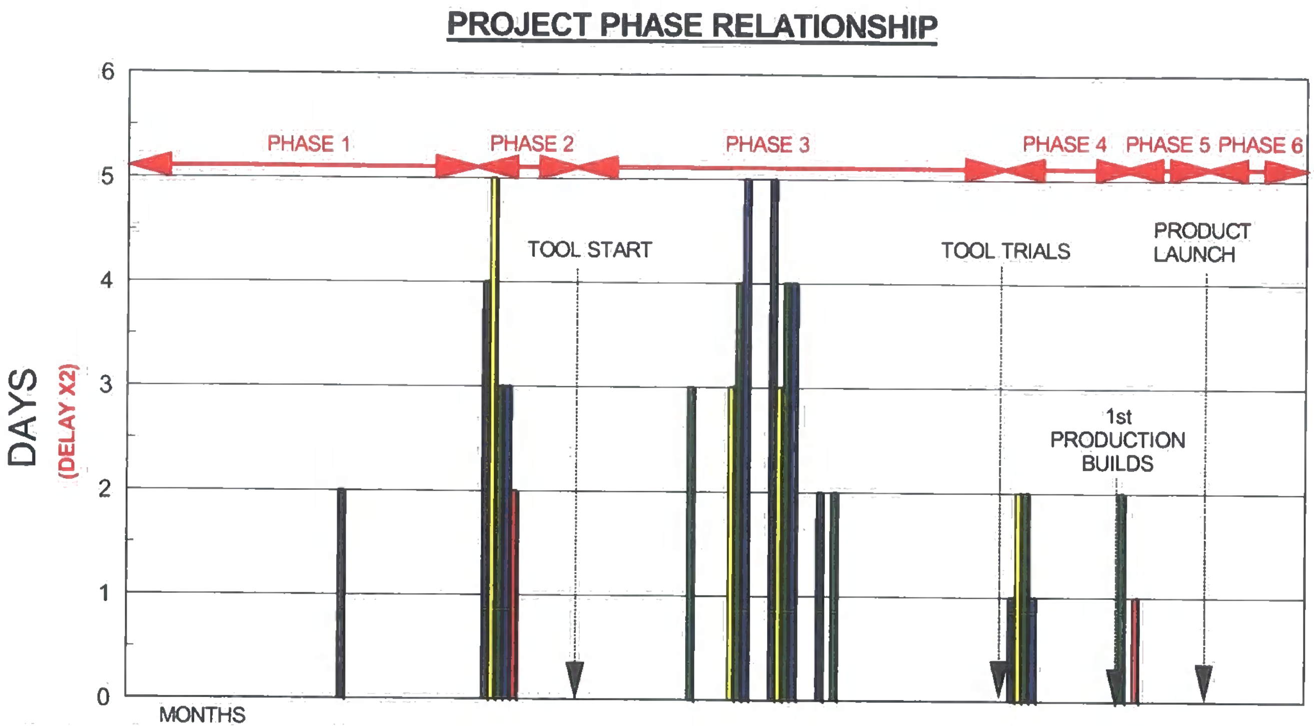
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	3	3

Fig.44 Capital Spend Tracking case study 006


TOTAL QUALITY ANALYSIS FIRST 6 MONTHS PRODUCTION

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
REJECTS ●	60.00	40.00	40.00	24.00	22.00	15.00	12.00	13.00	14.00	12.00	12.00	12.00	12.00	21.00	15.00	12.00	12.00	10.00	10.00	11.00	11.00	12.00	12.00	11.00
RETURNS ◆	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.43	0.43	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.26	0.26	0.26	0.26	0.26	0.26

Fig.45 Quality Analysis case study 006



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ■					2			4						5	2				1					
Spec.Changes ■								5					3	3					2					
Tool Dev. ■								3				3	4	4	2				2		2			
Supplier req. ■								3					5	4					1					
Other ■								2													1			

CASE STUDY 006 ***FLYMO TC300 AIR CUSHION LAWNMOWER***

Fig.46. Project delays due to changes according to the PHASE of implementation

8.4.3 PROJECT TEAM ORGANISATION

The project was introduced using a multi-functional team consisting of personnel from:

1. Research And Development (R&D)
2. Production Engineering
3. Marketing
4. Purchasing (Project Team Leader)
5. Tooling

6. Manufacturing Assembly
7. Quality
8. Industrial Design (External Resource)
9. Accounts

The author was the manager of the R&D design team during this project, responsible for the engineering integrity of the product, performance testing and safety approvals; as well as the management of the development budget. A senior 'Project Engineer' from the R&D design team was responsible for the design engineering of the product; and delegated to represent the R&D function in the introduction team. The team had an appointed Team Leader, from the Purchasing department, and the team met on a monthly basis during the project. Some of the team members, excluding the R&D member, had also been involved with the previous product in the range i.e. the TC350, 35cm variant (Case Study 005), which had suffered a number of delays due to 'late engineering changes and changes to the specification requirement.

8.4.4 QUALITATIVE CASE STUDY RESULTS

The project was regarded as a success, in that the product was introduced on time and within cost targets. The capital budget was well controlled, with no significant overspend, and the quality of the product good. The overall view of the team was that they were able to launch the product on time and meet the objectives of the project for the following reasons:

1. The influence of a good strong team leader.

The Team Leader was a strong individual, good communicator with experience of product launches in the company including projects that were problematic. The Team Leader had also been involved in the design of Flymo's NPD Methodology and the Product Introduction Control template, therefore was committed to the plan and displayed 'ownership' of the project plan to the other team members.

2. The availability of a 'Master Model' machined (CNCed) from the CAD data.

The Master Models were used by the team to verify the performance of the product in operation, that is, cutting and collecting grass, and were used to benchmark the new product against existing Flymo and competitor products. The level of performance was defined and agreed between the Marketing, Quality and R&D members. The Master Models were also used as a vehicle to define and agree the aesthetic appearance (styling) of the product, thereby illuminating any ambiguity or misinterpretation of engineering drawings, artistic sketches and other prototype models, by non-technical team members. Design aesthetics was a major cause of conflict in the TC350 project, therefore, the team members actually 'signed' their names on the Master Model of the TC300, as being the agreed design for the product launch. The Master Models were also used to design packaging, conduct F.M.E.A and D.F.M. studies, design assembly jigs & fixtures and perform (small quantity) 'Trial Builds', on the production line to de-bug the assembly process and test equipment. The team members claimed that this enabled most of the issues highlighted by the team studies to be addressed within the critical path of the project. It also enabled the marketing team to complete the user instructions, TV commercials and advertising brochures in plenty of time to allow corrections to be done, all from Master Models.

3. Fewer conflicts between Marketing and the R&D functions compared to the TC350 project.

The team worked well together with noticeable confidence that the project would be launched on time and fewer conflicts between departmental functions. The senior management was also more 'comfortable' with the project, being able to 'see' it perform against the competition and to be able to watch the development take place with updated revisions of component parts applied to the Master Models.

4. The availability of an agreed Product Introduction Control 'template' for the introduction plan of activities.

There were no disputes in the team with regard to the project plan and they were happy that their activities and involvement in the project had been done at the optimum stages of the project. Therefore, all of the planned F.M.E.A. and D.F.M. activities were carried out with the results acted upon before the design was 'frozen'. The improved planning in the project also improved the moral of the team.

8.5 CASE STUDY No. 007 - THE KENWOOD CUISENE FOOD MIXER

COMPANY: KENWOOD Ltd. PROJECT PERIOD: 1995 – 1997

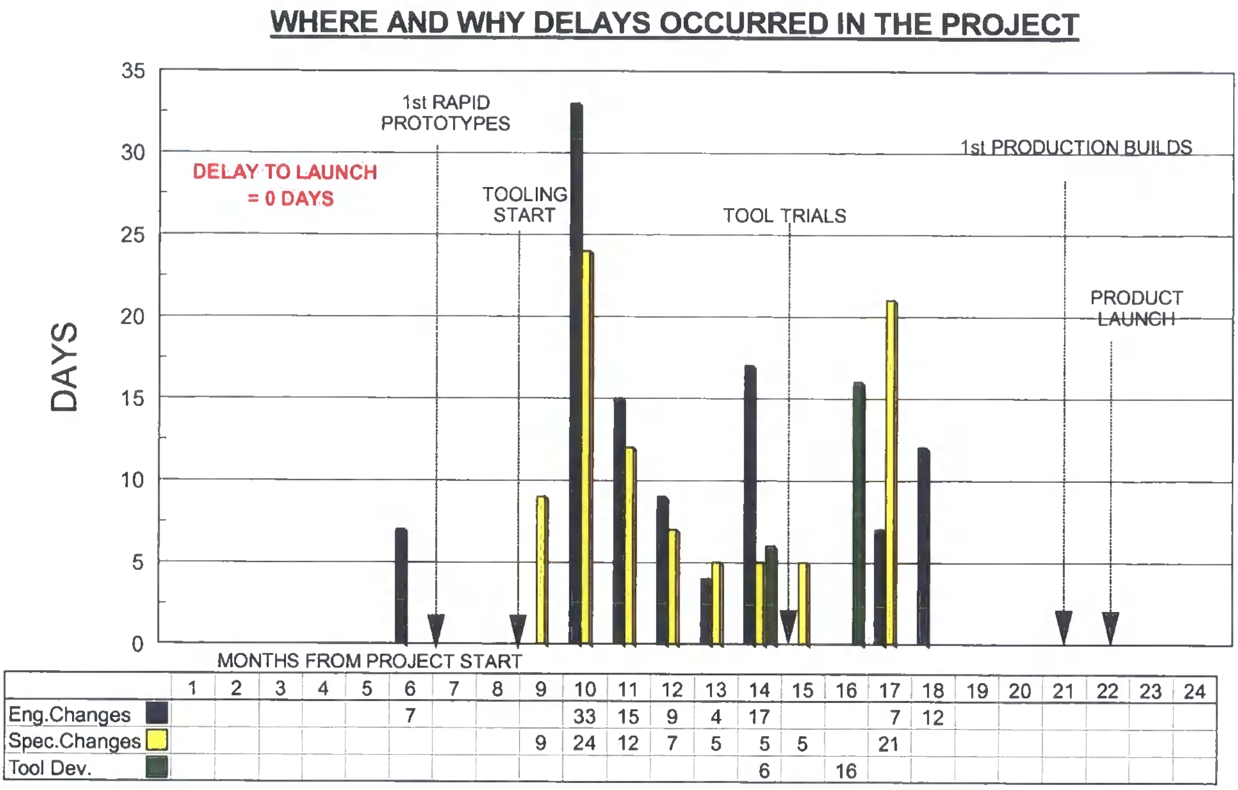
8.5.1 PROJECT BACKGROUND AND OBJECTIVES

The Cuisine Food Mixer project was initiated to complete a product range for Kenwood consisting of the ubiquitous Kenwood Chef, as a premium price product; with lower priced 'food processors' at the lower end of the market. The Cuisine was therefore intended to occupy a 'mid priced' positioning in the market. The product was also intended to be made mainly of plastic (including gear chain drive) in order to provide significant savings in material and manufacturing costs compared with the 'Chef' flagship product.

During the development of the project, Kenwood had no discernable methodology for the introduction of new products and therefore project milestones and controls were ill defined. A small 'multi-functional' group of people was involved in the project, and tasked with the responsibility of introducing the new product, but without clear accountabilities and regular meetings. The product was designed using 3D CAD (SDRC IDEAS) with Rapid Prototyping used extensively. However, the RP models were only used for technical studies by the designers and not exposed to any team members outside the Engineering domain.

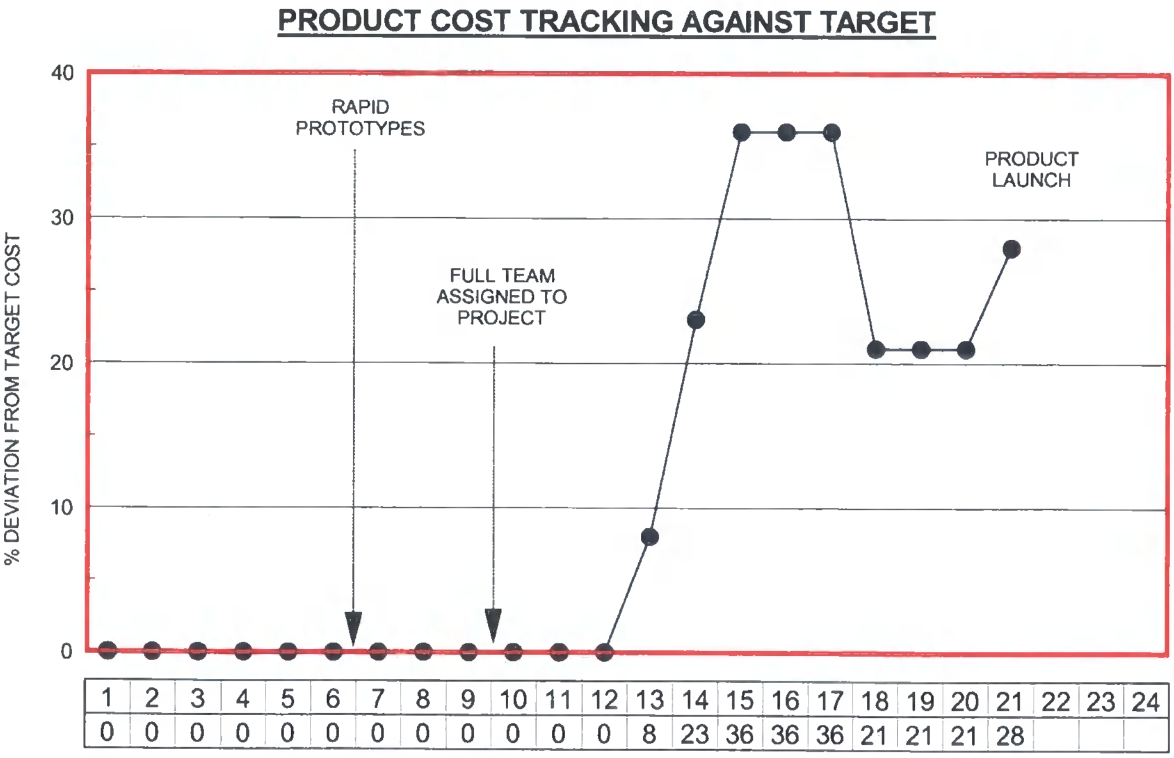
8.5.2 QUANTATATIVE CASE STUDY RESULTS

The following tables and graphs represent the key quantitative data gathered during this case study.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ■						7				33	15	9	4	17			7	12						
Spec.Changes 🟨									9	24	12	7	5	5	5		21							
Tool Dev. 🟩														6		16								

Fig.47. Where and Why delays occurred in case study 007



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	0	0	0	0	0	0	0	0	0	0	0	8	23	36	36	36	21	21	21	28			

Fig. 48. Product Cost Tracking case study 007

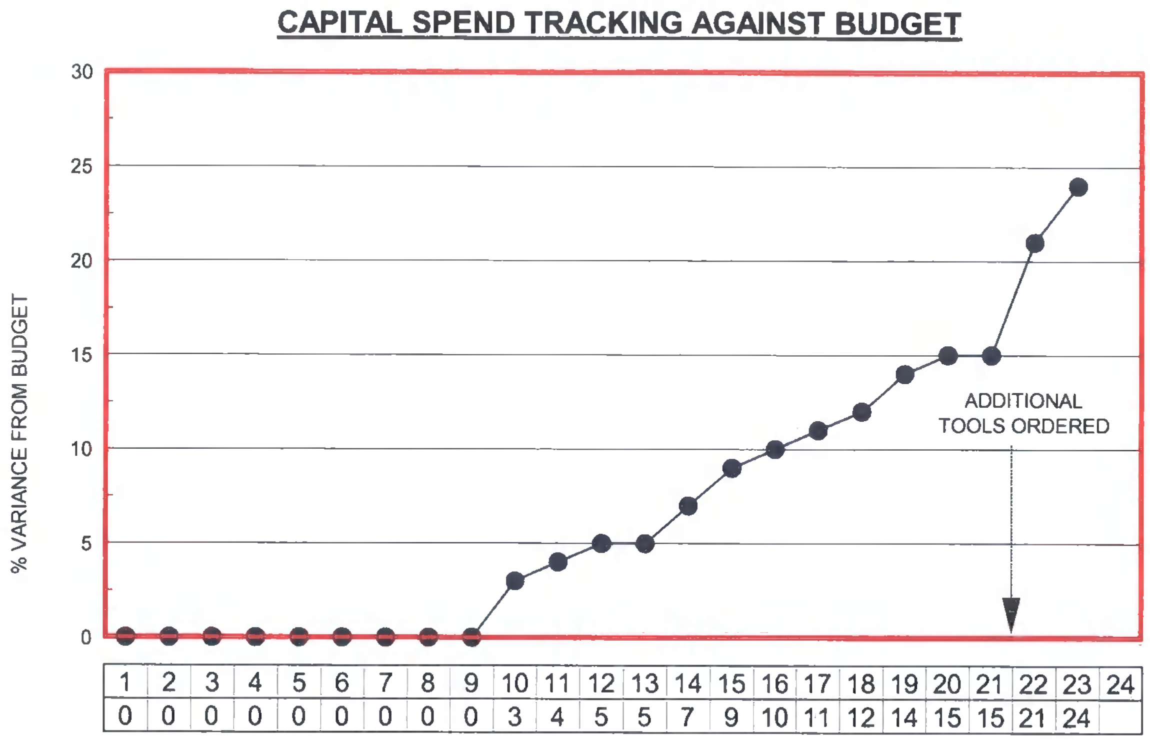


Fig.49. Capital Spend Tracking case study 007

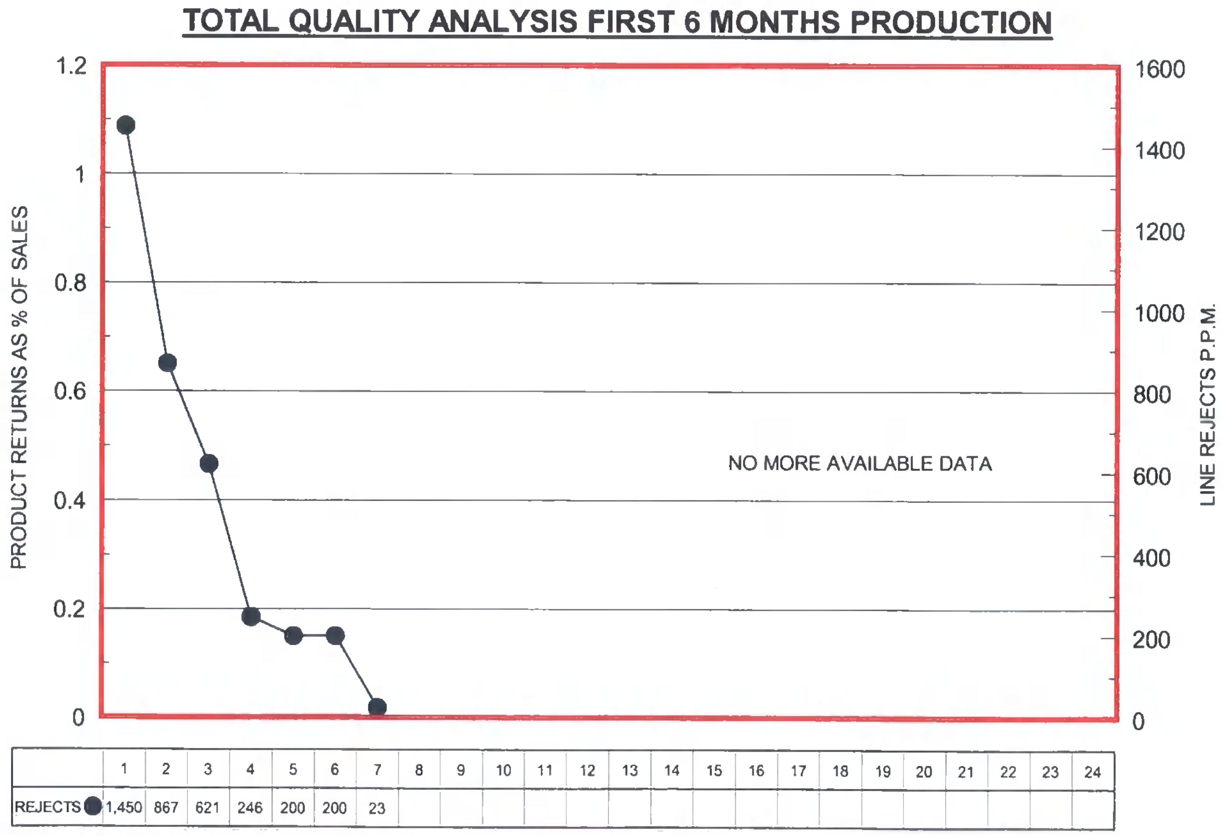
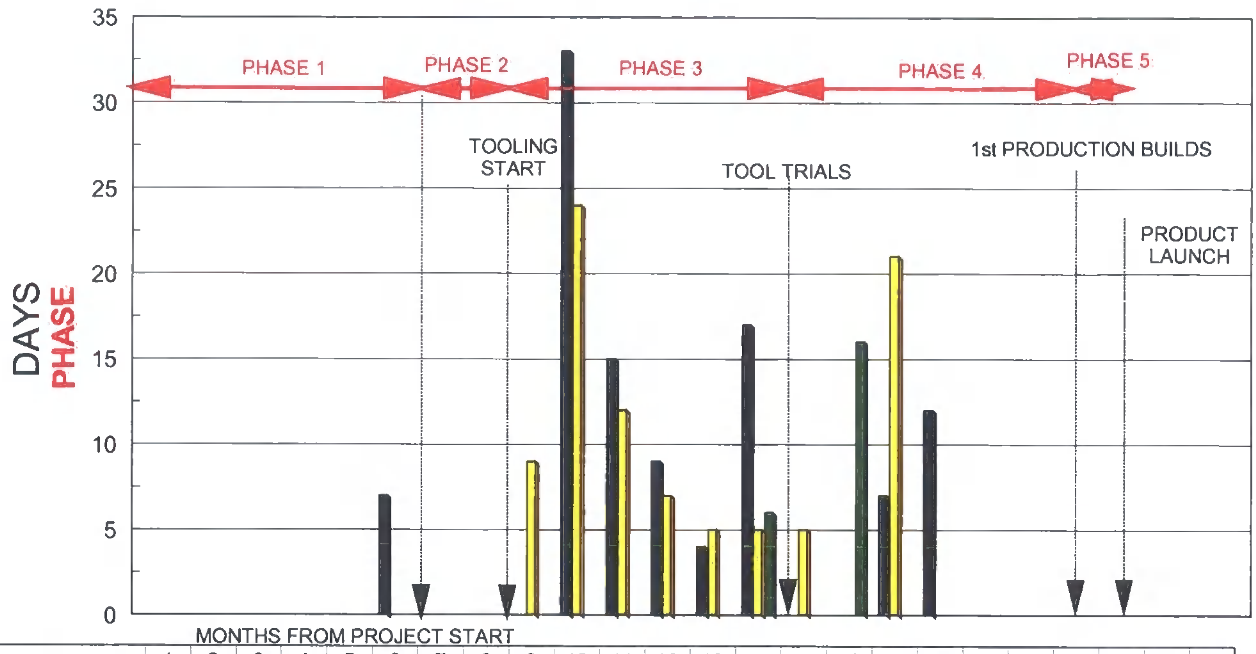


Fig.50 Quality Analysis for case study 007

PROJECT PHASE RELATIONSHIP



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ■						7				33	15	9	4	17			7	12						
Spec.Changes 🟨									9	24	12	7	5	5	5		21							
Tool Dev. 🟩														6		16								

CASE STUDY 007 ***Kenwood CUISINE FOOD MIXER***

Fig.51. Project delays due to changes according to the PHASE of implementation

8.5.3 PROJECT TEAM ORGANISATION:

Multi functional teamwork in this project was unstructured and without clear accountability until the final twelve months of the project. In the final twelve weeks a team leader was appointed, from Product Marketing, and representatives from the following functions were briefed and took ownership of the project:

1. Engineering
2. Purchasing

3. Marketing (Team Leader)
4. Tooling
5. Accounts
6. Sales
7. Manufacturing assembly

The author, as Director of Engineering, was responsible for the management of the Engineering function in the company, which included Tooling.

8.5.4 QUALITATIVE CASE STUDY RESULTS

This project benefited from a number of technologies that were available during the development phases of the product. An experienced design engineer, using state of the art computer aided design tools, with a CAD package from 'SDRC Ideas' was used to design the product. This enabled the geometry for the product component parts to be described in three dimensions (3D), which in turn enabled Rapid Prototyping technologies to be used. Rapid Prototyping *was* used extensively in the project, which accounted for about 15% of the capital spend on the project. However, as discussed earlier, the rapid prototypes were used exclusively by engineers and were not used for studies by Marketing, Manufacturing assembly or other functional studies.

Whilst a multi-functional team was appointed to the project from the initial stages, the team did not operate to any specific methodology. The individual roles of the team members were unclear and left up to individuals to sort out during the project. Key project milestones were also not clearly defined in the project making critical path planning difficult. The Project Management was left up to the engineers in the team.

The appointment of the author as Director of Engineering in the company initiated the development of a new methodology for the NPD process. The new methodology ensured that each functional activity in the project was carefully planned to allow individuals to contribute efficiently. Some elements of the 'new' methodology were applied to the later stages, after completion of the production tooling, of this project. The team members were exposed for the first time to samples of the new product from 'off-tool' parts. The team immediately identified problems from the off-tool parts. Issues such as 'difficult to assemble parts, performance issues in bench testing against competitor products were identified, including the fundamental ability of the product to do the job (mix dough). Tests carried out in a 'test kitchen' also revealed serious weaknesses in the 'gear train'.

The above issues prompted significant redesign and development with subsequent changes to the production tooling. Launch dates were threatened by these changes, however, the pressure to maintain targeted launch dates was equally intense. Engineers worked long hours and many weekends to make up for the time needed to redesign the product and to design new features into the product belatedly required by the Marketing team. The net result was the product *was* launched 'on-time', but the project was highlighted in the company as an example of 'how not to introduce a new product'.

Fig.52 The Kenwood Cuisine Food mixer

8.6. CASE STUDY No. 008 - THE KENWOOD MEDIUM SIZED DEEP FAT FRYER

COMPANY: KENWOOD Ltd. PROJECT PERIOD: 1996 – 1997

8.6.1 PROJECT BACKGROUND AND OBJECTIVES

Deep Fat Fryer products, used to cook chips, fish, battered food and chicken etc. are regarded as generally messy products to use and difficult to clean, by the consumer. Food particles tend to be left in the cooking oil after the cooking process, which degrades the oil requiring regular replacement and cleaning. However, if cleaning is not done regularly the degradation process also results in oil residue being 'burnt' onto the inside of the fryer bowl. Oil also solidifies on the outer surfaces of the product discoloring it, blocking the integral filter and leaving the product looking and smelling dirty. The competitive products available on the market at the time were difficult to dismantle for cleaning without risking the chances of water ingress into the electrical components.

The new product was intended to address the problems by allowing the product to be easily disassembled for cleaning. This included the facility to removal the entire electrical assembly in one operation, allowing the rest of the product to be immersed into a domestic 'dish washer' for thorough cleaning. This feature presented a unique selling point for the product that was patent protected by Kenwood. The concept launch to the market place immediately created an urgent demand for the product from retail outlet stores such as Argos and Boots etc.

8.6.2 THE STRATEGIC USE OF RAPID PROTOTYPES IN THE PROJECT

Kenwood had suffered from poor product introductions in the past (see case study 007), therefore a new NPD methodology was developed by a multi-disciplinary team to address the previous issues. Key people from each department were involved in the design of the methodology under the guidance of the author. Embedded within the methodology was a process to maximise the use of Rapid Prototype components and to ensure that each member of the team had an opportunity to *see* and use them in their various investigations.

The 'strategic' use of Rapid Prototyping formed the basis of a *business agreement* between the NPD project team and senior management, that committed the project team to introduce the product *on time* and within the financial and quality targets agreed at the start of the project. In return, the senior managers of the company agreed to release the money to fund the cost of the multiple prototypes for use in team studies such as VE, FMEA and DFM.

The business agreement involved the drawing-up of a Rapid Prototyping Strategy (*StratPro)* Plan, see Fig. 58. The *StratPro* plan was a controlled document constructed by the NPD team following a number of RP strategy meetings, and used as justification for the cost of the RP models to the senior managers. The RP components were present at all project team meetings, *and* senior management reviews to 'gauge' the progress of the project. Team-based FMEA, VE and DFM investigations were carried out as well as tooling studies, packaging and assembly studies. The RP components were also used for some performance testing, safety approval studies, technical manual and commercial photography. The RP components used together with a new NPD methodology, using *agreed* pre-defined KPIs, designed by the team, was closely monitored by the senior managers in the company.

8.6.3 QUANTITATIVE CASE STUDY RESULTS

The following tables and graphs represent the key quantitative data gathered during this case study.

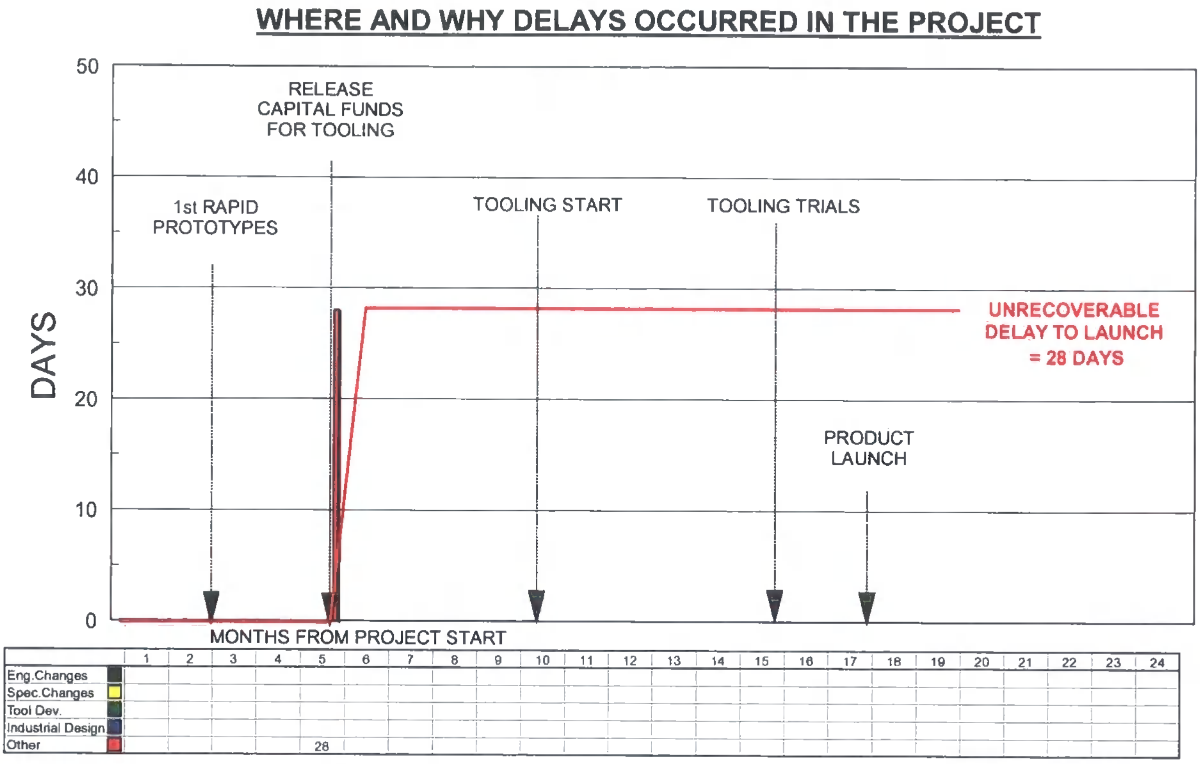


Fig.53. Where and Why delays occurred in case study 008

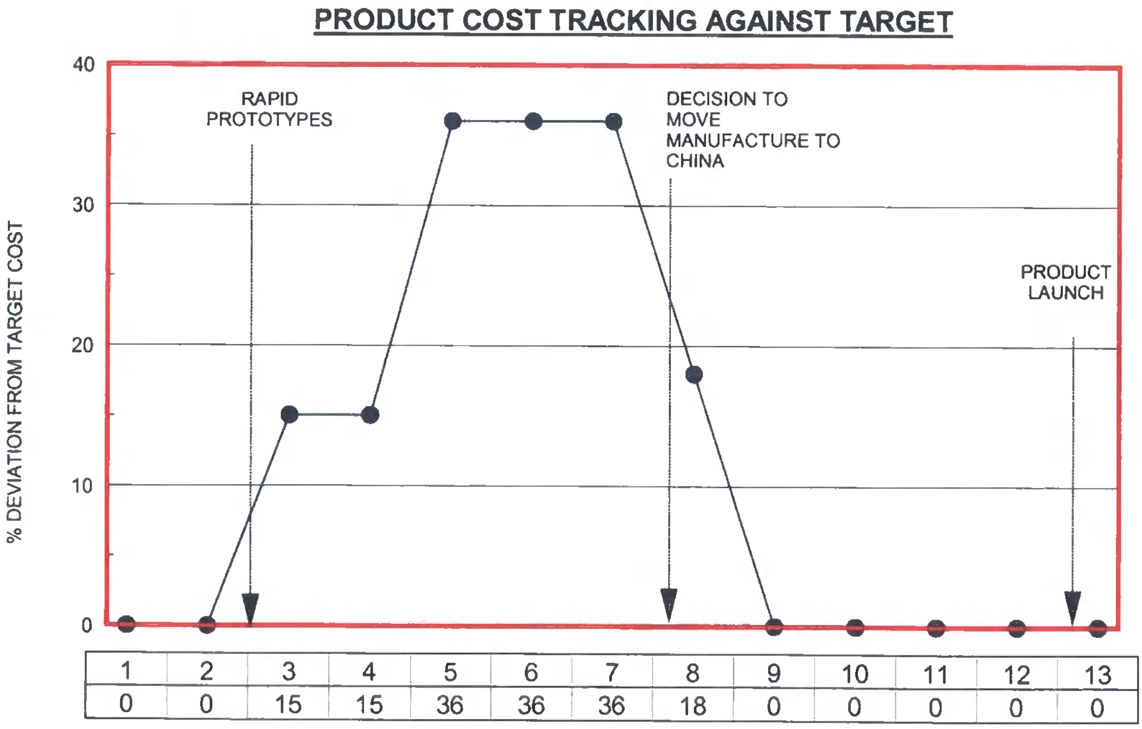
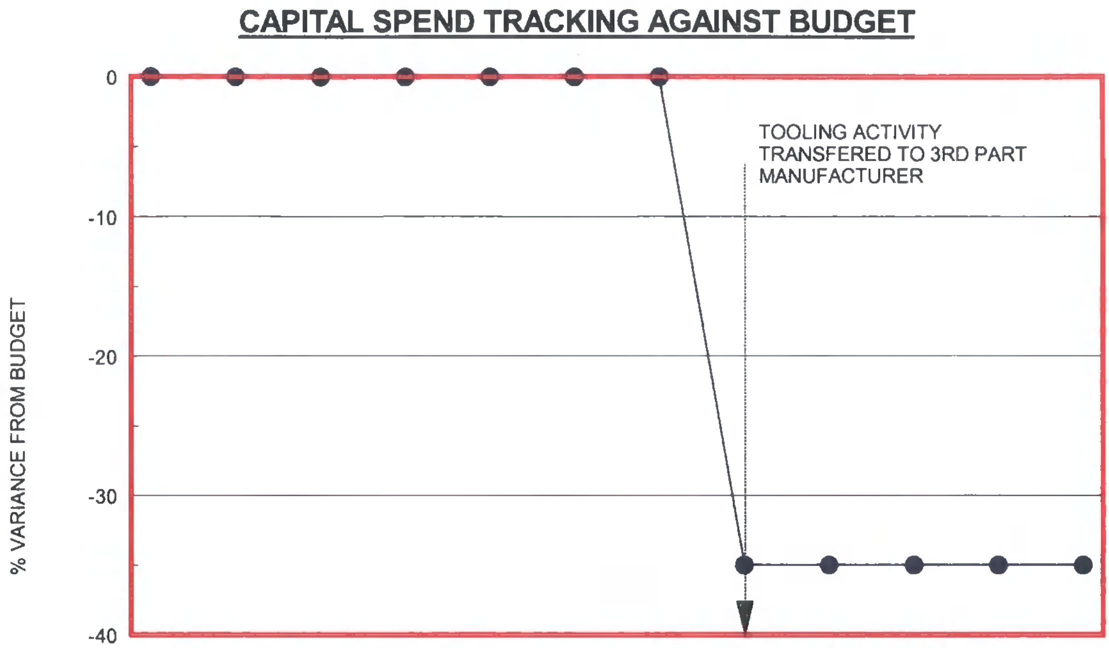
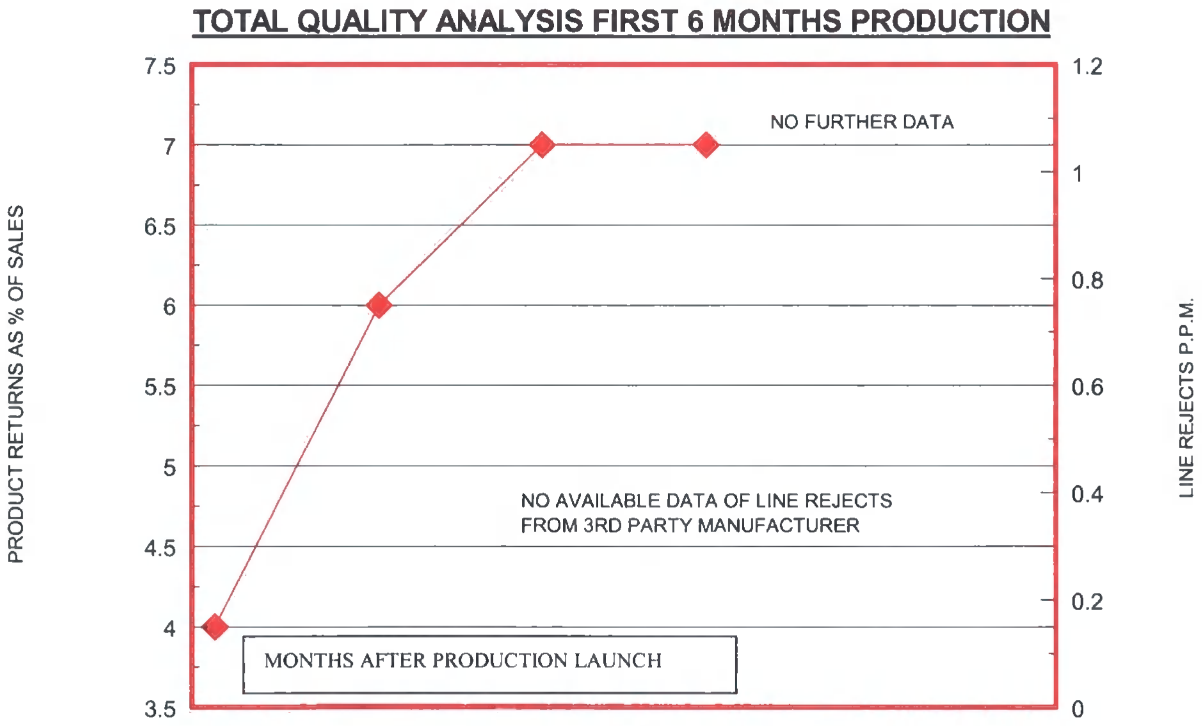


Fig.54 Product Cost Tracking for case study 008



1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	-35	-35	-35	-35	-35

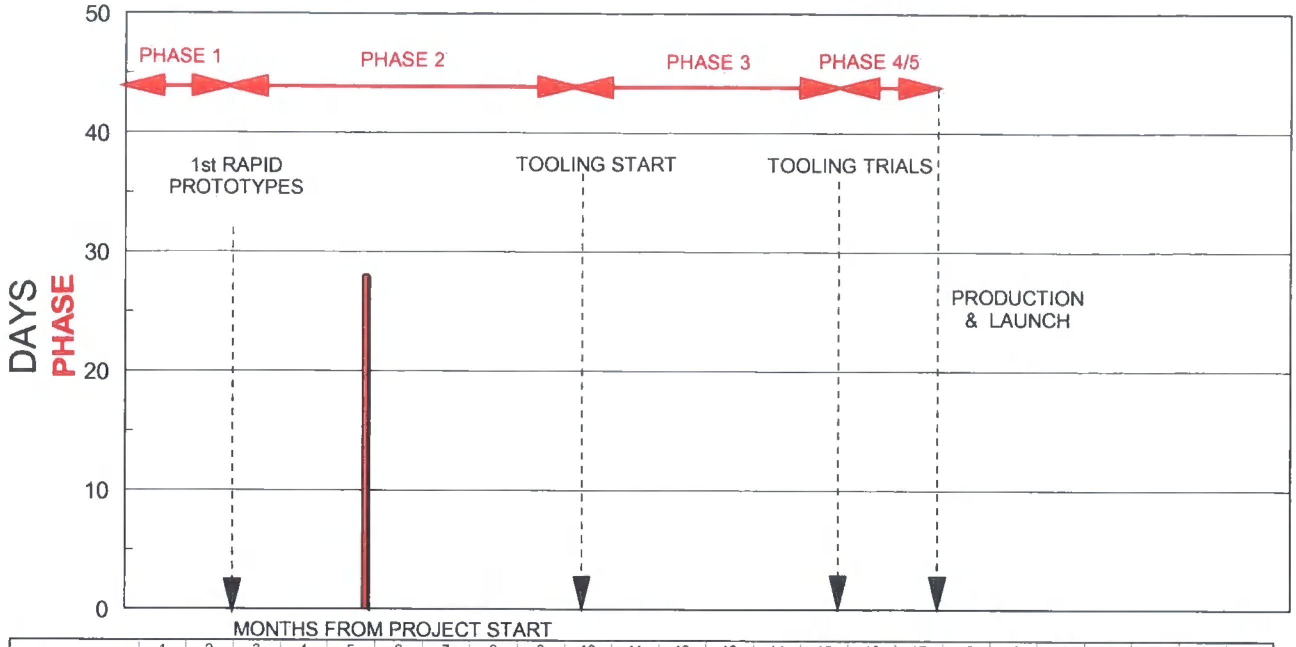
Fig. 55 Capital Spend Tracing for case study 008



	1	2	3	4	5	6
REJECTS ●						
RETURNS ◆	4	6	7	7		

Fig.56 Quality Analysis for case study 008

PROJECT PHASE RELATIONSHIP



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ⬛																								
Spec.Changes 🟨																								
Tool Dev. 🟩																								
Industrial Design 🟦																								
Other 🟥					28																			

CASE STUDY 008 ***Kenwood MEDIUM SIZED DEEP FAT FRYER***

Fig.57. Project delays due to changes according to the PHASE of implementation

8.6.4 PROJECT TEAM ORGANISATION:

A multi functional team were assembled to introduce the product that were briefed and made clear of the project objectives, their roles and accountability. The team consisted of representatives from:

1. Engineering Design
2. Purchasing
3. Marketing (Team Leader)

4. Accounts
5. Tooling
6. Industrial Design (Kenwood's own industrial product design team)
7. Manufacturing assembly (prior to transfer to China)

The author, as Director of Engineering, was responsible for the management of the Engineering function in the company, which included tooling. Sub Groups were set up within the team to manage key tasks in the project, such as:

1. Product Cost calculations and reports.
2. Product Packaging, instructions and artwork.
3. DFM studies, trial builds and training.
4. Product Acceptance Testing (PAT) for Safety, Performance and Reliability.
5. Tooling and Rapid Prototyping.
6. Quality-up-front, including the management of FMEA sessions.

RAPID PROTOTYPING STRATEGY PLAN

Project.....................................

DEPT.	*RP REQUIREMENTS*	*STUDIES*	*COST*	*RETURN*
Engineering design	All proposed injection moldings to be prototyped in SLA format	Dimensional clash detection and patterns for silicon moulds also initial verification of styling with marketing Product Manager	£18k	No tooling changes after phase 3 of project
Engineering design	6 off sets of resin castings of all moldings	Performance, approvals and design FMEA studies also VE team studies	£3.5k	Verify product costings and no tooling changes after phase 3 of project
Production Assembly	1 off set of 'top clamshell' moldings in SLS format	Motor assembly trials and jig & fixture development	£670	Completed Jig & Fixtures for pre-production trials
Production Assembly	3 off sets of resin castings of all moldings	Assembly training and development of line procedures and process FMEA studies	£1.3k	Target full production capability within first month of prod.
Marketing	3 off sets of resin castings of all moldings	Verification of aesthetics and ergonomics. Verify user guides via focus groups operating prototype models	£1.3k	No tooling changes after phase 3 of project with verified user manuals on-time
Quality	Use same parts as Production Assembly team	Design , Component and Process FMEA studies	£0	No tooling changes after phase 3 of project
After Sales	Use same parts as Production Assembly team	Service training and completion of spares and service manuals	£0	No tooling changes after phase 3 of project
Sales	3 off sets of resin castings of all moldings	Exhibition models and key-account demonstration models	£1.3k	Improved initial order intake of new product

TOTAL RP COSTS	RETURN SUMMARY
£26.07 k	No tooling changes after phase 3 of project full production capability within first month of prod. Improved initial order intake.

Project Manager/ Team Leader...Date/Issue.....................................

Fig. 58 Rapid Prototyping Strategy Plan.

8.6.5 QUALITATIVE CASE STUDY RESULTS

The product was introduced one month late, not because of a failure in the project team rather the senior management team delayed the release of the capital funds (referred to in the project plan as CSE release) for tooling, due to cash flow issues in the company. Also, the release of a competitor product, during the development process, forced an increase in the heater power specification to match the competition, this however did not effect the critical path in the plan. A decision was also taken, within two months of launch, to have the product assembled in China instead of the UK. This was also accommodated in the planned time scales without delaying the launch.

The team Leader for the project, who was also the Marketing Product Manager, issued a report for the senior managers in the company from which the following comments were taken:

> *'The team worked well with excellent cross department communication, and achieved their objectives'*
>
> *'Product costs were tightly controlled and achieved targeted margins'*
>
> *'Senior Management delayed the project by not signing capital requests on-time'*
>
> *'The disciplines in the new methodology kept the teams activities on-time'*
>
> *'FMEA investigations identified the big issues for the team to address'*
>
> *'DFM studies were not entirely relevant due to the transfer of the product assembly to China'*
>
> *' The Product Design freeze happened according to plan'*

The team reported no serious issues to the Engineering Director (the author) during the project, and appeared to generally enjoy the project and the team meetings.

The Strategic use of RP components (*StratPro*) seemed to provide an effective way for the team and the senior managers to carry out investigations and implement 'changes' within the critical path of the project. The project was a step forward in the company's capability and confidence to introduce new products efficiently.

The following case study will apply some of the findings of the previous case studies to re-test tools such as Strategic Rapid Prototyping, concise project management reporting documentation; and further applications of the Cost Weighting model. The objective here is to see if NPD performance can be improved with the application of these tools.

8.7 CASE STUDY No. 009 - THE DOMNICK HUNTER CONDENSATE DRAINS

COMPANY: DOMNICK HUNTER. PROJECT PERIOD: 1999 – 2000

8.7.1 PROJECT BACKGROUND AND OBJECTIVES

Domnick Hunter, as a manufacturer of ' compressed air treatment' equipment, produces a range of 'condensate drains'. These products are intended to 'trap' condensed water and oil that is discharged from compressors in a compressed air system. The condensate is very often corrosive and damaging to pipelines and ancillary equipment, and therefore must be removed from the system. Condensate Drains are small pressure vessels connected in a compressed air system, which have a reservoir to hold the condensate waste. There is also an electronic, capacitive, level sensor in the drain, which will sense when the drain is full of condensate, open a solenoid valve and discharge the waste material without venting any of the compressed air.

Domnick Hunter has been manufacturing drains for several years and the key objectives for developing a new range were as follows: -

1. Add new innovative features and improve reliability.
2. Reduce manufactured cost.
3. Reduce service downtime.
4. Improve installation flexibility and inter-connection options.
5. Improve styling, ergonomics and reduce size.

With the above objectives in mind a multi-disciplinary team was assembled in the company to design and introduce the new products. The company had recently developed a new NPD methodology, under the guidance of the author, for the introduction of all new products based on multi-disciplinary participation. The design of the methodology involved members from each discipline and therefore had their input and the 'buy-in' of the team.

As part of the revised NPD methodology, Domnick Hunter used a set of control documentation, known as the Product Pack in the company. This is very similar to the control documentation discussed earlier in this research which contains all of the essential information of a project under development such as: -

1. A NPD summary sheet containing a brief summary of the project.
2. A Product Costing sheet showing targets and cost build-up information.
3. A Capital Investment break down for tooling etc.
4. A document detailing the product design deliverables and performance specification.
5. A Project Plan in the form of a Gantt Chart.

The above controlled documentation, as discussed earlier, was used to remove any ambiguities in the project objectives and deliverables within the team <u>and</u> the senior managers. It was also decided to employ *Strategic Rapid Prototyping* in this project to help to ensure that the project objectives could be achieved, without the need for later development changes and delays from off-tool parts. The project would be a 'test case' for Domnick Hunter to see if the combination of multi-disciplinary teams, with a revised NPD methodology, new control documentation and the strategic use of Rapid Prototypes could improve the company's ability to efficiently introduce new products.

The NPD team member responsible for placing all of the production tooling in the company also chaired a RP Strategy meeting. The RP Strategy meeting, as described in earlier chapters, is a meeting of all functions in the project team that may benefit from having a prototype of the product.

A Rapid Prototyping Strategy document was produced from the above meeting (Fig. 59) to establish each member's requirements for prototypes and to commit to various returns for the investment and the additional time required for the manufacture and evaluation of the RP's. A time 'window' was provided in the project plan to enable the NPD team to carry out their respective investigations such as FMEA, VE and performance testing etc. before committing the production tooling for cast and moulded parts. The time window, during Phase 3, of the project added fourteen days to the critical path to production launch. In return the team committed to 'no changes after tooling commitment' in phase 4 onwards.

RAPID PROTOTYPING STRATEGY PLAN

Project.....................................

DEPT.	*RP REQUIREMENTS*	*STUDIES*	*COST*	*RETURN*
Engineering design	All proposed castings to be CNC'ed from stock aluminum	Pressure burst testing and 'level sensing' performance testing	£8k	No tooling changes after phase 3 of project
Engineering design	All plastic moulded parts to be prototyped using SLS	Performance, approvals and design FMEA studies also VE team studies	£2.5	No tooling changes after phase 3 of project
Production Assembly	One complete prototype	Assembly line training and jig design	£670	Completed Jig & Fixtures for pre-production trials
Production Assembly	3 off sets of resin castings of all moldings	Assembly training and development of line procedures and process FMEA studies	£1.3k	Target full production capability within first month of prod.
Marketing	3 off sets of resin castings of all moldings	Verification of aesthetics and ergonomics. Verify user guides via focus groups operating prototype models	£1.3k	No tooling changes after phase 3 of project with verified user manuals on-time
Quality	Use same parts as Production Assembly team	Design , Component and Process FMEA studies	£0	No tooling changes after phase 3 of project
After Sales	Use same parts as Production Assembly team	Service training and completion of spares and service manuals	£0	No tooling changes after phase 3 of project
Sales	3 off sets of resin castings of all moldings	Exhibition models and key-account demonstration models	£1.3k	Improved initial order intake of new product

TOTAL RP COSTS	RETURN SUMMARY
£15.07 k	No tooling changes after phase 3 of project full production capability within first month of prod. Improved initial order intake.

Project Manager/ Team Leader..Date/Issue.....................................

Fig. 59 Rapid Prototyping Strategy Plan for case study 009.

8.7.2 CASE STUDY RESULTS

The results of this case study will be presented using the 'weighting model', described in chapter 9 of this research. The weighting model will calculate the 'weighted' cost for each day of delay, according to the phase of the project. The basic objective of the weighting model is to help the NPD team to evaluate the 'cost' associated with accommodating delays in a project, with respect to the phase involved.

By way of example, a project team may wish to delay the start of production tooling, in order to produce more prototypes for approval studies. The alternative may be to conduct the approval studies from off-tool parts later in the project. However, as discussed earlier, if modifications were required it would be much more difficult, costly and time consuming if production tools needed to be modified.

The 'weighted' change profile for the project is shown in Fig. 60, with an associated 'shark's fin' diagram, shown in Fig. 61.

CASE STUDY 009

PHASE	1	2	3	4	5	6
DELAYS / PHASE (CD)	0	0	14	0	0	0
WEIGHTING FACTOR (F)	1	21	54	89	181	181
PENALTIES / PHASE (PU)	0	0	756	0	0	0
PENALTY COSTS/ PHASE (CP)	£0	£0	£26,460	£0	£0	£0

STANDARD DAILY RATE (R)	**£35**
TOTAL PROJECT PENALTIES (PP)	**756**
TOTAL PROJECT COSTS (TC)	**£26,460**

Fig. 60 'Weighted' change profile for case study 009

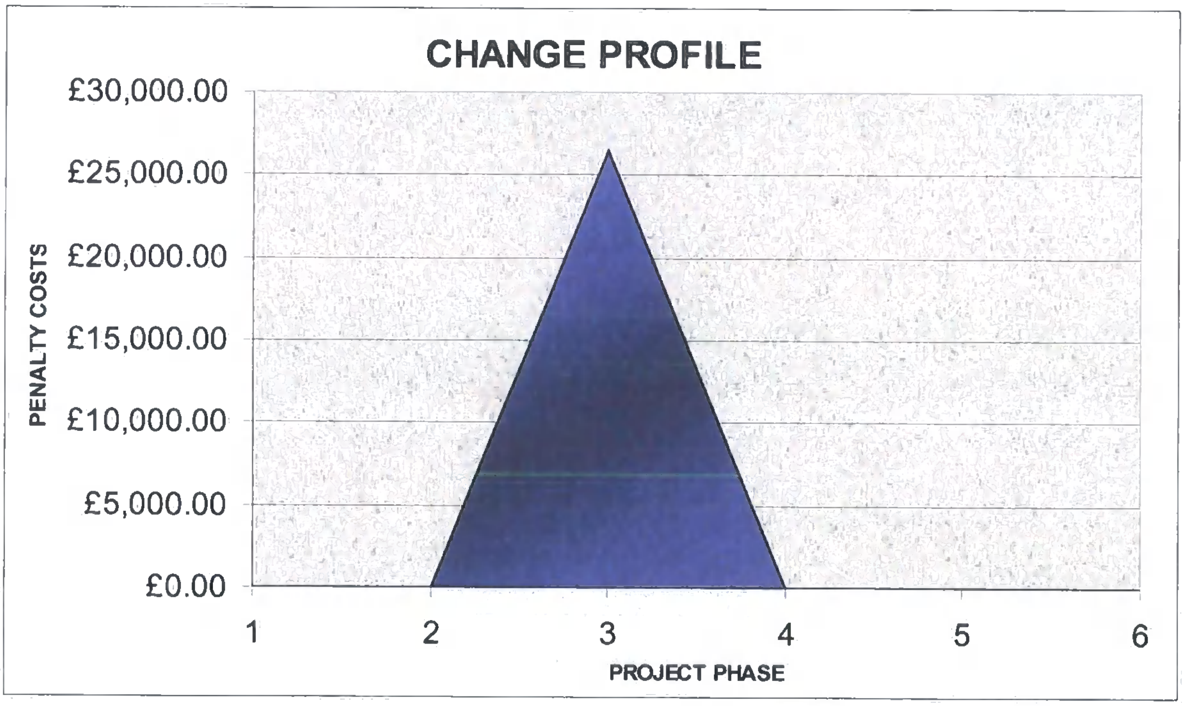


Fig. 61 'Shark's Fin' diagram showing change profile for case study 009

8.7.3 QUALITATIVE CASE STUDY DISCUSSION AND CONCLUSIONS

A number of initiatives coincided with the introduction of the new Drains for Domnick Hunter: –

1. The design and use of a formalised NPD methodology.
2. The use of control documentation detailing project status and deliverables for the NPD team and the senior managers.
3. The strategic use of Rapid Prototypes in the project.

The planned launch date was delayed 14 days to accommodate a 'change window' to allow changes to the *Specification* and the *Engineering* configuration of the product, following studies carried out from Rapid Prototypes. Since this was an unrecoverable delay, the total cost to the project was the total RP costs plus 14 days lost production. As shown in the 'cost weighting model', changes executed during phase three were three times less costly than changes executed after phase four of the project. Therefore, changes executed during phase three in the project would be approximately one third of the cost of the execution of the changes after phase four. It was also estimated that some of the VE saving meetings (conducted during the change window) would have been omitted if they were conducted after tool completion.

RP models were produced for the team linked to an RP Strategy agreement. This provided a number of benefits such as: -

1. NPD team was able to beat the VE targets set by the senior management.

2. The marketing team was able to demonstrate the new product to customers before launch and establish volume orders and the manufacturing team was 'ready' to build product having developed assembly jigs from the RP models.

3. The design team were able to 'fine tune' the product from a safety perspective following extensive performance tests from RP's. Non-destructive safety approvals tests were conducted for Low Voltage Directive & Electromagnetic Compatibility approvals and modifications made during the 14-day 'change window' period.

The above discussion would seem to endorse the decision made by the team to add 14 days to the critical path to the launching the product, pending Rapid Prototype studies. Also, the inclusion of concise project control documentation helped to remove ambiguities within the team and the senior managers with regard to project deliverables. This had been the cause of conflict and 'late changes' in previous NPD projects.

The poor reliability issue was traced to a sub contractor who assembled and tested the electronic sub assembly. This sub contractor was not included in the RP strategy discussions.

Fig. 62 Case Study 009 Domnick Hunter Modular Drains

CHAPTER NINE

DERIVING A WEIGHTING MODEL FOR THE IMPACT OF CHANGES

9.1 OBJECTIVES OF THIS CHAPTER

The objective of this chapter was to quantify the impact of engineering and specification changes according to when they were implemented in an NPD project. The following KPIs were considered:

KPI 1 The achievement of targeted launch dates.
KPI 2 The achievement of targeted Product Costs.
KPI 3 The control of project Capital Spend.
KPI 4 The achievement of Product Quality Targets.

It was discussed in the review that project teams often sacrifice one KPI in order to 'save' another, depending upon the type of project under development. For example, the team may allow overspend in the capital-tooling budget in order to make Engineering changes to reduce Product Costs; or to accept Product Cost variances in order to achieve Project Completion Timescales. Reinertsen *et al* (1991) discusses the trade-off of KPI priorities in NPD, with respect to the type of project under development, tabulated in Fig. 62.

PROJECT TYPE	*PRIORITISED KEY PERFORMANCE INDICATORS*		
	LOW	*MEDIUM*	*HIGH*
STRANGER INNOVATIVE NEW PRODUCT	CAPITAL SPEND	PRODUCT COST	**LAUNCH DATE**
REPEATER DERIVATIVE OF ABOVE	LAUNCH DATE	PRODUCT COST	**CAPITAL SPEND**
COST SAVING / VE QUALITY, COST/VALUE RATIO	LAUNCH DATE	CAPITAL SPEND	**PRODUCT COST**

Fig.63. Project KPIs prioritised according to project type

As discussed in the review, project teams found it difficult to evaluate the impact of engineering changes at the time of implementation and the resulting propensity to cause 'delays' to production launch. This difficulty in quantifying the 'impact' of a change, for example to reduce product costs was exacerbated during the development of an innovative new product (i.e. a Stranger) where the potential for a monopolistic product opportunity existed and pressure was biased towards *launch date*s. Therefore, an attempt has been made in this chapter to provide a 'weighting model' for engineering and specification changes, expressed as a cost, allowing a true comparison with other KPIs. This may help project teams to evaluate the impact of delaying a project to accommodate a change and provide an efficiency profile for the project, to be explained later in this chapter.

9.2 THE IMPACT OF ENGINEERING AND SPECIFICATION CHANGES

To remind the reader: *Specification changes* were defined as changes to the specification of the product. Specification changes may derive from modifications of the requirement from the customer, or misinterpretation by sales and marketing, or a redefinition of the project deliverables from within the organisation developing the product. *Engineering changes* are changes generated through technical studies to improve the product's ability to meet (or exceed) the specification. Engineering changes may also may also be initiated to improve the product's perceived value, aesthetics, ergonomics, assembly, or through a re-evaluation of the design proposal by the NPD team to maintain the following NPD KPIs: -

KPI 2 The achievement of targeted Product Costs.
KPI 4 The achievement of Product Quality Targets.

Data gathered from the case studies show 'Where and Why delays occurred in a project' due to the implementation of specification and engineering changes. The delays were defined as the 'unplanned time in days, taken to execute a change'. This may be the time taken for a designer to change drawings on a CAD system and/or the time for the toolmaker to change the production tools. This was time not accounted for in the planning of the project to determine the production launch date. It has also been discussed that these delays have the potential of effecting some of the KPIs in a project. Two of the KPIs, which may be at risk due to specification and engineering changes, are:

KPI 1 the achievement of targeted launch dates (with associated loss of sales).

KPI 3 the control of project Capital Spend for production tooling.

From the review of previous work, specification and engineering changes were identified to be one of the main causes of late launches in NPD projects. Moreover, the need to make changes in the later stages of a project were identified as generally 'poor technique' and possible indicative of an inefficient NPD methodology. The results of the case studies have suggested that late changes requiring expensive 'tooling' modifications may have been avoided if the investment for 'prototype models' was provided to identify flaws and verify product performance, before the start of production tooling manufacture. The weighting model will be used later to evaluate the impact of a change with respect to any benefits and provide an efficiency profile of the project.

For example, with specific reference to case study 006, it can be seen that changes initiated before the commitment of the production tools had only a small effect on the critical path to launch. However, changes implemented during and after the tool making process created delays that were not always recoverable before the production launch dates, thereby delaying the launch. Also, delays in the later stages of a project provide fewer opportunities to recover lost time by using contingency resource. This suggests that the impact of a change depend upon when the change was initiated in the project.

9.3 EXPRESSING THE IMPACT OF CHANGES AS A COST

The 'impact' on a project's KPIs from specification and engineering changes may be expressed in both quantitative and qualitative terms. From a quantitative point of view, as discussed above, the parameters effected by specification and engineering changes are cost and time. These parameters will be listed below:

C_D = Change Delay

This is the number of days (unit days) taken by the designer to implement a single change resulting in a delay to the project schedule.

R = Standard daily rate

This is 'the cost' for the design resource, per day.

C_C = Cost to implement design changes ($C_D * R$)

This is the cost for design resource per day to implement changes.

T_T = Time to change production tools

This is the time period required to change the production tools, to represent the changes described by the designer.

C_T = Cost to change production tools

This cost was based on toolmaker's time for modifying production tooling together with any additional materials required.

However, if the time taken for C_D and T_T also result in time added to the critical path to product launch, then this may also effect sales turnover targets. In some cases extra, contingency, resource may be assigned to a project to 'recover' time lost due to the above, including extra time; that is overtime worked by the design team and external toolmakers to 'catch up'. Further cost variables are therefore generated from this: -

C_R = Cost for contingency resource

This is the cost for design resource working at an overtime rate or the addition of extra resource (internal or external) allocated to the project.

C_S = Cost for lost sales

This is the loss in sales contribution, due to a delayed launch of the new product.

From the above discussion, the cost impact (C_A) of specification and engineering changes may be expressed purely as a cost in the following way:

$$\mathbf{C_A = C_C + C_T + C_R + C_S} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

The author, by the nature of his employment, was able to directly access and review the above costs in each case study. Although, due to commercial confidentiality, it is not appropriate to reveal the detail of the costs in this research, it was possible to 'quantify' them in relative orders of magnitude:

Cost to implement design changes	C_C	Low
Cost for contingency resource	C_R	Medium
Cost to change production tools	C_T	High
Cost for lost sales	C_S	Very High.

The above suggest that, for example, it may be more cost effective to 'recover' lost time by using contingency resource (C_R), to prevent loss of sales revenue (C_S). However, it was also seen in some of the case studies that the use of contingency resource, to recover lost time, was not always possible if change requests occurred at a late stage in a project. This suggests that the team's ability to 'recover' lost time is reduced as the project progresses, especially after the production tooling process. The impact of engineering changes may also be expressed in the form of a 'logic truth table' where a '1' depicts the likelihood of particular costs being incurred in the project, and a '0' being an unlikely event (Fig. 64):

	PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6
C_C	1	1	1	1	1	1
C_R	0	1	1	1	1	1
C_T	0	0	1	1	1	1
C_S	0	1	1	1	1	1

Fig.64. Propensity of costs incurred due to changes, with respect to the project PHASE.

As discussed earlier in chapter three, the project PHASE refers to a specific stage in a project following the completion of certain milestones with other key milestones still remaining.

Change requests occurring during phases 5 & 6 may also take the form of 'running development', where the manufacturing process may, or may not, be disrupted. Engineering changes are occasionally implemented during phase 6 to either: improve the product performance following feedback from the field or, to reduce quality problems in the manufacturing process. Changes during phases 5 & 6 may stop the manufacturing process in order to implement the change including product already released to the customer may be 're-called' for modifications. In some cases changes to the product specification after phases 5 & 6 may require re-approval by independent bodies, for example, to maintain a CE or UL rating for the product. This in turn may result in multiple variants of the same product available in the field, making product support a complicated task for the sales outlets and the manufacturer. Therefore any changes during phases 5 & 6 are viewed as the most costly time in the project. Changes during phases 5 & 6 may be disruptive to production daily volumes or stop production pending expensive remedial action.

It can be seen from Fig. 64 that changes have an increasing 'negative' cost impact on a project as the project progresses through each phase. It has also been shown above that not only does it becomes increasingly difficult or costly to implement a change, but the designer may be restricted to making only small changes without the need for significant delays, toolmaker costs or the need to re-tool the faulty component.

The above discussion supports the findings of Berliner et al (1988) who described the effect of costs incurred and committed to a project as the project progresses through phases leading up to final production (see Fig. 65).

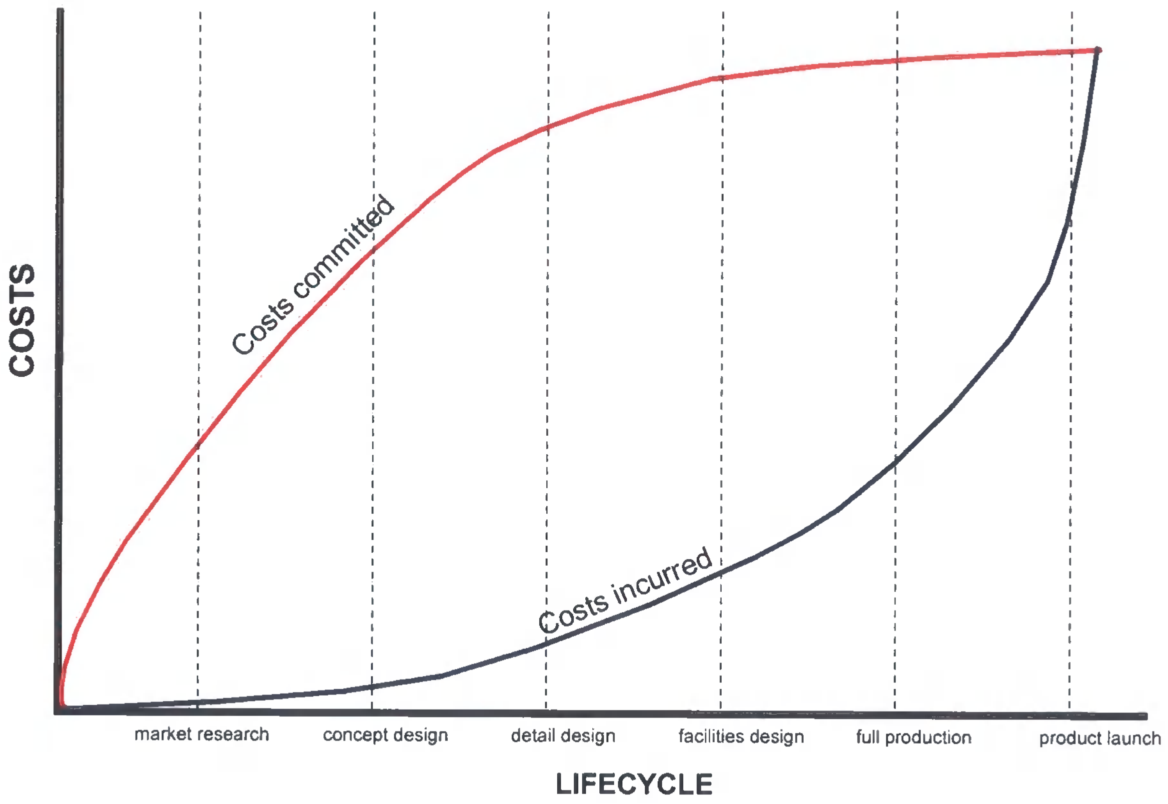


Fig.65 Costs committed and incurred in a project. Source Berliner and Brimson 1988

The study by Berliner and Brimson (1988) was discussed in detail earlier in this research but to remind the reader: Berliner *et al* (1988) claimed that about 80% of the total costs of a product lifecycle were committed during the early phases of the development. This is at a stage where little or no costs had been 'incurred' e.g. tooling costs. 'Committed costs' include the material and manufacture costs of the product but also the packaging, distribution and disposal costs of the product. The above graph also shows that it is only possible to have a small influence on the 'committed costs' during the latter phases of the lifecycle, without 'incurring' large costs to make the correction. This is consistent with the findings of the case studies.

9.4 DERIVING A *PENALTY* WEIGHTING FACTOR FOR CHANGES

Since the precise details of various monetary 'costings' were available to the author during each study, costings for items such as labour time, supplier (toolmaker) costs and profit margins from product sales were known during each project. Whilst the details of these costings are commercially confidential, and therefore cannot be revealed in this study, trends and relative costings, and proportional weightings, will be discussed.

We have seen that the *negative* impact of changes increases as the project progresses through each phase leading up to production launch. Therefore, it was decided to apply a *'cost penalty weighting factor'* to each day taken up by the implementation of a 'change'. The magnitude of the *weighting factor* was selected according the *phase* when the change was implemented. This provides a representation of the 'cost impact' of a change and ultimately how efficiently a project was introduced, or to provide a framework to assist a project team to decide if indeed a change should be accommodated in the project. A penalty-weighting factor example based on relative costing data, available to the author, was quantified and applied as follows:

Standard Daily Rate **R**

This is the cost for the design resource per day, working at a standard rate therefore the weighting factor proposed is:

$$R = 1$$

Cost for contingency resource **C_R**

This is the cost for design resource working at an overtime rate or the addition of extra resource (internal or external) allocated to the project. This was estimated to be about three times the standard resource cost per day, therefore the weighting factor proposed is:

$$C_R = 3$$

Cost to change production tools **C_T**

This cost was based on toolmaker's time for modifying production tooling together with any additional materials required. This was calculated to be approximately 15 times the cost of standard working rate, therefore the weighting factor proposed is:

$$C_T = 15$$

Cost for lost sales **C_S**

The loss of sales contribution due to each day of delay to full production launch depends, of course, on the daily volume and profit contribution of the product in question. Therefore a **C_S** weighting factor for each project may be calculated using the following formula:

Weighting factor ($\mathbf{C_S}$) = (unit profit (P) x daily production volume (V))/ standard rate (R)

$$\mathbf{C_S = (P \times V) / R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Many of the projects studied in this research were regarded as providing incremental sales growth to their respective businesses, rather than a simple replacement or *facelift* to an existing product i.e. a Stranger rather than Repeater. Some projects studied actually provided a monopolistic opportunity, in that no competitive product existed in the market. In these cases, $\mathbf{C_S}$ values were calculated to range between 150 - 270 times the cost of design resource (working at standard rate R) for each day of lost production. Therefore the value of this factor is a variable according to the project:

$$\mathbf{C_S \sim 150} \text{ to } \mathbf{270}$$

Precise C_S factors for Stranger projects can be calculated using the above expression (2). A variation to this formula, to accommodate product replacements (Repeaters), is described later in this chapter.

It can be seen, from the $\mathbf{C_S}$ factors that the loss of sales contribution is by far the most significant cost associated with delays due to the implementation of unplanned changes. However, it was also seen that not all of the changes in the case studies resulted in an 'unrecoverable' delay to the production launch. During phases 1 to 3 of a project, before the commencement of production tooling, project teams were often able to use contingency resource to recover 'lost time'. However, if the changes involved modification to tooling, contingency resource options were not always a solution to time recovery. Tooling modifications are usually very time-consuming activities that may directly effect the critical path of the project. Tool modifications involving CNC machining or 'spark erosion' techniques are automated procedures that follow a prescribed routine according to the geometry of the modification. A study conducted in Flymo by the then tooling manager Belcher (1995 not published), provided time and cost examples of tooling modifications for the design engineers in the R&D department. From this study the most basic modifications to tooling took a week, with more complex modifications taking up to 12 weeks. The tool modification time becomes a greater percentage of the remaining project time, as the project advances. Therefore, the propensity of an unrecoverable delay to a project was seen to increase with subsequent phases. From the study conducted at Flymo, the larger complex NPD projects with longer introduction periods also tended to involve longer time periods for tool modifications. The proportional impact of tooling modifications with respect to the remaining time to launch tended to remain constant and independent of the size of the NPD project.

From the above discussion, it was therefore decided to apply the weighting factor for $\mathbf{C_S}$ proportionally and according to the phase in the project where a change took place. The probability of delays to the product launch and subsequent loss of sales revenue (Cs) due to changes, were estimated and shown in Fig.66.

	PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6
Probability	0	10%	20%	40%	95%	95%

Fig.66 Probability of loss of sales revenue (Cs) due to changes, according to phase.

By way of example, the following table (Fig. 67) was produced to show the 'cost penalty weighting' factor for changes according to the phase of implementation. The chosen value for was **C_S = 170**, however, this value was applied proportionally according to the table in Fig.65, with **C_S = 10%** of **170** in phase two and **C_S = 20%** of **170** in phase three etc.

	PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6
R	1	1	1	1	1	1
C_R		3	3	3	3	3
C_T			15	15	15	15
C_S	0	17	35	70	162	162
F	**1**	**21**	**54**	**89**	**181**	**181**

Fig.67 Total Penalty Weighting factor (F) for the impact of changes according to phase

It is recognised that some changes, such as minor 'running development', implemented after product launch (phases 5 & 6) may not effect the production output in a project. However, since changes after phase 3 have been shown to be inefficient in terms of tooling cost and resource time, all changes made during phases 5 & 6 will be weighted as described allowing comparisons to be made between projects. The above Weighting Factors for Changes according to Phase can be shown graphically in Fig.68.

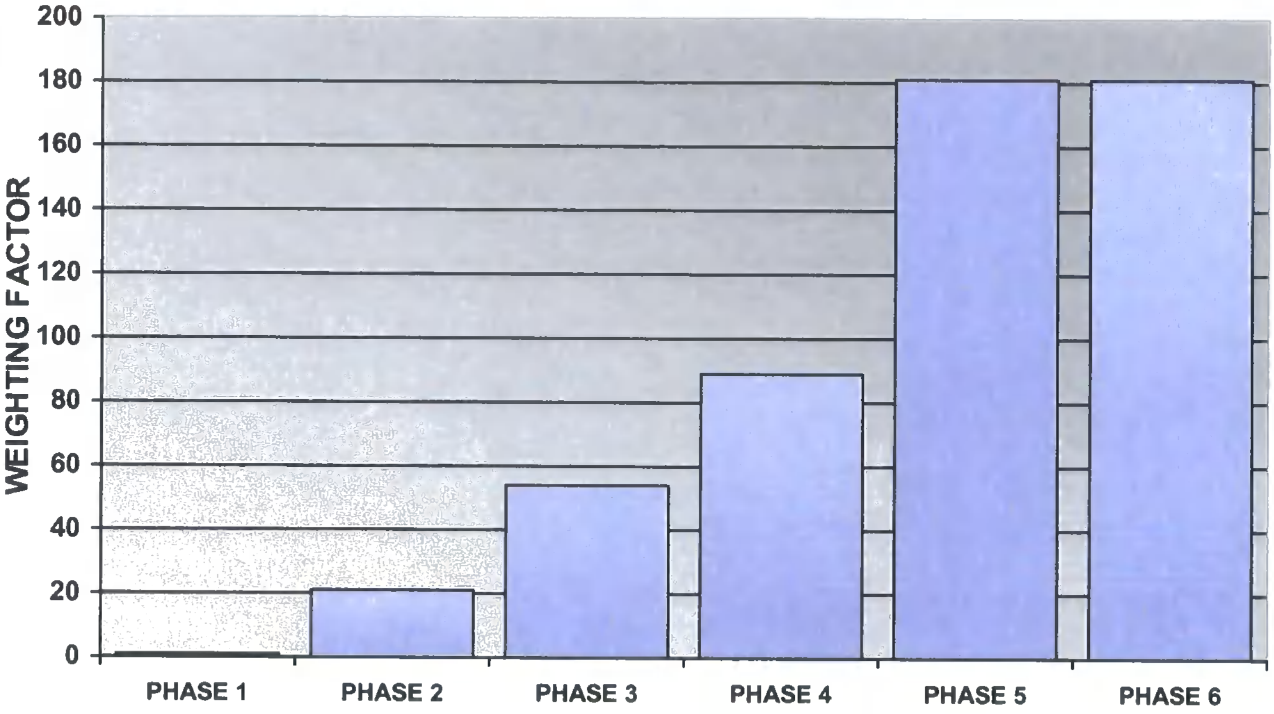


Fig.68 Cost Weighting Factors for Changes according to Phase of implementation

It has also been claimed in the review that 'Prototyping Cycles reduce the need for late changes in a project' (Wheelwright 1997); since one of the key objective of prototyping cycles is to test and prove a development concept before the commitment of production tooling. The weighting factors may assist the design team to justify the cost and delays associated with further prototyping cycles, during early phases of a project, rather than risking changes to production tooling in later phases.

The discussion, so far, has resulted in a number of variables to quantify the relative cost impact of changes according to the phase of implementation, as well as predicting the total cost impact on the project. These parameters will now be summarised:

i) Standard daily rate (R)

This cost (unit cost, Pounds or Dollars etc.) is used as a 'calibration' for the model and was defined as 'the cost' for the design resource per day, to implement a change, working at a standard daily rate.

ii) Change delay (C_D)

This is the number of days (unit days) taken by the designer to implement a single change resulting in a delay to the project.

iii) Total change delays per phase (T_D)

This is the total number of days (unit days) taken up by implementing all of the changes in a phase.

iv) Penalty units per phase (P_U)

This is the total number of penalty units applied to each phase by multiplying the 'Total change delays per phase', by the weighting factor (F) for each phase shown in Fig.67.

$$P_U = T_D * F$$

v) Costs per phase (C_P)

This is the 'Penalty units per phase' multiplied by the 'Standard daily rate'.

$$C_P = P_U * R$$

vi) Penalty units per project (P_P)

This is the sum total number of all of the 'Penalty units' incurred during the project.

vii) Total project penalty cost (T_C)

This is the 'Penalty units per project', multiplied by the 'Standard daily rate'.

$$\mathbf{T_C = (P_P * R)} \quad \dots\dots\dots\dots\dots\dots (3)$$

The following parameters may be used to test the model:

viii) Daily production volume (V)

This is the volume of products manufactured per day after the production launch. This value would be a target at the start of a project, becoming an 'actual' value after launch.

ix) Product profit contribution (P)

This is the predicted financial contribution (unit cost, Pounds or Dollars etc.) due to the sale of each new product.

In addition to known values at the start of a project, the following parameters may be used as a verification of the model from 'actual' data available upon completion of the project. This may be useful in 'post project review' meetings by the NPD team.

x) Unrecoverable delay (D)

This is the 'actual' delay to full production launch (unit days) due to the delays that could not be 'recovered' using contingency resource.

xi) Actual loss of sales contribution (S)

This is the 'actual' loss of sales (unit cost, Pounds or Dollars etc.) contribution due to unrecoverable delays to the full production launch.

$$\mathbf{S = P * V * D} \quad \ldots\ldots\ldots\ldots(4)$$

xii) Actual cost of contingency resource (C_R)

This is the actual cost of all the 'contingency' resource required to minimise the delay to full production launch described earlier.

xiii) Actual cost of tooling changes (C_T)

This is the actual cost to toolmakers to make the necessary changes to the production tooling to implement changes.

xiv) Total actual project costs due to changes and delays (C_A)

This is the 'actual' total cost to the project due to the implementation of unplanned changes expressed as follows:

$$\mathbf{C_A = C_C + C_T + C_R + C_S} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The parameters listed *(i)* – *(ix)* provide variables for a model to 'predict' the impact of changes in terms of cost. The 'actual' data *(x)* – *(xiv)* can be used as a verification of the 'accuracy' of the model following project completion.

Following the above it is now possible to test the model by simply comparing the difference between the following two cost expressions:

Expression based on the prediction model (unit cost). $\mathbf{T_C = (P_P * R)} \ldots\ldots (3)$

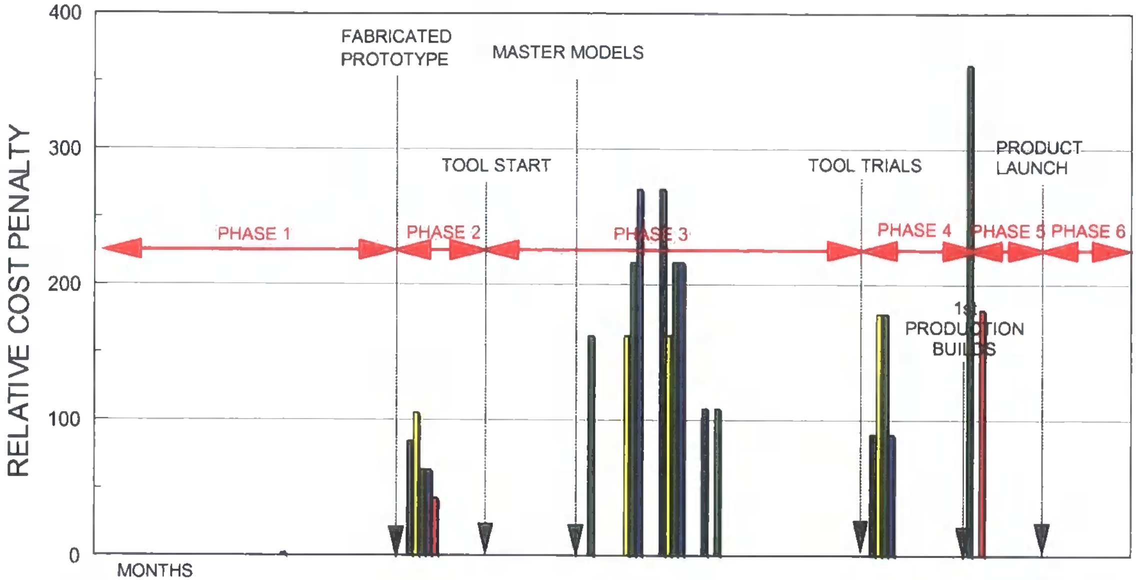
Expression based upon actual data (unit cost). $\mathbf{C_A = C_C + C_T + C_R + C_S} \ldots\ldots (1)$

9.5 TESTING THE *PENALTY WEIGHTING* FACTOR MODEL

It should now be possible to test the above weighting factor model by applying the factors shown in Fig.67, to delays in real projects from the case studies. In order to do this a consumer durable product, case study 006, was selected. A *penalty-weighting* graph was produced to show the *penalty factors* for each day of delay caused by a change, according to the phase of implementation (Fig. 69a).

By comparing Fig.69a and Fig.69b for case study 006, it can be see that the profile has altered significantly, depicting the 'weighting' impact of each change in the project. The impact of 'phase one' changes (shown in Fig. 69a) hardly register on the chart, whereas changes in the later stages are weighted heavily.

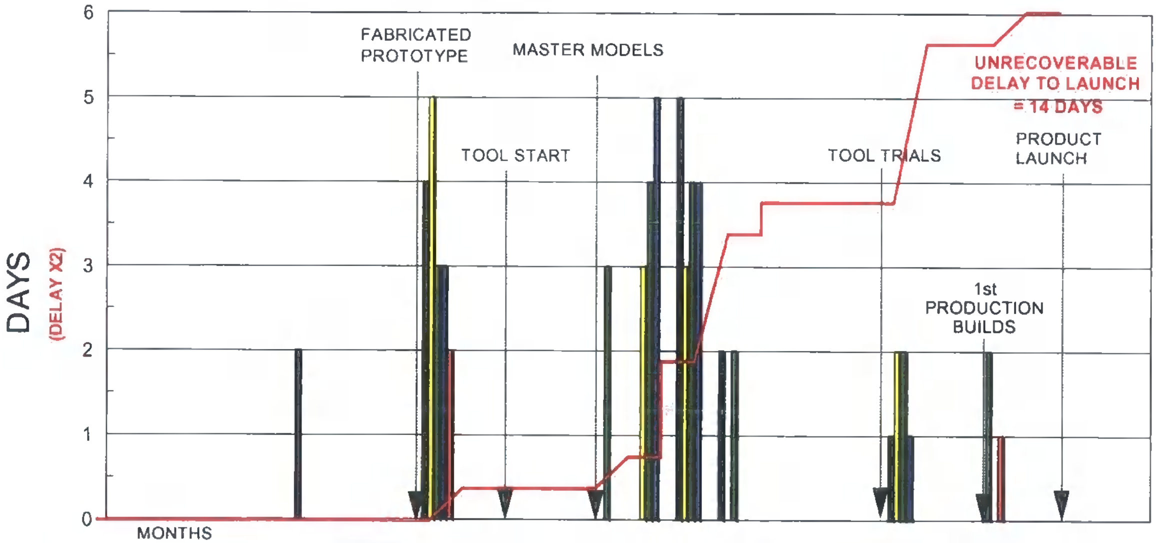
RELATIVE COST IMPACT TO PROJECT DUE TO CHANGES



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ■					2			84						270	108				89					
Spec.Changes 🟨								105					162	162					178					
Tool Dev. 🟩								63				162	216	216	108				178		362			
Supplier req. 🟦								63					270	216					89					
Other 🟥								42													181			

Fig.69a. Penalty weighting table applied to case study 006

WHERE AND WHY DELAYS OCCURRED IN THE PROJECT



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Eng.Changes ■					2			4						5	2				1					
Spec.Changes 🟨								5					3	3					2					
Tool Dev. 🟩								3				3	4	4	2				2		2			
Supplier req. 🟦								3					5	4					1					
Other 🟥								2													1			

CASE STUDY 006 ***FLYMO TC300 AIR CUSHION LAWNMOWER***

Fig.69b. Where and Why delays occurred in a project for case study 006

As discussed earlier a penalty weighting of 'one' is equivalent, in terms of cost, to one man-day of design resource working at a standard labour rate. Therefore if it is assumed that the standard daily rate for this organisation is £55, further analysis may be carried out from the following table of variables (Fig.70).

PARAMETER	*SYMBOL*	*UNITS*	*VALUE*
STANDARD DAILY RATE	R	POUNDS	£55
TOTAL PENALTY UNITS	P_P	UNITS	2072
TOTAL PENALTY COSTS	T_C	**POUNDS**	**£113960**
DAILY PRODUCTION VOLUME	V	UNITS / DAY	*confidential*
PRODUCT PROFIT	P	POUNDS	*confidential*
UNRECOVERABLE DELAY	D	DAYS	14
ACTUAL LOSS OF SALES	S	POUNDS	£105000
ADDITIONAL RESOURCE	$C_C + C_R$	POUNDS	£1740
TOOLING CHANGES	C_T	POUNDS	£28006
TOTAL CHANGE COSTS	C_A	**POUNDS**	**£134746**
ACCURACY OF MODEL	*A*	%	*15%*

Fig.70 Variables used to calculate the cost of changes (from case study 006)

The above analysis shows a comparison between theoretical, cost of changes, and actual cost of changes. There is a discrepancy between the two figures highlighted of about 15% which was viewed as being an acceptable deviation for a model to be used for estimating the relative impact of changes according to the phase of implementation.

For further verification the model was applied to case study 005 as an extreme example of an inefficient project, which produced the results shown in Fig.71:

PARAMETER	***SYMBOL***	***UNITS***	***VALUE***
STANDARD DAILY RATE	R	POUNDS	£55
TOTAL PENALTY UNITS	P_P	UNITS	20973
TOTAL PENALTY COSTS	T_C	**POUNDS**	**£1153515**
DAILY PRODUCTION VOLUME	V	UNITS / DAY	confidential
PRODUCT PROFIT	P	POUNDS	confidential
UNRECOVERABLE DELAY	D	DAYS	187
ACTUAL LOSS OF SALES	S	POUNDS	£1402500
ADDITIONAL RESOURCE	$C_C + C_R$	POUNDS	£1400
TOOLING CHANGES	C_T	POUNDS	£22600
TOTAL CHANGE COSTS	C_A	**POUNDS**	**£1439100**
ACCURACY OF MODEL	*A*	*%*	*~20%*

Fig.71. Variables used to calculate the cost of changes (from case study 005)

Other test examples of the model indicated deviations up to 21%, with an average of 9%, with the model showing more accuracy with fewer delays per project. In order to fully prove the model as a way of 'predicting' the total cost of changes; it would be necessary to apply further case studies for comparative analysis. However, if the model were to be used as a comparative 'tool' only, as in this research to compare NPD introduction methodologies, absolute calibration of the model becomes less important, since adjusted factors would be applied to projects.

9.6 GRAPHICAL REPRESENTATION OF CHANGE PROFILES

Change profiles for projects have been represented graphically showing 'where and why' changes occurred in each case study, and also showing the same data with 'weighting' factors applied to represent the *impact* of each change. Fig.72 shows a table of 'total changes per phase', a 'weighting factor' and the 'penalty weighting' for each phase. The subsequent penalty weighting for each phase can then be presented as a relative *cost* by multiplying by the 'standard rate', shown in the table. When the penalty weighting data is plotted for each phase, either as a cost or dimensionless, a profile of the change activity is produced which will be termed a 'sharks fin' diagram shown in Fig.73.

The 'sharks fin' diagram provides an 'at a glance' picture of where the change activity occurred and from the amplitude of the 'sharks fin', will give an indication of the impact of the changes. The 'sharks fin' diagram may be used as a visual comparison between projects from which conclusions may be drawn with regard to how efficiently each product was introduced. The 'area under the curve' of the 'Shark's fin' diagram, represents potentially wasted, or unnecessary expenditure in the project, since the amplitude of the 'Shark's fin' diagram derives from one or all of the following: -

1. Unplanned resource time costs, to implement changes.
2. Unbudgeted toolmaker costs to modify production tools.
3. Lost Sales revenue.

CASE STUDY 005

PHASE	1	2	3	4	5	6
DELAYS / PHASE (CD)	0	0	25	131	24	20
WEIGHTING FACTOR (F)	1	21	54	89	181	181
PENALTIES / PHASE (PU)	0	0	1350	11659	4344	3620
PENALTY COSTS/ PHASE (CP)	£0	£0	£74,250	£641,245	£238,920	£199,100

STANDARD DAILY RATE (R)	**£55**
TOTAL PROJECT PENALTIES (PP)	**20973**
TOTAL PROJECT COSTS (TC)	**£1,153,515**

Fig.72. Impact of changes table for a case study 005

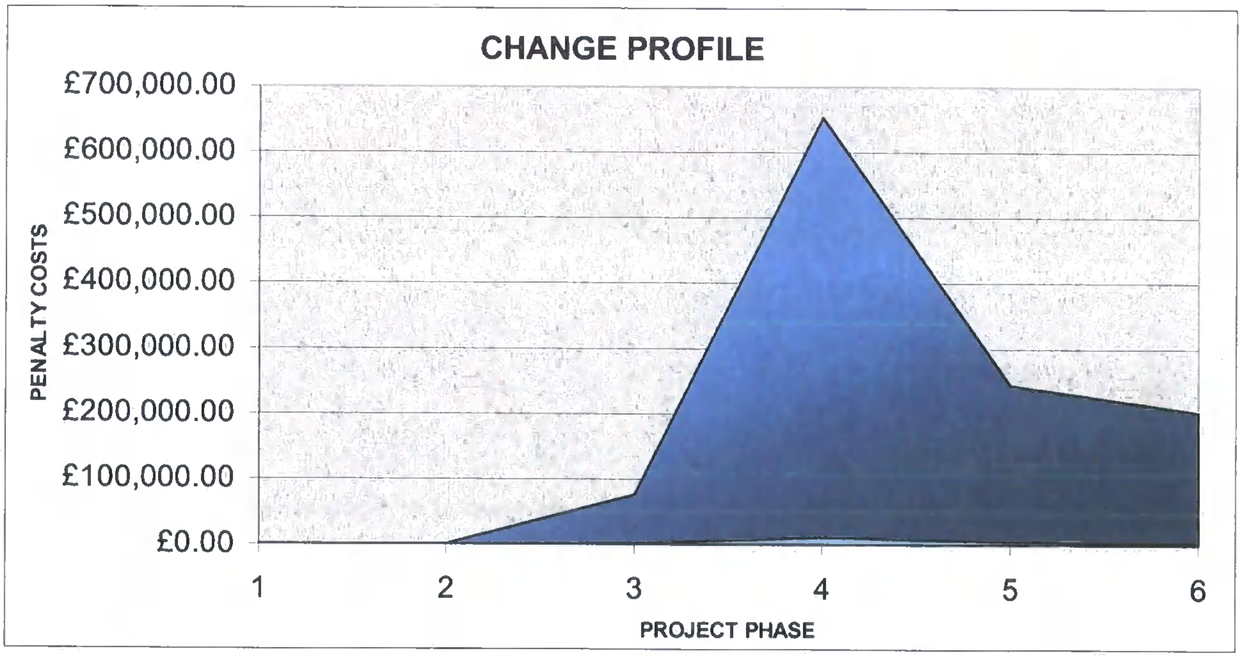


Fig.73. ‘Sharks Fin’ diagram showing cost weighting profile for case study 005.

With reference to Fig. 73, it can be seen that the change profile peaked during phase four of the represented project. This has been discussed earlier as inefficient in terms of cost and time.

9.7 CALIBRATING THE MODEL FOR PRODUCT 'REPEATERS'

The above model was based upon the development of products offering a significant incremental profit contribution to the organisation involved. However, some NPD projects involve relatively minor modifications to an existing product to replace or (face-lift) a product already in the market. In a similar way modifications may be made to an existing product to improve its quality value, or reduce costs (Value Engineering). These projects may also be analysed using the above model by substituting *incremental* profit contribution for *differential* contribution to the business. Therefore the Product Contribution (P) of the face-lift or Value Engineered product may be expressed as the difference in contribution before and after the project:

(P) For face-lift or Value Engineered product = $P_1 - P_2$

Where P_1 = contribution of product before development, and P_2 is the contribution after completion of the project. This will reduce the significance of *Cost for lost sales* **(C_S)** due to a late launch in the weighting model, thereby increasing the significance of parameters such as *Cost to change production tools* **(C_T)** and *Costs for contingency resource* **(C_R)**.

9.8 THE QUALITATIVE IMPACT OF CHANGES ON TEAMWORK

The case study results also indicate that the impact of changes has a qualitative effect on the introduction team members, depending upon where changes occurred in the project. With reference to the case study results discussions, it can be seen that late specification and engineering changes in a project also create a number of negative emotional reactions such as:

1. Increased pressure and stress level within the team members to maintain KPI's.
2. Break down of teamwork and increased 'friction' between key members of the team when project KPI's are under threat.
3. General low moral from the design team and production toolmakers following numerous 'tedious' re-design exercise.

The above factors seem to become more evident as the project progresses through the later stages of development however. There is also evidence from the case studies, to show that changes identified in the early phases of a project may have a positive effect on human emotional response in the from of enhanced 'job satisfaction' e.g.

1. Increased enthusiasm and ownership when the project KPIs are under control.
2. Enhanced teamwork and cooperation when the project KPIs are under control.
3. Enhanced morale in the team when using an agreed NPD methodology.

By way of example, case study 08, showed that the changes identified during phase 2 of the project indicated that the team investigations *were* contributing to the improved development of the project. The Value Engineering savings identified in this project were also examples of 'positive impact of change' together with changes identified as a result of FMEA studies. This also had the effect of enhancing teamwork spirit and improving morale in the team, especially when the savings were positively recognised by the project manager.

The qualitative impact of changes according to the phase of implementation may be represented in the following way Fig.74:

WHERE THE CHANGE WAS IMPLEMENTED	***QUALITATIVE IMPACT***
PHASE ONE	VERY POSITIVE
PHASE TWO	POSITIVE
PHASE THREE	NEUTRAL
PHASE FOUR	NEGATIVE
PHASE FIVE	NEGATIVE
PHASE SIX	VERY NEGATIVE

Fig.74. Qualitative impact of changes with respect to the Phase of implementation

It was not possible however to express the qualitative impact of changes in terms of cost. Nevertheless as described in the case study methodology, a view was taken that qualitative results such as these were important, in order to understand *how* the project was executed, and needed to be included in the analysis of each case study.

To illustrate the above; the author has known key design engineers to leave a company after being involved in a project that fell into difficulties due to late specification changes imposed by the marketing team. In contrast it has also been seen that the effectiveness of a team's ability to 'work together' is enhanced when a project goes well.

9.9 CONCLUSIONS FROM THIS CHAPTER

The above model may allow NPD teams to evaluate where a change should be implemented in a project. However, according to many authors (e.g. Smith *et al* 1991, Burns *et al* 1994 and King *et al* 1995) 'innovation' is a fundamental part of the product development process, which may indeed precipitate changes. It may be therefore concluded that 'changes' should be expected, and indeed encouraged, by project managers in order to accommodate innovative ways of enhancing the product offering through activities such as Value Engineering, Intellectual Property protection (patents); or general team activity to reduce costs.

The above discussion suggests that it would therefore be beneficial to provide a 'window for change' in the NPD process to identify the most appropriate time for innovative team activity, rather than totally restrict changes in a project as a 'cost generator'.

The above derivation of 'cost impact' of changes may assist a project team to identify the most appropriate 'window for change' where changes should be encouraged and where they should be resisted, within the context of the project. This raises a further question (to be addressed later) how to prepare/equip the NPD team to enable them to complete their innovative activities during the *window for change*.

It has been shown that a *Shark's Fin,* peaking around Phase 2, results in a more cost-effective (efficient) project, than one peaking during progressively later phases. This must be viewed with respect to the relative amplitude of the peak, and the context of the project. However, it may be concluded that as the Shark's Fin moves further to the right in Fig. 75, the change will have a greater cost impact on the project. The same rule of thumb applies as the amplitude increases so does the impact of the change.

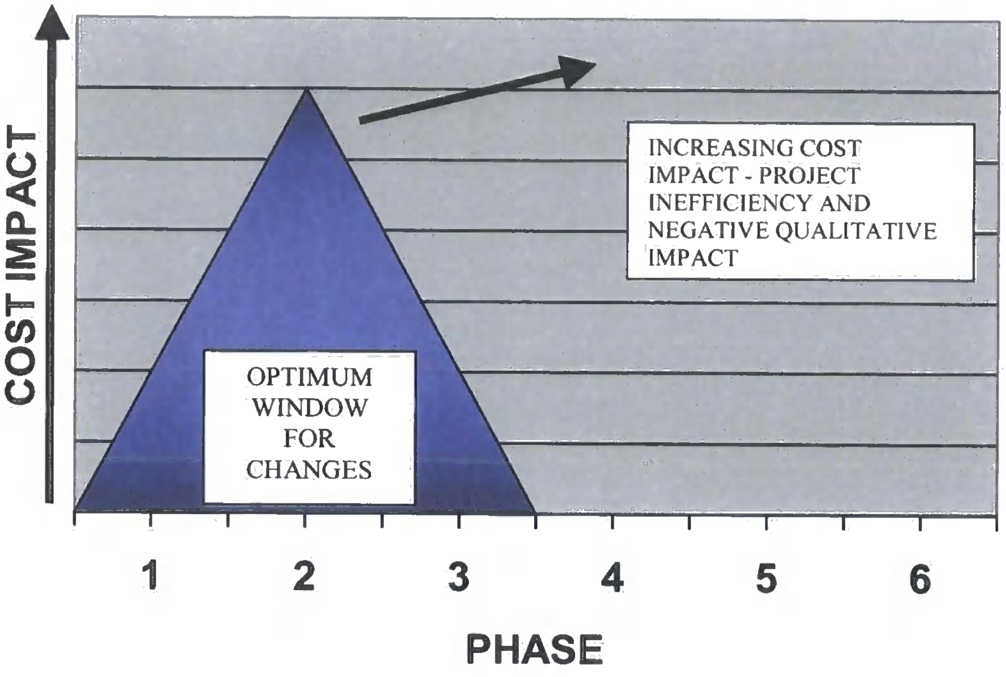


Fig.75. Optimum window for implementing changes

By way of example, Fig. 76 shows the *Sharks Fin* peaking at high amplitude during phase 6 of a project, depicting an inefficient project. This project example was as a Stranger, with the product offering a monopolistic opportunity to the company involved. Therefore the 'launch date' was identified as the priority KPI. Other characteristics of the project are tabulated to provide a qualitative perspective (Fig.77).

The following chapter will apply the weighting model to the case studies describe in chapter 8, to produce Shark's Fin diagrams of the change profiles, together with the general characteristics of each project; from which further conclusions may be drawn.

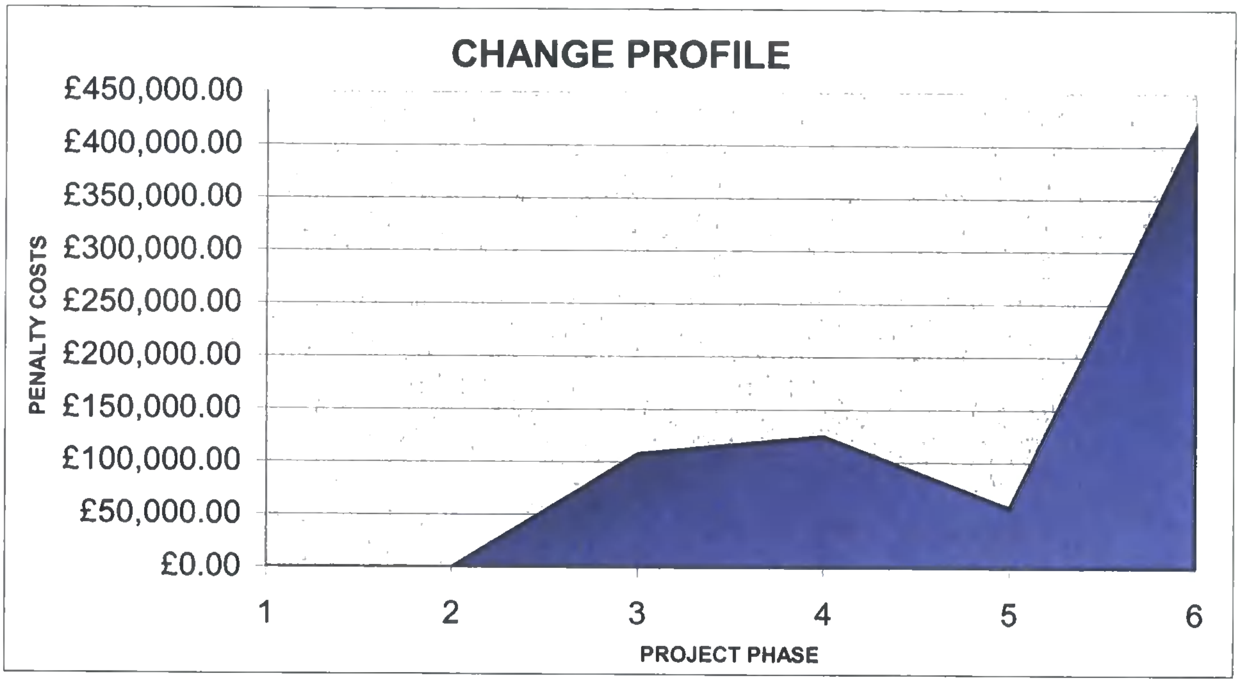


Fig.76. *Sharks Fin* change profile example

PARAMETER	PROJECT CHARACTERISTIC
TYPE OF PROJECT	STRANGER
INNOVATIVE ACTIVITY	HIGH DURING PHASE 3&4
KPI 1 TARGETED LAUNCH DATES	ACHIEVED (priority KPI)
KPI 2 TARGETED PRODUCT COSTS	NOT ACHIEVED
KPI 3 CONTROL OF CAPITAL SPEND	NOT ACHIEVED
KPI 4 PRODUCT QUALITY TARGETS	NOT ACHIEVED
TEAMWORK IMPACT	NEUTRAL
CONCLUSION	INEFFICIENT PROJECT

Fig.77 Project Characteristics of change profile in Fig. 76

CHAPTER TEN

CASE STUDIES ANALYSIS AND CONCLUSIONS

10.1 OBJECTIVES OF THIS CHAPTER

Throughout this chapter the case study results were analysed to identify trends from which conclusions were drawn. The Key Performance Indicators (KPIs) of a NPD project, identified earlier in this research, were used together with the change profiles discussed in the previous chapter to determine how efficiently each product was introduced. Both qualitative and quantitative results were included in the analysis, including a table of 'project characteristics' to provide a complete 'picture' of how each project was introduced. Each analysis included a list of recommendations, such as alternative tools and techniques that may have benefited the project, from each project team.

10.2 ANALYSIS METHOD

A model to quantify the impact of changes was described in detail in the previous chapter; this model was used in the analysis of the case studies. The example table shown in Fig. 72 lists the delays due to changes for each phase of a project, the 'weighting factor' for each phase and the 'penalties' for each phase. This data may be expressed as a cost or dimensionless and was used to generate 'Shark's fin' diagrams for each of the following projects. Data from each case study was therefore substituted to generate 'Shark's fin' diagrams for each project which was used to assist in the analysis. From the 'Shark's fin' diagrams it was possible to discuss how 'efficiently' each product was introduced from the amplitude of the 'fin' and where (which phase) it peaked. As discussed in the previous chapter, the 'area under the curve' of a 'Shark's fin' diagram, represented potentially wasted, or unnecessary expenditure in a project, since the amplitude of the 'Shark's fin' diagram derives from one or all of the following: -

1. Unplanned resource time costs, to implement changes.
2. Unbudgeted toolmaker costs to modify production tools.
3. Lost Sales revenue.

It was hypothesised that the 'unnecessary expenditure' in a project may be avoidable given improvements in the NPD methodology such as the strategic use of prototypes in the project, which was also considered in the analysis. The total 'unnecessary expenditure' may also be viewed with respect to the total budgeted investment in the project to provide an indication of how 'efficiently' a product was introduced. By way of example, if it were planned to invest £500k in tooling and resource time to develop a new product and the 'Total Project Penalty Costs' (T_C) were in the order of £250k; then this would represent a significant inefficiency in the project.

The table showing 'project characteristics' completed the analysis 'picture' for each case study, to enable conclusions to be drawn from both a *quantitative* and *qualitative* perspective.

10.3 CASE STUDY 004: THE FLYMO GARDEN VAC

The data from the results section has been applied here to calculate an 'Impact of Changes' profile for this case study (see Fig. 78), with a 'Shark's fin' diagram shown in Fig. 79. Fig.80 tabulates the general characteristics of the project. These figures will be used in the analysis.

CASE STUDY 004

PHASE	1	2	3	4	5	6
DELAYS / PHASE (CD)	0	0	57	40	9	66
WEIGHTING FACTOR (F)	1	21	54	89	181	181
PENALTIES / PHASE (PU)	0	0	3078	3560	1629	11946
PENALTY COSTS/ PHASE (CP)	£0	£0	£107,730	£124,600	£57,015	£418,110

STANDARD DAILY RATE (R)	£35
TOTAL PROJECT PENALTIES (PP)	20213
TOTAL PROJECT COSTS (TC)	£707,455

Fig.78. Impact of Changes for case study 004.

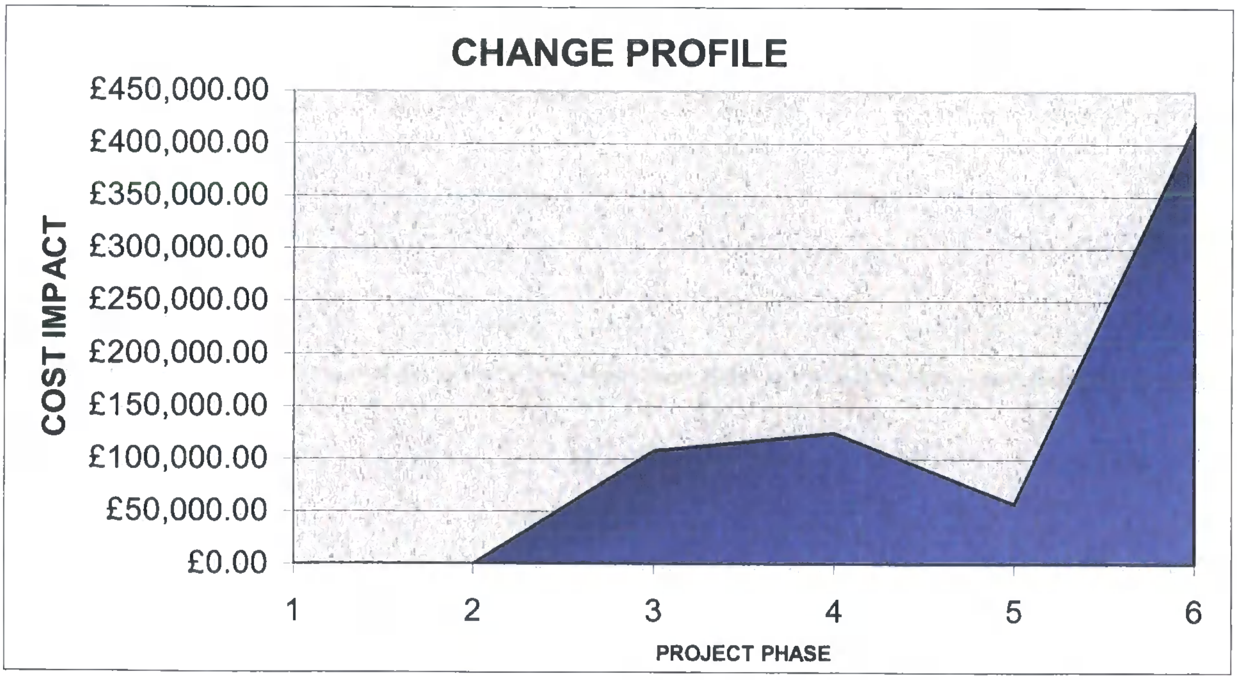


Fig.79. 'Shark's Fin' Change Profile for case study 004.

PARAMETER	PROJECT CHARACTERISTIC
TYPE OF PROJECT	STRANGER
INNOVATIVE ACTIVITY	HIGH DURING PHASE 4 - 6
KPI 1 TARGETED LAUNCH DATES	ACHIEVED (priority KPI)
KPI 2 TARGETED PRODUCT COSTS	NOT ACHIEVED
KPI 3 CONTROL OF CAPITAL SPEND	NOT ACHIEVED
KPI 4 PRODUCT QUALITY TARGETS	NOT ACHIEVED
TEAMWORK IMPACT	NEUTRAL
CONCLUSION	INEFFICIENT PROJECT

Fig.80. General Characteristics of the project in case study 004.

10.3.1 CONCLUSIONS TO CASE STUDY 004

The only KPI in this project that was achieved was the 'launch date', all other key performance indicators of the project were placed secondary to launching this project on time, since the innovative features in the product offered a monopolist opportunity for Flymo. The product *was* launched on time and achieved tremendous success from a business perspective but is viewed here as an 'inefficient' project. There were significant cost deviations (against targets) and capital budget levels were severely overspent. However, the new product was so successful from a business perspective, that revenue from the Garden Vac outstripped Flymo's sales of Hover Mowers, their core product, in the first 12 months of launch.

Flymo, at the time, did not have a well-defined NPD methodology, which hindered the team establishing timely clear project deliverables and targets. The project was seen as a benchmark step-forward in teamwork cooperation between departments, since the whole team *were* involved from the start of the project. The early formation of the team generated a very positive 'atmosphere', further enhanced by the enthusiasm and support from senior management. The introduction team did not, however, have available to them 'representative' prototypes for meaningful team studies such as FMEA, VE and DFM, which prevented conclusions to these studies until delivery of the production tools. The amount of 'post project' development, from off-tool components, was attributed to 'poor' quality prototypes. The prototype models used in the project were 'hand fabricated', that is, not made directly from CAD data such as SLA or CNC methods, and used mainly for aesthetic and ergonomic studies by the Marketing and Engineering functions. Thus the prototypes were not totally representative of the production intent, neither was the model capable of disassembly for team studies and this lead to some frustration for the team. The results also show a high degree of product returns in the first year of launch, with corresponding high 'line reject' rates which the manufacturing team members thought they could have reduced if suitable prototypes had been available. The product cost status was not verified until phase 3 of the project, which resulted in a great number of changes in an attempt to hit targets which were not, in the end, achieved.

The change profile shows a high degree of activity during phases 4 and 3 and after the completion of the tooled parts, i.e. at a high cost impact to the project. It was viewed by the team that; if higher fidelity prototypes had been available for team studies by each department, this would have avoided many of the late changes and would have provided an earlier indication of cost deviations. There was also significant ‘post launch’ (phase 6) development.

From a ‘qualitative’ perspective, the introduction team was highly motivated and ‘enjoyed’ working as part of a multi-functional group, which included some key external suppliers. Also since the product was a ‘new’ category, a great deal of excitement and interest was generated from the senior management, which fuelled the enthusiasm of the team. Unfortunately, the issues associated with poor prototypes frustrated an otherwise positive team view.

The prototype model *was* used successfully to reach an agreement between the Marketing and Engineering function with regard to styling aesthetics and product performance. This greatly enhanced the personal relationships between the Marketing and Engineering team members and removed the ‘silo mentality’ and distrust that previously existed between the two. However, even the aesthetic attributes were not verified early enough to update the design before production tooling had got under way. The following summarises the team’s recommendations for future projects:

1. Provide more accurate prototype components for team studies.
2. Have the prototype components made available to each functional discipline.
3. Provide control documentation identifying project deliverables and cost status reports.

10.4 CASE STUDY 005: THE FLYMO TC 350 AIR-CUSHION LAWNMOWER

The data from the results section has been applied here to calculate an 'Impact of Changes' profile for this case study (see Fig. 81), with a 'Shark's fin' diagram shown in Fig. 82. Fig.83 tabulates the general characteristics of the project. These figures will be used in the analysis.

CASE STUDY 005

PHASE	1	2	3	4	5	6
DELAYS / PHASE (CD)	0	0	25	131	24	20
WEIGHTING FACTOR (F)	1	21	54	89	181	181
PENALTIES / PHASE (PU)	0	0	1350	11659	4344	3620
PENALTY COSTS/ PHASE (CP)	£0	£0	£74,250	£641,245	£238,920	£199,100

STANDARD DAILY RATE (R)	**£55**
TOTAL PROJECT PENALTIES (PP)	**20973**
TOTAL PROJECT COSTS (TC)	**£1,153,515**

Fig.81. Impact of Changes for case study 005.

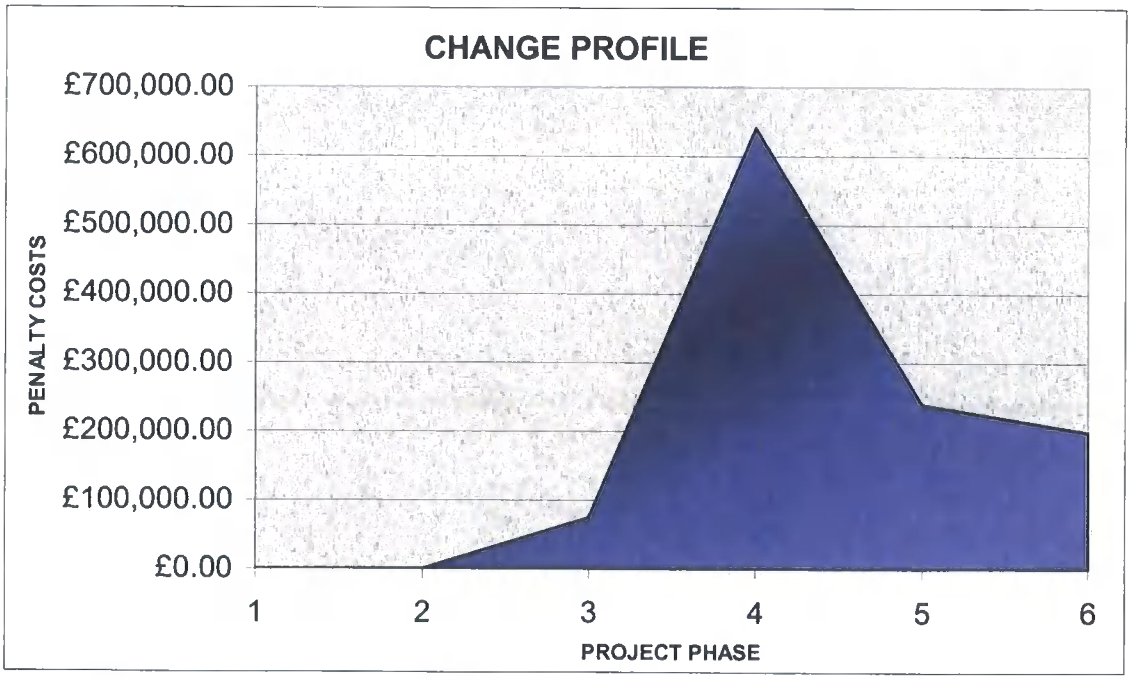


Fig.82. 'Shark's Fin' change profile for case study 005.

PARAMETER	PROJECT CHARACTERISTIC
TYPE OF PROJECT	STRANGER
INNOVATIVE ACTIVITY	HIGH DURING PHASES 4 -6
KPI 1 TARGETED LAUNCH DATES	NOT ACHIEVED (priority KPI)
KPI 2 TARGETED PRODUCT COSTS	NOT ACHIEVED
KPI 3 CONTROL OF CAPITAL SPEND	NOT ACHIEVED
KPI 4 PRODUCT QUALITY TARGETS	NOT ACHIEVED
TEAMWORK IMPACT	VERY NEGATIVE
CONCLUSION	VERY INEFFICIENT PROJECT

Fig.83. General Characteristics of the project in case study 005.

10.4.1 CONCLUSIONS TO CASE STUDY 005

The TC350 project was regarded as a 3rd generation air-cushion grass collecting lawnmower by Flymo, offering many innovative features to aggressively attack market share held by competitive 'wheeled-rotary lawnmower' manufacturers. The initial conceptual development involved many engineering and technical problems, which accounted for the first two years of the project. However, this conceptual development, according to Manufacturing and Marketing team members, had: 'progressed far beyond a stage where their contribution could significantly benefit the project without substantial redesign of the product'. This resulted in a degree of disownership from those team members and precipitated many changes to the design proposal to get them 'back on board'. This caused delays to the project, gross overspend of capital funds and conflict within the team.

It can be seen from the results that the 'unrecoverable delay' totaled 187 days, and there was a further 210 days 'post launch' development. The majority of the 'delays' in the project occurred *after* the completion of the plastic injection mould tools. This was when the team members were eventually able to carry out their studies, with engineers and marketing Product Managers able to establish performance criteria from off-tool parts. The results of the team investigations were many *Change Requests* with subsequent changes to the production tools, causing delays and *unbudgeted* modification costs. Product quality data also indicates high 'line rejects' and 'returns' during the first year, which was attributed to poor team studies.

Product cost tracking showed the product to be 58% above target, at time of launch, which was reduced from 68% over target during the course of the project, resulting in a number of engineering changes to bring the cost down. This in-turn contributed to the gross overspend of the capital budget for the project, which exceeded budgeted figures by almost 160%, due to the late unplanned changes to the production tools. In fact, there were so many changes to some components, such as the motor mounting plate, that some of the completed tools were scraped and re-tooled.

It is significant to note that the team did, not reach a 'Firm Product Proposal' in the form of an agreed list of deliverables, until after the production tooling was complete. This would suggest either a failure in the team to agree the objectives and deliverables before the commencement of the tooling, or poor information, or prototypes, available to enable to the team to reach a decision. The change profile figures show a high degree of activity still taking place after 'Product Launch'. Late changes of this nature, as discussed in this research, are expensive to implement, time consuming and may have only a marginal effect on the objective.

According to the members of the team, the whole project was difficult to manage due to constant changes and the lack of clearly defined objectives and NPD methodology. Also, the fabricated prototype models did not accurately represent the level of the design on the drawing board, nor was it possible to disassemble the prototypes for team studies. This directly contributed to misleading information derived from initial FMEA, DFM and Product Costing studies. 'Non representative prototypes' were also of little use to evaluate product performance, ergonomics and tooling investigations, resulting in many unplanned changes at a late stage in the project. The NPD team's recommendations for future projects were: -

1. Involve key team members in the identification and agreement of the project objectives.
2. Provide more accurate prototype components for team studies.
3. Have the prototype components made available to each functional discipline.
4. Provide control documentation identifying project deliverables and cost status reports.
5. Identify a clear milestone in the plan where deliverables are finalised.
6. Identify a clear milestone in the plan where the product proposal is finalised.
7. Issue copies of the updated plan and deliverables at each team meeting.

10.5 CASE STUDY 006: THE FLYMO TC 300 AIR-CUSHION LAWNMOWER

The data from the results section has been applied here to calculate an 'Impact of Changes' profile for this case study (see Fig. 84), with a 'Shark's fin' diagram shown in Fig. 85. Fig.86 tabulates the general characteristics of the project. These figures will be used in the analysis.

CASE STUDY 008

PHASE	1	2	3	4	5	6
DELAYS / PHASE (CD)	2	17	35	6	3	0
WEIGHTING FACTOR (F)	1	21	54	89	181	181
PENALTIES / PHASE (PU)	2	357	1890	534	543	0
PENALTY COSTS/ PHASE (CP)	£110	£19,635	£103,950	£29,370	£29,865	£0

STANDARD DAILY RATE (R)	**£55**
TOTAL PROJECT PENALTIES (PP)	**3326**
TOTAL PROJECT COSTS (TC)	**£182,930**

Fig.84. Impact of Changes for Case study 006.

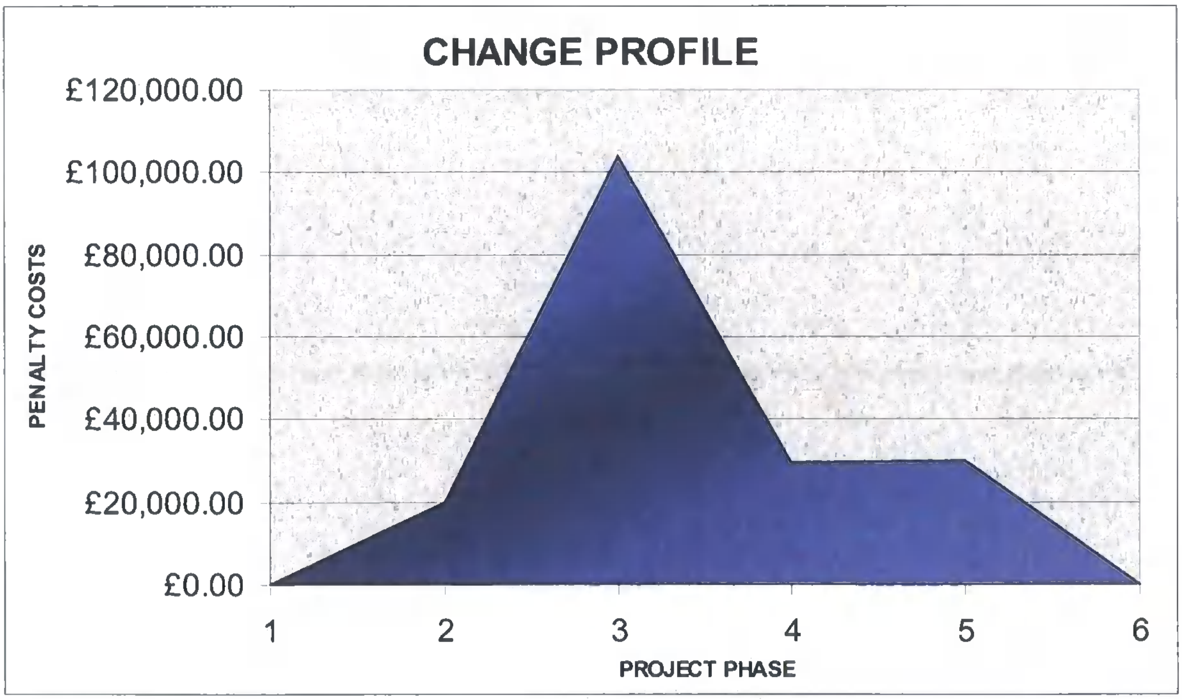


Fig.85. 'Shark's Fin' change profile for case study 006

PARAMETER	PROJECT CHARACTERISTIC
TYPE OF PROJECT	REPEATER
INNOVATIVE ACTIVITY	HIGH DURING PHASE 2&3
KPI 1 TARGETED LAUNCH DATES	ACHIEVED (priority KPI)
KPI 2 TARGETED PRODUCT COSTS	ACHIEVED
KPI 3 CONTROL OF CAPITAL SPEND	ACHIEVED
KPI 4 PRODUCT QUALITY TARGETS	ACHIEVED
TEAMWORK IMPACT	VERY POSITIVE
CONCLUSION	EFFICIENT PROJECT

Fig.86. General Characteristics of the project in case study 006.

10.5.1 CONCLUSIONS TO CASE STUDY 006

The TC300 product was a further development of the TC350 product for Flymo and a 'Repeater' in terms of innovative contribution, however, the targeted launch date was made the priority KPI. The new product was also targeted to significantly reduce costs over the TC350 product. Therefore, very few components were common to the two products, requiring new production tooling. The project team was also faced with increased product performance targets that demanded significant re-design of airflow and cutting mechanisms. A challenge set by the marketing team was to significantly out-perform the TC350 product in terms of 'grass collection density', i.e. weight of grass clipping collected for a given area of grass cut of the same area.

It can be seen from the results that, the 'critical path' delay to launching the product was only 14 days, which was a significant improvement from the TC350 project. Product costs were well controlled, being only 4% higher than the initial target. The Capital Budget was also well controlled with only a 3% overspend at the end of the project. Line Rejects and Product Returns were also well below levels of the TC350 product.

According to the team, the project benefited from a good Team Leader and a clear 'agreed' procedure (NPD Methodology and control documentation) for the team to work to. It is very clear that the provision of a RP model, closely representing the manufactured product, was 'invaluable' to verify the product in terms of performance, aesthetics, cost and build construction methods. The RP model (which was called *The Master Model*) was used to carry out detailed studies such as FMEA and DFM. The *Master Model* actually carried a label attached to it showing signatures of the key team members as confirmation by the team that they were happy with the:

1. Product performance levels and ergonomics
2. Product aesthetics
3. Product construction with proposed manufacturing methods
4. Product Safety, approvals compatibility and Serviceability
5. Product Packaging design
6. Product costings

The signatures on the Master Models constituted a simple 'business agreement' between the introduction team and senior management who 'funded' the extra expense for the models. The funding for the models was agreed on the basis that the product would be launched on time and within the agreed KPIs for cost and investment.

The project team achieved all of their objectives and the product provided a significant increase in market share and contribution to the business. It also greatly enhanced the company's confidence in their ability to develop and launch products on time, as well as controlling the KPIs identified at the beginning of the project. The strategic use of Rapid Prototypes, representing a business agreement with the team and management, was to be adopted in future projects. The recommendations from the NPD project team were to: -

1. Adopt the methodology used for this project as a template for all future projects.
2. Appoint a 'steering committee' with members from each department. To regularly update the template from findings of future projects.
3. Compile an illustrated booklet describing the philosophies and key elements of the new NPD methodology for future NPD teams to use as a checklist and basis for reference.
4. Present the new Flymo methodology and booklet to the other Electrolux group companies such as 'White Goods', 'Floor Care', Outdoor Products Europe (Husqvarna), and Outdoor Products U.S.A. (Poulan WeedEater).

10. 6 CASE STUDY 007: THE KENWOOD CUISINE FOOD MIXER

The data from the results section has been applied here to calculate an 'Impact of Changes' profile for this case study (see Fig. 87), with a 'Shark's fin' diagram shown in Fig. 88. Fig.89 tabulates the general characteristics of the project. These figures will be used in the analysis.

CASE STUDY 007

PHASE	1	2	3	4	5	6
DELAYS / PHASE (CD)	7	0	146	56	0	0
WEIGHTING FACTOR (F)	1	21	54	89	181	181
PENALTIES / PHASE (PU)	7	0	7884	4984	0	0
PENALTY COSTS/ PHASE (CP)	£420	£0	£473,040	£299,040	£0	£0

STANDARD DAILY RATE (R)	**£60**
TOTAL PROJECT PENALTIES (PP)	**12875**
TOTAL PROJECT COSTS (TC)	**£772,500**

Fig.87. Impact of Changes for Case study 007.

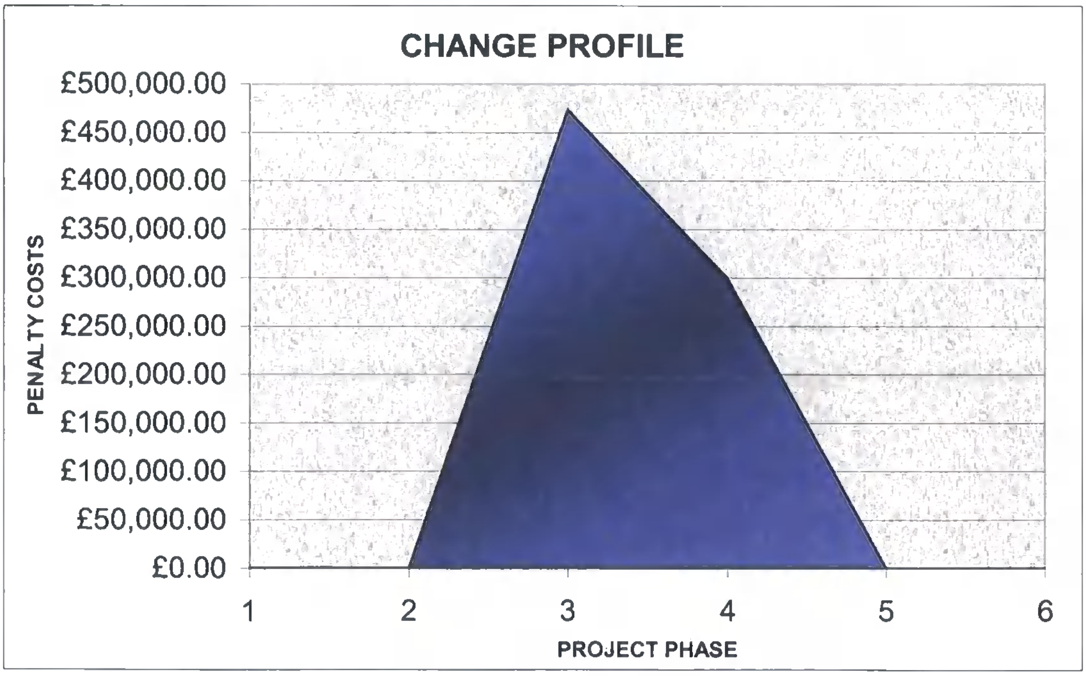


Fig.88. 'Shark's Fin' Change Profile for Case study 007.

PARAMETER	PROJECT CHARACTERISTIC
TYPE OF PROJECT	REPEATER
INNOVATIVE ACTIVITY	HIGH DURING PHASE 3&4
KPI 1 TARGETED LAUNCH DATES	ACHIEVED (priority KPI)
KPI 2 TARGETED PRODUCT COSTS	NOT ACHIEVED
KPI 3 CONTROL OF CAPITAL SPEND	NOT ACHIEVED
KPI 4 PRODUCT QUALITY TARGETS	ACHIEVED
TEAMWORK IMPACT	VERY NEGATIVE
CONCLUSION	INEFFICIENT PROJECT

Fig.89. General Characteristics of the project in case study 007.

10.6.1 CONCLUSIONS TO CASE STUDY 007

Even though a multi-functional team was appointed to this project they did not carry out their detailed studies and investigations until the production tools were complete and production parts were available. Moreover, the team did not agree the project deliverables and agree a 'firm product proposal' until very late in the project, i.e. too late to change. The team was not collectively involved in the planning of the project and did not identify key milestones such as the timing for an agreement of the 'firm product proposal'. This indicates a fundamental problem in the methodology used to introduce this product. Also, rapid prototypes were only used for studies within the engineering domain denying essential input from other functions.

This case study is an illustration of how an NPD project can fail to achieve all KPIs such as the control of capital spend, despite having a multi-functional team, 3D CAD and Rapid Prototype components. The team members raised a number of issues and recommendations for future projects:

1. The NPD methodology was unclear with an unstructured multi-functional team involvement in the project, resulting in vague team accountabilities and poor communication.
2. Fundamental product performance issues were identified, from 'off tool' parts, requiring significant redesign and tool modifications in the final stages of the project.
3. There was a gross overspend in the capital budget due to tooling modifications.
4. Unplanned additional parts were required to provide last minute changes to the specification.
5. Rapid Prototype components were not made available for investigations outside the Engineering domain. Product, issues identified by Marketing, Production and Purchasing team members, were not identified until the production parts were available.
6. The team failed to agree a 'Firm Product Proposal' before the commencement of the production tooling. This milestone was only reached 3 weeks before launch, which resulted in a number of (heated) debates in the team with regard to the agreed deliverables. This is again a symptom of poor NPD methodology.

The project initiated a complete review of the NPD methodology used in the company.

10.7 CASE STUDY 008: THE KENWOOD MEDIUM SIZED DEEP-FAT FRYER

The data from the results section has been applied here to calculate an 'Impact of Changes' profile for this case study (see Fig. 90), with a 'Shark's fin' diagram shown in Fig. 91. Fig.92 tabulates the general characteristics of the project. These figures will be used in the analysis.

CASE STUDY 008

PHASE	1	2	3	4	5	6
DELAYS / PHASE (CD)	0	28	0	0	0	0
WEIGHTING FACTOR (F)	1	21	54	89	181	181
PENALTIES / PHASE (PU)	0	588	0	0	0	0
PENALTY COSTS/ PHASE (CP)	£0	£32,340	£0	£0	£0	£0

STANDARD DAILY RATE (R)	£55
TOTAL PROJECT PENALTIES (PP)	588
TOTAL PROJECT COSTS (TC)	£32,340

Fig.90. Impact of Changes for Case Study 008

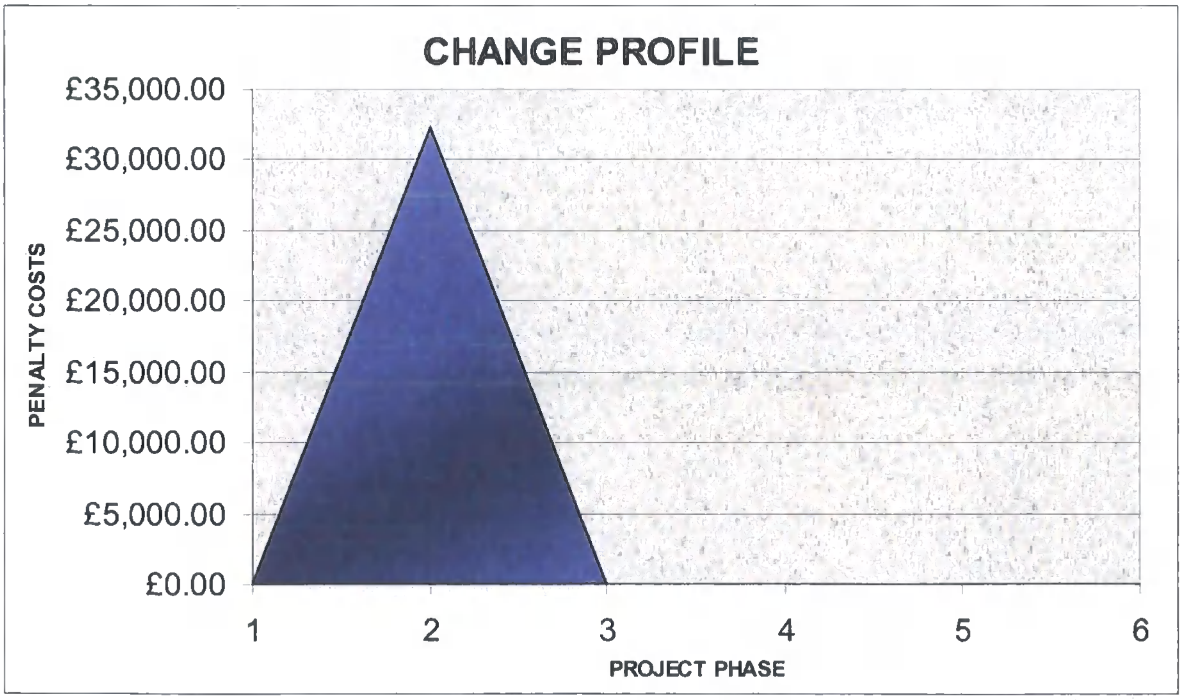


Fig.91. 'Shark's Fin' change profile for case study 008

PARAMETER	PROJECT CHARACTERISTIC
TYPE OF PROJECT	REPEATER
INNOVATIVE ACTIVITY	HIGH DURING PHASE 2
KPI 1 TARGETED LAUNCH DATES	ACHIEVED
KPI 2 TARGETED PRODUCT COSTS	ACHIEVED (priority KPI)
KPI 3 CONTROL OF CAPITAL SPEND	ACHIEVED
KPI 4 PRODUCT QUALITY TARGETS	ACHIEVED
TEAMWORK IMPACT	VERY POSITIVE
CONCLUSION	VERY EFFICIENT PROJECT

Fig.92. General Characteristics of the project in case study 008.

10.7.1 CONCLUSIONS TO CASE STUDY 008

A ‘window for change’ was identified in the project plan for this product, which was after the completion of team studies from the RP models. The small number of ‘unplanned’ changes during the project suggested that the project team managed this project well. The ‘tight’ control of the product costs and capital budget for tooling also suggests a well-run project and that the recently updated NPD methodology, developed by the team, was working. Very few deviations occurred in the product specification, deliverables having been clearly established at an early stage in the project.

One exception to this was a change to increase the heater power output due to the simultaneous launch of a competitor product. However, this change request came early enough in the project to avoid delays.

Rapid Prototype models were used in all of the multi-disciplinary 'team' studies such as FMEA and VE. The team members claimed that this provided a number of opportunities for the team to meet and take part in constructive debates with regard to the efficient design configuration of the product.

It may be concluded that the lack of late change requests from all of the team members was assisted by the strategic use of the RP models together with a clear NPD methodology for the project. This encouraged the team to resolve issues before the completion of the production tools.

The project was viewed as being very successful by the senior management team at Kenwood and restored confidence in their ability to launch products on time and within cost and capital targets.

10.8 CASE STUDY 009: THE DOMNICK HUNTER CONDENSATE DRAINS

The data from the results section has been applied here to calculate an 'Impact of Changes' profile for this case study (see Fig. 93), with a 'Shark's fin' diagram shown in Fig. 94. Fig.95 tabulates the general characteristics of the project. These figures will be used in the analysis.

CASE STUDY 009

PHASE	1	2	3	4	5	6
DELAYS / PHASE (CD)	0	0	14	0	0	0
WEIGHTING FACTOR (F)	1	21	54	89	181	181
PENALTIES / PHASE (PU)	0	0	756	0	0	0
PENALTY COSTS/ PHASE (CP)	£0	£0	£26,460	£0	£0	£0

STANDARD DAILY RATE (R)	£35
TOTAL PROJECT PENALTIES (PP)	756
TOTAL PROJECT COSTS (TC)	£26,460

Fig. 93 Impact of Changes for case study 009.

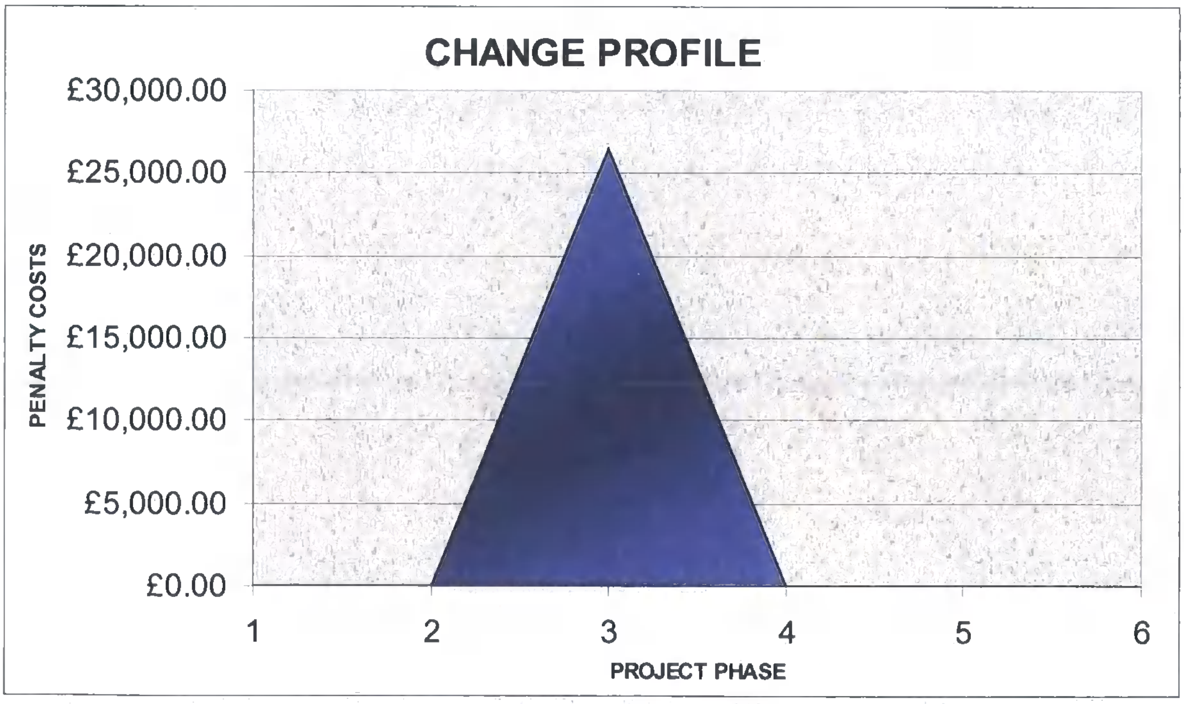


Fig. 94 'Shark's Fin' change profile for case study 009.

PARAMETER	PROJECT CHARACTERISTIC
TYPE OF PROJECT	REPEATER
INNOVATIVE ACTIVITY	HIGH DURING PHASE 2
KPI 1 TARGETED LAUNCH DATES	NOT ACHIEVED
KPI 2 TARGETED PRODUCT COSTS	ACHIEVED
KPI 3 CONTROL OF CAPITAL SPEND	ACHIEVED
KPI 4 PRODUCT QUALITY TARGETS	ACHIEVED (priority KPI)
TEAMWORK IMPACT	VERY POSITIVE
CONCLUSION	EFFICIENT PROJECT

Fig.95. General Characteristics of the project in case study 009.

10.8.1 <u>CONCLUSIONS TO CASE STUDY 009</u>

From the start of this project, Domnick Hunter had all of the elements of efficient NPD, identified from the above studies, already in place such as: -

1. Multi-functional teams in NPD.
2. A clear NPD methodology and Gantt chart template designed by representatives from each function.
3. Clear NPD control documentation.
4. A clear methodology for the strategic use of Rapid Prototypes.

The priority KPI in this project was to improve the quality of the product followed closely by product cost reduction. The company was seeing very little contribution to the business from the old products due to a combination of poor quality and excessive costs thereby stimulating the need for a new range.

From the initial studies of the RP models, the team identified many opportunities to improve the reliability of the product and to exceed cost saving targets through Value Engineering. However, the resulting new product proposal required extensive proving trials on the production lines and FMEA studies to ensure the reliability of the finished product. Therefore, the team decided to delay the project by a further 14 days to fully conclude the team investigations using additional RP models. The team also used the weighting model described above to evaluate the impact of delaying the project before the commencement of tooling, rather than risk delays later in the project. The impact weighting of the 14-day delay during phase two of the project, together with the additional VE savings, was used to justify the delay and cost of additional RP models to the senior management team.

Apart from the 14-day delay to launch, the cost savings targets were exceed and the product reliability was significantly improved. There remained however, some reliability problems of sub-contracted electronic sub assemblies for the product. The sub-contractor was not included in the RP strategy discussions, which was the only recommendation from the team for future projects.

10.9 CONCLUSIONS AND CASE STUDY COMPARATIVE ANALYSIS

From the analysis of the individual case studies, it was possible to make some comparisons of the relative attributes of each project and draw further conclusions. Many of the case studies achieved the priority KPI, such as targeted launch date, by sacrificing other KPIs such as Capital Costs or Product Costs and were therefore cited as being inefficient projects in the analysis.

An example of this was case study 004 the Flymo Garden Vac that was launched on time with none of the other KPI targets achieved. Even though the senior management team in the company was delighted to have the product in the shops as planned, the analysis shows the project to be inefficient. The change profile shows that the 'innovative' team activity occurred from phase four of the project and on into phase six, with significant post launch development taking place. Post project reviews by the team cited a number of changes (listed in the qualitative analysis) for application to future projects. The next case study (005) is particularly useful for comparison with the above case because both projects were in the same company and were consecutive. The comparison also affords a consideration of differences between a 'Stranger' and 'Repeater' product development processes. Case study 005, also by Flymo, implemented a number of initiatives together with the application of a new NPD methodology and achieved all of the KPI targets resulting in a 'very efficient project' with enhanced qualitative impact on the team. This project was however, regarded as a 'Repeater', being a variation of an existing product, and the *efficient* performance of the team may be *partly* attributed to prior knowledge and experience. This explanation was not consistent with case study (007), by Kenwood, who also developed a 'Repeater' product, which was shown in the analysis to be an inefficient project – achieving only the priority KPI.

Thus comparisons across the efficient introduction of the Hover Mower (006) and the inefficient introduction of the Kenwood product (007) may indicate that improvements in methodology were not due to general improvements in the industry or to the experience of the project manager (author). From observation of two different teams in two different companies it seems that improved efficiency is not simply related to a product being a repeater but a combination of improved methodology applied repeatedly.

This observation is substantiated by the second Kenwood project (008), which showed an improved performance, compared with the previous case (007). Once again, after the 007 project, the introduction team (discussed in the qualitative analysis) modified the NPD methodology for the next project (case study 008) implementing many of the recommendations in this research together with the use of RP models within the multifunctional team.

Case study 009 is a useful example of product development efficiency and a conclusion to this work. It might be expected to enjoy the benefits of teamwork and methodology improvements as well as the author's ability to manage and deliver improvements. The data and discussion in the analysis points out the significant improvements in case study 009 compared with all of the other cases and relates these improvements to the technical and organisational improvements.

Case study 009 provided further evidence to show that NPD project efficiency can be significantly improved by ensuring the following initiatives are included in a project:

1. Multifunctional teams with clear roles and accountabilities are used in the project sharing the workload through 'sub group' activities.
2. A clear NPD methodology, designed by the team, is used to provide guidance and 'familiar' templates for application by the team.
3. Robust project management techniques are applied together with appropriate control documentation.
4. Project deliverables are clearly identified and communicated through activities such as the Innovation Forum with the priority of the KPIs identified.
5. A strategic approach to Rapid Prototyping is adopted to maximize the benefits in all team activities and to provide a business case for the added cost and time for producing RP models.
6. The weighting model presented in this research can be used to evaluate the relative benefits of delaying a project to accommodate S&E changes and product enhancements resulting from innovative team activities.

10.10 CRITICAL REVIEW OF WORK

At this stage in the research it was appropriate to critically review how the results of the case studies were obtained, together with the methodology used. The nature of the methodology and conclusions in the case studies need to be discussed with respect to these topics in the extant literature. It was believed that significant differences existed between the present work and earlier, published studies, which resulted in the unique contribution from this work. The second part of this review will consider the opportunities and constraints arising from the cross-comparison of the case studies presented.

A significant characteristic of the case studies discussed in the literature was that they derived from a narrow academic, sociological or technical perspective rather than a broader industrially derived base. Limitations of the studies cited in the literature were identified at an early stage and indicated that they tended to be either; based on a single project or a number of projects, all conducted within a relatively short space of time. They were without exception based upon external observation of processes rather than being based upon the observations of participants. Moreover, there was very little consistency in the KPIs used in the previous work, some of which were identified as inappropriate in the research. This present work did not suffer the deficiencies described above because the research was carried out by the project manager (author) and included a number of projects over a period of several years, with a common set of KPIs used throughout the analysis. However, it is common to find that moving from one methodological approach will probably mean the trading of one set of constraints for another. This is obviously the case here.

Thus, a characteristic of this type of research, as discussed earlier, was the constraints imposed by the nature of 'action research', in that, the research did not follow the classical scientific approach. The approach adopted here was a hybrid methodology using scientific analysis methods and management/social science observation techniques, taking a more anthropological perspective of observation of people interacting in multifunctional teams within a highly technical task environment and subjected to changing technology and methods. The research methodology also evolved as the research progressed, in that, a method of analysing the data, in the form of an efficiency-weighting model, was not developed until after most of the case studies were complete.

The other issue of some importance in this critical review relates to the timescale of the work and the changes in the companies involved in the studies. The following factors therefore may influence the fidelity of any comparisons made between the individual case studies: -

1. Considerable time elapsed between each project together with the evolution of technology and the experience of the author.
2. The criteria of what was, and was not, acceptable NPD performance was contextually sensitive to each company.
3. There were different individuals in each project team with different skills and experience, making scientific performance comparison difficult.

In spite of the above constraints and limitations it was concluded that the direct availability of considerable first hand data was too valuable an opportunity to miss and that acceptability of the above reservations was worthwhile.

The other aspect that benefits from discussion here relates to the limitations and qualifications of the cross-comparison of the individual cases. All of the projects were carried out in real product development conditions and were subject to practical constraints and pressures, thus, projects could not be stopped and could not be repeated; the results had to be gathered in real time or not at all. In addition to this important constraint, in terms of scientific method, the comparison of the analysis of the results also required some care. As indicated earlier the results were gathered over a considerable time period and so any comparisons across cases needs to be seen against a moving historical context. This is particularly important because both technology and methodology were evolving rapidly over the period. Care needs to be taken to avoid the well-known pitfall of historical reviews. It is important to recognise that any individual case has to be seen in its historical context. Comparisons of case 004 with case 009 needs to recognise the very different technical, organisational and methodology context of the cases.

Further, the author has also attempted to compare the results of the case studies, scientifically, without the benefit of a 'control' in the experiment in that it was not possible to totally nullify the influence of the author in each project. The job function of the author during the case studies also prevented him from allowing any project to run into difficulty thereby altering the conditions of the experiment.

CHAPTER ELEVEN

CONCLUSIONS

11.1 INTRODUCTION

Manufacturing Industry has continually searched for ways of improving its ability to deliver new and better products to the market as quickly as possible. Finding new ways of improving the NPD process was the initiative behind this research and its *raison d'être.*

This research, over a period of 12 years, has attempted to build upon previous work, including other doctoral studies, by providing more empirical data and evidence to identify some of the root causes of problems in NPD projects. Quantitative and qualitative research methods were used in the study to contribute to existing knowledge in both the Engineering and Business management domains.

The research approach included a review of the extant literature on the NPD process with particular focus on the role and contribution of multifunctional teams in the process. Case studies formed a key part of the data collection process whilst using a set of derived Key Performance Indicators to quantify the results. The specific research deliverables from chapter two are summarised below to remind the reader:

1. Review the extant literature and practical examples of the New Product Development Process in manufacturing industry.
2. Review Teamwork concepts in NPD.

3. Identify appropriate NPD Key Performance Indicators and conduct case studies.
4. Derive a model to quantify the effectiveness of teamwork activities in NPD from case studies.
5. Investigate, and test out, techniques for improving the effectiveness of teamwork activities in NPD.
6. Draw conclusions and identify opportunities for further research.

11.2 CONCLUSIONS FROM THIS RESEARCH

Following the review, it was concluded that many of the claims of the effectiveness of multifunctional teams in the NPD process were anecdotal in nature and often promoted by authors with a commercial interest in the subject. There was also a lack of empirical evidence to support the effectiveness of 'tools' such as Rapid Prototyping and Failure Mode and Effects Analysis in the NPD process. In order to address this need, case studies were conducted to provide a rich source of empirical data from products introduced in consumer durable and industrial markets. The provision of quantitative data, together with qualitative explanations of the outcome of a project, enabled conclusions to be drawn from an engineering and management perspective.

Inconsistencies in NPD measurement techniques were identified in the literature together with the need to provide user-friendly methods for controlling and reporting KPIs. Therefore, a set of Key Performance Indicators were derived and used in the case studies. The KPIs allowed the NPD teams to clarify project deliverables and to precisely target values that were relevant to the business needs of the organisation and the type of product under development. It was found that by defining and prioritising the KPIs at an early stage in a project, delays associated with the management of irrelevant parameters were minimised.

A project control pack consisting of a collection of 'single sheet' documents was configured to represent the status of each project KPI. The resulting Product Pack assisted with the 'project management' of projects by providing concise reports for team meetings and milestone appraisals by senior managers. It was found that the Product Pack reduced the incidences of misinterpretations of the project deliverables, which were identified as sources of late changes and project delays.

A method of reducing 'Fuzzy front end' delays in NPD projects was presented in the form of a controlled brain-storming session called the *Innovation Forum.* The Innovation Forum brought together key stakeholders in the project definition process, such as Marketing and Engineering, together with any other functions capable of innovating solutions to a market requirement. The Innovation Forum placed the accountability of defining the project deliverables with the key stakeholders and encouraged ownership of delivery.

A *Sub-Group* concept was proposed for the management of key activities during a project such as tooling, FMEA, VE and the update of the Product Pack documents. Sub-Group leaders reported their activities at each project team meeting, thus saving time in the main project meeting by retaining accountability of problem solving within the Sub-Group.

A model was presented to represent the 'impact' of changes in an NPD project with respect to the timing and magnitude of each change. The model provided a tool to enable a team to gauge the benefits of a proposed change with respect to the costs of implementation. The model also enabled an efficiency profile (Shark's Fin diagram) to be plotted for each project to provide an indication of the effectiveness of the NPD methodology used and tools such as RP and FMEA.

A methodology for the 'strategic' use of Rapid Prototyping (*StratPro*) was explored as a strategic management tool in NPD. The StratPro methodology proved to be an effective way of placing the business accountability for the costs and benefits of Rapid Prototyping, with the NPD team.

11.3 OPPORTUNITIES FOR FURTHER WORK

The future work can progress in two interrelated directions: future work based upon existing data and material, and work using the present methodology and analysis to consider future projects.

Over the twelve years of this work much more data has been collected than is presented here. Indeed, inclusion of all of this data would have swamped the structure of the thesis and the case studies given here were chosen to be illustrative of the process that has been observed and recorded. A key question in proposing this aspect of future work relates to the answering of the question 'How can this additional data be used profitably?' The way forward is two fold; the application of the existing analytical approach to different existing cases, perhaps identifying different or new causal relationships and the possible reductionist approach of considering certain aspects for consideration in more detail. Secondly, the additional data can be used to refine the analytical approach itself. A broader and deeper consideration of the data could lead to the establishment of an industrially grounded product development philosophy that could underpin a practical and effective integrated 'tool kit' of methods and technology. Time permitting such work could evolve into an extremely useful text book or work manual.

The second area of future work could be the extension of the method and analysis to future new projects. A list of recommendations for improving NPD performance was provided in the conclusions to chapter ten. This list may be used as a 'check list' for further testing without the managerial influence of the author. Similarly, it would be interesting to explore how the approach and conclusions drawn from 'mass produced' products would relate to other product areas, such as 'one-off' manufacture.

The empirical quantitative and qualitative data results from the case studies were a key deliverable in this research. Future data will provide a number of opportunities for further analysis including comparative studies with NPD projects from other industries such as automotive and defence.

Finally, it is inevitable that any form of analysis or model is open to improvement and this is the case here. For example, and of particular importance, the weighting factors proposed in this work appear to be helpful but have not been fully developed. At the present time the values of the factors used here give results that seem to be particularly useful, but the values applied to the illustrations were arbitrary and the whole aspect of the work related to the 'sharks fin' diagram would benefit from further data collection and analysis.

A model was presented to quantify the 'impact of changes' according to the timing of implementation. The model allowed an 'efficiency profile' of a project to be calibrated and plotted for projects. The weighting factors in the model, shown in Fig.66, were established from company data where the author was employed. Opportunities in the future could be provided for calibrating and using the model to investigate performance weighting factors that are contextually specific to other priorities, perhaps in other companies, further techniques for improving NPD performance could be evaluated from this data. The model may be used to benchmark a number of projects against each other to test out new techniques and to evaluate the effectiveness of various tools such as QFD, FMEA and VE.

All of this work has been industrially based, working with real product development projects. To a large extent continuation or extension of the work by the author, will depend upon the author's future career moves and job functions.

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