DESIGN CHAIN MANAGEMENT: INTER-ORGANISATIONAL COORDINATION OF PRODUCT DEVELOPMENT IN THE UK AUTOMOTIVE INDUSTRY

by

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CONTENTS

TABLES

FIGURES

ABBREVIATIONS

BMW	Bayerishe Motoren Werke
CAD	Computer aided draughting and/or design
CAD/CAM	Computer aided design and manufacture
CAE	Computer aided engineering
CAM	Computer aided manufacture
CIE	Computer integrated engineering
CIM	Computer integrated manufacture
CNC	Computer numerical control
D0	Rover D-Zero event (Programme Approval Phase)
DFA	Design for assembly
DFM	Design for manufacture
DNC	Direct numerical control
DTI	Department of Trade and Industry
EDI	Electronic data interchange
ESI	Early supplier involvement
FEA	Finite element analysis
FMEA	Failure modes and effects analysis
GM	General Motors
IGES	Initial graphics exchange specification
MIT	Massachusetts Institute of Technology
NC	Numerical control
NEDO	National Economic Development Office
OEM	Original equipment manufacturer
PDL	Rover Product Development Letter
PIL	Rover Product Investigation Letter
QFD	Quality function deployment
R&D	Research and development
SCM	Supply chain management
SMMT	Society of Motor Manufacturers and Traders, UK
TQC	Total quality control
TQM	Total quality management
UK	United Kingdom
USA	United States of America

ACKNOWLEDGEMENTS

I am grateful for the support of a research scholarship from the Economic and Social Research Council between 1991-94 (No. R00429134281), which has enabled me to devote time to explore new literature, and to pursue and develop the theme of *design chain management*, as presented in this thesis. My hope is that my personal advancement may be of benefit to future scholars and of practical benefit to industry.

I give special thanks to my supervisor Nigel Slack for his encouragement, constructive advice, and friendship throughout the writing of this thesis. His wisdom and moral support guided me through the mountains when I could not see a path to follow. Similarly, the Operations Management Group has provided a collegiate environment in which to belong: their support is duly acknowledged and thanked.

I would like to thank the Rover Group for providing their collaboration in this research: their product engineers and purchasing staff immediately saw the benefit of the research. Similarly, this thesis would not have been possible without the component companies who spared valuable time for this project. The anonymity of participants prevents a public acknowledgement to key individuals, in order to protect the identity of the companies involved. Nevertheless, mention is afforded to Prime-Computervision, who assisted the early approach to Rover on this occasion, and Dick Main of Rover's Forwards Programmes (Purchasing), who acted as my *gatekeeper* to Rover Group and suppliers.

My journey along the path of research has benefited greatly from my previous projects on CAD/CAM, first with Colin Appleby, and later with Chris Voss, Graham Winch and Vicky Russell. The collective support and friendship of my fellow doctoral students both current and past is also acknowledged and appreciated. My dear friends - Henrique Corrêa, Yvon Dufour, Carlos Hemais, Liu Hong, Lars-Uno Roos and Leticia Veruete-Rodriguez - have collectively inspired me to continue along the long road of doctoral research. Their endeavours showed me that spending several years in pursuit of an idea was worthwhile and to them this thesis is a tribute of thanks.

My interest in automotive design was inspired by my neighbour, John Sheppard, who was a member of Sir Alec Issigonis's close-knit design team for the *Austin Mini* and other vehicles from the 1950s to the 1970s. I hope that an interest in this subject may be furthered by those who read this thesis. Automotive design has changed considerably since John's time, and will undoubtedly continue to change in the future: the product is evolving, as too the process to design, make, sell and support it.

The encouragement and support of my fiancée, Alessandra, have seen me through the final two years of writing. Studying for a PhD alongside each other has been a strength and of continual intellectual comfort, especially knowing that we are not isolated in our pursuit of knowledge and advancement.

Finally, my deepest thanks go to my parents whom I have waited until now to acknowledge. It was they who first inspired me to ask questions of why things happened, and to search for explanations. This thesis signifies the culmination of many years of study, but is by no means the Zenith of my questioning.

Thanks to you all.

D.T.

DECLARATION

No portion of this thesis has been submitted in support of an application for another degree or qualification from this University or any other Institute of Learning.

ABSTRACT

This thesis examines the inter-firm management of product development between a vehicle manufacturer and six component suppliers actively participating in the design and development process. It introduces the notion of *design chain management*, in a similar way to the supply chain concept has been used to describe logistics and purchasing relationships. This concept enables the product development process to be considered at the inter-firm level between supplier and vehicle manufacturer.

Specifically, the research investigates: the nature of the inter-firm design process; the changing requirements of the inter-firm relationship; and the mechanisms that promote inter-firm design transactions. There is an extensive literature review, integrating related themes in product development; coordination mechanisms; inter-firm relationships; information processing; and supplier involvement. This review develops the key components for managing design at the inter-firm level, which forms the basis for an empirical examination of one UK vehicle manufacturer and six of its component suppliers. The empirical part consists of in-depth analyses of the design management process within each case study, and across the buyer-supplier relationship.

The research presents a classification of suppliers involved in product development based on their relative responsibility for design, and the position each enters the product development process. The thesis concludes that the core suppliers involved in early exchanges of design information require more attention to long-term structural mechanisms, such as supplier development initiatives, than to the use of CAD/CAM or EDI. In particular, suppliers are investing in placing their own staff permanently within their customer premises, in the form of guest (resident) engineers, and this is an area in need of further research. In addition, there is a need for post-project reviews at both the vehicle programme level and the individual system and component level. As project management is devolved to the supply base, the ability to project manage both internally and externally will determine those firms able to compete effectively in the market place.

IMAGINE.

It's mid-August. The temperature is a balmy 81°. An open road stretches invitingly before you. And you, lucky you, have just eased yourself behind the wheel of a gleaming, open-topped, Rover 200 Cabriolet.

You settle into the contoured sports seat.

... the elegant burr walnut veneer dashboard.

... an airbag to protect you. (And a twin alarm system to protect the car).

... the award-winning 16 valve K-Series engine ...

The power operated triple layered hood glides over you.

In the moment that takes, a reassuring thought comes to mind. Rover put their Cabriolets through the same stringent water pressure tests as their saloons and hatchbacks.

"Thank you Mr. Rover Designer" you murmur to yourself. Though in the back of your mind you seem to recall that it was in fact Signor Pinin Farina who designed the Rover 200 Cabriolet's elegant hood.

......

Source: Advertisement for the *Rover 200 Cabriolet* (July 1994)

1 INTRODUCTION

1.1 Background

Sitting behind the steering wheel of a car, one would be correct in assuming that the feeling and experience of the vehicle were a reflection of the marque: a Jaguar car, for example, *feels* like a Jaguar car because that is what is important to the car's designers. It is akin to a signature: a unique description of the product. However, one would be wrong to assume the vehicle manufacturer has *designed* all the car. Vehicle design is a subtle art of defining the product's specification and requirements (such as the *feel* or aesthetic) and gathering the skills necessary to turn concept into commercial reality.

The design and development of a modern car require the coordination of many different skills, and knowledge. A single company cannot acquire all of these in-house, as once may have been done, but must look to the network of suppliers for inputs of design and process expertise. The ability to manage these suppliers within the vehicle manufacturer's project management process will provide a key competitive advantage to companies in the future. As Ivor Owen, Director-general of the Design Council in the UK, recognises:

> As the global marketplace becomes more competitive, the key to survival will be to integrate internal functions, together with suppliers, into a concurrent engineering operation.[1]

Over the past decade, competitive advantage has revolved around delivering products quicker to the customer, ensuring quality throughout the production and delivery phases and doing them cheaper. The result of these changes has been a concentration on purchasing and supply management, and logistics management. As these *downstream* operations become *leaner* (Lamming, 1993), focus will necessarily shift *upstream* to the origins of the product (or service). Central to achieving this are the product development relationships that a company will form with its outside suppliers. This network of design contributions may be considered a *design chain*. Yet, very little research work has been devoted to studying these relationships, in particular the division of design responsibility. Much has been done to look at internal relationships, but few studies have extended this work to include the early involvement of suppliers in product development.

1.2 Design chain management

The study of supply chain management (SCM) has in recent years received increasing attention, not least from the acute awareness by firms that the satisfaction of the customer (both immediate and final) requires a focus by all participants in the supply of the product. SCM involves a complex supply network (of both manufacturing and service operations) within the operating boundaries of a business or industry. In the automotive industry, for example, this network is characterised by a variety of companies involved in the manufacturing and distribution of vehicles and their component parts, as well as the supply of raw materials. Hence, the key focuses of SCM are the manufacture and distribution chains of a business or industry. Supply chain management has been defined by Harrison and Jones (1990, p.283) as: "the management of all or some of the businesses that add value to the goods or services ultimately received by the end customer".

Since SCM concerns those operations that add value to the goods and services, there is often an assumption that development of the product, or services, is implicit to the process of supply (for example Harrison and Jones, 1990). However, this does not *explicitly* define product development as part of the supply chain, rather focusing on the processes that add value. This view is certainly valid where no inter-firm design relationship exists. For example, either where the focal organisation undertakes all design engineering and process engineering tasks as intra-firm activities, or where those external parts supplied in the design of a product are standard catalogue parts requiring no alteration (for example, non-specialised fasteners). In these circumstances, the design of the product requires no further external expertise (either product or process) other than that found within the focal firm. Hence, there is no chain of activities between firms. Nevertheless, the contribution of design and development activities within the supply network has received recognition:

- Bessant (1991) argues that, whereas inter-firm relationships were once predominantly based on materials procurement, a variety of other activities are now undertaken, *inter alia*, design, purchasing, expertise/consultancy, distribution and marketing.
- Guy and Dale (1993, p. 30) reinforce the role of the supplier in design activities: "The supplier base must be treated as an extension of the buying organization, especially the buyer's design process ..."
- Macbeth and Ferguson (1994, p. 36) acknowledge the design process as a "... particular supply chain ..."
- DeToni *et al* (1994) view the design process as an element of the modern supply transaction, within the *service* supply chain. Whereas the traditional supply chain has

been based upon material supply transactions, a new approach to supply has emerged based on material and service activities:

> The supplier does not simply offer the buyer his production capacity, but rather innovative, design and logistics capabilities. This complex of information and technical collaboration consolidates a continuous and interactive dialogue between the upper and lower ends of the productive chain. (DeToni *et al*, 1994, p. 5)

The design process can, therefore, be seen as part of the supply chain. A premise of this thesis is that a design chain is embodied *within* the total supply network, but its management should receive different, yet integrated, attention. Design and supply transactions are different; there is, for example, in design: high task uncertainty; a need for inter-firm organisational structures (teams); and the transfer primarily of information. Due to these differences, it is useful to distinguish between those operations that are design-related, and those that are finished goods related.

Design chains (also referred to here as encompassing development) can be viewed as a specific form of supply chain that relates to the transfer of information between organisations in the pursuit of product design and development. Whereas supply chain management focuses on the manufacture and distribution relationships of a business, design chain management is defined as *the management of the participants, both internal and external to a focal firm, that contribute the capabilities (knowledge and expertise) necessary for the design and development of a product which, on completion, will enable full-scale manufacture to commence.*[2] This definition focuses the design chain on the process of creating the product such that production may begin; hence, the chain involves participants from concept, detail engineering, process engineering, prototype manufacturing, and after launch. The elements of design chains are elaborated further in Chapter Five. Figure 1.1 illustrates the key components.

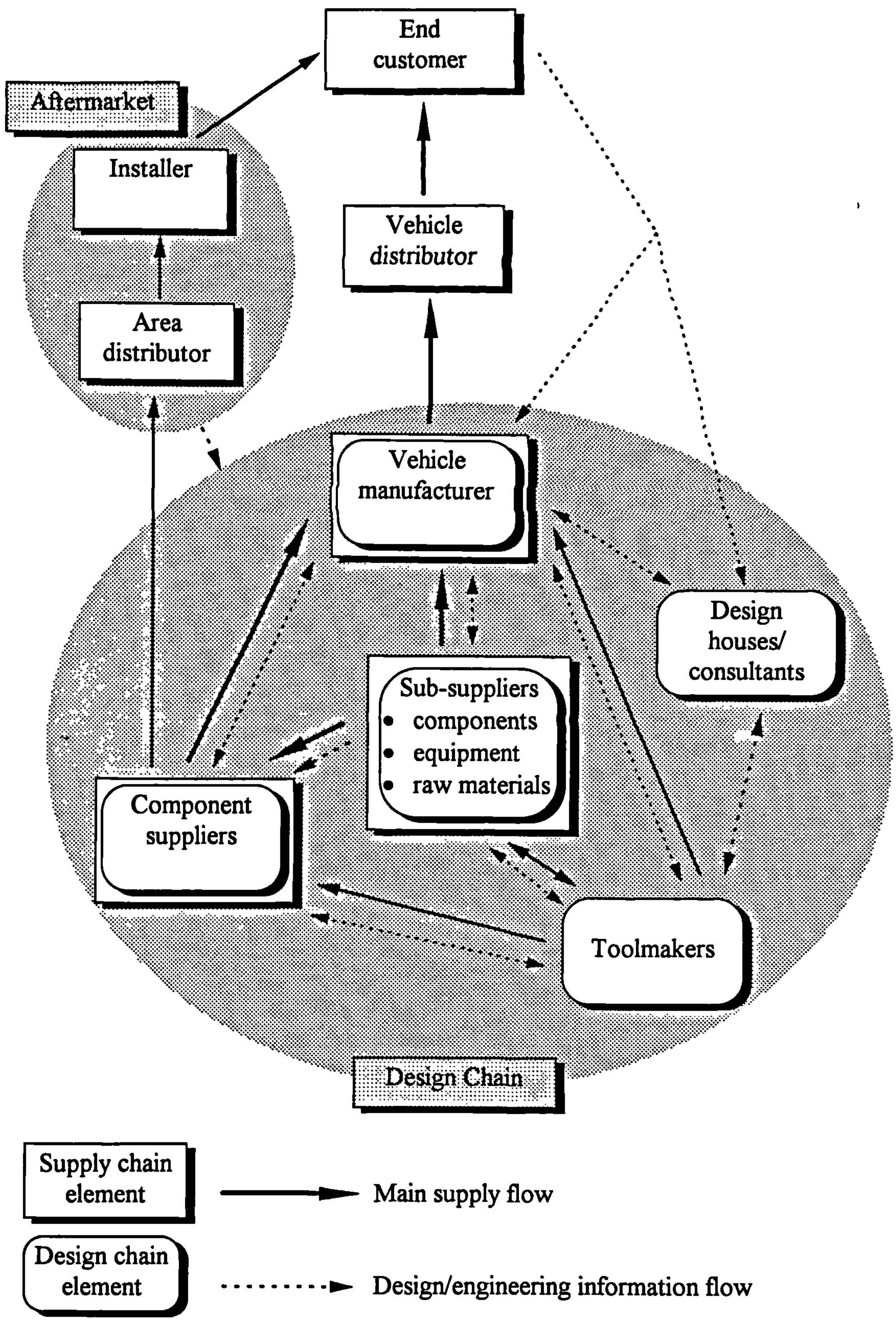
1.3 Objective of the research

The main goal of the present research is to determine the changing nature of the inter-organisational engineering design process between a vehicle manufacturer and its suppliers. This process involves relationships where design expertise resides both internal to the focal organisation (vehicle manufacturer) and external to it (through a network of specialist suppliers). These suppliers are not merely parts' suppliers, but contribute specific knowledge to designing the overall product, in the form of vehicle components, systems and process knowledge.

1.4 Rationale for a study of the automotive industry

The research has focused on a study of the product development process within the UK automotive industry, for a number of reasons. First, a major finding of previous research conducted on Rover Group Limited (Twigg, 1990) was the description of a fundamental change in the design and development activities of automotive manufacturers, namely the increasing contribution of *external* organisations to the product development process. The increasing demand for new technologies and the acceptance that a single company could no longer retain in-house all the necessary design and process capabilities was witnessing a new set of relationships developing between motor vehicle manufacturers and their suppliers (based on the exchange of engineering design information). In 1991,

Figure 1.1 The total supply network (design and supply chain)



there was no evidence of any studies following this phenomenon, despite evidence that the Rover Group was one company actively seeking such relationships with component suppliers. This observation was echoed by Cusumano and Nobeoka (1992, p. 283) in their review of research performed on the automotive industry, by a need to analyse the structure and process of inter-organisational coordination:

> Although some studies exist on differences in supplier relationships by regions, no study concentrates on the supplier coordination process in product development, and there are even fewer studies on other forms of inter-organizational coordination.

Second, in recent years there has been increased attention paid to the management of supply chains, with one sector - the motor industry - being particularly noteworthy. Since this study has proposed differentiating design chain management from supply chain management, it seemed appropriate to investigate elements of the design chain in this particular industry, thereby enabling a clear understanding of the similarities and differences in parallel.

Third, since the late 1980s, the motor industry has witnessed significant changes to the way product development is managed. Organisations have experienced the shortening of product development lead times, the application of concurrent engineering practices, the improved integration between functions (and the use of cross-functional teams), and the flattening of organisational structures (Bertodo, 1988). Much of this work has focused on the internal operations of the firm, and where there have been external operations, these have largely been controlled through internal processes. However, since more design and development effort is being directed externally, together with respective levels of control, research was needed to understand better these new relationships. The motor industry is, therefore, a suitable sector for study given the undoubted application of these changes to it.

Fourth, the motor industry provides a rich data set of information on effective product development and this present study complements previous work performed on it. Despite attention being paid to the automotive product development at an international scale (Clark and Fujimoto, 1991; Cusumano and Nobeoka, 1992), there is a deficiency of detailed work on this in the UK. The UK industry operates differently to those of other European countries, the USA and Japan. This research seeks to highlight this whilst, at the same time, drawing attention to the topic of design chains.

Finally, since the topic of research concerns managing the product development of a complex product, the motor industry is well suited for study. Both the product and process of the industry are complex, as Fujimoto (1989, p.149) emphasises:

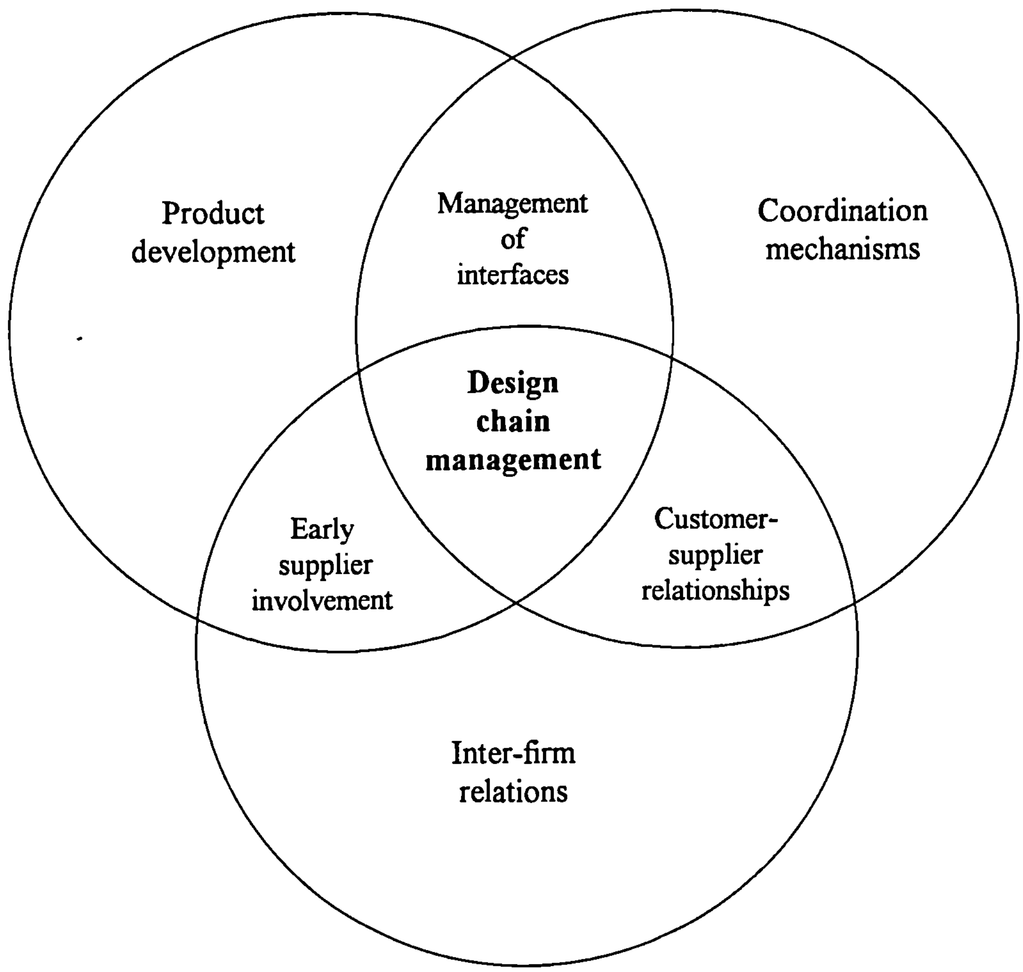
> The car is a complex fabrication assembly product which involves numerous functions, components, and production steps. Consequently, development of its product and process requires a large project, involving hundreds or thousands of specialised engineers and planners.

The organisation of this development process requires both the internal effort and, increasingly, the contribution of external suppliers of material, components, and engineering and production expertise. Thus, the industry provides an excellent opportunity to investigate these organisational and inter-organisational issues.

1.5 Scope of the study

The thesis is centred on three main areas of literature: product development; inter-firm relationships; and mechanisms for coordination. Figure 1.2 illustrates these three themes and the areas of overlap between them that will be the focus of this study.

Figure 1.2 Three themes in design chain management



1.5.1 Product development

The research has used the information-processing perspective of product development, based on Clark and Fujimoto (1991), as its main framework. This framework was chosen given that various approaches to product development are used by firms. No generic process is applicable and, therefore, a perspective following the information flows was deemed appropriate.

Much of the literature on product *development and innovation regards the process as* essentially internal to a firm. In the cases where inter-firm relations are indicated, these have concentrated on technological collaborative agreements (such as joint ventures or partnerships), often for policy or organisation behaviour study. The present research examines the product development process at the operational level, to determine the parameters in which management decisions are set, and the dynamics of inter-firm relationships. It has adopted an approach that focuses on the information processing perspective of inter-firm linkages. This has enabled the boundary of the firm to be extended to the information system boundary, thereby including the contribution of external design expertise.

1.5.2 Inter-firm relationships

This thesis has examined the literature on inter-firm relationships from the network perspective of the Swedish School (such as Håkansson *et al*, 1987) to the applied model of lean supply developed by Lamming (1993). These provide understanding of the inter-firm development of both product and process technology. Where the network approach has considered the contribution of suppliers of technical knowledge to the product development process, this has generally been construed of as a complete process innovation or basic/applied scientific research. A re-examination of the network literature should indicate its applicability to acknowledging other forms of supplier knowledge, such as technical process capabilities or engineering design input. Lamming's (1993) work on automotive suppliers provides a rich description of the evolution of the buyer-supplier relationship. These illustrate the emergence of suppliers whose relationships require some degree of product development input. This research will expand upon this theme.

1.5.3 Mechanisms for coordination

One objective of the research has been to examine the coordination mechanisms used in inter-organisational relationships. The work of, *inter alia*, Galbraith (1973), and Lawrence and Lorsch (1967b) on intra-firm integration mechanisms may find application to the buyer-supplier relationship of the automotive industry. Research by the author with Voss and Winch (for example Twigg, Voss and Winch, 1992) had observed integration problems with suppliers involved in product development, whilst examining CAD/CAM implementation. Consideration has therefore been given to the application of intra-firm coordination mechanisms to the inter-firm relationship, in the absence of any such study. This idea was further supported by Adler (1988) who had developed a typology of coordination mechanisms, applied at the interdepartmental interface. Since the start of the present research, there has been one application of integration mechanisms to inter-firm relationships in the automotive sector (Bensaou, 1992), although not specifically to the product development process.

1.6 Organisation of the thesis

The thesis is organised in nine chapters. The process of inter-firm product development will be examined and discussed through a review of literature in Chapters Two to Five. Different models of the product development process are presented and discussed in Chapter Two, together with alternative organisational structures used for supporting product development.

Chapter Three concentrates on the automotive industry, describing an information systems generic model of automotive product development, and then examining and discussing the changing role of buyer and supplier in inter-firm relationships. In particular, it describes the emerging relationships affecting inter-firm product development.

An information processing framework is developed in Chapter Four for meeting the information requirements of inter-organisational product development. The coordination of activities is discussed at both the intra and inter-organisational level, and a typology of inter-organisational coordination mechanisms developed. The components of automotive design chains are examined and discussed in Chapter Five, where the design capabilities of suppliers are constructed to form a typology of supplier involvement.

The methodological procedures are explained in Chapter Six, where the appropriateness of the case study methodological approach is presented. The project has focused on a single host organisation (a vehicle manufacturer) to understand the nature of its product development process, together with a selection of cases that represent a range of supply inputs to this process. Chapters Seven and Eight present the design management approaches of these cases, the key participants, and examine specific examples to illustrate the differences and similarities that will enable a better understanding of the buyer-supplier product development relationships.

Finally, in Chapter Nine, the main findings of the research are examined and the implications of these are presented. Some directions for future research are proposed, where areas of inter-organisational coordination or limitations of this project have been found to warrant further investigation.

NOTES

1. 'Design tool that too many ignore', *Ingenuity: The Financial Times Engineering Review*, 14 September 1993, p. 5.
2. The term *design chain management* was first proposed by the author in April 1991 to shape the design and development relationships witnessed in an earlier study (Twigg, 1990) within the supply chain of Rover Group Ltd. This definition of design chain management has been submitted for inclusion in Slack, N. (Ed) *The Blackwell Dictionary of Operations Management*, Blackwell: Oxford (in press).

2 PRODUCT DEVELOPMENT

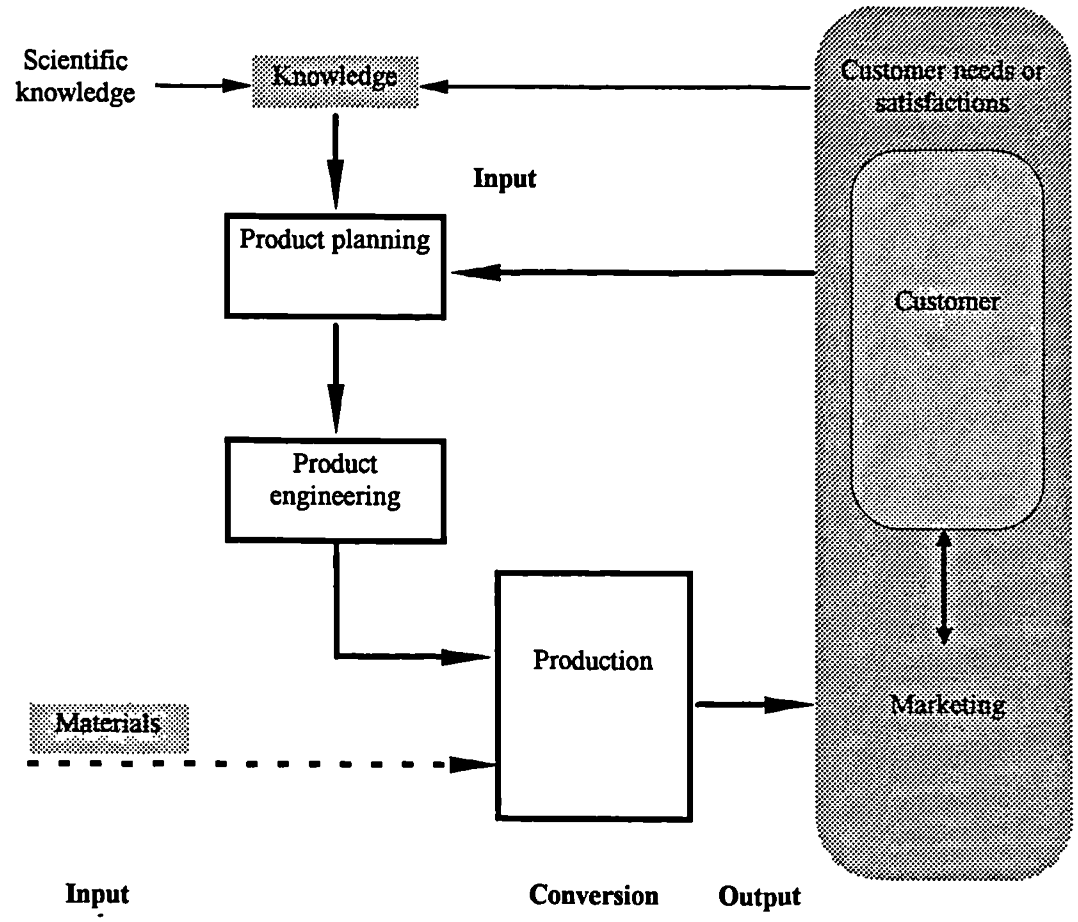
2.1 Introduction

This chapter reviews the literature on product development, highlighting the range of models available to firms and researchers to investigate the process, and discusses the key elements of the process. It shows how the product development process has evolved from being stage controlled, through cross-functional, overlapping phases towards an integrated, iterative process.

Product development is the process of converting resources (knowledge and materials) into a commercial product through several sub-activities (such as product planning, engineering and production) (Twiss, 1986). Figure 2.1 illustrates this conversion process. There are two elements to this process: the conversion of knowledge (technical and market) into a product plan; and the use of materials and process knowledge to convert the product plan into a final product.

An important element of figure 2.1 is the source of knowledge. This may be from basic and advanced research, or market/customer needs: these are commonly referred to as *technology-push* (Schumpeter, 1964) and *demand-pull* (Schmookler, 1966). Rothwell and Zegveld (1985) incorporate these two models into an interactive model of technical change (figure 2.2), which is not unlike the conversion process in figure 2.1. The benefit of Rothwell and Zegveld's model is self-evident: product development is a combination of both technological developments (push) and meeting market needs (pull). Despite

Figure 2.1 Product development as a conversion process



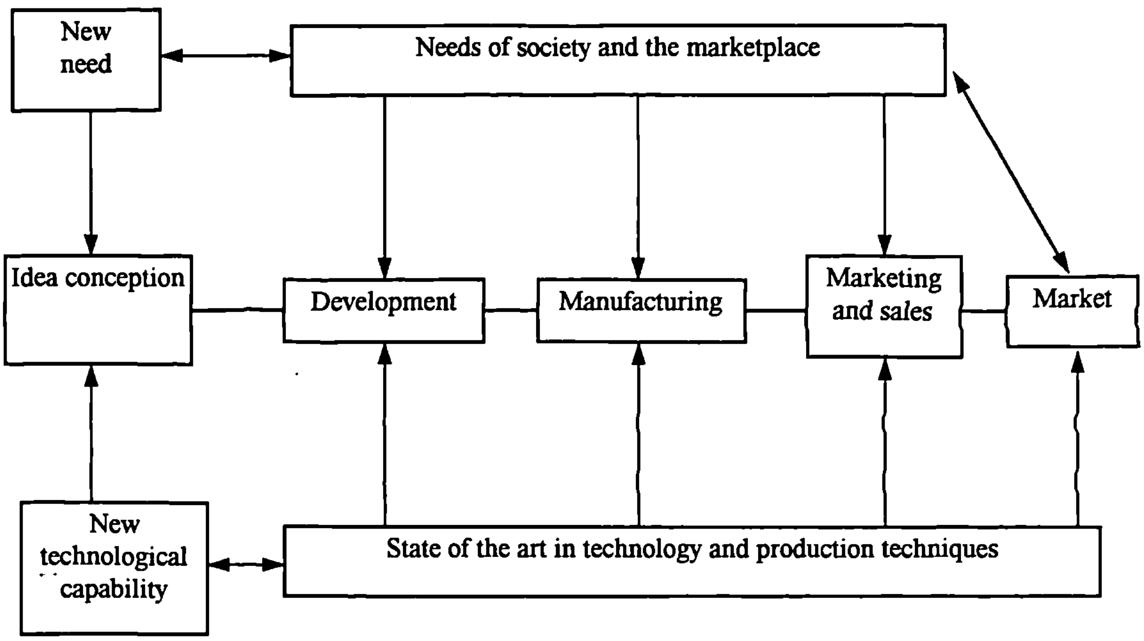
Source: after Trygg (1991) and Clark and Fujimoto (1991)

being acknowledged for sometime, customer driven development has received renewed attention as *the voice of the customer* is heard (Hauser and Clausing, 1988).

2.2 A definition of new product

To begin an examination of the new product development process, the term *new product* requires definition, since newness is a relative term to a specific situation. Hayes,

Figure 2.2 Interactive model of technical change



Source: Rothwell and Zegveld (1985)

Wheelwright and Clark (1988) express new development projects in terms of changes that range from incremental to radical, in both product and process technology. At either extreme, a radical change could be the introduction of a new core product (creating a new market), whereas an incremental change would be expressed by component changes through a planned engineering change. Between these extremes exist *next generation* products - changes that include the next generation of a core product, an addition to the product family, or add-ons and enhancements. Henderson and Clark (1990, p.9) distinguish new products by changes to their core concepts and components, hence:

1. incremental: where relatively minor changes occur to an existing product;
2. radical: where new technical and commercial skills result in a new product with new markets and applications;
3. modular: where a core design concept (the basic underlying knowledge) is changed, while the way the components of the product are linked together (the architecture) is left unchanged;
4. architectural: where the overall architecture is changed, while leaving the components and core design concepts they embody unchanged.

They argue that successful product development requires: *component knowledge* (knowledge about the core design concepts and the way they are integrated into the component); and *architectural knowledge* (knowledge about the way the components are integrated into a coherent whole). This is a useful distinction between the knowledge requirements for product development, and hence the location of responsibility for new product development. In the automotive industry, for example, the architectural knowledge of the product will be located clearly with the vehicle manufacturer (the external integrity of the product as translated through the product strategy) whilst component knowledge (internal integrity) may be more widely distributed between vehicle manufacturer and suppliers of components, component systems, and design houses; these are discussed later in Chapter Three. Hence, the process of development will experience different levels of activity and structure in each phase, depending on the relative type of *newness*. This process of development is now examined.

2.3 The activities within the product development process

A plethora of models can be found in the literature on product development, each illustrating their approach to the total process and placing specific emphasis on particular sub-activities. These differences are clearly visible from the two main perspectives to product development represented in the literature: a marketing and consumer orientation (for example, Crawford 1983; Urban, Hauser and Dholakia 1987), and a technology and operations orientation (for example, Twiss 1986; Wheelwright and Clark 1992). Each perspective outlines similar broad activities, only with varying degrees of concentration; figure 2.3 illustrated the similarities among four examples of product development model. The purpose for this comparison is to demonstrate the various emphases placed by models and the essential similarity in the overall process. These models have been extrapolated from their originals to highlight the stage process but figure 2.3 does not represent the entire process. For example, figure 2.3 suggests that Hayes, Wheelwright and Clark (1988) do not specify the development of a new product strategy plan, whereas they do in fact view such a development plan as implicit to the process. The features of each stage reflect the differentiation of functionally separate tasks, and their elaboration into further sub-divisions. Cooper and Kleinschmidt (1986) choose to distinguish 13 separate activities in their model of product development[1], but for the purposes of this discussion, however, it is necessary only to be aware of the broad band of activities.

A simplified model of the new product development process is presented in figure 2.4, based on the work of Crawford (1983). Two points are noteworthy of this model: first,

Figure 2.3 Various models of the product development process

NEDO (1979)	Booz, Allen and Hamilton (1982)	Souder (1987)	Hayes, Wheelwright and Clark (1988)
	New product strategic plan		(*)
Identify need or want Specification	Focused idea generation	Exploratory	Knowledge acquisition
Conceptual design	Concept development	Concept development	Concept investigation Basic design preparation
Preliminary cost estimate Evaluation	Business analysis		
Detail design Prototype	Prototype development Testing	Prototype development Prototype testing Market development	Prototype building and testing Pilot production run
Manufacture	Commercialisation	Manufacturing start-up	Manufacturing introduction and ramp-up
Product launch		Marketing start-up	
Product review		Technical service	On-going enhancement Phase-out

Note: The divisions act as approximates to illustrate similar activities across the models. These divisions should not be viewed as limitations on possible over-lapping activities.

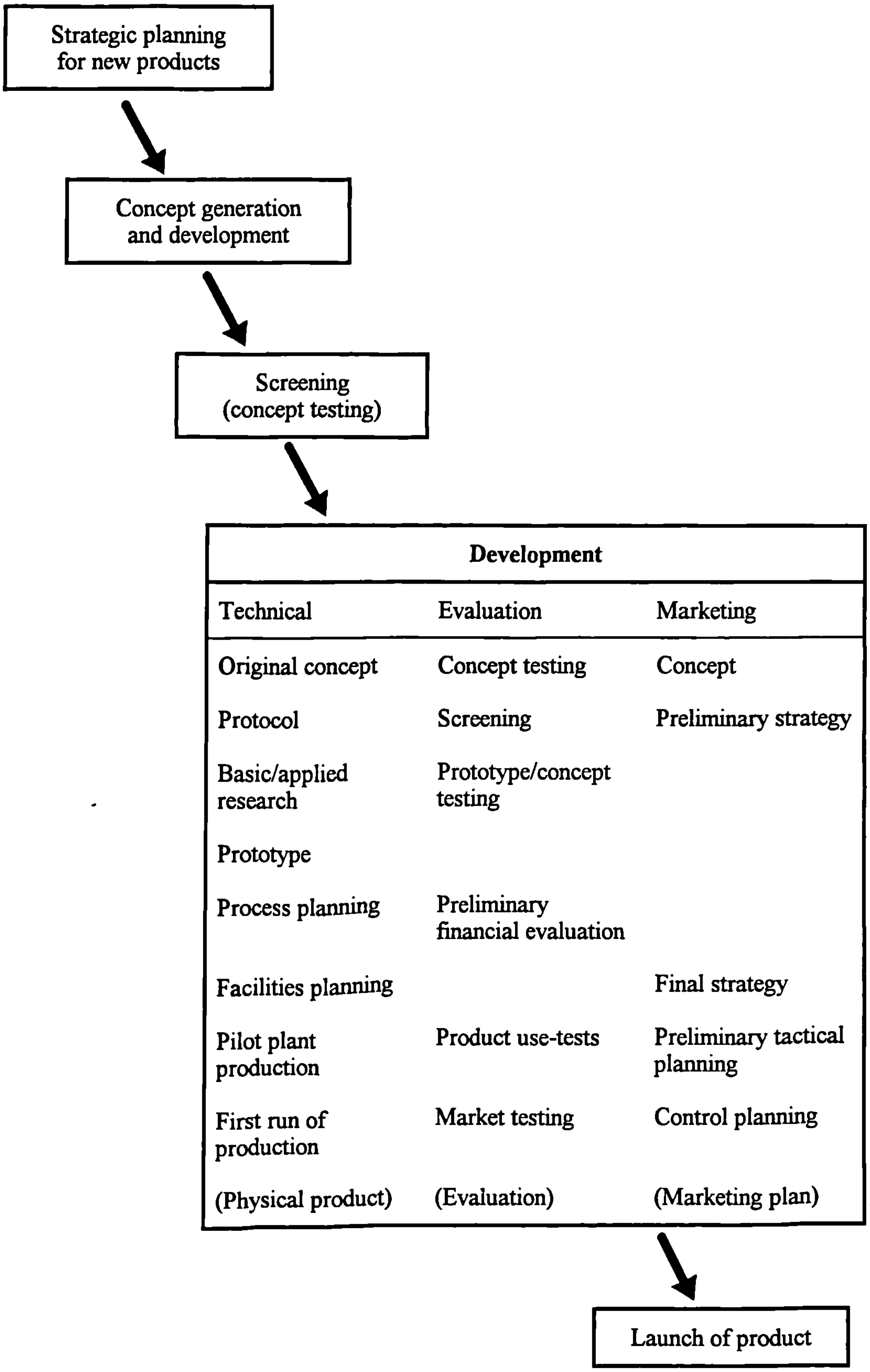
(*) A strategy formulation stage is assumed to have taken place in this model.

the process develops out of a strategic planning stage; and, second, the development stage emphasises the parallel roles of the technological and marketing development, and the contribution of an evaluating function.

The importance of a product strategy to precede the product development process is also emphasised by Booz, Allen & Hamilton (1982), Urban *et al* (1987), and Freeman (1982). In their model, Booz, Allen & Hamilton precede the idea generation stage with the interaction of various strategy activities - business strategy, new products strategy and new product strategic plan.

A spectrum of innovation/product strategies is available to an organisation, from proactive to reactive strategies. The choice of strategy will largely depend on the resource structures, type of business, and strategic orientation of the organisation (Urban *et al*, 1987). Proactive strategies reflect organisations that have an aggressive policy towards growth, and commit resources in the pursuance of customer needs and technological opportunities, design new products, and anticipate changes in market behaviour. A proactive strategy will utilise every activity of the product development process, whereas following a reactive strategy, such as responsive, imitative and defensive strategies, will see fewer development activities being undertaken internally, because these are carried out by competitors and outsiders (Urban *et al*, 1987). A reactive strategy may be chosen over a proactive initiative where, for example, markets for new products are too small to recover development costs, the firm has insufficient development resources, or little innovation protection is available to the firm. Since firms generally have a portfolio of products, it is almost certain that a variety of proactive

Figure 2.4 The new product development process



Development		
Technical	Evaluation	Marketing
Original concept	Concept testing	Concept
Protocol	Screening	Preliminary strategy
Basic/applied research	Prototype/concept testing	
Prototype		
Process planning	Preliminary financial evaluation	
Facilities planning		Final strategy
Pilot plant production	Product use-tests	Preliminary tactical planning
First run of production	Market testing	Control planning
(Physical product)	(Evaluation)	(Marketing plan)

Source: Expanded from Crawford (1983)

and reactive strategies will exist within the firm. This heightens the importance for any new product strategy plan to be in line with both the business and existing product strategies of the firm.

The strategy stage of the process begins by clearly stating the purpose of new product development. This will involve establishing the overall direction of activities (such as strategic orientation), the setting of specific objectives, and the general policies to facilitate meeting these objectives. Crawford (1983) refers to this combined statement as a *product innovation charter*.[2] Once the purpose of product development has been defined, various concepts can be created and tested. These concepts may originate from technological ideas, or customer needs, and represent product opportunities rather than actual products. Any concepts will then receive a preliminary evaluation, after which successful concepts will be developed or enhanced.[3] The developed concepts can then be screened. Screening provides an opportunity to evaluate alternative product concepts, whereupon more resources may be provided to a selection of concepts for further review, prior to a final go/no go decision. The screening stage will also determine whether a product development programme or project is to be established, depending on the extent to which fundamental R&D is required.

The process of developing a product concept into a commercial reality, requires three parallel activities: technical, evaluative, and market planning (Crawford, 1983). These three activities transform rather generalised and vague concepts into specific products. Beginning with a verbalised product concept, the technical activity focuses on the available technologies to develop preliminary product configurations (such as product sketches or clay models). These are followed by prototypes and final specifications, and the completion of manufacturing activities. Simultaneous to these activities is the evolution of a marketing plan, through which the proposed marketing actions can be formulated and tested prior to the completion of the technical product. To ensure that the technical and marketing activities are consistent with each other, and that the outcome and rate of development are fulfilling the requirements of product strategy, a review procedure (evaluative activity) exists between these two operations (Crawford, 1983).

At some point within the development process a decision will be made to commercialise the concept. This may be at the point of screening, or after further development work. However, the launching of the product will only take place once the three phases of development have been completed, although much of the preliminary work will have taken place throughout this stage. The launch of a new product is not the end of the process, since feedback may be provided to new projects or existing product programmes, with line extensions and product improvements.

The discussion so far indicates that some development activities may not be used under certain strategic situations. The degree to which particular activities are undertaken in the development process is also a reflection of the type of product. Souder (1987) compares the cost and duration of new product innovations across eight industrial sectors, using the eight stages indicated in Table 2.1.[4] Although his findings provide some support for the conventional pattern of cost distribution for innovations across each stage, exceptions to conventional thought were found and can be explained by the

Table 2.1 Stages of the life-cycle model for means-generated innovations

Stage	Label	Description
1	exploratory	search and inquiry activities, often funded by corporate monies, usually phenomenon oriented
2	concept development	concept elaboration, extension, and substantiation activities aimed at the clarification or elaboration of previously generated ideas or concepts
3	prototype development	differs from stage 2 in that a commercially relevant prototype, first model, or product has been identified and is targeted
4	prototype testing	laboratory, field, or production-scale evaluations
5	market development	market generation, demand simulation, and market analyses activities
6	manufacturing start-up	initial production runs, scale-up, and preparation for full-scale activities
7	marketing start-up	preparation for full-scale market entry
8	technical service	follow-on market and technical activities that accompany the introduction of the new product

Source: Souder (1987, table 4-1)

study's concentration on means-generated innovations. However, the aggregation of certain stage costs provides a reasonable reflection of the different orientations of industrial sectors, namely in those activities their efforts are concentrated. Table 2.2 provides a summary of the aggregation of total development and marketing costs. These data show that the glass, machinery, plastics and transportation industries have the bulk of their projects' expenditures in research, development, and engineering activities, whereas the bulk of project expenditures for the chemicals, electronics, food and metals industries appear to be in marketing and production activities.

Table 2.2 Aggregated stage costs for means-generated innovations (by percentage)

Industry	Development costs (Stages 2 and 3)	Marketing costs (Stages 5 and 7)
Glass	45	15
Machinery	45	17
Plastics	51	22
Transportation	40	18
Chemicals	16	34
Electronics	17	20
Food	31	39
Metals	25	42

Note: Stage 2 is concept development; stage 3 is prototype development; stage 5 is market development; and stage 7 is marketing start-up.

Source: Souder (1987, table 4-3)

2.4 Product development as a stage model

Product development consists of the movement of a product idea from concept through to market availability. This process involves a variety of distinct phases that have been traditionally viewed as individual, pre-determined steps, each of which required completion *before* subsequent stages could begin. In its simplified form, a new product is likely to have been transformed through the following stages: concept generation and screening; product design; prototype development and testing; process development; pilot production; and final production.

Taken as discrete steps, this linear (or sequential) process requires the completion of product design and prototype activities prior to the release of data to manufacture. This step-by-step process has been likened to a relay race in which the baton is passed from one runner to the next (Takeuchi and Nonaka 1986; Uttal 1987): the work of an upstream stage (for example, product engineering) is only passed downstream (for example, to process engineering) when the stage is complete. In extreme cases, this approach is typified by reference to 'over the wall' engineering, where little-to-no discussion takes place between upstream and downstream phases, and designs are transferred unidirectionally (as a batch *transmission* of *information*). It is only when senior management is ready to accept responsibility for the completed work of its area that the project is *signed-off* for work by the next group. This sequential approach has been a dominant form of product development in US and European companies since the 1960s (Uttal 1987).

Hence, a characteristic of the stage model is the use of control mechanisms, determining go/stop decisions between each stage. Cooper (1990 and 1994) refers to this as the *stage-gate* process. Typical of this approach is the NASA-type phased project planning (PPP) system (also known as the Phased Review Process): "Under this system, a new product development project moves through different phases ... in a logical, step-by-step fashion. The project proceeds to the next phase only after all the requirements are satisfied, thereby minimising risk" (Imai *et al*, 1985, p.349).

2.4.1 Examples of the stage model

Two examples serve to illustrate the process of development in a simplified, linear form and the elements of project management used in the sequential stage approach. The first is a composite case - Medical Electronics Incorporated - based on several companies' experiences, whilst the second, is the Eastman Kodak Company (Wheelwright and Clark 1992).

2.4.1.1 Medical Electronics Incorporated

In 1991, Medical Electronics Incorporated (MEI) introduced a portable, premature infant heart monitoring machine, the MEI 2010, into the market (Wheelwright and Clark, 1992). The 2010 product had undergone five development phases on reaching the market place: concept development; engineering prototyping; production prototyping; market acceptance testing; and market introduction.

Concept development: The concept originated in 1984, from informal discussions between an electrical design engineer and a marketing specialist. It was the electrical design engineer who championed the idea, and engineering who focused attention on the concept; it was only when marketing grasped the idea that the project made it into the *active* list of the 15-20 company projects. Various features of the final product (such as sensors and software) had there origins, however, from existing projects within MEI; hence, the creation of the final concept - and allocation of a capital budget in late 1986 -

was seen as a convergence of existing ideas, in the absence of any formal written proposal until 1991! During the formal concept phase, Marketing took responsibility for project leadership.

Engineering prototyping: On allocation of a formal capital budget, the project was assigned to the project manager (the design engineering manager); hence, project leadership was transferred to the engineering function. Despite managing three other projects, he was able to devote 40% of his effort to the 2010. (Besides project managing, he retained responsibility as functional head of the electrical engineering subgroup - MEI had five engineering subgroups, each with functional heads.) The engineering project team consisted of three additional electrical engineers and a mechanical engineer (who reported to the head of the mechanical engineering subgroup for individual task assignments). This division in reporting procedures created working and communication difficulties for the project manager. Similarly, management of the project was further compounded by there being 38 staff across five subgroups, undertaking nearly 20 projects between them. Moreover, as new staff were employed, repetition of previous exploratory suggestions and tasks occurred as poor communication inhibited transfer of current work and experience.

The first engineering prototype arrived in late 1987; this enabled marketing to get more involved since they could now 'feel and touch' the concept. The second engineering prototype, which arrived in the following spring, further enabled marketing to show a visible item to customers. Customer feedback of the desired features was *informally* communicated from marketing to engineering; engineering was still involved in undertaking numerous tasks before completion of the engineering phase. Finally, in late 1988, after a third or fourth prototype - the company was not certain as to the number - engineering validated the engineering design and handed over the project to production.

Production prototyping: Manufacturing first became formally involved in late 1988. Although some early observations to the project had been made in review meetings, manufacturing had waited for the *validated engineering design* before proceeding with outlining production tasks, creating material lists, preparing vendor plans, or establishing factory test procedures (with engineering).

General responsibility for the 2010 was taken by the manufacturing vice-president, although much of the day-to-day responsibility was given to a manufacturing engineer. The original plan for a batch of 10 units was delayed due to changes in the vendor base, requirements for tighter tolerances and improved vendor operations capabilities. Even after a nine month delay, only 75% of the pilot batch was represented by the work of production vendors; the remaining 25% had been custom built by job shops. Market acceptance finally received the pilot units in late 1989.

Market acceptance testing: The objective of this phase was to validate the product and ensure consistency of performance. The phase involved a wide range of testing and approval processes: life testing; government approval testing; and testing early prototypes with customers. The technical issues were handled by the quality assurance group, whilst customer matters were overseen by marketing.

Quality assurance developed a market acceptance test plan at the end of 1989; however, since the project was already behind schedule, the normal six to nine months of testing was reduced to four months. Customer testing showed a need to redesign the product in three areas (two minor changes and one major change being required). The two minor changes were acted upon immediately, but the major engineering change required formal agreement. Finally, amended prototypes were ready by autumn 1990. By this time, the original and amended launch dates had passed by. In an effort to release the product from quality assurance, only mandatory government standards and functional performance requirements were tested and met. The customer ease of use and serviceability issues were cut back.

Market introduction: Even once the testing was complete, the launch date was delayed two months as manufacturing found material faults amongst commodities sourced from the 25% of vendors not involved in the pilot batch. Although engineering changes were still in progress, manufacturing and marketing, under pressure from senior management, finally approved the first release of the product in January 1991.

The success of the product led to over use by customers. One result of this was frustration over how difficult it was to use, but also over the ease of breaking the wheels (due to over-use). In addition, there were further technical and service problems. Moreover, shortly after their launch, a major competitor introduced a premature infant monitoring device, which appeared easier to use, although perhaps not offering as many features.

2.4.1.2 Eastman Kodak Company

The Eastman Kodak Company has a similar, functionally oriented product development process to MEI, referred to internally as the Manufacturability Assurance Process (Wheelwright and Clark, 1992). The process uses a series of phases, which are functionally controlled in both focus and operation. Kodak uses a set of *phases* and *gates*. Six distinct phases describe the development process: customer mission/vision; technical demonstration; technical/operational feasibility; capability demonstration; product/process design; and, acceptance and production.

After an initial customer mission/vision phase, the R&D group undertake a series of technical demonstration and feasibility tasks; on completion of these, commercialisation begins as the project passes from engineering, through production and quality assurance to the market place. Although similar to the process at MEI in terms of phases, Kodak differs from MEI in that it has a clear customer mission statement (rather than being fuzzy) and controls the management of the process through gatekeepers and stakeholders (there are clearer demarcations between phases). At the transition stage of each phase, a gatekeeper (upstream) releases the project to a stakeholder (downstream) in the next phase. In this way, *control* is maintained over the project at a single point, or 'gate'. Although each stage is undertaken sequentially, there is some overlap of R&D and engineering in phase four.

2.4.2 Advantages and shortcomings of the stage approach

The sequential approach is held to have several advantages (Uttal, 1987; Shenas and Derakhshan, 1994). First, the distinct stages make the process easy to manage and control since each stage is pre-determined and each stage can be reviewed. Second, uncertainty is reduced before the next phase begins, since the information received downstream is assumed to be complete. In this way, risk can be better managed if the appropriate control (review) mechanisms are in place. Third, the phased approach assists in optimising functional expertise, since each manager can focus on a limited number of tasks. Hence, if a primary performance driver is resource utilisation, for example, advantages may accrue from clearly dividing the tasks in this way. Finally, engineers can be kept active by participating on a variety of projects.

However, as the two cases show, many problems can arise from the linear approach. For example, it may create products that are difficult to make, inappropriate for the customer, and extremely slow to reach the market (Uttal 1987). Coddington (1987), referring to the development of highway and construction industries' equipment, sees the traditional 'blacksmith' approach (where cut-and-try methods of subsequent build eventually lead to a durable although costly machine) as having three major shortcomings: first, the increased length of time spent on new product development; second, the increased cost of development resulting from the expensive need for experimental build; and third, a resultant machine that has been over-designed, and which is not cost competitive.

One explanation for the delay to market can be attributed to the need for product redesign, resulting from a failure to involve manufacturing early enough in the design phase: "... traditionally, in the UK, products are first designed in isolation and then designed for manufacture, resulting in long lead times because of production problems" (Burman 1992, p.61). If the principles of design for manufacture, quality function deployment and Taguchi methods were incorporated, much time, effort and money could be minimised by the early interaction of product, process and customer need in the design stage (Stoll 1986). Hence, there is a need for interdisciplinary inputs, including customers and suppliers (Hart and Baker, 1994).

Shenas and Derakhshan (1994, p. 31) in supporting many of these disadvantages, highlight many weaknesses with the sequential design process:

> ...there is little overlap between design and manufacturing decisions. The ultimate goal ... is usually lowest cost, when the goal should include optimal product performance, quality, robustness and conformance. Additionally, such issues as manufacturability, quality control and ease of assembly are not considered until the later production modules, when a design change may be very costly. ... production planning, support analysis, maintenance and reliability are considered separately from the design process. The designers by themselves must select the particular aspects and parameters of the product with minimal input from production engineers who are responsible for the implementation ... consequently, information is lost as the design progresses through consecutive production modules. ...Finally, designers usually do not set cost reduction as a goal because they are not aware of cost information owing to poor communication with the manufacturing experts.

Cooper (1994), whist accepting that the stage model can promote discipline and reduce technical risks, sees the over-formality of the stage model as a major shortcoming. For example, the process is laborious, requiring dozens of tasks to be checked-off at each review point. One means of increasing the through-put time is to overlap activities within the process.

2.5 Overlapping product development

Imai *et al* (1985) consider the sequential approach to be inappropriate for development that requires speed and flexibility, hence as the criteria for competing through product development have advanced since the mid-1980s, so too have approaches to the process itself: *simultaneous engineering, concurrent engineering, forward engineering, integrated problem solving, parallel engineering, team approach, and life-cycle engineering* are some of the terms that have been applied to the evolving process (Imai *et al,* 1985; Stoll, 1986; Andreasen and Hein, 1987; Uttal, 1987; Coddington, 1987; Clark and Fujimoto, 1991). The use of sporting metaphors has also developed with Imai *et al* (1985) citing the rugby football approach to product development by Honda, where an *overlapping* of activities provides an improved setting for product development. The essential objectives of simultaneous engineering, for example, are captured well by Rolls-Royce Aero Engines: "Simultaneous engineering attempts to optimise the design of the product and manufacturing process to achieve lead times and improved quality and cost by the integration of design and manufacturing activities and by maximising parallelism in working practices" (Broughton, 1990, p.26).

The sequential approach is considered by Imai *et al* (1985) as inappropriate for the development of engineering projects that require speed and flexibility. In their study of five Japanese engineering cases (Fuji-Xerox, Honda, Canon, NEC, and Epson), they identify *overlapping* product development as a factor that assists firms, *inter alia,* to reduce total development cycle time and enable competition through flexibility (the adaptation of the development process to changes in the external environment).[5] Overlapping development is where downstream activities receive resources prior to the completion, but after the start, of the upstream task. Figure 2.5 illustrates the sequential process against the overlapping phases of development. Two types of overlapping development model can be identified: those where successive tasks are undertaken in parallel, as information (sometimes as technology) is transferred at each interface; and those where a greater overlap extends across several phases and, thus, several tasks may be undertaken simultaneously.

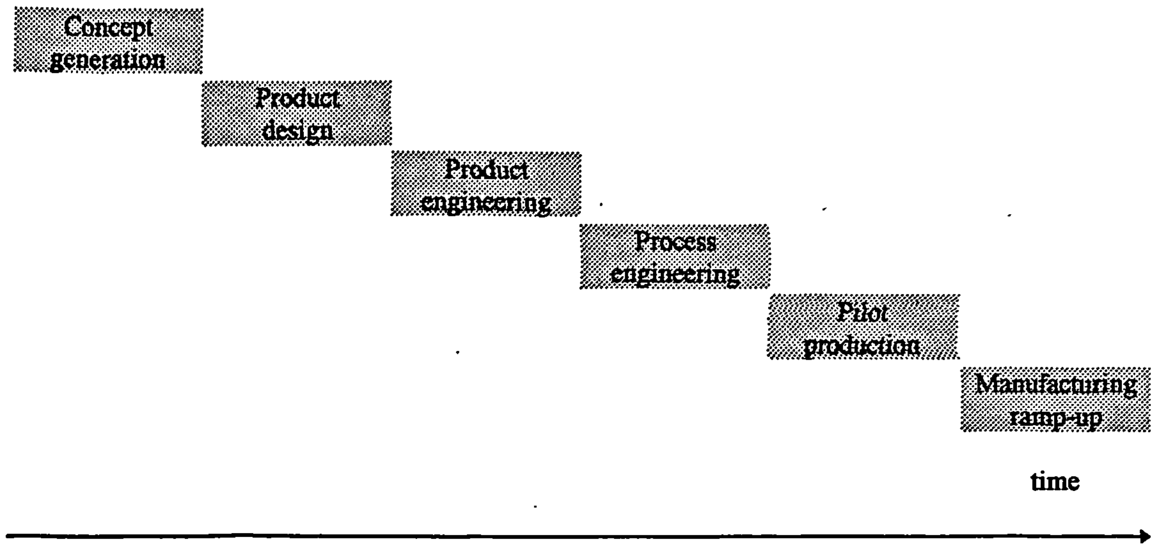
2.5.1 Example of a partial overlapping approach

Wheelwright and Clark (1992, pp. 156-59) illustrate a revised linear model with the case of General Electric, where there was a partial overlap between the design/process and manufacturing/planning phases, through the use of cross-functional phases and integrated tasks through using a project team approach.

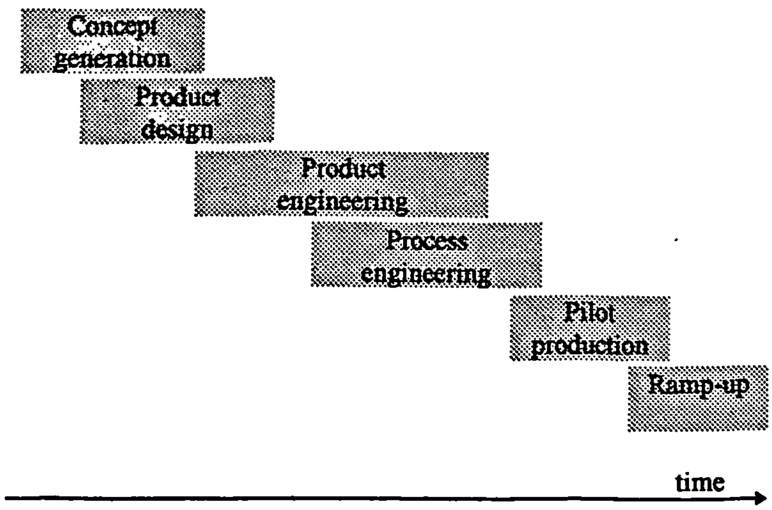
The *tollgate* process, as they term it, is based on seven stages (or themes) which have superimposed onto it 10 programme phases, defined by a management review procedure. Hence, the programme phases manage the process of development through the seven themes (see figure 2.6). By using relatively short programmes, senior management is able to maintain control over the process and to manage risks by having the opportunity to change direction or emphasis at each review stage, before the risks become too great. Hence, risk management is the primary performance driver, although the process does enable the maximisation of resource utilisation.

Figure 2.5 Alternative approaches to product development

(a) Sequential phases

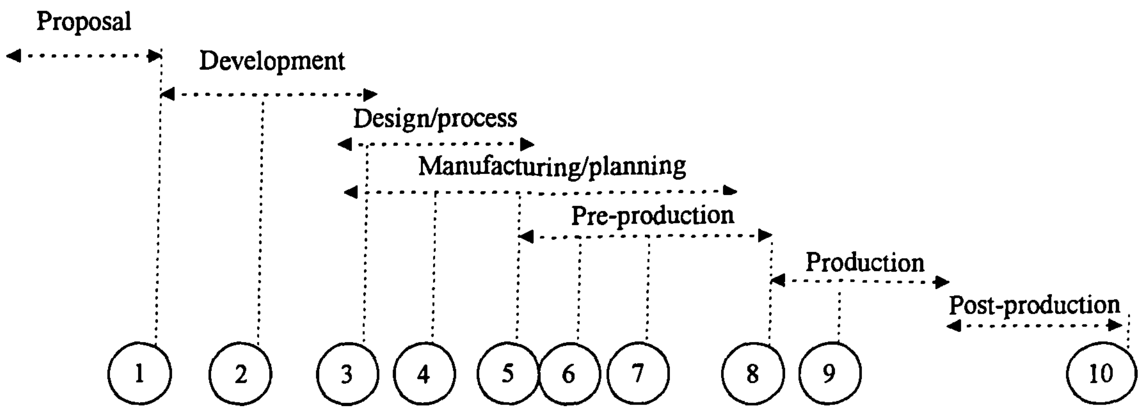


(b) Overlapping approach



Note: The duration of phases indicated is nominal and therefore should not to be representative of actual development projects. In figure 2.5 (b) the product and process engineering phases are deliberately longer to imply longer duration.

Figure 2.6 Tollgate process at General Electric



	Programme Phase/Review	Objective
1	Customer/consumer needs	Quantification and articulation of the nature of the customer need(s). Generation of product line management/marketing concurrence on desired product specifications.
2	Concept review	Conceptualisation of product design alternatives in response to definition of customer need. Authorisation to develop product prototype(s).
3	Feasibility review	Presentation of product design approaches.
4	Preliminary design review	Agreement on product design and manufacturing approach. Authorisation to make pilot equipment.
5	Final design review	Final product design. Final equipment design.
6	Critical producibility review	Verification that in-plant production on prototype equipment replicates final process (in small scale) as it pertains to product process, and equipment
7	Market/field test review	Review of results of market and field tests conducted with products made on prototype equipment.
8	Manufacturing feasibility review	Final equipment review in production mode.
9	Market readiness review	Verification that all marketing steps have been completed prior to product introduction.
10	Market introduction and follow-up	Determination of what changes (if any) need to be made in product, process, etc.

Source: Wheelwright and Clark (1992, exhibit 6-5)

First, a specification of the customer needs is developed and reviewed, once marketing and line management are in agreement over the detail of the desired product specifications. Only after this review can the development of the concept design and authorisation for prototyping begin. Alternative product designs are conceptualised, in relation to the customer needs and development concludes with a feasibility review.

Some overlap between design and manufacturing occurs during the design/process and manufacturing/planning phases. In order for a preliminary design review to be approved, agreement between the product design and manufacturing approach is required. Only then can authorisation be given for making pilot equipment. The final design review, at which product and equipment designs are agreed, sees the beginning of the pre-production phase. The manufacturing and planning phase is still operating concurrent to these activities.

During the pre-production and final stages of manufacturing/planning, prototype equipment verifies that the final process is representative of product, process and equipment outputs - this is checked through the critical producibility review. Similarly, the market/field test review establishes the results of prototype manufactured products. Production begins once a manufacturing feasibility review has taken place. It is during this stage that the preparation for the market place is verified (market readiness review). The final review stage occurs after market introduction has taken place, in order to determine any likely changes to product, process or equipment.

Some of the essential features of General Electric's development programme is the extensive use of integration mechanisms (a liaison team, programme manager, and cross-functional phases), when compared with Kodak or MEI, and the more centralised, senior management directed review process. The close control of the process by senior management lends itself to a better assessment of risk; in this way, the more coordinated and linked approach of General Electric may be more appropriate where time-to-market and a coordinated technical/marketing strategy are important elements of the development process.

Another example of this partial overlapping approach is provided by the development of the Fuji-Xerox FX-3500, medium-sized photocopier (Imai *et al*, 1985; Takeuchi and Nonaka, 1986). Fuji-Xerox inherited a traditional PPP system from the parent company which it revised in two ways: first, it reduced the number of development phases from six to four (combining and redefining some) and, second, through changing the sequential approach into, what Fuji-Xerox refers to as, the *sashimi* system (*Sashimi* is a Japanese culinary dish where slices of raw fish are tilted on a plate, one slice overlapping the other). Essential to this approach is extensive social interactions amongst the team members, but also other parties involved, such as a cooperative network of suppliers. The result of using this revised PPP system was a shortening of the total development time from 38 months for a similar prior model to 29 months for the FX-3500.

2.5.2 Example of an extensive overlapping approach

The second model of overlapping requires a greater overlap across stages. This approach is typified by Honda's development of a city (1200cc engine) car in 1981, and Canon's development of the *Autoboy* (*Sureshot*) lens shutter camera in 1979. Honda's rugby football approach to product development involves all core project members seeing through the development from start to finish, with the responsibility for combining all phases. This continuous approach is intended to smooth out potential problems that can arise at the adjoining phases, as projects are traditionally passed from one phase to the next. Similarly, there was extensive overlapping in Canon's development process: design engineers followed the project to ensure it was being produced as they had envisaged, and manufacturing engineers advised on design aspects to ensure the design met with their requirements.

2.5.3 Advantages and shortcomings of the overlapping approach

A disadvantage of the earlier stage model was its failure to incorporate related development activities, as Hart and Baker (1994, p.83, italics in original) suggest: "... product development activity is not only iterative *between* stages but also *within* stages". However, the overlapping approach has overcome this through encouraging multifunctional discussion within each activity stage. This promotes a quicker process, as problems are considered concurrently.

Imai *et al* (1985) extol the benefit of the overlapping approach to the faster speed of development and increased flexibility, as well as the sharing of information and a variety of human resource management issues. For example, it can foster a generalist's strategic view, enhance shared responsibility and cooperation, stimulate involvement and commitment of the workforce, and orientate the organisation towards problem solving. On the other hand, overlapping development increases the burden of managing the process exponentially, increases ambiguity, tension and conflict with the group, and increases the burden of coordinating the intake and dissemination of information (Imai *et al*, 1985, p. 351).

2.6 Integrated product development

The integrated approach differs from the overlapping model insofar as a greater emphasis is placed on cross-functional input *throughout* the development process and the early release of information to downstream activities. For example, process engineering has the opportunity to discuss implications for the design at concept stage, enabling faster feedback of redesign requirements and consideration of phasing in new capital equipment. Hart and Baker (1994) criticise the overlapping (parallel processing) model for neglecting customer and supplier inputs, and for the lack of convergence on stages. They propose a multiple convergent process that enables multifunctional decision-making to take place between stages. Their argument for greater control to take place at the gates (or points of convergence) is expressed as follows:

> .. the [product development] process is a series of information gathering and evaluating activities, and as the new product develops from idea to concept to prototype and so on, the information gathered becomes more precise and reliable and the decisions are made with greater certainty. Therefore as the development project progresses, there are a number of natural points of evaluation and a

> number of types of evaluation (market, functional) which need to be carried out in an integrated fashion. Hence there are multiple convergent points. (Hart and Baker, 1994, p. 86)

Wheelwright and Clark (1992) provide a framework that accommodates these points (figure 2.7). Three functional areas are indicated and their participation across the product development process: engineering (focusing on product design); manufacturing (including process development, manufacturing engineering and plant operations); and marketing (responsible for market research and sales). This can be seen as an integrated approach, and three points are noteworthy: first, other functional areas could be added to figure 2.7, together with customers and suppliers; second, iteration of participants can take place *within* stages; and third, integration mechanisms (such as review meetings) act as convergence points - redressing the criticisms of Hart and Baker (1994).

The author has witnessed such a process in a clutch manufacturer in which 10 separate groups (including customers) were identified as participants at review meetings, with varying degrees of inputs throughout the process. An important key point to emphasise is that although a group may not undertake a particular activity, the review procedure enables them to have an early input. For example, manufacturing has the opportunity to propose and investigate concepts early in the process, and similarly marketing does not wait for full-engineering prototypes before interacting with the customer (Wheelwright and Clark, 1992). The aim of the integrated approach is to improve integration and promote the effective early involvement of all participants.

Figure 2.7 Cross-functional integration

Functional activities	Phases of development: Concept development	Product planning	Detailed design and development: Phase I	Detailed design and development: Phase II	Commercial preparation	Market introduction
Engineering	Propose new technologies; develop product ideas; build models; conduct simulations	Choose components and interact with suppliers; build early system prototypes; define product architecture	Detailed design of product and interaction with process; build full-scale prototypes; conduct prototype testing	Refine details of product design; participate in building second-phase prototypes	Evaluate and test pilot units; solve problems	Evaluate field experience with product
Marketing	Provide market-based input; propose and investigate product concepts	Define target customer's parameters; develop estimates of sales and margins; conduct early interaction with customers	Conduct customer tests of prototypes; participate in prototyping evaluation	Conduct second-phase customer tests; evaluate prototypes; plan marketing rollout; establish distribution plan	Prepare for market rollout; train sales force and field service personnel; prepare order entry/process system	Fill distribution channels; sell and promote; interact with key customers
Manufacturing	Propose and investigate process concepts	Develop cost estimates; define process architecture; conduct process simulation; validate suppliers	Detailed design of process; design and develop tooling and equipment; participate in building full-scale prototypes	Test and try out tooling and equipment; build second-phase prototypes; install equipment and bring up new procedures	Build pilot units in commercial process; refine process based on pilot experience; train personnel and verify supply channel	Ramp-up plant to volume targets; meet targets for quality, yield, and cost
Key milestones	• concept for product and process defined	• establish product and process architecture • define program parameters	• build and test complete prototype • verify product design	• build and refine 2nd phase prototype • verify process tools and design	• produce pilot units • operate and test complete commercial system	• ramp up to volume production • meet initial commercial objectives
Key decisions	CONCEPT APPROVAL	PROGRAMME APPROVAL	DETAILED DESIGN APPROVAL	JOINT PRODUCT AND PROCESS APPROVAL	APPROVAL FOR FIRST COMMERCIAL SALES	FULL COMMERCIAL APPROVAL

Source: Wheelwright and Clark (1992, exhibit 7-1)

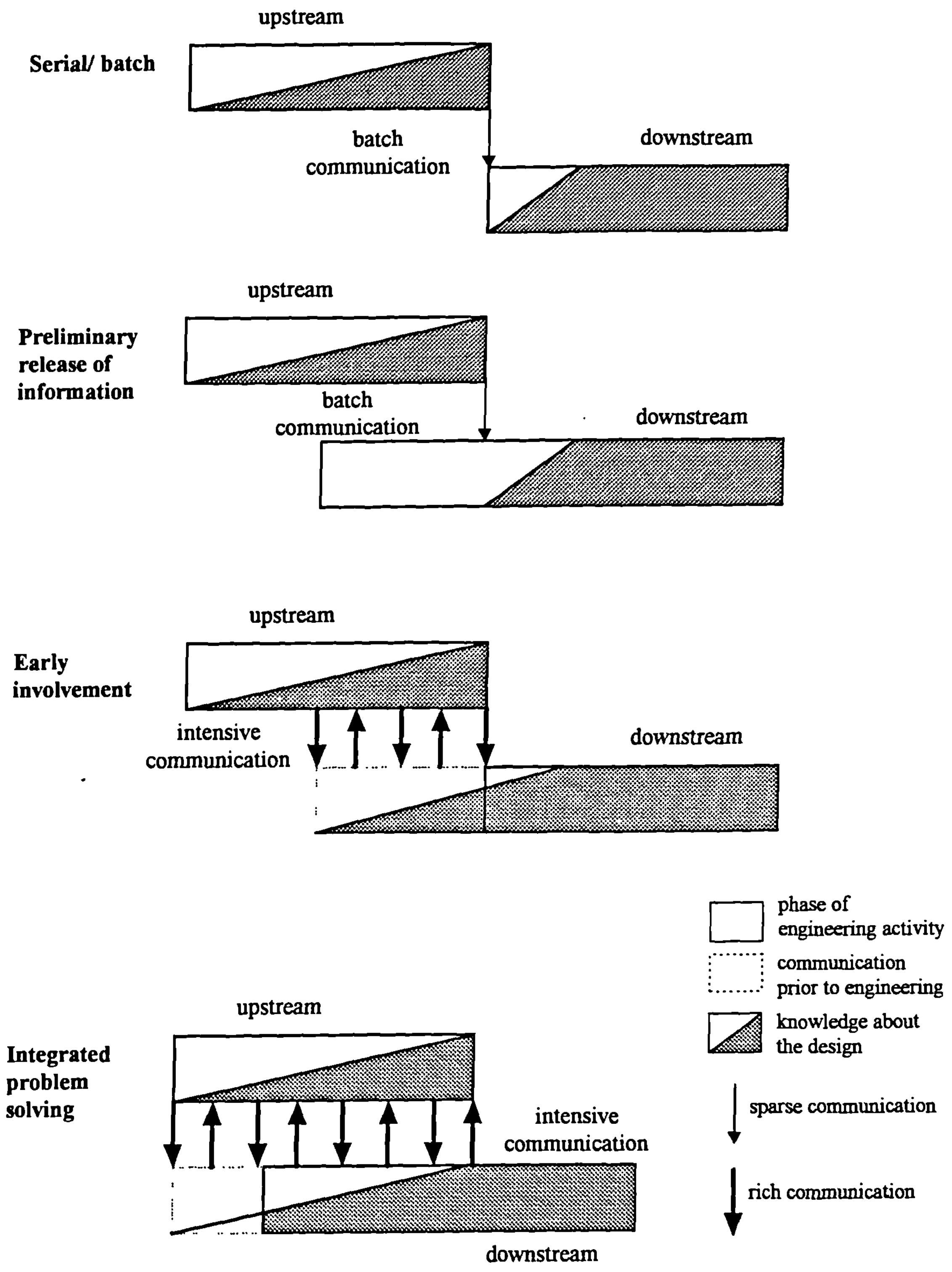
The milestones in figure 2.7 indicate opportunities for each function to focus attention on their respective activities and to see how these interface with other functions. Hence each phase and milestone should have an element for all participants.

2.6.1 Integrating upstream and downstream operations

The overlapping and integrated approaches promote communication and transfer of information by bringing together multifunctional teams at critical points in the product development process. It may range from relatively simple early release of information to intensive two-way communication. From a study of the world automotive industry, Clark and Fujimoto (1989, 1991; Fujimoto, 1989) show that effective integration between activities in product development requires the early release of information, intensive two-way information flow, and mechanisms to facilitate these aims. These will be examined in detail in later chapters, but a preliminary outline of the transmission of information across activities assists in reviewing the various models of product development process, thus emphasising the benefits of an integrated approach.

Figure 2.8 illustrates four situations of activity interaction. Figure 2.8(a) is characteristic of the sequential, single batch transfer of information. In this, information is only transferred when the upstream activity has been completed. Thus, no account is taken of the downstream requirements. Figure 2.8(b) and (c) characterise overlapping problem-solving. A partial overlap may occur as the downstream activity begins work on the project without the availability of upstream information. The transfer of information is similar, insofar as it is transmitted only on completion of the upstream activity. If

Figure 2.8 Upstream-downstream interaction



Source: Wheelwright and Clark (1992, exhibit 7-4)

information is released earlier, downstream operations have the opportunity to begin their work and recommend necessary changes to the product design. Finally, figure 2.8(d) shows the integrated approach: upstream and downstream activities are linked in both time and communication. Information is shared from the start and feedback is integral to the process: it is both rich in quality and intensive.

The discussion thus far has outlined alternative approaches to the process of product development. It has been shown that the sequential approach, although reducing technical risks, is time-consuming. The integrated approach is advocated where products are complex and intensive iterations are required to deliver products speedily to market. The process, however, is only part of a company's product development equation. The organisation of the activities structures the process and through the resources available to it, which now receives discussion.

2.7 Organisation structures for product development

There are a variety of organisation forms under which product development can be organised, since the choice of structure will be subject to, *inter alia*, the availability of resources, the competitive environment (such as the speed of product introduction), and the age and variety of the product base. For example, as the management of product development has incorporated the need for cross-functional coordination, reductions in lead times and so forth, there has been a movement away from the traditionally organised functional structure, towards alternatives with tighter project management through which tasks may be undertaken simultaneously.

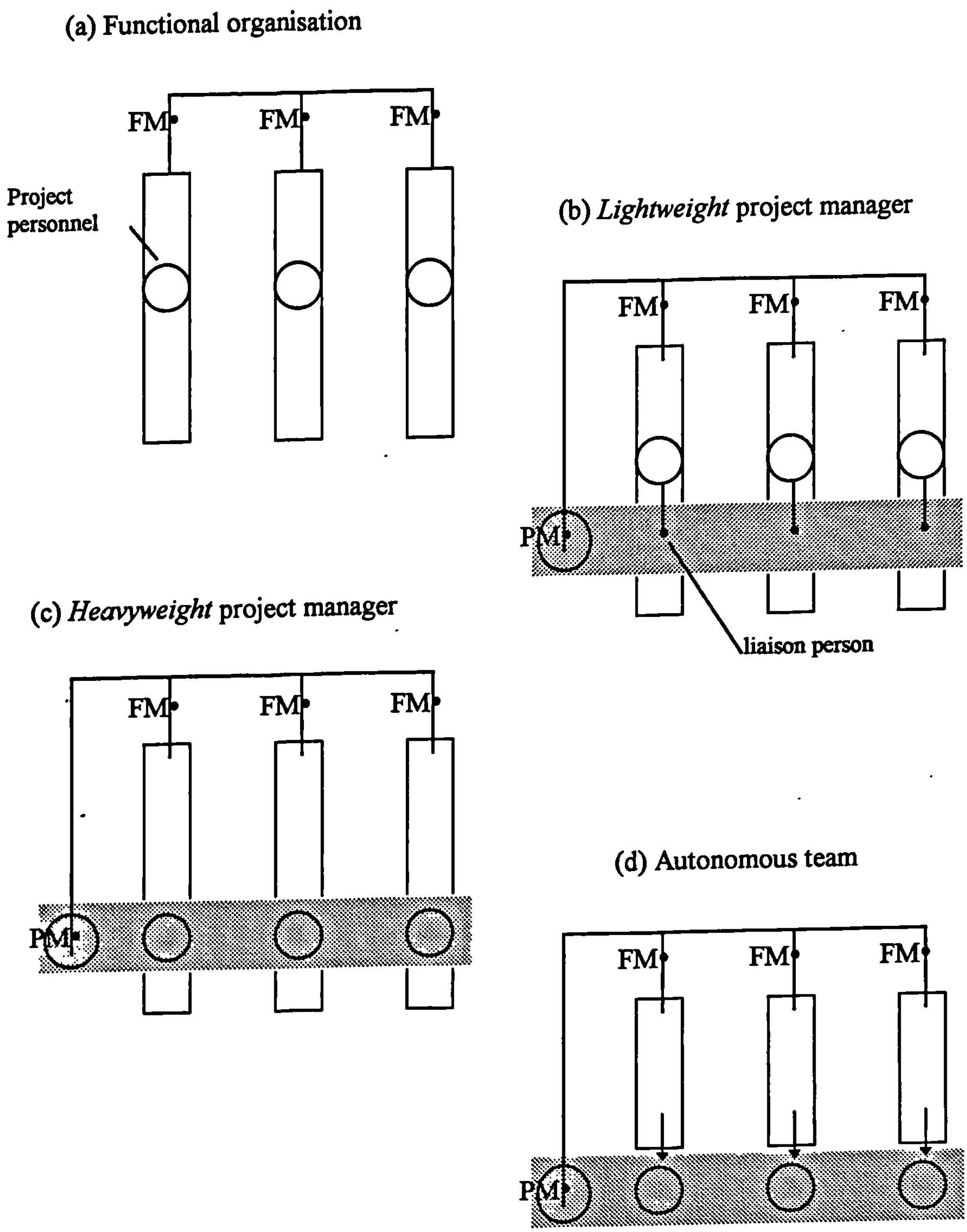
Larson and Gobeli (1987 and 1988) identify five separate project management structures along a continuum, based on the work of Galbraith (1971): a spectrum of alternative structures can be considered from a pure *functional organisation*, with increasing importance of tighter project management towards a pure *project-based team*. A pure, functional based organisation aims to maintain functional (or discipline) strengths whilst supporting many projects, whilst a pure, project based organisation specialises development around a single product within a dedicated project team. Lying between these extremes are structures based on the combination of these two pure forms: the *matrix* organisation. Three hybrid forms can be identified within the matrix structure: *functional matrix*, *balanced matrix*, and *project matrix* (Larson and Gobeli, 1987 and 1988; Harrison, 1992).

Similarly, the work of Clark (with Hayes and Wheelwright, 1988; 1991; with Wheelwright, 1992) reflects both the pure and hybrid structures. Using work originating from Fujimoto (1989), four dominant organisational structures for project activities can be identified: the *functional* organisation; the *lightweight* project manager; the *heavyweight* project manager; and the *autonomous* team. All of these organisational forms are now examined in more detail, together with the balanced matrix; figure 2.9 provides a brief illustration of each organisational form.

2.7.1 Functional organisation

This is the traditional hierarchical organisation under which a project is sub-divided and assigned to specialist groups operating within functional areas (such as engineering, production, marketing and administration), and whereby authority for the development

Figure 2.9 Organisational forms for product development



Notes:
FM functional manager
PM project manager

Source: Wheelwright and Clark (1992, exhibit 8-1)

project cascades down through the organisation from senior management, through the ranks of middle management and to the lower management levels. In this way, the project is passed (as a completed task), like a baton in a relay race from one team member to the next. The main responsibility for the project shifts from function to function as it progresses, and is coordinated by the respective functional heads. Any liaison will be conducted through the head of function; hence, it can become an extremely bureaucratic system.

Projects based in this way have several advantages (Child 1977). First, the simple structure makes economical use of managerial tasks and control. Second, it enables the centralisation (or pooling together) of available experts and resources, especially important in the innovation process where specialist technical expertise is critical, costly and often scarce. Third, clearly defined career paths, and peer grouping, can assist the hiring and retaining of specialist staff. Conversely, there are weaknesses with this form. When there are a multitude of projects being undertaken simultaneously, competition for resources can lead to conflicts over the relative priorities of individual projects. Functional speciality can lead to an over-emphasis of the departmental goals, rather than to achieving the goal of the project. Finally, there may be a lack of motivation or enthusiasm when commitment of personnel is spread across projects (see Youker 1977).

2.7.2 Project team

Also referred to as *venture* team (Crawford, 1983), *tiger* team (Hayes *et al*, 1988), *skunkworks* (Quinn, 1985), *task force* (Slack, 1991) and *permanent team or cell* (Winch, Voss and Twigg, 1991), this organisational form consists of a project manager who is given responsibility for a project team composed of a core group of personnel from several functional areas, assigned on a full-time basis for the life of the project. This team is separated from the functional structure and controlled by a manager responsible for the completion of the project; hence, the functional managers have no formal involvement. The project manager has responsibility for both internal coordination and external integration, and has direct control of all personnel throughout the duration of the project. In this way, responsibility is centred on one individual, who coordinates the entire process, rather than the distributing of authority inherent in the functional structure.

The advantages of this structure are the singleness of purpose and unity of command, the clear focus of a single objective, the effectiveness of informal communication, and the central authority of all the necessary resources (Youker 1977). In particular, the development of teamwork, together with a single leader, enables conflict to be managed efficiently. On the downside, this structure disrupts the regular organisation, since the project is only a temporary event, facilities are inevitably duplicated and may be viewed as being used inefficiently, and personnel may have problems re-entering the organisation after project completion - a problem exists of personnel losing their 'home' in the functional structure whilst away (Winch *et al*, 1991).

An illustration of such a project team is provided by Winch *et al* (1991). A UK automotive manufacturer established a fully independent project team to develop an entirely new vehicle model, whilst simultaneously using its existing matrix to maintain incremental development for improving and expanding the existing model ranges. The project team, known as the Vehicle Concept Group, was established with two explicit objectives: first, to centralise the early stages of concept and design of a vehicle into a single group; and second, to develop a fully paperless design of a vehicle (through the extensive use of a fully integrated CAD/CAM system).

The project team was headed by a project manager who reported directly to the board of directors (by-passing the director of product engineering). The staff consisted of 19 permanent design engineers drawn from three sub-functional areas; 30 seconded staff from other specialist engineering sub-functions; and five seconded manufacturing engineers. The project manager was responsible for the vehicle development throughout the development process, and had *functional* responsibility for the permanent members of the project team; although responsible for the seconded staff's role on the project, their career development remained under the direction of their sub-functional heads.

The experience of this organisational form was mixed. On the one hand, internally the group had been perceived to be cohesive and effective. On the other hand there had been considerable criticism of the group from outside. First, a number of people stated that it had been criticised for being reluctant to bring in further expertise from outside when needed. These comments would seem to have been a natural consequence of developing a tightly knit group. Second, there was considerable uncertainty inside and outside the group about its longer term role. It had been set up with the task of developing the concept for a new vehicle. As this task progressed questions were raised whether the group should continue to have responsibility for developing the vehicle through the later stages of its life cycle. In this case should the group have been enlarged to involve a wider range of functions, or should it have evolved into a matrix approach? There was considerable resistance to the former from the functions who saw the group as eroding functional strength and power.

2.7.3 Matrix organisation

The third basic form of product development structure lies between these extremes and combines elements of these two pure forms by integrating the vertical functional structure with a horizontal project structure. Support towards a hybrid of these two structures can be found first in the findings of an early study to investigate differences in organisational structure and the effectiveness of such organisations, by Burns and Stalker (1961). This study is one of the contingency theory school, which includes *inter alia* the work of Woodwood (1965), Galbraith (1973), and Lawrence and Lorsch (1967a and 1967b).

Burns and Stalker examined 20 British firms in the electronics industry, and sought to explain how technological and market changes affected the way firms manage innovation. They observed two opposing management styles: first, an *organic* style, characterised by a highly flexible and informal organisation, based on teams that could adapt to the problems being undertaken; and second, a *mechanistic* style, which was more formal, hierarchical, bureaucratic and rigid in form.

Burns and Stalker concluded that both forms of structure were effective as organisational forms, but under differing situations: the organic form in rapidly changing markets and technologies, and the mechanistic under stable conditions. These two management types were applied by Burns and Stalker to variations in structure between organisations. However, such differences can be identified within the operations of the firm. Hall (1962) used these in a similar conceptual polar categorisation to examine intra-organisational structures. He concluded that research and development departments tended to be organised around the organic form and production departments under the mechanistic form (see Winch *et al* (1991) for further discussion on this distinction). Similarly, Oakley (1984) discusses the appropriateness of these structures to the organisation of product design units.

Firms are unlikely to adopt either of the pure forms of organic or mechanistic, but a balance between the two - depending on the nature of the firm, the industry, and the projects being undertaken. Hence, firms may consider adopting a structure combining the characteristics of both the functional and project organisation.

> Matrix management is a 'mixed' organizational form in which hierarchy is 'overlaid' by some form of lateral authority, influence, or communication. In a matrix, there are usually two chains of command, one along functional lines and the other along project lines. (Larson and Gobeli, 1987, p.126).

Indeed, the matrix organisation tries to maximise the strengths, and minimise the weaknesses, of both the project and functional structures (Youker 1977). The functional organisation is organised around technical inputs, such as engineering, and is generally efficient in the utilisation of resources and skills, but is less effective in achieving project objectives, whereas the project organisation is more effective in achieving project outputs - the product but is less efficient in the use of resources (Harrison 1992). Both of these structures are unidimensional, whilst existing in a multidimensional environment; hence, the matrix organisation aims to balance the objectives of the long-term technical expertise of the functional structure with the short-term objectives of the project (Youker 1977).

The matrix organisation developed primarily out of the USA aerospace industry during the 1960s, as firms realised the need to lead by both technical performance and coordination of project management (Galbraith 1971). The matrix structure offered the opportunity to balance these objectives and to assist in the coordination of a project across formal organisational boundaries. Unfortunately, despite these advantages, a number of human relations problems arise from the matrix structure. Despite their interdependence, conflicts may develop between the project manager and the functional departments, due to differences in cultures and objectives.[6] Individuals may have divided loyalties, resulting from the dual subordination, and this in turn can lead to project and functional managers realising diminished authority over their respective domains. The matrix organisation can be complex, ambiguous and is often uncertain! These complexities and ambiguities are an inherent reason for adopting the matrix structure, and is not a consequence of its use (Harrison 1992).

2.7.4 Choice of organisational structure

Table 2.3 provides examples of factors likely to influence the choice of organisational structure for a specific project (see also Lock, 1992). From these characteristics, it is clear that for products such as farm equipment, where the technology is standardised and the product is small, product development may be organised functionally. In contrast, the significantly complex nature of a nuclear submarine would probably suit a matrix structure. Similarly, a project organisation would be suitable for companies of complex, time critical products.

The identification of these organisational alternatives does not limit firms to just one structure. It is possible that a firm could utilise all three basic structures, selecting an organisational form, as appropriate, for a specific project. Similarly, a firm could be generally based around a matrix structure, but be project organised within the engineering function.

So, what characteristics dictate a company's choice of structure? In 1971, Galbraith established that the choice of organisational structure will be related to the degree of authority between function and project (figure 2.10), as well as the use of integrating mechanisms (such as task forces, teams and liaison roles) and the formal information system (such as procedures, plans, and review meetings).

Galbraith's model has been used by Vasconcellos (1979) to differentiate the matrix structures of 17 research institutes in Brazil. Using ten factors (for example, project

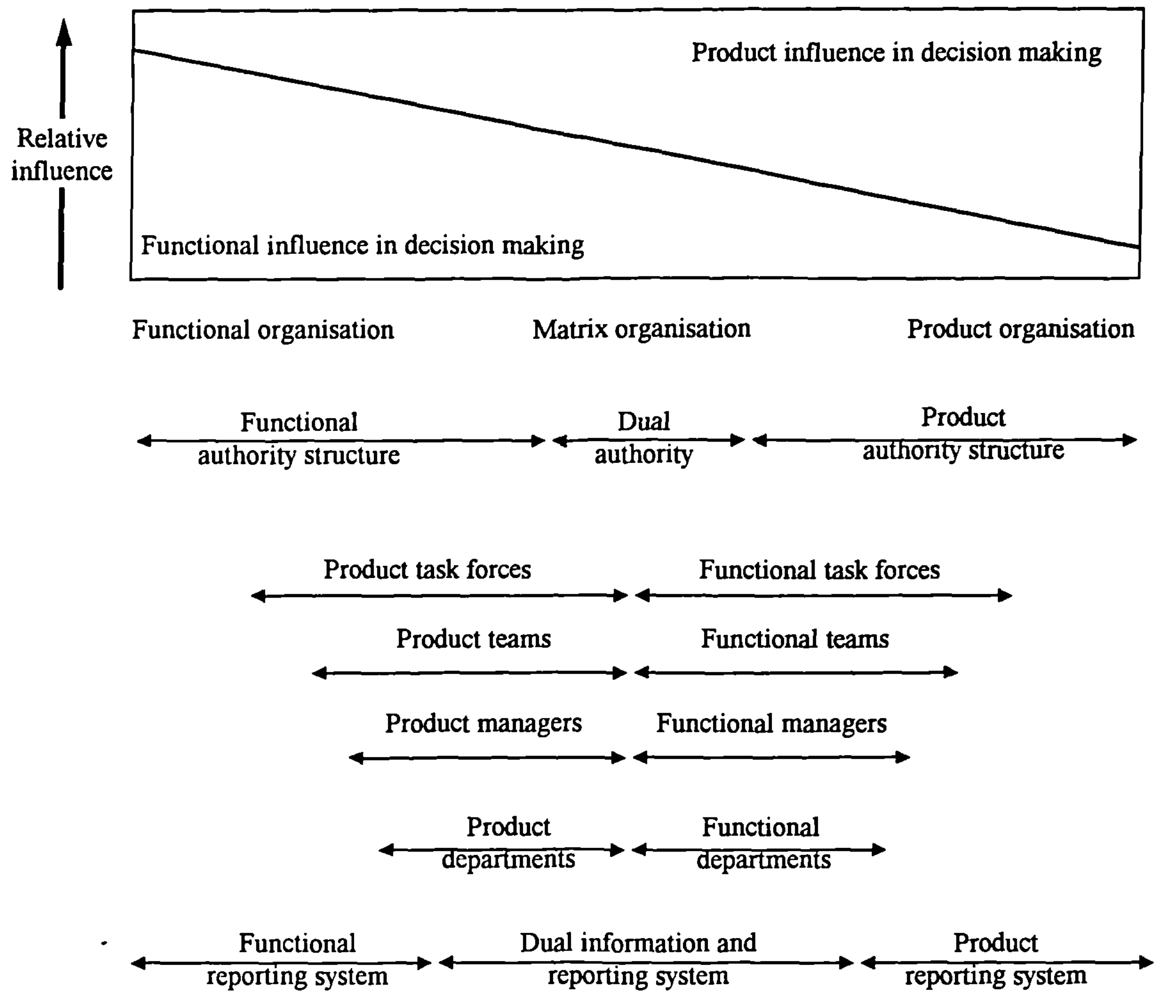
Table 2.3 Comparison of the three major organisational forms (by design characteristic)

Characteristic	Functional	Matrix	Project
Uncertainty	Low	High	High
Technology	Standard	Complicated	New
Complexity	Low	Medium	High
Duration	Short	Medium	Long
Size	Small	Medium	Large
Importance	Low	Medium	High
Customer	Diverse	Medium	One
Interdependency (within)	Low	Medium	High
Interdependency (between)	High	Medium	Low
Time criticality	Low	Medium	High
Resource criticality	Depends	Depends	Depends
Differentiation	Low	High	Medium

Source: adapted from Youker (1977, figure 5)

deadlines, quality, purchasing, and human resource allocation) to measure the authority of project managers, Vasconcellos's findings suggested four organisations as being project oriented, thirteen organisations as having some form of matrix, and no organisation with a functional orientation. These results were inconsistent with the author's longitudinal experience of the field sites that suggested some organisations of a matrix structure with a high emphasis on functional organisation, and others with a strong project structure. Considering this observation, Vasconcellos argues that

Figure 2.10 Range of alternative organisation designs



Source: Galbraith (1971, figure 3)

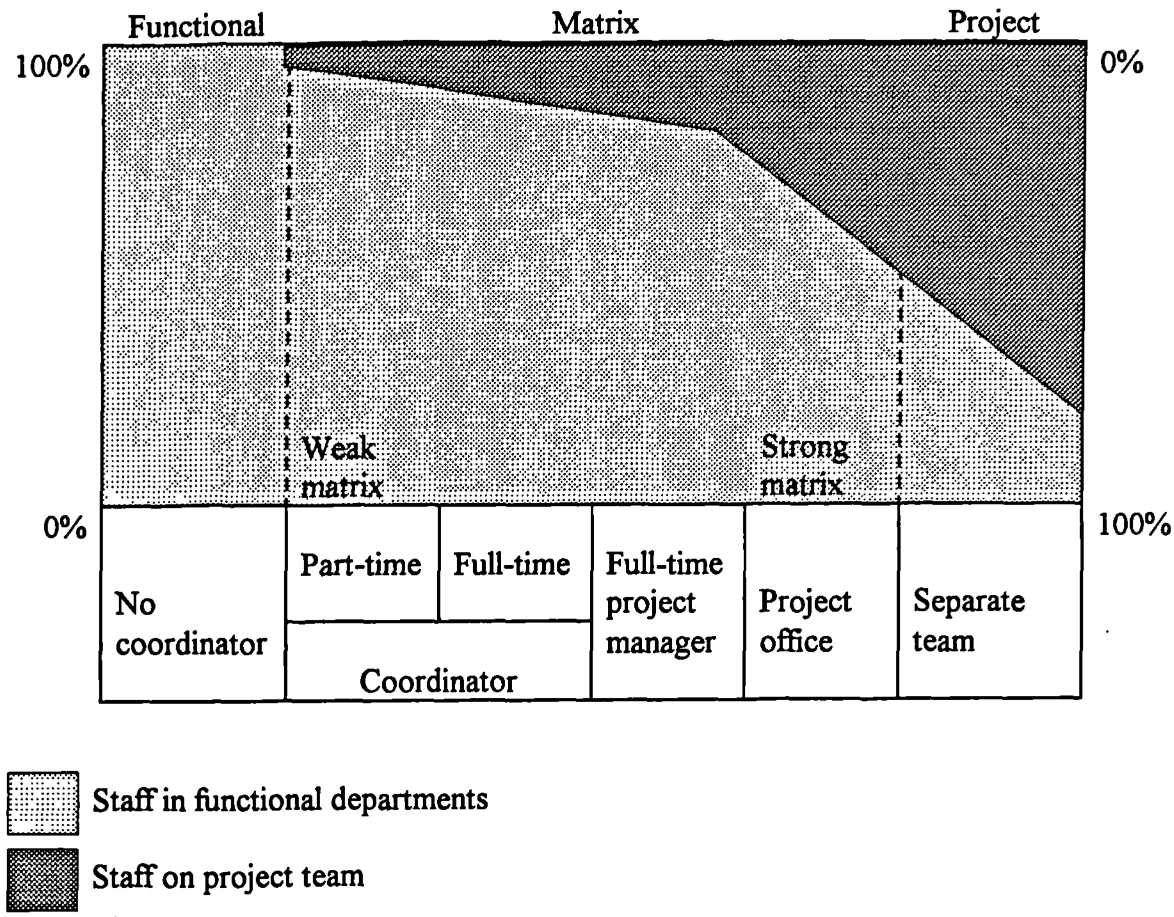
authority cannot solely be used to differentiate matrix structures, and two additional variables should be included to improve Galbraith's model: the communication pattern, and the additional roles of project managers. Two organisations may have similar distributions of authority between a project and functional manager, but communications between each respective manager and the project team will lead to significant differences between the resulting structures. Second, differences may be highlighted when the project manager is given additional duties, most importantly where the project manager is, at the same time, also a functional manager.

An adapted version of Galbraith's model is presented in figure 2.11, in which a continuum is presented from functional to project organisation, separated by a combination of matrix structures from a weak matrix near functional to a strong matrix near project. The distribution of staff is based on the percentage of staff working in their own functional departments versus full-time staff on the project team. It is evident that under the functional organisation there are no staff on a project team. However, the boundary between functional organisation and matrix occurs when an individual is given part-time responsibility for coordination across functional boundaries (the position of the weak matrix). As the role of integrator gives way to that of decision maker, the matrix organisation assumes a stronger matrix with a full-time project manager.

2.7.5 Differences in matrix organisation

This revisiting of Galbraith's model highlights the need to categorise further the matrix structure. Larson and Gobeli (1987) use the relative influence of functional and project managers to define three forms of matrix: functional matrix; balanced matrix; and project matrix. Harrison (1992) adds a further category, that of *contract* matrix, which can exist in multi-company (often global) projects. In this case, each 'function' may be carried out by a separate organisation, linked by weak lines of authority and often based merely on contractual and purchase order agreements. Each company will endeavour to maximise

Figure 2.11 Organisational continuum



Source: Youker (1977, figure 6)

its own best interests, thus if the project is to be managed effectively, the companies must be integrated and considered as a global entity: the matrix organisation offers the best structure to enable this.

2.7.5.1 Functional matrix

This lightweight (or weak) form of matrix maintains personnel in their functional groups, but designates a project manager with limited authority to coordinate the project across the different functional areas; the project manager may be a junior manager, such as a design engineer. The project is entirely under the control of the project manager, who coordinates, liaises and monitors its progress. Each functional area is represented through a liaison representative who coordinates related issues to the project manager. However, the functional managers retain responsibility and authority for the design and completion of technical requirements within their discipline (specific to elements of the project), and hence to the *allocation of resources*.

Clark (1991) sees the project manager as lightweight in three ways. First, there is no direct influence over engineers at the working level, and the product manager has little leverage over the activities outside of engineering (such as manufacturing and marketing), despite having liaison representatives. Second, the project manager has little status or power within the organisation, since he has a middle-management or junior position to command such respect. Third, the project manager is a coordinator, using concepts developed by others to coordinate and manage potential conflicts.

2.7.5.2 Balanced matrix

Trygg (1991) has likened the balanced matrix to a form of *middleweight* project manager. Larson and Gobeli (1988) see the project manager in this structure as being assigned to oversee the project and share the responsibility and authority for competing the project with the functional managers. Project and functional managers jointly direct many work-flow elements and jointly approve many decisions. More specifically, project managers schedule, control, and monitor the timing and activities of the project, and integrates the contributions of the various disciplines, whilst functional managers assign personnel and execute their part of the project according to the plans of the project manager (Larson and Gobeli, 1987).

2.7.5.3 Project matrix

This form of matrix requires a stronger project manager than under the previous structures. A project manager is assigned to oversee the project and has *primary* responsibility and authority for completing the project. Staff working on the project will be under the control of the project manager, although they are likely still to reside in their specific functions. Similarly, functional managers will assign personnel as needed, provide technical expertise, and oversee the long-term career development of their personnel. It is essential that the project manager is able to command authority over the functional heads, hence it is likely that they be relatively senior, or at least equal to them.

Hence, Clark (1991) sees the heavyweight project managers as follows. First, the project manager will have *direct* influence over the personnel working in the various functions - engineering, marketing and manufacturing. Second, since the project manager will be of senior management level (head of function, or chief engineer of a division), he will wield considerable status and power within the organisation. Third, he plays an active role in directing and evolving the product, thus performing more than mere coordination of activities. In this respect, the project manager extends his influence beyond the organisation, into the market place, to integrate external activities, besides the internal coordination already expected from him.

Larson and Gobeli (1987) have compared these three matrix hybrids across a variety of factors. Table 2.4 summarises these findings. First, they consider the advantages of each matrix: efficient use of resources, project integration, flexibility, information flow, discipline retention, motivation and commitment. The disadvantages include: power struggles, heightened conflict, reaction time, monitoring and control, excessive overhead, and experienced stress.

Table 2.4 Comparative advantages and disadvantages of the three matrix hybrids

Advantages	**Functional matrix**	**Balanced matrix**	**Project matrix**
Resource efficiency	High	High	High
Project integration	Weak	Moderate	Strong
Discipline retention	High	Moderate	Low
Flexibility	Moderate	High	Moderate
Improved information flow	Moderate	High	Moderate
Improved motivation and commitment	Uncertain	Uncertain	Uncertain
Disadvantages			
Power struggles	Moderate	High	Moderate
Heightened conflict	Low	Moderate	Moderate
Reaction time	Moderate	Slow	Fast
Difficulty in monitoring and controlling	Moderate	High	Low
Excessive overload	Moderate	High	High
Experienced stress	Moderate	High	Moderate

Source: Larson and Gobeli (1987, table 2B)

2.7.6 Effectiveness of the five organisational structures

Five alternative organisational structures for project management have been examined, and a brief summary is provided in table 2.5. Of these five project structures, wide support can be found in favour of the project team and project matrix being the more effective for product development projects. Based on research results, Clark (1991) argues that the heavyweight project manager and the project team are the most efficient forms of organisation for product competitiveness, shorter lead time and engineering efficiency.

This finding is generally supported by the research of Larson and Gobeli (1988). Their study compared the performance of 540 development projects in terms of cost, schedule and technical performance of all five project structures. When comparing the success outcome, there was no single best way to organise projects; nevertheless, project team, project matrix and balanced matrix shared equal success rates. Furthermore, when project complexity was analysed, only the project team structures showed considerable suitability for very complex projects. However, project matrix (heavyweight project manager) was satisfactory for both complex and less complex projects. Clark (1991), cites the example of Nissan in Japan, which, having moved from a middleweight to a heavyweight project management orientation, was very successful in product development in the early 1980s.

These results emphasise a strong preference towards strong project leadership. This is supported when the actual and recommended structures are compared. Figure 2.12

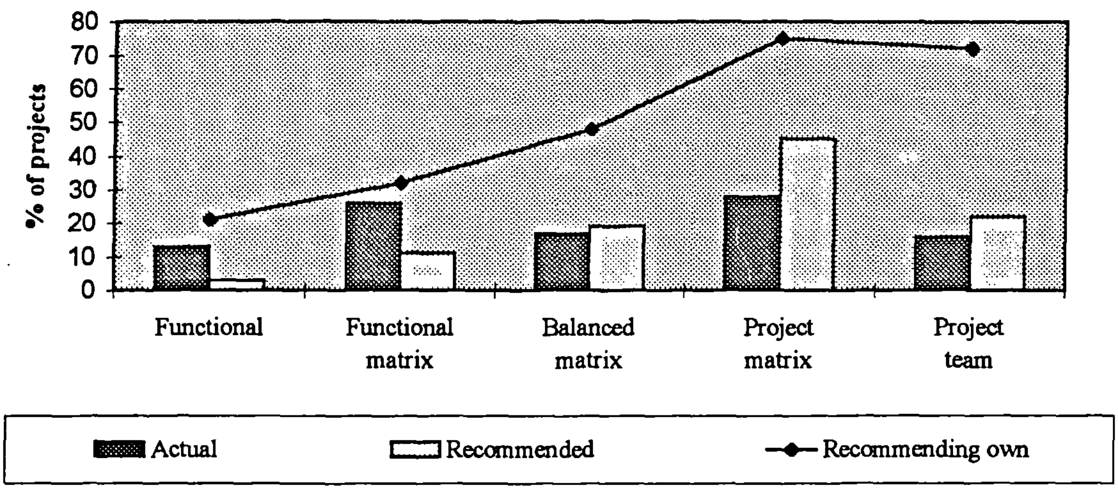
Table 2.5 Project management structures

Functional organisation:	The project is divided into segments and assigned to relevant functional areas and/or groups within functional areas. The project is coordinated by functional and senior management.
Functional matrix (or *lightweight* project manager):	A person is formally designated to oversee the project across different functional areas. This person has limited authority over functional people involved and serves primarily to plan and coordinate the project. The functional managers retain primary responsibility for their specific segments of the project.
Balanced matrix:	A person is assigned to oversee the project and interacts on an equal basis with functional managers. This person and the functional managers jointly direct work flow segments and approve technical and operational decisions.
Project matrix (or *heavyweight* project manager):	A manager is assigned to oversee the project and is responsible for the completion of the project. Functional managers' involvement is limited to assigning personnel as needed and providing advisory expertise.
Project team (or *tiger* team):	A manager is given responsibility of a project team composed of a core group of personnel from several functional areas and/or groups, assigned in a full-time basis. The functional managers have no formal involvement.

Source: based on Larson and Gobeli (1987, table 1)

illustrates the distribution of structures actually used and those recommended by the same sample. The difference in the distribution illustrates that although a particular structure may not be used by a firm, it may have been favoured (circumstances permitting). When the distribution of those recommending their structure is viewed, again the project matrix (75%) and project teams (72%) are favourable. Similar results were found when unsuccessful projects were examined - 64% and 54% respectively; although a project had been considered a failure, the project matrix and project team maintained strong support for future projects. (Although the majority of their respondents were project managers, Larson and Gobeli found no significant differences in their results when the responses from top management and functional managers were compared.) Noteworthy is a general word of caution by Larson and Gobeli (1988) made against the use of either functional organisation or functional matrix for innovation projects.

Figure 2.12 Recommended vs. Actual Project Structure



Number of projects studied:

Functional	N=72
Functional matrix	N=140
Balanced matrix	N=87
Project matrix	N=154
Project team	N=87

Source: Data from Larson and Gobeli (1988)

Drawing on research in the pharmaceutical industry, Henderson (1994) highlights the fluidity of organising product development (innovation), suggesting that either organising by function or product can only be a temporary solution. Companies need to respond to changing conditions, and to prevent any dominance of either function or product; thus continuous adaptation is required, perhaps moving along the continuum on a regular basis, or changing the type of project manager used. For some companies she studied, "it meant the active cultivation of a culture in which every individual was continually reminded to wear 'two hats': a functional, or disciplinary, hat and a product-orientated, or therapeutic, hat" (Henderson, 1994, p. 105).

2.7.7 Formation of project teams

These various organisational forms illustrate the combination of resources available to a firm, and the respective weighting they give to project management methods. Other than the pure functional structure, where the control and completion of the project rest solely with each functional head in turn, successful project management requires the appointment of a project manager and a specifically selected team.

A project manager may be a representative of any function. However, an individual will be selected largely on his/her competence to coordinate the required activities to bring about the successful completion of the project. Therefore, the project manager requires skills in leadership (acting as both politician and diplomat, when necessary), decision-making, and being able to assume responsibility. The range of responsibilities for a project manager is clearly different from those of a functional manager. In summary, a project manager should have responsibility for: *what* is to be done; *when* the task will be undertaken; *why* the task will be undertaken; *how much* money will be available; and *how well* the total project will have been completed. Whereas a functional manager should be concerned with: *how* the task will be done; *where* the task will be undertaken; *who* will undertake the task; and *how well* the functional task will have been integrated (Harrison, 1992).

There are four elements that promote an effective project team: multifunctionality; responsibility; commitment, and experience and proficiency (Bower and Hout, 1988). First, project teams comprise representative members of the departments that provide an essential service to the project. The availability of staff, required level of contribution, number of projects and so forth will determine both the number and definition of personnel assigned to the project on a full-time or part-time basis. Functions represented will normally include: marketing; sales/purchasing; engineering/development; manufacturing/production; quality; logistics; finance; and sometimes the customer, and/or suppliers of parts, materials and equipment. Second, the team must be given responsibility and the authority to undertake the project. Each member will have both individual and collective responsibilities: they are both specialist of their *home* department and ambassador of the project, responsible for balancing the needs and objectives of both groups. In the majority of companies, however, the project, rather than functional requirements, will take precedence should resource availability need to be considered. Third, there must be commitment throughout the team, and senior management, towards team-working and the project itself. Fourth, each team member should be able to contribute both experience and proficiency to perform the necessary tasks required of them.

Since each development project is unique, the team should be based on personnel whose collective competencies *provide the means to tackle each task. Teamwork is therefore* essential. Some companies promote teamwork through identifying the characteristics of individual team members, thereby developing a team spirit as the capabilities of the whole team become apparent. One means used by companies is a *Belbin* exercise: individual team members complete a self-perception assessment, the results of which emphasise particular traits useful in teamwork. Eight roles in teamwork can be identified: chairperson; company worker; shaper; plant; monitor-evaluator; resource investigator; team worker; and completer-finisher (Belbin, 1976). The identification of these roles does not create the team, but it does provide a benchmark for the project manager to allocate tasks. The success of the team still requires the leadership skills of the project manager to coordinate and motivate the team towards achieving the project goal.

2.8 Summary

The chapter has illustrated the evolution of product development in both the process (sequential to integrated) and its organisation (functional to project-based). The evolution of the organisational forms can be clearly seen in figure 2.13. The multifunctional team illustrated in the diagram is an advanced form, as suggested in the review of integrated product development. This form extends the team beyond the company boundary to incorporate both customers and suppliers, and has been

Figure 2.13 Trends in engineering management styles

Focus	Task	People
Function and company	Conventional hierarchical (pre-1960s)	*Matrix* organisation (1960s-1970s)
Product and customer	Project management (1970s-1980s)	Multi-functional team (1980s onwards)

Source: Bertodo (1989b, figure 1)

recommended as the appropriate type of organisation for managing complex projects, such as automotive products (Clark and Fujimoto, 1991).

Similarly, for complex products, an integrated development process is recommended that allows overlapping between phases with a multifunctional team. Thamhain (1994) proposes ten criteria for implementing an effective integrated product development process, based on *best-in-class* management practices. First, *detailed planning* is required of all activities and participants (including support groups, suppliers and subcontractors) to help identify and establish effective communication linkages and critical information transfer points. Second, the project should be sub-divided by *natural groupings* to reduce complexity. Third, a *clear business mission* should be communicated by senior management, enabling a strategic vision of the goals to be shared. Fourth, *interface management* is essential between disciplines and activities.

Fifth, the collective skills of the team should accommodate *technical and other skills* (such as cost management) necessary to solve problems and produce the agreed-on results. Sixth, fostering a *professionally stimulating work environment* is important for maintaining the interest and commitment of personnel, and for minimising conflict. Seventh, *cross-functional communication* requires the implementation of coordination mechanisms (this will be reviewed in chapter four). Eighth, *key networking individuals* (such as gatekeepers) require identifying to communicate effectively both internally and externally, and to assist technology transfer. Ninth, *rewards and motivation* are important signals for reinforcing cross-functional team performance. Finally, *good leadership* influences all of these through their actions.

In their review of successful users of overlapping phases, Wheelwright and Clark (1992) have shown that effective simultaneous engineering requires a combination of:

- early release of information;
- intensive, two-way flows of information;
- effective computer and organisational integration;
- analytical methods and tools; and
- multifunctional teams.

First, the early and frequent release of preliminary (often only partial) information from the upstream phase enables the downstream phase to initiate problem solving prior to the information being finalised. Hence, product design and process can be undertaken simultaneously. By doing so, the design engineer, for example, is able to realise the effect of the design on manufacturing, and implement changes at the design phase where the majority of cost and time savings are possible. Second, since there is an element of uncertainty in this information, and as it is subject to revision, there will be a requirement for frequent communication from downstream back upstream. The net result is that effective overlapping requires frequent and intensive two-way communication. Third, frequent two-way information exchange requires effective integration, both through information systems that can provide shared product and process models and databases (such as CAD/CAM), and organisational mechanisms (such as at the engineering/design/manufacturing interface). Fourth, the use of information integration can be enhanced through use of analytical methods to optimise a product design for manufacturing and customer requirements (such as design for manufacture, Taguchi methods, quality function deployment). Fifth, multifunctional teams ensure each activity necessary for the project is represented, this includes external contributors such as equipment vendors and parts suppliers.

These criteria illustrate the changing nature of product development, from a focus on functional specialism - referred to as *functional silos* at the farming equipment manufacturer John Deere (Anderson, 1992) - to a focus on a strategic direction supported by cross-functional and inter-firm networks (Bertodo, 1988). These observations will be discussed further, in the forthcoming chapters, as the elements of an integrated development process are examined in the form of design chain management.

NOTES

1. Dwyer and Mellor (1989) have used this model to survey product development activities in Australian manufacturing firms, and provide detailed analysis of the activities involved.

2. A detailed examination of the formulation and characteristics of the *product innovation charter* can be found in Crawford (1983, Chapter 3).
3. Crawford (1983, p. xii) notes that the pre-R&D stages had gained in importance during the 1970s. Whereas a typical new product in the late 1960s was derived from almost 60 ideas, a product in the early 1980s would originate from only seven. This reduction Crawford suggests was due in part to strategy, early market analysis, and a serious system of concept testing.
4. Souder (1987) examined the projects of innovations that had been means-generated, that is to say that they had originated from the development of ideas from within the firm, and had not been in response to other firms, a documented customer need, or an explicit customer request. This distinction should be recognised when interpreting Souder's findings.
5. The other five intrafirm factors are: the contribution of senior management in a catalyst role; self organising project teams; a multilearning environment; subtle control; and, organisational transfer of learning (Imai *et al*, 1985, pp. 342-62).
6. Katz and Allen (1985) provide a thorough discussion of the performance relationship between project and functional managers in upstream (R&D) activities.

3 AUTOMOTIVE PRODUCT DEVELOPMENT

3.1 Introduction

This chapter examines the process of product development within the automotive industry. A generic model is presented based on the work of Clark and Fujimoto (1991), from which consideration is then given to the contribution of suppliers within this process. A review of the changing supply base will follow, highlighting the conditions under which suppliers contribute to the design and development process. (Further detailed examination of types of supplier is presented in Chapter Five.) Finally, the role of purchasing is examined since this is a critical link between the internal development process and outsourcing to the supply base.

The UK automotive industry is a hybrid of long established industries, the products of which are an amalgamation of many different types of material, crafts and expertise. Where once a single company could design, develop and build a vehicle alone, the numerous material technologies and related design and development costs require the involvement of a plethora of companies across the manufacturing industries. The UK domestic car industry is dominated by eight companies: Rover Group (a subsidiary of BMW), Ford, and its subsidiary Jaguar, Vauxhall (a subsidiary of General Motors), Peugeot, Honda, Toyota, and Nissan. The remaining participants are specialist producers, such as Rolls-Royce, Morgan and TVR.

Supporting these vehicle manufacturers is a multiplicity of companies differing in both size and operation, from international system manufacturers, to fabrication outfits - the components sector. In 1993, it was estimated that the turnover of this sector was £14.7 billion (*The Financial Times*, 16 February 1994). The diversity of components supplied to car manufacturers is vast, with the major production inputs consisting of: engine and chassis; electrical; drive, transmission and steering components; suspension and brake systems; body components; and a variety of other components, systems, and raw materials - such as climatisation systems, audio systems, batteries, paint (coating), and tyres (Sleigh, 1993). Appendix A details an extended product list based on these component divisions to illustrate this diversity and complexity of supply.

This variety of products brings with it a vast array of skills, knowledge and expertise, in research, design, development and manufacturing. No single vehicle manufacturer can retain all of these skills - although Fiat was, until the early 1990s, able to retain most production requirements in-house (Sleigh, 1993) - so outsourcing of necessary design, development and manufacturing is made to the supply base. These issues will be returned to later in this chapter and in Chapter Five.

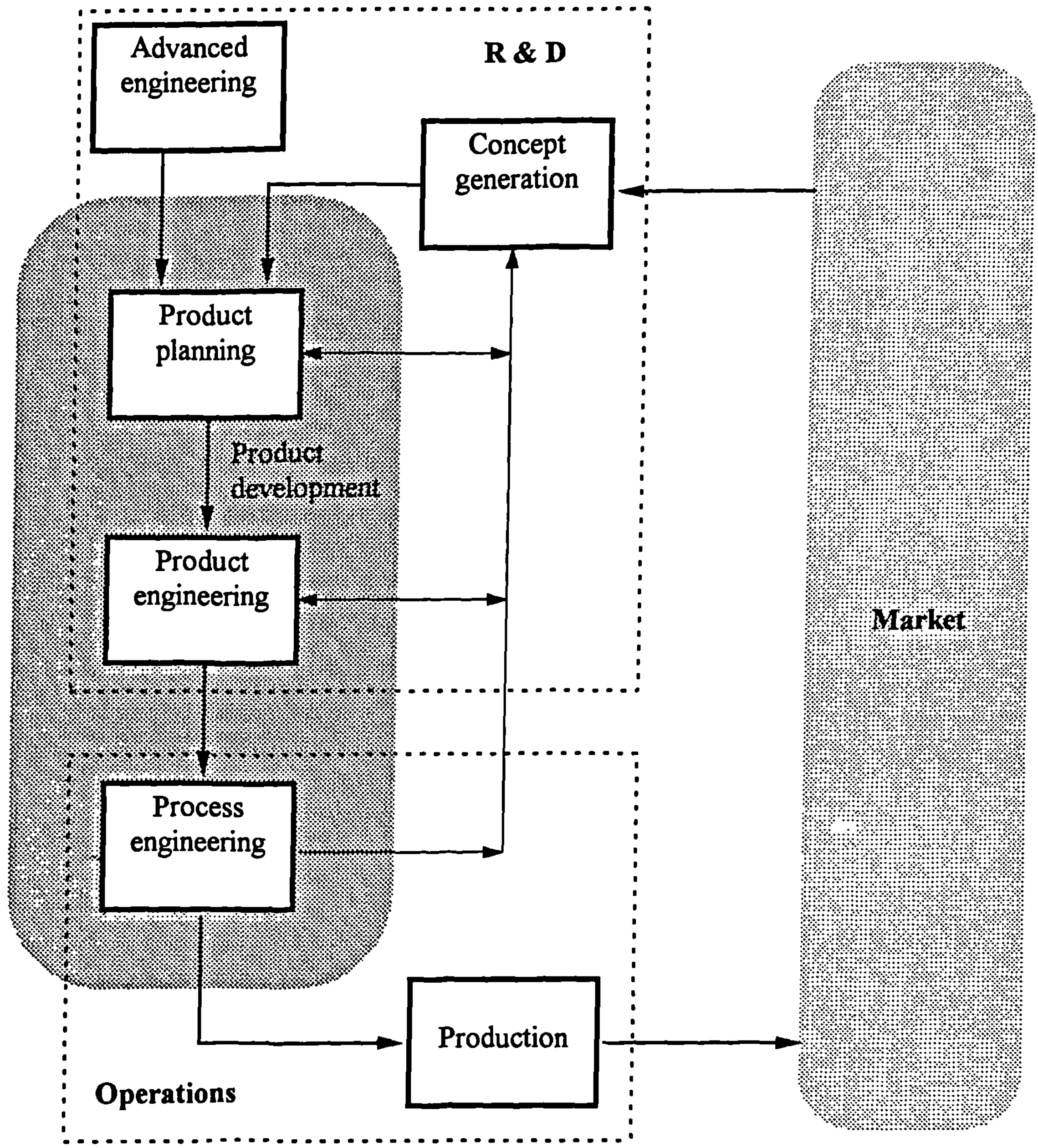
3.2 Automotive product development

Clark and Fujimoto (1991) present a simplified model of the product development process, which is a generic model for fabricated and assembled products (such as automotive products). Their model expresses the various stages of the process as key assets of information, broadly based around common activities: concept generation, product planning, product engineering, process engineering, and production. Figure 3.1 illustrates these stages based on the model presented in figure 2.1. This thesis is mainly concerned with the activities indicated by the *product development* shaded area, but before reviewing these, the concept development stage is discussed. The following review of the process is largely based on the comprehensive work of Fujimoto (1989, appendix 2; with Clark, 1991).

3.2.1 Concept generation

This activity is characterised by the creation of a *product concept*. This will reflect a balance of what is technically possible, economically feasible and wanted by the market. It consists of a product description of what will satisfy the customer's needs. Vehicle manufacturers use three principal sources of information for generating the vehicle concept: market information, strategic plans, and advanced engineering (Clark and Fujimoto, 1991). First, firms utilise product clinics, focus groups and detailed statistical analysis of market research to gather the thoughts and preferences of existing, and would-be, customers. Second, strategic plans enable firms to take a long-term view of their product range, developing family platforms with which to introduce model year changes, or major face-lifts in response to changing customer preferences or to incrementally introduce new technological improvements. Where firms have a wide range of vehicle platforms, strategic plans can assist in focusing available engineering and manufacturing resources, and the timing of new product introductions. They may include product specifications such as engine choice, image, price range and so forth. The availability of an award-winning engine, for example, may encourage extending the

Figure 3.1 Product development as an information system



Source: Similar to Trygg (1991, figure 1.4) and Clark and Fujimoto (1991, figure 10.1) product-life of a design. Third, advanced engineering develops solutions for eventual integration into future models. Miller (1994) identifies three contributing activities: outlining and proving innovative technical designs; managing joint research programmes with external groups; and creating and testing experimental prototypes. Typical examples include new diesel engines and electric powered vehicles.

Clark and Fujimoto (1991) found that three types of manager are given leadership responsibility for concept generation: functional specialists (typically from either marketing or advanced engineering), product planners (usually from marketing), and product managers. Of these, they found that the product managers tend to maintain the best links with downstream activities. However, of importance in managing the concept stage is a balance between leadership, creativity, and cross-functional involvement. Clark and Fujimoto (1991, p. 110) conclude that: "Especially during the first few months of a project, clear concept leadership, together with wide involvement of other functions, appears to be an important aspect of effective concept creation".

The output of this stage is a set of broad product specifications that embody the product's description in terms of the customer's requirements; for example, 'a family tourer that is environment friendly, with a feeling of security'.

3.2.2 Product planning

This activity translates the product concept into *specifications* for detailed product design - a product plan. In the automotive industry, this product plan includes specifications for styling, layout, major components, cost performance targets, and technical choices, and is a process of negotiation and trade-offs between each (Clark and Fujimoto, 1991). For example, if a new engine is planned for an existing model, changes in the engine compartment may mean repositioning of component systems (such as air-conditioning units). This may have knock-on effects with the cooling system or wiring-harness; thus, each group will compete for space, dimensions and their individual component/system integrity. At this stage, most information assets will still be intangible, but physical models and early-stage prototypes may be used for, *inter alia,* styling and layout evaluations, and advanced component testing. It is at the end of this stage that top management will approve, or not, the commitment to full-scale activities in product engineering. Clark and Fujimoto see styling, layout and component choice as critical elements of this stage.

3.2.2.1 Styling

Styling is a bridge between concept and detailed engineering. It requires intensive two-way communication as the abstract, verbal and two-dimensional descriptions of the concept are translated into a three-dimensional form (clay and plastic models, and CAD generated product data for later use on body development) whilst maintaining the product integrity of the total vehicle concept. Face-to-face communication between the concept originators and the stylists is paramount, since subtle-nuances cannot be defined in written form. The body and interior styling are typically separate design departments consisting of industrial designers, modellers, technicians and aerodynamic and ergonomics engineers (Clark and Fujimoto, 1991). Many vehicle companies use specialist styling studios such as Ital Design or Karmann.

3.2.2.2 Layout

Layout (or packaging) determines the available space requirements for mechanical components, body frames, luggage and passengers (as in the example given above). This activity begins with determining the key dimensions and key component configurations of the basic package; Clark and Fujimoto (1991) found that in most companies they studied this activity preceded detailed styling. It is a key activity and responsibility for layout may be located with the concept creator - facilitating concept-layout coordination, the product manager - common practice in Japan, or with a specialist engineering unit, within advanced engineering or body engineering.

3.2.2.3 Major component selection

In Chapter Two, the definition of new product illustrated the range of choices a firm makes on balancing the integrity of the product *vis-à-vis* the number of carry-over parts, available external engineering capabilities, and selection of basic components over new technologies and materials. Using existing parts reduces cost for re-tooling and design, reduces reliability risks, but can affect the design quality in terms of customers' perspectives of the newness of the total vehicle. Similarly, outsourcing engineering can reduce the long-term technical capability of the firm, or reduce the negotiating power with suppliers (Clark and Fujimoto, 1991). (The issue of technical outsourcing will be revisited in Chapter Five.) The configuration of the product may raise conflicts between component and test engineers, as each compete for particular component choices. Therefore, the ability of product managers and other interfunctional staff to resolve conflicts play an important role in this activity.

The completion of product planning is a critical stage in the overall process. It is here that approval is given by senior management to proceed with the project. The product architecture and interior mock-ups should be complete, the clay model approved, the cost and performance targets specified, and the overall packaging and basic component selections complete (Clark and Fujimoto, 1991).

3.2.3 Product engineering

This activity transforms the product planning specifications into *detailed* product designs, and signifies the full-scale commitment to engineering resources. Product engineering is a series of *design-prototype-build-test* cycles, until a detailed product design is officially approved. It consists of three major activities: detailed design drawings (from targets and constraints); trial prototype components (from the drawings); and engineering prototypes that are tested using prototype tooling at both component and total vehicle levels, checking against the original target and concept. One frequently cited issue of prototype testing is the authenticity of the tooling to reflect production. Prototype parts are frequently produced using prototype part specialists; hence, the prototype parts do not reflect production fit and finish of the ultimate parts' suppliers.

Product engineers have to realise the concept in terms of real parts/components, but also meet the business requirements, such as cost and performance. Negotiations and trade-offs are again prevalent as the product design is realised. Design engineers typically convert the specifications into CAD generated data, which can be shared with adjoining parts and process engineering.

Increasingly, the use of computer-based technologies is having an impact on these activities. For example, rapid prototyping is a technique that allows product designers to produce a resin prototype from CAD stored data. The Rover Group uses this technique and found that for one redesigned part, rapid prototyping reduced the delivery time from nine weeks to only three days (*The Engineer*, 30 April 1992). This enabled testing of flow characteristics sooner than normal, which meant that the test results could be shared earlier with other component groups.

Each engineering project is divided into manageable parts, based on process step and component, and reflects the organisation of the company (compare Clark and Fujimoto, 1991, figure 5.1). Typical product divisions for a European volume producer would include body, chassis, interior, electrical, and power-train (engine and transmission). A vehicle producer also divides responsibility for components or processes to external agents (such as suppliers, sub-contractors, and specialist agencies). Hence, management of product engineering for complex products requires the use of computer-based product databases to track and inform changes that may occur from both internal and external design groups. (This issue of integration is again raised in Chapter Four.)

3.2.4 Process engineering

This activity is sometimes referred to as industrial or manufacturing engineering, and involves translating detailed product designs into process design requirements. The output of this activity are the final shop-floor production processes, hence the following activities are undertaken: plant design (for example, material flows and plant layout); hardware design (for example, tools, jigs, dies and equipment); software design (for example, NC part-programming); and work design (for example, standard operating procedures) (Clark and Fujimoto, 1991). Process engineering is normally the concern of production, hence, staff may be located in any number of production sites. Some companies have begun locating staff within product engineering to facilitate product/process coordination. It is this simultaneity of activities that will be returned to in Chapter Four, as coordination mechanisms are discussed.

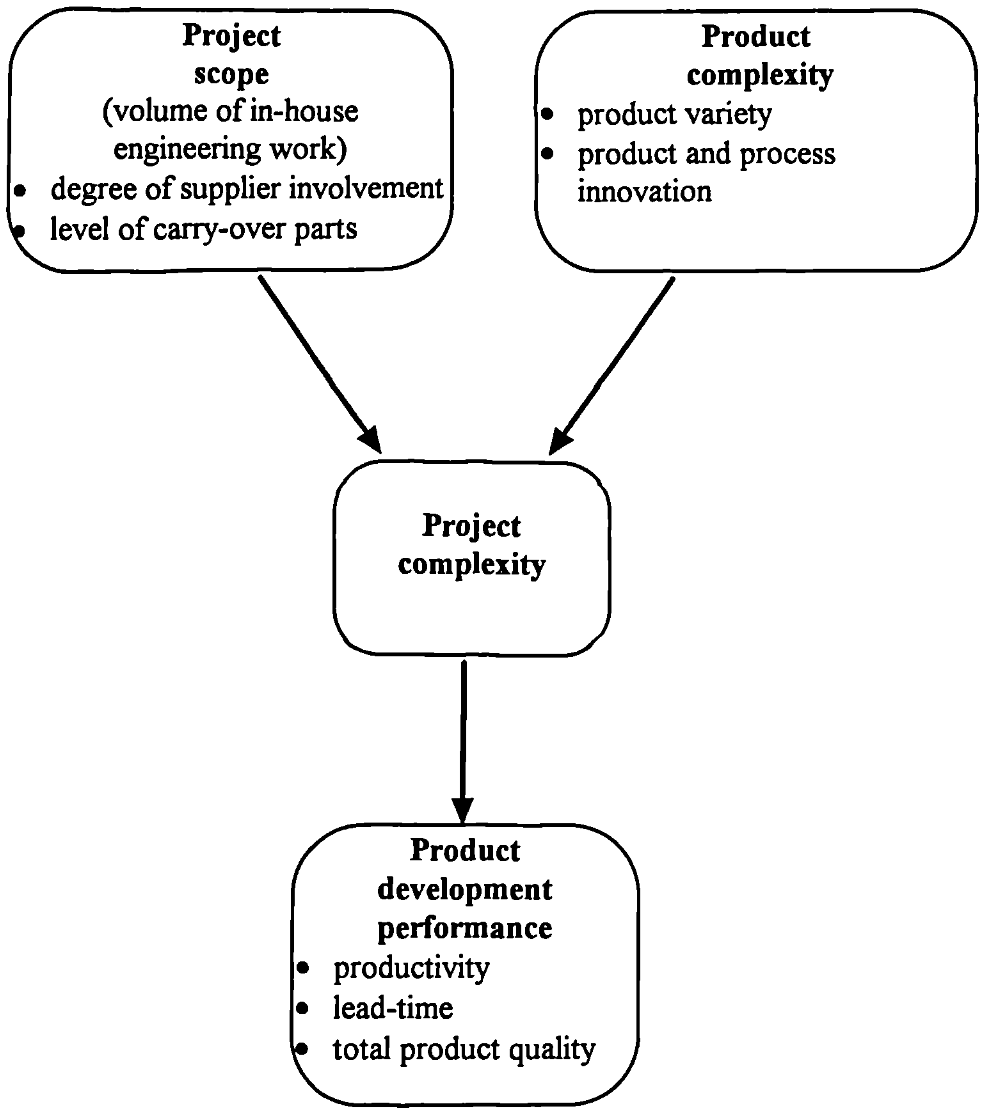
Reviewing the overall product development process, and referring to the findings of Chapter Two, several themes appear important for effective delivery of the product.. Product development in its integrated form requires intensive two-way communication, and where possible downstream operations should have the opportunity to use information more quickly, for an early start - particularly between product and process engineering. One of the key characteristics of product development is problem-solving; in some cases, this takes the form of test-build cycles. An important aspect for participants is negotiation for individual parts or processes, whilst aware of the need for total vehicle integrity; hence, there will be a need for trade-offs to be made. Across these different themes there will be a need for effective mechanisms, such as strong leadership, to augment conflict resolution should this be necessary.

3.3 Project strategy

A new vehicle is part of a company's strategy to attract fresh, or retain existing, customers. A firm may choose any number of characteristics as part of its design policy. Miller (1994) observes typical policies as including: world-wide under-body concepts; basic upper-body concepts; variations and face-lifts; technical features (such as engines and power-train); and differentiating factors such as quality, safety, innovation and product life.

In developing a project strategy, Clark and Fujimoto (1991) suggest that a firm will consider the level of trim required, engine-body combinations, degree of innovation, the role of supplier, and the number of carry-over parts from previous models. The cumulative effect of these choices, they argue, will be the level of project complexity and thus will affect productivity, lead-time and total product quality - all elements of company performance. Figure 3.2 outlines the main features of product development performance, and the role of suppliers in determining project performance. Once product variety and level of innovation have been determined for a project, attention focuses on the location of engineering work. The scope of a project is the volume of in-house engineering work performed by a vehicle manufacturer: this can be influenced by the degree to which engineering capability is outsourced to suppliers and the level of parts carried over from previous models.

Figure 3.2 Major influences on product development performance



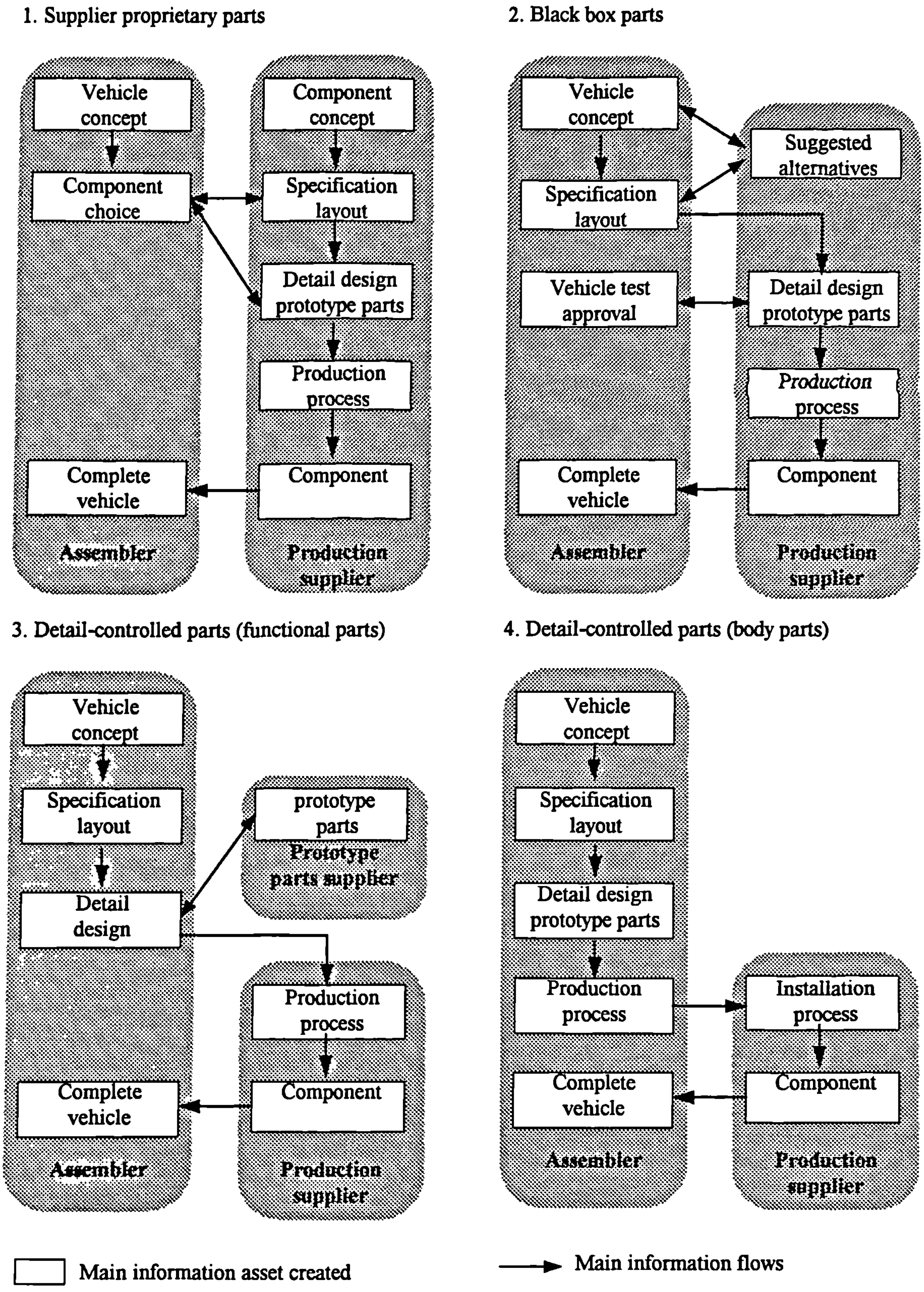
3.3.1 Supplier participation

Since Chapter Five discusses in detail the degree of supplier involvement, a summary of Clark and Fujimoto's work illustrates the importance of suppliers to the product development process. Their study of 20 vehicle manufacturers - three US, nine Western European, and eight Japanese - found large regional differences in the participation of suppliers in vehicle design and development. They defined and examined the contribution of external resources to the internal organisation in the following terms: *supplier proprietary parts* - parts developed entirely by parts suppliers; *black box parts* - parts whose basic engineering (functional specification) is performed by car makers and whose detail engineering is done by parts suppliers; and *detail-controlled parts* - parts developed entirely by the car maker, although subcontracting of production may occur. The activities of these suppliers are shown in figure 3.3, based on the generic model already outlined.

Clark and Fujimoto calculated the share of suppliers' costs in engineering parts to be 52% for Japan volume producers, 14% for US volume producers, 36% for European volume producers, and 31% for European high-end specialists. Thus, Japanese firms were more dependent on suppliers for design input than the US or European manufacturers. In particular, Japanese firms relied on suppliers to perform detailed engineering for components whose functional specifications they developed in-house (figure 3.4).

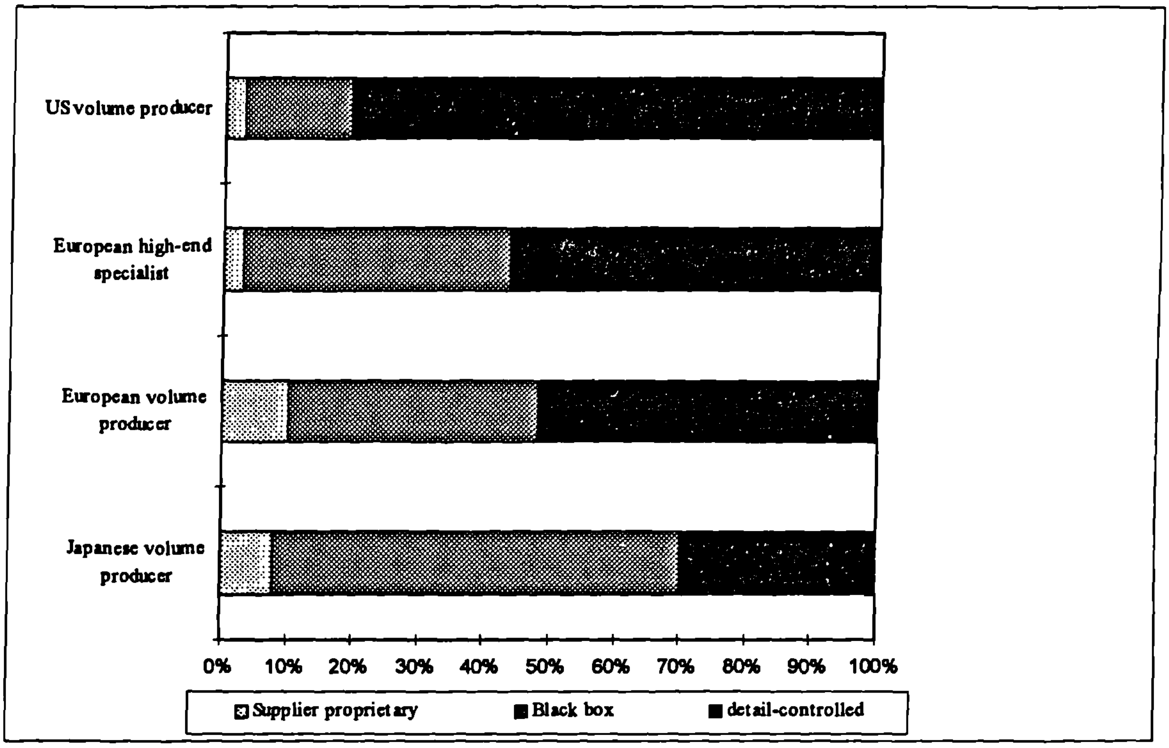
When these differences were correlated with unadjusted productivity measures, in terms of engineering hours and lead time, the greater use of suppliers was found to reduce project scope (the percentage of unique parts developed in-house by the car maker) and thus the engineering hours and lead time. In general, they also found that greater supplier involvement by Japanese firms accounted for their advantages in engineering hours and lead-times.

Figure 3.3 Typical information flows with parts suppliers



Source: Clark and Fujimoto (1991, figure 6.5)

Figure 3.4 Types of parts engineered and supplied by suppliers (by assembler type)



Note: parts are shown as fractions of total procurement cost

Source: Clark and Fujimoto (1991)

However, it should be remembered that the data on which Clark and Fujimoto based their conclusions are for projects for the period 1982-87, since when US and European vehicle manufacturers would appear to have been placing more engineering work in the hands of suppliers. There has been a conscious development toward early supplier involvement by many industries and it would be surprising to find no shift in supplier involvement as a result. Figure 3.4 acts as a reminder that there are structural differences between US, European and Japanese supply relationships and engineering traditions, which will be discussed later.

There is a caveat to Clark and Fujimoto's study, however, in their contribution to understanding inter-organisational coordination, since they only concentrated on the internal operations of new projects, and Cusumano and Nobeoka (1992, pp. 283-84) have reservations on the underlying assumptions used. First, their analysis of supplier parts assumes uniformity of design contribution across all regions, and only identifies two categories of design contribution: supplier proprietary, and black box parts. For simplicity, they assumed all suppliers worldwide contributed 30% of design work for black box parts. This is a surprising assumption given the vast regional differences in supply relationships. Cusumano and Nobeoka note that independent engineering firms are also excluded that may play an important role in US product development.

Second, their study neglects the internal mechanisms for managing projects, such as partitioning design-tasks and sequencing, which von Hippel (1990) sees as critical to efficient and innovative product development. Cusumano and Nobeoka's remarks could go further and apply the concept of task partitioning to inter-organisational management, thereby looking at project boundaries rather than firm boundaries. Third, their study does not explore multiple project coordination, but only a sample of one project per manufacturer. This limits the findings to the commonality of particular projects, whilst neglecting how parts are shared, designs modified, and other knowledge acquired for product development. Finally, consideration should be given to how firms plan and support multiple product development activities, particularly since there are many different activities, options and decisions both within the firm and with suppliers.

Nevertheless, the evidence of Clark and Fujimoto's study suggests that car companies are outsourcing to suppliers important tasks and components, and suppliers are equally as fast as car makers at component development, without any loss of lead-time to the car maker. These are important findings since they support the idea that suppliers not only have a role to play in development, but there is certainly no negative affect for project performance (measured by lead times).

3.4 Supply relationships

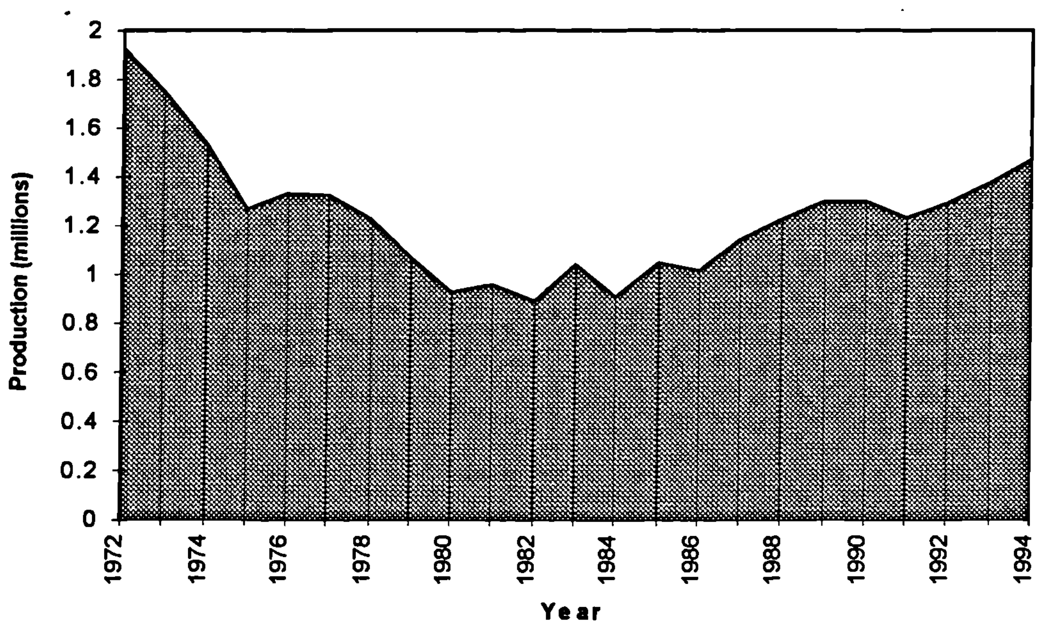
Vehicle manufacturers have been increasingly moving towards closer relationships with their suppliers. Much of this has been due to the adoption of just-in-time (JIT) and Total Quality Management (TQM) techniques, where the benefits of these processes become apparent through an integrated and responsive supply base. Similarly, effective simultaneous engineering requires integrating suppliers into an extended knowledge base. Synchronous to these are other supplier development policies, such as the rationalisation of the supply base, and promotion of *preferred* suppliers (primary, direct suppliers) who are able to assume greater responsibility for particular operations. However, supplier development is much more than an elaborate operation of buying parts from a smaller number of leading suppliers: it is a commitment by both parties to integrate and coordinate their operations together.

For this to be achieved, it is necessary for both buyer and supplier to move away from the adversarial relationships and short-term views that characterised relationships throughout the 1970s and 1980s in the European automotive industry. It requires a shared vision of their joint operations, based on a long-term view of the relationship, multiple contacts maintained at several organisational levels, and mutual trust and respect. In this way, information can be shared freely and integrated problem solving undertaken on product design and production operations. An important basis for these demands is a true understanding of each other's operation. Hence, the *open-book* accounting practice has emerged reinforcing the necessary mutual trust and can allow true costs to be measured.

These changes are characteristic of an evolution of the customer-supplier relationship spanning more than 20 years. Lamming (1993)[1] classifies a four-phase model of supply relationships that traverses this period: *Traditional* (pre-1975); *Stress* (1972-85); *Resolved* (1982 onwards); and *Partnership/Japanese* (1990 onwards). Each phase emphasises aspects of vehicle manufacture thinking and market changes from which suppliers have responded to buyers. The general trend affecting the UK automotive industry is illustrated in figure 3.5 that shows the falling total UK production in cars from the early 1970s to the mid-1980s. Emerging out of the partnership model, Lamming (1993) identifies *Lean supply*, as characteristic of global operations in partnership. Table 3.1 summarises the evolution of these models, which is discussed below. It may be that Lean supply is representative of the conditions under which design chain management can operate within the total supply network.

The Traditional buyer-supplier relationship existed up to the early 1970s, and was characteristic of the period of expansion experienced until that time. This relationship was based upon design originating either from the vehicle builder or the component manufacturer, with research and development only being discussed where a specialist supplier input was required. Information restriction was prevalent, with suppliers' cost structuring and buyers' requirement levels being unknown to the other party. Competition was essentially closed, with new orders for one supplier resulting in the loss of business for another, only when the existing supplier was unable to satisfy the changing demands of the buyer's Purchasing Departments. This situation was accepted by suppliers, since there was reasonable capacity in the market and it was not difficult to remain competitive. However, with the receding market of the mid-to-late 1970s, severe pressures created fissures in both the personal and commercial relationships that had existed in the traditional situation.

Figure 3.5 UK passenger car production



Source: SMMT data

Table 3.1 The evolution of customer-supplier relations (traditional to lean supply)

Model	Nature of competition	Basis of sourcing decisions	Role of data/ information exchange	Management of capacity	Delivery practice	Dealing with price changes	Attitude to quality	Role of R&D	Level of pressure
Traditional (before 1975)	Closed but friendly; plenty of business	Wide; enquiries; lowest bid; price-based	Very restricted - minimum necessary	Few problems; some poor scheduling	Large quantities; buyer's choice: steady	General negotiation (annual); a game win/lose	Inspection; arguments/ *laissez-faire*	One-sided: either assembler or supplier	Low/medium; steady: predictable
Stress (1972-85)	Closed and deadly; chaotic	'Dutch Auctions'; price-based	A weapon; one-way; supplier must open books	Spasmodic: no system to deal with chaos	Unstable; no control; variable; no notice of changes	Conflict in negotiation; a battle lose/lose	Aggressive campaigns; SQA, etc.	Shared, but only for cost reductions	High/ unbearable: volatile
Resolved (1982 onwards)	Closed; some collaboration; strategic	Price; quality and delivery	Two-way; short-term e.g. forward build	Gradually improving; linkages appearing	Smaller quantities; buyer's demands stabilised	Annual economics plus; negotiation; win/lose	Joint effort towards improvements	Shared for develop-ments	Medium: some sense of relief
Partnership/ Japanese (1990 onwards)	Collaboration; tiering; still dynamic	Performance history; long-term source; costs	Two-way; long-term e.g. knowledge of costs	Coordinated and jointly planned	Small quantity; agreed basis; dynamic (JIT)	Annual economics and planned reductions win/win?	Joint planning for developments	Shared: some black or grey box	Very high: predictable
Lean supply (in transition)	Global/ local; technology collaboration; strategic	Early design involvement; target costing/ value analysis	Two-way; technical/ commercial; EDI	Synchronised; flexible	True JIT: local, long-distance and international	Progressive negotiated reductions	Mutual agreement; perfection is goal	Integrated; supplier expertise/ assembler systems integration	Very high: mutual and self-imposed

Source: Lamming (1993; tables 6.3 and 7.2)

In their attempts to reduce unit costs, vehicle manufacturers focused on reducing suppliers' prices and exploiting their *buyer's market*. The result of this marginal costing was suicidal supplier costing and increased dual sourcing policies, as the suppliers' position was further weakened through buyer's insistence on open costing information policies. Paradoxically, the need for cost reductions led to improved design liaison, although secrecy of design excellence remained prevalent.

The need for a strong supply base was resolved in the early 1980s, as vehicle manufacturers attempted to resolve the stress phase which had developed, not least through relaxing the tactical buying philosophy and in developing the concept of collaborative research and development and improving the advancing of information on planned model and production programmes. Improvements to the buyer-supplier relationship were further essential due to the interest being shown in the concept of *just-in-time* manufacture and supply (a requirement of which is a trust between buyer and supplier, which the dual sourcing and rationalisation of the previous years had sorely damaged).

The resolving of conflicts from the 1970s can be observed as a check for the possible development of Japanese style relationships. Although the success of the Japanese buyer-supplier relationship owes much to its cultural setting - a collective vision of working towards the economic success of Japan, rather than an individual company - and to the arrangement of trading groups, with few suppliers, long-term partnerships, common strategies and equity exchanges (Twigg, 1990), elements of this model have entered UK supply relationships. Japanese vehicle manufacturers entrust their suppliers with design responsibilities (without manufacturer interference), and this closer cooperation is reflected by quality throughout the company and supply base; the mutual confidence in each other, helps support a smooth supply network necessary for low inventory, regular delivery (*just-in-time*) operations.

Recognising the differences in environment and structure Lamming proposes a further evolutionary stage, beyond partnership: lean supply. In short, this model entrusts greater design responsibility on the supplier (black box and grey box developments), as operating uncertainties are resolved through joint discussions, reciprocal dialogue of information, and long-term cost knowledge (based on open-book accounting practices). Furthermore, the in-depth understanding of supplier operations resident in the partnership model extends confidence through coordinated capacity management to the provision of long-term sourcing contracts, with annual price discussions. Lamming views the lean supply model as comprising of:

- fewer, larger and more *talented* companies who are the central provider of complete component systems;
- a tiered supply base, differentiated by the nature of the services each supplies. There will be a small group of *preferred* supplier in close partnership with the vehicle manufacturer, who will be responsible for their own supply base; hence, there will be a cascading of responsibility for coordination and control of the network, around principal nodes;
- collaboration on design and R&D between the vehicle manufacturer and preferred suppliers, with early supplier involvement;

- stronger vertical and horizontal relationships to share expertise (higher interdependence);
- global sourcing and operations, and multi-market presence;
- competitive advantage based on best practice, continual improvement and ability to collaborate.

3.4.1 Emerging relationships affecting product development

There is growing evidence (Imrie and Morris, 1992; Turnbull *et al*, 1992; Sleigh, 1993) that vehicle manufacturers are developing towards the lean supply relationships identified by Lamming (1993). A perusal of Sleigh's examination of vehicle-supplier relationships indicates very similar policies across all the vehicle manufacturers examined. Some of the characteristics sought in the emerging suppliers directly impact upon the design relationships being examined in this research.

3.4.1.1 System suppliers

First, retaining fewer, more talented and larger suppliers suggests a movement towards system suppliers, where design and development expertise will be sought from a network of suppliers, but coordinated through only one primary supplier - responsible for that part number/ module. The first requirement along this route is for a reduction in the number of direct suppliers to the vehicle manufacturer. Vehicle manufacturers have substantially reduced the number of suppliers (for a vehicle) during the 1980s, as figure 3.6 indicates. This has been happening since the 1970s, when Ford introduced supplier

Figure 3.6 Reduction of Component Suppliers (by selected company)

Company	1981	1982	1983	1984	1985	1986	1987	1988	1989
Peugeot	>2000	→	→	→	→	1229	→	→	900[a]
Renault					1415	→	→	900[a]	
Rover		1200	→	→	→	→	700		
Ford:									
Europe		2500	→	→	→	→	900		
UK			→	→	→	→	600		

a anticipated figures (company estimates)

Source: data from House of Commons (1987; p. xvi)

quality assurance programmes (Lamming 1993). All vehicle manufacturers have supplier rating systems that assist in determining those that are suitable, capable and willing to undergo changes to maintain best practice supply and improve performance.

Some examples from Sleigh (1993) indicate that the modular supplier, as coordinator of other tiers of supply, is receiving wide recognition within the international automotive industry. Volkswagen is selecting suppliers who can progress from being parts suppliers to taking responsibility for the development and supply of modules/systems. Their intention is that all functional parts of new models will, in future, be entirely based on pre-developed components; thus, suppliers will be integrated early - into pre-development - to provide pre-developed modules for storage in a *Goal Catalogue*.

Perhaps less extreme, Fiat subdivides each new model into 440 system and major component areas (such as seats, bumper, fascia assembly, heating and ventilation system), each of which they ultimately see as being the responsibility of a single supplier. The potential supplier for each of the 440 modules/systems is rated by product and by capability, and then on a project management classification of A, B, C1 or C2. Category A suppliers will have product development ability in its own specialised area, and as a result will be assured of bidding for design and development, as well as supply contracts. Price is a qualifier in being a category A supplier, but of importance too are the product development lead-time, delivery schedule time, delivery quality and reliability, component weight control and reduction, and where possible the standardisation of small, high volume parts from a Fiat-issued catalogue of approved parts. Category B suppliers are potential A-grade suppliers, to whom Fiat second personnel for 6-12 months to improve their operating methods. Category C suppliers may be able to attain A/B grade after improvements, otherwise they are likely to become the subcontractors to the others.

Nissan's approach in design management is to promote reciprocal understanding in design and development. Comments made by the purchasing director of Nissan in 1992 (cited in Sleigh, 1993, p.36) bears testimony to this:

> To match the ever shortening model-change cycles a supplier has to have the necessary development facilities and engineers to support our new model programmes. A key element of this is also project control - basically understanding what you are doing and by when it has to be done - and then meeting commitments. By following a single sourcing policy we can commit more time to each supplier to help ensure our design and development needs are clearly understood.

In its strive for supplier continual improvement, Nissan sends Supplier Development Teams to supplier sites to advise on problems relating to both their products and other customers. Nissan considers management attitude, technical capability, quality and delivery reliability as the most important criteria for supplier selection; price competitiveness is important, but is not an order-winning criterion (Carr and Truesdale, 1992).

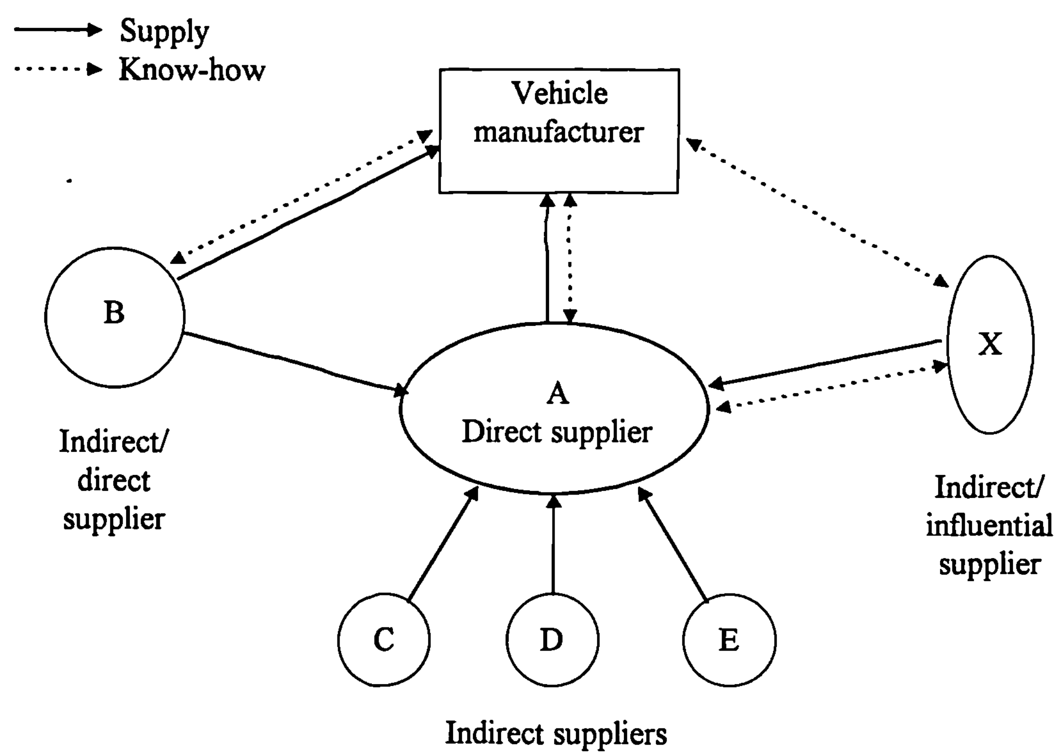
It is interesting to note the different perspective of Japanese firms to supplier relationships. Carr and Truesdale (1992), in a study of Nissan's UK suppliers, comment on the different approaches to supplier-selection by vehicle manufacturers. They cite Ford and Rover as seeking *best-in-class* through *buying* a component, whereas Japanese customers would *develop* a relationship to assist the supplier become 'best in class'.

3.4.1.2 Tiering of the supply base

The second effect is on the tiering of component supply. In 1993, it was estimated that there were over 200 first tier component system makers in the UK (such as GKN and Lucas), with probably 10,000 second and third tier small component makers (*The Financial Times*, 16 February 1994). In their efforts to incorporate fewer, more talented primary suppliers in partnership, the traditional number of direct suppliers to the vehicle manufacturers will decrease further.

Lamming (1993, p186) cautions against referring to *tiering* in describing the various lean supply relationships, preferring instead to use direct and indirect suppliers, in order not to suggest similarities between Japanese style (*keiretsu*) relationships and the materialising non-Japanese forms.[2] Figure 3.7 illustrates the main participants in the supply relationship with vehicle manufacturers. Supplier A is a direct supplier to the vehicle manufacturer. It integrates components and process knowledge from other suppliers (B, C, D, E, and X) into a component system that is supplied directly to the vehicle manufacturer, as a pre-assembled unit - a *system integrator* (Macbeth and Ferguson, 1994). Since B, C, D, and E supply A, they are indirect suppliers to the vehicle manufacturer.

Figure 3.7 Direct and indirect supply



Source: Lamming (1993, figure 7.4)

Supplier B, however, is a special case. It also supplies directly to the vehicle manufacturer so has a dual role. It may even be a system integrator for some component systems, whereas for others it supplies indirectly through supplier A. Macbeth and Ferguson (1994, p. 130) illustrate this scenario with the case of anti-skid braking (ABS). Lucas Braking Systems and Bosch Electronics were previously equivalent suppliers of ABS, until Bosch became a system integrator; it now purchases parts from Lucas for pre-assembly in a Bosch ABS system which it supplies to vehicle manufacturers.

Supplier X plays another special role. It is an indirect supplier, but has an influencing role in the supply relationship. A similar emphasis was placed on indirect/influential suppliers by Twigg (1990) who, in investigating CAD/CAM adoption by component suppliers, recognised the toolmaking supplier as having a specific role in the design relationship: it straddles the supplier-vehicle manufacturer divide, in some cases working directly with the vehicle manufacturer, and in others with the supplier (with manufacturer approval).

Blenkhorn and Banting (1990), in a study of Canadian first tier automotive suppliers, reported close relationships between these and second tier suppliers based on, *inter alia*, continuous communication and the sharing of technical knowledge.

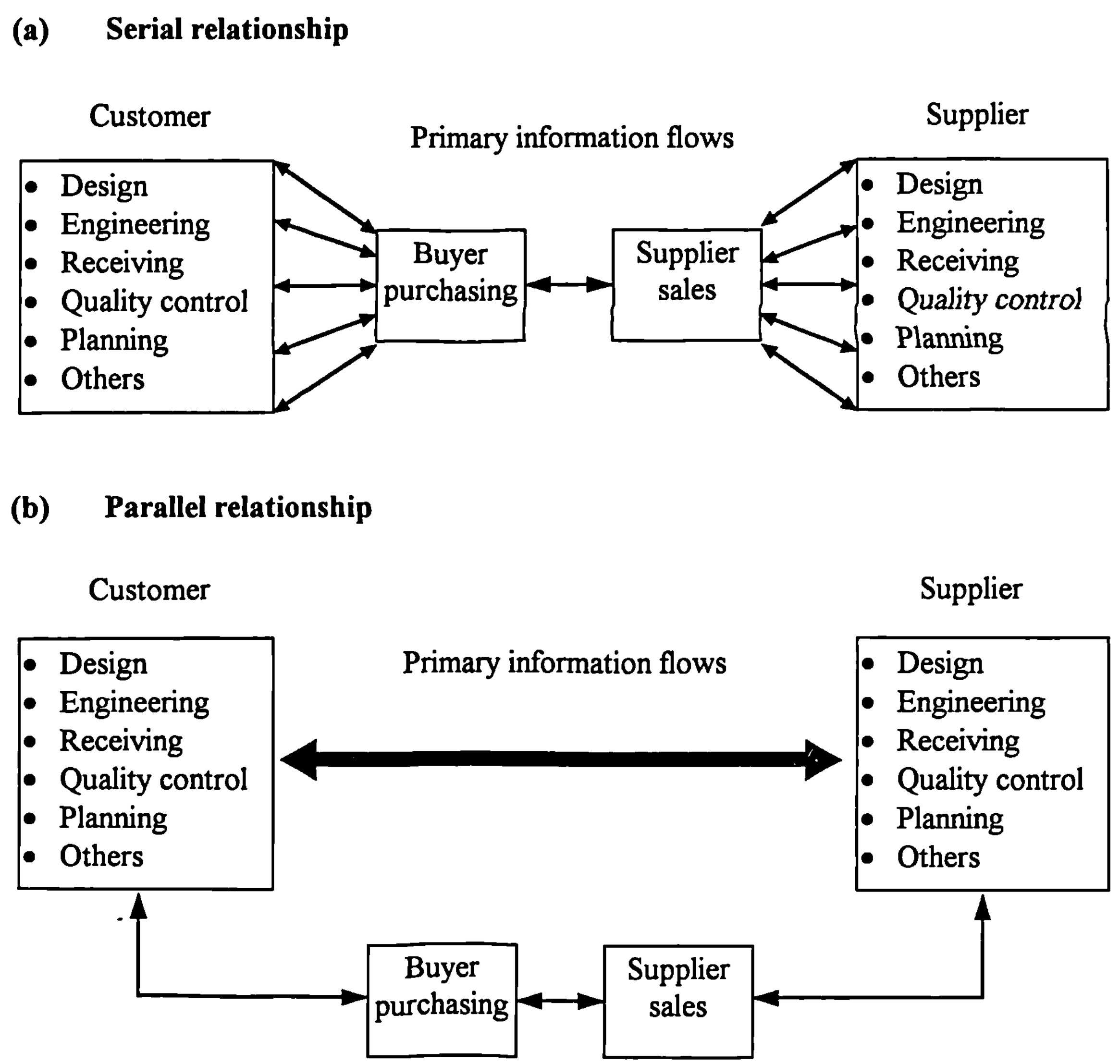
> One first tier supplier has chosen the top three or four second tier suppliers in major product categories and invited them to participate in a long-term relationship, similar to the type of relationship that the first tier supplier would like to have with OEMs. Other evidence of closer relationships include daily interfacing with suppliers, supplier/plant joint action problem-solving committees, participation in the other firm's business with suggestions for cost reduction, and more involvement in parts design. (Blenkhorn and Banting, 1990, pp. 8-9)

In summary, one can see the emergence of specific direct suppliers who will, in future, command greater responsibility from the vehicle manufacturer for the design and making of components, assembly of component systems, quality assurance and delivery scheduling for the vehicle manufacturer (Macbeth and Ferguson, 1994). In addition, many of these suppliers will undertake R&D, management of subcontractors, and use EDI in support of JIT supply (Lamming, 1993, p. 189). Where product development is concerned, these system integrators will have major responsibility to control/manage the project management process with indirect suppliers. It is this transfer of project management responsibility that will probably be a key focus for effective design chain management, if vehicle manufacturers are willing to devolve these duties.

3.4.2 Role of purchasing

Although Clark and Fujimoto (1991) refer to external inputs to the development process, they do not examine the role of purchasing in this transaction. It is nevertheless a crucial partner in inter-organisational coordination, not least because many of the failures of the stress model are directly attributable to the adversarial policies of the purchasing functions at that time. Figure 3.8 illustrates two forms of buyer-supplier relationship and the role purchasing has to play in each. The first is typical of the serial model of product development in which the buyer's purchasing department transacts with the sales/commercial department of the supplier, in which most information transactions occur between them. Carter and Ellram (1994) see three advantages with this configuration. First, by concentrating the transfer of information in one location, purchasing acts as a valve able to prevent an overload of information elsewhere in the

Figure 3.8 Role of purchasing in buyer-supplier relationships



Source: Carter and Ellram (1994, figures 1 and 2)

firm. Second, this centralised role wields considerable power, which enables purchasing to respond quickly to changing market conditions. Third, centralisation of communication channels through one point reduces the possibility of incorrect data being transferred. An effective centralised database would, of course, negate this argument.

Figure 3.8(b) illustrates a parallel form of purchasing in which the integrated team approach is advocated. In this arrangement, the buyer's purchasing department and the sale's department of the supplier assume liaison roles, facilitating and coordinating the transactions through functional and supplier integration (Carter and Ellram, 1994). A major disadvantage that they see with this form is the amount of effort required to manage the exchange of information. Guy and Dale (1993) disagree with this central role for the purchasing department in product development, seeing it as the converse polarised role of design in this relationship. Two firms in the defence industry they studied advocated the involvement of the purchasing team in a cross-functional interface. Hence, the focus of coordination should perhaps be on the team integration, rather than individual functions.

Guy and Dale (1993) do, however, admit that in the absence of a truly cross-functional team approach, the purchasing department is well equipped to manage inter-organisational design transactions. First, purchasing staff have the ability to manage the multiplicity of relationships that will occur. Second, if allowed to develop the technical expertise, it could be a valuable source of advice on alternative materials and suppliers. Table 3.2 summarises the main criteria that they view facilitate an effective purchasing/design interface.

Figure 3.9 illustrates a simplified diagram of the two major sequences in buyer-supplier product development transactions. During contract negotiations, purchasing and sales play key roles in coordinating the commercial transactions; however, during the design, development and production stages, the key transactions are between design and manufacturing engineers in both organisations.

Table 3.2 Criteria for an effective purchasing/design inter-organisational interface

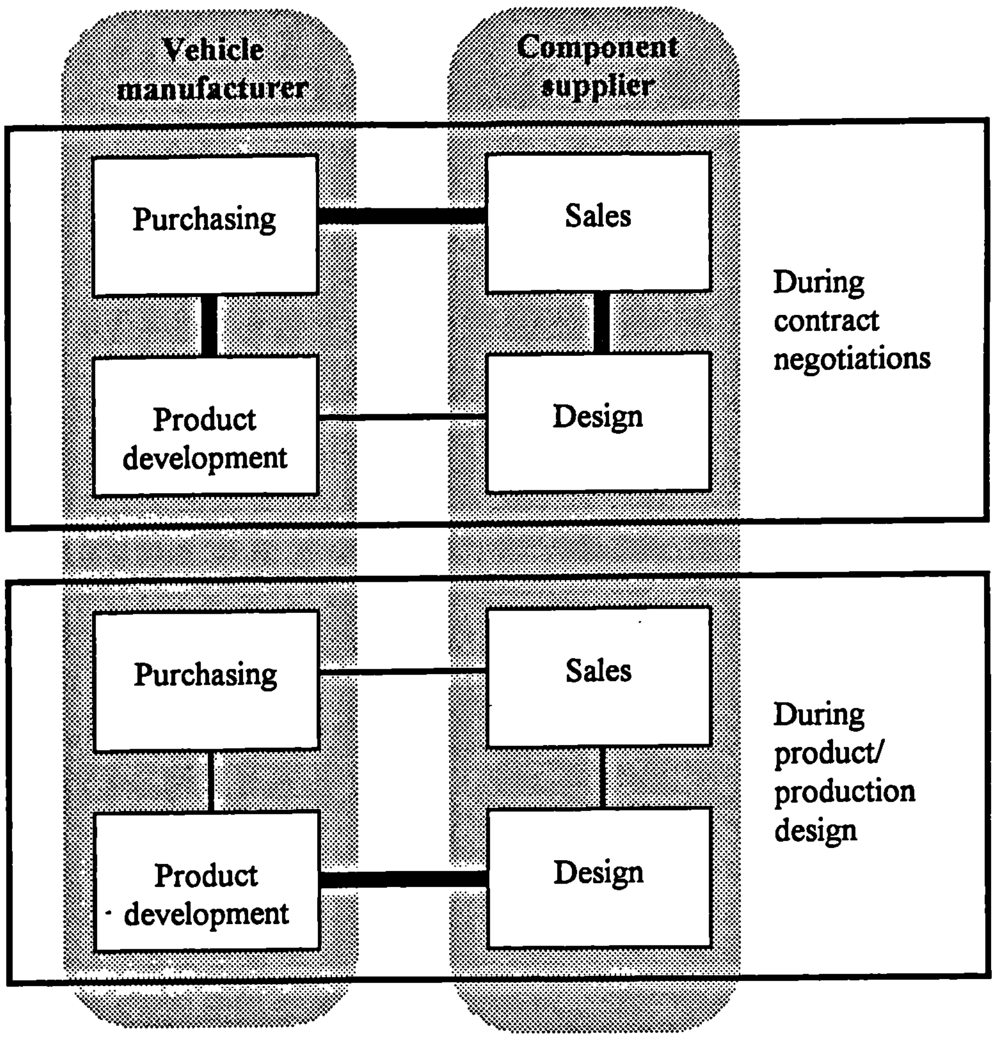
Relationship focus	Criteria
Purchasing	• well defined goals about the interface; • identify areas of cost reduction; • develop supplier relationships; • staff with engineering qualifications; • knowledgeable about DFM and concurrent engineering philosophies; • staff set and control the pace of change in the interface.
Design	• design engineers should see themselves as part of the manufacturing process; • staff rotation with purchasing enables a commercial orientation to the design process (attention to cost reduction).
Supplier	• the supply base is an extension of the buying organisation, especially the buyer's design process, and must understand the buyer's goals and strategies; • long-term commitment, demonstrated through resource commitment; • viewed as part of the buyer's concurrent design team.
Organisation	• culture ready to welcome change; • acceptance for constant reappraisal; • close team proximity.

Source: compiled from Guy and Dale (1993)

3.5 Summary

The criticisms raised by Cusumano and Nobeoka (1992) would indicate a need to better stratify supplier participation in inter-organisational product development, and the need to investigate appropriate mechanisms for effective coordination. The coordination issues are now raised in Chapter Four and the supplier involvement in Chapter Five.

Figure 3.9 Role of purchasing in design transactions



Source: based on Lenau *et al* (1991, figure 2)

The emergence of a more stratified supply base, based on direct and indirect suppliers, where project management responsibilities are devolved to the direct supplier, reinforces the need to examine design relationships in more detail. The examination of the literature of this emerging trend suggests that only those suppliers able to command project responsibility and capability in R&D will enter the major direct supplier role. Therefore, the management of design relationships is, and will, determine specific patterns of component supply.

NOTES

1. These models originate from Lamming (1986) in which four models of buyer-supplier relationship were observed between Austin Rover (now Rover Group) and its supply base.
2. Discussion over the subdivision (or tiering) of the automotive supply base may be found in Bessant *et al* (1984), Watanabe *et al* (1987), Twigg (1990), Imrie and Morris (1992), and Turnbull *et al* (1992; 1993).

4 COORDINATING INTER-FIRM COMMUNICATION

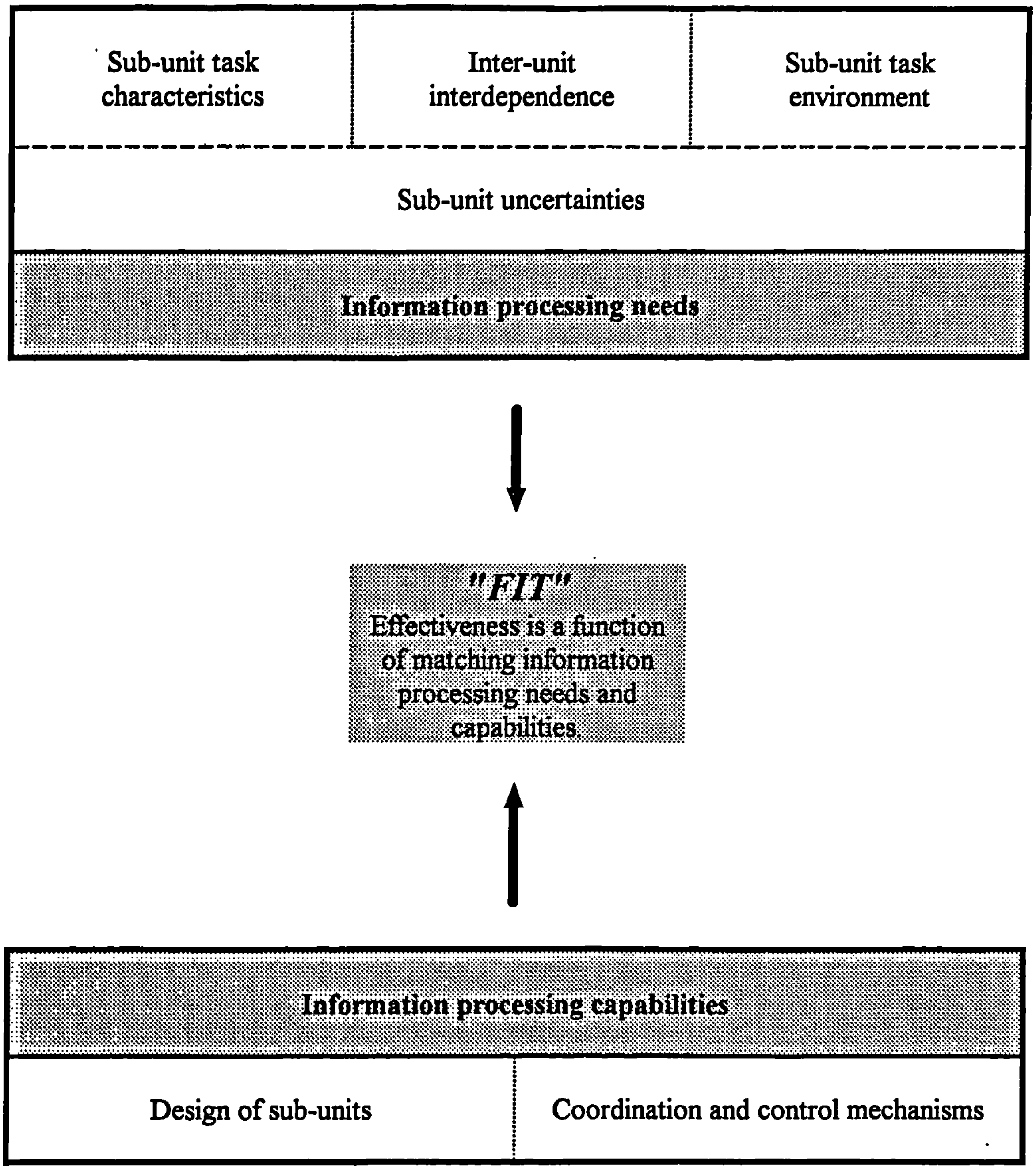
4.1 Introduction

In Chapter Two, the various demands on new product development were discussed and an integrated, information processing system approach to product development was developed. Effective product management requires the development of a project management process, and organisational and information transfer mechanisms to facilitate this. Using the information system model already espoused, the information requirements of the process are now considered to construct a framework for analysing those components necessary for coordinating product development activities in a design chain environment. As the design chain increases in importance, there will be an increased need for effective coordination mechanisms, as higher levels of interdependence are required between a focal firm and their suppliers of design and development information. This framework will be developed from examining, first, the intra-firm perspective, and then extending this understanding to the inter-firm situation.

4.2 An information processing model

A starting point in considering coordination mechanisms is to consider briefly the information processing requirements of the buyer-supplier relationship. For this, an information processing framework, derived from the work of Tushman and Nadler (1978) and the later adaptation by Daft and Lengel (1986), is presented in figure 4.1. This model has an intra-organisation perspective, and recognises two requirements in

Figure 4.1 Information processing model



Source: Composite of Tushman and Nadler (1978, figure 4) and Daft and Lengel (1986, figure 6) information processing: the needs of the organisation, and the capabilities to meet these. The effectiveness of any information processing provision is therefore the match (or fit) between these two elements.

Tushman and Nadler (1978) argue that an organisation's tasks vary according to the degree of uncertainty. They identify three sources of uncertainty derived from contingency theory: task characteristics (Galbraith, 1973); task environment (Thompson, 1967); and task interdependence (Lawrence and Lorsch, 1967b). They see the information processing capabilities as being met by the design of the sub-units (such as in the organic or mechanistic fashion discussed in Chapter Two), and the implementation of coordination and control mechanisms that link the various sub-units. The alternative coordination and control mechanisms will be discussed later in this chapter.

Recognising the absence of the application of the basic model to inter-organisational coordination, Bensaou (1992; and Venkatraman, 1993) developed an adapted version of this model, applying it to inter-organisational coordination between US and Japanese vehicle manufacturers. The operational constructs of Bensaou's framework are listed in table 4.1. Bensaou again specifies three types of uncertainty as determining information processing needs: environmental; task; and partnership. A significant departure from the previous models is the combining of task characteristics and interdependence (task uncertainty), and the introduction of partnership uncertainty. Partnership uncertainty, in this context, is defined as "the uncertainty a focal firm perceives about its relationship with a business partner" (Bensaou and Venkatraman, 1993, p. 8).

Table 4.1 The operational constructs of Bensaou's inter-organisational coordination framework

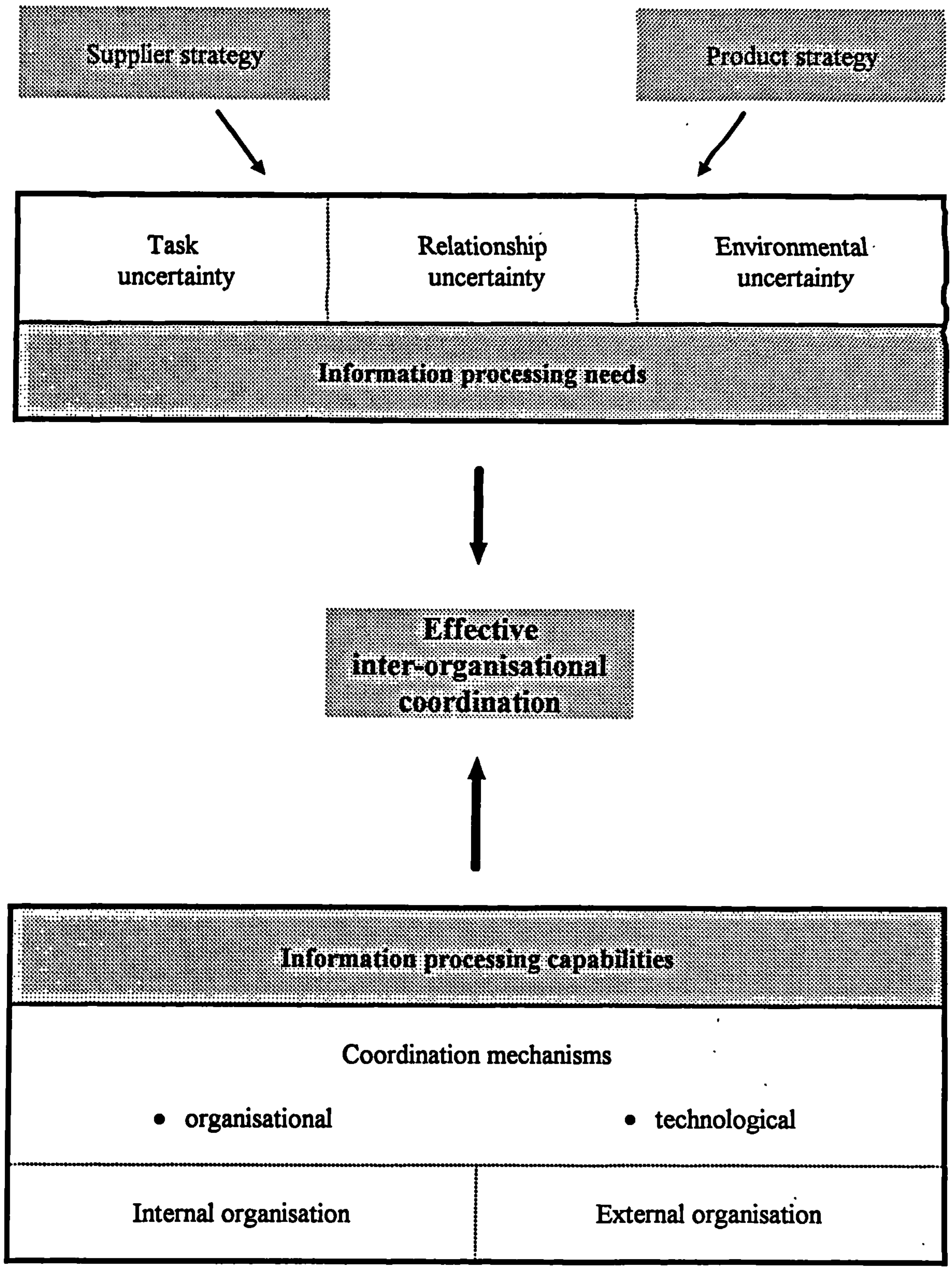
Information processing needs	**Information processing capabilities**
Environmental uncertainty • dynamism (changes in product) • product complexity • market capacity	Structural mechanisms • multiplicity (number of communication channels) • frequency (of mutual visits) • formalisation (control/coordination)
Partnership uncertainty • mutual trust • manufacturer's asset specificity • supplier's asset specificity	Process mechanisms • conflict resolution • commitment • joint action
Task uncertainty • analysability • variety • interdependence	Technological mechanisms • scope of the use of information technology • intensity of electronic data interchange (EDI) • EDI use for engineering • EDI use for purchasing

Source: Bensaou and Venkatraman (1993)

The framework presented in this thesis, whilst recognising the contribution of Bensaou's model, adopts a different emphasis of coordination that approaches a more operational, rather than organisational design, perspective. Bensaou's framework, for example, mutually excludes the cross-categorisation of mechanism dimensions. It is the contention of this thesis, however, that this may incorrectly identify the type and range of mechanisms used in product development coordination. Bensaou's study concerned coordination *per se* and, hence, specialisation on product development of this present study may reveal unique relationships not adequately covered by his constructs. Investigation of the dynamics of coordination requires consideration of the information exchange relationships themselves. For example, whilst frequency of mutual visits (structural mechanism) and intensity of EDI use (technological mechanism) are factors to consider, they may not describe the capability of information processing, whilst use of telephone or facsimile machine may be as effective. Similarly, mutual visits may reflect the number of task forces empowered to rectify engineering changes or prototype build issues. It is not the number that is of importance in determining effective capabilities, rather it is the appropriateness to fulfil a task - having considered all other options.

A revised framework is presented in figure 4.2 that considers the information processing capabilities available to vehicle manufacturers, and their information needs for product development. This marries the information processing needs of Bensaou, with the information processing capabilities in figure 4.1. The information processing needs of a vehicle manufacturer for product development are determined by the uncertainty of tasks to be undertaken, the uncertainty of environment, and the perceived uncertainties in relationships it establishes with external organisations for engineering resources. These challenges are similar to those confronting intra-organisational coordination. However, two antecedents play a crucial part in determining these needs: the supplier strategy, and the product strategy (Chapter 3). Supplier strategy influences both the task uncertainty and inter-organisational relationships. Firms are increasingly seeking closer links to suppliers for inputs to product development and production. The nature of these relationships and certainty over completion of specific tasks will determine the level of

Figure 4.2 Information processing framework for the coordination of inter-organisational product development



information processing needs. Similarly, the product strategy will influence both of these factors, as well as the environment in which the organisations operate. Hence it seems appropriate to utilise the information processing needs determinants proposed by Bensaou. However, one departure seems necessary: whereas Bensaou uses the term *partnership* uncertainty to consider an asymmetric perception of the relationship, this thesis will adopt *Relationship uncertainty* and consider this to reflect the perceptions of both supplier and focal organisation. One important reason for this is that partnership assumes an open relationship, which may not have yet been reached.

Figure 4.1 shows that intra-organisational information processing capabilities can be provided by organisation design and utilisation of coordination and control mechanisms. At the inter-organisational perspective, the framework in figure 4.2 considers these as coordination (organisational and technological mechanisms) issues, and product development process (internal and external) issues. In the second case, this refers to the organisation and management for product development of both the vehicle manufacturer (internal) and the supplier (external). This is a departure from Bensaou's model, in order to overcome the considerations given above, and to present a model in which alternative mechanisms, as opposed to their determinants, can be examined.

The marriage of these needs and capabilities will result in effective coordination. However, whilst it is hoped to offer new understanding to this coordination relationship, it is not within the remit of this study to offer a measure of effectiveness of mechanisms. As will be explained later, a portfolio of mechanisms is available for any one project, and effectiveness of mechanisms necessarily reflects the perceived effectiveness of project (by both parties of that relationship). In examining these coordination mechanisms, it is hoped to understand better the dynamics and interactions under specific conditions.

Hence, the capabilities to meet the vehicle manufacturer's needs will be based upon: (1) the vehicle manufacturer's ability to organise and manage internally its product development process (internal organisation); (2) the supplier's ability to organise and manage internally its product development operations (external organisation); and (3) the availability of appropriate coordination mechanisms to facilitate information transfer between (1) and (2). These elements are now discussed in detail, culminating in a typology for inter-organisational coordination.

4.3 Coordination of product development capabilities

In figure 4.2, the information processing capabilities of a firm were identified as requiring a combination of organisational and technological coordination mechanisms to meet the information processing needs of its product development process. Trygg (1991) proposes a systems-based model for coordinating development and production activities. He identifies two critical influences on the coordination of these activities: *technological factors* - material tools, tools and advanced manufacturing technologies - and *organisational factors* - culture, structure, and people.

Organisational structures consist of two elements: the division of activities and the coordination of tasks (integration). Fujimoto (1989; with Clark, 1991) proposes three dimensions to examining organisational design of product development: functional specialisation; internal integration; and external integration. He observes that previous literature on organisational design has concentrated on aspects of functional specialisation and internal integration, but an examination of today's car industry also requires consideration of external integration (Fujimoto, 1989, p. 115).

In Fujimoto's study, internal integration corresponds to those internally developed activities which assist in higher internal integrity in terms of information assets, and for simplicity, he includes suppliers' contributions to product development as part of this process thus not specifically differentiating their activities: he notes that their separation would not change the basic nature of his research argument (Fujimoto 1989, footnote 39, p. 101). Thus, his external integration dimension does not refer to suppliers' information assets, but to those of the market (customer).

This is an important distinction between Fujimoto's use of the information processing system and the one developed in this thesis. Since the focus of this research is the contribution of suppliers' information assets to vehicle design and development, the market (customer) relationship has been assumed as implicit in the concept and specifications developed from the product strategy of the vehicle manufacturer. This external integration is assumed as part of the marketing/R&D and marketing/customer interfaces. The contribution of market (customer) inputs to component/sub-system design will be coordinated through the vehicle manufacturer, as part of the product strategy process. Hence, this thesis will distinguish between internal and external integration, where external integration refers to coordinating *supplier* (and other service) inputs to product development.

A general consensus in the literature is that the effectiveness of new product development (in terms of cost, quality and timing) is greatly determined by the quality of its project management approach, the technology being used, and the organisational characteristics (Adler and Helleloid, 1987 [1]; Bertodo, 1989b). Adler (1988), continuing his work with Helleloid, investigates these organisational features through five key organisational variables: *skills, procedures, structure, strategy* and *culture*. It is argued by Adler that these represent a continuum along which the focus for organisational learning changes from task orientation to the wider organisation, and hence gains in magnitude. The procedures and structure issues will be discussed in detail later, but first, skills, strategy and culture warrant a mention.

Traditionally, skills were seen as a person's accumulated capabilities through their long working experience, but the participant in product development today requires more subtle skills, such as problem-solving, teamwork, leadership and negotiation. Many of today's product engineers need to be able to design, draft and understand the cost management of his work. Not all the necessary skills will lie within one function, or in-house. For example, design and drafting may be undertaken by the same, multi-skilled individual in one firm, whereas in another, the drafting responsibility may reside elsewhere. If two people are employed, then immediately there is a need for communication and coordination.

Whatever the choice of integration mechanism, there should be a strategic view of their purpose both internally and externally. Is supplier development important for the company, and should early supplier involvement be encouraged? If so, how? Does the firm have access to all operations in-house? If not, how best can existing capabilities be coordinated with those external to the operations?

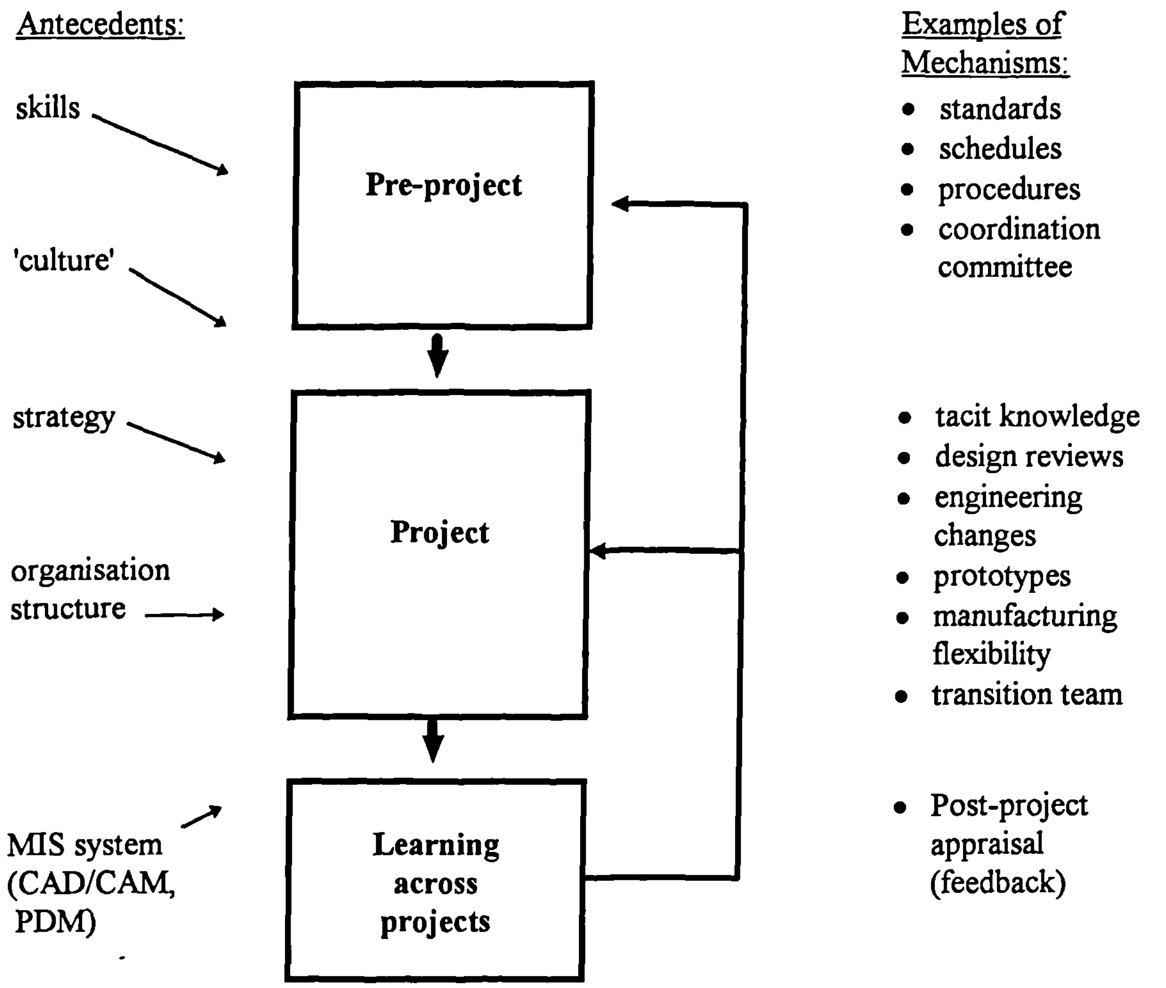
Differences in, *inter alia*, core values, norms, attitudes and sometimes language can pose cultural challenges to product development (Harrison, 1992). Product engineers, for example, have often been at logger-heads with purchasing over the best supplier with whom to outsource. Purchasing might argue for an alternative supplier based on cost, whereas the tacit requirements of previously successful work would seem strong arguments by the design engineer for an alternative. Effective cost management by engineers may assist reduce such tensions, as responsibility shifts to component designer's for their budgets.

Based on the discussion of this section, figure 4.3 illustrates some of the important determinants of coordinating development projects. Whilst limited as an overview, the diagram provides an integrated perspective of the issues of coordination.

4.4 Internal integration

Issues surrounding organisational structures for product development were discussed earlier in Chapter Two, and alternative forms presented that assist in the over-arching structure in which product development activities exist. Central to this discussion is the contribution of contingency theory to the integration of functional units (Lawrence and Lorsch, 1967; Galbraith, 1973) and the coordination of tasks therein. The terms

Figure 4.3 Coordination determinants for a development programme



integration and coordination are often used synchronously in examining these issues, as illustrated by Van de Ven *et al* (1976, p. 322): "Coordination means integrating or linking together different parts of an organization to accomplish a collective set of tasks."

This demonstrates the concentration of examining coordination from an intra-firm perspective. However, as the following definitions illustrate, they are equally applicability to inter-firm coordination, later discussed.

> *Integration* is defined as the process of achieving unity of effort among the various subsystems in the accomplishment of the organization's task. *Task* is defined as a complete input-transformation-output cycle involving at least the design, production, and distribution of some goods or services. By these definitions, the boundaries of organizations will not always coincide with their legal boundaries. (Lawrence and Lorsch, 1967b, p.4, italics in the original)

Figure 4.1, earlier, showed that information processing needs are characterised by interdependency of tasks, task uncertainty and environment uncertainty. Internal integration can thus be seen as a requirement for improving or maintaining the internal integrity of the information assets for product development (Fujimoto, 1989).

There is a wealth of research concerning the effective coordination of the functional interfaces relevant to design activities. Typical amongst these are: marketing/R&D interface (for example, Crawford, 1983; Souder, 1987; Urban *et al*, 1987), and engineering/production interface (for example, Adler, 1988 and 1995; Carlsson, 1990; Dean and Susman, 1989; Ettlie, 1988; Trygg, 1991). Each examination considers various mechanisms appropriate for improving coordination between sub-units across the respective interface. In a study of nine companies, Ettlie (1988) found six methods being used to promote design/manufacturing integration: design/manufacturing teams; compatible CAD systems; common reporting positions; design for manufacturing; engineering generalists; and R&D lead time reduction. Ettlie suggests this final method indicates the strategic importance given to improved integration for competitiveness. Dean and Susman (1989) propose four approaches to improving design/manufacturing coordination: the use of manufacturing sign-off; an integrator role to act as liaison; cross-functional teams; and a combined product/process design department. Soderberg (1989), referring specifically to improving product and process engineering integration, identifies three steps that companies should consider: co-locating the two functions; rotating staff between functions; and reducing the disparity between career paths, incentives, pay and job specifications.

Earlier work by March and Simon (1958) suggests two ways of coordinating the tasks within organisations: by programming, and by feedback (mutual adjustment). Considering this work, Van de Ven *et al* (1976) propose three predominant modes of coordination: impersonal mode (coordination by programming); personal (vertical or horizontal) channels; and group (scheduled or unscheduled) meetings - both forms of mutual adjustment. Galbraith (1973) classifies integration mechanisms further, as: rules, programmes or procedures; computer communication networks; hierarchical sub-unit control; goal setting; lateral linkage; and product sub-units. However, all of these integrating mechanisms may be defined by organisation or technology type (figure 4.4), and are now discussed, before proposing a detailed integration typology.

4.4.1 Integration through organisational structures

A number of organisational mechanisms have been suggested to improve integration. A useful starting point is the work on lateral relations proposed by Galbraith (1977), namely: direct contact; liaison roles; task forces; teams; integrator roles; and matrix organisation. Mintzberg (1983, p.91) views these liaison devices as being used "... where tasks are, at the same time, (1) horizontally specialized, (2) complex, and (3) highly interdependent." These are widely used as intra-firm mechanisms (see for example Fujimoto, 1989).

Figure 4.4 Organisation and technology integration mechanisms

Organisation mechanisms	**Technology mechanisms**
• Direct contact / physical proximity	• Decision rules in software
• Liaison role	• Electronic mail
• Secondment	• Video-conferencing
• Task force	• CAD/CAM
• Project team	• Product database system
• Role combination	
• Permanent team (or cell)	
• Integrator function	
• Combined department	
• Matrix organisation	

Source: based on Winch, Voss and Twigg (1991)

In their study of CAD/CAM implementation, Winch, Voss and Twigg (1991), consider additional organisational mechanisms that can assist in integrating product development activities, namely: *secondment* of staff from one function to another; *role convergence*, where previously separate jobs are merged (Voss, 1985); and *cells*, where previously separate specialisms, such as tool design and process engineering, are combined (Lee, 1988).[2] Each mechanism is now discussed in turn.

Direct contact: This is the simplest, quickest and easiest form of engineering/manufacturing liaison, and may involve setting up meetings, design reviews, encouraging *ad hoc* meetings, encouraging informal contact in coffee lounges, and so forth. Factors such as the existing company culture, and the location of engineering and manufacturing influence the success of this mechanism. The continuity of employment of personnel within the organisation is also likely to be a factor here as longer serving employees build up personal networks.

A mechanism that promotes direct contact is *physical proximity*. This can be simple and inexpensive; moving groups or departments together in the same building, office or even across the same desk is a very effective way of promoting communication. Winch *et al* (1991) found three cases where informal contact had been facilitated by physically locating manufacturing engineers in the same area as design engineers. On a larger scale, BMW and Chrysler both see the advantage of reducing the physical distances of information flows as achieving reduced product development cycles (Shenas and Derakhshan, 1994).

> BMW has created perhaps the largest single research engineering centre in the European [automotive] industry in pursuit of simultaneous engineering principles. Its Fiz centre in Munich ... houses nearly 6,000 engineers, none of whom has to walk more than 150 metres to talk to a colleague. It allows a first-concept designer to discuss easily with a production-line engineer (the building houses prototype production lines) the manufacturing practicalities of even an outline design idea. ... The design of the building is based on the concept that, if physical distances between two designer engineers are greater than 150 metres, the easy interchange of ideas or discussion of problems is discouraged. (Shenas and Derakhshan, 1994, p.35)

Liaison role: These promote two-way communication, and two types were found by Winch *et al* (1991). The first type is the pairs form, where the manufacturing person has an identified opposite number in engineering. The second type is where a particular group within one function also reports to another function (for example, engineering may have staff located within manufacturing).

Secondment: This involves transferring (seconding) a representative for a period of time in another activity area (for example, a manufacturing engineer to the product development team in engineering). The benefit can be two-way: to bring into one function the considerations of another function; and, at the end of a secondment, to bring the project through to the home function.

Task force: This is a widely used technique for solving particular finite problems. They can be distinguished from committees in the sense that they are usually responsible for the implementation of policies rather than policy formation. Two cases cited by Winch *et al* used task forces on a temporary basis to review the working procedures and protocols of the CAD/CAM system, to meet the requirements of downstream operations.

Project team: This is cross-functional and can be distinguished from task forces by the full-time and, usually, longer term nature; most notable is the product development team. (This was discussed more fully earlier.)

Role combination: This is where tasks, previously performed by a number of separate people with different skills, are brought together to be done by one category of personnel. Ettlie (1988) considers the *engineering generalist* in this capacity. Within the engineering function there appears to be a general move towards a role convergence between engineers and drawing staff on contract, or product, design work. Within manufacturing, convergence is occurring between the roles of tool designer, NC programmer, and process planner. With role combination, other forms of integration become less necessary as a variety of skills are possessed by one individual, but the depth of skill needed is a limiting factor in its widespread use (Winch *et al*, 1991).

Permanent team (or cell): Cells are permanent cross-functional project teams providing a very high level of integration, configured around a common database in CIM. Such teams can work closely together on a major project, or a series of projects of similar characteristics. Key to the team's success would seem to be size: it must be large enough to contain the necessary functions for the design and manufacturing tasks, but not too large so that it becomes *fragmented*.

Winch *et al* found two examples. The first case, defined around *surface modelling*, was a permanent team of four people (NC programmers and design engineers), sitting together in the design office. Both groups needed the surface model for their work and the NC programmers downstream had a vital interest in the way in which the original model was generated. The second case, a cell set up around a single, new vehicle project, was composed of twenty designers, analysts and engineers from four functions. This group worked as a single team in an open plan office, seconding other members as required. They were responsible for the majority of the final stage of design and development of a vehicle, and all work using a unified CAD/CAE data base.

Integrator function: This fulfils the same need as the liaison role, but on a larger scale (Tushman, 1977). Two distinct types of integrator function that bridge the engineering/manufacturing interface exist. First, the true integrator role (as described by Galbraith, 1970) which is product oriented, typically reporting direct to executive level management, rather than within an individual function. Second, the specialist, associated with the development of information systems or quality assurance (QA). This role is quite distinct from that of the systems manager responsible for the daily running of the system. The emphasis of the specialist integrator is not so much on initiating system innovations, but supporting and coordinating local initiatives from operational managers.

Combined Department: Sometimes the presence of a common data base with CIM raises the question as to the need for separate functions or organisations. Where the sources of differentiation can be minimised, it is feasible to establish combined departments. A reorganisation in line with the system configuration may, for example, facilitate a more effective design process. John Deere & Company, for example, formed a combined, production engineering/product engineering department with the co-located production engineers switching reporting to the product engineering manager (Anderson, 1992). This co-location differs from the *physical proximity* form due to the change in reporting arrangements. Winch *et al* (1991) found one case that combined the manufacturing engineering and design engineering functions into a single engineering organisation, whilst another case, on a smaller scale, combined the design and analysis departments into a single department after installing CAE and CAD.

Matrix Organisation: This mechanism is the most sophisticated lateral linkage mechanism in Galbraith's hierarchy, and was earlier described in detail.

4.4.2 Integration through technology

Technology can be used to assist integration through its accurate, complete and timely transfer of data. There are two principal ways in which technological integration can be accommodated: through information technologies, such as Artificial Intelligence, expert systems, electronic mail and video-conferencing; or, through functional databases, such as CAD/CAM (Trygg, 1991; Winch *et al*, 1991). Shenas and Derakhshan (1994) note that although electronic interfaces are critical for efficient transfer of routine information, they cannot substitute the necessary physical interaction of people. A number of key technologies are now discussed.

Expert systems: Winch *et al* (1991) found a number of companies beginning to experiment with expert systems to support coordination. In particular, one company was using in-house developed software (an artificial intelligence type shell) of structural features of components that had been defined in manufacturing terms. In another case, a company had developed a tool library of preferred tools with manufacturing, held within the CAD system, from which design engineers were expected to design components that could be made from these tools.

Electronic mail: The need to ensure a variety of people, in different world time zones, receive information speedily is promoting the use of electronic mail (e-mail), and *voice-mail*. Not only can messages be delivered directly to individuals, but some companies are adopting groupware to enable centralised sharing of information. British Aerospace, for example, has implemented a groupware system called DUCK (Designers as Users of

Cooperative Knowledge) to enable their distributed engineering teams to share their experience. DUCK provides simultaneous, multiple computer access to a project log (*The Financial Times*, 26 April 1994).

Video-conferencing: Video-conferencing (or teleconferencing) has received increasing interest in industries, particularly in aerospace, where project development teams have been dispersed internationally. Ford Motor Company used this mechanism extensively in the development of the *Mondeo* global car. The responsibility for development was given to teams in different countries: Ford of Europe had primary responsibility for the basic engineering and integration of the components and sub-systems; Ford (in the USA) engineered the V6 engine and automatic transmission, and provided air conditioning expertise; and four design centres in Italy, Germany and two in the USA undertook body design work. The coordination of this process relied heavily on complex video-conferencing, supported by processing from a Cray super-computer, thus enabling engineers in all locations to work simultaneously on drawings (*The Financial Times*, 29 March 1994).

Multimedia: This is a relatively new, but increasingly powerful, communications tool. Within one system, a variety of packages can be combined into an interactive medium. For example, designers can communicate using video-conferencing, send information by e-mail, access decision support software and a product library, or interact simultaneously with another designer on a shared document or CAD model, able to discuss it in real-time. The limitation of this technology, at present, would appear to be the method of transmission. Transferring CAD-related information, and simultaneously sharing it, will require the widespread use of ATM high speed networks, enabling a broadband communication, and enabling data transmission in seconds rather than tens-of-minutes. At present, these are few, due to the cost of installation.

CAD/CAM: CAD/CAM is frequently espoused as an integrating technology, but this can only be achieved if its integration with organisational needs is implemented properly (Adler and Helleloid, 1987; Ettlie, 1988; Twigg, 1990; Twigg and Voss, 1992). Nevertheless, CAD can provide a mechanism for integrating cross-functional activities, and can assist in consolidating upstream and downstream operations into a cohesive product development process. There is an opportunity with CAD/CAM to provide a focal point for product development information, which can be accessed by all parties (see product database below). For example, if held digitally, part-programming data for NC machines can be extracted from the CAD system and delivered to tooling and manufacturing operations. However, as Twigg *et al* (1992) note, procedures and standards may need to be reviewed to ensure drawing conventions and data positioning interface correctly between the different parties. CAD/CAM can assist in prototyping and pre-assembly work. The Boeing Company, in its development of the *Boeing 777* aircraft, for example, adopted two important changes to its product development coordination. First, it working closely with its major customers (Condit, 1994), and second, it utilised an extensive CAD system:

> The 777 was pre-assembled digitally, with computer-aided design which allowed Boeing's design engineers, production experts and tooling specialists to work together. In the past, tooling problems and manufacturing glitches surfaced only when the final aircraft was about to be assembled, resulting in lots of expensive reworking: this time, the glitches were spotted by Boeing's computers so the 777's body and wings fitted together straight away. (*The Economist*, 12 March 1994)

Product database system: A significant benefit of integrated CAD/CAM is the provision of a centralised database containing design and manufacturing related information on each product. This can be accessed by various functional groups - engineering, marketing, purchasing, finance, manufacturing, and servicing - and provides all necessary data on each product. One cause of error in the product development process is the misinterpretation of information, so centralising it in digital form ensures that current data is only used, and errors due to conversion from paper to stand-alone systems are avoided.

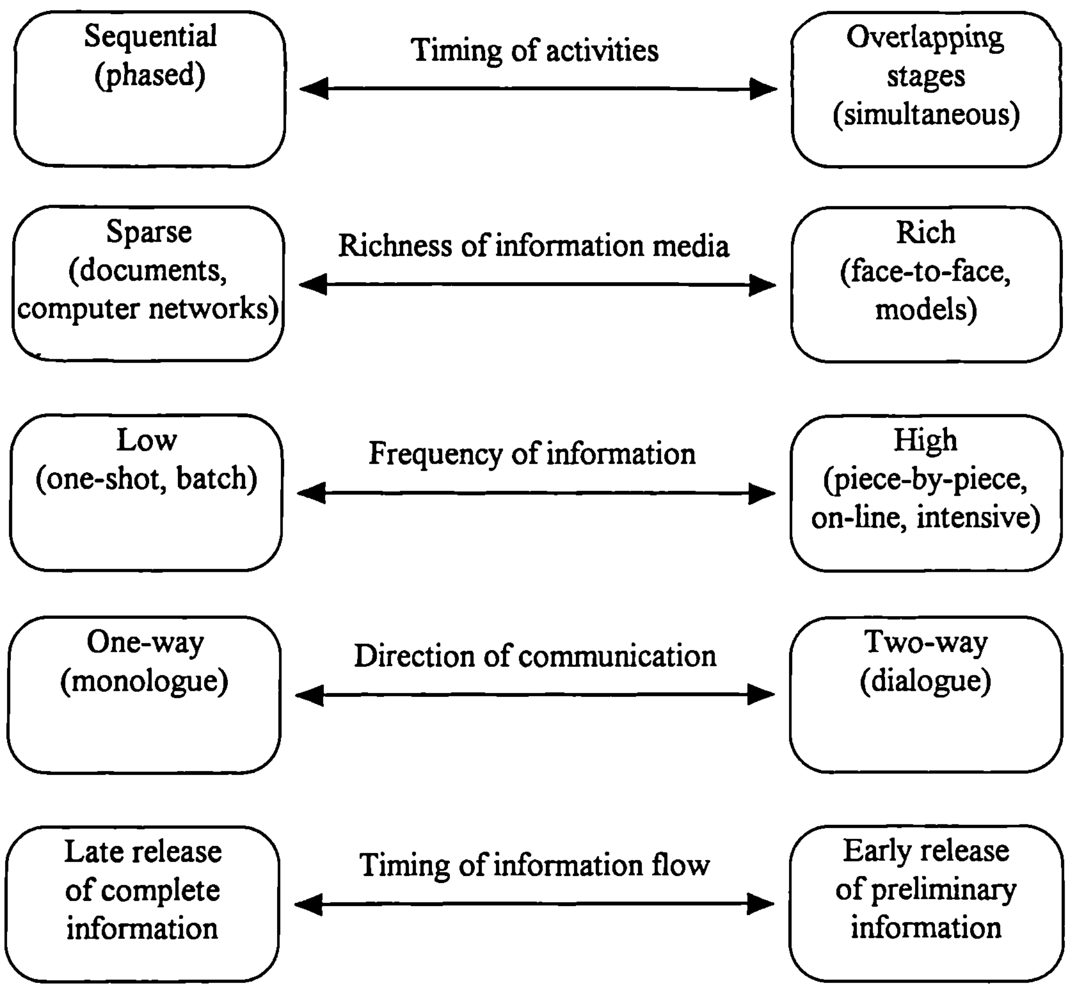
4.4.3 Patterns of communication

The previous two sections have illustrated a variety of organisational and technological integration mechanisms. Before presenting a typology of mechanisms, it is worthwhile considering the types of communication pattern these mechanisms aim to serve. Figure 4.5 illustrates the dimensions along which communication of upstream and downstream activities can be integrated. Four dimensions can be identified that determine the quality and effectiveness of communication: timing, richness, frequency, and direction of information (Clark and Fujimoto, 1991; Wheelwright and Clark, 1992). Figure 4.5 typifies the extremes of product development process discussed in Chapter Two. Where the process is sequential, information tends to be seldom exchanged, except as a single one-shot batch late in the particular stage. Conversely, an integrated approach to product development is facilitated through richer exchanges of information (such as face-to-face contact and the use of product models), more intensively and frequent. This situation encourages the early release of preliminary information, such as sketches and models, thereby providing a mechanism for discussion.

4.4.4 A typology of coordination mechanisms

A variety of mechanisms are thus available to companies to improve the internal coordination of their product development activities, for example, through joint

Figure 4.5 Dimensions of communication between upstream and downstream activities



Source: Clark and Fujimoto (1991, figure 8.2) & Wheelwright and Clark (1992, exhibit 7-3) product/process design teams, design for manufacture, and the early release of design information to manufacturing. The use of effective procedures and structures are imperative if, *inter alia*, up-to-date drawings are to be issued, and technology (for example CAD/CAM) is to be realistically employed - such that engineers do not strive towards over-complexity where optimisation is more appropriate (Adler, 1988).

Adler (1995) proposes a typology of design/manufacturing coordination mechanisms that distinguishes five modes of interaction: *non-coordination*, *standards* (or rules), *schedules and plans*, and *mutual adaptation* (Thompson, 1967), and *teams* (Van de Ven, Delbecq and Koenig, 1976).[3] His critique of the literature on coordination mechanisms led him to consider these five modes at three stages of the product development process: pre-project phase; design-phase; and manufacturing-phase.[4] Figure 4.6 illustrates this typology.

In an earlier version of this typology, Adler (1988) considers the quality of information flow of each coordination mechanism as: one-way, stilted two-way, or two-way. These quality dimensions can be considered to be comparable to the independent (pooled), sequential, and reciprocal information flows defined by Thompson (1967). Van de Ven *et al* (1976) add the team arrangement to Thompson categories. Although Adler (1995) does not use these information flows in his adapted typology, it is useful to refer to them, in the light of Van de Ven *et al*. Three categories of information flow can be identified which characterise these groups: *sequential* (one-way flow), combining Thompson's first two groups; *reciprocal* (stilted two-way flow); and *iterative* (two-way flow), based on the team arrangement.[5] This dimension has been added to figure 4.6 to highlight the varying degrees of information flow characteristic in each mechanism.

Figure 4.6 A typology of design/manufacturing coordination mechanisms †

	Pre-project phase	**Design phase**	**Manufacturing phase**
Non-coordination ‡	Anarchy	Over-the-wall	Work-arounds
Standards	Compatibility standards (S)	Designers' tacit knowledge of manufacturing (S)	Early manufacturing start with early design data (S)
		Design rules (R)	Manufacturing flexibility (S)
Schedules and plans	Capabilities development schedules (I)	Sign-off (R)	Production prototypes I. engineering fit II. build-test cycles (R)
Mutual adjustment §	Coordination committee (I)	Design reviews (R)	Engineering changes (R)
Teams	Joint development (I)	Joint product/process design team (I)	Transition team (I)

Notes: † Three types of information flow: S - sequential; R - reciprocal; I - iterative)
‡ Information flows have not been indicated due to the absence of coordination
§ An additional mechanism is available, that of post-project appraisal (I)

Source: Adaptation and expansion of Adler (1988, Exhibit 11; and 1995, Figure 2)

Figure 4.6 indicates the variety of integration options available to firms. It may be obvious to conclude that the earlier measures are taken to improve coordination upstream, the better the process of development. However, there may be occasions that firms will require flexible manufacturing operations or engineering changes later in the process. These mechanisms should be seen, therefore, as complementary to each other: the key issue is to have effective mechanisms in place, and not mechanisms *per se*!

Adler's (1995) primary objective is to develop understanding of how established design and manufacturing departments coordinate their activities, and how these departments should coordinate to manage efficiently their interdependence.[6] Adler (1995, p.148) notes:

> As the phases of work unfold within a time-bound project, departments typically experience different degrees and types of interdependence, and they interact with varying intensities and via different coordination mechanisms. And as a result, in the course of a product development project, neither interdepartmental interdependencies nor coordination mechanisms are constant over time.

Since this thesis is concerned with the coordination of effective design management (post-concept), focus on these phases of product development is appropriate. Each mechanism is now discussed under the typology presented in figure 4.6. As a precursor, the *non-coordination* of phases warrants separate attention. In Chapter Two, the *traditional* approach to product development was characterised as separated activities, where communication only took place between phases. The non-coordination modes in figure 4.6 are typical of this process. However, non-coordination may also include the absence of a CAD or CAM strategy (Adler, 1995), or a failure to integrate properly technology and organisation (Ettlie, 1988; Twigg and Voss, 1992).

4.4.4.1 Pre-project phase coordination

In the context of this thesis, pre-project coordination corresponds to those activities that will impact on the design and manufacturing activities, yet precede the initiation of a given project. The output at this phase will be a set of design and manufacturing capabilities.

A number of activities may take place during the pre-project phase, and may include: the setting of standards to be used throughout the project (both product and process related); the schedules and project timing plans (including any review meetings and build-test dates); the coordination of functional strategies; or the building of a cross-functional team.

Compatibility standards (sequential): By establishing standards early in a project, or as corporate policy, the need of reciprocal discussion may be reduced. Standardising the number of variants in commonly used components early in the project can assist greatly the process of downstream operations. For example, where there are complex assembly operations, prior discussion with product designers to limit the variety of fastener size used will have positive effects on purchasing, logistics and manufacturing in terms of cost, time and quality. Such standards may be either firm or project specific but require detailed discussion by all relevant parties at an early stage. Other types of standard may include: setting producibility standards; creating *approved parts'* databases; or centralising a product definition database in which CAD/CAM facilities in all departments and divisions must be compatible.

Capabilities' development schedules (iterative): Coordination can be greatly enhanced if all capabilities are working uniformly to a prescribed set of objectives and schedules. The effective implementation of CAD/CAM, for example, requires cross-functional development and integration in formulating a cohesive strategy (Adler, 1995; Twigg and Voss, 1992). The coordination of strategies enables planning in the knowledge of the activities of other functions, which can lead to a reduction in inappropriate design specifications, or process expectations. Of course, this requires an effective two-way exchange of information. Whilst Marketing and Manufacturing have increasingly moved towards explicit strategy formulation (aided by the work of, *inter alia*, Platts and Gregory, 1988; Hill, 1993), the author's personal experience of interviewing Engineering personnel leads to the impression that their strategy is far more implicit, and that coordination of strategy is not always widespread. The dysfunctional result of this was acknowledged by Twigg (1989) in a specialist UK vehicle manufacturer in the late 1980s: a middle manager in Engineering with a key integrating role between engineering/manufacturing interpreted differently the manufacturing strategy of the company. In the context of one programme of work, this misinterpretation created tensions at this interface.

Coordination committee (iterative): An example of a coordination committee is the Product Policy Committee at Rover Group Limited, cited in Bertodo (1989b). This committee represents all functions of the company and has vehicle programme directors reporting to it. New product development plans are assessed *vis-à-vis* the operations of individual functions; any conflicts can be resolved prior to the commitment of resources to downstream operations.

Joint development (iterative): Bertodo (1989b, p. 20) cites a pre-concept joint development event involving a core, cross-functional team, and vehicle programme director. This event enables the project to incorporate: the maximum carry-over of components, processes and technologies; shelf-engineered components; an assessment of available powertrain units for the new models; and, the existing manufacturing constraints.

4.4.4.2 Design-phase (project) coordination

The aim of this phase is to convert the design capabilities into a product specification. Increasingly, firms are identifying the needs of manufacturing in the design engineering phase through such techniques as design for manufacture (DFM) and design for assembly (DFA). Many of the mechanisms discussed now contribute to these techniques.

Design engineers' tacit knowledge (sequential): Design engineers may be able to accumulate tacit knowledge of manufacturing practices over time from previous projects or experience, thereby ensuring designs are producible. This may be achieved through *job rotation* or internship schemes. Saeed *et al* (1993) argue for design engineers to develop *focused manufacturing knowledge*, gained through working in a specific manufacturing environment; in this way, many manufacturing-related engineering changes can be avoided. A draw back of relying on this type of coordination is the time-related knowledge of the designer. Twigg (1989) cites an example of design engineers *assuming* their tacit knowledge of manufacturing's practice was correct, when in fact circumstances had changed. They were physically distanced from the manufacturing site, and whereas assumptions had been made about the available space for new process equipment, the assembly line layout had dramatically changed since last the design engineers had visited, resulting is substantial engineering changes being made late in the process from manufacturing.

Design rules (reciprocal): It is possible to codify, either manually or through software (for example in CAD/CAM systems), formal procedures in the form of decision rules and design rules that reflect the considerations of downstream functions. Wheelwright and Clark (1992, Chapter 9) refer to the *rules of thumb* used for a fabricated, assembly product. These included focusing on minimising the number of parts and part numbers in a design, and eliminating adjustments, fasteners, and jigs and fixtures. In addition to the rules, there were identifiable impacts on performance. Twigg *et al* (1992) cite an example of one company using in-built software (an artificial intelligence type shell) of structural features of components *specified* in manufacturing terms. Another case had moved to imposing design rules through its CAD system because design staff were defining radii geometrically as straight lines (whilst labelling them as radii), the result of which was corrupted geometric data feeding into CNC part-programs. Adler (1995) cites a case where producible printed-circuit board fabrication specifications increased from 40% to 95% over two years, due to the implementation of software based design rules: CAD/CAM enabled the designer to verify automatically the design conformance to producibility rules. The main advantages that Adler (1988) sees with design rules are, *inter alia*, the learning across projects that can occur to the whole organisation as new knowledge about manufacturing capabilities is progressively accumulated and, the tighter control and definition by manufacturing of procedures necessary for the development of these rules.

Manufacturing sign-off (reciprocal): This procedure enables manufacturing to accept or refuse responsibility for making the product to design specification. There is often a proviso that manufacturing is able to veto the specification if unfeasible, or refuse it if associated documentation is insufficient.

Producibility design reviews (reciprocal): According to Carter and Ellram (1994, p. 16): "Product design review is a detailed reassessment of the configuration and tolerances of parts manufactured by a process. The *objective ... is to optimize* a product's design, given an understanding of its intended use." They advocate design reviews as a mechanism for improved product quality. In an exploratory study in one buyer-supplier relationship, they compared the effectiveness of product design review with process capability analysis, and found that 95.8% of the quality improvement in the product was attributable to the functioning product review committee. Design reviews are common *within* the design process: as end-of-design-cycle reviews, as reviews of completed designs (such as Stage Gates), or as specialist reviews addressing the issue of producibility, thus incorporating manufacturing (producibility) engineers. A balance is required as to when this review occurs: if at the end of the design cycle, the design may be performance-optimised, but not producible in manufacturing's view! In addition, Adler (1995) found that one company in his study resisted producibility improvements at this stage, since the *knock-on* affect to related components meant time-consuming revisions to already accomplished design work. Adler (1988, p.38) argues that manufacturing (producibility) engineers who review design *in-progress* need to be located within the design function to maximise frequency of informal consultation.[7]

Joint product/process design teams (iterative): Joint design teams enable manufacturing engineers to begin developing process designs at an early stage, and offer informal advice to product designers on producibility aspects of emerging designs (Adler, 1995). These become necessary when manufacturing's needs cannot be suitably captured by tacit knowledge of designers, design rules, manufacturing sign-offs, or design reviews. Whilst preliminary definition may have been discussed at pre-project stage, it is joint teams that manage the finer detail at the project phase. As Adler (1988, p.33) remarks: "Truly joint teams are rare; a more common procedure allowing two-way information flow - albeit stilted - between manufacturing and design is the design review."

4.4.4.3 Manufacturing-phase (post-design) coordination

This phase requires coordination after the release of design data to manufacturing or a more refined characterisation of the product design has been specified. The result of this phase is a product that customers will accept.

Manufacturing flexibility (sequential): Manufacturing has long been the domain of individuals expected to turn drawings into reality. This often meant working around drawings (so-called *tweaking*) to make sense of them - that is, from a manufacturing (producibility) perspective! One improvement to this *non-coordination* perspective has been to build flexibility into manufacturing operations (see Slack, 1991, Chapter 5) and Corrêa (1994) for a detailed discussion of manufacturing flexibility). Adler (1988) suggests this is the second most popular form of post-design coordination, behind engineering changes.

Early release of design data (sequential): The early release of design data provides manufacturing with the opportunity to begin preliminary work on verifying producibility problems of the design, as well as instruct the parallel development of process design.

Production prototypes (reciprocal): A schedule-based form of coordination is the use of prototypes. There are various occasions when prototypes may be used (Wheelwright and Clark, 1992, Chapter 10): *mock-up* prototypes are used for addressing product design issues at concept and engineering stages; and, design-build-test cycles address product/process fit issues at pilot production stage. Complete system prototypes tend to be constructed at concept and pilot production stages, whereas subsystem and component levels are more generally used to address specific integration queries.

Engineering changes (reciprocal): Engineering changes enable manufacturing, marketing, and even customers to propose changes to the product design, and is a commonly used form of mutual adaptation:

> In a frequently-encountered scenario, design 'throws the drawings over the wall' to manufacturing, and in subsequent months manufacturing sends back a list of changes required to ensure design producibility. (Adler, 1995, p. 156)

An important issue for companies is how to manage effectively the timing and communication of engineering changes. One technological solution is the use of product data management (PDM) systems, which can ensure downstream changes return swiftly and accurately to upstream activities. However, as Twigg (1989) found, many systems track design changes, but do not necessarily keep all relevant parties informed. Clark and Fujimoto (1991, p. 121) suggest learning from the Japanese experience, where only changes that add value to the product take place after final release of drawings, but the necessity of any such changes are minimised through early, meaningful and fast implementation, rather than the bureaucratic checks and balances epitomised in Europe and the USA.

Transition teams (iterative): An improvement to the engineering change procedure may be made by co-locating design engineers in manufacturing, after design sign-off to manufacturing, thus forming a *transition team*. Design engineers are seconded on a temporary assignment, but in a full-time capacity, thus enabling problems encountered in the early stages of manufacture to be resolved quickly - fast feedback of engineering changes. However, whereas the previous mechanism distances the two functions, co-location helps alleviate the common problem of design personnel moving to a new project on release to manufacturing and thus being reluctant to revise now *old* designs. An advantage of this form of coordination is that it enables design engineers to have first-hand experience of the design/process fit issues, for input to future projects (see *designer's tacit knowledge of manufacturing*).

An additional mechanism that may be used after the entire project has reached volume levels of production is the *post-project appraisal* (referred to earlier in figure 4.3). This would appear from the literature to be practised rarely, but where it is, inter-functional dialogue is encouraged. One tool used in these appraisals is the project data (in terms of tracking costs, time and quality performance) held in management information systems; such reviews are only beneficial if lessons are learned and appropriate action taken in future projects.

4.5 External integration

A typology of internal integration mechanisms has been considered largely based on existing work of functional interface studies. These mechanisms can also be used at the inter-firm perspective. For example, in the automotive industry, component suppliers may be selected largely on their ability to respond quickly to late engineering changes through flexible manufacturing processes; similarly, supplier manufacturing engineers may be invited to the vehicle manufacturer to comment on prototypes at the production build phase. Hence, the mechanisms presented in figure 4.6 have application across firms. However, as suppliers of external engineering resource are increasingly requested to contribute earlier to product development, additional mechanisms must be considered.

Figure 4.7 presents a revised typology of coordination mechanisms for inter-organisational communication. Important additions to the typology are the use of electronic data interchange, supplier development teams and committees, and technological gatekeeper at pre-project phase, the producibility/manufacturing engineer and guest engineer at design phase, and the site engineer at manufacturing phase. These additional mechanisms are now discussed in detail, and specific examples of the previous mechanisms are highlighted where references to particular inter-firm situations provide benefit to the previous discussion.

Figure 4.7 A typology of inter-organisational coordination mechanisms †

	Pre-project phase	Design phase	Manufacturing phase
Standards	Compatibility standards (S) Electronic data interchange (S) CAD/CAM data exchange (S) Cost management (I)	Designers' tacit knowledge of manufacturing (S) Design rules (R)	Early manufacturing start with early design data (S) Manufacturing flexibility (S)
Schedules and plans	Capabilities development schedules (I) Relationship assessment (R)	Sign-off (R)	Production prototypes I. engineering fit II. build-test cycles (R)
Mutual adjustment‡	Supplier development committee(I) Gatekeeper (R)	Producibility design reviews (R) Producibility/ manufacturing engineer (R) Guest engineer (R)	Engineering changes (R) Site engineer (R)
Teams	Supplier development team (I) Joint development (I)	Joint product/process design team (I)	Transition team (I)

Notes: † Three types of information flow: S - sequential; R - reciprocal; I - iterative

‡ An additional mechanism is available, that of post-project appraisal (I)

4.5.1 Pre-project phase coordination

Electronic data interchange (sequential): Electronic data interchange (EDI) enables the electronic transfer of information (both intra and inter-firm) through computers. Increasingly, this is being done by EDI service suppliers, through a value-added network (VAN). Originally, EDI was used for routine transactions, such as purchase orders and invoicing, but it is now receiving wider application, such as integrating electronic mail systems, and exchanging engineering graphics and NC programming data. EDI has two major benefits in supply coordination: the elimination of re-keying the same information into different computer systems; and the reduction of errors (Bessant, 1991). However, much of the benefit of EDI accrues where systems are directly compatible, and it will be several more years until an EDI standard is widely adopted. One estimate is that the International Standards Organisation's EDIFACT will be responsible for 90 per cent of European EDI transfers by 1997 (*The Financial Times*, 23 October 1993).

It is likely, therefore, that the role of EDI service suppliers will continue as they compete on guaranteeing successful data exchange between systems, particularly if customers continue to use different EDI systems. However, for EDI to be effective, there must be trust within the supply relationship. Lamming (1993, p. 198) adds a cautionary note to the effectiveness of EDI, citing problems, in the 1980s, of mistrust and ownership of drawings. He sees the full use of EDI developing where the partnership model is established.

CAD/CAM data exchange (sequential): One means of coordinating design activities is through the transfer of design information. Traditionally this has been through the medium of blueprint drawings. However, since the early 1980s, the widespread use of CAD/CAM has witessed the experimentation of CAD/CAM data exchange. CAD/CAM data exchange is a particular form of EDI warranting separate discussion because it plays a significant role within inter-firm *design* relationships. Three basic types of exchange can be identified: (1) identical system, requiring no changes; (2) direct translation, where a specific conversion is made between two different systems; and (3) neutral format (for example, SET, IGES, and VDA-FS).

In the automotive industry, the transfer of design data electronically with suppliers has been encouraged since the mid-1980s. To this end, Ford, Rover and Jaguar were amongst the first UK companies to use neutral formats in 1983-84 (Barley, 1989). The importance of a compatible CAD/CAM system, or a reliable exchange system, was recognised by Twigg (1990): in a study of CAD/CAM adoption by Rover suppliers in 1987/8, many firms had selected systems capable of successfully exchanging CAD/CAM data with their customers (not solely Rover). These suppliers tended to require significant iteration with their customer in design work, especially in aesthetic and safety critical work. This phenomenon was mirrored by the non-adopters interviewed, who expressed a need to purchase directly compatible systems where iterative design relationships existed. This situation was eased with the provision of dedicated bureau services (such as Deltacam, Birmingham) and the position of Prime-Computervision as a significant vendor to Rover, Jaguar and Ford in the UK.

Cost management (iterative): Understanding the cost of design, development and production of a new product helps focus attention on the total design. By implementing a cost management system as part of all new projects, suppliers and customers can work together on delivering an optimised product, given available resource. For example, as part of Rover's RG2000 programme, suppliers are expected to provide detailed operating costs, and for all new projects Rover design engineers are given responsibility for component costs (*Management Today*, 1 May 1992). In a similar mode, Ford established 200 teams comprising Ford and supplier personnel to apply cost reduction analysis to selected components. They analysed the entire supply chain from design to finished vehicle, with the aim of eliminating waste throughout the supply chain (*The Financial Times*, 12 July 1994).

Relationship assessment (reciprocal): The establishment of a relationship assessment - as opposed to an asymmetric supplier assessment - programme may act as a catalyst for coordination through highlighting deficiencies in existing mechanisms and processes. Lamming (1994), in a report on supply relationships, indicates only 28 per cent of suppliers conduct formal appraisals of their customers. Since integration of design activities requires iterative (or reciprocal) communication, a relationship assessment would seem an appropriate mechanism to focus effectiveness.

Supplier development committee (iterative): In the same way that coordination committees act on intra-firm development, supplier development committees provide a forum for selected suppliers to assist in improving supplier development programmes. These committees are highly selective, based in part on openness between the parties.

Lamming (1993, p. 215), for example, sees supplier development as: "the natural companion for cost transparency ..." Hence, supply relationships that are based on the disclosure of information will enable customers to provide insight to the suppliers operations, and conversely, for suppliers to comment on customer's operations (Lamming, 1993; Macbeth and Ferguson, 1994).

Gatekeeper (reciprocal): The literature also identifies individuals, *gatekeepers* (Allen, 1977) or boundary-spanning roles (Tushman, 1977 and 1979), who are gatherers of information, and advisors on technological matters. In his study of scientific laboratories, Allen (1977) observed a number of key personnel to whom others sought technical advice. He characterised these *technological gatekeepers* as high technical performers, who were generally first-line supervisors, and who had exposure to external technical sources (including refereed journals). However, Allen cautions that the use of gatekeepers should remain informal.

Despite this caution of Allen's, a formalised form of gatekeeper is emerging. This is generally a person who resides in the organisation and maintains a constant awareness of the available skills in the supply and knowledge bases external to the company, which may be used for new product programmes when required. Hayes *et al* (1988, p.113) refer to this emergent form of gatekeeper: staff of long-standing experience in their industries, whose network of acquaintances in suppliers, customers and competitors place them at the forefront of learning about new technological developments. Macdonald and Williams (1992), in a study of 125 gatekeepers, found an equal split between those who formally or informally gathered technological information as part of their job responsibility.

Supplier development teams (iterative): Many customers have established supplier development teams who assist suppliers in improving their operations performance; typical applications are in quality, and in eliminating design and manufacturing problems. The aim is for these teams to be a temporary measure, to raise supplier competence to the requisite level, and for the supplier to self-sustain the required performance (Macbeth and Ferguson, 1994).

Joint development (iterative): Joint development at the inter-organisational level includes the involvement of suppliers at pre-concept stage. This will be elaborated on in Chapter Five, but suffice it to mention that early supplier input to product development is becoming more widespread (Birou and Fawcett, 1994). However, the occasions when concept designers and suppliers meet to iterate potential assembly issues are rare indeed. In a meeting at a vehicle manufacturer in April 1995, a number of suppliers were invited to discuss supply issues for a power-assisted steering pump with product and concept designers, manufacturing engineers, and purchasing representatives from the vehicle manufacturer. It was noted by all parties that this was the first occasion that all participants in the design, development and manufacture of this component system had met in one place! One finding of the meeting was the high variation in standard fasteners being used across the product range: this caused assembly and inventory difficulties. There was no objection from the design engineers towards the standardisation of fewer fastener variants, and carrying these over in future projects. Hence, early joint development can enable manufacturing issues to be resolved upstream in the process.

4.5.2 Design-phase coordination

Producibility/manufacturing engineer (reciprocal): An example of a supplier manufacturing engineer is provided in Appleby and Twigg (1988). In 1987, a prototype inlet manifold for the award-winning Rover *K-series* engine was being developed. Design responsibility lay with Rover's product designers, but the tacit knowledge of process (aluminium sand casting), tool design, and so forth, lay outside Rover's expertise, and required external input from the supplier and toolmaker.[8] Suppliers may act more directly to promote their process knowledge to the vehicle manufacturer. Around Detroit (USA) many plastics' suppliers maintain *technical application centres* to assist in plastic componentry design and analysis. Along with computer analysis facilities, plastics' engineers are providing advice to vehicle designers on plastic's material technology (*Machine Design*, 8 August 1994).

Guest engineer (reciprocal): Guest engineers are technical specialists who are employees of a *supplier* of technology or design expertise, but who reside on a permanent or semi-permanent basis at a *customer* organisation.[9] Their purpose is to ensure the effective integration of a supplier's technological expertise with the customer's needs. They may only maintain contact with their *home* company on a weekly basis, whilst working full-time with the design team of their host customer. This form of coordination was introduced into Honda's simultaneous engineering teams in the late

1970s (Hartley and Mortimer, 1990) and is frequently used in Japan.[10] It is now finding widespread use within the world's automotive industry, but reference to it in the literature is a little sporadic, and its meaning often assumed (see for example Clark, 1989, p.1261). Although referring to the exchange of customer experts into suppliers (so-called *resident experts*), Macbeth and Ferguson (1994, p. 85) highlight a major concern of relevance to guest engineers: "The mandating of such [resident] experts is a big issue so that there is no doubt in anyone's minds about the acceptable range of decisions such people are empowered to make."

Joint product/process design team (iterative): An example of an inter-organisational design team is provided by the re-design of the console fascia for the Rover 200/400.[11] The original console had been designed by Honda in three sections, using 12 fasteners and anti-squeak tape. Rover wanted a one-piece component, and formed a project team comprising of material supplier, finished component supplier, a toolmaker and two modelmakers. The result was an improved and quicker fitting fascia, a significant reduction in the amount of anti-squeak tape used, and parts no longer required painting. Overall there was a saving of one million pounds Sterling for Rover.

4.5.3 Manufacturing-phase coordination

Site engineer (reciprocal): Site engineers are an extension to the supplier development team, discussed earlier. They are customer employees who provide specific input at the supplier firm to tackle on-going difficulties at the prototype or manufacturing stage.

4.6 Interdependency and coordination

Coordination mechanisms are used to assist meeting information processing needs, where there is uncertainty and interdependence between tasks and environment. At the design/manufacturing interface, for example, these mechanisms can help ensure product/process fit at both intra and inter-firm levels. If the use of mechanisms is extended to other interfaces, at both levels, then product, process and customer fit can be examined. Customer fit in this context is similar to the external integration considered by Fujimoto (1989).

Depending on the uncertainty of this fit between information processing needs and capabilities (see figure 4.1), different coordination mechanisms are needed. This uncertainty has two dimensions: the degree of interdependence, and the degree of analysability (Adler 1995). Various studies have examined these dimensions, *vis-à-vis* alternative coordination mechanisms (for example, Adler 1995; Tushman and Nadler, 1978; Van de Ven *et al*, 1976). It is generally accepted, since March and Simon (1958), that as tasks increase their need for greater intensity of information transfer, due to greater interdependency, there is a tendency to move towards higher level mechanisms. The use of teams and integrating technological systems gain in necessity, for example, as additions to standards and plans. Van de Ven *et al* found the least costly mechanisms (impersonal rules and plans) were used the most for intra-organisational coordination, whilst lateral relations and group meetings were used the least, due largely to their perception as being inefficient and costly.[12] Hence, an ordering of mechanisms can be established based on, *inter alia*, complexity, cost and information processing capacity

(Tushman and Nadler, 1978). In general, firms will attempt to reduce uncertainty through the lower order mechanisms. Figure 4.8 illustrates this effect.

It should be noted, however, that the ranking in figure 4.8 does not infer increasing effectiveness. There are no *ideal* forms of coordination, since effective use of integration mechanisms is context specific. For any development project, there may be more than one product/process fit problem, for example, each requiring different levels of interdependence. Similarly, the degree of interpretability reduces as a product moves from concept to market (Adler 1995). In the early stages of concept, the project is abstract in nature, becomes less abstract as design specifications are detailed, and realises

Figure 4.8 Mechanisms for coordination and control

Mechanism	**Complexity**	**Cost †**	**Information processing capacity**
1. Rules and programs	Simple	Cheap	Low
2. Hierarchy	↓	↓	↓
3. Joint planning			
4. Either or both			
↙ Formal information systems (e.g. MIS) ↘ Lateral relations (e.g. teams)	Complex	Costly	High

Note: † see footnote 12 for a counter argument on costs

Source: Tushman and Nadler (1978, figure 2) concrete character as production ramp-up begins. Similarly, each mechanism is only as good as its ability to resolve a problem. Adler (1995) refers to a case where a joint product/process design team appeared to have an impossible task to solve: there were thousands of constraints to which an aircraft's tubing route had to satisfy; the manufacturing engineers were unable to solve these at design stage, and it was only after a CAD system provided a representation of the aircraft that the tubing fit could be analysed against the constraints.

Hence, "the optimal coordination approach for the project will involve a portfolio of mechanisms, the mix being determined by the relative importance of the different types of fit problems" (Adler, 1995; p.159). For example, a firm may use manufacturing staff early in the design phase to set general standards, but then rely upon sign-offs to check their compliance; others may designate liaison staff to conduct occasional in-progress design reviews, whilst others may implement fully integrated design teams.

Hence, one might predict that the choice of integration mechanism will be a function of the character of the development required, whereby the level of carry-over parts being used, or the *newness* of project (minor refinements versus major changes) will determine the required level of fit.

4.7 Summary

This chapter began by presenting an inter-organisational framework for considering coordination of product development. Its purpose was to link the previous chapters on product development and the information systems perspective to the mechanisms available to coordinate the inter-organisational process. This differs from the work of Bensaou (1992) due to the concentration on following the product development process and on examining a range of alternative mechanisms, rather than analysing their dimensions. The examination of coordination mechanisms began with consideration of those used in organisational design, and their application to the organisational-technology integration issue in previous work by the author (see for example Winch *et al*, 1991). An alternative typology by Adler (1988 and 1995) was examined and extended as an appropriate typology of inter-organisational coordination.

NOTES

1. Adler (1988) also considers industry characteristics a further factor.
2. The original list of Winch *et al* (1991) included technological integration mechanisms suitable for CAD/CAM implementation: these are dealt with elsewhere in this chapter.
3. A sixth option exists, namely, ignoring any coordination: thus during the pre-project phase one might find a situation of anarchy, with design proceeding to throw *their* designs over the proverbial wall, and manufacturing working around any problems to deliver *a* product (emphasis intended).
4. Adler (1988; 1995) uses these phases in a notional form to help clarify the range of coordination possibilities, whilst acknowledging that there is overlap between the stages.
5. This revised categorisation of information flows was used in a survey of CAD/CAM implementation by Winch *et al* (1991). The work demonstrates the variety and distribution of mechanisms used by firms for engineering/manufacturing coordination.
6. Adler (1995) recognises the possibility to sub-divide further - distinguishing conceptual design from detail design, and pilot production from mature production - particularly since coordination takes different forms within each.
7. However, in his later report, Adler (1995, p.155) notes that most manufacturing engineers who reported to design management progressively lost the acuity of their manufacturing point of view. Similar arguments are given in Twigg (1989), where the design and manufacturing operations of a vehicle manufacturer are separated by site, and the traditional input of

manufacturing 'over a drink in the social club' had been lost to the design engineers. To counter this loss, manufacturing engineers were seconded to Engineering, under the project manager's authority. However, after several years in this role, they were beginning to lose identity from their manufacturing peers, whilst maintaining an *outsider* label from the surrogate engineering group.

8. At the time of interview, the supplier saw no need for acquiring CAD, assured that their expert knowledge would secure the production contract. Some years later the author met the design engineer for this project who confirmed the essential input of that particular supplier and toolmaker. His footnote to this recollection was that after the prototype work, the production contract was given to a rival supplier, whose *design* expertise was not necessarily on a par with the other. This is an example of the adversarial relationships that existed at that time.
9. This definition of guest engineers differs from that of Lamming (1994) who sees them as: (1) employees of the customer who are located at the supplier, working on process and product improvements; or (2) employees of the supplier working at the customer. This first definition is similar to that of site engineer in the presented typology.
10. Womack *et al* (1990, pp. 146-7) cite several examples of resident design engineers assigned by Japanese first tier suppliers to work in customers development teams up to two to three years prior to production.
11. 'One-piece console breakthrough', *Engineering*, Vol. 233, No. 1, 1993, p. 12
12. As higher levels of interactions are involved, a natural assumption is that the overall cost of implementing these mechanisms will increase. Adler (1995, pp. 160-1), however, hypothesises that differences will occur dependent on the complexity of product. Where, for example, complexity of product/process fit is high, then the overall cost may be lower: lower levels of interaction may require frequent iterations (hence, become time-consuming), and it may be impossible to formulate standards; in contrast, the team approach may be more cost effective since this provides a forum for dealing specifically with complexity!

5 INTER-FIRM ROLES IN AUTOMOTIVE DESIGN AND DEVELOPMENT

5.1 Introduction

In Chapter One, the main components of design chains were outlined, and subsequent chapters have sought to demonstrate issues relating to their management. In this chapter this theme will be explored further by examining the inter-firm design and development process.

The previous chapters have emphasised the importance of upstream stages of the product development process to the cost, timing and quality of manufactured product; this is the embryo of design chain management. In the same way that the manufacture of a product requires inputs, the design and development of a product require the accumulation and codifying of information, such as customer requirements, advances in technology, manufacturing process knowledge and so forth. These inputs may be internalised by the firm as vertical integration, which has been the traditional form of design work, or external resources may be utilised, as Clark and Starkey (1988, p.80) indicate:

> Previously design had been conceived as an activity always undertaken within the vertically integrated enterprise as in the case of Ford ... However, design may be subcontracted and bought in, or designers may subcontract supply and assembly whilst retaining control over aspects of distribution.

A good illustration of such an approach is found in the retail and textile industry. Since the mid-1920s, the retail company Marks and Spencer has taken over the control of design throughout an entire *filière* or chain. (Similarly, in Italy, the specialist textiles firm, Benetton, has developed a strong control over design with its suppliers.) Marks and Spencer now plays a dominant role as the focal enterprise shaping the directions of design for its suppliers, insofar as it has established networks of knowledge and competencies that involve over 800 suppliers of raw materials, equipment suppliers and finished goods (Clark and Starkey, 1988). In these relationships, Marks and Spencer acts as coordinator of design activities, and buyer of finished goods.

K.B. Clark (1989), in his study of supplier involvement in automotive product development, recommends a re-thinking of the traditional concepts of vertically integrated supply:

> There is evidence ... that integration of capability between upstream and downstream firms without financial ownership (i.e. an integrated supplier network) may be more effective in developing new technology and new products than an enterprise where the upstream firm is a wholly owned subsidiary of the downstream firm. At least in the development process, the implication is that the vertically integrated firm actually is less integrated than the network of independent suppliers. (p. 1261)

As P.A. Clark notes, in earlier work on the Rover SD1 project with Whipp:

> Since [the 1960s and 1970s], many corporations have reassessed their in-house specialists and have concluded that external agencies are a superior source of [design, innovation, and R&D] advice. This conclusion is largely based on the simple fact that external agencies specialize in *new problems* which require the learning of new analytical skills. The external agency experiences the new problems in a variety of settings and therefore has the best opportunity to shape the problems and to design novel, appropriate solutions. (Whipp and Clark, 1986, p. 203, italics in original)

One benefit the notion of design chain management may have is in helping focus attention on the inter-firm development process. The field of economics refers to this process as *inter-firm innovation*; however, the use of this term lacks appreciation of the dynamic interaction of participants throughout the development of the product or the managerial decisions required to coordinate and synchronise the various operations. Innovation is seen as the commercialisation of the R&D activity, often internal to the firm, or as an inter-firm activity where design contributions are received as licences or joint ventures. It assumes a black box that transforms R&D inputs into a commercial product, with little exploration of the operations activities therein. As Whipp and Clark (1986, p.128) also acknowledge, the contribution of certain parties (notably component suppliers and production workers) to design in the automotive industry were not commonly recognised in the innovation literature at that time; however since, attention has been drawn towards the concept of networks - in particular, technological networks.

5.2 Technological networks

One of the earliest references to the *network* is the concept of *organisation-set* proposed by Evan (1966), in which the firm operates in a set of relationships with other organisations delivering and receiving inputs and outputs, and regulating their activities. It was not until the mid-1980s, however, that the concept of networks received renewed interest, mainly for investigating inter-firm relationships, and for understanding the strategies, structure and management processes therein. This has been particularly strong in the fields of marketing and purchasing, industrial economics, and strategic management. DeBresson and Amesse (1991), in their review of the literature, deduce that three conditions are likely to induce firms to enter this form of inter-organisational design: strong technological and market uncertainties; the need for multiple sets of complementary technical developments, which even the largest firms cannot acquire; and, the possibility of super-additive gains.

The concept of network has found wide acceptance in the inter-firm exchange of design/development information (Håkansson *et al*, 1987; Clark and Staunton, 1989; a special issue of *Research Policy*: see DeBresson and Amesse, 1991 and Freeman, 1991). When supplier inputs of technological knowledge have been examined as part of a network, they have largely been seen in terms of process innovations (suppliers of equipment), or the supply of basic/applied research, such as scientific laboratories (Håkansson *et al*, 1987; Häusler *et al*, 1994). Westney (1988) sees this as a firm's external *knowledge network*, consisting of both suppliers for developing new knowledge, but also others from whom to draw upon for existing knowledge. Whilst the term *network* has been widely used, many different forms of relationship are regarded within the concept, for example, *filière*, *milieu* or *chain* (Clark and Staunton, 1989, p. 159).

5.2.1 Characteristics of networks

Håkansson (1987) defines a network on three dimensions: actors, activities and resources. In every network, there are actors and a focal firm: in this thesis, the focal firm is the Rover Group, and the other actors are their suppliers. Each performs or controls operations, and controls particular resources and knowledge. Two types of activity are present within the network: transformation, and transaction. Transformation activities centre on the operations of the actor, whereas transaction activities link these transformation operations, perhaps across many linkages. Hence, a key feature of the network is the development of long chains and clustering of activities around particular operations; these may remain within specific sectors, but may also cross them. In the hydraulics sector, for example, Håkansson (1989, p. 141) found that:

> Some actors try to operate in various network combinations connected with the hydraulics field, something which is also reflected in their identity, as well as their resource base and structure of their activities. Other companies instead combine a network in hydraulics with a network in some other technological area such as electronics or rubber.

This is an important observation since firms determine which networks they belong to on the complementarity of their assets (Teece, 1986) *vis-à-vis* those assets of others with whom they seek to collaborate. If these complementary assets are balanced, the interdependence between actors and activities will lead to more efficient forms of transaction as each actor learns to perform these activities better. The most common types of dependencies affecting product development networks are technical, knowledge, social and logistic (or administrative) dependencies (Håkansson, 1987). As these transactions become more established and stable, routines and informal rules will be created (Håkansson, 1987, p. 16). It is this informal nature of networks, sometimes referred to as *milieu* relationships, that plays a significant role in the success of collaboration (Czepiel, 1979; Häusler *et al*, 1994).[1]

Four further dimensions help characterise a network: first, the *functional* interdependency across transactions; second, the power actors exert through the control of the activities; third, the current and previous knowledge and experience of the actors define the activities within the network; and, fourth, the network develops and changes over time, bringing in (and discarding) new actors and operations, and resources

(Håkansson, 1987). An example of this from the 1980s was General Motors' purchase of the Hughes aircraft company to exploit electronic design capabilities in car design.

Lawrence and Dwyer (1983) suggest three types of coordinating relationship can be identified within an inter-firm network: markets, hierarchies, and clans. The first two derive from the work of Williamson (1975), who argues that inter-firm transactions will be organised around either a price mechanism (the market) or hierarchy (the firm).[2] The clan relationship, on the other hand, is based on long-standing transactions, often of an informal tacit nature. Williamson (1975) identifies three determinants of transaction costs: asset specificity; uncertainty; and frequency. It is argued that if the asset specificity of a particular transaction is high, firms will tend towards internalising these costs through vertical integration.[3] If one considers technological asset specificity, however, this argument may not run true. In circumstances of short product development times, and increasing sophistication of technology, one benefit of a specialist supplier will be the ability to appropriate learning from the customers with whom it collaborates. Over time, a positive-sum gain may appreciate to all customers by the intimate relationship the supplier shares with each one of them. If this supplier was subsumed into the corporate giant, this technological learning may be severely reduced. Therefore, consideration must be given to the opportunity cost of the transaction.

Some authors have emphasised the organisational learning aspects of partnerships. Westney (1988, p. 344) indicates two dimensions of their learning curves: how to manage the relationship between partners and, how to transfer learning effectively throughout the firm, and then how to add value to it for improving products, services, or processes. Doz (1988) reinforces this need of managing the interface. In his examination of technology partnerships, he concludes that managerial, rather than technical, reasons are strong causes of collaborative failures, and suggests three areas to consider. First, whilst initial collaboration is based on strategic complementarity, long-term partnerships require management of cultural differences, uncertainties, and misunderstandings, as well as the elimination of hidden agendas. Second, a joint coordinated approach is required from both partners, especially from senior management. Third, consideration should be given to *managing* the operating interfaces, rather than allowing *ad hoc* adjustments to develop.

5.2.2 Types of technical collaboration

Firms may choose to collaborate for many different reasons; table 5.1 lists those reasons identified by Contractor and Lorange (1988), with two additions from Dodgson (1991, cited in Lamming, 1993). Alongside each entry, examples have been extrapolated from Lamming's review to indicate some of the joint ventures within the automotive industry. It is noteworthy that within this thesis, the reasons of *complementary technologies* and *vertical quasi-integration* are strong reasons for closer collaboration with suppliers within the design chain paradigm. The increasing use of component systems in vehicle design is making necessary collaborative links between previously unconnected suppliers. Not only is the sharing of design responsibility becoming increasingly necessary between assembler and supplier (vertical quasi-integration), but the modular and system design discussed in Chapter Three is requiring suppliers to collaborate with other suppliers who have complementary assets to complete the project (such as the Ford modular door listed in table 5.1). Together, these form the long chains and clusters characteristic of the

Table 5.1 Strategic contributions of joint ventures

Reasons for collaboration	Automotive examples[†]
• *Risk reduction* Product portfolio diversification Dispersion and/or reduction of fixed costs Lower total capital investment Technological uncertainty[‡]	Active suspension systems (Moog/ Lotus) Allante prestige sports model (GM Cadillac/ Pininfarina)
• *Economies of scale and/or rationalisation* Lower average cost from larger volume Lower cost by using comparative advantage of each partner	Several car models (Honda/ Rover)
• *Complementary technologies and patents* Technological synergy Exchange of patents and territories	Ford's request for modular doors (Budd/ Johnson Controls/ Standard Parts)
• *Co-opting or blocking competition* Defensive joint ventures to reduce competition Offensive joint ventures to increase costs and/or lower market share for a third company	(Caterpillar Tractor/ Mitsubishi)[§]
• *Overcoming government-mandated investment or trade barrier* Receiving permit to operate as a 'local' entity because of a local partner Satisfying local content requirements	Ikeda Hoover supplying seats to Nissan (UK) (US Hoover/ Ikeda Bussan)
• *Initial international expansion* Benefit from local partner's know-how	NUMMI (GM/ Toyota)
• *Vertical quasi-integration* Access to materials, technology, labour, capital, and distribution channels Regulatory permits Benefits from brand recognition Establishing links with major buyers Drawing on existing fixed marketing establishment	N/A
• *Technological complexity*[‡]	N/A

Sources: Contractor and Lorange (1988, table 1-2); † Lamming (1993, pp. 87-89); ‡ Dodgson (1991, cited in Lamming, 1993); § Contractor and Lorange (1988) network concept. Hence, similarities of these collaborative reasons can be found with the three categories of technical cooperation in networks defined by Håkansson (1987): *horizontal complementary* cooperation (akin to complementary technologies); *vertical* cooperation (akin to vertical quasi-integration); and *horizontal competitive* cooperation.

Freeman (1991), referring specifically to innovation networks, categorises 10 types of network (table 5.2). He stresses that these are not mutually exclusive and the larger firms may engage in multiple types of relationship. This list differs from many of the previous views of network collaborations, in that it extends a widely held view of collaboration existing within advanced R&D facilities, to include the contractual and non-contractual transfer of knowledge and design expertise.[4] In particular, he recognises the role of subcontracting and supplier networks in innovation, and of informal networks.

Table 5.2 Categories of innovation network

1. Joint ventures and Research Corporations
2. Joint R&D agreements
3. Technology exchange agreements
4. Direct investments (minority holdings) motivated by technology factors
5. Licensing and second-sourcing agreements
6. Sub-contracting, production-sharing and supplier networks
7. Research Associations
8. Government-sponsored joint research programmes
9. Computerised data banks and value-added networks for technical and scientific exchange
10. Other networks, including informal networks

Source: Freeman (1991, table 1)

5.3 Approaches to managing design expertise

The first stage in assessing how to manage design expertise is to consider the available engineering resources in terms of its capabilities (knowledge and skills). The process of product design and development requires the accumulation and codifying of knowledge in the form of a product. How this is achieved will depend on the availability of resources and expertise (competencies) to convert these into the product. A firm must decide how it is to balance these resources since, in the case of complex products, it is unlikely to be able to retain all available resources and expertise to design, manufacture, distribute and market the product. Where design is concerned, a firm may consider realising its capabilities, and utilising those of other firms as bought-in expertise.

5.3.1 Core capabilities

In recent years, there has been much discussion given to the core competencies (or capabilities) of a firm, and hence to concentrate internal resources on those tasks that maintain the firm's competitive advantage. NEC, for example, has had great success through over 100 strategic alliances, enabling access to technological expertise (particularly in semi-conductors) whilst maintaining a core strength in components and central processors - its *strategic architecture* (Prahalad and Hamel, 1990, p. 80).

The core capabilities of a firm have been defined in various ways, as:

- "... the collective learning in the organization." (Prahalad and Hamel, 1990, p. 82)

- "a set of differentiated skills, complementary assets, and routines that provide the basis for a firm's competitive capacities and sustainable advantage in a particular business." (Teece, Pisano and Schuen, 1990, p.28; cited in Leonard-Barton, 1992, p. 112)
- "the knowledge set that distinguishes and provides a competitive advantage." (Leonard-Barton, 1992, p. 113)

Applying this notion of core capabilities, Leonard-Barton (1992) examines the management of new product and process development projects, and identifies four dimensions of its knowledge-based capabilities: first, *knowledge* and *skills* embodied in people (often tacit in nature); second, knowledge embedded in *technical systems* (includes both information and procedures); third, *managerial systems* (informal and formal ways of creating and controlling knowledge); and fourth, *values* and *norms* in undertaking the other three dimensions. She notes that this dimension is often overlooked.

A firm will assign different importance to each of these dimensions, which is the hallmark of its character: for example, a design studio may rely heavily on the knowledge embodied within its employees (skills). Leonard-Barton stresses that a firm's core capabilities are evolving and that a firm's survival depends upon successfully managing that evolution. Therefore, managers of new development projects face a paradox: "core capabilities *simultaneously* enhance and inhibit development." (Leonard-Barton, 1992, p. 112, italics in original) Table 5.3 compares the positive aspects of a firm's capabilities with the potential rigidities that may ensue from such a focused strategy. She cites several companies who managed these rigidities through various activities, namely:

benchmarking against *best practice* operations; using cross-functional integration; and seconding engineers through job rotation. She concludes that all four dimensions will need to be addressed if a capability is to become a core activity.

Table 5.3 The paradox of core capabilities in development projects

Dimension	**Capabilities (positive)**	**Rigidities (negative)**
Skills/ knowledge	Excellence of project members (such as professional elite)	Weakness to attract and retain elite in non-dominant disciplines
	Technical sophistication of company staff to perform intra-firm testing, for example	
Technical system	Accumulated knowledge of past talented staff embodied in the systems, procedures and tools	Skills and processes in software or hardware become outdated quickly
Managerial expertise system career	Mechanisms to encourage innovation (such as reward and incentive systems)	Dominance of technical vs. project management in development
Values and norms	Power and ability of individual project members to champion innovation (empowerment)	Expectation of rewards for innovative actions (empowerment as entitlement)
	Cultural bias toward a dominant discipline (with associated higher status for it)	Lower status for non-dominant disciplines (hinders cross-functional integration), for example: • who travels to whom? • self-fulfilling expectations; • unequal credibility; • wrong language.

Source: compiled from Leonard-Barton (1992)

A practical application of core capabilities is provided by Venkatesan (1992) who developed a strategic sourcing policy for Cummins based on identifying systems or sub-systems, rather than proprietary, individual components. The main feature is to determine which subsystems are significant for the success of future product generations. To be strategically important, sub-systems must: be perceived by customers as having important product attributes; require highly specialised design and manufacturing skills and specialised physical assets, that few suppliers can provide; and, be technologies where a significant technological lead may be gained. Any decision to maintain them in-house will also depend on the relative advantage of a supplier's design and manufacturing capabilities and whether the company could afford to catch up with the best suppliers and retain design and manufacture.

Venkatesan (1992, p. 102) argues that a distinction should be made between producing a subsystem in-house and *controlling* its design and manufacture by remaining an expert of its architectural knowledge (earlier referred to in Chapter Two). This knowledge requires an elaborate understanding of customer requirements, systems parameters and component specifications that together define the distinct product. It is the control of this aspect of product development that provides a key aspect of a company's competitive advantage. As Venkatesan (1992, p. 103) contends:

> ...when capable subsystem suppliers exist, it is not so important to be able to design and manufacture the subsystem [in this case the engine] in-house as it is to have the ability to specify and control the performance characteristics of the subsystem.

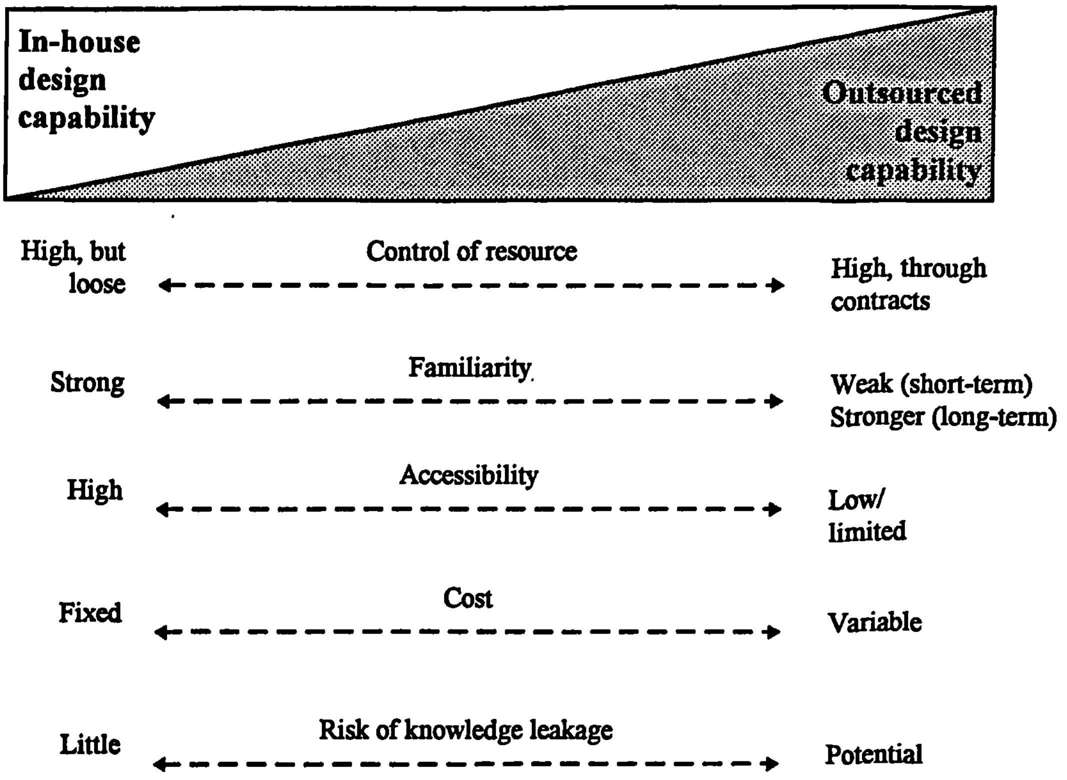
The result of this analysis was the outsourcing of pistons - a component previously considered as strategic. However, to ensure control, Cummins maintains close integration with suppliers through, for example, design analysis and reviews, prototype machining and testing equipment, and manufacturing process validation and certification procedures.

The lessons to be drawn from considering the core capabilities in product development are two-fold. First, a firm must clearly identify what are its critical core capabilities in terms of strategic component systems, thereby enabling selection of outsourcing routes that enhance, rather than diminish, their long-term competence. Second, whatever the sourcing decision, a key competence should be the ability to *manage* (or control) these external inputs. This requires not only suitable coordination mechanisms (see Chapter Four) but also individuals with the competencies to oversee the necessary process and relationships. To achieve these, it is necessary to understand the parameters of design, which are now examined.

5.3.2 Design capabilities

There is a range of alternative design capability choices available to a firm in managing the design and development process. At one extreme of this continuum, a firm may retain all the necessary design capabilities in-house, whilst at the other end, a firm may outsource design work and act as a focal point for the coordination of the design process. Between these extremes, there exist options with varying degrees of internal and external design capability. Figure 5.1 illustrates this range of choices as a simple continuum. As expressed in the previous section, these choices are analogous with the make-or-buy decisions of supply.

Figure 5.1 The design capability continuum



This continuum is similar to the three approaches to design management expressed by Bruce and Morris (1995) - in-house, out-house, and a mixture of the two - and reflects the different design responsibilities of automotive component suppliers identified by Appleby and Twigg (1988). (The specific types of outsourced design capability are discussed in detail later in this chapter.) Laage-Hellman (1987) presents a similar continuum for process development interaction. He argues that, in general, few cases represent the extremes, since process development necessitates interaction between the customer and equipment supplier, consultants and so forth.

Bruce and Morris (1995) present four factors influencing the design management issues of in-house/out-house approaches: accessibility; familiarity; control; and cost. To these factors, a further parameter requires inclusion: risk of knowledge leakage from the design relationship (Dodgson, 1993). Hence, five parameters can be examined which influence the design management choice:

- *Accessibility*: A dilemma along the design capability continuum is to what extent the outsourced design capability is accessible to the focal firm. Three conditions determine this: the complexity of the product, the amount of design work required, and the need to meet deadlines (Bruce and Morris, 1995). Companies have adopted a variety of mechanisms to facilitate accessibility, for example, the use of CAD/CAM technology, guest engineers (engineers from supplier firms who permanently *reside* in the customer company), and multi-media communication (such as video-conferencing).[5]
- *Familiarity*: A competence of importance in the design and development of a new product is familiarity with the corporate product range, manufacturing processes, materials and market requirements (Bruce and Morris, 1995). Internally, this issue has long been of concern. Traditionally, design has thrown drawings *over the-wall* to manufacturing, whereupon much time, effort and cost have been spent tweaking the design to fit manufacturing's requirements. Examination of this internal interface was discussed in Chapter Four where, for example, familiarity of manufacturing's requirements early in the design process through DFM and DFA would assist greatly in shortening development times, quality and overall project management control.

  If this analogy is transferred to the design capability decision, two issues arise. First, in-house design has been regarded as a one-way communication process - vehicle manufacturers design a component and outsource production to the most favourable bid (on whichever competitive bidding criteria are used). No concern is given to DFM or DFA since the designer assumes knowledge of these requirements. For standard items, an *experienced* designer may be able to use this accumulated knowledge. However, for particular elements, communication with component suppliers is vital if unnecessary iterations are to be reduced (Appleby and Twigg, 1988). Second, where process knowledge plays a significant role, the familiarity with this process may lead to the outsourcing decision. Whichever the case, the component supplier has a vital role in the design process, in a similar way to the internal design/manufacturing interface.

Familiarity is thus dependent on communication and the strength of the relationship between focal firm and external engineering resource. Where trust and partnership develop out of supply relationships in the long-term, opportunities may exist to transfer design capabilities too. Lamming (1993, p.183) provides an example of this: Renault transferred design responsibility for all of its seating to a specialist supplier, Epeda Bertrand Faure. The movement towards greater partnership and trust was one reason given by some component manufacturers in their strategic adoption of CAD/CAM systems (Twigg, 1990): expertise in design capability, and effective communication (enhanced through CAD), enabled them to maintain a leading supply role.

- *Control*: Maintaining design capability in-house enables strict control over the design management process. As increased outsourcing occurs, tighter project management skills and controls are required. Whilst the *contract* (with penalty clauses) may act as a driving force for external engineers to work to schedule, this authority becomes weak if effective communication mechanisms are not in place to facilitate its completion. The use of a product data management database may assist in this, combined with regular project review meetings. As Twigg (1990, p.131) argued:

> As the location of design authority is dispersed, there will be an increased need for the automotive company to control the design data - ensuring the interlinking (or marrying) of components with one another. One means ... is for CAD/CAM technology to act as the necessary coordinating medium.

- *Cost*: The overall cost of design resourcing will determine the location of sourcing, and will involve contracting, transaction and negotiation costs (Williamson, 1975). Although external services tend to be costly, Urban *et al* (1987, p. 297) acknowledge that "sometimes the total cost of an internal staff is higher than using outside suppliers on an interim basis ..." An issue of major concern is the allocation of fixed and variable funding, since external design inputs will be funded as a variable cost. A shift to outsourcing may occur if fixed costs are viewed as too great, given limited resource utilisation of specialist staff, or potential lack of maintaining currency of knowledge. Paradoxically, as external sourcing of design becomes an integral part of a firm's development process, and as relationships become stable, this resource may need to be considered as pseudo-fixed. One issue that firms will need to consider is, having moved further towards a greater share of outsourced design, the indirect cost of moving back towards in-house design may be considerably greater.
- *Knowledge leakage*: Whilst deliberate disclosure of commercially sensitive information is unlikely within technological networks (Macdonald, 1993), firms are none-the-less concerned that experience gained through collaboration with a supplier may be transferred to competitors as knowledge embedded with supplier's design capabilities. Clark and Fujimoto (1991, p.142) emphasise one downside risk of using

black box suppliers as being the potential leakage of basic design and styling ideas to competitors. However, a supplier's design capabilities are themselves the accumulation of specialist knowledge from working with a variety of customers, so there is an argument that without supplier collaboration, the benefits of their accumulated design capabilities would not exist and innovation may proceed at a slower rate. Contract research organisations, for example, are often brokers of technology - providing important sources of technical expertise - by using their accumulated up-to-date knowledge and experience, and synthesising it to meet customer requirements (Haour, 1992). A strong argument limiting the risk of knowledge leakage in the automotive industry is presented by Lamming (1993, p. 210, footnote 12), who argues that since the industry is a close-knit community, any leakage would soon be realised, thus discrediting a supplier's reputation.[6]

Considering these issues, a range of influences on design sourcing across the capability continuum can be examined (figure 5.1). The control of in-house resources needs to be high to ensure project success, but it may be relatively loose since all activities can be controlled under organisational mechanisms. Outsourced design requires greater control, but the use of contracts, with penalty clauses for delay acts at the extreme as a powerful measure. Alternative control mechanisms should be sought, however, especially in the long-term as development partnerships rely on trust and cooperation. In-house design has the advantage that there is strong familiarity of the product family, processes and corporate strategy by the designers and engineers. In contrast, outsourcing design generally leads to a weaker understanding of these, especially in the short-term, but where long-term relationships and contracts persist, this familiarity becomes stronger and this factor becomes less differentiated from in-house design. In-house design is generally assumed to be highly accessible to the firm; exceptions to this may exist with multi-site operations, where physical proximity may exclude access to product development partners. Whilst it may be argued that outsourced design capability may be limited in accessibility, determination to complete the design and/or development work may improve access. One influence on locating design resources will be cost. The funds allocated to specific projects take into account the share of both fixed and variable costs. As design operations become leaner, identifying the design and development competencies of a firm, availability of funding for external expertise may limit the extent to which such a strategy may be undertaken. Finally, security of technical knowledge: as explained above, a strong impetus to prevent deliberate dissemination of competitive product knowledge is the threat of *black-listing* due to spurious activities. Despite this, there still remains a potential leakage of technical knowledge through outsourcing design work. It is natural, for example, for a supplier to learn from their experiences and embody these as improvements in their next client's product. Reduced risk, of course, occurs through in-house design. An additional influence on the choice of outsourced design capability will be the long-term relationships that exist with suppliers who are considered development partners (Bruce and Morris, 1995; Lamming, 1993).

The five parameters influencing design management choice apply equally to process technologies as to product. Whitney (1988, p. 88) describes how Nippondenso cultivates in-house development of automation in order to: eliminate proprietary secrecy problems; reduce mark-up costs from equipment vendors; and, build long-term familiarity of the company's design philosophy within the project teams.

Since the capabilities with which a firm wishes to compete do not remain static over time, the design capabilities retained or outsourced by a firm will reflect its strategic response to the competitive environment. Hence, firms traverse the continuum as their operating parameters change. Whipp and Clark (1986), in their study of the Rover car company, illustrate the various design capability transformations that Rover underwent this century:

- *1905-32*: In its infancy, Rover's design capability appears to have been without strategic direction and by *proxy*. For example, in 1905 Rover brought in a contract designer to design and build a small car, assisted by purchasing licences for major components, and in 1910, a new contract designer was hired for 18 months, whose designs formed the basis for cars until 1924. Design was not seen as a specialist function; indeed, the Works Manager was responsible for design, in terms of annual revisions for assembly. Another move to buy in design capability was the acquisition of the Sangster car factory in Birmingham, with its low-cost model. However, the newly released Austin Seven in 1922 competed on cost and out performed the Sangster.
- *1932-71*: Rover undertook a revolution in their design capabilities. After near financial disaster in 1932, Rover developed an internal design capability for the first time, under the direction of S.B. Wilkes - a design engineer. He introduced two significant changes: first, robust car designs[7] were developed which could be stretched over a number of years - the *P-series*; and second, the chassis and engine were standardised as basic components, receiving only incremental development. By the end of this period, internal design teams were responsible for car design; however,

their knowledge base was deficient in a number of areas and thus relied on a number of large suppliers for, *inter alia*, car bodies, dies, assembly line equipment, and paint plants.

- *1971-82*: This period saw an attempt to establish a total design capability. Some of this was due to the facilities present after the creation of the British Leyland Motor Corporation, and the new thinking of executives acquired from Ford. A Specialist Car Division was created, and the *SD1* project was the focus to centre this design capability.[8]
- *1982 onwards*: Again, Rover returned to outsourcing much of its design capability. Linking up with Honda of Japan, Rover has developed a number of robust designs, stretching over a decade or more. Similarly, since the mid-1980s, Rover has increasingly relied upon specialist suppliers for component design work (Appleby and Twigg, 1988). Into the 1990s, Rover has continued to benefit from Honda's design capabilities, and those of notable component suppliers.

Hence, Rover's design capabilities would at first glance appear to have turned full circle. However, car design and production in the 1990s are very much different from the beginning of the century; the complexity of the car has increased immensely over the century, as too has materials knowledge. Also, Rover has never been typical of vehicle manufacturers; for example, unlike Ford, Austin or Morris, design was not seen as a strategic element for Rover until the mid-1920s.

5.4 Design chains in the automotive industry

As a general trend, the increased use of technology and new materials in the product, and the concentration toward core capabilities, means that the identification and management of external design capabilities have grown in importance. In the case of *complex* products, such as in the automotive industry (which have both a high user interface and product integrity), an extensive network of external sources of information may be necessary that contribute knowledge and expertise to the design and development of the product.

The process of designing and developing an automobile resembles a complex web of organisations interacting and contributing to a chain of activities. The traditional nature of the manufacturer-supplier relationship was dominated by suppliers who supplied a finished component, often from engineering designs supplied by the vehicle manufacturer or, designed by the supplier from specified requirements. However, increasingly, suppliers are contributing to design and engineering work much earlier in the process, such that they are more than purely manufacturing sites. The various elements of the total supply network - supply chain, aftermarket and design chain - were earlier illustrated in figure 1.1.

5.4.1 The Zeta thermoplastic air-intake manifold [9]

This notion of a design chain can be illustrated through the development of Ford's electronically fuel-injected 1.6 litre Zeta engine, introduced in 1992. One of the most innovative components was a thermoplastic air-intake manifold, developed over a three year period. The air-intake manifold is typically manufactured in aluminium but the use of nearly 90 per cent plastic in this particular component led to the following benefits: 60 per cent weight savings; 20 per cent cost savings; improved fuel economy and performance; and increased flexibility in design and manufacture, since more complex shapes could be integrated into the component.

The air-intake manifold is a performance critical component (Appleby and Twigg, 1988), for which reason design work is normally undertaken in-house by the vehicle manufacturer. Ford's design engineers sought material knowledge from Du Pont in their early design work, but were unable to resolve problems of noise and vibration, dimensional stability, or the material's temperature capability. For these reasons, a project team, based around concurrent engineering principles, was gathered bringing together a variety of engineering resources (both in-house and outsourced) to solve these problems:

- Ford engineers brought manifold design and engineering expertise;
- Du Pont brought material knowledge, supplemented further by a dedicated CAD designer using techniques for material performance;
- Dunlop Automotive Composites was the moulder of the final component, and contributed process expertise;
- Tooling Products were the tooling specialists;
- Klöckner, a process technology specialist, assisted Dunlop with designing the final production cell;

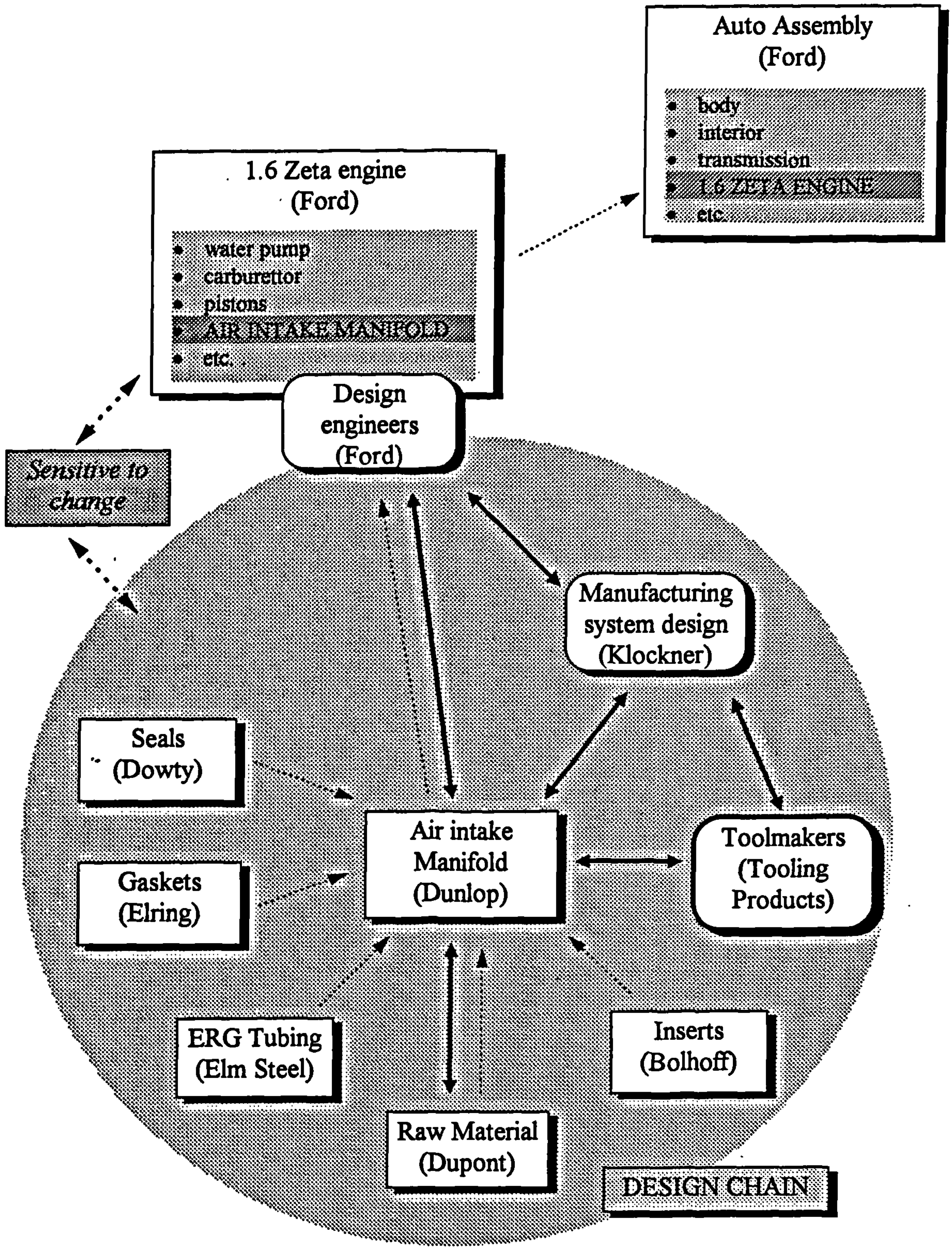
- Other specialist component suppliers contributed standard parts to the design: Bolhoff (inserts); Dowty (seals); Elring (gasket design); and Elm Steel (ERG tubing).

These various design iterations have been transposed onto figure 5.2, as an example of a design chain, where complementary assets of suppliers have been brought together in the design and development of a particular component. If individual chains were then extended for other major components, a web (or network) of chains would ensue.

The collective design and process iterations of this integrated, multi-firm project team exemplifies the notion of design chain. Several important points can be drawn from this example:

1) The design engineers of vehicle manufacturers require access to materials knowledge, either through material manufacturers (such as Du Pont), or research laboratories (such as universities): mechanisms must be in place, therefore, for them to access this knowledge base, perhaps through the gatekeeper mechanism;
2) The component manufacturer has production knowledge that is important for product design. In the case of the air-intake manifold, Dunlop must coordinate the supply and assembly of further components to deliver the final component to the customer. Where parts are standard, or are being carried-over from previous designs, there will be little requirement for new design input. However, where a design may be radical, performance, safety, or aesthetic critical (Appleby and Twigg, 1988), design contributions by all parties may be necessary. Hence, design for manufacture increases in importance and requires manufacturing inputs.

Figure 5.2 Example of a design chain - air-intake manifold for the Ford 1.6 Zeta engine



3) Toolmakers have a pivotal role to play in design iterations between vehicle manufacturer and component supplier (Twigg, 1990). Their contributions are both to the product design, and development of process tooling.

4) Equipment suppliers can provide new understanding to both product and process design. As attention focuses on design for assembly, equipment suppliers may increasingly be asked to advise on layout implications for product design.

5.5 Supplier involvement in product development

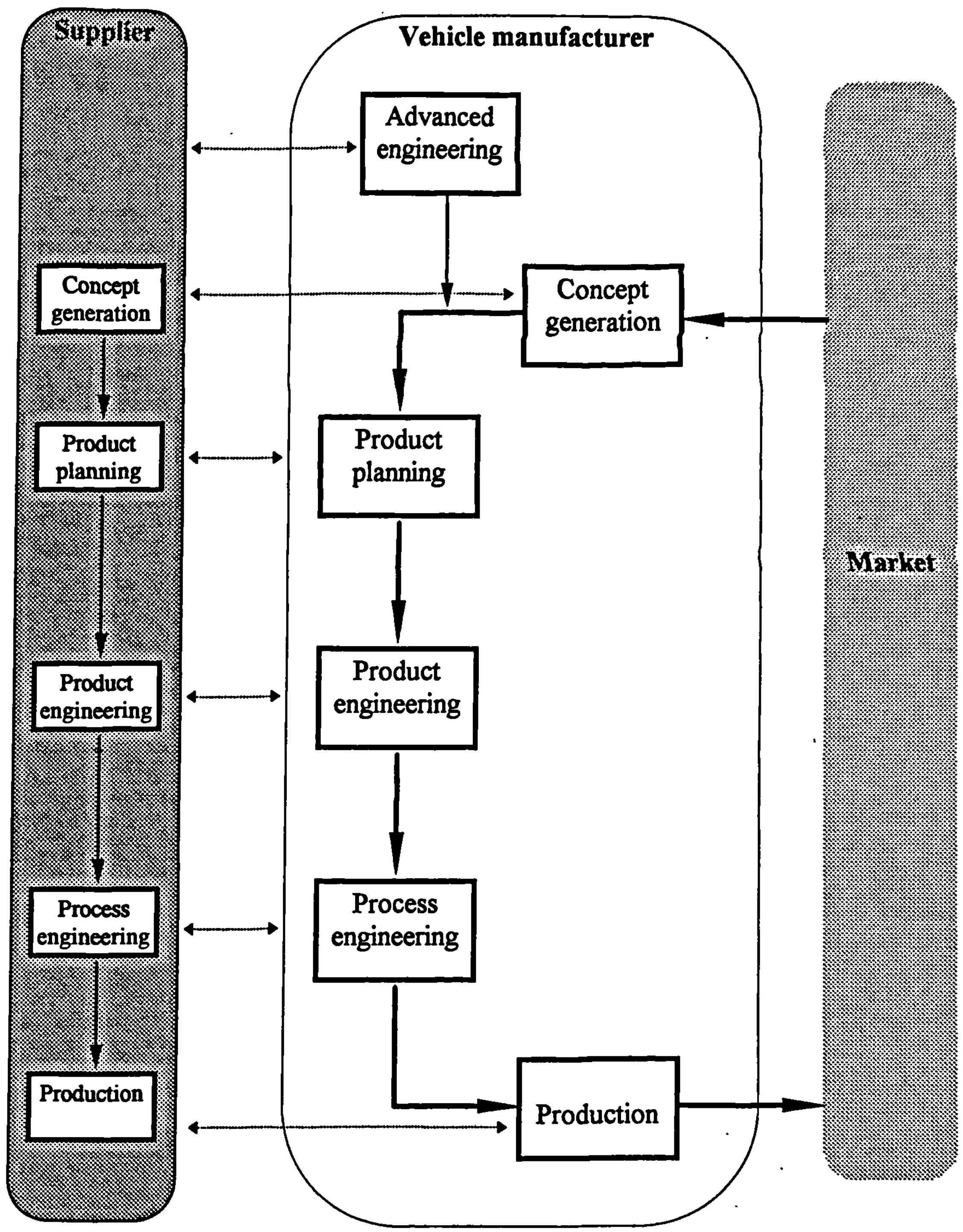
There are many examples of suppliers' early involvement in product development, for example: Cadillac, where 75 per cent of their development teams have supplier representatives; Xerox, who have included suppliers in partnership since the early 1980s; and, Boeing, who co-locate suppliers in the manufacturing facility (O'Neal, 1993). Whilst indicating their *involvement*, these illustrations do not extend our understanding of the content of this participation. Birou and Fawcett (1994) have undertaken a detailed comparison of European and US supplier involvement in product development activities, investigating the *dimensions* (extent and type) of their participation. However, whilst their examination provides useful insights to the degree of supplier participation as team members, it does not distinguish between the types of product developed, and hence supplier type. In this section, alternative views of supplier participation in product development will be examined, in order to compile a composite view of supplier involvement along the design capability continuum proposed earlier.

The movement towards closer supplier involvement in design and product technology responsibility has increased over the past decade. Evidence of the supplier having a greater authority in the design process in the automotive industry, for example, was provided by Ford, Jaguar and Rover to the House of Commons Trade and Industry Committee (1987).

An important insight to distinguishing between supply and design chains of operations is the contribution made by individual organisations during various stages of product development. Figure 5.3 illustrates a simplified view of supplier input to various stages of the vehicle manufacturer's product development process:

1) At concept stage, for example, design houses (such as, Karmann, Pininfarina, or Ital Design) may contribute design expertise to styling [10], or suppliers of body components may contribute manufacturing advice to model stylists, where manufacturing finish might influence aesthetic.
2) At the detail engineering stage, multinational *component system suppliers may take* responsibility for proprietary parts (such as GKN), or others may provide *black box* designed parts (such as Lucas, Motorola, or Rockwell); as in the Ford Zeta case cited earlier, material producers also have a role to play in design; the properties of new materials or application in novel ways may require specialist input to the design process.
3) At the process engineering stage, manufacturing knowledge is paramount, and again external expertise may be sought. Toolmakers are particularly important here, especially for body aesthetic items - see the case of body die tooling in Clark and Fujimoto (1991) - as too are equipment manufacturers, raw material suppliers, or process specialists (such as, in casting or plastic injection moulding).

Figure 5.3 Supplier-vehicle manufacturer information exchanges in product development



Note: Individual feedback has not been indicated for simplicity. Each stage represents an activity, rather than an organisational unit.

Clark and Fujimoto (1991) propose a categorisation of supplier involvement in product development, based on the creation of information assets for a particular component (see section 3.3.1 earlier):

1) *Supplier proprietary parts* (parts developed entirely by parts suppliers): these are catalogue items (for example, batteries and spark plugs) which are low cost, or the vehicle manufacturer has little control over quality.

2) *Black box parts*: parts whose basic engineering (functional specification) is done by the vehicle manufacturer, but whose detail engineering is performed by parts' suppliers (for example, functional parts and subassembly systems). This translates into an approximate 30:70 division of engineering responsibility in favour of the supplier. The vehicle manufacturer is able to utilise supplier knowledge, whilst maintaining control of basic design and total vehicle integrity. Suppliers therefore have a competitive edge through their knowledge accumulation. These parts tend to be high design quality, yet relatively low cost. The risks of this outsourced capability are: a potential dependency on suppliers' engineering capabilities, thereby diminishing negotiating strength; knowledge leak to competitors (as discussed earlier); and vulnerability to loss of technological capabilities. Therefore, it is important for vehicle manufacturers to maintain the core capabilities in-house.

3) *Detail-controlled parts* (functional and body): parts that are developed entirely by the assembler from functional specification to detail engineering, although subcontracting of process engineering and production may occur. In the case of body parts, Clark and Fujimoto found that vehicle manufacturers tend to do process engineering in-house and lend the tools and equipment to the suppliers.

However, this categorisation does not adequately incorporate the important role that process engineering makes to the design as well as production of the part. For example, in injection moulding, the toolmaker has an important role as a third party; thus, the supplier may act as a liaison between toolmaker and vehicle manufacturer.

These roles were incorporated by Appleby and Twigg (1988) in a broad classification of design responsibilities within the sector. Where a supplier has total design authority, the customer outlines the parameters in which the component must operate (the design specification), but the responsibility for the design input and quality standards lies with the supplier; this is typical of black box and *proprietary* black box subassemblies (such as drive units and clutches). At the other extreme, there are suppliers of, for example, catalogue items (such as fasteners), with little design input into the automotive product. Appleby and Twigg (1988) defined these varying design relationships, assigning simple ratios of design authority to introduce a debate into the division of design responsibility in the supply-assembly chain (table 5.4).

Between these two extremes are a variety of situations where suppliers and assemblers are in a situation of mutual interdependence, in which components are critical in terms of safety and performance, or are important to the overall design and cosmetic appearance of the vehicle. Typical suppliers with this relationship include the producers of inlet and exhaust manifolds, valve springs, steering wheels and trim. Of importance for this group is the requirement for design interaction and communication between supplier and assembler. For example, in the design of inlet and exhaust manifolds, the internal port

Table 5.4 Design authority and component type

Supplier Input	Design authority (supplier: assembler ratio)	Characteristics	Examples
Black box	80:20	Subassemblies, proprietary parts; major design authority with supplier; black box dimensioned by assembler	Electrical accessories, clutch, brakes, drive assemblies
Performance/ safety/cosmetic critical components	60:40 to 40:60	Specification purchasing by assembler; design for performance or cosmetic aspects by iteration between supplier and assembler; specific supplier inputs being design for manufacture; specific assembler inputs being dimensioning for performance and so on.	Inlet and exhaust manifolds, cylinder heads, blocks; steering wheels and trim; valve springs, crankshafts
Standard Parts	20:80	Assembler specifies and purchases from standard parts lists; in-house technical development by supplier for a wide range of customers	Fasteners

Source: Appleby and Twigg (1988)

dimensioning - critical for engine performance - is performed by the assembler, whilst the casting supplier will contribute to the design through its knowledge of the casting process. Conversely, performance related expertise may reside with the supplier, such as in the design of valve springs. Computer simulations of new engine developments are carried out by spring manufacturers, and spring design can enhance and modify engine performance (Twigg, 1990).

Where components are cosmetically important, yet safety critical (such as steering wheels, bumpers, and certain trim items), the supplier has a process-related expertise and responsibility to produce designs which interrelate with the complete vehicle (as envisaged by the assembler) - for example, the steering wheel with the fascia. Although there may be an important independence from the supplier, such as with an expertise in new materials (for example, urethane mouldings), design responsibility is more evenly divided (Twigg, 1990).

Appleby and Twigg (1988) identified tooling as a fourth type of design authority. This provides a necessary input of production process knowledge, which ensures a producible design. Both the vehicle manufacturer and the component supplier have specific design and process knowledge which give them authority in designing an individual part, or group of parts; each may make an input into the other's design operations - particularly when changes arise in neighbouring (or interlinking) parts - but may also receive an input from tooling operations.

Further examination of supplier involvement in product development necessitates consideration of the Japanese model. An important aspect of Japanese supply relations is the involvement of suppliers in the design and development of products. Kamath and Liker (1994) propose four types of supplier involvement evident in Japanese product development: partner, mature, child, and contractual (table 5.5) - each may play different roles to different customers:

- *Partner*: Typical suppliers in this role are first tier providers of subsystems, where full-service of design and manufacture occurs, for example: heating, ventilating and air-conditioning systems; exhaust systems; alternators; and seating. However, Kamath and Liker observe that there exists a misconception outside Japan that *all* first tier suppliers are treated as close partners. In specific circumstances, partner suppliers may have an input to the pre-concept stage where specifications for the subsystem are determined. Because of the complexity of product, and the necessary involvement, there is intensive communication between both parties.

- *Mature*: These suppliers design and manufacture complex assemblies as full systems, for example, door panels. However, due to fewer technological capabilities, they contribute less design responsibility than the partner suppliers. In this case, the customer provides critical specifications, such as performance, interface requirements, or space constraints, and the supplier takes responsibility for detailed design and prototyping (build/test cycles). Again there is intensive communication from concept stage onwards.
- *Child*: There is greater joint development work with this supplier, but this is largely in the form of minor product changes. The supplier may act as consultant at the concept stage, but its major role does not occur until detailed design and testing. However, the customer is likely to undertake critical testing of the parts internally. Communication is not intensive until the component prototyping stage.
- *Contractual*: In this role, the supplier is seen as an outsourced manufacturing centre. All design work is by the customer; only where there is a unique manufacturing capability (such as flexible automation), would a supplier's design input be sought. Thus, communication only becomes frequent during late prototyping and manufacturing ramp-up.

Table 5.5 Supplier roles in product development (the Japanese model)

	Partner	**Mature**	**Child**	**Contractual**
Design responsibility	Supplier	Supplier	Joint	Customer
Product complexity	Entire subsystem	Complex assembly	Simple assembly	Simple parts
Specifications provided	Concept	Critical specifications	Detailed specifications	Complete design
Supplier's influence on specifications	Collaborate	Negotiate	Present capabilities	None
Stage of supplier's involvement	Pre-concept	Concept	Post-concept	Prototyping
Component-testing responsibility	Complete	Major	Moderate	Minor
Supplier's technological capabilities	Autonomous	High	Medium	Low

Source: Kamath and Liker (1994)

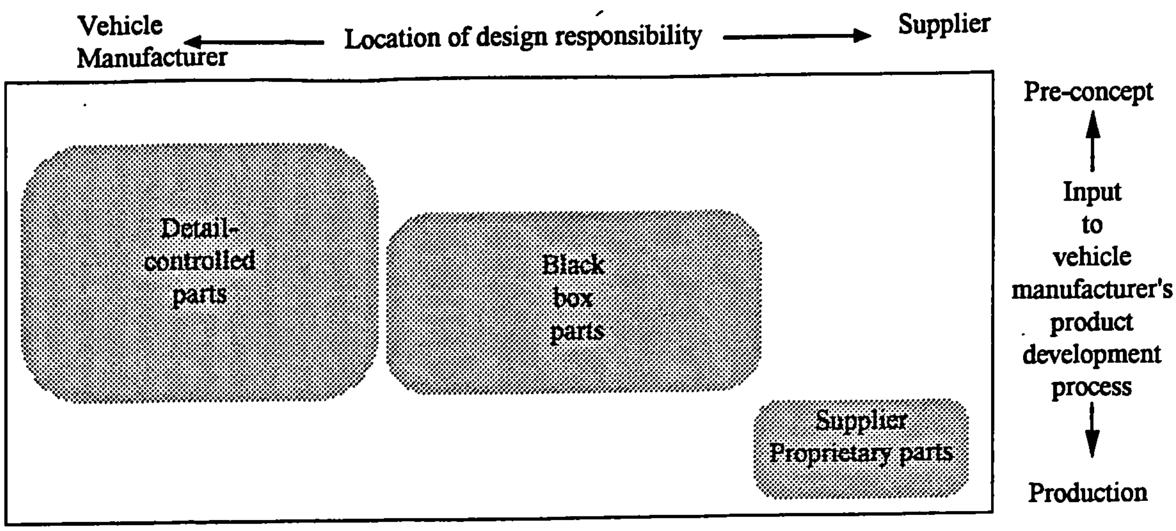
Lessons from the Japanese model of supplier-customer relations have led to an advanced model of supply being advocated by many firms (see, for example, Lamming's partnership model in Chapter Three). Bonaccorsi and Lipparini (1992) investigated the supplier role in an advanced model of supply in the product development process. However, this investigation takes little account of the design capabilities of the suppliers involved.

In aggregate terms, the level of supplier involvement in design and development activities may be more than half of the total procurement cost of engineering. In automotive engineering, for example, 10 per cent of engineering procurement costs is for supplier proprietary parts (for example, off-the-shelf items, such as, tyres or batteries), 40 per cent is for *black box* items (for example, systems or modules designed and developed to customer specifications by primary suppliers), and the remaining 50 per cent is designed and developed in-house by vehicle manufacturers *(Clark and Fujimoto, 1991)*. What these figures do not demonstrate, however, is the increasing *grey box* element where suppliers may sit-in with a vehicle manufacturer and provide process knowledge for product design work. For example, a foundry has process expertise that is essential to contribute to the design of an intake manifold, if design for manufacturability is sought. Similarly, these figures do not emphasise the design consultant's contribution at concept stage. Such organisations provide design and development expertise as a professional service and may provide prototype parts; however, they do not manufacture parts.

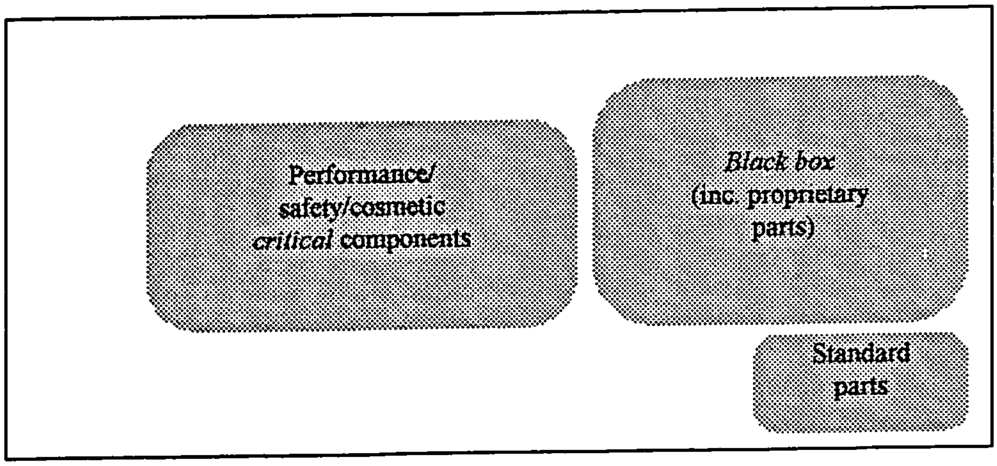
Hence, the classifications of supplier involvement proposed by Clark and Fujimoto (1991), Appleby and Twigg (1988), and Kamath and Liker (1994) require re-examination. This may be achieved by examining the location of design responsibility between vehicle manufacturer and supplier with the input into the vehicle manufacturer's product design process. Figure 5.4 transposes these typologies onto such a matrix. The position of each supplier type has been hypothesised based on the approximate degree of design authority/contribution made by each party, and the first major input to the design process by the supplier. Thus, whilst a supplier may largely contribute manufacturing knowledge

Figure 5.4 Typologies of supplier involvement in automotive product development

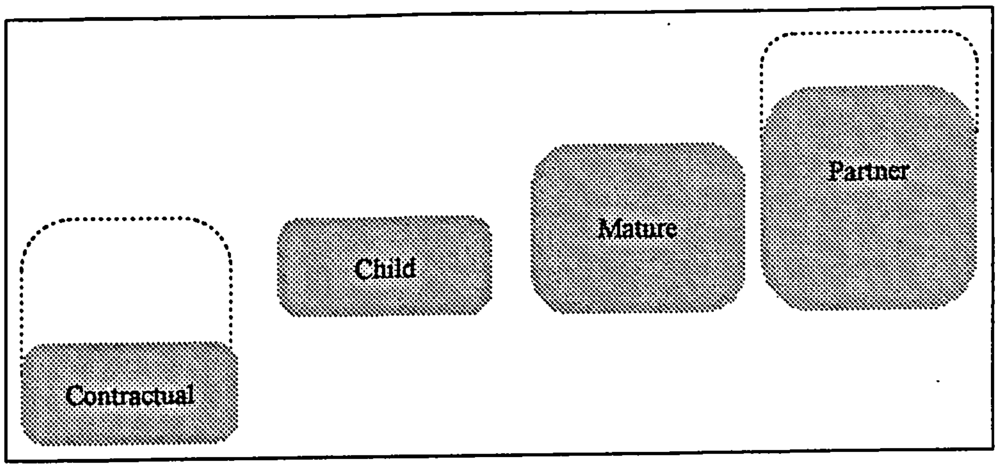
(a) Clark and Fujimoto (1991): generic supplier roles



(b) Appleby and Twigg (1988): UK supplier roles (based on Rover Group)



(c) Kamath and Liker (1994): Japanese model

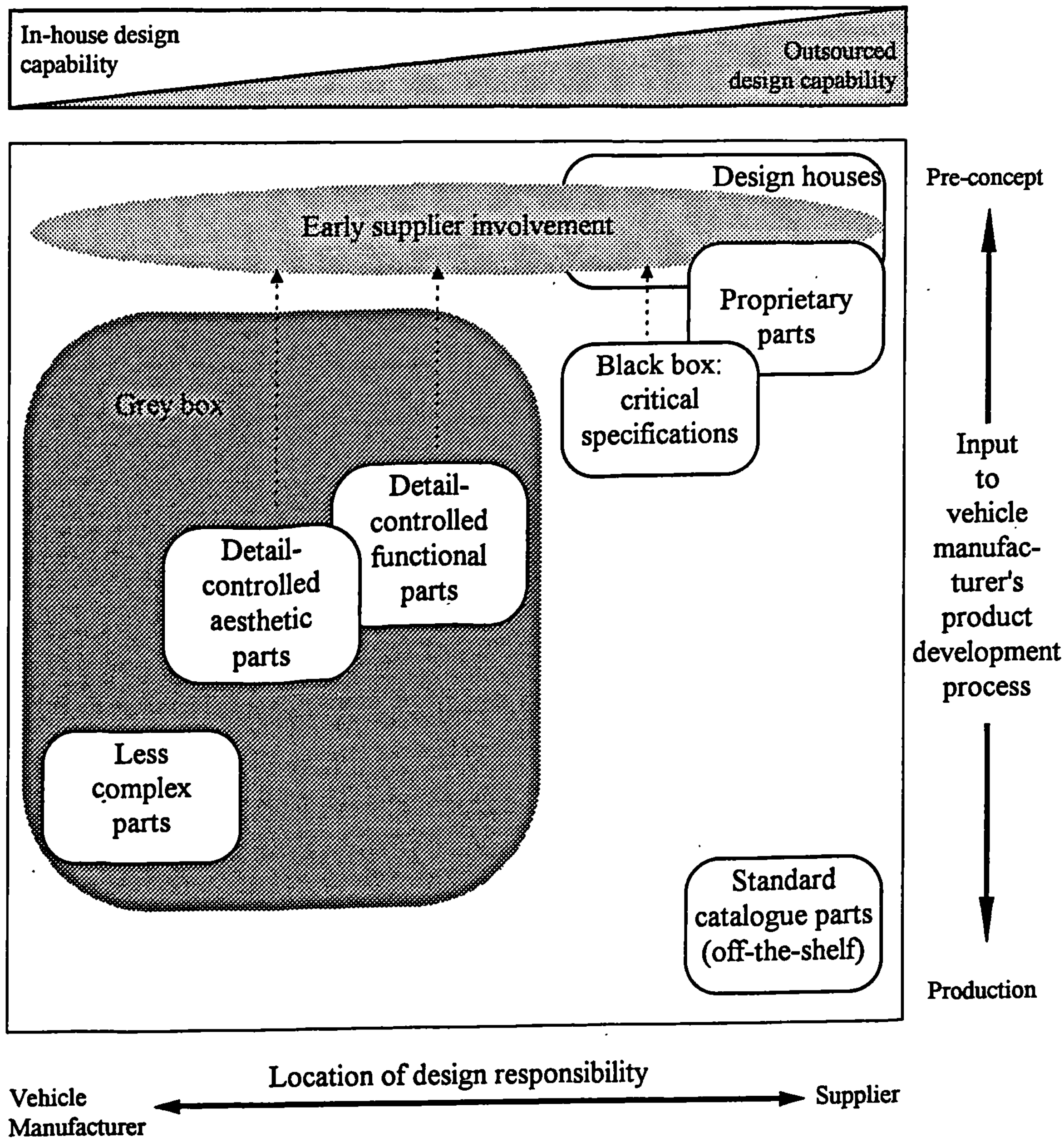


Note: These diagrams are nominal representations of each pair of authors' work.

to design engineers, it would nonetheless be appropriate to indicate an input closer to detailed design rather than production stage.

Figure 5.5 presents a composite of supplier involvement in the product development process. It is a nominal indicator of supplier involvement in the UK automotive industry, based on the author's experience and the relative positions indicated in figure 5.4. The figure extends the previous classifications to incorporate *additional dimensions*. The grey box area indicates the ambiguous contributions made to largely vehicle manufacturer design work, especially process and assembly knowledge held by the supplier. Second, proprietary items have been divided into two types: those that are designed to customer specifications, yet comprise *proprietary technology* of the supplier (for example drive shafts); and those that are proprietary catalogue items, where design and development by the supplier occurs independent of the vehicle manufacturer, and contact with the customer occurs as the delivery of a finished item. Third, a *less complex* parts category has been added to reflect in-house designed parts that require little external design input. These parts reflect the availability of both design and process knowledge competence within the vehicle manufacturer. (In practice, there may be overlaps between the categories: Kamath and Liker (1994) refer to Nippondenso as providing *both* standard catalogue parts and the option of proprietary parts design for customers.) The characteristics of each category are summarised in table 5.6, together with typical examples of component parts. Not included in figure 5.5 and table 5.6 are the suppliers of material or toolmakers referred to earlier. It is assumed that their participation may occur at any point in the development cycle, and with any category of supplier.

Figure 5.5 Supplier involvement along the design capability continuum



Notes:

1. This diagram is nominal in its representation of supplier positions.
2. The positions of supplier involvement are relative to the vehicle manufacturer's request for supplier involvement in the product development activities.
3. The contributions of toolmakers have not been included, since they are assumed to participate with all supplier categories.

Table 5.6 Typology of supplier involvement

Supplier Input	Characteristics	Types of Example
Assembler in-house design	Core competencies/aesthetic critical	Major body panels; engines; electronic management systems
Design houses	Design and prototype work	Cabriolet hoods; body styling
Proprietary parts	Major systems and subsystems; similar to black box but reliant more on proprietary technology	Clutch; brakes; drive assemblies; seating
Black box: critical specifications	Subassemblies; major design authority with supplier; black box dimensioned by assembler	Electrical accessories; modular doors
Detail-controlled: functional parts	Specification by assembler; design for performance by iteration between supplier and assembler; technical knowledge sought (mainly process related); specific assembler inputs being dimensioning for performance and so on.	Inlet and exhaust manifolds; cylinder heads, blocks; valve springs;
Detail-controlled: aesthetic parts	Specification by assembler; design for cosmetic aspects (aesthetic) internal and external by iteration between supplier and assembler; specific supplier inputs being DFM/ DFA	Exterior trim: Bumpers; wheel trim; Interior trim: Fascias; steering wheels
Less complex parts	Specification by assembler; minimal supplier input mainly process-related	Fabrications
Standard catalogue parts (off-the-shelf)	Assembler specifies and purchases from the supplier's standard parts catalogue. In-house technical development by supplier for a wide range of customers (may be proprietary technology)	Fasteners; gaskets; audio equipment; batteries; alternators (in the case of Nippondenso)

Finally, an area of early supplier involvement is highlighted: this area signifies the movement towards which some supplier firms are being asked to have early inputs to the design process. In some cases, this involves pre-concept discussions, particularly in the case of aesthetic critical parts (for example, bumpers or fascia) where material type, and aesthetic are critical components of styling and definition of the marque. Formal involvement for such suppliers may not occur until later in the process, but their tacit knowledge of process is invaluable at this genesis period.

Two categories of supplier-provided engineering resource can also be identified: those with specialised expertise (able to undertake in-house R&D and provide complete systems or sub-assemblies), and others who although unable to undertake original work are able to offer specific process (often tacit) knowledge and toolmaking skills (O'Neal, 1993). Such contributors may be the *silent designers*, referred to by Dumas (1988). Hence, the network of design and engineering expertise extends throughout the design base.

Extending Dumas's terminology, one might consider *silent partners* an apt label for those suppliers of product, process and material engineering knowledge: they may not be the end supplier, but are the purveyors of expertise. The use of informal networks plays an important role within design chains. Process engineers (also known as manufacturing and industrial engineers) have expertise on how a product can be manufactured, which are importance contributions to interactive design. Hence, their contribution is often the tacit knowledge they can input to product development, as opposed to the codified *formal* specifications latent in traditional exchange mechanisms.

5.6. Summary

This chapter has developed the components of design chains further and examined the supplier role in automotive product development. It began by examining the concept of network and showed that technical collaboration and outsourcing of design capabilities require careful management of the relationship (coordination) from all partners. A typology of suppliers has been presented in terms of design capability, which may help understand their different participating roles in product development. As supplier inputs move upstream, the role of partnership relationships under Lamming's *lean supply model* will become increasingly important: in particular, "[The use of complementary technologies and patents] is perhaps the core of technical change in lean production." (Lamming, 1993, p. 205) The inter-organisational coordination issues are now examined through analysis of several suppliers involved in design chains with a UK vehicle manufacturer, using the inter-firm information processing perspective developed earlier.

NOTES

1. On a cautionary note, Macdonald (1992) suspects that the undertaking of technological collaboration may bring about the dilution of the effective informal information networks that underpin the ability of firms to innovate and compete!
2. The use of transaction cost analysis (Williamson, 1975) in networks has caused much debate (see for example, Jarillo, 1990; Ciborra, 1992), not least since industrial networks are unbounded, with one firm's network crossing many others. However, boundaries may be drawn around particular parts of the network enabling analysis for such an approach.
3. Walker and Webber (1984) provide a detailed application of the transaction cost approach to make-or-buy decisions within the US automotive component industry.
4. Afriyie (1988) emphasises that focus has been biased towards R&D activities and technology hardware in studies on technology transfer and policy analysis, whilst the roles of other knowledge assets (such as design capabilities) have been largely neglected. This thesis

supports this view insofar as much attention has focused on the *Research* with less emphasis on the *Development*.

5. Twigg (1990) provides a detailed examination of CAD/CAM. The use of multi-media in outsourcing design capability is currently being examined in a European Commission funded project, SMAC (Suppliers & Manufacturers in Automotive Collaboration).
6. One potential threat was experienced by Rover in 1965, when the Pressed Steel Company was acquired by British Motor Corporation (BMC) - a major competitor. Rover relied on Pressed Steel for car bodies and advice on the handling of new materials. Thus, Rover had entrusted them with knowledge on their future vehicle styling and innovations (Whipp and Clark, 1986, p.77). This matter was settled in 1968 with the formation of British Leyland Motor Corporation, which included the merger of, *inter alia*, Rover and BMC.
7. For a detailed explanation of robust designing (*vis-à-vis* lean designing) see the work of Gardiner cited in Clark and Starkey (1988). Robust designs enable a design template to be developed into future variants - what in the automotive industry is termed *family platforms*. A transformation can be followed as a composite design is reworked and then stretched into a design family (for example the Ford *Cortina*). Japanese automotive manufacturers have become particularly successful at this.
8. It should be noted too, however, that component suppliers and Rover's labour force contributed design expertise to the *SD1* project (Whipp and Clark, 1986, p. 129).
9. This example, and figure 5.2, is extrapolated from secondary material in the article: 'Working as on', *Vehicle Engineering and Design*, Vol. 2, No. 2, pp. 7-8, in *Engineering*, Vol. 232, November 1992.
10. Design Houses are a form of contract research organisation. Haour (1992) provides a detailed examination of the issues in utilising contract research organisations as a source of external technical expertise.

6 RESEARCH METHODOLOGY

6.1 Introduction

In Chapter One, the rationale for a study on the automotive industry was outlined. The preceding chapters have emphasised the need to understand the dynamics of the product development process, and the context of design and process expertise communicated was emphasised. The nature of the inter-firm design relationship is extremely complex and this has been illustrated in the previous chapters. However, further contextual explanation is required, to understand better the dynamics of these operations, with analysis of the experiences of a vehicle manufacturer and a number of its OEM suppliers.

6.2 Research approach

Discussion of the research approach requires consideration of the research objectives, alternative research strategies, the contributions of other studies, and the choice and definition of the unit of analysis.

6.2.1 Research objectives

The broad objective has been to determine the changing nature of the inter-organisational engineering design process between vehicle manufacturer and automotive component suppliers, where these suppliers contribute specific knowledge to the design of the overall product. This has been achieved through:

1. describing the elements of the emerging inter-firm design relationship (*vis-à-vis* the internal product development process);
2. determining the critical information process needs in a specific project;
3. determining the mechanisms used to incorporate knowledge/expertise *external* to the firm; and
4. examining the dynamics of (1) with (2) and (3).

The research has been directed towards the operations issues concerning the management of this development process across firms, and has adopted an information processing perspective of inter-firm linkages.

6.2.2 Choice of research strategy: case study

Yin (1989) outlines five research strategies available for social science study: experiment, survey, archival analysis, history, and case study. *Each strategy is appropriate under* specific research conditions and presents alternative approaches for data collection and analysis.

The first task, in identifying the choice of research strategy, is to determine the purpose of the study, which may be exploratory, descriptive, or explanatory. The decision will be determined by: the type of research question being asked; the extent of control that the investigator has over the actual events being studied; and, the degree of focus on contemporary versus historical events (Yin, 1989).

Table 6.1 Choice of research strategy for an exploratory investigation

Strategy	Form of research question	Investigator control over events	Focus on contemporary events
Experiment	how / what / why	yes	yes
Survey	who / what / where / how many / how much	no	yes
Archival analysis	who / what / where / how many / how much	no	yes / no
History	how / what / why	no	no
Case study	how / what / why	no / possible	yes

Source: adapted from Yin (1989, table 1.1)

This research project is essentially exploratory in nature, investigating *what* are the process and antecedents that shape the buyer-supplier relationship. In this respect, any one of the five research strategies is appropriate. However, since the research questions have sought explanation as to *how* the supplier and vehicle manufacturer conduct product development and *why* particular issues promote or hinder the exchange of design information, the experiment, historical, and case study approaches appear appropriate. Thus, with the focus of research on contemporary events, and with little control over the events available to the investigator, Table 6.1 suggests that the case study is the most favourable strategy to pursue. Similarly, since the concept of inter-firm design transactions is not adequately explored in the academic literature, it is essential for the investigator to be present throughout the data collection process. The clarification of concepts, and appropriate interpretation of the subject to informants is necessary to ensure consistency in data collection. The case study approach is suitable for this task.

The research strategy has involved, therefore, an empirical and descriptive approach to studying the product development process. This reflects a tendency of qualitative research to be actively used where areas of study are newly explored and/or where the dynamics of relationships are to be investigated. Table 6.2 outlines the main characteristics of the qualitative, case study approach. The case study approach is particularly appropriate under conditions where the research subject is poorly understood, where relationships and structures need to be developed further, and where complex interrelationships exist: all of which are characteristics of this study.

A qualitative approach was adopted for this research, in part from the complexities surrounding the relationships between a focal company and its suppliers involved in product development. This approach is well suited for developing a comprehensive view of a complex, multi-person organisational process: the research investigates a complex network of technical, product-process, organisational, managerial and contractual related issues. Moreover, since this study extends beyond the boundary of a single firm - to an inter-organisational process - there has been an increased need to understand further the complexities of this process as it exists under different organisational structures and as it operates within different, yet mutual, operations.

The research is concerned with investigating two sets of relationships: first, the intra-firm complexities for the focal vehicle manufacturer, and those for each of the supplier firms; and second, the complexities of the inter-firm transactions. The case study is a suitable vehicle to reflect these complexities because of the closer involvement with the research subjects, and of its advantage where interrelationships (both internal and external) are complex: the primary goal of this approach is to discover the relationships and structures (Table 6.2).

Table 6.2 Main characteristics of the case study strategy

1. Useful in the exploration of unknown, or poorly understood, areas.
2. Useful in generating, or formulating, hypotheses.
3. Allows for exploration of poorly understood research subjects and concepts. Does not rely on standard instruments, but permits multiple methods. Data is fixed by triangulation.
4. Has advantages where the proposed subject is unknown territory or when interrelationships are complex; for example: those involving interpersonal behaviour.
5. Permits little control over research variables or experimental design.
6. Requires time in *gaining access and is labour and time intensive in practice.*
7. Primary goal is to discover relationships and structures.
8. Permits the use of flexible and unstructured techniques for research which may vary between cases studied.
9. Allows a close relationship with research subject and, through this, to gain access to privileged and confidential information.
10. Has only questionable validity for other cases across a population.†

† the question of validity is raised later in this chapter, when the issue of analytical, rather than statistical, generalisation is argued as valid for the case study approach.

Source: adapted from Bessant and Grunt (1985, table 3.1)

6.2.3 Relationship to other studies

In the absence of prior studies on the management and coordination of inter-organisational integration in *product development* in the UK motor industry, it was decided that a quantitative approach was not appropriate (as previously discussed). Bensaou (1992) adopted a quantitative approach, using existing knowledge of integration mechanisms, in examining inter-organisational coordination in the buyer-supplier relationship in the USA and Japanese motor industries: however, his work concerned the relationships throughout the entire production process from design to manufacture, whereas this research concentrates on a detailed examination of part of this process.

Bensaou contributes new understanding to this relationship but does not apply his examination of integration mechanisms solely to the inter-organisational *product development* relationship. In addition, it casts a wide net over the production process, at a single moment in time, and is limited by the asymmetry of the data set: *the supplier-buyer relationship is examined solely from the viewpoint of the buyer* (motor vehicle manufacturer), with little to no regard to the supplier's management processes. Hence, although a number of determinants of the product development process can be identified and examined from a quantitative perspective, without a thorough understanding of the practising process to be examined and the dynamics under which it operates across firms - which themselves have localised processes - the resultant findings limit the analysis to that of the focal vehicle manufacturer, and will not enable an understanding and examination of the relationship - an exchange transaction.

A qualitative approach provides useful data given the absence of case studies that investigate the project management of a highly complex product across a network of contributing firms. Although there are excellent examinations of the product development process of motor vehicles (for example, Clark and Fujimoto, 1991; Fujimoto, 1989; Wheelwright and Clark, 1992), these view the process largely from an asymmetric perspective - that of the vehicle manufacturer project management process - and often as a single entity, or as a set of systems following the same process. The existence of various project management styles is recognised (see for example, Wheelwright and Clark 1992) but these are generally viewed as isolated processes.

This research provides, therefore, a case study in which a central project management process (the vehicle manufacturer) is examined, together with a network of associated project management processes (those of external suppliers of parts and expertise) whose *collective* contributions are to the same product. Suppliers of components enter the vehicle manufacturers' product development processes at different times, and have different types of input. It has been necessary, therefore, to examine each process separately and to assume non-uniformity.

6.2.4 Unit of analysis

The research has adopted a single-case, embedded design.[1] The single case is the product development process of Rover Group Limited. Since this process involves multiple buyer-supplier design relationships, and a variety of simultaneous project management programmes, these are considered sub-units of the case study. Thus, there are multiple units of analysis embedded within the case study.[2]

Yin (1989, pp. 47-49) presents three rationales for the single-case as an appropriate research design, namely where: (1) it is the *critical case* in testing a well-formulated theory; (2) it represents a rare or unique case; or (3) where a phenomenon has previously been inaccessible to observation or analysis. As the research is seeking to explore the phenomenon of design chains, with little previous available research, and no previous studies of the UK inter-firm product development process have been found, the rationale for a single-case seems appropriate.

Where a single-case has many sub-units, as in this case, a more complex (embedded) design may be appropriate. The use of sub-unit, cases can provide insights and focus into the larger case study, and in this situation of examining dynamic relationships would appear a necessary choice. (The major disadvantage of this choice of design is been the threat of concentrating too heavily on the sub-units, at the expense of the larger unit of analysis.)

The unit of analysis (operational definition) for this study is the product development relationship that exists between a single vehicle manufacturer and six automotive component suppliers that contribute design-engineering expertise. Hence, the operational boundary of the study is the information system boundary of the product development process. This boundary includes the product development organisation of the vehicle manufacturer (focal organisation), and the project management organisation of a selection of automotive component suppliers. Each firm is a system (intra-firm process) unto itself, but is also an element of the wider information system of the focal organisation. Across these sub-units, the inter-firm process has been examined.

Within the vehicle manufacturer, the product development organisation refers to those members engaged in major product development projects - this level of analysis equates to that used by Fujimoto (1989).[3] In the case of the Rover Group, the organisation is separated by product division, namely: Land Rover; small and medium car; and large car. Each of these divisions operated autonomous project engineering teams, but in a few cases used the same purchasing staff (see Chapter Seven for more details) as other divisions. Similarly, in the component suppliers, there were project teams dedicated to working solely with Rover Group (across all divisions), whereas in others, there were project teams who would tend to work with Rover, but may also have clients in other UK and European car companies.

Automotive project management usually requires that multiple projects (model year changes or new developments) are undertaken simultaneous within the organisation, thus the organisation represents a bundle of projects. This research examines the management process relevant to multiple projects, whereas Fujimoto (1989), for example, concentrates on the management of a single project with individual product development organisations. Indeed, preliminary discussions with automotive suppliers suggested the opposite to an underlying assumption of Fujimoto's work: that vehicle manufacturers manage all of their projects in a similar way (Fujimoto, 1989, p. 152). This assumption may be due to the need for standardising data for macro level analysis.

However, although there exists a broad, project management process, the availability of resources (especially people and time) means that project leaders manage the process in-line with these; hence, the process differs in almost all cases. Hence, it is necessary for a micro study of this nature to account for these differences.

The choice of the primary research organisation (focal organisation) was based on:

1. evidence that it had been actively *increasing* the contribution of component suppliers to product development activities;
2. it had been a previous research site of the author and therefore offered familiarity; and,
3. there was a greater possibility of frequent access to research subjects since it was locally situated.

Rover had been actively encouraging CAD adoption by its suppliers during the 1980s and had welcomed and encouraged their participation in engineering development. In some areas of expertise, Rover was now relying significantly on utilising external engineering resources. Building of existing cooperation between the Purchasing Department of Rover Group and the Operations Management Group at Warwick Business School, participation was sought with Rover Group in this project. The six suppliers were selected for reasons of manageability - given time and access constraints - and differences in product and operation - explained in the following section.

6.3 Research procedure

The topic of product development is highly confidential and competitively sensitive to investigate. Not only are the specific product designs of competitive importance, but also the systems (protocols, organisation, and procedures) used in bringing them to market. The depth of analysis required for such a study can also be daunting to would-be interview sites. For these reasons, the approach made to companies to participate in the research was taken with great care: a resultant feature of which was an eight month time-lag between first approaching a motor vehicle manufacturer and gaining approval to undertake the study. This initial time-lag was added to by intermittent meetings due to operating time-scales and the availability of staff. Later in the project, participation with supplier companies became uncertain due to relevant senior executives being overseas for considerable time-periods. The early approach to senior executives was also seen as essential for the study, since only then could an appropriate framework over access and clearance be established with working in the product development organisation.

In April 1993, a meeting with a senior executive at Prime-Computervision - a key supplier of Advanced Manufacturing Technology to the UK and World motor industry - resulted in new contacts being made in the Rover Group - one of the major UK volume motor manufacturers. Between May and June 1993, a series of initial interviews with Product Engineering staff at the Rover Group was undertaken during which the validity for a study on design relationships was confirmed. Indeed, initial discussions indicated the research field was of current concern to the Rover Group and the approach to the company had been timely.

These interviews led, by way of a circuitous route, to a formal approach to the Purchasing Department for Rover participation in the project.[4] The participation sought was to interview a number of suppliers with product design and process knowledge, as well as the Rover personnel who liaised with them. At this time, it was emphasised that participating companies would receive three deliverables from the study: a research report based on the findings of their company (this would be privy to them alone); a general report based on the collective synthesis of all companies; and, time permitting, a briefing meeting at which the findings would be discussed with all participating companies. In this way, the project has sought to feedback findings to industry as they are found, and to validate the importance of this area of study through feedback. In addition, results have filtered back to Rover through personnel in Quality and Reliability, and the European SMAC project.[5]

In October 1993, a senior manager based in the Purchasing Department was assigned by Rover as coordinator between Rover, its suppliers and the author. The Rover coordinator served an important role in alleviating uncertainty over access to information and gave authority to the project both within and outside the company. A previous study by the author, with another automotive company, had experienced significant problems when working on automotive product development where staff were reluctant to discuss issues, due to uncertainty over the authority and limits of the project.

Discussion then took place on the selection of the suppliers for study. First, the author compiled a list of operations and components - based on the author's experience, provisional interviews, and a literature review - which frequently require engineering or manufacturing dialogue between vehicle manufacturers and component manufacturers. Hence, a number of key components were identified from a product system that illustrated the variety of design expertise employed: those that required a combination of internal and external design inputs. The variety of expertise used in the design of a product was illustrated in Chapter Five, but may indicate specialist, technical knowledge (such as spring dynamics), process knowledge (such as casting), critical performance knowledge and so forth.

This list was refined through discussion with the Purchasing Department, and a final list of firms was then compiled in consultation with the Supply Directors of Rover Group. Eight commodities (otherwise known as components or parts) were finally identified for study. Two of the commodities were designed by the same firm, hence in total a group of seven suppliers was finally agreed upon. Discussion with the firms resulted in six suppliers agreeing to participate in the study - the seventh firm was willing to assist, but time constraints on their part excluded them from the final study.

6.3.1 Summary of the interviewed firms

In total, seven firms provide data for this study. The Rover Group is the focal company: a manufacturer of small, medium and large cars (for example, mini, Rover 200, and Rover 800) and four-wheel drive, off-road vehicles (for example, Land Rover and Range Rover). Table 6.3 lists the six participating suppliers, and the seven commodities originally investigated. These are divided by supply area: powertrain and electrical; trim and hardware; and chassis.

ELECTRICAL was chosen since the harness commodity undergoes a large amount of technological change, especially near to manufacturing ramp-up. The electrical harness is an interesting commodity to investigate, since it is an integrating system, which may continue to undergo changes until the final stages of design, and may be the last element to have the design *fixed*. However, it is also one of the first required for production, since it is the spine of the vehicle's electrical system. Rover Group has, over the past decade, gradually reduced its competence in electrical design to such an extent that, today, it is fully dependent on external, electrical design engineers. EXHAUST is a provider of exhaust systems and catalytic converters. Rover is one of its major customers. Exhaust systems were selected for study since this plays an important part in the performance of the engine. Exhaust systems are increasing in design sophistication and close dialogue is required between engine designer and exhaust system engineer. DRIVE-SHAFT is a supplier of drive shafts. It is a *front-end* design engineering supplier, with a major role as a *black box* designer.

PLASTIC provides small and medium-sized plastic injection mouldings (including wheel trims and fascia components). BUMPER provides medium to large-sized plastic injection mouldings (especially the bumper). Where these components interface critically with styling, they have an input at the *front-end* of a design programme. Finally, WINDOW provides engineering expertise in window regulators.

Table 6.3 Summary of the supplier firms (by vehicle component area)

Supplier	Commodity
PowerTrain and Electrical	
ELECTRICAL	Electrical harnesses
EXHAUST	Exhaust systems
DRIVE SHAFT	Drive shafts
Trim and Hardware	
PLASTIC	Small to medium plastic mouldings
BUMPER	Medium to large plastic mouldings
Chassis	
PLASTIC	Wheel-trim plastic mouldings
WINDOW	Window lift regulators

6.4 Validity

The validity of the case study approach used in this research requires examination of the quality of constructs used, whether the findings are generalisable - that they have external validity, and the reliability of the methodology and findings.

The first criticism made against case studies is often that the methodology fails to develop sufficient operational measures, and that findings are too subjective. For these reasons, the units of analysis were chosen that provided processes that could be examined in whole, and standard protocols provided base-line information of these processes. Similarly, to ensure validity of data, the key informants were selected based on their contribution to the key roles across the buyer-supplier relationship, namely

Purchasing/Sales and Design Engineering staff. In this way, key events and activities could be verified. Lastly, draft case studies were discussed with key informants for verification purposes.

A second major criticism of case studies concerns the generalisation of findings. The disadvantages of the case study are the time consumed in gaining access to companies, and the question of validity of the conclusions to other cases in the vehicle (or similar competitive) industries. Nevertheless, the case study approach offers the most appropriate method for analysis in the absence of other comparable studies, given the need to understand better these relationships and to contribute new analysis to a rapidly increasing topic of discussion on product development management. The criticism of generalisable research is usually applied to the failure of case studies to establish statistical generalisation based on samples or populations. However, as Yin (1989) emphasises, it is a mistake to consider case studies as representing *samples* of a population, rather case studies can be used for analytical generalisation. In this way, inferences from the case study findings may be generalised to a broader theory, and verified through their replication.

There could have been a potential problem with the case selection procedure. Although suppliers work actively with vehicle manufacturers, the past decade has seen significant rationalisation of the supply base and poaching of staff (both to and from the vehicle manufacturers). A shroud of mistrust still exists in the supply base over research projects seeming to permeate from their customers. A concern may exist over the bias of firms used. First, the Rover Group may not be representative of vehicle manufacturers.

Indeed, concern should be directed toward the representativeness of the findings, rather than the representativeness of the firm to the population. The firm uses external engineering resource far greater than many other automotive companies, and reflects the context of a firm committed to using external sources of expertise. A view supported by Ian Robertson (Group Purchasing Director) who, when referring to the increasing use of suppliers' engineering resource, stated: "All car makers are moving in a similar direction, but Rover is probably ahead of its European rivals" (*Management Today*, 1 May 1992).

Second, the list of suppliers does not represent all suppliers that can potentially contribute engineering expertise to the Rover Group. The suppliers were chosen to reflect examples of design relationship that existed, and to provide opportunity to examine more closely the exchange and integration of operations. Concern may be raised as to the preponderance of firms that have established design links, that may be of *concern* to the Rover Group, or are uniquely unusual and *of interest*. However, such concerns ignore the purpose of the research, which is *to provide insight and understanding of the dynamics of the process*, and such selection of firms is conducive to achieving this.

This leads to the third criticism of research design, namely: reliability. Critical here is whether the research can be repeated, with the same results. For this reason, the procedures are well documented, and a research protocol was used to map the process. Since there are specific participants in the existing buyer-supplier relationships, similar results would be expected on repeating the research. A flexible case study protocol was used to exploit the context surrounding the buyer-supplier relationship. Projects are not uniform and it was necessary to have an adaptable framework that would reflect this, yet allow consistency of data collection. An exploratory project requires immediate investigation of the context of decisions. An aide-mémoire (Appendix B) enables base-line information to be collected, whilst allowing flexibility for contextual discussions.

Two final concerns of validity are the assumptions made of the process being investigated, and changes that may occur over time to the research field. The literature on product development often assumes that a process in place will be rigidly followed, and that such a process has well-established procedures. This is not always the situation and, as such, a quantitative survey may not have been appropriate of the *in situ* process. For this study, any changes in policy will be reflected in the cases and add to the context of decisions made. Second, a further problem relating to time is the subject of new *rules* and programme methods that new models require, or the individual thoughts of programme directors. Hence, one potential flaw in the research design might be the changes occurring through the course of study. However, since the project is investigating the processes in question, where these have occurred they are documented. Thus, the findings will still remain valid, since they are again context relevant.

6.5 Research interview

Each interview consisted of a semi-structured dialogue primarily with management personnel. These interviews were of 1-2 hours duration and were divided into three sections: general information about the company itself; the process of project management within the firm; and issues surrounding the liaison and exchange of design related information between vehicle manufacturer and supplier. The key points of the interview schedule were outlined in an aide-mémoire (protocol) - presented in Appendix B.

In summary, information sought about the company included: competition and market environment, buyer-supplier relationships, organisation structures (such as ownership, and management structure), planning and decision making (inter- and intra-firm), production operations, and so forth. Additional information on the firms was obtained, where possible, from, *inter alia*, newspaper reports, company annual reports, computer-based sources of company data, and internal company documents.

6.6 Summary of research approach

The research method used in this thesis is:

1. qualitative in nature;
2. case study oriented - where the case study is a single-case, embedded design;
3. the unit of analysis is the buyer-supplier relationship, set within the boundaries of one vehicle manufacturer and six automotive component suppliers (with early involvement to the product development process); hence, there are two focuses for study: (a) the intra-firm process at each site; and (b) the inter-firm process;
4. Semi-structured interviews are the basic data collection method.

NOTES

1. There are four types of research design: single-case (holistic); single-case (embedded); multiple-case (holistic); and multiple-case (embedded). Yin (1989) provides a useful outline of the strengths and weaknesses of each design.
2. This situation is not, however, a multiple-case, embedded design, since all internal projects are governed by the same over-arching *corporate* programme.
3. Using Fujimoto's definition of product development organisation, the product development organisation is defined as "a set of activities which converts market information and technological information into tangible/intangible assets for commercial production" (Fujimoto, 1989, footnote 5, p. 151). Within this, product planning, product engineering, and process engineering are included, but those research activities that are not directly related to commercial production are not.
4. The importance of gaining Purchasing's support cannot be over-emphasised. The Purchasing Department plays a central, pivotal role in buyer-supplier relations, and Product Engineering personnel saw Purchasing's full support as vital.
5. *Suppliers and Manufacturers in Automotive Collaboration* is a RACE Programme funded project of the European Commission, investigating ways of enabling automotive manufacturer engineers to have real-time access to automotive suppliers' product databases. The project involves 14 partners, including Rover Group, TRW, and Renault.

7 DESIGN MANAGEMENT IN ROVER GROUP

7.1 Introduction

The main purpose of this chapter is to describe the project management procedure at Rover Group, and to illustrate the main strategies used to incorporate suppliers in the design and development process. The key procedures that affect project management and supplier involvement are identified, most notably the use of cost management procedures, the role of staff engineers, and the CAD/CAM data exchange policy. This chapter is based largely on interviews with Rover Group engineering staff and purchasing staff, who liaise with the suppliers reported in Chapter Eight.

7.2 Company background

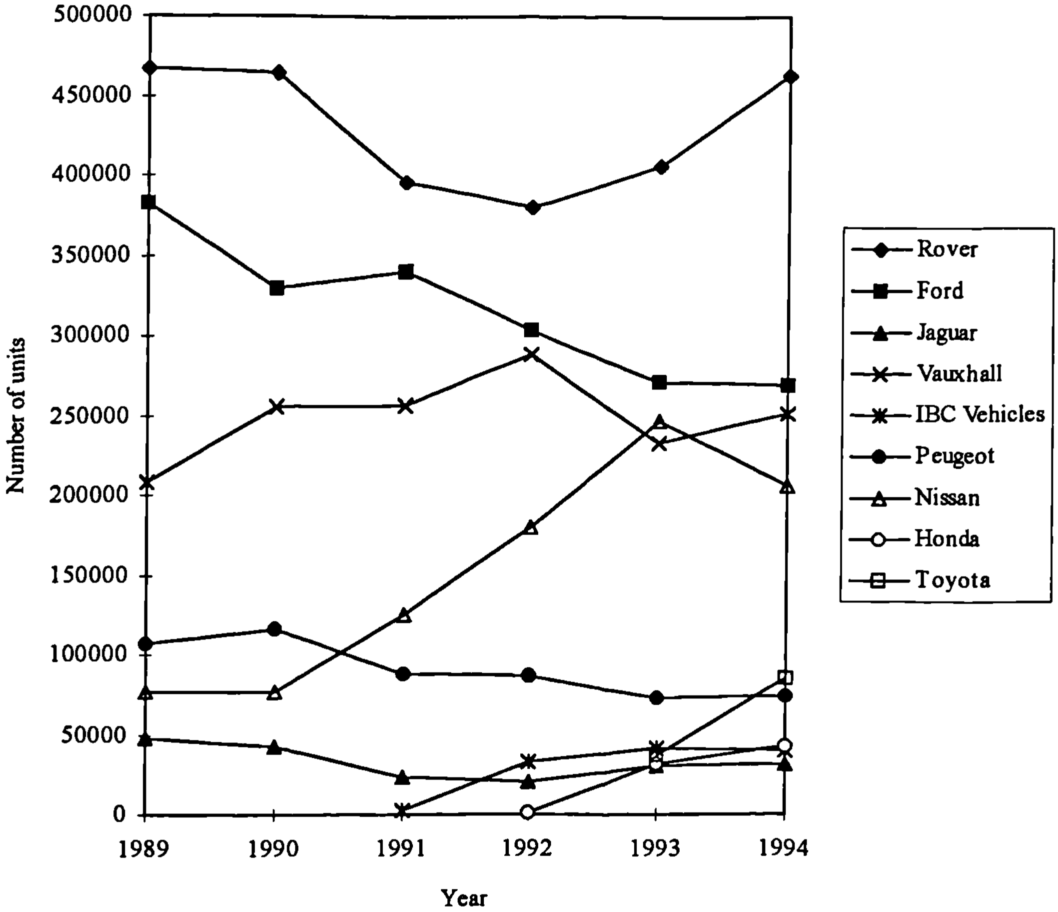
Over the past decade, Rover Group has been transformed from a company in decline to a competitive player in Europe. Although a medium volume manufacturer, Rover Group has changed its image from that of a mass producer to an *upmarket, niche, prestige player* (*European Monitor Business*, 3rd Quarter 1994). A considerable factor in this turnaround has been the collaboration with the Honda Car Corporation that began in 1979. For example, the Rover 200, 400, 600 and 800 models are all based on joint development with Honda, and each company sells the other approximately £400 million of car parts per year (*The Financial Times*, 22 February 1994). The benefit of this collaboration was emphasised most strongly to the author on 1 February 1994: whilst conducting an interview with a Rover product engineer, at the Canley site in Coventry, the announcement was made that BMW had bought Rover Group from British Aerospace for £800 million. The overall atmosphere of the product engineers in the open plan office was concerned with how the working relationship with Honda would be affected, more than how BMW might affect Rover.

In 1993, vehicle sales totalled 442,000 units (Rover cars: 368,500; Land Rover: 73,500) and the total sales revenue of the Rover Group was £4,301 million, with export markets accounting for 41% of total sales (*European Monitor Business*, 3rd Quarter 1994) and the total UK workforce was 33,900 (*The Financial Times*, 24 February 1994).

Rover Group continues to be the largest producer of passenger vehicles in the UK (figure 7.1). In 1994 it produced over 390,000 cars, 71,000 Land Rover *Discoveries* and *Range Rover*, and over 24,000 commercial vehicles (car-derived vans and Land Rovers). Figure 7.2 illustrates the production rates for Rover Group over the 1989-94 period. An interesting feature of this graph is the increase in Range Rover and Land Rover Discovery production, where markets in the USA and Europe have increased sales of these models considerably in recent years.

The production and engineering facilities of Rover Group are based at six primary locations. The Longbridge site, in Birmingham, is the main assembly plant responsible for the Rover 200/400, Metro, and Mini, as well as the manufacture of engines, transmissions and castings. The majority of the Purchasing function is located at Longbridge, although Land Rover related purchasing activities are based in Solihull. The Solihull site, to the East of Birmingham, is the assembly plant for Land Rover

Figure 7.1 UK car production (1989-94)

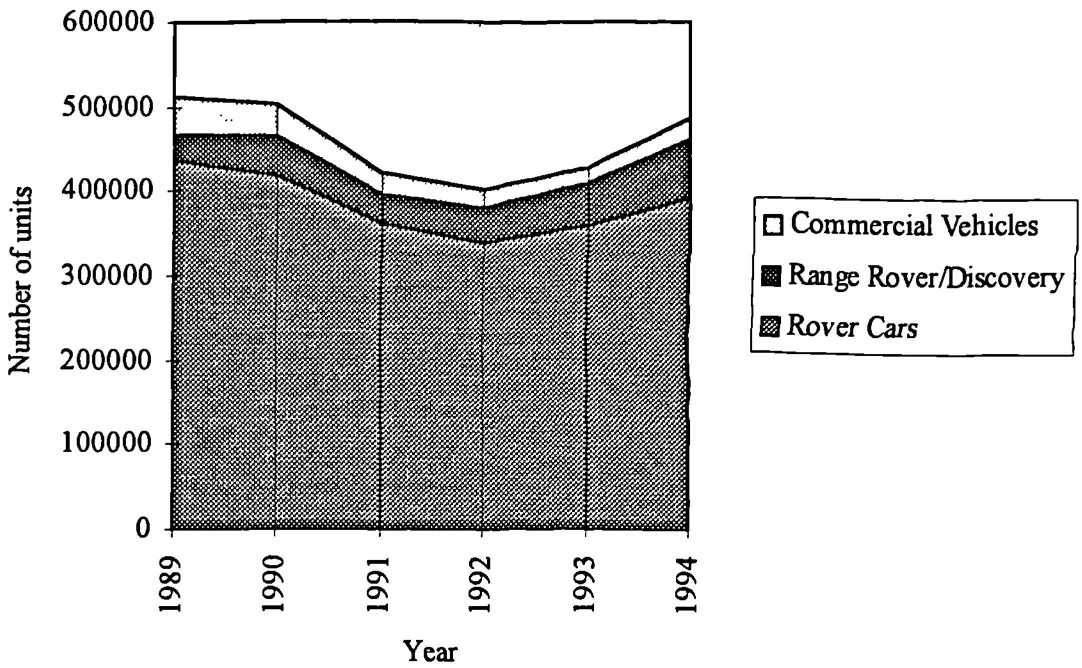


Note: Rover figures include Land Rover Discovery and Range Rover

Source: SMMT data

Defender, *Discovery* and *Range Rover* models. It also manufactures engines, transmissions and components. The third production site is at Cowley, in Oxford. This is the assembly plant for Rover 800, 600, MG RV8, Maestro, and Montego. In Swindon, there is a body and pressings facility, and tooling for Body-In-White. Canley, in Coventry, accommodates the vehicle concept and design, Group product engineering, and commercial divisions. At Gaydon, near Banbury, there is a vehicle design and

Figure 7.2 Rover Group production (1989-94)



Source: SMMT data

testing facility with climatic wind tunnels, prototype build centre, structural analysis facilities, component test laboratories and engine test facilities. In 1995, it has been announced that Rover is expanding this engineering facility. From 1997, all new vehicle design and development operations will take place at Gaydon (*The Financial Times*, 13 March 1995).

Table 7.1 summarises the main product families of the Rover Group in 1995. Many of these are long-standing products, such as the Mini, which was launched in 1959, or the Land Rover, which originates from the 1940s. Many of these vehicles form product platforms for which there are a series of planned changes throughout their life cycle -

normally model year changes, but also possible radical changes. These changes enable new technology (process and product) to be introduced, and for market appropriation to be maintained through styling changes. The commercial/specials segment is characterised by car derivative vans and Land Rover derivatives. The Land Rover *specials* are vehicles produced to customer specification such as army ambulances, fire-tenders and so forth. The specialist nature of the specification requires bespoke design, which also requires supplier participation for particular commodities (parts or systems).

Table 7.1 The product *families of the Rover Group (1995)*

Segment	Examples
Large-car	• Rover 800
Mid-sized	• Rover 600
Compact	• Rover 200 • Rover 400
Supermini	• Rover 100 (Metro)
Mini	• Rover Mini
Speciality/roadster	• Rover MG RV8 • Rover MGF
Sport-utility	• Land Rover Discovery • Range Rover
Commercial/specials	• Land Rover Defender • Land Rover specials (such as fire tenders) • Maestro

7.3 Organisation for product development

Product development in Rover Group is organised on a project matrix basis, around cross-functional project teams. There are three vehicle business units: Small and Medium Car (for example, Mini, Metro, 200 and 400 models), based at Longbridge; Large Car (for example, 600 and 800 models), based at Cowley; and Four-by-four vehicles (for example, Land Rover and Range Rover), based at Solihull. A further business unit is the Body and Pressings operations in Swindon. These business units were established in February 1991 to focus attention on particular vehicle operations. Each vehicle business unit is responsible for the total vehicle programme assigned to its unit, and there is a Project Director within each respective business unit to manage each vehicle project. Each project is sub-divided into smaller elements, for which project (team) leaders are assigned to manage these. For each commodity, an autonomous, core team is established to project manage that component or system. Typically, this team will comprise a component (design) engineer, a purchasing representative (agent), technical support, and a representative from the selected supplier of the commodity. The component engineer is given responsibility for the cost management of that commodity (this issue is discussed in detail later in this chapter).

Discussions with members of different core teams indicate a wide variation in their operations, not least since there is no policy on how core teams are set-up and function. Once a core team is assigned to a project, they decide what is to be done, based on their experiences. This flexibility of approach did not find approval from some interviewees from the purchasing function. They wanted clearer definitions of responsibility and were informally adopting an approach developed by one of their colleagues to facilitate this process. In the absence of a policy, one purchasing agent had specified the activities required of all team members, to determine the location of responsibility - an example of this is provided in Appendix C. This unofficial framework was finding widespread use amongst several project teams.

A related issue concerned the coordination of core teams, and whether this was purchasing or engineering led. The transfer of cost management responsibility onto design engineers was supported by team members, but several purchasing managers considered their expertise in liaising with the supply base was not being utilised. The view was expressed that purchasing managers had developed many contacts with outside organisations, had an overview of the entire business and, as such, were in a position to cross-fertilise projects. At the time of interview, the design/component engineer was commanding a greater role in design and management tasks within core teams.

Each vehicle business unit is supported by several corporate facilities: the testing facilities at Gaydon; Forward Programmes; and Group Engineering. Forward Programmes is a multi-functional group responsible for undertaking concept, styling, and packaging for new projects. Vehicle styling develops the vehicle's concept into a physical form, whilst concept engineering (also known as detailed design) converts the designer's model into engineering expressions using CAD. The CAD generated models are kept on a product database to ensure product integrity throughout the development and manufacturing stages. The first prototype of a new model is produced within this activity. Through the Purchasing function, Forward Programmes also provides feasibility lists and features lists for incorporation into new projects, during which time potential suppliers will be identified together with their engineering process availability and willingness to participate in design and development. It is through this responsibility that the liaison with suppliers, referred to above, is channelled into the company's product development process. In this way, the expertise of the Purchasing function assists in the pre-selection of suppliers, rather than as part of the *in situ* core team.

Group Engineering is a multi-disciplinary function with specialist engineering functions within it. Powertrain Engineering comprises departments investigating engines, transmissions, engine management systems, fluid systems and emissions. Body In White is responsible for engineering the physical structure of the vehicle. Trim and Hardware are responsible for the exterior and interior features such as seats, fascias, and climatic controls. Electrical is responsible for all aspects of electrical/electronic vehicle systems. Chassis Engineering is responsible for front and rear suspensions, manual and power steering, braking systems and engine mounting systems. Engineering Support Services provide a technical/analytical service, such as prototype engineering, vehicle evaluation and reliability testing, and material technology.

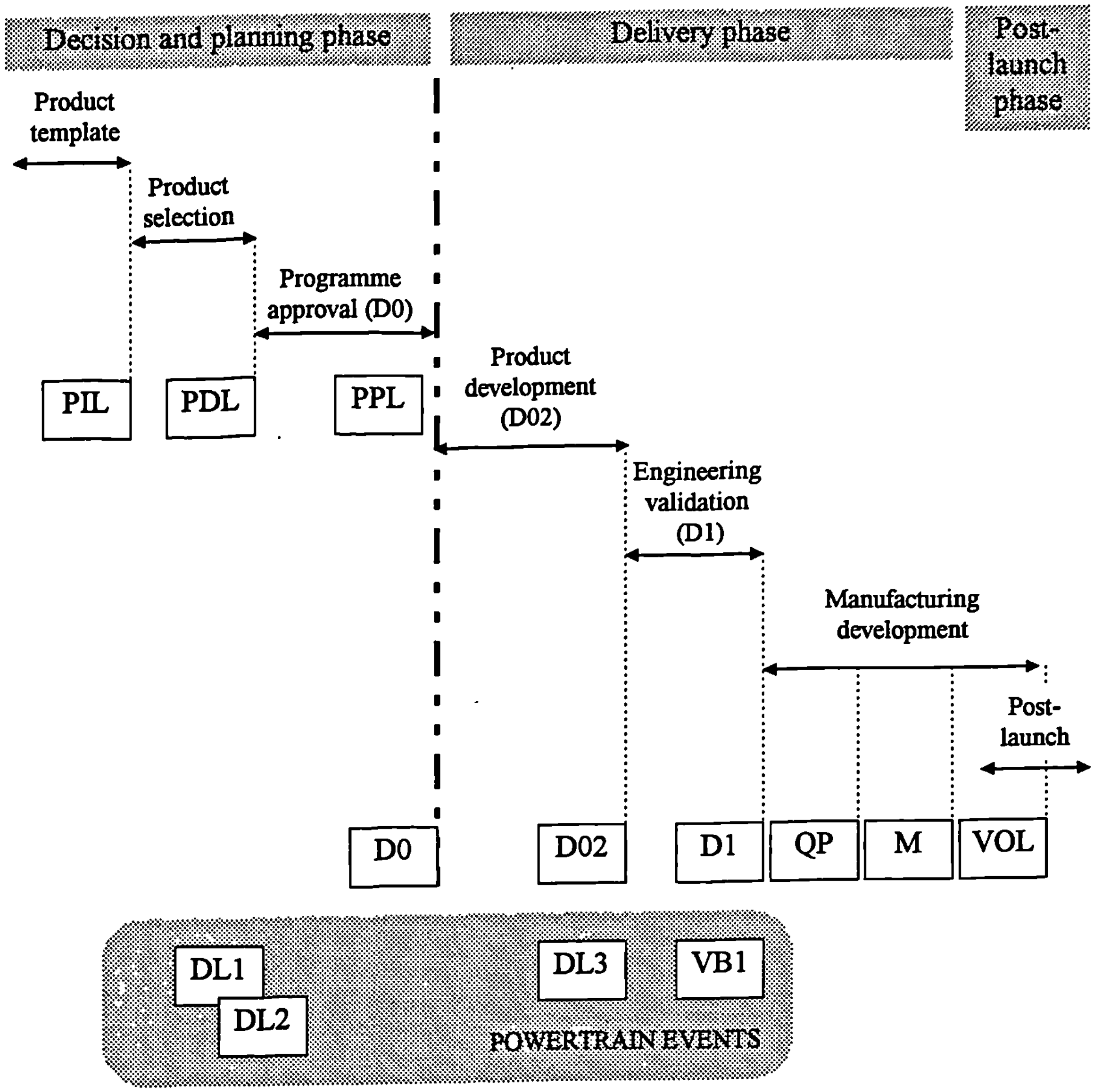
7.4 Product development process at Rover Group

The project management programme of Rover Group is principally a tollgate system (such as the General Electric example in Chapter Two). There are three broad phases - the decision and planning phase, the delivery phase, and the post-launch phase - which are further divided into sub-phase activities. Each sub-phase is driven by milestones, at which time a review activity takes place. The overall process is illustrated in Figure 7.3.

In July 1993, a *Project Management Policy* (Issue 3.0) was implemented by the Rover Group, to supersede the existing Project Management Guidelines (Issue 2). These guidelines were, as the title suggests, only guidelines and, although widely distributed to project teams, interviews with both engineering and purchasing staff revealed that many personnel had never used or seen this document. In the past, it has been at the discretion of project managers and programme directors to determine the techniques followed. The development of Issue 3.0 was seen as a move towards integrating the project management approaches, and all other project management guidelines were withdrawn from use in January 1994, when Issue 3.0 became a Rover Group Policy document - to be adhered to by all project teams.

The integrated nature of the project management policy (PMP) forms the basis of Rover's achievement of BS5750, and is reflected in the other procedures incorporated within its framework, namely: timing management guidelines, a cost management process, problem and release management process, reliability management process, and a product supply procedure (also known as the *design methodology*). This latter document was developed in 1989 with staff from the Advanced Technology Centre at Warwick University and Rover engineers and provides a structured approach to design.

Figure 7.3 Project management process at Rover Group



PIL	Product investigation letter	M	Manufacturing build
PDL	Product development letter	VOL	Volume production
PPL	Product policy letter	DL1	Powertrain concept phase
D0	Programme approval event	DL2	Powertrain development phase
D02	Product development event	DL3	Powertrain validation phase
D1	Engineering validation event	VB1	Powertrain validation build 1
QP	Quality proving build		

Note: Although shown as a sequential series of steps, these phases are cross-functional with early involvement of later stages.

The design methodology provides a procedure for determining solutions to specific product objectives, and to ensure all feasible information sources, tools and techniques have been considered in that selection process. The structured nature of the design methodology means that it has not been formally incorporated into the PMP document. The PMP has a less rigid system of control, which relies upon the project team to determine how best to undertake the project, whilst driven by a checklist of success criteria for each milestone of the process.

Large Cars was the first business unit to test the new policy, both informally and formally as part of their product investigation letter in February 1994. The implementation of the PMP has followed a cascade approach, with each copy being issue controlled. A company-wide learning programme has introduced the policy to senior groups of staff who, in turn, cascade its purpose further across the organisation. The reason for this approach has been to move away from the situation cited earlier, where the guidelines were received, but not acted upon. The first cascade involved the senior and middle management staff of the Purchasing Department in January 1994.

Rover Group has adopted an integrated approach to product development, with all functions and activities having an input to all stages of the process. The PMP was designed for use by all product/project teams, functions and associates, as a guide to how Rover Group conducts product development, manufacture and post launch activities. (Post launch is included since there will be occasions when model year changes constitute minor programmes.)

Using the generic information systems approach outlined in Chapter Three, the product development process at Rover Group is now outlined. In the absence of a single project management approach by Rover Group prior to the PMP, the following description of Rover's development process is a composite based on interviews and the emerged PMP. However, the review milestones have remained constantly throughout the previous procedures and these enable an understanding of the key events that are undertaken.

7.4.1 Concept generation

The concept generation stage of Rover's project management process is termed the *product template phase*. The basis for all of Rover's product programmes is the *Business Template*, which is derived from the Corporate Plan. This phase develops this template into a broad specification for a product - be it a complete vehicle or a powertrain unit. The perceived customer wants are analysed against the overall external environment to generate a *Product Template*.

In Chapter Three it was indicated that vehicle manufacturers use three main sources for generating the product concept: the strategic function, the customer and the research and technology function. Rover begins by considering its strategies, objectives and policies. The strategic function reviews all collaborative agreements (especially those held with Honda) to consider this effect on the proposal, as well as provide appropriate corporate performance targets. Consumer research and analysis are undertaken to establish the trends/opportunities and requirements of, for example, environmental, safety/security, quality and reliability. The team liaises with the Research and Technology group to analyse technology trends and technology opportunities, to review any proposed materials against current and anticipated legislation and company targets and policies (such as ozone depleters, recycling, and exhaust emissions), and to review anticipated competitor developments.

The vehicle aesthetics are developed as concept themes and concept packages, and Rover and Land Rover marque values reviewed. The Power Unit packaging requirements, including possible future applications, is also defined at this stage. Consideration is also given to potential carry-over parts, and ways in which complexity can be reduced. Rover reviews all existing projects in order to look for parallels for joint development of new parts and to incorporate any common themes for the sharing of design and tooling.

The respective Business unit will be nominated for responsibility for the project, and unit definitions and respective supply and logistic *strategies identified. The logistics strategy* is developed at this phase, to drive the downstream operations of design and manufacturing feasibility, thereby developing logistics, design and manufacturing simultaneously. Rover establishes their *preferred supplier strategy* at concept, which also accounts for any collaborative agreements and in-house manufacturing requirements already underway. After having identified these, a synthetic model cost is calculated based on piece price assumptions (including nominated suppliers), and incorporates components logistic costs; preliminary timing plans are constructed, together with developing supplier success criteria.

Finally, programme costs, resources and timing are established. The overall project team costs are determined (such as the engineering resource, facilities, prototype materials and so forth), and project leader, key players and project skills identified. An overall objective milestone plan is determined for the whole programme, and timing plans estimated for long-lead time items, build, tooling and capital expenditure milestones. The interaction of other programmes such as manufacturing and facilities, or Research and Technology, is also determined for their input to the overall schema.

At the end of this phase, a review meeting is held when the product template is evaluated against the Corporate Plan. The successful completion of this activity culminates in the issuing of a *Product Investigation Letter* (PIL).

7.4.2 Product planning

At Rover Group, product planning consists of two phases: *the product selection phase*; and the *programme approval phase* (known as the *D-Zero* (D0) event).

7.4.2.1 Product selection phase

This phase generates and reviews several product opportunities that meet the requirements of the Product Template. The successful completion of this phase culminates in the issuing of a *Product Development Letter* (PDL) and the commitment of engineering resource to achieve a robust D0 event (which signifies programme approval).

A design theme is established by Styling for both exterior and interior designs, as 2D and 3D models. Initial colour and trim are developed, and ergonomics models used to assess interior comfort. Scale models are developed for investigating the aerodynamic principles of the design themes, and the mechanical unit (under bonnet package) is also agreed.

The majority of components for use are identified from several sources. First, potential Research and Technology (or shelf engineered projects) are identified and selected. These must have reached R0 (or later) - an equivalent Research and Technology phase to D0. Second, the maximum number of carry-over parts is considered in relation to the capability of the project to accommodate these. Third, the maximum number of blue-print components is considered for inclusion. A blue-print component is one that is accepted as a company standard over all products, thereby assisting reliability, major piece part savings and manufacturing processes. Another example is a parameter blue-print, where the dimensions of a component change, but all the design principles remain constant (Internal *Quality and Reliability Briefing*, 1992). Before making any changes to any existing or carry-over components, a review is undertaken of the design/supply integrity to alleviate expensive changes to components across all business units.

There is substantial supplier involvement at this stage. Whilst Purchasing and Engineering identify and discuss preferred suppliers, supplier nominations are made for all known parts, make-or-buy components are identified, and vendor tooling lead time constraints and cost estimates are discussed. Those suppliers that have been nominated are briefed about the manufacturing reliability targets and logistics objectives.

Effective Cost Management (ECM) commences for all elements of the programme. Detailed product development costs are estimated for the product feasibility study, and an outline of product development costs is made through to volume production. An objective timing plan is prepared for the programme, indicating the interaction of other programmes (both approved and proposed) and vendor timings.

If a *unique* powertrain project is being undertaken, the powertrain concept phase (DL1) is expected to be completed within this phase. The successful completion of this phase is the issuing of the vehicle/component PDL.

7.4.2.2 Programme approval phase (D0)

This phase develops the selected product and aims to achieve the resolution of all timing, financial and technical concerns, including the building and testing of simulators. D0 is *the* key programme review. If the programme requires powertrain concept and development activities (DL1 and DL2 respectively), these are carried out in this phase - unless a unique powertrain project has already begun.

The entire programme team ratify the vehicle styling with full engineering, manufacturing and logistics feasibility, plus marketing agreement. Several models are produced: a fibre glass model for market research, a master model developed on CAD for early surfacing feasibility, and a full-size aerodynamic test and development model. This phase sees the interior and exterior styles approved and signed-off, colour and trim agreed, the surface measurement released to downstream stages, and the powertrain and mechanical unit packages approved and signed-off.

One of the main activities within the D0 phase is the production of design specifications for each component or system. Any *critical* design characteristics must be identified and confirmed at this stage, with all blue-print designs and planned carry-over components finalised. A detailed Product Definition is developed, including specifications, styling, number of options, number of colours (interior and exterior), and number of parts (degree of complexity). Any Research and Technology projects should have been selected but only if there is sufficient confidence that the technology can be adapted at a product D0. All components or systems design have Failure Mode Effects and Criticality Analysis (FMECA) performed which help determine the development plans.

This phase also involves establishing the intended manufacturing processes. DFM and DFA are important elements of the design process, hence any intended processes and process technology is considered for inclusion in the design process. Similarly, the manufacturing and logistic feasibility are determined, as well as the decisions on in-house and outsourcing, where and how specific components or systems are to be made. The product design should evolve in conjunction with the intended supplier, in-house manufacturing and the logistics strategy. By the end of D0, the purchasing route should be established and the majority of suppliers nominated. The tooling plan for in-house and outsourced parts should be agreed and signed-off by all parties during the phase.

There are regular review meetings by the project team, most importantly to define and agree such issues are complexity, late configurations, component assembly levels, and supplier capacity planning. The product development plans, costs and resource levels should be agreed and communicated to all parties involved. The project timing plan through to volume production should be loaded onto the Rover Project Management (RPM) database with key milestones indicated. (The RPM is viewed by Rover as a key mechanism for providing a central resource for maintaining coordination of the project.)

The culmination of the D0 event is a draft *Product Policy Letter* (PPL) for the vehicle/component, which is sent for Rover Group Board of Directors' approval. This PPL defines the priority for this programme within Rover Group. If the programme is approved by the board, a PPL is issued. This signifies the continuation of the project programme and demonstrates commitment of the Rover Group of resources to it. This resource will include long-lead funding to deliver the product to volume, having first established its priority in terms of volume and existing product plans.

7.4.3 Product and process engineering

Product and process engineering activities involve two phases at Rover Group: the engineering development phase (D02), and the engineering validation phase (D1).

7.4.3.1 Engineering development phase (D02)

The Engineering development phase (D02) is a design-prototype-build-test cycle through which vehicles can be built and tested from a robust engineering design specification, and within the financial constraint of the programme. The successful completion of the D02 event is indicated by the authority for all parts to be production tooled. If powertrain projects are undertaken, this phase will include the DL3 validation phase.

All styling elements are finalised in this phase, and any under-bonnet elements should be updated to the latest design level and signed-off. These allow a full production intent specification to be released and a bill of material to be drawn-up. All components and systems should have functional performance measures, and the design FMECA is reviewed and updated from the previous phase. Any problems should be registered centrally in the project management system.

All components and systems are brought together in a D02/DL3 build phase, to test representative vehicles and prove all major derivatives and options. The last cars (or power units) should be built by manufacturing to maintain authenticity of production. After this, a level of Engineering sign-off should be reached that indicates a design has developed to the point that can be validated during the D1 phase and is capable of proceeding to full manufacturing phase.

All components and systems are procured off production release specifications and drawings, and supplier parts are tested under a Conformity of Production (COP) test programme. Regular project management team reviews take place, particularly regarding cost issues.

7.4.3.2 Engineering validation phase (D1)

The engineering validation phase (D1) involves the building and testing of a vehicle with production parts that meet engineering's specification. (Powertrain validation is conducted at DL3, and activity VB1 *forms the start of process validations.) The* successful completion of this phase occurs with zero-warranty and with a supportable level of confidence that there are no major engineering concerns outstanding, and the project continues to meet the financial and timing commitments proposed at the D0 event. By the end of D1, the project should ideally receive engineering sign-off, but on average, 70 per cent of projects receive engineering sign-off by the end of this stage.

Process engineering and manufacturing requirements are validated from parts sourced from the final production system, and reliability critical items are checked. Lists of reliability critical items are generated at the concept stage, based on past experience, and include items that: have a poor service history or an unproven service history; are safety critical; would cause expensive maintenance if they failed; have stringent tolerances for manufacturing or performance; have life limitations that adversely affect cost of ownership or availability; and those that have long procurement lead times.

Although design engineers have the opportunity to consult component reliability information, interviewees reported the need for late engineering changes, or short availability of time for final design, often means there is little time available to consult this information. Similarly, guarantee and warranty/validation test information receives little review for the same reasons. On a related issue, the warranty information collected is acquired for cost recovery, not specifically for customer satisfaction, so there is a question as to how this loop can be closed to ensure that warranty information captures customer satisfaction information, and hence can be fed into the product design process.

7.4.4 Production

There are several phases that may be viewed as pre-production, and production validation activities: quality proving, manufacturing build, volume, and post-launch.

The *quality proving phase* (QP) is the quality maturation phase. Vehicle parts are built off production ready tooling, utilising production facilities both in-house and at suppliers. The successful completion of this phase is signified with the signing-off of product development, and after manufacturing has identified and resolved all conformity to production concerns. Product development sign-off is achieved when the following sign-offs are complete: Engineering, Logistics, Manufacturing, and Service.

The key objective of the *manufacturing build phase* ('M' build) is to enable both in-house operations and suppliers to run production facilities at track speed to ensure manufacturing assignments, logistics support and so forth are prepared for full production. All components or systems are manufactured off production tools and production facilities. Manufacturing may only proceed to volume when a product sign-off document is released.

The *volume phase* may include advanced volume, or a ramp-up plan for proposed volume production. These units are the first vehicles built from the completed company infrastructure, and should meet launch criteria.

Finally, each Business Unit (Small and Medium, Large, or Four-by-four) will support *post-launch* activities identified by the commercial division. The hand-over of the project to the current engineering team takes place at this stage.

7.5 Effective cost management

Effective cost management (ECM) is a set of procedures for the control and management of component costs for all new programmes. It has three objectives: first, to provide a level of confidence over the cost elements of a new model programme at the D0 event, to enable an informed decision of the viability of the programme; second, to establish clear ownership of cost by the component engineer; and third, to design to a cost rather than cost a design, through working with suppliers over cost levels, *vis-à-vis* quality and reliability (Rover Group ECM Document). Hence, the product development process at Rover can be seen to be driven by the ECM process. The responsibility for total component costs is given to the component engineer from the initial design phase through to post-volume production. Although, other members of the core team may be delegated some cost cutting measures, the final responsibility generally lies with the component engineer.

For every new component being designed, a *cost pack* is developed by the core team. This pack will be managed by the component engineer responsible for that component/option, and consists of a sketch of the component, the expected volumes, the target weight and so forth. In conjunction with Purchasing, the core team identifies all potential suppliers (if no preferred supplier is available) and a cost pack is sent to the potential suppliers to establish an initial understanding of costs, and to allow suppliers to demonstrate their experience and knowledge into a written response. The core team refine the specification further and a quotation analysis form (QAF) is sent to each supplier. Comparison of the completed QAFs leads to nomination of the final supplier, who will then join the core team. This normally takes place within the product selection or programme approval phases, although purchasing staff reported some supplier selection continuing after the D0 event for non-critical, standard components. Where necessary, the supplier's expertise is utilised to develop a detailed design specification to achieve a robust design, from which detailed costs can be generated. A cost target can then be set, with the core team, and especially the supplier, committing to deliver to this target cost. It is then the responsibility of the component engineer to adhere to these costs.

The skills required of component engineers are now increasingly different from those previously required. With the responsibility for ECM comes a need for new skills in negotiation, time management, computer literacy, teamwork, leadership and so forth. In general, design engineers accepted the need to take responsibility for managing component cost, however, concern was expressed over the appropriateness of undertaking ECM prior to the D0 event, by a senior engineering manager. He argued that ECM determined a fixed design too early in the process, at a time when alternative ideas were still benefiting from discussion. In his view, "there is a need for an early release of 'quick and dirty' design ideas - approximates rather than rigid finalities - with which suppliers and designers can work." This view may reflect a traditional design engineering concern that design should lead costs, but nonetheless it was surprising to hear this from a senior manager.

7.6 Supplier strategies

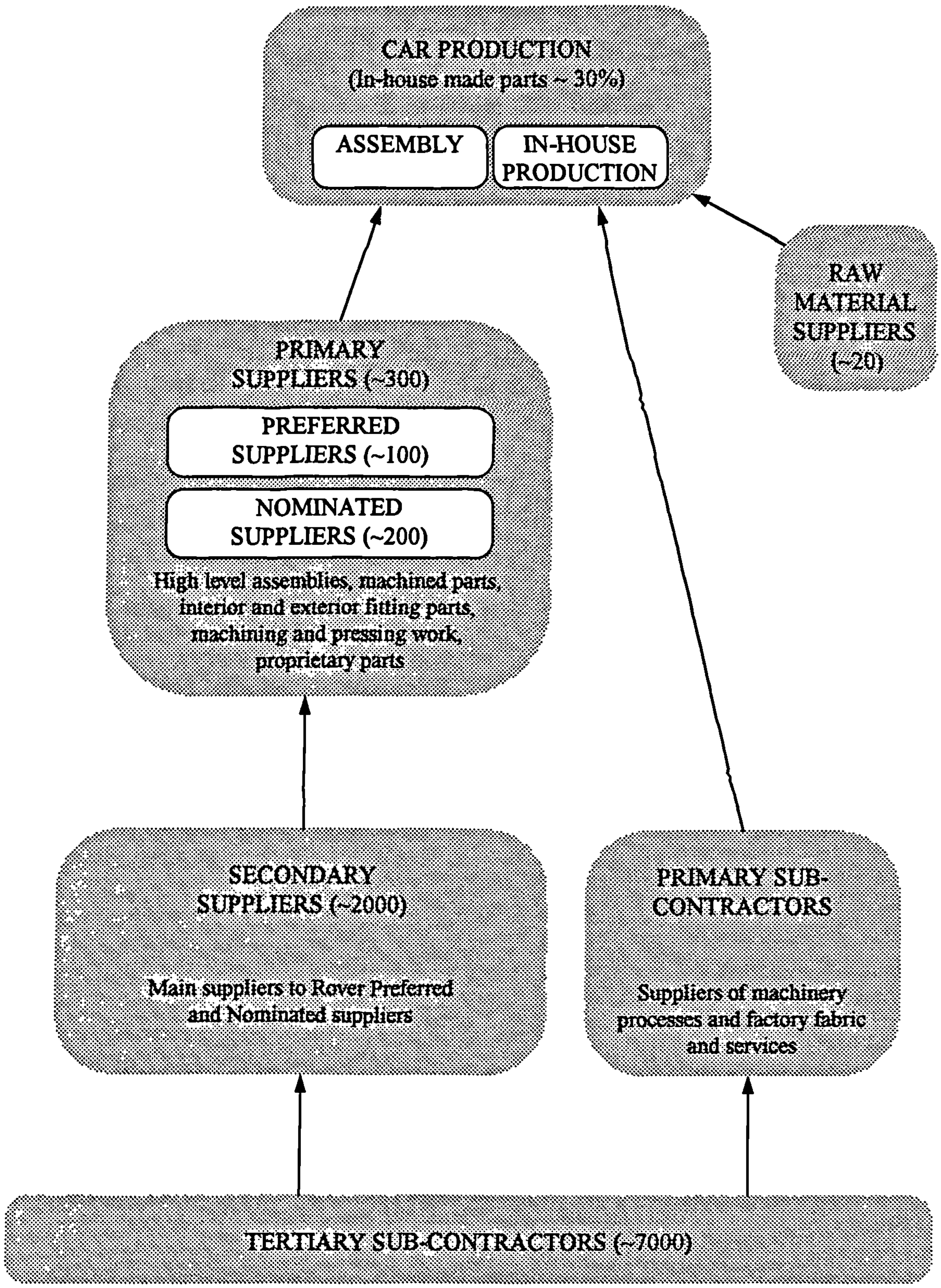
The Rover Purchasing Quality Strategy (1991-95) has within it, three processes that focus attention on Rover's supply base. These are supplier reduction, component strategy development and supplier selection, and supplier development. These processes illustrate the importance of suppliers to Rover's design and development process and the formal procedures for coordinating their participation.

In Chapter Three, supplier reduction was seen as a general trend by all vehicle manufacturers. As key suppliers are integrated into the product development process, further reductions progress and, in the case of Rover, by late 1989, there were approximately 300 primary suppliers, with a further 2,000 secondary suppliers (Bertodo, 1989a). Figure 7.4 characterises the supplier structure at that time. Since 1989, Rover has continued to rationalise its supply base from over 2,000 to about 700 in 1994, with plans to reduce this figure further to 360 by 1997 (*The Financial Times*, 5 November 1994). Concurrent to this supplier reduction, in 1992, Rover began a process of identifying strategic long-term suppliers, in a move to focus supplier expertise in a core group of primary suppliers; by 1994, approximately 360 core suppliers were accounting for 75 per cent of Rover's purchases (*The Financial Times, ibid*).

The second process involves component strategy development and supplier selection. The Purchasing and Engineering functions periodically meet to discuss component strategy, covering issues such as carry-over parts, blue-print designs, and strategic components. Since 1991, databases have been created to hold this information for new vehicle programmes to access. Taking a pan-business perspective, and to some degree a vision of the future, purchasing staff and staff engineers (discussed later) cooperate to identify potential strategic suppliers.

The third process is supplier development, discussed in Chapters Three and Four. In 1991, Rover began a process of selectively involving guest engineers in their product development activities. Whilst this is specified as a clear supplier process, discussions with Rover staff in early 1995 indicates that there are many guest engineers working within Rover Group, but little was known as to their numbers and depth of participation. (This issue is re-visited in Chapter Eight.) Synchronously to this, in 1992, Rover established supplier development teams to assist particular suppliers in meeting the requirements of RG2000, in much the same way as Nissan sends supplier development teams.

Figure 7.4 Supplier structure to support new product development



Source: Bertodo (1989a, figure 3)

7.6.1 RG2000 and supplier selection

A simultaneous programme to these, if not a driving force behind them, is RG2000: a supplier specification to ensure Total Quality and continuous improvement from the primary suppliers. In 1987, Rover Group began their Total Quality Initiative and a culture of continuous improvement. In 1990, RG2000 was specified to extend this philosophy to the first tier suppliers. Prior to RG2000, Rover Group already had a supplier quality assessment system (ARG100), but the new programme linked both operational quality systems with strategic issues. A pre-requisite for RG2000 is supplier accreditation to BS5750 (or EN29000/ISO 9000), but it goes further, assessing supplier attitudes to its workforce, Total Quality, its corporate strategy, and how it meets customer needs. The long-term aim of RG2000 is that supplier partnerships will evolve, whereupon both Rover and supplier will understand each other's business needs. Within Purchasing, there is a technical group of engineers - Purchase Technical Support - who are a supplier development team with responsibility for assessing suppliers for conformance to RG2000.

Rover Group recognises four categories of supplier as part of the RG2000 supplier initiative:

1. proprietary/jointly designed components/systems;
2. major functional and non-functional components and assemblies;
3. simpler components in normal or high volumes;
4. less complex or special components in low volumes (*Supplier Business Specification RG2000*).

Along with quality standards or institution accreditation, the suppliers of categories one and two components are required to demonstrate capabilities in project management, total quality improvement, and business performance to be accredited the higher category RG2000. Referring to figure 5.5, these two categories are similar to those supplier groups - proprietary, black box, detail-controlled functional and aesthetic parts - that are being required to have an earlier involvement in product development activities. Hence, Rover attributes 30 per cent of their supplier rating system specifically to assessing the project management capabilities of these two categories. The RG2000 specifications are extremely detailed, but the key points for category one and two suppliers are: the presence of a project manager; formal systems and procedures in place for planning, reviewing and implementing design and development activities (for example, suppliers should be able to demonstrate a project plan and review programme, to undertake design FMEA at component and system level, and to perform prototype manufacture, development and approval); control procedures of process planning, tooling and capacity planning; quality systems and procedures are reviewed, in line with legislative requirements or Rover group requirements; and the application of RG2000 principles to the subcontractors of these major suppliers. This latter point reinforces the emerging pattern of responsibility being placed on primary suppliers identified in Chapter Three.

In summary, RG2000 assesses the project management process of the supplier, to ensure, *inter alia*, there is: detailed design component information; a good paperwork procedure and an effective project management process is in place; a framework for process critical capabilities and component critical capabilities; and a consistent approach to project management is terms of *attention to detail.* These measures reflect the needs of early involvement being requested of suppliers in product development.

7.6.2 Supplier inputs to design and development

At the styling/concept stage, there is very little supplier involvement at present. However, where there is a need to assess feasibility of manufacture and so forth, a supplier will be sought for their manufacturing expertise. In this case, a list of strategic suppliers will be consulted that Purchasing has established with the assistance of the staff engineers. By the D0 event, 80-90 per cent of the suppliers for a project should ideally be nominated, although the selection of suppliers equates approximately to the following pattern: 300 selected prior to D0, 600 having been selected by the D0 event, and 1,200 by the D1 event (Rover Supply Manager respondent). It is very important to know which suppliers are involved as early as possible. Many suppliers in trim may be nominated at the pre-digitising stage, to ensure their input of manufacturing expertise. Suppliers of seats and door casings are examples of components where the supplier will be identified early in the development process.

An example of the benefit of supplier participation in design is a plastic injection moulding of the fascia for a Rover Large Car project. The team leader assigned a project manager to oversee the design and completion of the component. Personnel were drawn to form a core team, and included: the Rover project manager, a supplier technical liaison representative, a toolmaker (selected by the supplier), and liaison staff from Rover manufacturing (Large Cars), and Rover production. Besides the supplier representative on the core team, the supplier firm dedicated three further personnel to work inside Rover for about three days per week, and two at the supplier company, reflecting the need for continual dialogue between both Rover and supplier design staff for a detail-controlled aesthetic component.

Supplier input was seen as significant for cost reduction and ease of manufacture. By changing a mould line from 15 degrees to 18.5 degrees (a supplier design suggestion), for example, it was possible to include the glove-box as an integral part of the fascia moulding, thereby eliminating the need for a separate mould, plus fixtures. For this component *re-design*, it was important for the supplier to see the final assembly position. The supplier suggested moulding in an internal mark on the fascia to assist positioning the component whilst on the assembly line, for ease of assembly. Similarly, it is important to have a manufacturing input too. For example, if the original specifications of separate design teams suggest using M6 and M5 fasteners for separate components, manufacturing may suggest that only one type of fastener could be necessary for both parts. If M5 fasteners only are used, then an estimated saving of £0.40 per vehicle could be made, which would be a considerable saving on volumes of 100,000 units. It is these types of benefits that are driving Rover Group towards closer involvement of suppliers in the design and development process.

7.7 The role of gatekeeper

Staff engineers are a Group Engineering Resource with separate staff engineer groups for Chassis, Trim and Hardware, Electrical, Powertrain, and Body Pressings. They work within all business units, across all model range sizes, and provide a central source of expertise to all vehicle projects - where and when required.

Staff engineers are examples of the *gatekeeper* form of coordination mechanism referred to in Chapter Four. The responsibilities of these gatekeepers are characterised by an electrical harness staff engineer. His primary role is "to act as an *indirect* interface with external suppliers", whilst the *direct* interface is the responsibility of each project team to liaise with suppliers. This particular staff engineer maintains a knowledge of new harness developments in three ways: first, by talking directly with potential harness suppliers (four of whom are UK based, and one France based); second, by working with Rover's Vehicle Cost Group to disassemble systematically competitor products, thereby enabling an understanding of their technology developments; and third, by attending trade shows and consulting technical journals. These latter sources of information tend to be of limited benefit since they focus on overall developments in the field, rather than providing specific technical solutions. Furthermore, he maintains direct links with several second tier suppliers, such as suppliers of electrical connectors and cable protectors in order to be aware of the larger design chain implications.

The second role of staff engineers is to ensure all business units are following any common component strategies. For example, that they are all using standard fuseboxes, connectors and so forth, wherever possible. Third, they work closely with Purchasing to determine component cost issues, enabling a reduction in costs as far as is feasible. Fourth, staff engineers need to be aware of new process technologies within their respective component business. Harness manufacture, for example, is a very labour intensive process; therefore, lowering the piece price (of which one-third is attributable to labour costs) necessitates working with suppliers for improvements in process technology.

The final role of the staff engineer is to act as arbitrator, on internal design issues. The need for engineering changes in a new project will lead, for example, to compromises from component engineers. If these cannot be resolved at the engineer level, then the staff engineer may intervene to assist. If it is still not resolved, then it will be escalated up to the team leader, or to the chief engineer for the project. An example of this latter case is where changes will impact on body-in-white. Generally, these design details are *frozen* early in the project, hence changes will require for the unfreezing of these, which can only be authorised at Project Director level.

Compiling the interviews of four staff engineers from Electrical, and Trim and Hardware, the overall role of staff engineers in Rover Group are:

- to liaise with Purchasing in formulating the supplier involvement strategy;
- to assist in the component strategy in terms of logistics, DFM/DFA, design for disassembly, and so forth;
- to liaise with Forward Programmes to discuss potential carry-over parts to future vehicle projects;

- to liaise on a component basis, and act as an information resource on the current technology;
- to act as gatekeeper to Marketing and Manufacturing about forthcoming product and process technologies, for example, in universities and supplier companies;
- to know about the new developments occurring in component technology and, where new materials are suggested by suppliers, they should liaise with material specialists to assess their suitability/appropriateness; hence, they liaise between suppliers and Rover Group on technical matters.

The position of staff engineer is generally assigned to personnel with extensive job experience within Rover's engineering activities. It is a *crucial integrating mechanism*, both internally and externally, and interviews with purchasing, engineering and suppliers reflected the importance that this gatekeeper's tacit knowledge plays in product development activities.

7.8 CAD/CAM data exchange

Since the mid-1980s, Rover Group has sought the exchange of product data in computer form with suppliers. In 1983, Austin Rover, as it was then, augmented a Computer Integrated Engineering programme to design, engineer and manufacture motor vehicles solely from data contained in a 3D computer model. A crucial part of this programme was the participation of suppliers in this, since at that time 60 per cent of a typical Rover car was constructed from bought-out materials. Twigg (1990) discusses this adoption policy and the subsequent affect on the supplier base in detail. Suffice it to say, by 1987, the adoption of CAD/CAM by Rover suppliers resembled the following pattern:

> a small number of suppliers had adopted 3D systems compatible with those of the Rover Group; a larger group had installed some CAD facilities which were not directly compatible with Rover but which were, potentially, compatible *via* a data exchange format; the majority of suppliers were concerned and interested in adoption but had made no commitment to invest; and, another large group had shown neither commitment nor interest in CAD related investments. (A Rover study cited in Twigg, 1990, pp. 98-99)

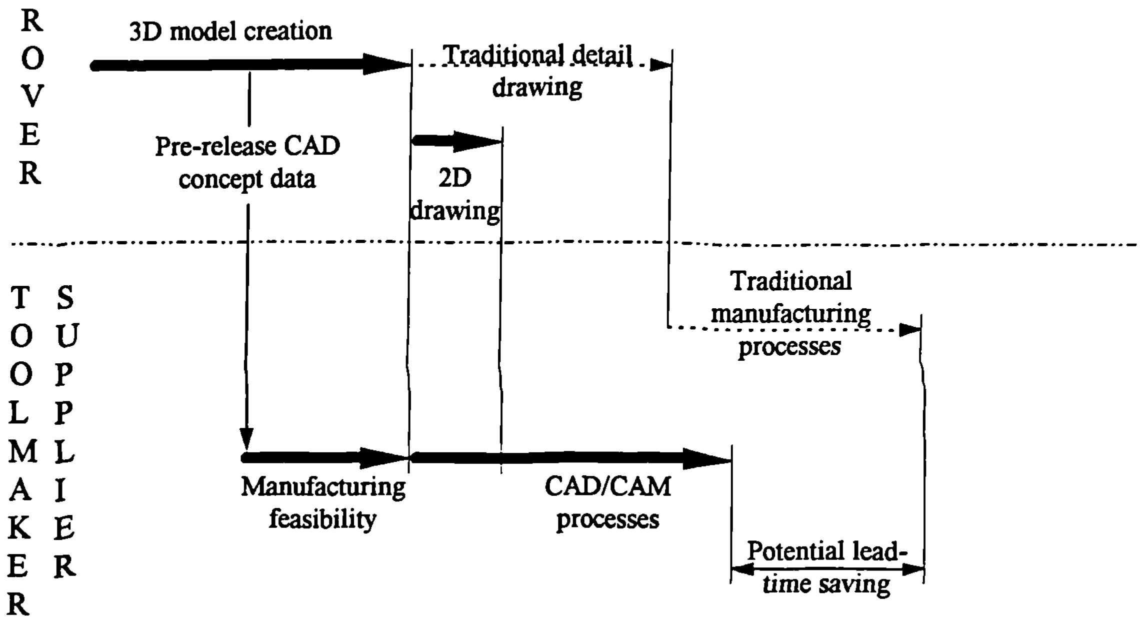
These findings of a Rover study were supported by the research during the same period by Twigg (1990), who concluded that the adoption of CAD/CAM by suppliers was critically determined by the opinions and perceptions of the design relationship between vehicle manufacturer and component supplier, particularly the need for design communication. In the absence of reliable data exchange formats, the choice of system was based upon the importance of parent company (Group), customer or internal considerations (Twigg, 1990). Where suppliers clearly demonstrated a black box design responsibility, Group compatibility of system or internal reasons determined the system choice, but where there was an iterative need for design communication between Rover and supplier, suppliers generally selected customer compatible systems either as a direct purchase or through use of a bureau service specialising in Rover supply.

The requirement for suppliers to have CAD/CAM systems compatible with Rover's systems still remains important in the mid-1990s. The transmission of design data in digital format, as opposed to manual drawings, is part of Rover's strategic aim of reducing cost, improving quality and developing products *right first time*. The aims were specified in the 1983 CIE programme, and appropriately drive the current strategy. To this end, Rover Group has a CAD/CAM data exchange policy that outlines the steps to be taken by suppliers in transmitting design data with the company. Three groups of external resources need to exchange design data with Rover, for Rover to be able to undertake concurrent engineering within the extended boundary of outsourced design expertise: suppliers; toolmakers (including jig, tool and facilities' suppliers); and contract design houses. Figures 7.5(a) and 7.5(b) illustrate the generic approaches to CAD/CAM data exchange based on whether Rover or the supplier has design responsibility. Where Rover has the clear design responsibility, the early release of CAD concept data enables toolmaker and supplier alike to determine manufacturing feasibility and prepare CAD/CAM processes sooner in the process. In the case of supplier design responsibility, Rover releases a design specification and maintains design liaison throughout the early design stages. These can be seen as extremes of a continuum between which a grey area is developing with a need for greater design and manufacturing liaison and feedback. Where a major interface exists between components, especially functional and aesthetic parts, suppliers are increasingly residing at Rover-based CAD terminals to complete drafting tasks, both for the use of the central product data management system, but also for liaison with Rover engineers.

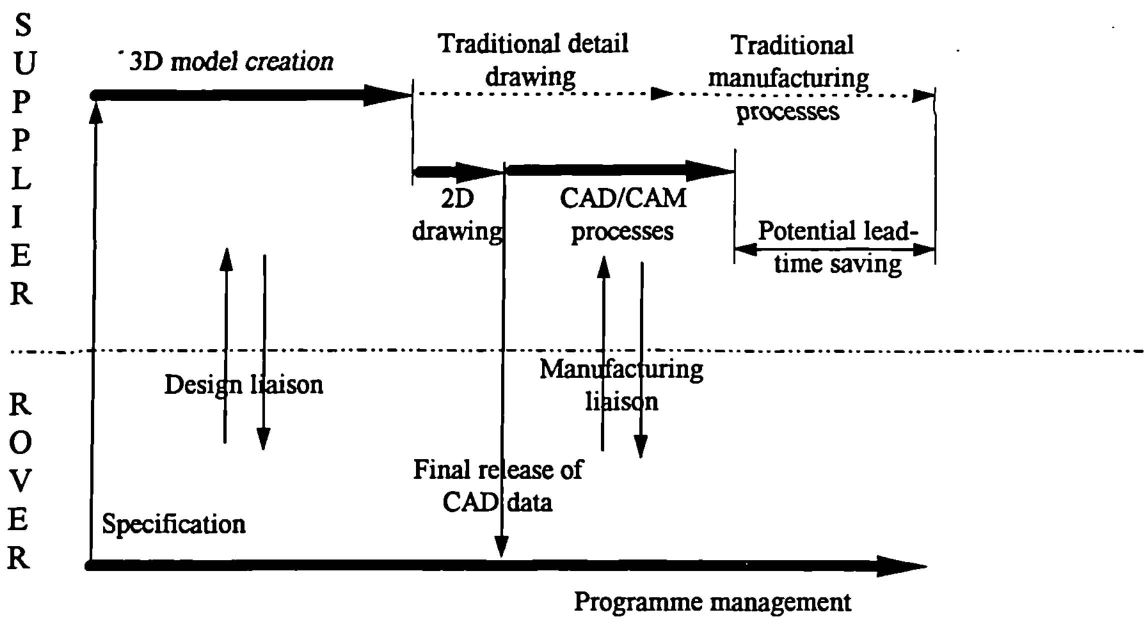
Rover prefers, where possible, for suppliers to select CAD/CAM systems that are directly compatible with the Computervision CADDS4X system (although other systems are used at Rover where specific applications are viewed as providing greater benefit). Wherever possible, suppliers are encouraged to adopt an identical system, for several reasons:

Figure 7.5 Rover/supplier design responsibility and CAD/CAM data exchange

(a) Rover design responsibility



(b) Supplier design responsibility



Source: Rover Group CAD/CAM Data Exchange Policy document (1991)

1. this eliminates data conversion requirements and associated problems;
2. there is no loss of geometric entities or design functionality;
3. engineers are able to share a common design environment and language;
4. there is no risk of data corruption from different software revision levels (Rover CAD/CAM data exchange policy, 1991).

The importance of sharing a common language was reinforced in an interview with a Senior Manager in Computervision (the major CAD vendor to Rover Group) in April 1993:

> Although there may be direct compatibility been a Computervision system and another vendor's system, the use of vocabulary is often different and can be confusing: a *picture* to one system may be a *drawing* to another. As a result, face-to-face discussions are imperative to ensure accuracy. However, when a common vocabulary is established, discussions of solutions by telephone are possible.

The type of data transferred also impacts upon decisions of system selection, since the specific format of the digital design information varies with the component or system. For example, powertrain components tend to require solid modelling information, body panels require 3D surface data, and turned components use 2D CAD data. In 1991, the availability of data exchange standards affected the various transfers of data in different ways. For example, for 3D wireframe and 3D surface modelling transfers, Rover recommended IGES, VDA-FS and Honda standards to suppliers, since they performed well in CAD/CAM data exchanges. For 2D detail drawing, IGES performed fairly well, but for 3D model-based detail drawings, IGES performed poorly. The presence of a CAD/CAM data exchange policy enables Rover Group to convey their exchange requirements, and to offer suppliers an indication of how data transfer may be achieved.

In support of this, Rover provides assistance to suppliers and toolmakers in the form of CAD/CAM advice, testing and joint development. The ability to transfer CAD/CAM data successfully is an important criterion in Rover's supplier selection procedure.

7.9 Summary

This chapter has outlined the project management process at Rover Group and demonstrated the holistic approach of the Project Management Policy (PMP). Whereas project teams have generally followed an *ad hoc* process to vehicle development in the past, the change towards a policy document in 1994 is drawing the company towards recognising the need for a standardised process. This enables individual project teams the flexibility to retain some autonomy of how the process is implemented, whilst providing control mechanisms through the checklists and review procedures. The supporting documents to the PMP also provide further control and analysis within this flexible approach.

Table 7.2 summarises the main features of the project management activities at Rover Group. The process has three main points of interaction with suppliers. First, suppliers who are seen as *strategically* important have an early input to the product development process, at the product selection prior stage, often helping prepare the product specification itself. These suppliers are generally system, key proprietary parts, or critical functional or aesthetic parts suppliers (as indicated in table 5.6). These suppliers will be nominated through discussions with purchasing agents and staff engineers. Second, the majority of suppliers should be selected by the end of the programme

Table 7.2 Summary of Rover's approach to project management

Project management elements	**Rover's features**
Characterisation of process	Phases and gates.
Dominant characteristics	Cross-functional project team focus, based in business units; core engineering support facilities.
Key mechanisms	Programme directors in each business unit oversee all projects. Project manager assigned to individual projects. Senior management review at key events. D0 event gives project go-ahead; QP event production go-ahead. Project status review meetings between Rover and supplier on monthly basis. Key partnership suppliers brought in at pre-concept and concept stages. Use of *guest engineers* and *staff engineers*. ECM and RG2000.
Major phases in a development project	7 stages (6 *key* gates/milestones): 1. Product template; 2. Product selection; 3. Programme approval (**D0** event); 4. Product development (**D02** event); 5. Engineering validation (**D1** event); 6. Manufacturing development (**Quality Proving** event/**Manufacturing** event/**Volume production**); 7. Post-launch. (Powertrain development has separate, but similar stages and events.)
Dominant type of project	Evolutions, enhancements and incremental improvements for model year changes: emphasis on speed. Platform/next generation projects largely performed in cooperation with Honda (although not exclusively).
Typical project duration	12-24 months for model year changes. 3-6 years for new vehicle projects.
Primary performance drivers	Customer satisfaction (through quality and cost reduction); Robust design; Technical performance; Speed.
Formality of process	Holistic in approach, but formalised reporting procedures through each gate. PMP supported by: timing management guidelines; cost management process; problem and release management process; reliability management process; and product supply procedure (design methodology).

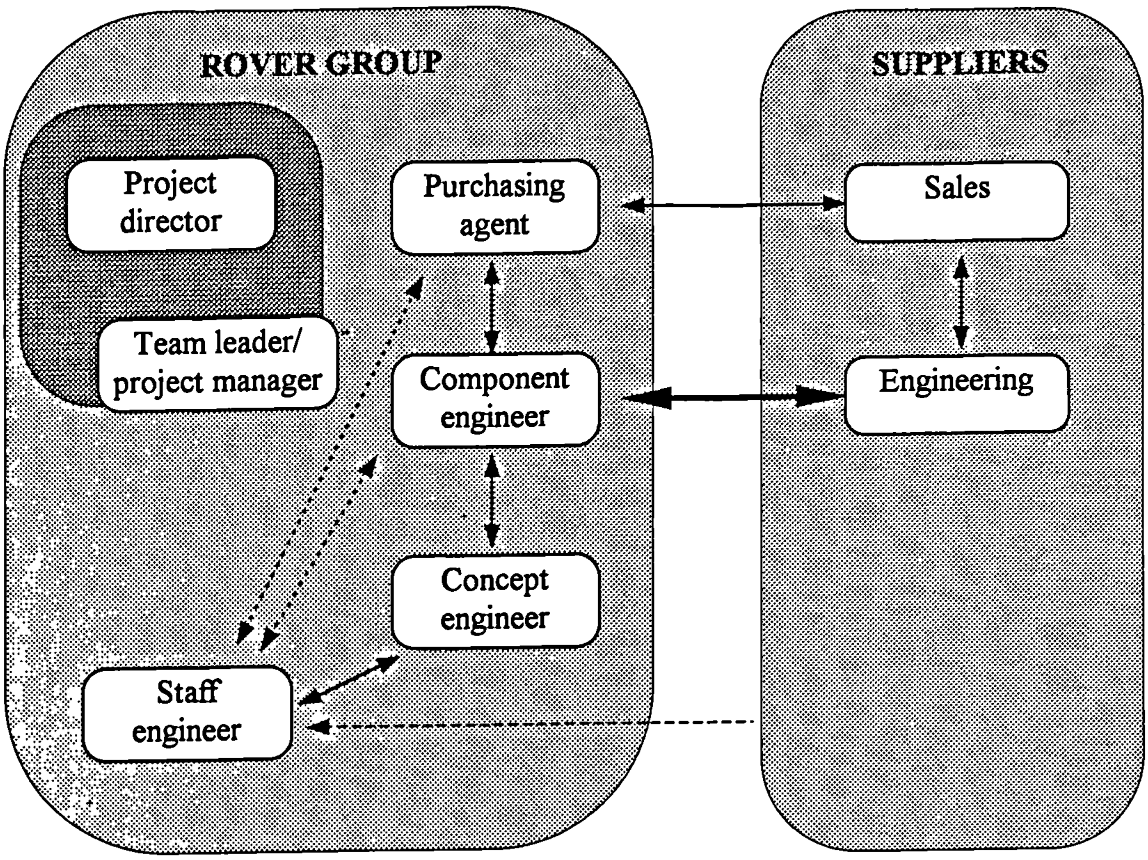
approval stage, when the D0 event takes place. Where suppliers are interfacing with long lead-time items, aesthetically critical or new technology parts, extensive interaction will already be taking place. For others, receipt of detailed specification will not occur until after the D0 event. Third, the final major interaction of suppliers in product development occurs in the engineering development phase (D02 event), which culminates in a robust engineering design specification. Any new supplier involvement after this event will generally involve outsourcing of standard production requirements, rather than product development activities.

Overall, Rover has several mechanisms for promoting suppliers who can meet the objective of closer product development participation: RG2000, supplier development teams to encourage continual improvement within supplier manufacturing processes, supplier circles for those suppliers most closely involved in *early* product development activities, open-book cost accounting to facilitate long-term cost reductions, and the encouragement of guest engineers to work on site at Rover.

One deficiency with the PMP is the lack of a formal procedure for capturing the experience of previous projects. Although the policy enables existing parts to be considered and carry-over parts are examined, discussions with component engineers, staff engineers, support staff and purchasing agents indicate an absence of a formal procedure for *every* project. There have been isolated post-project reviews, but these have been at the behest of project directors. Since the company was undergoing a substantial change in its approach to project management at the time of the research, there is reason to be believe that such reviews will become more widespread. There is a computer network known as the Group Learning Exchange Network (GLEN) which could provide one mechanism by which project experiences could be captured for future reference. However, the process of creating such data is time consuming for individuals and, at present, a voluntary exercise in which few staff choose to participate.

The key participants in design relationships between Rover and its suppliers are indicated in figure 7.6. At the interface between Rover and supplier, initial discussions involve the Rover purchasing agent and component engineer (project manager for a specific commodity), and the supplier sales representative and supplier project manager (normally based in engineering). This relationship signifies the traditional role of Purchasing and Sales, but with the added participation of Engineering. Along with these members of the project core team, staff engineers play a key role in advising Purchasing and Engineering of supplier capabilities. These design relationships are now examined in detail in Chapter Eight.

Figure 7.6 Key participants in design relationships between Rover and its suppliers



8 DESIGN MANAGEMENT IN THE DESIGN CHAIN: DESCRIPTION AND ANALYSIS

8.1 Introduction

This chapter examines the participation of particular suppliers in the design and development of vehicle components to the Rover Group. Six component suppliers are examined, along with three major examples of the design relationship with Rover Group. The cases are then analysed to determine the dynamics of the design relationship that exist between these suppliers and the Rover Group, and conclusions drawn of the main features of how inter-organisational design relationships are coordinated.

8.2 BUMPER (Case 1)

BUMPER is a *Preferred Supplier* to the Rover Group, and has been a manufacturer of medium and large plastic injection mouldings for approximately 20 years. Its main product lines are bumpers, fascias and grilles, and is in a unique position of being the sole supplier of bumpers to the Rover Group. Other major customers include Honda, Unipart (for aftermarket sales), Peugeot, and Volvo Truck. The major share of its business is spread between Rover, Honda and Unipart. The Unipart business is particularly important, since BUMPER has to guarantee the supply of bumpers to the aftermarket for up to 10 years after the effective life-cycle of a car model. In 1989, the company underwent a dramatic expansion, following which BUMPER has witnessed a doubling of both profits and turnover between 1991-94.

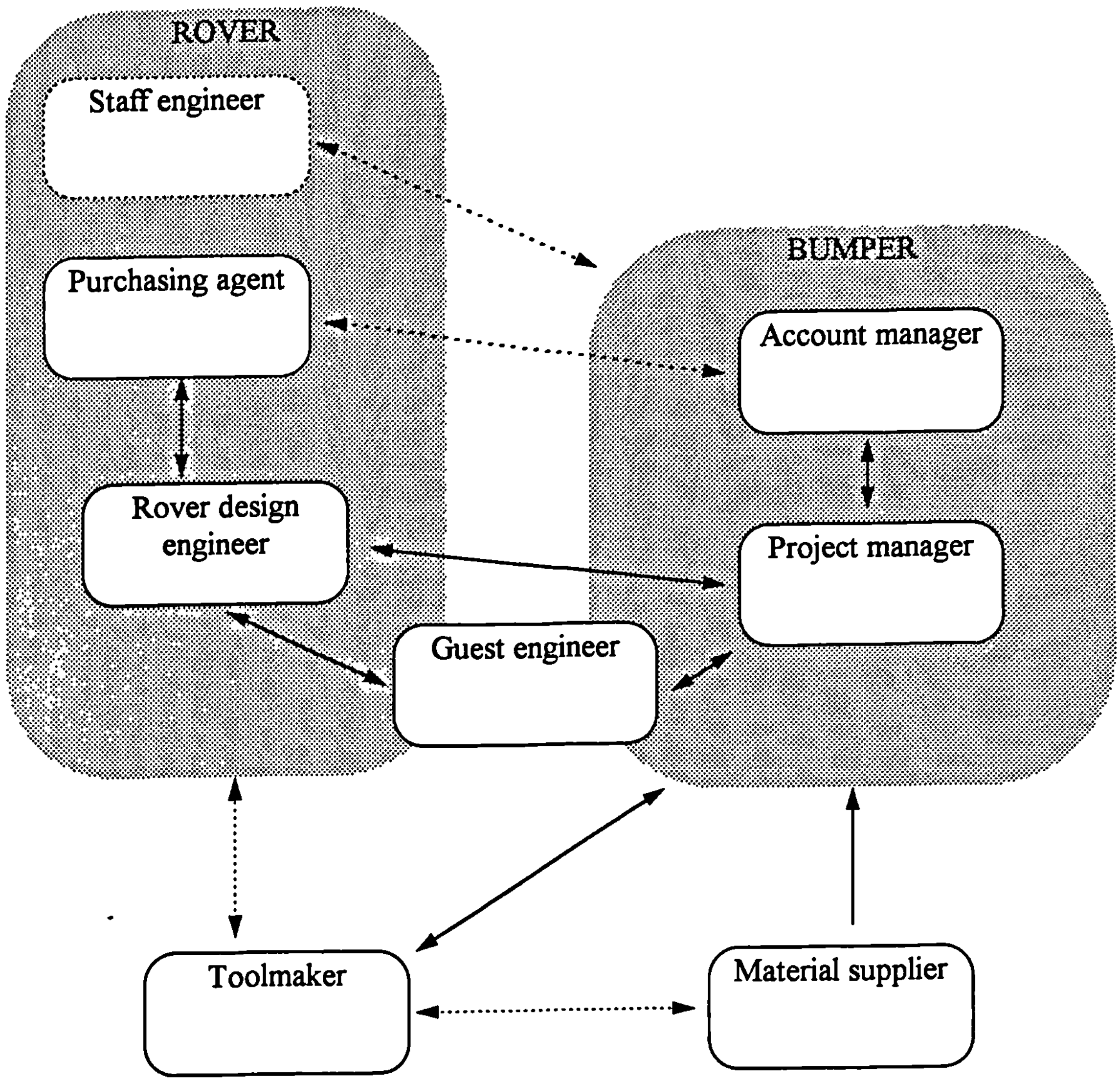
BUMPER is located in Warwickshire, midway between Rover's main production sites in Oxfordshire and the Midlands. It designs and manufactures injection mouldings on site. In the case of Rover bumpers, they have been traditionally injection moulded at Banbury and transported the parts to Rover's paintshop at Swindon, where the parts were colour painted. From there, parts would be transported to Cowley or Longbridge, as required. As part of a policy towards 'closing the loop' to control both the moulding and painting operations, BUMPER purchased this paintshop operation in the early 1990s.

8.2.1 Design relationship with Rover

The typical bumper for Rover Group involves two stages. First, a feasibility study will be requested on developing a bumper with the vehicle concept group. At this stage, engineering hours will be logged, and for this BUMPER has placed a guest engineer within Rover. A cost pack will then be generated and a *quotation analysis form raised.* It is normal for BUMPER to be awarded Rover's contracts, and the close relationship with concept reinforces this.

Figure 8.1 illustrates the design relationship between BUMPER and Rover Group. A typical project team for the bumper comprises: a project manager, account manager and guest engineer from BUMPER; a design engineer and purchasing agent from Rover; a toolmaker; and, a material supplier. There is a Design Review meeting each month for the project team.

Figure 8.1 Design relationship between BUMPER and Rover



In addition to the project team, BUMPER maintains a close working relationship with a Rover staff engineer from Trim and Hardware. The guest engineer resides permanently at Rover's Canley site, working mostly with the concept group. This arrangement is important since BUMPER works with the 'A' surface taken directly from the clay model at concept stage. The guest engineer is a former Rover employee, who took early retirement. Given the importance of Rover business, BUMPER recruited him to work solely on Rover projects. Besides the guest engineer, BUMPER's project manager is another ex-Rover employee. In total, BUMPER has nine project engineers devoted to automotive work, together with 3-4 account managers. On average, there are 6-7 projects underway in any one year, with an average length of a project being approximately 12-18 months; in the case of Land Rover projects, these are longer (3-4 years).

The material supplier has an important design contribution, insofar as it advises on the mould flow of the specific material to be used. Hence the relationships in figure 8.1 can be seen as representing the transfer of design and process expertise. BUMPER has been using one toolmaker, based in Hampshire, for most of its bumper and fascia toolmaking requirements for over 20 years, a result of which has been the development of a close design relationship. Rover communicates directly with this toolmaker: hence, a tripartite relationship exists between Rover, BUMPER and this particular toolmaker. This direct tooling relationship partly reflects the importance of bumper tooling to Rover, since they generally rely upon one set of tooling for a bumper, for the life-span of a model. This contrasts with Honda's approach of using three sets of tooling. This difference dramatically influences the design and timing of the tooling programme.[1]

Remuneration for design and development work between BUMPER and Rover is not completed until the project reaches volume. There are no separate project management fees - unless the decision to cancel the project is made - since these are covered in the price per unit of production.[2] Therefore, BUMPER ensures all contracts include both development work and production. However, this system of payment does not include the work of toolmakers. There is a long established agreement (approved by suppliers and automotive manufacturers) with the Toolmakers Guild for the payment of tooling work: one-third of total costs are payable on ordering a set of tools; two-thirds of the payment should be made on delivery of the tools; and final payment should be met one month after delivery.

BUMPER is experiencing a problem with Rover with regards to tooling payment. After having approved the cost of an order, Rover's purchasing function is taking 1-4 months to set the order, and pay for the ordering of materials. At this juncture, Purchasing issues a *Letter of Intent* towards the costs of the tooling. Meanwhile, BUMPER is expected to collaborate with the toolmaker on producing the tools, without the toolmaker receiving any payment from Rover. When one realises that the final cost for a set of tools may be £1.5 million, a *Letter of Intent* does not carry sufficient power for a toolmaker to commit engineering resource, in the absence of the one-third payment. The knock-on effect of this situation is that if BUMPER organises a meeting to discuss the design of a commodity, much of the meeting may be spent with the toolmaker asking Rover *when* the first payment will be made. This not only uses up otherwise valuable time, but accentuates the problem further. Hence, one major obstacle towards closer design relationships between Rover and suppliers who require upstream collaboration of tooling sub-contractors, appears to be the logistics surrounding the *Letter of Intent*. Despite encouraging suppliers to work in *partnership*, Rover has an apparent inability to place orders efficiently, which creates particular problems for injection moulding suppliers.

BUMPER does not have a formal, documented project management process, although it has procedures in place that control the process. This ensures conformance with BS5750, and RG2000. It follows a standard procedure with all customer requests, but believes in adapting the process to the specific project. For example, project managing a *fast track* programme (such as project ALPHA discussed below) is subject to different parameters, speed and size, compared to long lead-time projects (such as those typical of Land Rover). When there is sufficient time, CAD facilities will be utilised extensively; however, if time is critical, BUMPER finds it more manageable to perform manual drawings and to have a flexible, if not *ad hoc*, approach. The rigidity of CAD in a time pressure situation would hinder, rather than help. BUMPER finds that Land Rover's project management skills are less developed than those of the two Rover car business units.

The pressure of time is accentuated by the fact that, increasingly, there is no time available for soft tooling within the customer delivery schedule, not least due to delays in payment for tooling work. Hence BUMPER is faced with managing a tripartite relationship where there are conflicting tensions of a toolmaker wanting payment, and a customer demanding the meeting of prescribed project milestone reviews.

8.2.2 RG2000

BUMPER was one of the pilot companies for RG2000 accreditation, when the supply agents who assessed their procedures arranged only periodic visits. However, the supply agents now appear to be much more alert to the need for continual improvement, and are constantly checking that BUMPER is following the systems and procedures in place to meet the RG2000 specifications.

BUMPER believe there is a conflict between the operating procedures of RG2000, and the internal demands of Rover's divisions to accelerate the development process. The RG2000 procedure of D1, QP, M build, and Volume are satisfactory requirements for normal programmes, where time is adequate, but the demands of fast-track projects conflict with this procedure. Suppliers are required, from D1 onwards, to provide a Supplier Component Status Report (SCSR) at each development phase, as a project control and component quality record. These records are used by Rover both for project control and future auditing. As the project manager emphasised in one interview: "it is hard enough to get the parts produced to short schedules, let alone jump over all the paperwork requirements of RG2000." BUMPER argument that when Rover Sales and Marketing want a product to enter a market *window* within 12 months, then SCSR, control plans and so forth (requirements of RG2000) should be waived until a later date - that is *if* the supplier has demonstrated a track record of meeting quality and delivery reliability in the past. Otherwise, BUMPER may have to re-assess fast-track projects in terms of their viability to meet procedure requirements.

Alongside the demands of Purchasing for SCSR's BUMPER is realising an increasing demand from Rover's Logistics department. In response to this, BUMPER has employed a full-time logistics person to ensure design engineers meet all schedule commitments. Assigning a full-time person to this task has helped considerably, particularly during the M-build phase when confirmation of completed tasks becomes a daily task. Delivery reliability is a paramount objective for preferred supplier status, and the employment of someone to undertake this control reinforces this view at BUMPER.

Similarly, the project manager expressed the view that Rover's control plans for drawings, flow paths and so forth, there is no one of these that will satisfy the requirements of all projects: exceptions exist, and these should be firmly stated at the beginning of any new project, and an account of this fact should be made by all participants. The procedure has to be robust, yet flexible. At present, BUMPER believes the plans are too rigid.

An example of this is the difference in part and process complexity. A mould trial for a bumper means something completely different from a mould trial for door handles or interior parts. Since a bumper is *aesthetically critical*, it needs to be as near perfect as possible for the trial to be beneficial; this fact, plus the size of commodity, requires minimum lead-times of between 2-4 weeks, whereas other components may be achieved within a day. At present, the structure of the SCSR flow paths assumes one process path can represent all suppliers, but this does not reflect the different processes in component complexity.

BUMPER has practised an open-booking costing system for about 10 years. As a result, it was easy for them to adapt to the demands of UK automotive companies for first tier suppliers to adopt this system. The use of Effective Cost Management on Rover projects had no dramatic affect on BUMPER, since they had already practised such a working system - although not in name - with the Cowley-based Purchasing department, before ECM become standard practice.

8.2.3 Project ALPHA

The project management procedure outlined above typifies the early involvement of BUMPER in the design process with Rover. A variation to this procedure, however, illustrates how the design relationship, and its management, can be affected by early involvement. Project ALPHA, although possibly an extreme case, demonstrates how the process develops if, first, earlier supplier involvement is sought for an exterior body part, and second, the project is a fast-track programme.

ALPHA was a small car facelift project. It began in 1993, for planned volume in 1995. ALPHA was subtly different from normal Rover projects, since the Styling group had initiated the drive to undertake the styling change, and BUMPER were involved from the outset. A Styling engineer was nominated to explore the feasibility of several concepts, and the project manager at BUMPER was asked to support this process, particularly since it was to be a fast-track project, and decisions had to be quickly made for presenting a package to the Rover Board. BUMPER brought in a toolmaker to assist in the feasibility study.

The initial meetings were based around a clay model, where various ideas were iterated. The project manager (BUMPER) set about building the cost information, without the Sales team (which was unusual) but following the standard procedure at BUMPER. The reason for this was to meet a deadline set by Rover Engineering and Styling to present the overall costs to the Rover Board. Normally, cost packs are sent to BUMPER, and the project manager would build a quotation with the Sales department. The cost information was very broad, based on worse cost and ideal cost scenarios, which outlined a budget that could be presented. Since the project was to be a short development cycle, the presentation included a full breakdown of feasibility, prototypes, costs, ancillary equipment, packaging, tooling, product design and detail (based on BUMPER undertaking the work), material selection, and timing.

Once ALPHA had been approved, a project team was formed consisting of the Styling engineer, a design engineer, a purchasing agent, the BUMPER project manager, and the toolmaker. The project was to re-design the front-end of an established small car. Two obstacles were immediately apparent: first, the small car was notoriously one of Rover's worst body designs (in terms of dimensional stability); and second, the dimensions were not held on the CAD database, and few of the drawings were available too. The Styling engineer and BUMPER's project manager arranged a meeting with the toolmaker and design engineer, and as a group they devised a way of achieving a design from the clay model that the toolmaker could develop the tooling from. The steps taken were: first, to digitise the styling clay model; second, BUMPER's guest engineer detailed crude layouts of both the front and rear bumpers in three weeks; and third, this information was passed to the toolmaker who hand-made two models of the bumpers. When the Styling engineer, project manager, purchasing agent and toolmaker were all satisfied with the product integrity, sign-off was approved and these models were then re-digitised. The data was then re-smoothed (re-drawn), so that the drawing matched up with the tooling points. The two models were then scanned to produce cutter paths for the tools.

Parallel to this process, once the models had been signed-off as being visually acceptable to Styling, a full stacking exercise was undertaken at the toolmakers. (A stacking exercise is a type of prototype-build-test cycle, for establishing the progress of work for the entire programme.) A new bonnet was prepared by Rover, and two fenders were taken that had been validated by engineering. These parts were then hung around a frame together with models of the bumpers, headlamps, and grille (another BUMPER responsibility). This provided an occasion for all participants (including body-in-white) to establish the level of fit, particularly since with such a fast track programme, there was little time to stand back, look, check and assess everything. The whole exercise took around 8-10 hours, with a number of follow-up actions for all participants to undertake.

This stacking exercise provided an important opportunity to coordinate everyone's involvement, as well as ensuring a robust direction for moving downstream with the project. The view of the project manager was that this opportunity to interact is absolutely crucial for the success of a fast-track programme. Once everyone was satisfied that the project was viable, further engineering detail was developed, and tooling continued. The need to respond to engineering changes was constant throughout the project. Information was being constantly exchanged between Rover, BUMPER and the toolmaker on a daily basis (using telephone, fax, and informal face-to-face visits), such as changes to the tools and providing the engineering detail for the 'B' surface design. This continued and status meetings were held, initially fortnightly, until a consensus decision was taken by the team that the intensity and frequency of information exchanges between the three companies could be relaxed. Thereafter, meetings were returned to the normal monthly design reviews.

Rover felt that with the compressed development programme, there was no time for any prototyping, and there would be no initial engineering validation (D1) event. ALPHA moved directly from product development (D02) into quality proving (QP). This decision created some problems. First, a new department had been established at Rover since the project began - Complex Quality Department (CQD). CQD attended one of the monthly status meeting and requested BUMPER to initiate a QP event - parts produced off tools and off production equipment. BUMPER argued that CQD could call the next phase a QP build, but from BUMPER's point of view, this would still be a D1 event, if not something more upstream.

At the time of interview (April/May 1994), the QP event (Rover's interpretation) had just taken place - three days ahead of schedule. There was no slippage in the programme. The process had taken approximately 12 months from feasibility to off-tools production (QP). In April 1993, initial discussions had begun with Styling, and the effective starting point had been the feasibility study in June 1993.

The project manager viewed building a capable team as paramount for the success of a fast-track project like ALPHA. BUMPER had worked on a previous Rover fast-track project for a sports car bumper. This was achieved in only nine months. Unfortunately, some Rover staff believed this demonstrated the way forward in shortening bumper development; however, the time compression could only be achieved because all of the body-in-white information was available as CAD data, and it was only for the development of one bumper. The bumper had been changed using *existing* body-in-white information, thus the top-line, bottom-line and mating faces on the body surfaces (using existing pick-up points) could be quickly established. In the project manager's view, the only possibility of achieving faster lead-times is to *freeze* the body-in-white information earlier, and to get it right first time.

One hindrance to forging stronger relationships with Rover is that there is a high turnover of staff on projects. BUMPER reckons on 3-6 months to develop the trust and dialogue required for a design and development team. They have an excellent working relationship with Styling, Engineering, and Purchasing. However, in the past, BUMPER has found a high turnover of purchasing agents involved through the course of programmes. On ALPHA there was only one purchasing agent, but for another car project there were two purchasing agents, and for a Land Rover project there had been at least three or four. This can cause problems because new purchasing representatives frequently ask for justifications of decisions made over a year before.

At QP phase of ALPHA, BUMPER had still not received a fully released production drawing from Rover. This was causing knock-on affects. The demands of RG2000 required SCSR's to be completed with an issue number, but since none had been released, BUMPER was having to complete forms with 'no formal release of drawing yet' written in place of a part number. (At the time of QP, the only drawings for ALPHA in BUMPER's possession were their own *digitised* originals.) This was contrary to

BS5750 which required a fully released drawing, before tooling could commence, or ancillary equipment could be purchased. However, by waiting, the delivery schedule would be missed. This situation illustrates BUMPER's view that there needs to be a greater degree of flexibility within the existing Rover system to accommodate such programmes.

BUMPER also found that they were frequently asked to achieve cost downs in ALPHA. They reduced costs in excess of £70-80,000 from the initial quote, some of which meant that expenditure on ancillary equipment could not occur until after QP, which went contrary to the requirements of RG2000. The original plan was to scan the model for NC cutter paths, to cut two foam moulds, and cast back from these for ancillary equipment. However , this was waived until M-build. However, this course of action had been agreed in meetings (and minuted) in order to drop a further £12,000 from model making. The proviso was that ancillary equipment would be delivered for in time for M-build. One result of this was a strained relationship between BUMPER and Rover: some parties within Rover deemed BUMPER to be a supplier that was failing to meet the official instructions - not adhering to the SCSR instructions - despite the reality of BUMPER having a minuted agreement on this course of action.

Another cost reducing measure met with an unfavourable response downstream. BUMPER accommodated many changes in the development approach to assist in reducing the total cost of ALPHA. For example, the grille was put together using push nuts, instead of the more usual heat-staking method. This saved £20-30,000 to the budget. However, questions were raised by downstream operations as to why the heatstaker method had not been used. The suggestion of fixing had again been by team consensus, and was deemed the best solution to meeting the engineering and budget requirements.

BUMPER found that early in the design process of ALPHA there was a high degree of trust in making decisions over the project. However, the further towards volume the project proceeded, the more they were being asked to carefully minute the decisions of meetings, to safeguard these for future discussions. There appeared to be a changing relationship, because of RG2000 demands and the lack of continuity through the process from Rover staff.

8.2.4 Summary of BUMPER

BUMPER is a preferred supplier of Rover and supplies all of Rover's bumper requirements. Rover is a major customer (together with Honda-version vehicles) and the aftermarket. BUMPER has supplied Rover for over 20 years, and has developed a close working design relationship for over a decade. The main features of BUMPER's project management approach are presented in table 8.1. The process is contract driven, and is defined by the requirements of each customer's project management milestones. This follows a standard approach to managing all contracts, but is non-documented. The key mechanisms of this approach are the customer's milestones (stage gates), a dominant manager who oversees all projects, and a long-standing tripartite relationship between BUMPER, Rover and a toolmaker. BUMPER undertakes a design projects in response to customer requests. These may be as a reply to a specification, or as an early input at the concept stage of a new project.

Table 8.1 Summary of BUMPER's approach to project management

Project Management Elements	BUMPER's features
Characterisation of process	Contract driven (flexible procedure)
Dominant characteristics	Project team focus, with dominant project manager
Key mechanisms	Contract. Project manager overseeing all projects. Long-standing, tripartite relationship between Rover, BUMPER, and Toolmaker.
Major phases in a development project	Phases defined by customer's process (milestones are the same as Rover's)
Dominant type of project	Evolutions/all types (model year changes; experimental)
Typical project duration (months)	12-18 (Rover) 36-48 (Land Rover)
Primary performance drivers	Delivery reliability; Speed; Aesthetic conformance
Formality of process	Standardised, non-documented overall process - flexible for each contract. Procedures conform to BS5750 and RG2000.

A bumper is an aesthetic critical element of the total vehicle integrity and, as such, the design authority clearly resides with Rover. However, in order to ensure a close parity to style and to facilitate downstream requirements, BUMPER has based an employee permanently within Rover. BUMPER is accredited to BS5750 and currently meets the requirements of RG2000. BUMPER's primary performance drivers are reliability in delivering the final product for assembly, and hence each customer milestone - crucial for RG2000 accreditation, aesthetic conformance to the vehicle integrity, and speed of product delivery.

BUMPER uses both technical and organisational mechanisms in their exchange of design information. CAD information is exchanged, but their guest engineer uses the CAD system on site at Rover. Of major importance to BUMPER is the effective delivery and iteration of information, when necessary. Hence, BUMPER believes that for their product, telephone, facsimile and face-to-face meetings are the crucial mechanisms. Similarly, in the early stages of development, discussions are almost daily, whilst later the monthly status meetings are adequate mechanisms - unresolved tooling payments, notwithstanding. Finally, the stacking exercise is seen as an importance integration mechanism, since the whole product with all interfacing elements can be examined.

BUMPER has identified some problems in its design relationship with Rover. These revolve around the purchasing interface. First, the delayed payment for tooling work unnecessarily impacts upon the project review meetings with Rover and toolmaker, and places stress on an otherwise satisfactory and long-standing relationship. Second, in the case of project ALPHA, the speed of delivery necessitated non-conformance to RG2000. Despite assurances that this course of action received Rover authority, ill-feeling had arisen over a non-SCSR routine. Finally, the high turnover of purchasing staff at Rover experienced over several projects was frustrating to BUMPER, not least because a knock-on effect was the inevitable return to previous decisions made or re-negotiations.

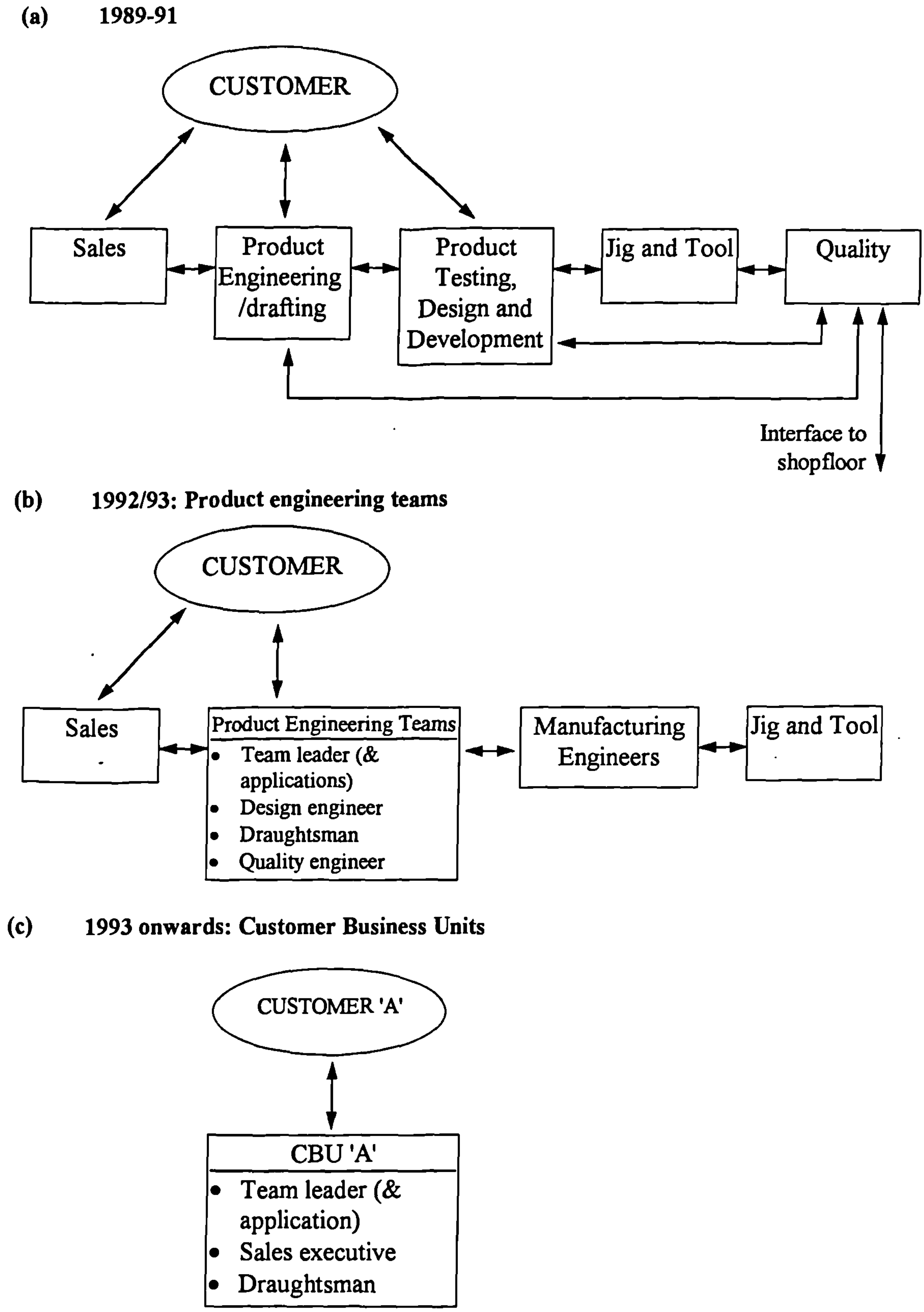
8.3 DRIVE-SHAFT (Case 2)

DRIVE-SHAFT is a major Original Equipment Manufacturer of drive shafts to the world automotive industry, and is located in Birmingham. It employs over 1,000 people in Birmingham and has a turnover of over £80 million (1993). It is a subsidiary of a UK parent, which has operations in France, Germany, Italy, Spain and the USA. The parent has three R&D centres (UK, Germany and USA) that support the line companies. The main customers of DRIVE-SHAFT include Rover, Honda, Toyota, Nissan, Ford and Chrysler. Rover is one of DRIVE-SHAFT's major customers, commanding approximately 40 per cent of sales; significantly, the Japanese vehicle manufacturers' UK transplants account for one-third of sales and is a growing segment of work. They have only one competitor in Europe - a GM subsidiary - and therefore have no independent competition. Ford has its own internal production line for drive shafts, but they use DRIVE-SHAFT's expertise for design work.

8.3.1 Project management organisation

Since 1989, DRIVE-SHAFT has undergone three re-organisations of its product development organisation. The first change occurred between 1989-91, when the company was traditionally organised with several functional areas interfacing with customers in product development (figure 8.2a). Individual functional departments existed for Sales (Commercial), Product Engineering, Product Testing, Design and Development, Jig and Tool, and Quality.

Figure 8.2 Product development re-organisation at DRIVE-SHAFT



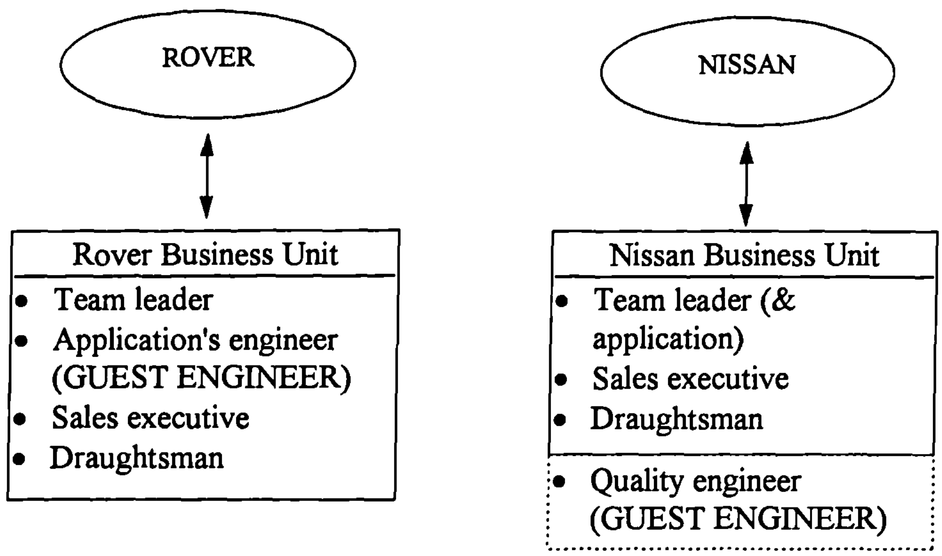
Between 1992/93, a closer focus towards teamwork was sought and Product Engineering Teams (PET) were created (figure 8.2b). Each team was given the responsibility to deliver a project from the concept stage through to volume production levels of approximately 10,000 units. Each PET consisted of: a team leader (also an applications specialist); a design engineer; a draughtsman; and a quality engineer. Under this structure, Sales was still a separate function, as were the manufacturing engineers - who were seconded onto projects as required. Jig and Tool also remained separate. In 1993, product engineering was again re-organised, but towards an individual customer orientation (figure 8.2c). There are currently six Customer Business Units (CBU), one each serving: Rover; Honda; Toyota; Nissan; Chrysler and others; and Ford. Each CBU consists of a team of three: a team leader; a sales executive; and a draughtsman. (There are three sales executives for the six teams.) Each CBU is co-located alongside the other CBU's. The only separation of activities is the CAD terminal for the draughtsman. Each CBU has a dedicated CAD terminal, but these are pooled together in a central office area. There a two Quality Engineers who serve all six CBU's, and they are located in the centre of the same office. Every month, each CBU presents their project to the other business unit team-leaders and the business unit director. This enables cross project learning, as well as feedback of ideas.

DRIVE-SHAFT has five factories on site in Birmingham: four factory lines producing individual component types, and one final assembly line. Each factory line has a manager, a manufacturing engineer, a resident engineer, Jig and Tool staff, a maintenance planner, and two or three maintenance engineers. The manager has the main control, although the CBU team leader retains responsibility for volumes up to

10,000 units. A resident engineer is located on each shop floor (these have been dispersed from the PET's and have responsibility for product development links to each CBU). Similarly, the manufacturing engineers have been dispersed from a central core to each shop floor. Each factory has its own Jig and Tool section. To maintain product development links between the factory lines and the CBU's, there is a CAD terminal located in each factory for Jig and Tool, the manufacturing engineers, and the resident engineers.

In February 1994, DRIVE-SHAFT located a guest engineer in the Engineering department at Rover's Longbridge plant for two days per week. This move was the suggestion of DRIVE-SHAFT in order to maintain close design and development links. This was in response to the retirement of the Rover Design Engineer who had sole design responsibility within Rover for drive shafts. His retirement meant a major loss of drive shaft design knowledge, hence the suggestion of DRIVE-SHAFT to locate a guest engineer within Rover. DRIVE-SHAFT had been successfully operating a guest engineer at Nissan since September 1993, where he was working four days per week. The guest engineers feedback product development opinions to each business unit. However, one drawback that DRIVE-SHAFT is experiencing with the guest engineer is that the customer tends to involve them in day-to-day operations, thus diminishing the amount of time spent on product development work. Figure 8.3 distinguishes between the two guest engineers. The Rover guest engineer is biased towards design engineering tasks, whereas the Nissan guest engineer is more oriented towards quality control tasks.

Figure 8.3 DRIVE-SHAFT's guest engineers



DRIVE-SHAFT's parent company has a Standard's Committee, which meets bi-monthly and is made up of one representative from each line company. Its purpose if to ensure manufacturing, quality and design standards are being met within the company, and best practice is being operated.

8.3.2 Design relationship with Rover

Requests from Rover for quotations for new projects typically involved discussions between DRIVE-SHAFT's Rover Business Unit (sales executive and team leader), and Rover's purchasing agent and staff engineer. (Since there is a high carry-over of parts, and the commodity is a mature product, the knowledge and experience of the staff engineer is preferred over a design engineer in the very early negotiations.) However, the introduction of a guest engineer in Rover, has drawn his expertise into these discussions.

DRIVE-SHAFT normally receives a well-defined specification for a new project, with a large number of carry-over parts (typically 75 per cent). The commodity is well-established and, therefore, only requires minor changes to it for each programme. Also, there is very little difference in the way each new project is managed between Rover and DRIVE-SHAFT. The major changes for new projects tend to be packaging-related (such as the length of shaft required). The specification Rover issues typically includes volume versus engine specifications, engine timings, and other vehicle data (such as engine and gearbox data). DRIVE-SHAFT analyses this data and usually forwards a design proposal within six weeks, which involves a joint meeting as outlined above. One week prior to this, DRIVE-SHAFT has an internal review meeting to put forward any required changes. As a preferred supplier, their proposal normally meets Rover's requirements. Although a preferred supplier, DRIVE-SHAFT stressed that they do not operate an open-book cost accounting system with Rover.

Once a contract has been agreed, project meetings occur each month, and continue with exchanges between the CBU, Rover's purchasing agent, and a Rover design engineer (in place of the staff engineer). Prototype drawings are undertaken between D0 and D1 phases, with parallel discussions continuing on product piece price, tooling, and production control. The sign-off of production drawings occurs at D1, and represents the drawing as intended. Pre-production (QP to M-build) occurs in close cooperation with the resident engineer on the factory line (as mentioned above). This engineer collaborates closely with the CBU and can be viewed as a manufacturing *mutual adjustment* mechanism. In general, DRIVE-SHAFT uses common procedures across all CBU's for project management, such as project timing plans, and prototype raising order procedures. However the management of the interface with each customer differs by business unit. In this way, the customer's requirements are centred on a few, familiar people, but control of the process conforms to company policy.

8.3.3 Summary of DRIVE-SHAFT

DRIVE-SHAFT is a preferred supplier of Rover and supplies all of Rover's drive-shaft requirements. Rover has been a major customer for over 20 years, and DRIVE-SHAFT has been working closely in design work with Rover for over a decade. They design and supply proprietary technology, with design authority residing clearly with themselves. Since their product is mature, with 75% of parts typically being carried over from each model, product development tends to be incremental. Due to this level of carry-over parts, Rover includes the staff engineer responsible for liaison with DRIVE-SHAFT in the early discussions on product development; however, once the contract is confirmed, a design engineer takes over from the staff engineer.

The main features of DRIVE-SHAFT's project management approach are presented in table 8.2. There are customer oriented business units, each of which consists of a core team of three staff (team leader, sales executive and draughtsman), and there is a resident engineer on each product line to ensure functional support. The business units are co-located. The development process for each business unit follows that of their respective customer, within an overall corporate project management approach that includes common, formalised procedures, such as project timing plans, and prototypes raising orders.

Table 8.2 Summary of DRIVE-SHAFT's approach to project management

Project Management Elements	DRIVE-SHAFT's features
Characterisation of process	Customer oriented business units
Dominant characteristics	Core team of 3 staff (team leader, sales executive and draughtsman); co-located. Liaison with functional support (resident engineer).
Key mechanisms	Cross-project learning through monthly review meeting (internal coordination). CAD facilities and resident engineer in all product areas to facilitate integration.
Major phases in a development project	Phases follow customer's process
Dominant type of project	Incremental (mature product)
Typical project duration (months)	N/A
Primary performance drivers	Delivery reliability; Functional conformance; 'Best practice' (manufacturing, quality and design)
Formality of process	Common formalised procedures, such as project timing plans, prototype raising orders.

A key integration mechanism is the cross-project learning exercise each month that enables each business unit to feed ideas into each other and maintain their collective knowledge for the benefit of all customers. Internal integration is more important to DRIVE-SHAFT, than external integration, after the contract has been secured. Therefore, DRIVE-SHAFT has given product development responsibility to resident engineers at the shopfloor, to work alongside manufacturing engineers, and jig and tool engineers. In addition, there is a CAD terminal located at each factory line, facilitating links to the business units. The main external mechanisms are a monthly review meeting with Rover, and a guest engineer residing in Rover for two days per week. The choice of this second mechanism was in response to Rover losing its own internal drive-shaft expertise through retirement. DRIVE-SHAFT realised a need for drive-shaft expertise in other design activities, and suggested the use of a guest engineer. However, a drawback to this has been the guest engineer's involvement in day-to-day operations that Rover employees seek. The primary performance drivers of DRIVE-SHAFT are delivery reliability of the final product, functional conformance and achieving best practice in manufacturing, quality and design - a corporate wide goal.

8.4 ELECTRICAL (Case 3)

ELECTRICAL is a division of a UK conglomerate, located in the North Midlands. It is a Preferred Supplier to the Rover Group. ELECTRICAL is divided into five business units, based around: wiring harnesses, fusebox and components (including electrical connectors), high tension and battery leads, cable, and light leads (in which it is a second tier supplier). In 1990 it formed a joint venture with a Japanese harness manufacturer, and they have a trading relationship in which ELECTRICAL sells cable and components to the Japanese partner and contracts services (such as corporate marketing, engineering, and computer services). Both companies are managed by the same management team.

The main customers of ELECTRICAL are Rover Cars, Land Rover, Honda, Toyota, Jaguar, and several others; in addition, it also supplies to domestic cable customers and tier two suppliers (such as they have tier one suppliers as their customers, not the vehicle manufacturers). In 1993/94, ELECTRICAL and its Japanese partner jointly provided over 80 per cent of Rover's harnessing requirements. Both companies supply harnesses to Rover, but the joint venture was established to support and supply the harnesses for the Japanese-based vehicles of Rover - Rover 200/400/600, and the Honda Concerto which Rover built for Honda. The Rover harnesses supplied by ELECTRICAL are solely for Rover designed vehicles, namely: Land Rover, Range Rover, Maestro, and Rover 800. (For the purposes of this thesis, only the wiring harness operations of ELECTRICAL are examined.) Management of the wiring harness is a production critical task. The harness is one of the final component systems to receive sign-off, yet is one of the first elements of the vehicle to be installed on the assembly track. Therefore control of the overall process is paramount to both the supplier and the customer.

8.4.1 Organisation changes to facilitate project management

Prior to 1989, ELECTRICAL was functionally organised, but in an effort to improve new product introduction, they began to use multi-functional teams. As a result, they devolved operational activities into the production units and created separate business units. Each business unit reports through to the General Manager on a monthly basis and, in order to deliver their expected capabilities, engineering and sales account teams were devolving to each business unit in 1994. ELECTRICAL's introduction to multi-functional teams was a result of the Rover 200/400 programme in 1989. During volume ramp-up, a disaster was narrowly averted. Major lessons were learnt from a project that consisted of a new car, on a new site, and with a new labour force. In particular, ELECTRICAL learned much about multi-functional teams. Although there had been a multi-functional team for the 200/400 programme, it had been badly formed, inadequately resourced, and poorly planned - although ELECTRICAL believed it had been planned well at the time. In order to complete the programme, ELECTRICAL needed to import management staff from the parent company, but since it was such a big issue with Rover, ELECTRICAL revisited the programme through a post-project appraisal, and augmented changes to their project management process.

Each business unit has the responsibility for manufacturing, engineering, sales, administration and finance. All operational elements are therefore controlled by the business units. Engineering has responsibility for new product introduction across all of the business unit functions. All business unit engineering activities have been devolved, except for a small nucleus - essentially the advanced engineering activities (such as the test laboratory which was too small to distribute out) - which acts as a central resource.

8.4.2 Project management

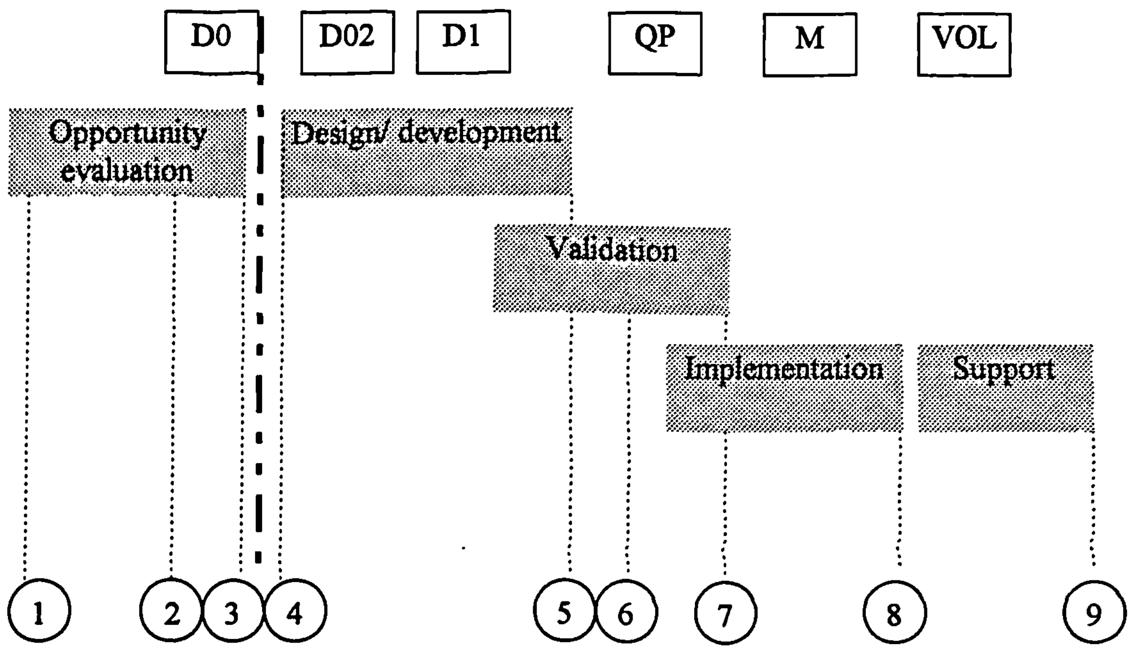
ELECTRICAL has a clearly defined project management process. This was first established in the harness business unit since this is where most projects are undertake; in reality, every model year change requires a new wiring harness, whereas for high tension leads, changes are not made until the end of an engine programme life cycle. Generally, 60% of a harness can be carried-over from previous model years, in which case the engineering resource may only be part of a person. However, in the case of Land Rover *specials* (where there are specific country variants of vehicle) or different engines requiring specific engine harnesses, there will be fewer carry-over elements.

Figure 8.4 indicates the main elements of the process. There is a high level of control, consisting of nine main points, over five stages: opportunity evaluation, design/development, validation, implementation, and support. (Rover's key milestones have been placed on figure 8.4, for comparison). It is the customer's delivery dates that drive each cycle. The previous project management process followed this overall procedure but it was performed informally, with review stages only being undertaken if necessary. This meant that each gate either consisted of a formal review meeting *or* a document sign-off. The present system requires *both* a formal review meeting and document sign-off.

For ELECTRICAL, the key process event is the overlap between design/development and validation. After every audit build, there are major engineering changes, which become critical if Rover delays the programme build phase. In one project, ELECTRICAL had to cope with over 2,000 engineering changes over a two month period, although 20% of these originated from within ELECTRICAL. Much of their design activity is about ensuring the product can be produced to the requisite process. Electrical harnesses can be produced by two methods: a fixed board, which is very labour intensive and slow, or a carousel which is faster, but less flexible. Each time an engineering change is requested, the project manager has to consider the likely impact on the available processes. One adaptation ELECTRICAL is making to their design work is the use of optimised designs, which will enable them more options to accommodate changes. By building flexibility into the product, ELECTRICAL believes they can maintain a quick response to Rover's schedule demands. Both Rover's engineering and purchasing departments are in favour of this optimised design route, because of the critical time pressures in delivering the harness.

The project management process identifies the skill requirements of each team member, and where in the project cycle they are to be used *(full-time or part-time): this assists the* creation of a resource profile. Figure 8.5 provides an example of a profile for a harness project. A harness project for ELECTRICAL is fundamentally a manufacturing facilities engineering process, rather than a product development and design process; hence, a project manager is not required to make a major input until after the programme has already begun.

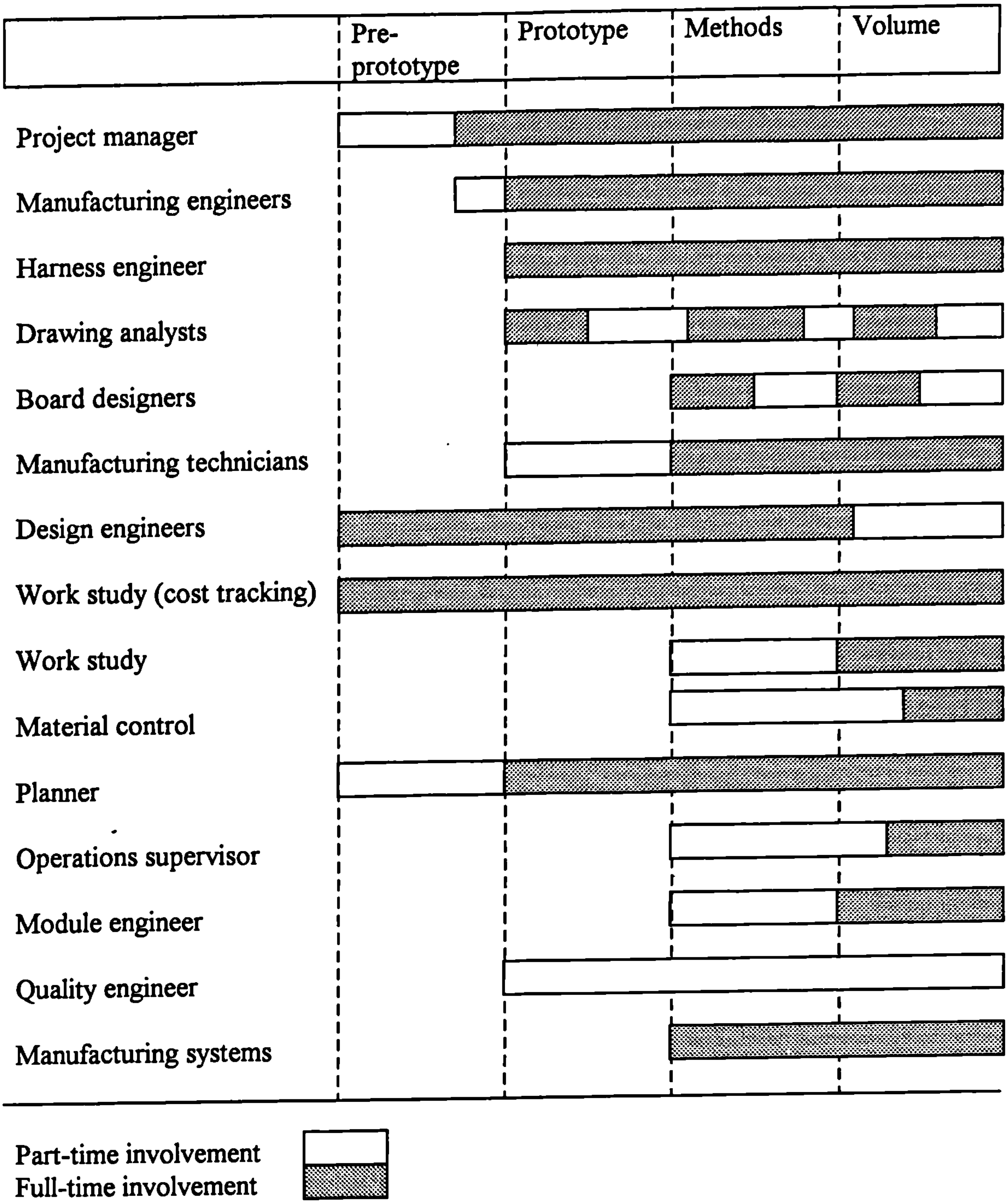
Figure 8.4 Project management process at ELECTRICAL



1	Approval to evaluate opportunity
2*	Approval to develop opportunity
3*	Product and project approval
4	Proposal acceptance review
5	Design review
6*	Investment approval and tooling release
7	Product release authorisation
8	Product launch review
9*	Project sign-off

Note: * key commercial decisions or activities

Figure 8.5 Team profile for ELECTRICAL projects



ELECTRICAL has approximately 12-15 design engineers who can be called upon to work on a project team. At any one time, there will be approximately 8-9 projects in harness that are significant enough to warrant the formation of a project team. Since the potential members of the team have other responsibilities, a team will only be formalised when a development activity has been approved to be undertaken. The assigning of a project manager and a team does not occur at the same time for all projects. For example, in Land Rover projects, there may not be a project team formed early on, but a group of people may well have been identified for it, since ELECTRICAL has staff permanently working on Land Rover projects. In addition, there is a senior project manager who oversees all Land Rover projects.

In 1994, ELECTRICAL was trying to co-locate the core team adjacent to the manufacturing operations. A crucial issue with this decision was that if the design (guest) engineer was spending most of his time at a CAD terminal, then his desk must be co-located with the team. Sixty per cent of the teams are housed adjacent to production, rather than sitting them in an *ivory tower* away from production. In this way, the design team can be close enough in order to raise issues easily with production. The project team maintains responsibility for the project into volume ramp-up, where there is a steady state - normally at volume and 90 days thereafter.

In the past, the customer would design the wiring harness and deliver a detailed drawing to ELECTRICAL, for them to manufacture and deliver the final commodity. The present process is essentially the same, insofar as ELECTRICAL is concerned with preparing to manufacture at capacity and deliver harnesses to the customer. Their main concern is to ensure manufacturing engineering input upstream in the process. By undertaking design engineering in-house, the design process has shifted the overlap of the customer from where it once was.

The Quality and Engineering Manager emphasised the importance of bringing the design work in-house, as follows:

> Now, ELECTRICAL is able to provide the cover for that element of the process [design and development] so that it is true simultaneous engineering. The front end of the process is about preparing the design for manufacture, and making sure that the customer doesn't botch up this so that it is awkward for manufacturing to make - which has previously been the cause of putting all of the costs up. That is the theory, and in reality it is actually the truth! It does work, so it is a win-win situation.

8.4.3 Design relationship with Rover

There are monthly project review meetings with engineering, purchasing and logistics staff from Rover ELECTRICAL has an excellent working relationship with Rover, evident by the use of guest engineers and confidence within Rover's logistics department to issue very late engineering changes. The logistical requirements of ELECTRICAL are well understood by Rover such that changes to the design can occur up to a very late stage with Rover being confident that delivery of finished harnesses will not be affected. The Commercial director attributes this to having guest engineers working closely inside Rover, and having dedicated project teams who have gained the trust of the people they deal with at Rover.

The original undertaking of design and development work by ELECTRICAL for Rover was a result of Rover depleting its expertise in electrical engineering (at least at component design engineer level). ELECTRICAL proposed the idea of a *guest engineer* to work within Rover's project management structure, thereby using their expertise to have an early input into the design process. The use of guest engineers means that there is constant feedback about a project to ELECTRICAL, which helps compress the development time, which further assists ramp-up because they know what to expect. The previous system meant that ELECTRICAL would critique the drawings for errors, or ask for technical details to check functional loading. They were not empowered with the authority, but such comments were necessary to reduce the number of engineering changes downstream. The adoption of guest engineering means that they are now empowered to do this.

It was as a direct result of working with their Japanese partner that ELECTRICAL suggested putting guest engineers into Rover. This policy has spread and they now have guest engineers in Honda, Jaguar, Land Rover, Rolls Royce and Massey Ferguson. The reasoning behind using the guest engineer in Rover was to improve the new product introduction process, by getting involved at a time when ELECTRICAL could influence the customer: at least that was their perception. The crucial reasoning was emphasised by the Commercial Director as follows: "If customers want tighter time-scales, but keep producing badly designed harnesses, how can we stop them doing that? One way of doing this is to put a guest engineer into the customer".

The placement of guest engineers in Rover, by ELECTRICAL, has not been without concerns. They are located inside Rover to work on a current model year, but increasingly, they are diverted into performing other tasks for Rover. An issue for

ELECTRICAL is whether to control their guest engineers, or to let them get as involved as much as they possibly can, thus becoming fully integrated within Rover, and commenting on future projects to assist design for manufacture. If no formal contract exists, how far should their staff contribute?

This highlights a key commercial issue for ELECTRICAL. When they introduced the guest engineer concept into Rover, the purchasing staff helped develop the current process of design relationship, and supported the venture. This group of staff has changed, and with it a different perspective that does not appear to understand the level of ELECTRICAL's engineering commitment to Rover's business. The guest engineer concept has assisted in developing the idea of partnership, but ELECTRICAL is worried that this may gradually be eroded. One result of this uncertainty is that ELECTRICAL is changing their operating procedures on development work. They are keeping track of the time they undertake on development and prototype work, and will charge it back to Rover if they do not finally receive the contract. At the same time, design engineers within Rover are wanting to see another guest engineer brought in.

This raises another issue of clarifying exactly what ELECTRICAL's involvement is about. Giving ELECTRICAL the money to refund the time that their personnel have spent is one issue, but their key business is not to perform development work, but to manufacture wiring harnesses. Their expertise and experience used early in the design process enables design costs to be reduced from the start, and they perform this work to assist their manufacturing operations. If their share of manufacturing business is reduced, the guest engineer will become a redundant coordination mechanism.

8.4.4 Project BETA

BETA is a Land Rover project which involved developing a composite harness for a model year change of several of the Land Rover products. ELECTRICAL met with Rover in late 1992 to discuss BETA, and the project was reaching ramp-up in late 1994. The original specification was to develop three harnesses, but early in development, this was reduced to two. Hence, a number of deviations (changes) were received early on, as the third vehicle's related elements were removed from the composite design.

Table 8.3 illustrates a summary of the number of deviations received through the development of BETA. Some of these deviations were proposed by ELECTRICAL, to meet manufacturing engineering requirements, whilst the majority originated from Rover. These deviations are compiled for the composite harness, but do not reflect the number of extra phases introduced for BETA. ELECTRICAL is finding increasingly that Rover is adding to the number of project phases. For example, during BETA, extra engineering validation phases (D12 and D13) were added to one of the BETA models, due to crash test failures. This brought forward the M-build by four weeks, and QP and M-build were run concurrently, since QP was off-tooling and M-build was off-tool and process. One dis-benefit of the extra build phase is an increased number of engineering deviations. Rover often raise more deviations because the extra event provides the opportunity to do this; however, for ELECTRICAL, these may be unnecessary changes. In addition, they find that many raised deviations are in fact incorrect. In 1994, for example, a drawing issued to ELECTRIC from Land Rover was 3 modifications old: a difference that the product management database at Rover should have indicated if the latest release drawings are being used.

Table 8.3 Number of project deviations in BETA (by origin)

Project phase	**ELECTRICAL**	**ROVER**
Product development (D02)	0	139
Engineering validation (D1)	24	178
Quality proving (QP)	73	345
Manufacturing build	50	293
Advanced volume/ Volume	10	121
Total number of deviations requested		**1233**

Some of these deviations were received as Rover undertook an initial static build and chose to re-route the harness through the bulk head, rather than the side panels as originally specified, in order to accommodate the inclusion of ABS, cruise controls and other elements. Further deviations were the result of an initial crash test failure, which required the re-routing of the harness as strengthening panels were added.

One problem ELECTRICAL faced on BETA was the high turnover of Rover purchasing staff they liaised with. Over an 18 month period from 1993 to late 1994, ELECTRICAL experienced three changes of purchase agent on BETA. This created tension in the relationship since there was a knock-on effect with payment procedures. The first purchase agent had agreed to the tooling and pricing at D1. However, he moved jobs and his replacement insisted on making changes to the previously agreed procedures. This person then moved, and a third person repeated the same exercise. Whilst ELECTRICAL was issued a *letter of intent* to proceed with tooling, it took them over 12 months to receive payment for this work. ELECTRICAL's experience is that their engineers sign-off a part, Rover receive the parts, and as purchasing are about to sign-off the part, the responsible person moves.

Due to the number of deviations received during BETA, ELECTRICAL proposed a post-project review of BETA to Rover. A multi-disciplinary team of Rover and ELECTRICAL staff has been established to examine the procedures and structures for improving product development cooperation.

8.4.5 Summary of ELECTRICAL

ELECTRICAL is a preferred supplier of Rover and is the sole supplier of electrical harnesses to Rover. Rover has been a major customer for over 20 years, and ELECTRICAL has been increasing its design contribution to Rover for over a decade, especially as Rover reduced its own internal competence to design and develop electrical harnesses. They now retain design authority over this component system, and since it is liable to receive substantial engineering changes, ELECTRICAL has 10 guest engineers permanently based at Rover, to try and pre-empt minor corrections, and to facilitate early feedback of design. In addition, there is a chief project manager with responsibility for Land Rover projects, since there is a high turnover of *special orders* requiring unique harness configurations. The need to reduce the time taken in engineering changes, ELECTRICAL is considering moving towards optimising the design of harnesses thereby building-in flexible configurations.

The main features of ELECTRICAL's project management approach are presented in table 8.4. The process is based on phases and gates, with a key driving force being to meet the needs of manufacturing-engineering. It is well defined and documented, with five phases and nine review gates. One of the key activities is the overlap between design/development and engineering validation. There are multi-functional teams, based around business units, such as harness. It was a result of an established close relationship with Rover that led to the introduction of multi-functional teams within ELECTRICAL. Engineering activities are centred around each business unit - except for a core of engineering services that are too small to warrant devolution - and design engineers are co-located with manufacturing engineers.

The key mechanisms that ELECTRICAL use for internal integration are the co-location of design and manufacturing engineers, multi-functional teams, based in business units, and a senior project manager to oversee Land Rover projects. All of these mechanisms have the objective of assisting manufacturing engineering, since the final engineering sign-off tends to occur just prior to production, and speed of final delivery is important. Liaising with Rover, ELECTRICAL has adopted a guest engineer approach in order to facilitate design for manufacture as early upstream as possible. The primary performance drivers of ELECTRICAL are delivery reliability and speed in responding to engineering changes.

Table 8.4 Summary of ELECTRICAL's approach to project management

Project Management Elements	ELECTRICAL's features
Characterisation of process	Phases and gates to meet manufacturing-engineering's needs
Dominant characteristics	Multi-functional teams, based in business units. Engineering activities devolved to each business unit, except a core of engineering services.
Key mechanisms	Senior project manager. Senior management review at milestones. Co-location of design and manufacturing engineers. Use of guest engineers. Overlap between design/development and validation (concurrent engineering).
Major phases in a development project	5 phases (with 9 review milestones): 1. Opportunity evaluation 2. Design/development 3. Validation 4. Implementation 5. Support
Dominant type of project	Evolutions, enhancements and incremental improvements (model year changes); speed is critical.
Typical project duration (months)	No typical project. (All vary)
Primary performance drivers	Delivery reliability. Speed (engineering change response)
Formality of process	Well defined and documented procedures.

8.5 EXHAUST (Case 4)

EXHAUST is a subsidiary of a UK private company, established in 1987. The parent company designs, develops and manufactures Original Equipment (OE) products, such as fuel tank systems, exhaust systems, and catalytic converters. EXHAUST is based in Coventry, and is predominantly a production site. The factory layout at EXHAUST has dedicated lines, but is flexible for future models. EXHAUST works closely with another division, based in Oxford, in developing exhaust systems and catalytic converters with its customers. In 1994, EXHAUST had a turnover of over £30 million, and it produces approximately 8,500 car sets (exhaust systems) per week. The main customers of EXHAUST are Rover, Honda and Saab. For example, it produces the exhaust systems for the Rover 200/400 (Honda Concerto), Rover Metro, Rover 600 (Honda Accord), and Saab 900 and 9000 series, as well as catalytic converters for Rover 200/400, Rover Metro, and Rover 600.

8.5.1 Product development

EXHAUST has adopted different design relationships with its customers. For example, Saab prefers to design their own exhaust systems, relying on EXHAUST for process engineering inputs. Honda, follows a similar procedure, designing their own exhaust systems in Japan, and sending the drawings across to the UK. EXHAUST feeds back design changes to Honda, but generally they find that these are not incorporated into the latest designs, but find their way into future modifications or model changes. The design procedure of Rover contrasts with both of these. Rover outlines the required scheme, and relies on EXHAUST to design the complete system. Since 1993, Rover has given complete design authority for the system to EXHAUST; previously, although EXHAUST performed the design work, the authority for design remained with Rover.

There is fierce competition in the OE market, and EXHAUST competes on the quality of product, price, delivery reliability, response time in prototype build, its design capability, and new product support. As a relatively small company, they are more reliant on Rover, than many other companies are with their customers. However, EXHAUST sees a major competitive edge for them is being able to respond quickly to Rover's needs and to provide prototyping facilities and experience. They have two main competitors, both UK based, of which one supplies Land Rover. However, each company has concentrated on aligning itself with a few customers, with a result that there is very little poaching of existing business, although they are still in competition with each other.

The project management process at EXHAUST consists of two stages. The first stage involves product design and development, which is undertaken at the division's Oxford site. The second stage is conducted by EXHAUST and involves the implementation project to take the design forward to production. EXHAUST follows Rover's project review phases very closely, with D1 and QP events being key activities. The commercial function of the parent company is responsible for all quotations to customers.

At the outset of a project, a New Products Introduction Meeting is held regularly, with representatives from engineering, production, quality, purchasing, and design. A total of 20-25 people are brought together into a project team for the entire process, but the product engineering phase, at EXHAUST, requires 10-12 core members. A project team typically represents engineering, sales, estimating, quality, production and purchasing. The core team has representatives from both EXHAUST and its Oxford division, with a project engineer from EXHAUST taking responsibility for coordination and timing.

When the design is agreed, there are key dates for the build phases (aligned to customer build requirements), and a *Letter of Intent* from Rover is issued for tooling. This signifies the contract has been awarded. However, the *Letter of Intent* tends to be issued late due to further engineering changes being demanded from Rover. (Rover has its own tooling engineers who have an input into the design process, and advise on tooling requirements.)

The design responsibility lies with the Oxford site. EXHAUST's design engineers have close links with customers, frequently exchanging ideas, and visiting, for example, Rover sites. A design review is held near to completion of the development stages, and previous similar designs are reviewed alongside the new product. By late D02, workable drawings are developed, and formal drawings are produced. There can be *agreed* late product development due to changes from associated parts, but these require the approval of EXHAUST. The design department is responsible for prototype testing (D1) and the Oxford site *accommodates prototype workshops and testing equipment* (such as vibration, dynamic performance, acoustic performance, and engine power testing equipment). There is close liaison between design engineers and manufacturing staff. The design engineers all have working knowledge of the manufacturing processes, and development staff have some manufacturing knowledge and experience. There is constant feedback of ideas to prototype stage from manufacturing engineers.

The sample build procedure signifies the handing over of the project from design to production. It involves three trial builds. The first quality proving build (QP) is run by the project team in conjunction with the engineering department to set up and prove out the manufacturing process. The second trial build incorporates the production staff into the core team, and the third trial build - advance volume build - is performed by the production engineers at EXHAUST, to finally prove the process. After QP, the project team conducts a post-project review. The entire process is documented step-by-step in a New Product Introduction Procedure, Timing Plan Procedure, and FMEA Procedure.

8.5.2 Summary of EXHAUST

EXHAUST is a preferred supplier of Rover and supplies a majority of Rover's car exhausts. Rover is a major customer (together with Honda). The main features of EXHAUST's project management approach are presented in table 8.5. The process is a detailed phase and gate system, following Rover's own milestones. This reflects the importance of Rover as a customer for design activities, since their other major customers generally perform their own design work, relying upon EXHAUST for production activities. Over the past seven years, EXHAUST has developed a close working design relationship with Rover, and design authority now resides with the design engineers of their sister company.

The project management process consists of two stages: product design and development, focused on the sister division; and manufacturing implementation performed by EXHAUST itself. This process is conducted by a cross-functional team from both divisions, and the project manager is assigned from EXHAUST. The process is formalised with documented procedures for new product introduction, timing plans, and FMEA. EXHAUST develops evolutions, enhancements and incremental

Table 8.5 Summary of EXHAUST's approach to project management

Project Management Elements	EXHAUST's features
Characterisation of process	Phases and gates
Dominant characteristics	Cross-functional team. Design responsibility focused on sister division, with transfer to EXHAUST at manufacturing implementation phase. Project manager assigned from EXHAUST to oversee entire process.
Key mechanisms	Design Review Meeting (D1) between EXHAUST and sister division, and Sample Build Procedure (QP) are key activities. Previous designs are formally examined. Post-project review.
Major phases in a development project	2 stage phase (following Rover milestones): 1. Product design and development 2. Manufacturing implementation
Dominant type of project	Evolutions, enhancements and incremental improvements (dependent on customer)
Typical project duration (months)	N/A
Primary performance drivers	Delivery reliability; speed in prototype build; design capabilities; new product support
Formality of process	Formalised/documented procedures: New product introduction procedure; Timing plan procedure; FMEA procedure.

improvements to existing products, and all previous designs are consulted during each new project. Finally, EXHAUST conducts a post-project review as part of their continuous improvement programme. EXHAUST sees their primary performance drivers as delivery reliability, design capability, new product support, but in particular for design activities, their speed in prototype build. This latter point is supported by the importance EXHAUST places on the design review meeting between the sister division and itself at D1, and the sample build procedure at QP.

Since EXHAUST received detailed specifications from Rover, their main concern is to ensure internal integration between the sister division's design and development group, and the manufacturing implementation team at EXHAUST. However, the sister division maintains close liaison with Rover through regular visits, and from Rover's own tooling engineers, advising on tooling requirements. In addition, there are monthly review meetings between Rover and EXHAUST to advise on progress. Internal integration is maintained through the cross-functional focus, and the role of the manufacturing oriented project manager.

8.6 PLASTIC (Case 5)

PLASTIC is a manufacturer of small and medium size plastic injection mouldings (up to 1000 tonne machines). It has been a supplier of solely automotive parts since 1987, providing both interior and exterior trim, and under-bonnet components, for example, cooling system components, safety trays, speaker grilles, mirrors, sunroofs (secondary supplier), wheel trims, and fascias.

PLASTIC has an annual turnover of between £15-20 million (1992/93), which has risen from £12 million in 1988/89. The company employs 380 people (three times the number it employed in the late 1980s) at Coventry, which is its sole UK site. It has a sister company in France, which cooperates with French car companies. Both companies design and manufacture independently, although along similar product lines; nevertheless, there is cooperation in the design of speaker grilles.

The managing director of PLASTIC emphasised in an interview in 1994: "We do not want to be *the* number one supplier of our product range alone, but want to share the top with a few others companies." His view was that, in this way, a group of core suppliers to the vehicle industry can have a greater portion of the *automotive pie*, and utilise their expertise to a greater extent.

PLASTIC is a first tier supplier to Rover, Ford and Honda, and a second tier supplier to Nissan. It is a Preferred Supplier to the Rover Group. It participates in design work with the UK based engineering centres of Rover, Honda and Ford, and in 1994, its design work with Rover was centred at the Canley site in Coventry. PLASTIC does not have the resources for research and development facilities, but has been nurturing an international collaborative relationship with a US plastics company since 1989, and a Japanese plastics company since 1993. They do not design collectively, but have exchanged design ideas for their *unofficial* partners to utilise their design expertise at a local level. For example, PLASTIC's experience in developing expansion tanks for Volvo was exchanged with the US company; at a later date, the US company exchanged their experience in developing plastic battery trays to PLASTIC. The managing director sees these relationships as one way of keeping informed with the technological developments of the industry, and of providing new design ideas to their customers.

8.6.1 Project management

There is a weekly, new product meeting each Friday morning. This is attended by the project control coordinator, all project managers, and representatives from manufacturing engineering, quality, production and logistics. Before each meeting, there is a New Product Timing Sheet produced for each set of new products (for each customer); these are updated weekly, providing data on customer timings and PLASTIC's expected times. The project control coordinator was a necessary creation to ensure communication between all PLASTIC's engineering staff and customers. Each day, all engineering project managers report their location to the project control coordinator. In this way, any customer request can be responded to immediately. The managing director believes this was an important development for maintaining close design relationships with customers. Similarly, the weekly project review acts as a mechanism for maintaining current state of expertise and for sharing experiences (not innovation) across customers. Occasionally, PLASTIC arranges for guest speakers to present to the meeting, in order to maintain their collective skill base and expertise.

8.6.2 Design relationship with Rover

PLASTIC has two guest engineers located within Rover. The first is a product manager responsible solely for Rover related interior trim. He spends two day per week at the Canley site. The second is a product manager responsible for interior and exterior trim, and wheel trims for both Rover and Ford projects. PLASTIC designs and manufactures the following product items for different Rover vehicles: vents; wheel trims; cooling tanks; splash shields; and a variety of fascia related components (such as instrument bezels, centre fascia console, and glove-box). In addition to this close relationship in design, PLASTIC recruited an ex-Rover purchasing agent to their Sales and Estimation team.

PLASTIC normally enters the product development process at post-concept stage. A cost pack from Rover is issued to PLASTIC and two other suppliers. This cost pack is then discussed internally between the Sales manager responsible for Rover accounts, and a designated engineer (by component area), who establish cost estimates based on the cycle time, material, tooling charges, and ancillary equipment (such as assembly jigs and gauges).[3] (They are a preferred supplier for wheel trims, expansion tanks and vents.) A quotation analysis form (QAF) is returned to Rover and if successful a *Letter of nomination* is received from Rover. The cost of design work may, or may not, incorporate the cost of tooling; this is decided by Rover. A design FMEA is undertaken only if PLASTIC is nominated as supplier.

Once Sales has issued a *Sales Engineering Note* (SEN), the project is effectively initiated. This SEN is a document that specifies the level of funding, and allows tracking of expenditure. It is the project manager who decides how this funding is to be allocated. A SEN is issued for individual items, or assemblies; hence there would be individual SEN's issued for right and left vents. With each SEN issued, an Advanced Quality Planning (AQP) file is raised. This document tracks the items through to volume at 5,000 units. The AQP consists of the product timing plan, QAF, quotations for tooling, design information, and a contact sheet listing all people who are likely to be involved in the development through to volume (typically the product manager, logistics, production, quality, manufacturing engineering, purchasing, and sales). These people meet on a regular basis, when changes are required. The timing plan is the responsibility of the project manager, who provides this for Rover.

At the design stage, the product manager and a CAD engineer work together on developing the design proposal. This is submitted to Rover for approval. If approved, PLASTIC orders the bought-out parts and initiate tooling for material, jigs and gauges. PLASTIC has in-house tooling facilities, but tooling is sub-contracted out to commercial toolmaking firms, with whom they work in designing the product. At D02, a prototype tooling and build event takes place. This normally requires only a model, therefore no off-tooling parts are required. Experience with Rover suggests that most development work continues unhindered until D1 (off-tool) build. PLASTIC normally expects to receive engineering changes after the D1 build. The engineering change procedure is undertaken by the manufacturing engineer.

Final project sign-off is only approved by the collective decision of the Engineering director, Commercial director, Finance director and product manager. The end of the new product development process is indicated when volume levels have reached 5,000 units - in some cases, this could be two years into production.

An inconsistency with Rover's project management system was illustrated by one of the guest engineers. If PLASTIC is given full design responsibility for a project, then they have responsibility and pressure to deliver to Rover's timing plan. This had never changed in PLASTIC's experience. However, if Rover retains full design responsibility, there are often late deliveries of detailed design from Rover to PLASTIC, which causes delays in tooling delivery. In such cases, PLASTIC may be asked to miss out the D1 phase to satisfy the longer term commitments of delivering the final parts on schedule. The decision as to who has design responsibility is related to the expected volumes. If the volume estimate is small, design work tends to be in-house with Rover; if, on the other hand, large volumes are required, Rover outsources the design responsibility to suppliers, such as PLASTIC.

8.6.3 Summary of PLASTIC

PLASTIC is a preferred supplier of Rover and supplies Rover with interior and exterior trim, such as fascias and wheel trim. Rover is a major customer, with whom PLASTIC has built up a close design relationship over the past five years. Although it does not have a research and development facility, PLASTIC has established mutual, international relationships with two companies to exchange product and process developments, for different target markets. The main type of project involves enhancements and incremental improvements to existing products, which may include aesthetic or technical improvements.

The main features of PLASTIC's project management approach are presented in table 8.6. The approach is based upon multi-functional teams, customer focused Sales staff and project managers. They have two guest engineers based at Rover for two days each week - one each for interior and exterior trim. In the case of Rover-related business, the guest engineers are the project managers. The process follows the key milestones of each customer's process, and is characterised by clearly specified procedures, tracked by an advanced quality planning document. This document is common to all projects and includes an appendix describing each customer's milestone review points.

Table 8.6 Summary of PLASTIC's approach to project management

Project Management Elements	PLASTIC's features
Characterisation of process	Customer focused multi-functional teams
Dominant characteristics	Team focus with functional support. Sales staff and project managers are customer focused.
Key mechanisms	Project manager. Weekly cross-project reviews. Senior management review at milestones.
Major phases in a development project	Phases follow customer's process.
Dominant type of project	Enhancements and incremental improvements; some aesthetic and technical improvements.
Typical project duration (months)	N/A
Primary performance drivers	Quality control. Deliver reliability. Customer response.
Formality of process	Clearly defined procedures: tracked by Advanced Quality Planning document (includes timing, costs, design information and so forth).

Internal integration is mainly achieved through their multi-functional approach and weekly meetings to review all ongoing new projects. This facilitates cross-project learning and reflects PLASTIC's current level of collective expertise. Their use of guest engineers has greatly improved their external coordination with Rover. Similarly, there is a full-time project coordinator who ensures any customer can immediately contact a project manager. This ability to respond quickly to customer demands is seen as extremely importance to PLASTIC. There are monthly review meetings with Rover, until the D1 phase, where PLASTIC expects greater iteration of design information, as engineering changes are demanded from Rover. Their products tend to have a high interface with other components and it is often not until D1 that the level of engineering fit can be established. Their experience is that most development work remains The primary performance drivers of PLASTIC are delivery reliability, quality control of design and production, and the ability to respond quickly to the customer throughout the process.

8.7 WINDOW (Case 6)

WINDOW is a manufacturer of window regulator systems, door mechanisms (latches and hinges), modular door systems, and seat adjuster systems. (The window regulator and seat adjuster systems can be manual, power, or electronically controlled.) Perhaps most significantly for WINDOW was the development of the modular door system in 1987. This product combines the regulator, motor and glass to produce an entire, self-contained unit which can be fitted directly into the door panel. WINDOW is currently the only UK based company to manufacture this product, and has a clear design and manufacturing expertise for this. WINDOW is part of a German, family owned business, with subsidiaries in the UK, Japan, Central and North America. The UK business was established in 1988 and is located in Coventry. In 1993, the turnover of UK operations was over £31 million sales, and over 8.5 million units volume. The company has experienced a steady and continual increase in both turnover and output in recent years, particularly in the regulator and door module sectors, with the regulator sector accounting for over 70 per cent of their turnover.

WINDOW's major customers are Rover, Ford and Volvo. WINDOW's share of Rover's business has developed significantly since 1991, so much so that in 1994, WINDOW was supplying nearly 50 per cent of Rover's window regulators. This increase was at the expense of business for one of their largest competitors, a French based company (referred here as LATCH), who competes in both window regulator and door mechanism sectors.

8.7.1 Project management

WINDOW has a structured approach to project management, consisting of three key elements. First, there is a corporate handbook on project management, which specifies in detail the purpose, organisation, procedure and planning systems for effective project management. This handbook also includes copies of most control documents and procedures, such as timing plans, activity checklists, and project status reports. Second, WINDOW has a 12 page project management procedure document. This is unique to each project and lists in precise elements, the tasks within each project phase, with the responsible function and necessary documents. It is a highly controlled procedure which acts as a checklist for each phase, and a total of 77 individual tasks to be completed. The company specifies eight project phases: development/inquiry; customer order; final design/pre-production; cost evaluation and prototype; tooling and procurement; first sample; mass production; and project evaluation. The third element is the project timing plan, which has 50 separate elements, spread over four broad phases that roughly correspond to customer phases: concept; design; procurement; and completion.

WINDOW uses cross-functional project teams consisting of Engineering, Pre-production, Sales, Logistics, and Quality Control. There is a limit of three projects that a project leader may be responsible for, at any one time, and team members are able to work on a maximum of five projects. At the time of interviewing WINDOW in 1994, the company was involved in product development projects with, *inter alia*, Rover/Land Rover, Ford/Jaguar, Honda, Volvo/Nedcar, and Peugeot.

Rover projects begin when a customer inquiry is received, which is discussed mainly between the Sales executive and Engineering. If a quotation analysis form is required, a full project team is gathered together and a detailed quotation presented. In general, once a project has begun, monthly review meetings are held at Rover of the core team, consisting of Rover design engineer, a Supplier Quality Assurance representative, and the Purchasing agent, together with WINDOW's project manager and Sales executive.

WINDOW is constantly evolving and improving its delivery of the RG2000 specification. As an *approved* supplier to Rover, they deem it important to maintain a close working relationship. In 1994, the only part of RG2000 they had yet to conform to was BS5750, but they were intending to reverse this situation by the end of the year. One change they were making to their project management procedure was to optimise it in line with as many customers are possible. WINDOW did not want to have separate project management procedures for each customer, or to favour one customer at the expense of another. These changes meant that they would be more closely aligned with the project management requirements of RG2000. There was an appendix attached to the procedure outlined above, which listed both Rover and Ford project management milestones to enable WINDOW project managers to control against these review targets.

One issue WINDOW saw for Rover itself was that they could learn something from the RG2000 specification. One project manager expressed a view that "Rover had to get its own house in order, and follow its own guidelines, if inter-firm coordination problems were to be reduced." This statement will become clearer with the review of project GAMMA.

8.7.2 Project GAMMA

GAMMA is an example of a project that was given to a first tier supplier to project manage. For the purposes of this thesis, GAMMA incorporates two separate projects; however, as the discussion will reveal, consideration of these two projects together illustrate issues of concern for outsourcing product development to rival suppliers.

Project GAMMA consists of an integrated, rear door module, and the front door window regulator and latch mechanism (GAMMA*) for a Land Rover project. As a door module, it is a *safety critical system*. The overall vehicle programme had originally begun in the late 1980s, and had been subject to several starts and stops over a seven year period. In 1991, Rover approached WINDOW to supply the integrated rear door module, and a separate window regulator for the front doors of the vehicle. WINDOW's major competitor, LATCH, was given the contract to directly supply Rover with the latch mechanism for the front doors, and to supply the latch mechanism to WINDOW for the rear door module - in this case, as indirect supplier to Rover (a similar situation to *Supplier B* in figure 3.7).

GAMMA is an example of a rear door module, incorporating an integrated handle and latch mechanism, which is supplied as a complete door module to the assembly track. (This integrated system has been designed for ease of assembly.) For this project, Rover selected the key participants and brought them together to design and develop the rear door module. From the outset, Rover contracted WINDOW as the final tier supplier for the rear door module, and this was formalised at the beginning of the project through a contract giving WINDOW total responsibility for the rear door module, and the front window regulator. Hence, it was Rover's responsibility, if they wanted to make engineering changes, to approach WINDOW as the first tier supplier, who would then approach the indirect suppliers to make those changes, thereby project managing GAMMA. This was the first project that WINDOW (UK) had taken responsibility to manage for a vehicle manufacturer, although the parent company had managed several such projects.

The GAMMA project team comprised:

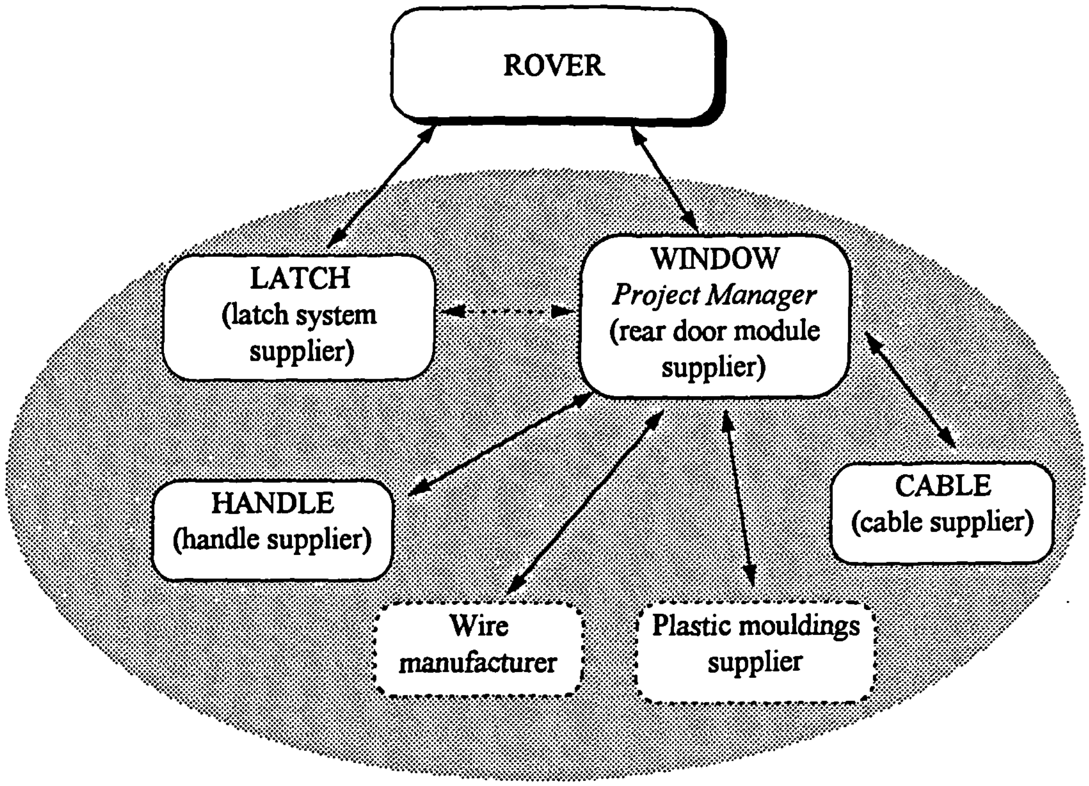
- WINDOW (Rover selected) - project manager and window regulator supplier;
- LATCH (Rover selected) - latch system supplier;
- HANDLE (Rover selected) - an internal handle supplier;
- CABLE (Rover selected) - a cable supplier;
- a wire manufacturer; and,
- a plastic moulding supplier.

Figure 8.6 outlines the key relationships within the development of the rear door module, and the supply of the front window regulator, and front latch mechanism. In the case of the rear door module, the relationship between the project and Rover should have been managed through WINDOW. However, although part of the design team, an exchange of design information developed directly between LATCH and Rover, with little transfer to WINDOW. In the case of the front latch and window regulator, these commodities were directly supplied separately to Rover: LATCH assembled the latch mechanism with parts from HANDLE and CABLE, whilst WINDOW supplied the window regulator to Rover.

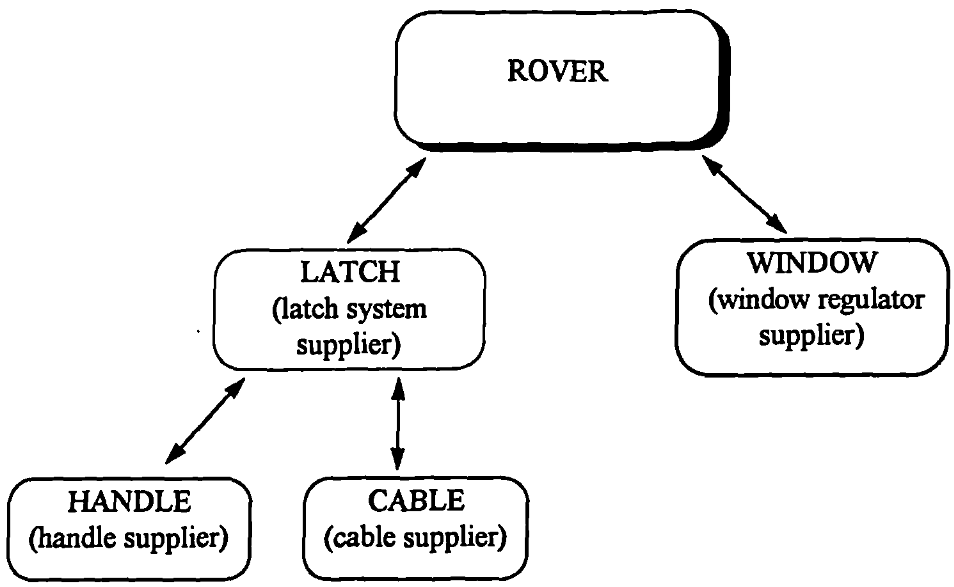
GAMMA can be viewed as a *black box* system. LATCH was given the characteristics and functional specifications for their black box, and were contracted to supply a complete latch mechanism to WINDOW. Similarly, WINDOW was contracted to provide the internal workings for a black box rear door. Instead of one line of communication, two separate lines developed between Rover and WINDOW, and Rover and LATCH for the GAMMA door module project. Unbeknown to WINDOW, Rover

Figure 8.6 Design relationships in project GAMMA and GAMMA*

(a) GAMMA (rear door module)



(b) GAMMA* (front door latch mechanism/window regulator)



frequently issued drawings and held review meetings with LATCH. In addition, WINDOW did not receive LATCH's design information until the end of engineering validation (D1). This lack of upstream information sharing caused problems at the QP phase, with delays of up to four weeks occurring for the delivery of new test equipment, which was required in response to knowing of changes in LATCH's design.

After two years of development, Rover requested WINDOW to assume full responsibility for the door module, not just the responsibility for project management. However, WINDOW was unaware of LATCH's procedures and drawings, and therefore felt they should not take full responsibility for it, particularly since the door module is a safety critical system, and there would be legal implications for system parts they had no control over.

The GAMMA project manager attributes a lack of discipline on the part of Rover for some of the problems that arose. In WINDOW's view, Rover should not have outsourced project management responsibility to them if Rover intended to constantly change design specifications and reporting lines without WINDOW's knowledge.

One example on GAMMA highlights the knock-on effect of failing to inform the project team. At QP phase of GAMMA, Rover changed a spring component on the internal handle without informing WINDOW. The rear door has to withstand a gravitational force impact test of 30G, but during quality proving, Rover found this spring had been incorrectly specified by Rover to HANDLE; hence, the springs had to be replaced. The failure of Rover to inform WINDOW resulted in WINDOW's test equipment being unable to test the revised internal release handle: the force was too great for the equipment. WINDOW had to purchase a new pneumatic arm, and revise the parameters of test programme software in order to test the internal release handle of the module.

Despite these types of problems, WINDOW has always met the delivery date, changing their internal timing plans and working over time to supply the customer: "Because at the end of the day, if you don't make the delivery date, the customer will always blame you. So you will do whatever is required to meet it" (Quality engineer).

8.7.3 Summary of WINDOW

WINDOW is an approved supplier that is aiming to acquire preferred status in the near future. At the time of interview, they still required BS5750 to fully satisfy the RG2000 specification, but were expecting this soon. WINDOW provides about half of Rover's window latch requirements and all of the modular door systems. They have had a close design relationship with Rover for over four years, based on their ability to design, develop and manufacture technical and systems solutions. They do not have any guest engineers within Rover, but they are actively considering this option for an earlier input to the design process. The primary performance drivers of WINDOW are delivery reliability and engineering functionality.

The main features of WINDOW's project management approach are presented in table 8.7. It is based on a highly formalised process consisting of eight phases and gates, with 77 individual tasks requiring separate attention. WINDOW has optimised its existing project management procedure to meet the requirements of all of customers by specifying the point of convergence between their respective review milestones.

Table 8.7 Summary of WINDOW's approach to project management

Project Management Elements	WINDOW's features
Characterisation of process	Phases and gates.
Dominant characteristics	Cross-functional teams. Optimised project management procedure to meet all customers' requirements.
Key mechanisms	*Project manager; senior management* review at milestones.
Major phases in a development project	8 phases (77 tasks): 1. development/inquiry 2. customer order 3. final design/pre-production 4. cost evaluation and prototype 5. tooling and procurement 6. first sample 7. mass production 8. *project evaluation*
Dominant type of project	Evolutions, enhancement and incremental improvements; both technical and increasingly systems solutions.
Typical project duration (months)	Varies
Primary performance drivers	Delivery reliability; Engineering functionality.
Formality of process	Highly formalised: Corporate handbook on project management; Project management procedure document (77 elements); Project timing plan (50 elements).

Project GAMMA illustrates a scenario where project management responsibility was devolved from a vehicle manufacturer to a systems supplier who, in turn, would need to manage a competitor. GAMMA demonstrated that devolving this requires effective inter-firm coordination to be in place, and reporting roles to be adhered to.

WINDOW communicates design information through CAD, telephone and facsimile, but most importantly face-to-face discussions. The monthly review meetings were a key coordination mechanism in achieving this. However, the existence of separate communications to LATCH was a hinderance to WINDOW being able to project manage GAMMA. The future adoption of a guest engineer is one possibility WINDOW sees for better securing effective coordination with Rover.

8.8 Analysis of the cases

The six cases illustrate a diversity of approaches to design relationships with Rover Group, and a variety of individual project management styles. The cases provide examples of component suppliers involved in the upstream activities of product development. This section compares and contrasts the cases to highlight the dynamic nature of the inter-firm design relationship. Whilst six cases cannot generalise these findings to a wider population, they nonetheless provide a basis from which a model for investigating design chains can emerge.

8.8.1 Supply relationship with Rover

Table 8.8 summarises the six cases and the main features of their relationship with the Rover Group. Some data is missing either because the case studies declined to release commercial information, or because no data was available. Five of the cases were *preferred* suppliers, and recognised by Rover as having actively participating in close design relationships with them. WINDOW - an *approved* supplier - was yet to be a preferred supplier, but was in the process of acquiring BS5750 accreditation, which would facilitate this. These cases are characteristic of the first tier suppliers described in Chapter Three: they offer a specialist competence to the vehicle manufacturer, and are amongst a select few who Rover are trying to develop closer partnerships with. Similarly, the cases demonstrate a substantial experience of design collaboration with Rover. Three of the cases - BUMPER, DRIVE-SHAFT and ELECTRICAL - have been participating in design activities with Rover for over 10 years, as well as supplying parts for more than 20 years each. All three are sole suppliers to Rover of many products. In the example of WINDOW, its presence in the UK has been shorter than the rest, and their main competitor has been located in Birmingham for over half a century. The introduction of modular door systems has given WINDOW a unique expertise which is providing them with a valuable, early input to design work with Rover.

Table 8.9 compares each of the cases against attributes characteristic of supplier involvement in design relationships. Using the typology expressed in Chapter Five, there are two proprietary parts manufacturers (DRIVE-SHAFT and EXHAUST), two suppliers who receive *black box* dimensions (ELECTRICAL and WINDOW) and two

Table 8.8 Comparison of the relationship between Rover and the six case studies

Characteristics	BUMPER	DRIVE-SHAFT	ELECTRICAL	EXHAUST	PLASTIC	WINDOW
Supplier status in Rover	Preferred	Preferred	Preferred	Preferred	Preferred	Approved
Main customers	Rover, Honda, Unipart	Rover, Honda, Toyota, Nissan, Ford, Chrysler	Rover, Honda, Toyota, Jaguar	Rover, Honda, Saab	Rover, Honda, Ford	Rover, Ford, Volvo
% Rover (% Rover's supply requirements)	30%+ (100%)	40% (100%)	N/A (80%)	N/A	N/A	about 20% (about 50%)
Age of closer design relationship	+10 years (>20 years Rover supply)	+10 years (>20 years Rover supply)	+10 years (>20 years Rover supply)	about 7 years	+ 5 years	about 4 years
Closeness to RG2000	Project management process meets	All	All	All	All	still requires BS5750
Open-book cost accounting with Rover	Yes	No	Yes	Yes	No	No
Additional control mechanisms	Full-time logistics person				Project control coordinator	

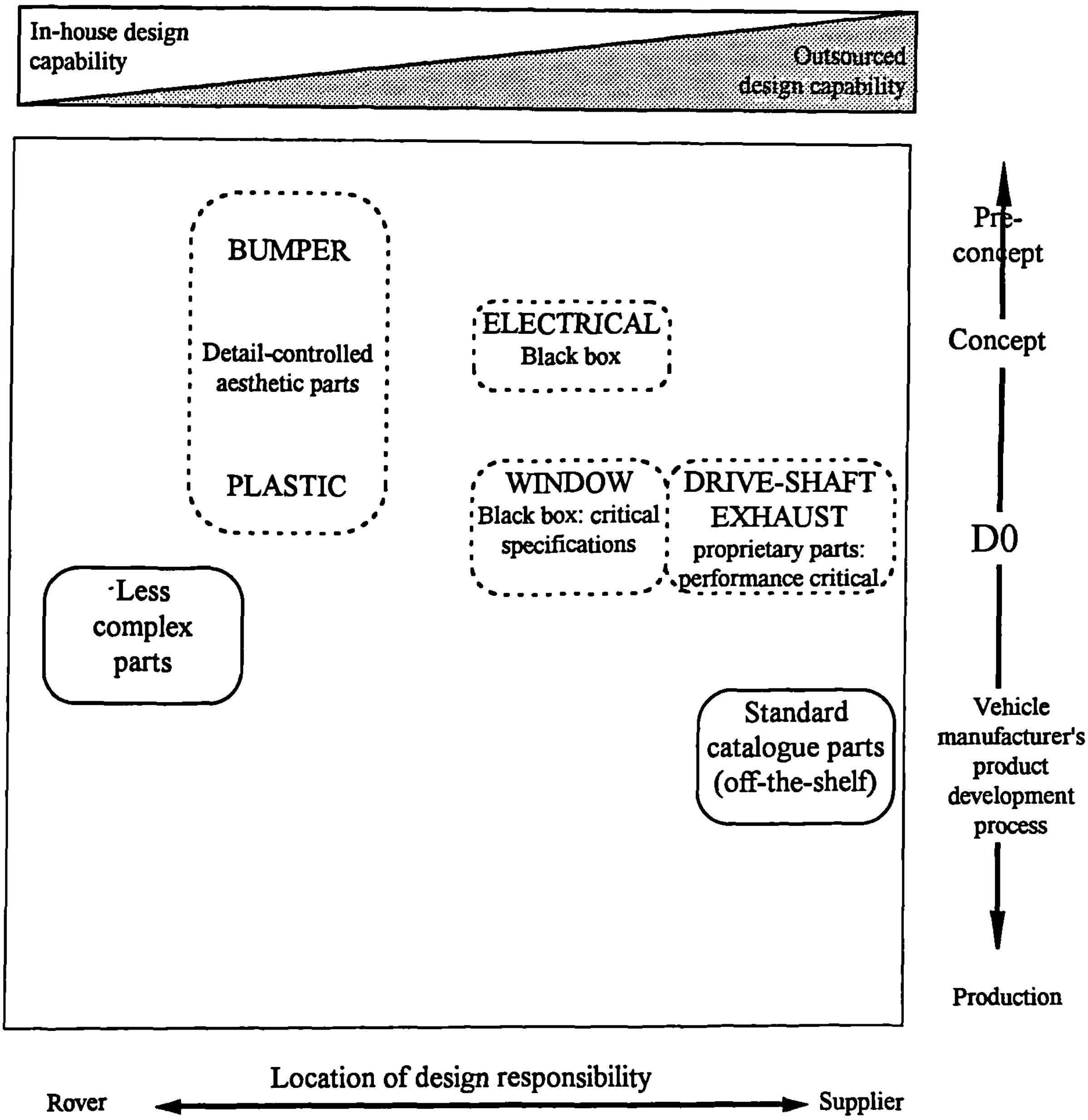
Table 8.9 Comparison of the design relationship between Rover and the six case studies

Characteristics	BUMPER	DRIVE-SHAFT	ELECTRICAL	EXHAUST	PLASTIC	WINDOW
Type of parts supplier	Detailed aesthetic	Proprietary	Black box	Proprietary/ performance critical	Detailed controlled / aesthetic	Black box / functional (safety critical)
Design responsibility	Joint	Supplier	Supplier	Supplier	Supplier	Supplier
Design authority	Rover	Supplier	Supplier	Supplier	Varies (volume dependent)	Varies
Product complexity	Simple assembly	Complex assembly	Entire subsystem	Simple assembly	Simple assembly	Entire subsystem
Specifications provided	Concept	Performance critical specifications	Detailed specifications	Performance critical specifications	Detailed specifications/ concept	Detailed specifications
Supplier's influence on specifications	Collaborate	Negotiate	Collaborate	Collaborate	Negotiate	Negotiate
Stage of supplier's involvement	Pre-concept/concept	D0	Concept	D0	Concept/D0	D0
Component testing responsibility	Complete	Complete	Complete	Complete	Complete	Complete
Guest Engineers in Rover (number)	Permanent (1)	2 days/week (1)	Permanent (10)	None (nil)	2 days/week (2)	Planned (nil)
% carry-over parts	Nil	typically 75%	60% (considering optimising design)	Low	Nil	Low

detail controlled body parts (BUMPER and PLASTIC). The characteristics in table 8.8 do not suggest any obvious matching of factors to component type. Indeed, this has not been its purpose. Table 8.9 illustrates the need to examine the types of component supplier (by design input) in more detail. An interesting distinction, for example, concerns the division of design responsibility and authority. BUMPER is jointly responsible for component design, but the authority to proceed, order, and manage resides with Rover. PLASTIC is responsible for design, but depending on the volume of parts required may not have the design authority. Distinguishing between these two factors would provide a clearer understanding of the roles of control and expertise in managing design chains.

Suppliers became involved in product development at times according to component type, based on the impact of the part on the total vehicle integrity (such as the aesthetic or number of interfacing parts). BUMPER, for example, had necessary impacts at the concept and pre-concept stages, as did PLASTIC for components such as fascias. ELECTRICAL's interfaces with a large number of other parts, and there is a critical time between engineering sign-off and production, which necessitates as much early involvement as possible to reduce engineering changes. It is useful to consider, therefore, the relative positions of the cases along the design capability continuum and the entry point to the product development process. Figure 8.7 positions each of the cases on the matrix. Applying this matrix to a larger data set could provide some useful insights into both the contribution of suppliers to product development, but also which supplier types required greater coordination of activities. It is interesting to note that the relative positions of ELECTRICAL and DRIVE-SHAFT are further right than might be expected, due to the absence of such specialist design engineers within Rover.

Figure 8.7 The position of each case along the design capability continuum



Notes:
1. This diagram is nominal in its representation of supplier positions.
2. The positions of supplier involvement are relative to the vehicle manufacturer's request for supplier involvement in the product development activities.

Two issues raised in the cases have a negative effect on design relations with Rover. First, there were several instances when purchasing staff changed jobs and rather than a senior purchasing manager accepting previously agreed decisions, new staff proceeded to review these and re-instigate negotiations. This had happened to BUMPER and ELECTRICAL. Second, several firms reported long delays over payment for tooling. An important element of many design chains is the role of toolmaker in the process; where *letters of intent* had been issued, there was concern from suppliers that these did not in fact accumulate to very much.

8.8.2 Project management

The project management approaches of the cases were discussed in detail in the summaries, and a composite is presented in table 8.10. Several of the companies have changed their organisation to be more customer focused: DRIVE-SHAFT, ELECTRICAL, and PLASTIC. All firms were using multi-functional teams. Whilst firms may have had individual project management processes, there was consensus that all processes should follow the customer's milestones, in this case Rover's. In hindsight, there is a clear benefit in this helping coordinate inter-firm activities. However, some firms had only recently decided to follow this course of action.

For many of the cases, the overlap between engineering validation (D1) and quality proving (QP) was a critical stage in the process. It is at this stage that the engineering fit can be tested against the other elements of the vehicle. In ELECTRICAL's case, this

Table 8.10 Comparison of the project management approaches of the six case studies

Project management process overview	BUMPER	DRIVE-SHAFT	ELECTRICAL	EXHAUST	PLASTIC	WINDOW
1. Characterisation of process	Contract driven (flexible procedure)	Customer oriented business units	Phases and gates to meet manufacturing-engineering's needs	Phases and gates	Customer focused multi-functional teams	Phases and gates.
2. Dominant characteristics	Project team focus, with dominant project manager	Core team of 3 staff (team leader, sales executive and draughtsman); co-located; liaison with functional support (resident engineer)	Multi-functional teams, based in business units; engineering activities devolved to each business unit, except a core of engineering services.	Cross-functional team. Design responsibility focused on sister division, with transfer to EXHAUST at manufacturing implementation phase. Project manager assigned from EXHAUST to oversee entire process.	Team focus with functional support. Sales staff and project managers are customer focused.	Cross-functional teams. Optimised project management procedure to meet all customers' requirements.

Table 8.10 (continued)

3. Key mechanisms	Contract. Project manager overseeing all projects. Long-standing, tripartite relationship between Rover, BUMPER, and Toolmaker.	Cross-project learning through monthly review meeting (internal coordination); CAD facilities and resident engineer in all product areas to facilitate integration	Senior project manager. Senior management review at milestones. Co-location of design and manufacturing engineers. Use of guest engineers. Overlap between design/development and validation (concurrent engineering).	Design Review Meeting (D1) between EXHAUST and sister division, and Sample Build Procedure (QP) are key activities. Previous designs are formally examined. Post-project review.	Project manager. Weekly cross-project reviews. Senior management review at milestones.	Project manager; senior management review at milestones.
4. Major phases in a development project **(NB. All suppliers 'match' Rover's process to meet RG2000 specification)**	Phases defined by customer's process (milestones are the same as Rover's)	Phases follow customer's process	5 phases (with 9 review milestones): 1. Opportunity evaluation 2. Design/ development 3. Validation 4. Implementation 5. Support	2 stage phase (following Rover milestones): 1. Product design and development 2. Manufacturing implementation	Phases follow customer's process.	8 phases (77 tasks): 1. development/inquiry 2. customer order 3. final design/pre-production 4. cost evaluation and prototype 5. tooling and procurement 6. first sample 7. mass production 8. project evaluation

Table 8.10 (continued)

5. Dominant type of project	Evolutions/all types (model year changes; experimental)	Incremental (mature product)	Evolutions, enhancements and incremental improvements (model year changes); speed is critical.	Evolutions, enhancements and incremental improvements (dependent on customer)	Enhancements and incremental improvements; some aesthetic and technical improvements.	Evolutions, enhancement and incremental improvements; both technical and increasingly systems solutions.
6. Typical project duration (months)	12-18 (Rover) 36-48 (Land Rover)	N/A	No typical project. (All vary)	N/A	N/A	Varies
7. Primary performance drivers	Delivery reliability; Speed; Aesthetic conformance	Delivery reliability; Functional conformance; 'Best practice' (manufacturing, quality and design)	Delivery reliability. Speed (engineering change response)	Delivery reliability; speed in prototype build; design capabilities; new product support	Quality control. Deliver reliability. *Customer* response.	Delivery reliability; Engineering *functionality*.
8. Formality of process	Standardised, non-documented overall process - flexible for each contract. Procedures conform to BS5750 and RG2000.	Common formalised procedures, such as project timing plans, prototype raising orders.	Well defined and documented procedures.	Formalised/documented procedures: New product introduction procedure; Timing plan procedure; FMEA procedure.	Clearly defined procedures: tracked by Advanced Quality Planning document (includes timing, costs, design information and so forth).	Highly formalised: corporate handbook on project management; project management procedure document (77 elements); project timing plan (50 elements).

stage is frequently followed by substantial engineering changes, not least because their product is a high interfacing element of the vehicle.

8.8.3 Design/development information flows

In Chapter Three, figure 3.3 distinguished between four types of information flow that were typical of assembler-supplier relationships. Examining the six cases presented in this research, further types of relationship can be identified. Figure 8.8 illustrates five variants of assembler-supplier information flow found in the case studies. Only DRIVE-SHAFT and EXHAUST, both proprietary parts suppliers, follow the examples identified by Clark and Fujimoto (1991). The characteristic of early supplier involvement in product development activities is noticeable for black box, body parts, interior trim, and functional parts that have been project managed by a first tier supplier. These figures are nominal representations to illustrate the iterative nature of early information exchanges.

The information exchange between ELECTRICAL and Rover involves joint design work from the concept phase through the placement of a guest engineer at Rover. Not only is the guest engineer participating in current projects, but increasingly the resident expertise is being sought for, as yet, unspecified projects. Similarly, BUMPER, in the case of project ALPHA, clearly assisted in suggesting alternative body styling, and developing the cost and specification information. This characteristic reflects the unique relationship that exists between BUMPER and Rover, and the reality that the project manager had established a close working relationship with styling from when he was employed at

Figure 8.8 The design/development information flows of the case studies

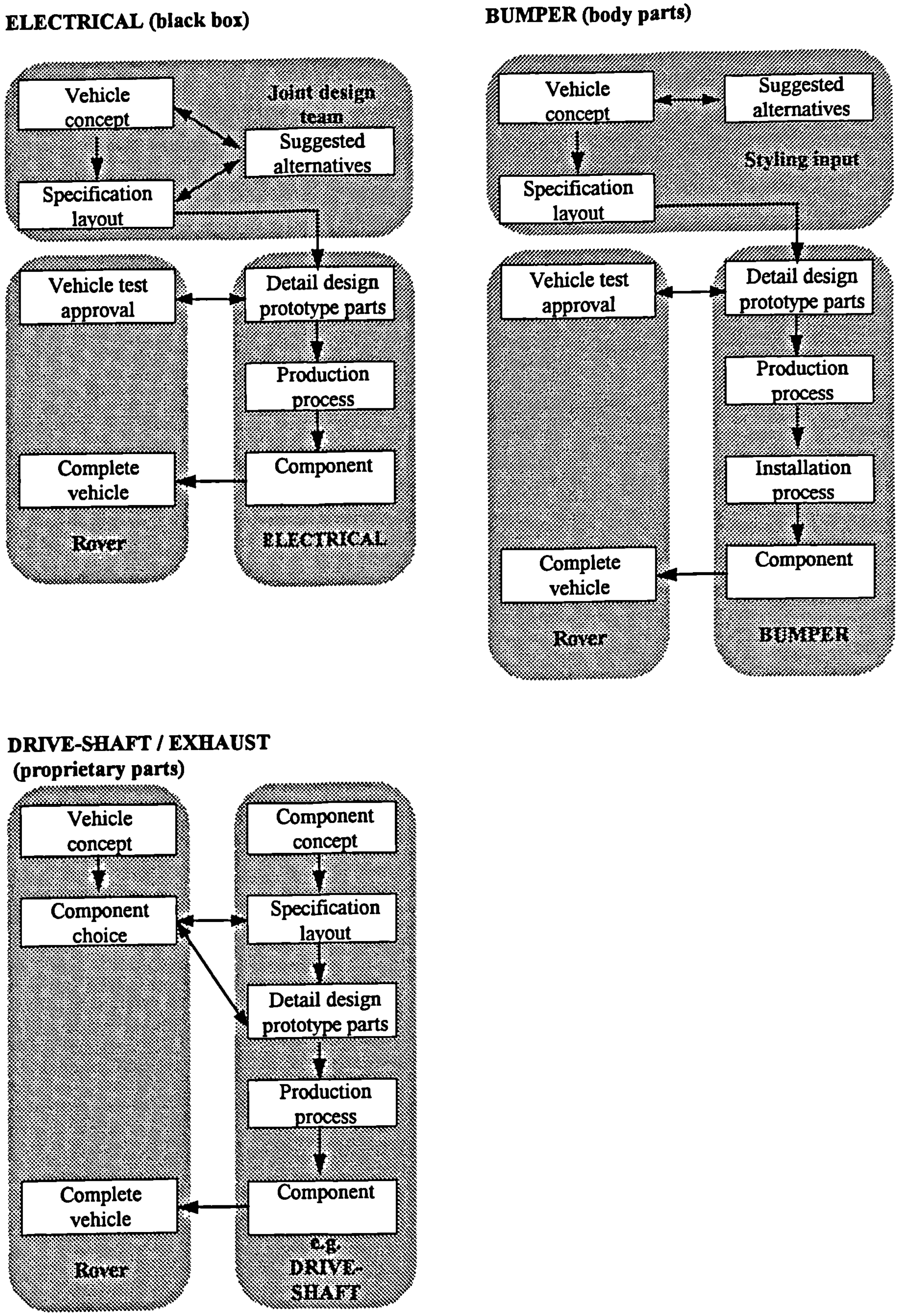
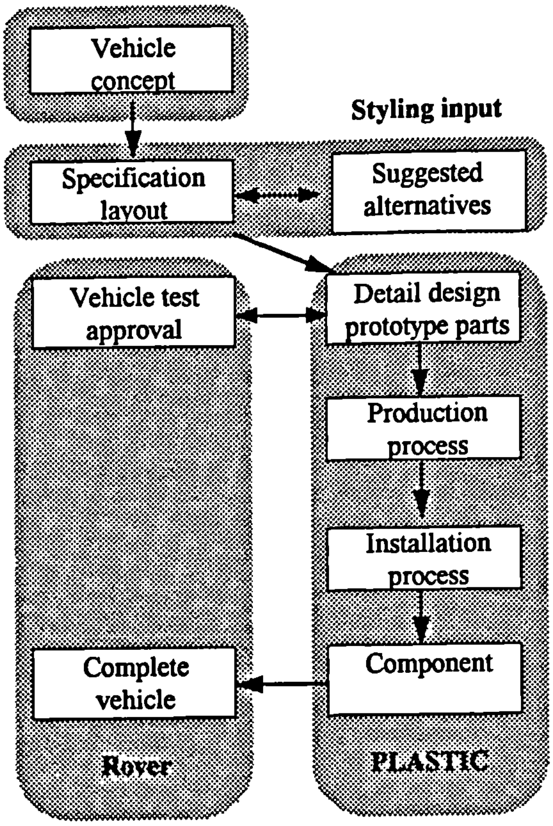
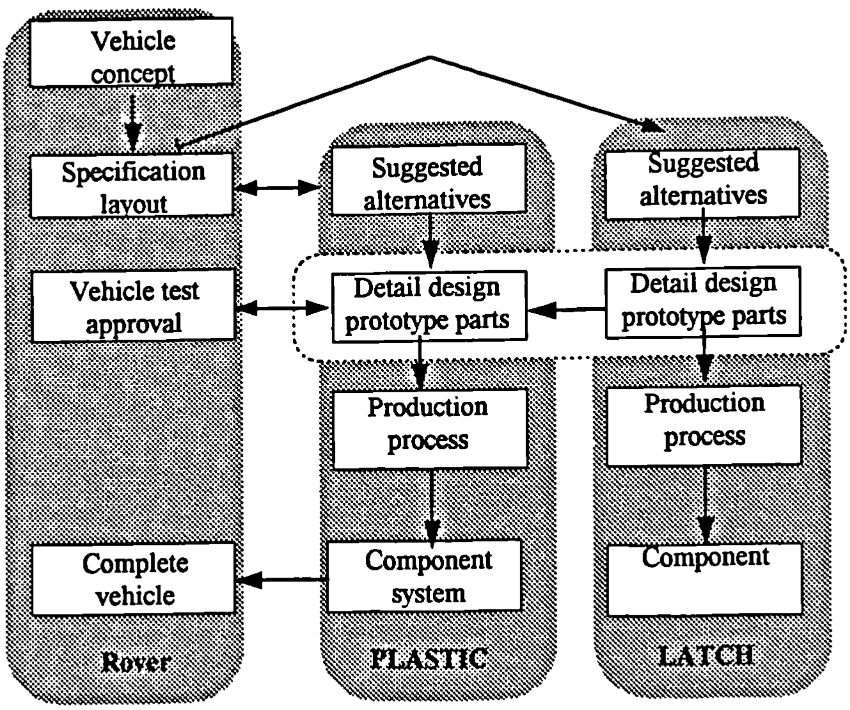


Figure 8.8 The design/development information flows of the case studies (continued)

PLASTIC (interior trim)



WINDOW (functional parts)



Rover. Nevertheless, if vehicle manufacturers are to outsource design expertise, this type of information flow may be found for other commodities too.

There is one key difference between the BUMPER and ELECTRICAL relationship with Rover. ELECTRICAL participates as part of a joint design team, whereas BUMPER is seen as part of the resident styling team. The size and nature of a harness project necessitates bringing in a large group of people to discuss development work, whereas the BUMPER team requires fewer members and benefits from a dominant project manager. This observation does not ascribe benefit or disbenefit to either case, but highlights this difference, since further research could explore the influences of this on the relationship.

PLASTIC has a design relationship not too dissimilar to BUMPER. There is a guest engineer working closely within Rover engineering, so although not influencing vehicle concept, they are collaborating on specifying costs and component requirements, which benefits PLASTIC insofar as the guest engineer can promote PLASTIC's expertise and processes as part of the specification.

The characteristics of WINDOW is influenced by the information exchanges differing in practice from that intended. The original arrangement was for WINDOW to project manage GAMMA; however, Rover did not relinquish control or authority, with the result that WINDOW's project responsibilities were undermined by LATCH liaising directly with Rover. Hence, the information diagram in figure 8.7 fails to represent the devolving of control to suppliers increasingly promoted by vehicle manufacturers.

8.8.4 Guest engineers

Table 8.11 summarises the number of guest engineers used by the cases. Four of the six cases have guest engineers working within Rover, and a fifth case is considering this option. These guest engineers have been used as a means of coordinating the product development process from Rover, through to production in their respective companies. The central purpose for using this mechanism is to provide an understanding of the production requirements as early in the process as possible. ELECTRICAL is the pioneer of the guest engineer in Rover and is widely using them with other customers. DRIVE-SHAFT was using guest engineers in two customers: Rover and Nissan. However, the use of these engineers was evidently different. In Rover, the guest engineer had an engineering bias, used in much the same way as the other examples in the cases. However, the guest engineer in Nissan was used for improving the quality of the product in a manufacturing engineer capacity.

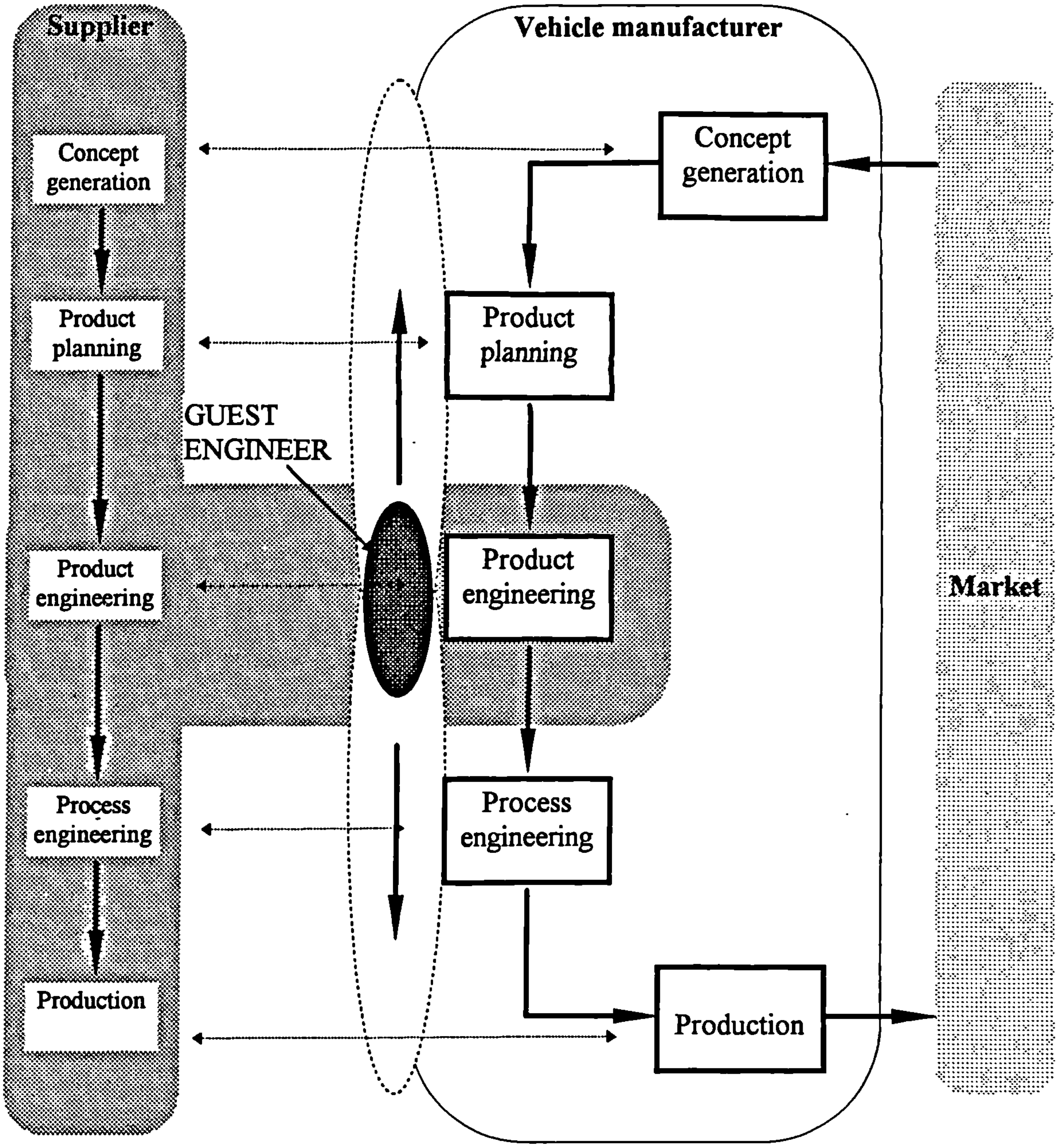
Table 8.11 Use of guest engineers by interviewed cases

Supplier	Rover	Land Rover	Honda	Jaguar	Nissan	Other
BUMPER	X	-	-	-	-	-
DRIVE-SHAFT	X	-	-	-	X	-
ELECTRICAL	X	X	X	X	-	2
EXHAUST	-	-	-	-	-	-
PLASTIC	2	-	-	-	-	-
WINDOW	*	-	-	-	-	-

* = planned

Figure 8.9 illustrates this difference. Guest engineers have been seen as an integrating mechanism between product engineering groups, as indicated in figure 8.9. However, two movements are acting upon their role: first, towards applications engineering in

Figure 8.9 Location of guest engineers



downstream operations; and second, increasing involvement in pre-concept specification creation. These findings raise a number of issues for the use of guest engineers. Should guest engineers become involved in pre-D0 activities such as pre-cost pack definition, and assist styling or concept, before supplier selection has taken place? Whilst suppliers continue to receive contracts, these issues remain unanswered; however, it is clear from ELECTRICAL that the perceived change in buyer-supplier relationships is denuding the trust that has enabled flexible participation in Rover's upstream activities.

8.9 Summary points

A number of points can be drawn from the cases that require further consideration. First, whilst all firms follow the traditional negotiation over contracts between purchasing and sales, a few variants have appeared. Those suppliers with guest engineers, are using them in this negotiation process, and in the case of DRIVE-SHAFT, Rover is involving the staff engineer.

A second point is that suppliers are responding to the demands of Rover to meet delivery targets in different ways. BUMPER, for example, has employed a logistics person to ensure Rover deadlines are met. PLASTIC has a dedicated project coordinator who maintains constant contact with project members, should the customer require information. A key coordination mechanism, in its broadest sense, is the need to maintain delivery reliability: this is a key element of RG2000, and the cases were aware not to fail in delivering the development product.

Several criticisms have emerged over the operating practices of Land Rover. Both BUMPER and WINDOW found that Land Rover project management skills were lacking those of the other Rover business units. However, it should be noted that Land

Rover has fewer projects, which tend to be of a long duration; and since the design stage of the projects examined in this thesis, Rover has implemented the PMP, which may over turn this observed shortcoming. One criticism of Rover is the issuing of the *letter of intent*, and the typical late issuing of it. Does this suggest something wrong with the system?

These cases represent suppliers at the forefront of actively encouraging upstream involvement in customer's product development activities. The mechanisms used to facilitate coordination are relatively straightforward: these reflect the need for ease of immediate communication and resolution of uncertainty. To this end, the guest engineer mechanism has been promoted by the suppliers to facilitate early input, largely to assist their own production processes. This type of mechanism will be limited insofar as there is finite space available within Rover, and suppliers will only be accepted under the guest engineer scheme if their components are deemed crucial to warrant it..

NOTES

1. Since one set of tooling is used, the engineering, development and manufacture time is longer. This difference in tooling arrangement may account, in part, for some of the differences found by Clark and Fujimoto (1991) between Japanese, US and European vehicle manufacturers' lead-times of tool dies.
2. In the UK, it is not usual for suppliers to ask for a project management fee up front. This contrasts sharply with BUMPER's experience with Volvo Truck, who expected this arrangement. In 1989, they initiated a three year development project of a bumper, where they project managed German, US and UK toolmakers.
3. This relationship has changed since a guest engineer has been residing at the Canley site: Rover staff often enquire about pre-cost pack definitions, since a resident expert is co-located with them. This raises the question of the role of guest engineers and whether they should help specify the cost pack which rival suppliers will also receive.

9 CONCLUSIONS

This chapter presents a summary of the findings of this research, and develops the implications of these for future research.

9.1 Summary of conclusions

The research reported in this thesis demonstrates the emergence of a new paradigm within the total supply network, which incorporates integrated product development and the early involvement of suppliers in design activities, and which is coordinated through a variety of integration mechanisms. It has developed new understanding of the design and development relationship between vehicle manufacturer and component supplier, highlighting the key participants and procedures of this process. The typology of inter-organisational integration mechanisms proposed in Chapter Four has found support from the cases studies examined. At the pre-project stage, the Rover Group has put in place various standards that assist in the coordination of design activities (such as effective cost management and RG2000), but perhaps most significant is the role of the staff engineer. This person uses his knowledge of the supply base to assist nominated suppliers, but also to improve the links between manufacturing and engineering through DFM and DFA. From the supplier initiative, the role of guest engineer is an important mechanism to ensure downstream activities (supplier operations) are considered upstream in the design process. Figure 9.1 summarises the mechanisms identified within this study that Rover, and supplier, are using to coordinate their joint activities.

Figure 9.1 Inter-organisational coordination mechanisms identified in this research

	Pre-project	Design phase	Manufacturing phase
Standards	Electronic data interchange CAD/CAM data exchange Effective cost management RG2000	Designers' tacit knowledge of manufacturing	Early manufacturing start with early design data Manufacturing flexibility
Schedules and plans		Sign-off	Production prototypes I. engineering fit II. build-test cycles
Mutual adjustment‡	Supplier development committee Staff engineer	Producibility design reviews Guest engineer	Engineering changes
Teams	Supplier development team Joint development	Joint product/process design team	

In Chapter Four, concern was raised over Bensaou's use of inter-firm coordination mechanisms *per se* to examine inter-firm relationships. Examination of these six cases illustrates the structural tasks that are implemented to effect communication of design information between firms. Although CAD/CAM, telephone, facsimile and so forth are used by firms, the findings contend that where firms are involved actively in early design contributions, face-to-face exchanges are of greatest importance. There is, however, no single mechanism that greatly facilitates coordination, rather emphasis has been placed on liaison, through specific liaison teams, programme managers, cross-functional teams and the monthly review meetings. Unlike other forms of inter-firm exchange, product development involves a large degree of uncertainty and risk. This necessarily requires extensive information exchange until such time as the design is *fixed* from both provider (supplier) and customer (vehicle manufacturer). Where this is a relatively simple part, or customer focused, the use of EDI, CAD/CAM and other mechanisms may have a greater influence. This thesis argues that for the core suppliers of design information - those which will manage the chain of suppliers - inter-organisational coordination requires the establishment of clear and effective pre-project mechanisms, from which design phase and manufacturing phase mechanisms can develop.

The case of project ALPHA, demonstrates the limitations of Rover's PMP procedures for so-called *fast-track* product development projects. These require a different management approach, together with new understanding from purchasing. For this to happen, the company must view this as different and instigate appropriate procedures.

It has been shown that some suppliers may undergo two stages of supply: supply based on production and/or logistics capabilities; and supply based on design and/or project management capabilities. As companies improve their supply logistics, attention will be drawn further towards upstream activities. In recent years, the focus of product development competitive advantage has been on time-to-market, overlapping problem-solving, and multifunctional teamwork encompassed within the philosophy of simultaneous engineering. This focus began on internal activities of the firm, but the issue of early supplier involvement has recently received more attention. In doing so, a better understanding is required of the types of supplier involved and the dimensions of their participation in inter-firm design activities. The supplier typology proposed in Chapter Five could assist in this, thus enabling a detailed methodology such as that of Birou and Fawcett (1994) to be applied to specific product categories, rather than at an holistic level. The paradigm of design chain management enables these issues to be drawn together, in relation to the other supply activities, and to place research, design and engineering activities within the total supply network.

In summary, the main findings of the research indicate that:

Coordination:

- there is no single mechanism for coordination;
- informal engineering exchanges have led to the increasing use of guest engineers as a mechanism;
- preferred suppliers are having an increasing involvement at the concept stage of product development.

Project Management:

- there is a need for a customer's project management process to accommodate so-called *fast track* projects;
- in the cases studied, Rover Group did not undertake a post-project review;
- there was no Rover policy towards roles and responsibilities of project core team members;
- the interface between product engineering and production (specifically engineering validation and quality proving) is an area continuing to generate major engineering changes.

Negotiator Roles:

- a variety of staff are being involved in the negotiation process between supplier and vehicle manufacturer: supply agent, design engineer, and *guest* engineer for the supplier; and purchasing agent, design engineer, and staff engineer for the vehicle manufacturer;
- more responsibility is being placed on vehicle manufacturer design engineers (such as Effective Cost Management) with a result that the role of Purchasing appears to be changing; where changes occur to Purchasing staff, the development process is temporarily halted by a perceived need to review contracts with suppliers.

These findings indicate a need for focus on the exchange relationship itself, through well understood procedures, with feedback of their effectiveness. It would appear that the vehicle manufacturer is not auditing the process or reviewing particular links. An audit is made of suppliers to conform to RG2000, but individual projects escape any audit. Many of the concerns of suppliers could be addressed by an internal review. Some suppliers are taking this need upon themselves to demonstrate issues of concern. The project management process needs to be viewed as a core competence for both vehicle manufacturer and supplier. As more design and development is devolved, the ability to project manage both internally and externally will determine those firms able to compete effectively in the market place.

9.2 A framework for design chain management

The discussion of inter-firm product development, and the analysis of the Rover Group and six of its suppliers, indicate various dynamics of design chain management. The main objective of the research has been to understand better this relationship and a framework is now developed that could be the basis for further investigation of this emerging paradigm.

First, the Rover Group, like many other vehicle manufacturers, is ranking the supply base through RG2000, preferred and approved supplier status and, more recently, strategic component supplier groups. These groups would imply some stratification of design relationships based on an ability to project manage particular operations.

Second, the analysis of the cases demonstrate that the flow of information is developing greater iteration at concept stage in the case of ELECTRICAL, BUMPER, and PLASTIC. This supports the typology of supplier classification presented in Chapter Five, which characterises a preliminary sharing of ideas in the form of early supplier involvement. This diagram provides a useful tool for examining relationships, and further examination of inter-firm product development could find these categories helpful.

Finally, the results of the cases suggest that Rover and its suppliers are devoting considerable time to concept and design activities, but problems with the overall system appear downstream with the need for engineering changes, and quality proving. Whilst the typology of inter-organisational coordination mechanisms indicate mechanisms for earlier input from downstream activities, the operation of the system for managing these appear to be a weak link in the process. Therefore, it is important to determine where in the process these are located and their effect on the relationship.

9.3 Further research

Since this research has been of an exploratory nature, many rich veins have been tapped into which further research may delve. Future research could be applied in two broad areas. First, at the level of the industry, since further work is required to characterise design chains, which a wider study could provide. Detailed examination is required of the widespread nature of design chains both within the automotive industry, but also others, most notably aerospace. How does the design chain differ by sector and region? In which industries does this paradigm play a leading role within a total supply network? Such an examination with the aerospace industry may also determine the similarities and/or differences in terms of project management style: is the automotive industry moving slowly toward the aerospace tradition of a company taking responsibility for the central design and final assembly, after selecting partners for the other major systems? Could beneficial lessons be learned from this sector?

Second, there are a number of issues at the strategic and operational levels that require better understanding, and further investigation. One might postulate that the natural growth of design chains will be the ever increasing movement towards outsourcing design work to suppliers and design studios, as the need for technological advancement and for incorporating supplier manufacturing knowledge increases. However the vehicle manufacturer will wish to retain value-added design work, marque related expertise (such as Rolls Royce in leather seat craftsmanship, and Jaguar with wood-inlaid fascias), and technological areas to minimise the transfer of proprietary knowledge. Hence, whilst there may be a movement towards vehicle manufacturers as coordinators of assembly, there will be a similar, yet specific, move towards coordination of design. This has two implications.

At the strategic level, an understanding of design chains is pertinent to developing corporate strategy, supplier relationship strategies, as well as manufacturing and engineering strategies. It may clearly be, as Lamming (1993) postulates, that a group of direct suppliers becomes established as the dominant nodes, coordinating their own supply bases on which to draw technical expertise.

The matrix of supplier design responsibility may prove a useful instrument in understanding these relationships. Suppliers could be indicated by project and by customer on a design responsibility/input to process index. This could help develop an understanding of their competencies and/or strengths and to assist explain strategic directions. Similarly, research could investigate the implications of moving from one position to another. A further development might be the examination of each supplier type (black box, grey box and so forth), and to determine their operations *vis-à-vis* the type of development project (incremental, radical, fast-track, and so forth).

At the operational level, further elements of the operation require definition and understanding, such as:

1. the flow of information through the design chain (sequential, reciprocal, or iterative);
2. the organisational forms that assist or inhibit this paradigm;
3. the adequacy of the supplier capabilities categorisation (perhaps it should be based on the information intensity within the design relationship);
4. the measures of performance that are appropriate for assessing effective design service;
5. the components that receive greater design outsourcing. A consideration of von Hippel's (1990) *partitioning* of design tasks may reveal which activities are more efficient when performed in-house, and those when outsourced.

There would appear to be scope for further investigation of the guest engineer form of mechanism. In Chapter Four, this form of coordination was introduced, and analysis of the firms studied showed it to be widely used, for a number of reasons. This research would suggest that guest engineering is a form of collaboration between the jointly owned partnership and informal linkages, and thus warrants further examination to determine its position *vis-à-vis* existing typologies of relationship. The importance of informal networks - and by implication the role of guest engineers - is their contribution of tacit knowledge to product development, as opposed to the codified formal specifications latent in traditional exchange mechanisms. Since their use in European firms would appear to be relatively recent - based on the firms interviewed no longer than five years - their use may be the start of a transition as this informal network of engineers becomes more formalised through the *internship* of guest engineering activities.

There is a need to understand their dynamics and forms and to identify good practice. Further work could define a typology of *guest engineering*, and examine the strategic and operational structures that support their effective use. Further understanding is required of the original stimulus for guest engineering, and how guest engineers influence the key operational variables of technology alliance and inter-organisational integration (in particular the quality, speed, dependability, flexibility and cost of the interaction).

Finally, there has been much discussion on core competencies which could benefit from the application of the supplier typology. Further examination is required of the selection process of *strategic component families* (Venkatesan, 1992). During the course of collecting the field data, the Rover Group began identifying core areas of specialism. This may, in future, have a strategic affect on the design capability sourcing decisions of the company, and hence on how suppliers contribute in-house. Therefore, further research could investigate the process by which these subsystems are identified and how this then relates to design capability sourcing decisions. Similarly, what affect does this have on the policy of guest engineers? What implementation is there for direct system suppliers? Are firms identifying vehicle subsystems based on their own core competencies, or is this reflecting the needs to manage better the development of a vehicle? Will preferred system suppliers be identified for these areas and brought in at the concept stage, or how will this new form evolve?

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APPENDIX A

Product classification

1. Engine and chassis

Advanced composite materials
Air cleaners
Air filters
Alternators
Anti-vibration sealing materials
Automotive polymers
Bearings - ceramic
Bearings - steel
Camshafts
Carburettors
castings - aluminium
Castings - malleable
Catalytic converters
Ceramics for automotive applications
Charcoal canisters and filters
Chassis frames
Compressors
Coolant thermostats
Cooling systems
Crankcase in aluminium
Crankshafts
Crankshaft vibration dampers
Cruise control - electronic
Cylinder liners/sleeves
Diaphragm and boots
Drive-by-wire
E-gas systems
Electromechanical components
Engineers
Engine blocks - aluminium
Engine control-related electronic devices
Engine covers/heads - aluminium
Engine management systems
Engine mounting/noise damping devices
Engine parts/components for emission control
Engine rocker arm covers in composite material
Engine valves
Engine vibration dampers
Exhaust control systems
Exhaust system silencers
Fans (and clutches)
Fans - visco
Fasteners
Fly wheels
Fuel injectors
Fuel injection - multi-point
Fuel injection - single point
Fuel injection equipment - electronically controlled
Fuel filters
Fuel pumps
Fuel rails
Fuel throttle bodies
Gaskets
Gas shock absorbers
Heat exchangers
Manifolds
Nozzles
Oil coolers
Oil filters
Oil pumps
Oil seals
Piston pin and rings
Radiators
Radiator fans - electronic, speed-controlled
Rubber hoses
Seals for cylinder head gaskets
Seals for exhausts
Seals for mechanical applications
Silencers (mufflers)
Sintered metal components
Sound proofing technology
Superchargers
Tappets
Turbochargers
Tyre cord fabrics
Valve lifters - hydraulic
Valve seals and guides
Valve train systems
Valves for engines

Vibration control technology
V-belts
Water pumps
Wheels - aluminium
Wheels - steel

2. Electrical

(i) Chassis
Actuators
Alternators/generators
Condensers
Direct ignition systems
Distribution
Distributorless electronic systems
Distributors
Electric cables - high tension
Electric cables - low tension
Electric heater systems
Electric modules
Electric motors - small
Electronic display systems
Electronic and transmission-related controls
Electronic brake-related devices
Electronic devices (other)
electronic ignition devices
Fibre optics
Fuel handling
Generators
Glow plugs
Ignition coils
Ignition systems
Magnetos
Modular connection systems
Multiplexing
Opto-electronic
Power and signal distribution
Printer circuit board design
Semiconductors
Sensors for engine and electronic devices
Solenoids
Spark plugs
Starter motors
Vehicle diagnostic devices
Voltage regulators
Wiring harnesses

2. Electrical

(ii) Body
Centrally-controlled lacking module systems
Connectors
Display systems
Electric and actuator motors
Fog lamps
Head-up displays
Heated windshield systems
Horns and buzzers
Instrument panels and controls
LCD modules
Lighting
relays and relay boxes
Signal and indicator lamps
Switches and switch systems
Switch combination for steering columns
Traffic and navigation systems
Tyre pressure monitoring
Wiper systems - front
Wiper motors and linkage parts
Wiper systems - rear
Wiper wash/cleaning systems
Wiring harnesses

3. Drive, transmission and steering components

ASR drive stop control system
Automatic clutches
Automatic transmission components
Clutch assemblies
Clutch covers
Clutch cylinders
Clutch disks
Clutch facings
Clutch - lock-up
Coil and stamped spring products
CV joints
Electronic clutch systems
Electrical and electronic systems for transmission control
Electronic control systems for 4WD
Electronically controlled automatic transmission
Electronic suspension control systems
Flywheel

Front axles
Front drive steer axles
Gearbox - manual
Hydraulic clutch controls
Limited slip differential
Locking differential gears
Non-drive steer axles
Power steering systems
Pre-filled clutch actuation sealed systems
Propeller shafts, drive shafts
Rack-and-pinion steering
Rear axles
Rear axle housings
Sintered metal components
Steering systems
Steering system - 4 wheel
Steering shafts, columns and gears
Steering wheels
Tie rod ends
Torque converters
Trailer axles
Transfer boxes for 4WD
Transfer cases
Transmission driveline systems, transaxles
Two mass flywheel
Universal joints
Visco-drive - viscous control units
Wheels - light alloy
Wheels - steel

4. Suspension and brake systems

Adaptive suspension
Air compressors
Air dryers
Air suspension systems
Air-actuated cam brakes for trucks
Air-actuated wedge brakes for trucks
Air brake systems for trucks
Air disk brakes for trucks
ABS - anti-skid brake systems
ABS electronic controls
ABS braking systems controls
ABS new electronic drive for calculating wheel speed
ASR drive slip control
Brakes - electronic control system
Brakes - power operated
Brake hoses
Brake pipes
Brake shoes
Brake vacuum boosters
Brake disk pads
Brake actuators
Brake corner modules
Brake drum assemblies
Brake disk assemblies
Brake control valves
Brake master cylinders
Brake systems
Coil springs
Damping devices
Friction materials (and linings)
Leaf springs
Shock absorbers
Suspension systems
Suspension electronic controls
Suspension system electronically controlled by electromagnetic clutch
Suspension load sensing valves
Suspension electronic ride control systems
Suspension - self-levelling systems
Suspension - struts/pistons
Torsion bars and stabilisers

5. Body components

Acoustic ceilings
Airbag systems
Anti-theft locking systems
Anti-theft locking systems - audible warning
Bodies and structures for vehicles
Body electronic systems
Body electronics - hydraulic power used for convertible top drives
Bumpers
Car interior components
Carpets
Cellular radios/telephones
Consoles/glove boxes
Dashboard with tubular strengthening
Dashboards and instrument panels
Dashboard-mounted tyre pressure monitoring system

Door operating system for CVs
Door trim panels
Exterior flexible urethane body parts
Exterior mouldings and trim for metal and plastic
Fibreglass body parts
Fuel tanks
Gas-filled lifters for seat adjusters, engine hoods, rear doors
Gas springs
Glass for vehicle windows
Heated windscreen
Information processing communication systems
Latches for doors, boot and bonnet - cars and CVs
Locks - central locking systems
Lock systems - electronic, infra red
Metal body pressings
Modular door systems
Modular front ends
Panels for passenger car bodies
Panels for truck and bus chassis
Plastic body components
Plastic panels for passenger car bodies
polished wood and components for quality interiors
Profiles/weather strips
Rubber dampers
Rubber mouldings
Safety restraints
Sealing products, adhesives, mouldings
Seat adjusters
Seatbelts
Seat cushions
Seats and seat springs
Seat systems - power adjusted
Seat fittings
Seat foam
Seat padding
Seat reclining devices
Spun bonded non-wovens
Sunroofs, sun hatches
Traffic information and guidance systems
Upholstery, cushions and mouldings
Wheel hub caps
Window frames
Window regulators (including power window regulators

6. Other

(i) Climatisation systems
Air conditioning/coolers
Condensers and evaporators for air conditioning
Electronic heater controls
Heaters
Heating and air conditioning controls

(ii) Audio systems
Car audio
Car stereo
Car video systems
Cellular telephones
Driver information
Two-way radio

(iii) Batteries

(iv) Paint (coating)

(v) Tyres

Source: Sleigh (1993, Vol. 4: appendix)

APPENDIX B

Outline of Interview Schedule

A. Context of operations

(Note: establish information for site, division and/or UK operations)

A.1. Describe the recent history: ownership, facilities and employment

A.2. Total turnover of the manufacturing operations of the site/company

A.3. Major product lines produced by the company and this division (on site/UK):

A.4. For each of these major lines, who are the major customers (esp. Rover)?

A.5. Describe how the unit/division fits into the structure of the larger corporation (organisation charts)

B. Product development process

B.1. Describe the company's product development (project management) process (Are documents/manuals available?)

B.2. Is this standard to the division, and company?

B.3. List the key stages of the process, together with the major players (functions/activities) in each stage.

B.4. What are the milestones/deliverables of each stage? Are these reports and/or meetings?

B.5. How do B.3 and B.4 above relate to Rover's process? (Position of D-Zero)

B.6. Who are the major customers you actively participate with in product development? For which product lines?

B.7. How would you describe the changes in this relationship over the last two years: increased, largely unchanged, decreased?

B.8. Over the last two years, how has the level of competition to provide product development expertise changed for each product line: increased, largely unchanged, decreased?

C. Project Team structure

C.1. Identify the members of the project team (full-time versus part-time).

C.2. Describe the scope of project team responsibilities.

C.3. At what stage is a formal project team formed: concept?

C.4. At what stage does the team relinquish responsibility (volume production?) If so, at what level of volume?

C.5. Where is the team located? Is it together?

C.6. How frequently does the team meet?

C.7. Do teams learn from other teams/customers?

C.8. Details of typical projects: size (man days) / frequency (projects per year) / length of project (months)

D. Project managers/team leaders

D.1. What is the scope of the project manager?

D.2. Describe their responsibilities?

E. Inter-Organisational Links

(Note: Need to differentiate general links and specific links)

E.1. Describe the nature of the inter-firm transaction. (What is exchanged?)

E.2. In what form is it exchanged?

E.3. How frequent is the exchange of information?

E.4. How is this exchange controlled, regulated and managed?

E.5. What is the level of trust/cooperation?

E.6. What information is exchanged at each stage?

E.7. What organisational coordination mechanisms are used?

E.8. What technological coordination mechanisms are used?

Note: Not all questions were asked at each interview. Due to time constraints and personnel interviewed, questions were selective.

APPENDIX C

An example of core team responsibilities (see footnote)

ACTIVITY	BUY	ENG	PTS	LOG	MFG	FIN	VCE
PLANNING							
1. Initial identification of core team requirement, and allocation of roles	1	1	1				
2. Ensure supplier appoints Project Manager	1	1	1				
3. Determine project feasibility - engineering		1					
4. Determine project feasibility - cost (commence ECM)	1	1					2
5. Determine project feasibility - capacity	2			1			
6. Determine project feasibility - timing	2	1		2			
7. Ensure production of Project Plan, and monitor regularly	2	1	2	2			
8. Ensure regular internal review of plan at supplier	1	1	1				
9. Communicate programme information - key dates		1		1			
10. Communicate programme information- volumes		1		1			
11. Communicate programme information - build requirements		1		1			
12. Produce Budget plan for prototypes/development funding	2	1				2	
DESIGN AND DEVELOPMENT							
1. Develop design specification, including reliability requirement		1					
2. Ensure D&D programme is compatible with project plan		1					
3. Discuss and agree D&D funding	1	2				2	
4. Carry-out ongoing review of D&D resource requirements		1					
5. Identify 'P' time aspiration, and design to suit		1		2			
6. Organise periodic formal design reviews		1					
7. Ensure design reviews feedback into overall plan		1					
8. Identify requirement and scope of Design FMECA		1					
9. Review design following initial Design FMECA		1					
10. Review process plan following initial Design FMECA		1	1		2		
11. Ensure higher assembly parts are considered		1			2		

12. Review function, performance and vehicle installation		1			2		
13. Consider complexity		1		1	2		
14. Identify in-service and after market requirements		1					
15. Identify component critical parameters		1					
16. Ensure Strategic Component Supplier Review implementation		2	1				
17. Product validation - identify requirements							
18. Product validation - monitor progress against plan		1	2				
19. Maintain drawing status		1	2				
		1					
PROCESS							
1. Identify location and method of prototype manufacture		1	2				
2. Agree inspection, test and identification of prototypes		1	2				
3. Agree change control system	2	1		2			
4. Ensure production and verification of process plan		2	1				
5. Ensure completion of initial Process FMECA, and ensure ongoing review		1	1				
6. Determine tool, fixture and facility requirements	2*	1	1				
7. Identify critical process parameters			1				
8. Ensure Control Plans are produced and reviewed			1				
9. Agree Conformance Testing requirements		1	2				
10. Monitor tool procurement and commissioning plan	1*	1	2				
11. Monitor facility procurement and commissioning plan		2	1				
12. Monitor gauge and test equipment procurement and commissioning plan		1	1				
13. Perform process critique once facility is in place		2	1				
14. Identify supplier process capability targets, and monitor achievement			1				
15. Review in-house storage and handling		2		1			
16. Review in-house assembly process		2			1		
17. Agree 'rate of climb' delivery plan			2	1			
18. Monitor sub-supplier control	1	2	1				

LOGISTICS							
1. Define Logistics functional specification				1			
2. Agree capacity requirements, and optimise facility utilisation			2	1	2		
3. Determine box/pallet design		2		1	2		
4. Agree number of boxes/pallets required				1			
5. Agree component identification and packaging		1		2	2		
6. Produce Budget Plan for boxes/pallets, including replacement provision				1		2	
7. Carry-out leadtime analysis		2		1			
8. Agree delivery method and frequency	2			1	2		
9. Agree pallet procurement and test plan				1	2		
10. Review 'P' time data	2	2	2	1			
11. Issue schedules to support delivery programme				1			
12. Monitor deliveries from D1 onwards	1			1			
COST/COMMERCIAL							
1. Develop and issue Cost Pack	2	1		2			2
2. Set initial Cost Targets (component, tooling, weight)	1*	1		2			2
3. Agree developed Cost Target with supplier							
4. Carry-out ongoing cost analysis	1	1		2			2
5. Maintain Cost Detail Tracking Sheets	1	1		2			2
6. Issue orders to support delivery programme	2	1					2
7. Discuss and agree warranty contract	1						
8. Agree non-standard contractual terms and conditions	1					2	
9. Ensure original equipment related price agreement in place	1					2	
	1						

Key: 1 = primary role; 2 = support role; * = with Tooling Engineer
BUY = Buyer; ENG = Engineer; PTS = Purchasing Technical Support; LOG = Logistics; MFG = manufacturing; FIN = Finance; VCE = Vehicle Cost Estimating

Note: This appendix is an outline of core team responsibilities as compiled by one core team for their personal management process. No inference should be made from this towards Rover Group policy.