The Use of Concurrent Engineering Methodologies

Achieving World Class Product Development Performance in the Automobile Industry

Report 8 of 8

Executive Summary

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in partial fulfilment of the requirements
for the award of the degree of
Engineering Doctorate

Department of Engineering
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March 1998

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ABSTRACT

This research project is about product development strategy and practice in the automobile industry. Specifically, it concerns the transformation of Rover Group body and tool development capability over four years from 1993 to 1997.

A single Rover Body and Pressings organisation was created in 1991. It encompassed the functions of Body Engineering, Press Tool Engineering, and Press Tool Manufacturing. As Engineering Director the Author had the opportunity to directly influence a significant portion of the body product creation process.

At the start of the research period the product development performance of Rover Body and Pressings was weak. Major investments in new press equipment could not depend on in-house die technology. Quality and cost delivery incurred customer dissatisfaction.

Resulting from the research are three innovations:

- The Engineering Quality Assurance Procedure was implemented as a disciplined stage/gate quality management system.
- A focused manufacturing strategy was implemented for die manufacturing based on die size.
- A new engineering design methodology was established utilising the scientific principles of metal forming technology as an integrated element in the design process.

These innovations were applied within the strategic framework of a new model describing a system view of the product creation process for body, at enterprise level.

The new product development process strategy was partially applied to two new vehicle programmes. One vehicle has since been initiated and delivered from within the new framework.

Strategic targets were defined for product development at Rover Body and Pressings covering product quality, development lead time, press tool cost and programme financial budget. The targets for quality and lead time were met during the research period. Although substantial progress is evident in physical performance the targets for press tool cost and programme budget were not met.

The major elements of the product development strategy applied in this research remain in place. The transfer of the strategic model of concurrent engineering to a wider context was demonstrated by applying it as part of the Rover Group product development reengineering project.

The leadership, and majority of intellectual development of the strategic innovations described in the research was solely the work of the Author while Engineering Director of Rover Body and Pressings. Supporting resources were used, under the direct leadership of the Author. Elements directly contributed by others have been clearly referenced.

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Glossary of Terms

AOK *After OK Panel*

BOK *Before OK Panel*

CAD *Computer Aided Design*

CADDS5 *CAD software trade name*

CAE *Computer Aided Engineering*

CAM *Computer Aided Manufacturing*

CATIA *CAD software trade name*

CV *Computervision Corp.*

CB40 *Land Rover Freelander*

D01 *1st Stage Engineering Prototype*

D02 *2nd Stage Engineering Prototype*

D1 *Validation Build*

E1,E2,E3 *EQAP Engineering Events*

EQAP *Engineering Quality Assurance Procedure*

FEA *Finite Element Analysis*

FLD *Forming Limit Diagram*

FTi *Forming Technologies Inc.*

HH-R *Rover 400 96MY*

IT *Information Technology*

M1,M2 *EQAP Die Manfg. Events*

MFE *Metal Forming Engineering*

MFT *Metal Forming Technology*

NC *Numerical Control*

NCBS *New Car Buyers Survey*

OEM *Original Equipment Manufacturer*

P1,P2 *EQAP Productionisation Events*

P38A *New Range Rover*

PMP *Rover Group Project Management Policy*

PR3 *MGF*

QP *Quality Proving*

QZ *BMW Quality Rating System*

R3 *Rover 200 96MY*

RBP *Rover Body and Pressings*

RBPE *RBP Engineering*

S/D *Static/Dynamic Balance*

SFDC *Shop Floor Data Collection*

SOP *Start of Production*

T1,T2,T3 *EQAP Die Tryout Events*

Tri-Axis *Transfer Press*

SECTION 1:

The Background to the Research Project

1. Introduction to the Research Project

This research project is about product development strategy and practice in the automobile industry. Specifically, it concerns the transformation of Rover Group body and press tool development capability over four years from 1993 to 1997.

The scope and content of the research are strategic. The project aimed to identify, and prove, a strategic framework for effective product development performance. As such, the range of subjects covered reflects the entire span of functional delivery processes embraced by the product creation *system* of a business.

In the 1990's, a collection of tools, techniques, and practices has become known as concurrent engineering. It is a basic premise of this research project that concurrent engineering is highly relevant to improving the enterprise wide product creation system.

The emergence of the Rover Body and Pressings business unit provided the opportunity to conduct this research. The placing of the body product engineering, press tool engineering, and press tool manufacturing operations of Rover Group into one organisational unit was a bold and unique step in 1991. This research portfolio documents how the problem of improving the weak performance of Rover Body and Pressings product development process was undertaken.

The research started out by considering product development effectiveness as a generic problem in the context of the automobile industry. A framework for the evaluation of product development performance was used to derive general hypotheses regarding the basis for effective practice.

These general hypotheses were applied to the specific context of body and tool development. Following diagnostic research an innovative model of body and tool engineering was proposed. The majority of the research portfolio covers the development, implementation, and evaluation of specific innovations required to realise this model.

Through the research period the initial ideas behind the research were refined and clarified. The emphasis in the research changed from the pursuit of lead time reduction, per se, to the knowledge intensification of the engineering design phase of development, supported by appropriate technology delivery capability.

The transfer of the innovations in the Rover Body and Pressings case was demonstrated by applying them to the new product introduction process of the Rover Group as a whole.

2. The Main Themes in the Research

2.1 Concurrent Engineering

Up until the start of the 1990's sequential models of product development had formed the basis of training of engineers and managers in the western world (Ward et al). As the 1990's have progressed this paradigm has been replaced with a new one based on concurrent design of product and process, and integrating life cycle criteria of the product in the development process (de Graaf 1996).

The term "Concurrent Engineering" was first coined in the Institute for Defence Analysis report R-338 to explain the systematic method of product and process design (Winner et al 1988).

To improve the efficiency of the product development process it is necessary to integrate the activities of the major business functions of a company, utilising changes in people practices, organisation, business processes, and information technology. Cleetus (1992) provided an extended definition of concurrent engineering that addresses this context:

> "Concurrent Engineering is a systematic approach to the integrated and concurrent development of a product and its related processes, that emphasises response to customer expectations and embodies team values of co-operation, trust, and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life-cycle perspectives, synchronised by comparatively brief exchanges to produce consensus."

It is in this wider corporate context of concurrent engineering that the links are to be found between the product development process itself, and the systemic attributes of the corporations ability to bring new product to market.

2.2 Metrics for Product Development Performance

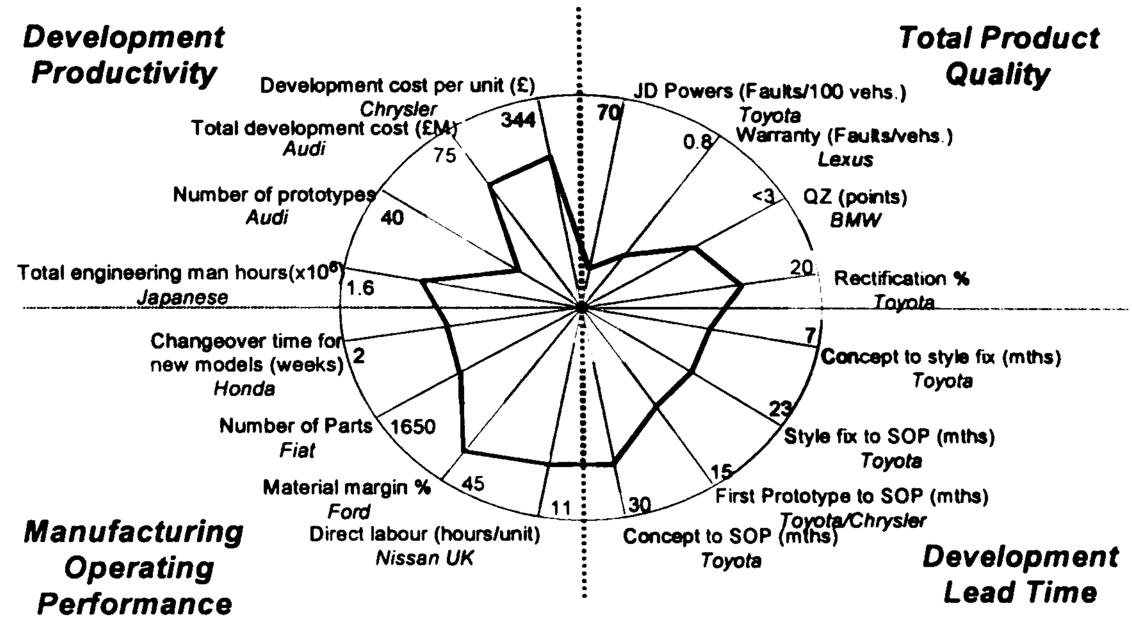


Figure 8.1: Metrics for the Evaluation of Product Development Performance in the Automobile Industry

(references in Appendix 1)

Four dimensions of product development performance were identified to distinguish competitive performance, and the practice of concurrent engineering.

Total Product Quality - reflecting both the functional and design performance of the product, and the consistent achievement of the engineering intent from the manufacturing process.

Development Lead Time - elapsed time from project approval to market presentation of the product.

Manufacturing Operating Performance - excellent manufacturing performance is a pre –requisite for concurrent engineering practice.

Development Productivity - the capacity to bring new product to market.

2.3 The Literature View of Best Practice

In their research on product development in the automobile industry, during the late 1980's, Clark and Fujimoto (1991) concluded that coherence in development practice and the factors of competitive success for a firm, is a determinant of high development performance (Clark & Fujimoto 1989a). They identified four themes, characterising high performing organisations:

i. **Superior performance in time, productivity and quality**; high performers pursued excellence in all three dimensions simultaneously (Stalk & Hout 1991, McGrath 1997).

ii. **Integration in the development process**; effectiveness in inter-functional working, and problem solving (Womack et al 1990, Clark & Fujimoto 1989b).

iii. **Integrating customer and product**; specific competencies in realising customer needs into deliverable product solutions (Pugh 1996, Clausing 1993).

iv. **Manufacturing for design**; transfer of manufacturing management know how into the management of development, and specific competencies in manufacturing processes directly supporting development, e.g. prototyping and die making (Clark & Fujimoto 1991, Whitney 1995).

Some researchers favour managerial explanations supporting examples of best practice based on teamworking, and organisational strategies (e.g. Clark and Fujimoto 1991, Nobeoka 1995, Scott 1994). Others explain best practice in terms of technology strategy (e.g. Whitney 1995, Carter & Baker 1991).

2.4 Benchmarking

As a by-product of Rover's recent business history the Author has had the privilege of developing close working relationships with Honda Motor Company, of Japan, and since 1994 BMW AG, of Bavaria.

Unique levels of access to two of the three most globally competitive automobile manufacturers in the world has strongly flavoured the shape of this research project.

2.5 Strategic Choices of Automobile Manufacturers

There are common themes of strategic development amongst competing automobile manufacturers, for example organisational development, CAD technology, and lead time reduction. However, there is no absolute consistent pattern of policy choice.

Figure 8.2 summarises the key strategies currently being pursued.

Emerging factors are product structure and platform strategy, globalisation of development, and changes in the relationship to suppliers in the development process.

Strategy	Chrysler	Ford	Honda	Toyota	BMW	VW	Rover
Platform Organisation	✓						
Balanced Matrix		✓	✓	✓	✓	✓	✓
Single Development Centre	✓		✓?	✓?	✓		✓
Globalisation of Development		✓	✓	✓		✓	
Lead Time as a Key Driver	✓	✓		✓	✓		
Single CAD System	✓		✓?		✓		
Higher Supplier Integration	✓		✓	✓			✓?
Core Competence Models	?	?	✓	✓	✓		
Product Development Alliances		✓				✓	✓
Overt Product Platform Strategy	✓	✓	✓	✓		✓	
Single/ Multi Brand	M	M	M USA Only	M	M	M	M

Figure 8.2: Product Development Strategic Thrusts of Automobile Manufacturers
(for references please refer to Appendix 2)

2.6 Product Development as Information Processing

The management of the flow of information has been a recurring theme in this research project. The view of product development as an information processing model is based on the fact that while project content usually differs from project to project, the development process steps are often repeated consistently (Adler 1996).

3. The Structure of the Research Portfolio

A review of the literature and product development strategy in the automobile industry revealed that all manufacturers are pursuing the goals and processes associated with concurrent engineering. Five general hypotheses were derived. The hypotheses were tested in two case studies.

Case 1: Body and Tool Development at Rover Body and Pressings

The first case study represents the major portion of the research project portfolio.

The body and die development process is a core element in the product development process of new vehicles (Clark & Fujimoto 1991, Ward et al 1995). It is a subset of the total vehicle development process. It carries a lower product and process complexity than a complete motor car.

The Author was appointed as the first Engineering Director of Rover Body and Pressings, a newly created business unit in Rover Group, in February 1991.

Case 2: New Product Introduction at Rover Group

Following the acquisition of Rover by BMW AG, a fundamental restructuring of Rover's product development operations took place in May 1996. In the new, autonomous, Design and Engineering function the Author was appointed Product Director, Luxury and Full Size 4x4, and Champion for the "Re-engineering" of product development in Rover Group.

A brief description of each portfolio report is given below.

Report 1: Abstract

A brief summary of the whole research project

Report 2: The Practice of Concurrent Engineering

This report reviews the status of practice in product development, and concurrent engineering, within the world automobile industry. It carries the main literature survey carried out for the research project. Definitions for product development and concurrent engineering are clarified, and the basis for measurement of product development performance is established.

From the literature survey general hypotheses are stated. A description of the overall structure of the research project concludes the report.

Report 3: A Product Development Strategy for Rover Body and Pressings.

This report deals with the derivation of a new product development strategy for Rover Body and Pressings. The generic hypotheses from report 2 are applied to the specific case of Rover Body and Pressings. These are to be tested through the implementation of a new strategic framework for body and tool engineering development.

A detailed calibration is made of the baseline performance at the start of the case. The results of a detailed causal analysis are used to identify the root cause factors for poor performance.

A new model of body and tool development is presented which gives precedence to the specification of high quality metal forming processes.

Concurrent engineering methods are to be used to create the metal forming process, and effective delivery processes are to be established to fulfil the process specification exactly. This model is the basis of the new product development strategy.

An overall change plan is the basis for implementation of the new model. An Engineering Quality Assurance Procedure is proposed to act as a stage gate process for management of the product development process, and is supported by other enabling actions.

Report 4: "Manufacturing for Design"; Towards World Class Die Manufacturing

This report covers the development and implementation of strategic changes needed to improve the operational performance of Tool Manufacturing department of the Rover Body and Pressings Engineering function.

The results of diagnostic research are presented. These include an operational audit, competitive benchmarking, and the identification of useful principles in the literature.

Strategic targets for tool manufacture are defined. The diagnostic results are analysed to determine the appropriate basis for action planning, and policy choices with respect to technology, operating practices, and manufacturing strategy.

Report 5: Choice of Engineering Design Methodology.

This report is concerned with the selection of an engineering design methodology to satisfy the objectives of the new product development strategy of Rover Body and Pressings.

The basis for choosing the configuration of the engineering design process is described. Observations of the relative information flow between the vehicle development programme and the body development programme are made. Trends in design methodology within Body Engineering are described which exploit the increasing use of engineering analysis as part of design synthesis.

It is concluded that Tool Engineering can be developed to emulate the trend in Body Engineering by using metal forming technology. A new engineering design methodology is described in the form of process steps with specific goals and responsibilities.

Report 6: Review of the Effectiveness of the New RBP Product Development strategy.

This report presents the results achieved following the implementation of the innovations to the Rover Body and Pressings product development process. The results are taken from late 1997 to capture the data from the Land Rover Freelander project, the first vehicle project to be initiated and delivered since the changes were made.

The results are presented against each of the four strategic targets for product development at RBP set out in portfolio report 3. The changes in overall product development performance are compared to the baseline performance at the start of the research period.

Report 7: The Reengineering of Product Development at Rover Group

The purpose of this report is to demonstrate that the innovations applied at Rover Body and Pressings are transferable to a wider product development process context.

The implementation of the reengineering project in Rover Group is described. A process configuration for product development under a reengineering scenario is derived. The main themes arising are analysed, and compared to those from the Rover Body and Pressings case.

Report 8: Executive Summary

An overview of the major elements of the research portfolio.

SECTION 2:

The Research

4. The Basis of the Rover Body and Pressings Case Study

This case was concerned with the product creation process relevant to the design and development of automobile bodies, and the assemblies, components, manufacturing processes and tools which they comprise. The product creation process of Rover Body and Pressings at the start of the case is shown below by the phase diagram in figure 8.3.

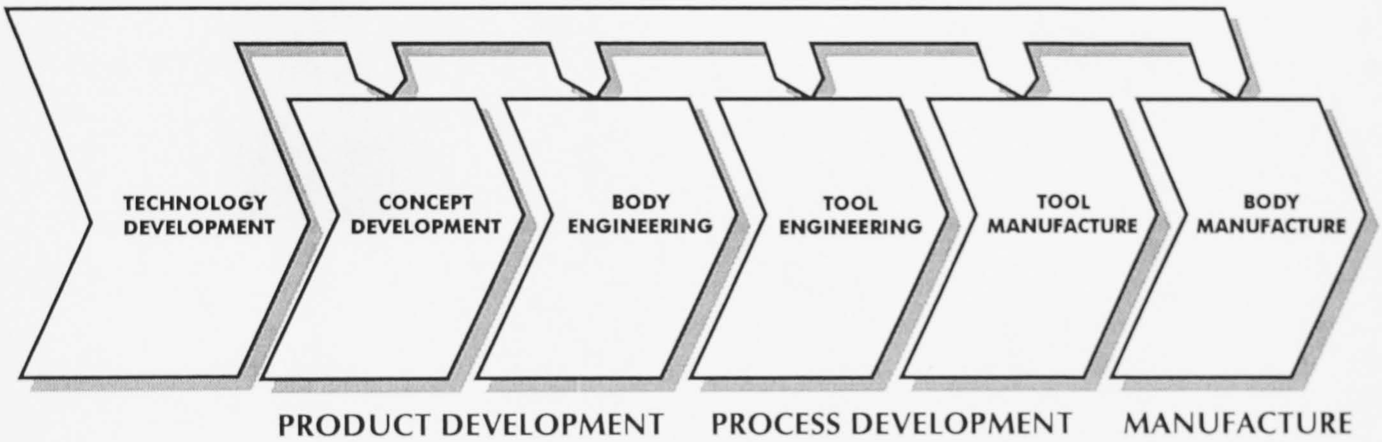


Figure 8.3: Phase Diagram of the Product Creation Process for an Automobile Body

Figure 8.4 shows a high level view of the Rover Group product creation process for the car bodyshell. Each box identifies a key process step.

There were three delimitations of the case study.

i. **Processes outside RBP responsibility** - The processes grey shaded in the boxes in figure 8.4 are excluded from the research of this case.

ii. **Development of Body Sub-Assemblies** - The product creation processes associated with these elements are excluded from this research.

iii. **Project Management Process** - The development of an effective Project Management System for RBP was the subject of another research project (Millard 1997) and so was not been included in this case research.

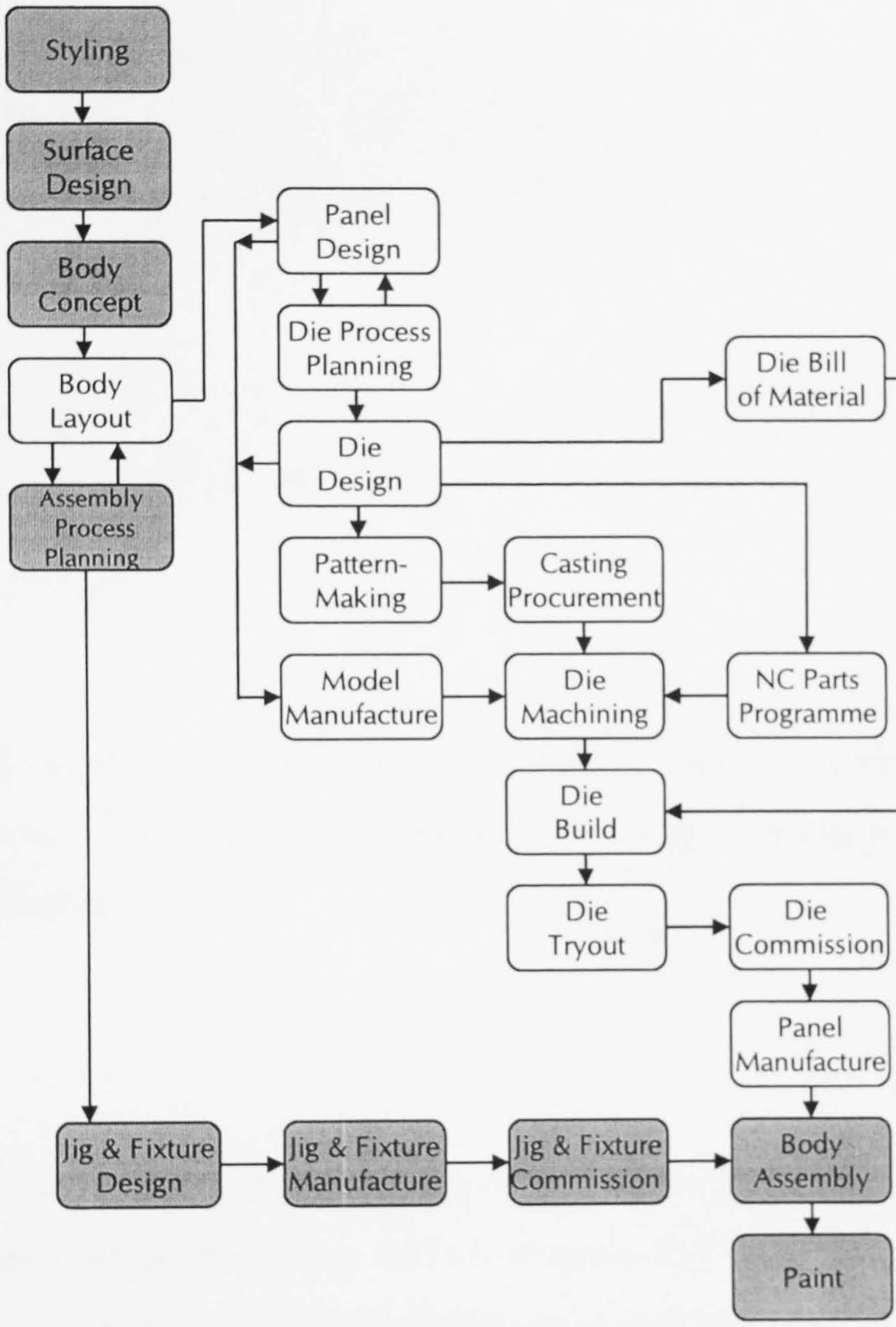


Figure 8.4: Rover Group Product Creation Process for Body

5. The RBP Hypotheses

The following hypotheses were derived by applying the general hypotheses to the Rover Body and Pressings case context.

5.1 That the four dimensions of world class automobile body and tool development are **Product Quality**, the **Cost of Press Tools**, **Press Shop Operating Practice**, and **Lead Time** from exterior design freeze to start of series production.

5.2 **Lead Time** has the highest impact on the competitiveness of the automobile manufacturer.

and

5.3 That the foundation upon which World Class body and tool development is built is the engineering excellence of the **metal forming process specification.**

leading to

5.4 The creation of an organisation operating a **new engineering development methodology**, which integrates the requirements and constraints of the automobile design and metal forming science into the specification of **capable metal forming processes**.

5.5 These processes are delivered to the press shop in a robust manner through the application of **excellent project management**, and state of the art press **tooling technology**.

Submission	Hypothesis				
	5.1	5.2	5.3	5.4	5.5
Report 3: A Product Development Strategy for Rover Body and Pressings	•	•	•		•
Report 4: Manufacturing for Design					•
Report 5: Choice of Engineering Design Methodology				•	
Report 6: The Effectiveness of a new Product Development Strategy at RBP	•	•			

Figure 8.5: Coverage of Hypotheses by Research Portfolio Submission

6. A Product Development Strategy for RBP

6.1 Summary of World Class Performance Metrics

Table 8.1 gives a 1993 summary of the selected metrics for each of the four dimensions of performance which comprised the evaluation model.

Metric	RBP 1993	Benchmark 1993
Product Quality		
NCBS - Sturdiness of Body	8.00-8.63	>9.00
- Body Workmanship	7.54-7.94	>8.60
- Overall Quality	7.82-8.15	>8.50
Body Cosmetic Quality - QZ	≅3.0	<0.5
Body Accuracy	70%	90%+
Component Supply Quality	5000 ppm	<300 ppm
Unplanned Rectification	0 to 480 mins.	0
Lead Time		
Lead Time (clay fix to SOP)	146 weeks	106 weeks
Programme level slippage	3 months	0
Panel Supply Achievement	95%	100%
Press Tool Cost		
Panels per Body	380	250
Tools per die set	3.5	3.0
Tool Cost Indices - Small	100	50
- Medium	100	95
- Large	100	75
Contract Performance Factor	1.2 to 1.5	Not Available
Press Shop Performance		
Overall Equipment Effectiveness	≅40%	>70%
Press Utilisation – Transfer	80%	80%
- Tandem	50%	80%
Die Change Time - Transfer	<5 mins.	<5 mins.
- Tandem	3 to 5 hrs.	<20 mins
Shots per part		
Press Run Length - Transfer	1500	<2000
- Tandem	5-8,000	<2000
Metal Utilisation	53%	>70%

Table 8.1: Summary of RBP Performance Metrics

6.2 Results of Causal Analysis

The following root cause areas were selected for as priorities for the change plan.

1. Quality Assurance Framework
2. Metal Forming Technology Competence
3. Skills and Knowledge Shortfall
4. Information Flow Integrity
5. Cross-Functional Integration
6. Press Tool Technology
7. Toolroom Operations Development
8. Integrated Scheduling Environment

6.3 Strategic Targets

6.3.1 Product Quality

Target: *Top quality component supply from transfer presses with RBPE manufactured tooling.*

When the £54M investment was made in two 5000 tonne transfer presses at Swindon, RBP was dependent on Honda die technology to commission and operate the presses. This target was defined to ensure that the technology competencies associated with the entire manufacturing process chain for the largest cosmetic stampings was consolidated in-house.

6.3.2 Lead Time

Target: *80 weeks from style fix to QP panels.*

This target was identified to ensure that a satisfactory information flow could be maintained within the vehicle development programme as a whole. In addition, it was a strategic aim of RBP, at the start of the case, to be a recognised supplier of press tools to Honda and this demanded a match to Honda's own lead times. The metrics selected were body engineering release to parts off tools, and body engineering release to start of vehicle production.

6.3.3 Press Tool Cost

Target: *Press tool costs competitive with Japanese average die prices.*

This target was defined to ensure that Rover Group did not incur a competitive disadvantage by manufacturing dies in house, and to enable RBP to gain external tooling contracts to fill open capacity resulting from Rover Groups long range plan profile.

6.3.4 Programme

Target: *Delivery to programme financial budget.*

This target was defined to improve customer satisfaction, and to eliminate the incidence of unplanned funding requirements.

6.4 A New Process Model for Body and Tool Development

The specification of capable metal forming processes sits at the very heart of the body product creation process. Therefore a new model of the body and tool engineering process flow was proposed, outlined in basic form in figure 8.6.

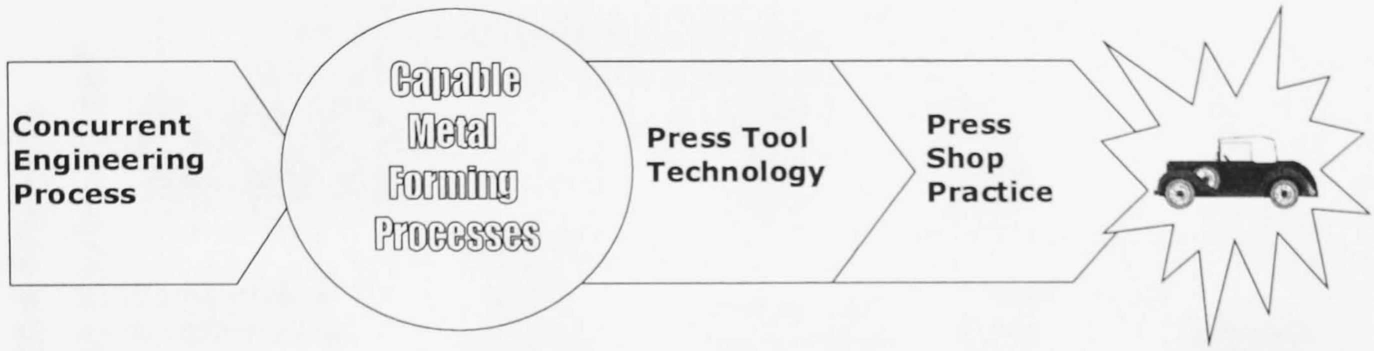


Figure 8.6: A New Process Flow Model of Body and Tool Engineering.

The model places capable metal forming process at the core. To the left a concurrent engineering process is envisaged which integrates the "voice of the customer" with the process technology needed to deliver the product requirements successfully.

During the concurrent engineering phase there is a pro-active emphasis to problem solving. Known problem areas from previous similar components are focused on and learning is integrated into new designs. The use of CAE tools to simulate processes supports problem solving.

In this model, the emergence of a metal forming process specification of proven capability is the key output from the design engineering phase, and a pre-requisite to the launch into manufacture of the stamping dies. In this way the development of engineering confidence in the metal forming process specification is clearly separated from the high cost processes of die manufacturing.

To the right of the metal forming process are the key implementation elements by which the metal forming specification requirements are fulfilled. Press Tool Technology implies the deployment of die design technology via appropriate die manufacturing processes and techniques. Press shop practices encompasses both the production process maturation of a die from new, and the operation of the dies in long term component supply to the customer.

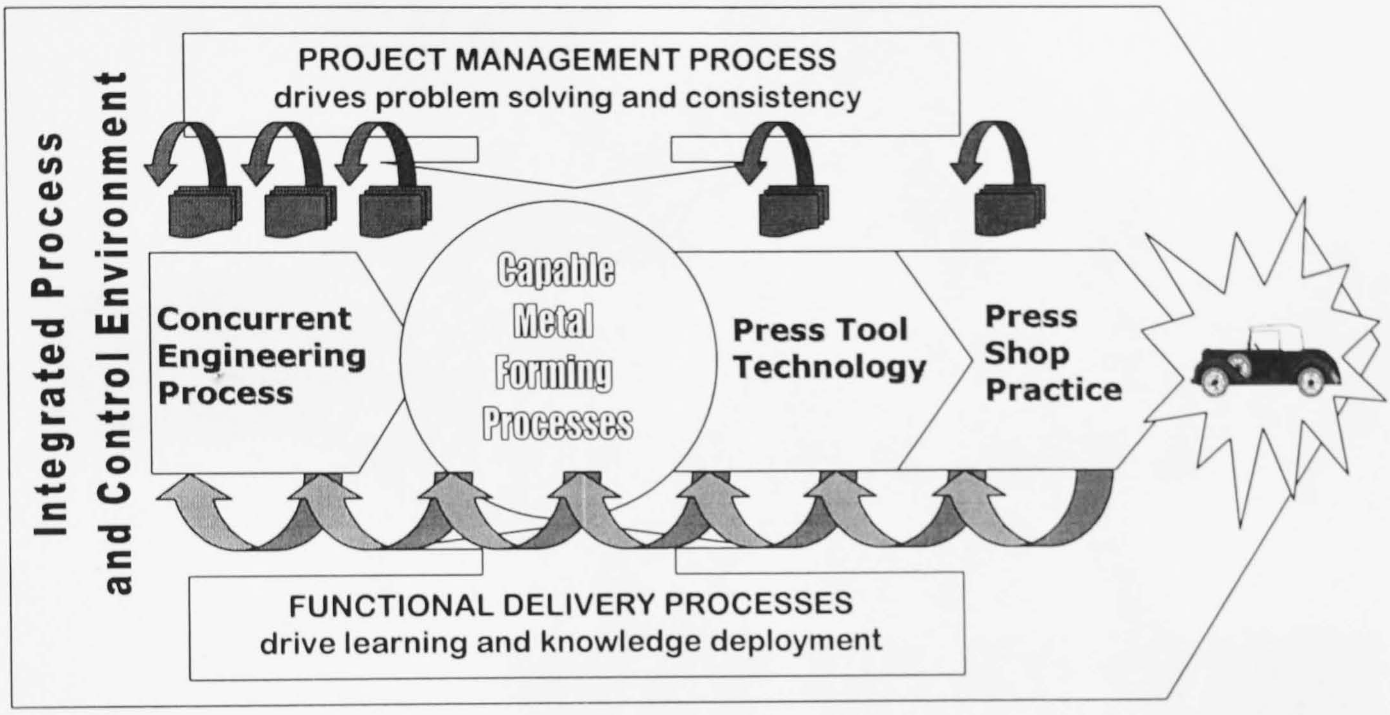


Figure 8.7: Completed Process Model of Body and Tool Engineering

The importance of knowledge capture in the development process is recognised by pursuing a strategy of specialisation of people both in process and by product. To complement this a project management process is needed to drive cross functional integration, problem solving and consistent conformance to the development process requirements. An integrated process and management control environment is needed to co-ordinate and regulate this complex information network.

The completed model shown in figure 8.7 expresses a new and innovative process strategy, for Rover Body and Pressings. This model was the basis for choice of specific actions and initiatives to implement RBP's product development strategy.

6.5 Change Plan Content

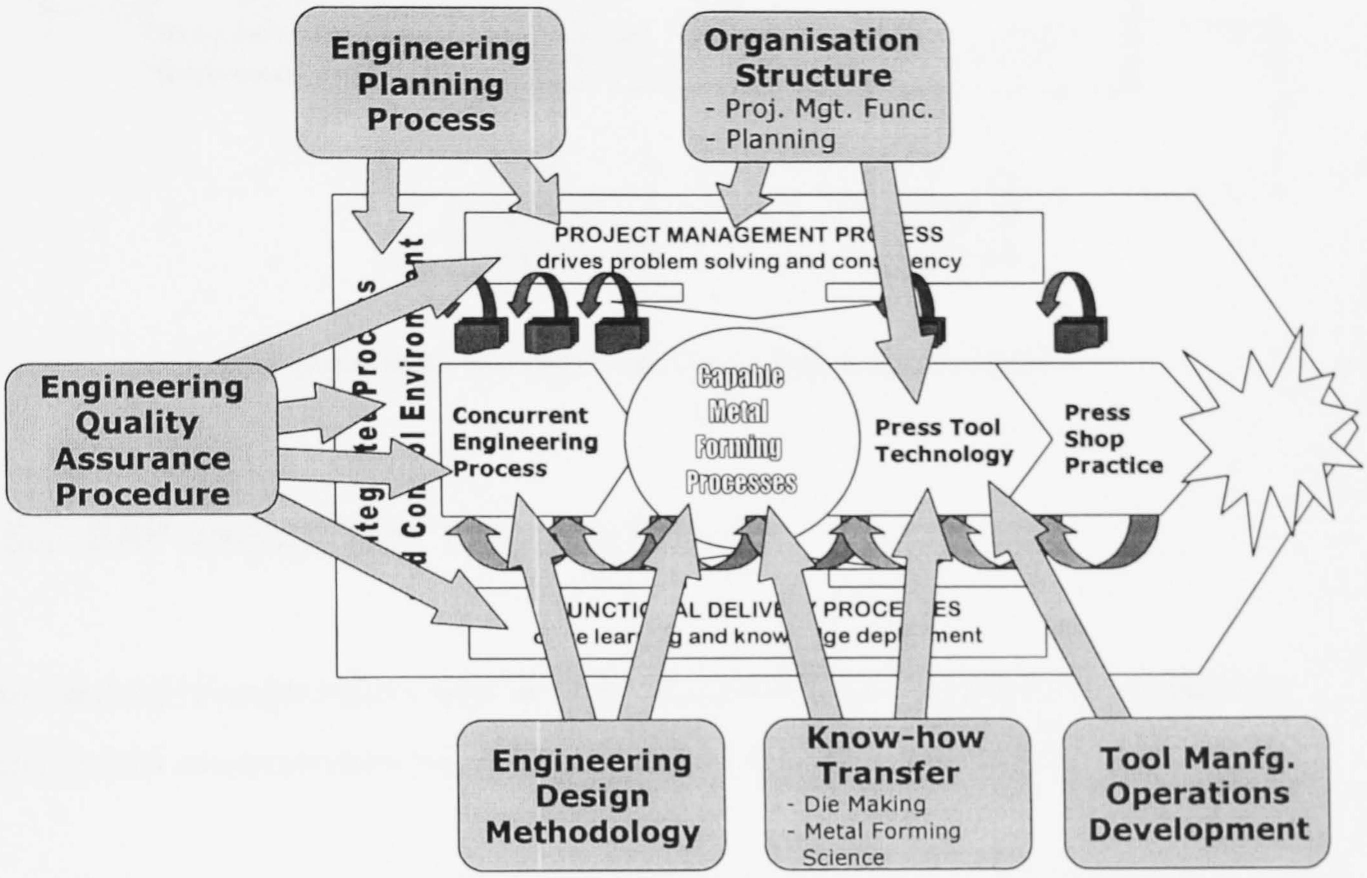


Figure 8.8: The linkage of change plan content to the RBP product development strategy model.

6.5.1 The Engineering Quality Assurance Procedure

It was clear that a stage-gate system of management control was a mandatory requirement for the product development process at RBP. A solution was needed which was compatible with other RBP business processes and the customer vehicle programmes in Rover Group.

Figure 8.9 shows the high level process flow with definitions for each event.

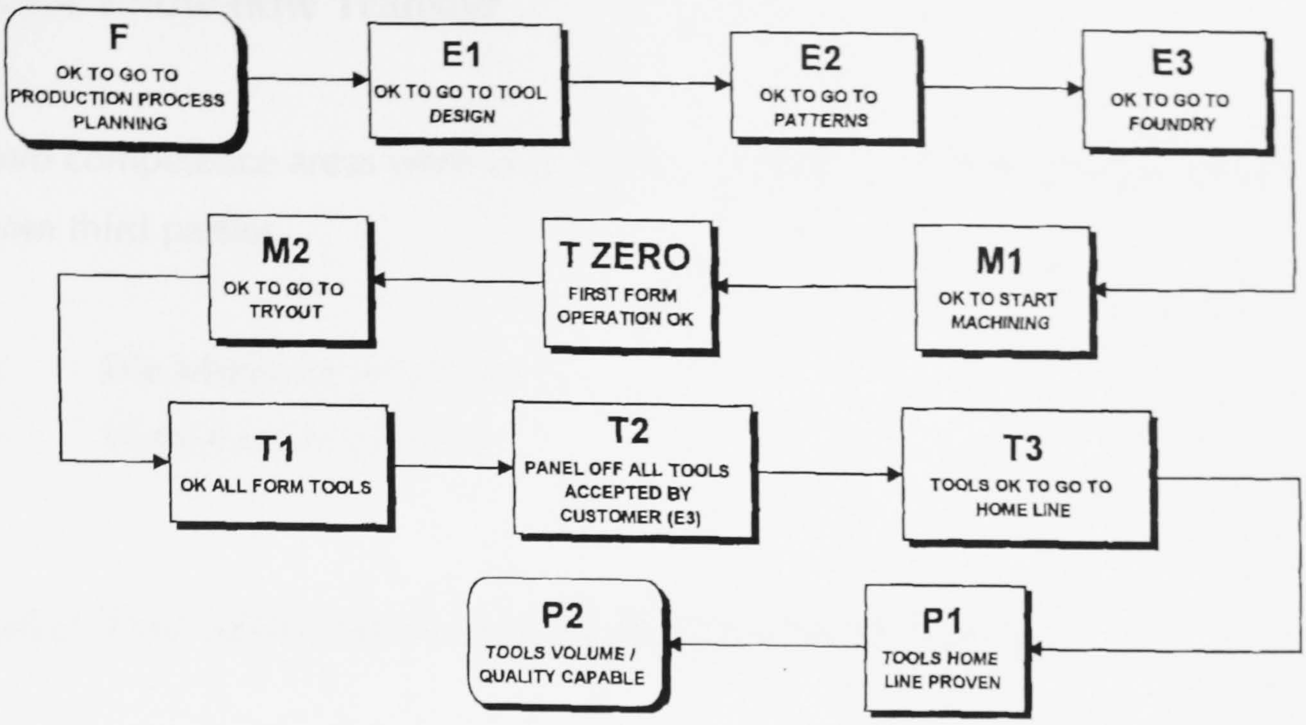


Figure 8.9: The high level process flow of EQAP

6.5.2 RBP Engineering Planning Process

The second change action was aimed at providing an integrated management and control environment related to management information systems.

The master scheduling of press tool production in the toolroom is the dominant planning constraint in the process. The detailed implementation of master scheduling is described in report 4 of this series.

6.5.3 Organisation Structure

Two organisation structure changes were made in support of the change plan - one at RBP business unit level, the other within RBP Engineering.

i. Establishment of a Project Management Function
ii. Decentralisation of the Planning Function

6.5.4 Know-how Transfer

Two competence areas were identified for accelerated transfer of know-how from third parties.

i. Die Manufacturing Practice
ii. Metal Forming Science

6.5.5 Tool Manufacturing Operations Development

Given a competitive position in the engineering technology of the press tools, and a capable metal forming process, the execution of the manufacturing process lies with the tool manufacturing operation.

The fundamental operational development of the Tool Manufacturing function is the subject of report 4 in this research portfolio, and is summarised in section 7 of this report.

6.5.5 Engineering Design Methodology

The proposed new model of body and tool engineering required a concurrent engineering process that can integrate the product design requirements of the automobile body with the process design parameters for individual panels.

The key output of this concurrent engineering process is the availability of a fully engineered, process capable, metal forming process specification.

The choice of an appropriate engineering design methodology was the subject of portfolio report 5 in this series, and is summarised in section 8 of this report.

Change Plan Thrust	Quality Assurance Framework	Metal Forming Technology Competence	Skills and Knowledge Shortfall	Information Flow Integrity	Cross-Functional Integration	Press Tool Technology	Toolroom Operations Development	Integrated Scheduling Environment
Engineering Quality Assurance Procedure	•			•	•			
Engineering Planning Process	o			o	•		•	•
Organisation	•			•	•			o
Know-how Transfer		•	•				o	
Concurrent Engineering Process (see Report 4)		•		•	•	•		
Toolroom Operations Development (see Report 3)	o			o		•	•	

o = medium link • = strong link

Figure 8.10: Links between change plan action thrusts and root cause areas

Figure 8.10 demonstrates that the change plan adequately covers the root cause areas.

6.6 Milestones and Pace

Figure 8.11 describes the change plan by specifying expected results for each year and relating these to the vehicle projects in delivery at the time. In a multi-project environment like RBP changes in practice are inevitably timed to coincide with new project workload.

Parameters	1992 CHAOS	1993 CONTROL	1994 SIMPLIFY	1995 FAST RESPONSE	1996 WORLD CLASS
Organisation	Geographic based Functional	Process based	- Focused org. by product - Reduced product range - Toolroom layout for flow	- Teamwork based - Lean manning	- Profit centre accountability
Project Mgt. Process	Project Team based	Project Mgt. process under development	- Contracts Process in place - Master Schedule in place	Simplified planning	High throughput achievement
Technology	Uncompetitive Die Standards	Simultaneous engineering to new standards	Common die standards with Honda	Forming technology capability	Process capability goals achieved
Projects in Delivery	- R17 5Dr	- P38A	- Accord Child Parts - PR3	- HH-R 4 Dr - R3	- CB40
Financial		Forecast achievement	Estimate perf. improvement	Reduced fixed costs	- World competitive pricing - 10% ROS
Lead Time (Wks) D0 - QP	140	120	100	90	80

Figure 8.11: Change Plan Goals and Milestones for RBP Engineering 1992-96

(Source: RBP Engineering 1994 Business Plan, January 1994)

Note that across the top of the table the stages from the change model (Arete 1992) are aligned to each year, and reflect the progress in performance in the two years that pre-date this research project. The most significant of the proposed changes are associated with the simplification stage, and were planned to occur during 1994, which was the pivotal year in the success of the change plan.

7. Manufacturing for Design

7.1 The Creation of Focused Toolrooms

Six thrusts were identified to form the framework of the action plan, as follows:

7.1.1 Creating Specialisation

It was decided to focus each operating unit as follows:

No.1 Shop, Swindon	- Small Dies
No.2 Shop, Swindon	- Large Dies (3600mm – 4600mm)
'T' Building, Cowley	- Medium Dies (1800mm – 2700mm)

An organisational template was developed for each manufacturing unit as shown in figure 8.12.

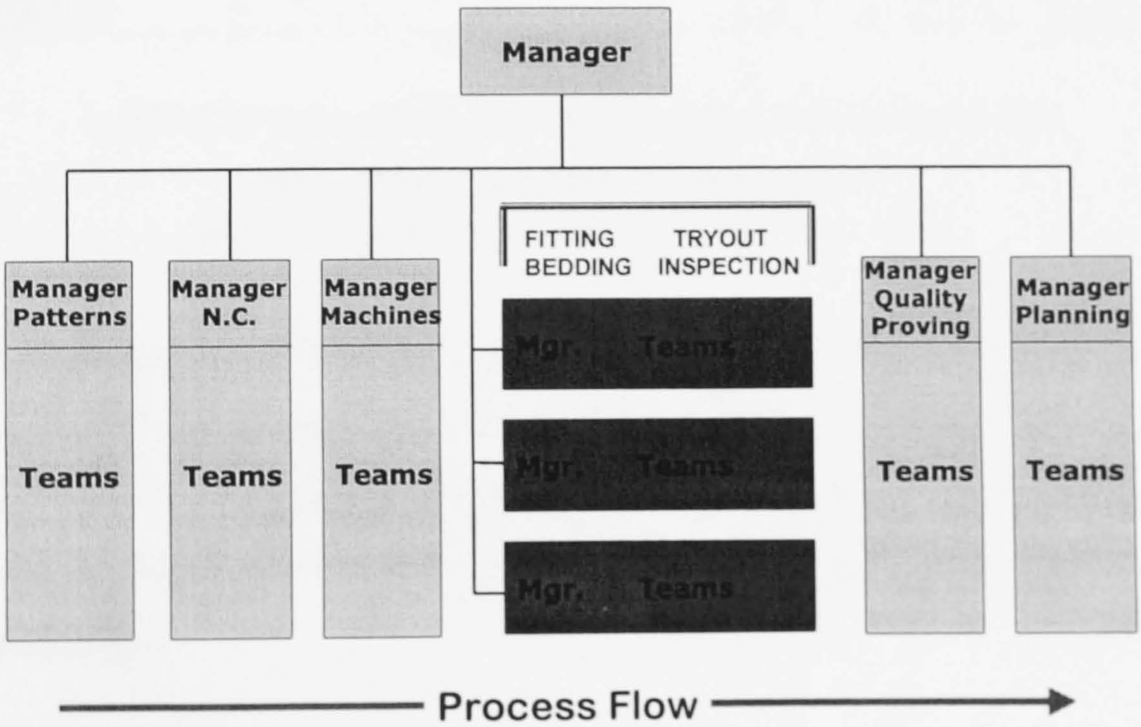


Figure 8.12: Organisation Template for Focus Tool Manufacturing Units

(source: Watts 1996)

7.1.2 Establishing Operational Targets

Analysis of the business model demonstrated the need to re-balance throughput and overall headcount. A capacity review was conducted for each unit, to clearly identify capacity bottlenecks, and define the appropriate facilities and manning balance.

The conclusion of this analysis phase enabled the consolidation of throughput and manning targets that could be used to brief the management teams of each manufacturing unit, and to describe the impact of the proposed changes on a business model.

Tool Manfg. Unit	Before			After					
	Dies p.a.	People		Dies p.a.		People			
		Hrly.	Staff	Dies	Δ%	Hrly.	Δ%	Staff	Δ%
Large	55	454	58	78	42	211	(54)	46	(21)
Medium	88	245	38	219	149	220	(10)	19	(50)
Small	132	*	*	230	74	70		6	
Totals		**699**	**96**			**501**	**(28)**	**71**	**(26)**

Table 8.2: Throughput and Manning Summary before, and after, focus Toolroom Implementation.
(source: Presentation to Rover Group Board Feb. 1994)

Table 8.2 compares the manning and throughput for scenarios before and after focus toolroom implementation. The step improvements shown were used to compute sales revenues and substituted into pro-forma profit and loss accounts for each unit. Figure 8.13 shows the consolidated position for total tool manufacturing.

	1993	1995 Template	Variance
Gross Sales Revenue		**30.6**	
Less outsourcing		(1.7)	
Net Sales Revenue	**27.9**	**28.9**	**1.0**
Operating Costs			
Direct Materials	-	-	
Payroll (Manpower Costs)	24.2	19.9	4.3
Depreciation	2.2	1.7	0.5
Overheads	5.9	5.4	0.5
Group Assessments	1.0	0.6	0.4
Total Operating Cost	**33.3**	**27.6**	**5.7**
Operating Profit/(Loss)	**(5.4)**	**1.3**	**6.7**
Return on Sales %	(19.4)	4.5	23.9

Figure 8.13: Summary profit and loss account templates for the proposed RBPE focus tool manufacturing implementation.
(source: Woodcock 1995)

7.1.3 Simplification of the Manufacturing Process

Three action steps were taken:

i. Toolroom Layout for Flow

ii. Facility Matching

iii. Addressing Capacity Bottlenecks

- Large tool tryout capacity at Swindon
- Inter bay transfer units at Cowley
- Tryout capacity at Cowley

7.1.4 Minimising Disruption of the Manufacturing Process

Part of the change plan concentrated on creating an environment within tool manufacturing which minimised disruption. There were five action elements as follows:

7.1.4.1 Centralised Material Control

The M2 event definition required availability for the tool build team of the whole parts kit for the die. To increase management control of material it was decided to centralise this activity at each site.

7.1.4.2 Manufacturing Process Link to EQAP

Three 'M' events were defined to place the tool manufacturing process within the overall EQAP stage/gate framework. Figure 8.14 positions these events in the high level process flow of die manufacture and summaries the key requirements at each event.

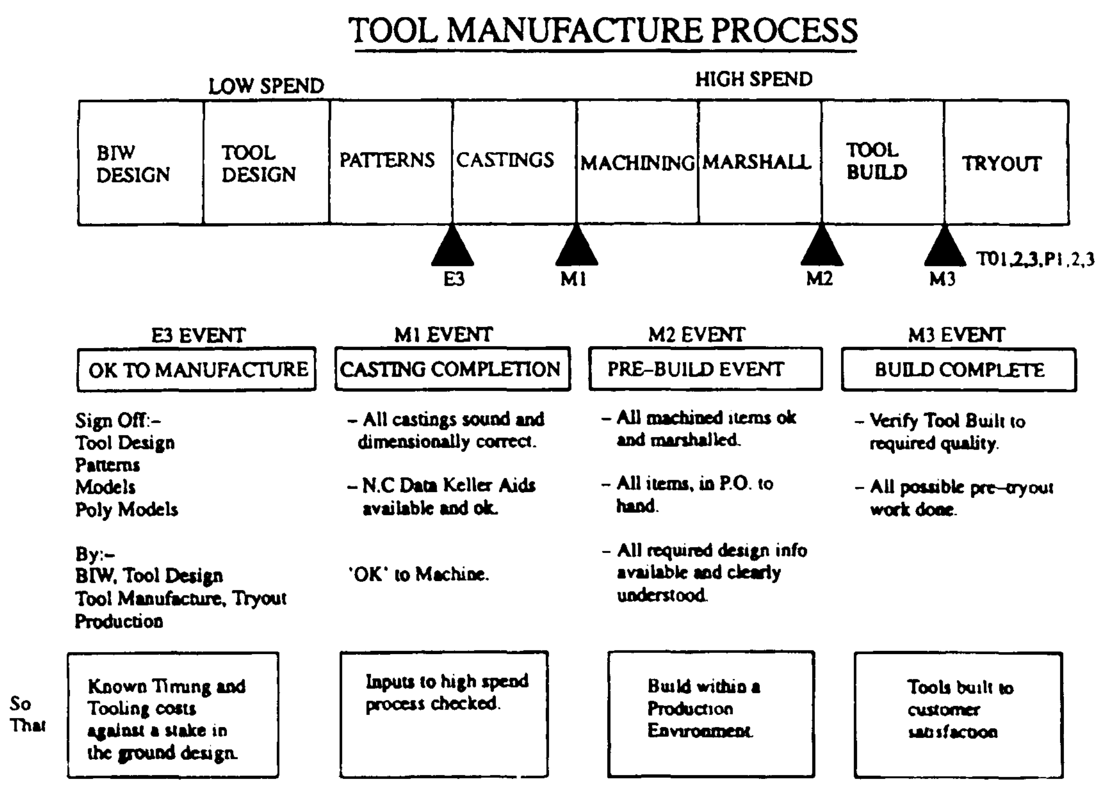


Figure 8.14: High Level Die Manufacturing Process Flow, including "M" Event Descriptions

7.1.4.3 Master Scheduling

Systems developments were undertaken to establish an information network that fulfilled the requirements of a manufacturing planning and control system, as set out by Vollmann et al (1984). Figure 8.15 shows the information flows and is annotated with the RBP system names.

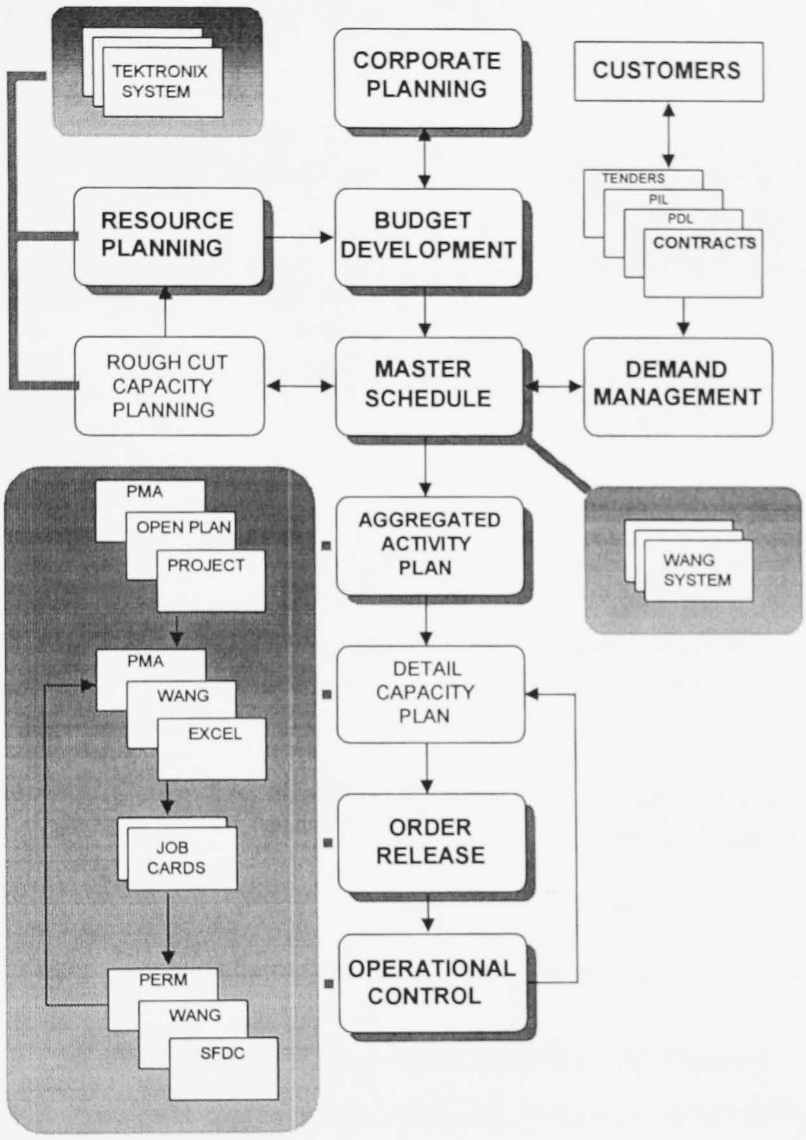


Figure 8.15: Implementation of an Information Structure for effective Manufacturing Planning and Control in RBPE

7.1.4.4 Shifting / Crewing Strategy

The main change was to eliminate the continental 168 Hour shift pattern in favour of a conventional 3 shift pattern to ensure continuity of manning.

7.1.4.5 Quality Infrastructure

The "Dry Build" centre was strengthened with additional co-ordinate measuring equipment and a scanner/digitiser.

7.1.5 Structure for "Make or Buy" Policy

Type of Tool	No.2 Toolroom		Cowley or No.1 Toolroom (or Outsource)	Outsource
	Main Flow	***Small M/C Centre***		
Draw	Punch B'holder Upper die	Gauges	Turned items, spring pins	Wipers, STD gauge units orthogonal casting machining
Trim & Pierce	U'die - 1 piece pedestal + cutting edge + cam drivers L'die - 1 piece stripper	Local steels CAMS Scrap cutters Gauges	Turned items Lift mechanisms Running stops Stop bolts	Wipers, pilots Punches + retainers, STD CAM units, Springs
Flange & Restrike	L'die - 1 piece buck & pod Loose pedestals Integral U'die Spring pad	Local steels CAMS	As Trim & Pierce + flange strippers	As above

Table 8.3: Sourcing evaluation of Core and Non-core elements of Large press tool manufacture.

7.1.4 Effective Financial Performance Measurement

It was proposed that the measurement system be changed from the cost recovery based method, to one based on measurement of earned value.

7.2 Change Plan Implementation

The change plan to implement the "Focused Toolrooms" strategy in RBPE comprised four elements:

i. **Operational Plan and Development and Approval**

A dedicated project team translated the chosen strategy into the detailed action plans to enact the operational changes needed to create the focused Toolrooms.

ii. **Organisation and Facility Re-structuring**

The selection, appointment, and announcement, of the leadership teams for each unit enabled the next stage of decision-making to be conducted in the open. The new unit management teams took over responsibility for progressing the implementation of manpower redeployment and facility re-structuring.

iii. **Consultation and Involvement**

Immediately upon publicly announcing the proposed Focused Toolroom strategy a formal framework was initiated to facilitate consultation with all effected parties. A high priority was placed on the full communication with, and involvement from, the Trade Unions as the major employee representatives.

iv. Rover Group Product Plan Demands

The delivery of the "Portfolio" projects within the Rover Group product plan was a strategic target of the proposed changes to the Toolroom operations. The timing and level of demand of each new vehicle project, and the relationship one to another, was seen as crucial to successful change management in the transition period.

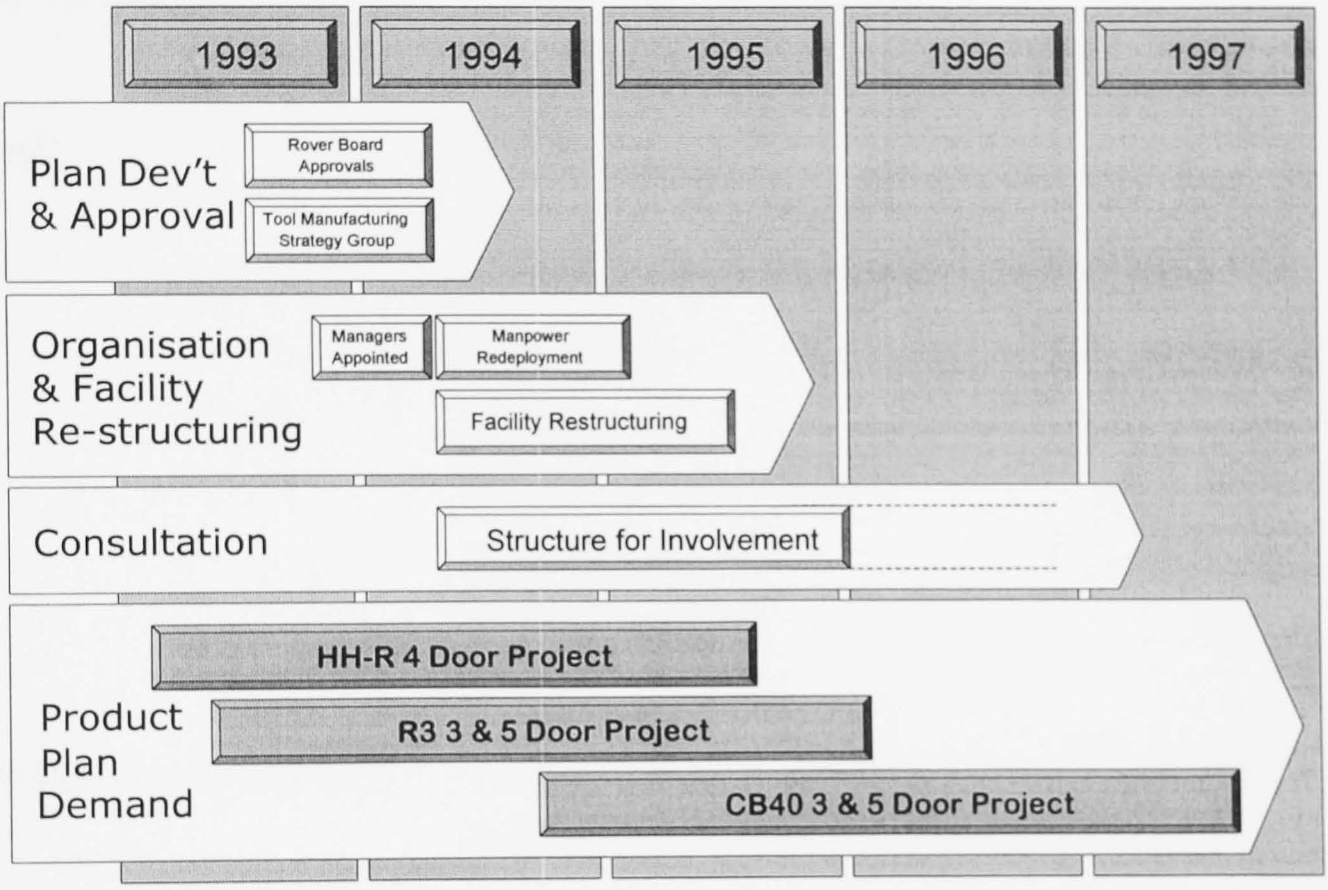


Figure 8.16: Overview of the Focus Toolrooms Change Plan

Figure 8.16 shows an overview of the whole change plan. Each of the four change plan elements is shown. The bars describe the principal activity streams within each element. The horizontal axis represents a five year time line.

7.3 Rover Group Project Commitments

The following dies were chosen as the core of the 1994 new tool manufacture workload supporting the R3 3 Door vehicle programme, SOP September 1995, and the HH-R 4 Door vehicle programme, SOP January 1996. CB40 dies were manufactured during 1995 and 1996 for SOP August 1997.

R3 3 Door

Large Dies:	Bodyside R & LH Front Door Outer R & LH Front Door Inner R & LH Bonnet Outer Bonnet Inner Bonnet Locking Platform Dash Lower RHD Dash Lower LHD
Medium and Small Dies:	26 medium and 21 small dies comprising 15% of the total dies of that size required on R3

HH-R 4 Door

Large Dies:	Bodyside R & LH Roof - Fixed Roof Roof – Sunroof
Medium and Small Dies:	50 medium and 20 small dies comprising 24% of the total dies of that size required on HH-R

CB40 Project

The following dies represented the major RBP work content on CB40, with the balance of dies outsourced:

Large Dies:	Bodyside 5 Door R & LH Roof – Sunroof Reinforcement - Roof Bonnet Outer Bonnet Inner Main Floor Crossmember Heel Board Rear Floor
Medium and Small Dies:	31 medium and 57 small dies comprising 29% of the dies of that size required on CB40.

8. Engineering Design Methodology

It is evident from the literature that the terms "Product Development" and "Engineering Design" are often used interchangeably. Product Development is often considered to be a range of activities spanning from marketing to manufacturing (Ulrich and Eppinger 1995, Andreason & Hein 1987). Engineering Design is considered to be a sub-process of product development (Wallace 1990, Finkelstein and Finkelstein 1983).

In recent years, there has been a shift in thinking about the design process. It has changed from an essentially sequential paradigm (Shigley and Mischke 1989, Pahl and Beitz 1984), towards an emphasis on integration and concurrency of product and process development (Winner et al 1988, Bullinger and Warschat 1996), usually referred to as "Concurrent Engineering" (Cleetus 1992).

In addition to integrated product and process development other researchers emphasise the importance to the success of product development of accurately capturing customer and market requirements (Pugh 1991, Clausing 1993).

The field of automobile body and tool engineering has been one of the first to exploit CAD technologies (Whitney 1995). Also, as a critical path sub-process of automobile development, the important influence of engineering practice in this process stream has been recognised by researchers into automotive product development (Ward et al 1995, Clark and Fujimoto 1991, Womack and Jones 1990). However, the focus of this research has been at a high level in the product development process stream, and offers little insight at a detailed design methodology level.

The wide range of the literature on design theory and methodology contains consistent themes regarding the basic structure of design activity, and practically useful frameworks to guide decision making in configuring the design process.

Table 8.4 summarises the focal activities for each stage in the design process and identifies the corresponding issues for design managers.

Design Process Stage	Focal Activities	Design Management Issue
Concept	Analysis Synthesis Application of rules	Static/Dynamic status Use of knowledge
Embodiment	Simulation Integration	CAE & Skills CAD & Skills
Detail	Automation Execution Costs	CAD Configuration
Evaluation	Target Confirmation Design support	Role of prototypes & simulation CAE Tools

Table 8.4: Summary of Issues arising from the literature on design

Body and tool engineering is concerned primarily with the execution of static product concepts, and technically over-constrained designs. This implies the pre-eminence of importance in the design methodology of:

i. Embodiment design of automobile bodies and press tools.

ii. The analysis and evaluation of design solutions influencing the total system architecture and sub-system performance.

8.1 The Role of Information Technology in Design Methodology

The exponential development path of the microprocessor is well known and continues to outstrip the pace of software development. The main implications of this to engineering design practice in industry are that processing power has become more affordable, and is carried out more locally to the engineer.

These advances in information technology will enable fundamental changes in the design methodology. The three most important points are:

i. Integration of engineering analysis functionality with the mainstream geometry design tools.

ii. Automation of routine design processes, e.g. the use of parametric design technology, enabling greater focus by designers on value adding engineering design.

iii. "Best in class" vs. integrated solutions - the growing capability to exploit open systems architectures to avoid trade-offs in the functionality of major modules in the CAD system, e.g. surface design.

8.2 Human Resource Issues and Engineering Design Methodology.

Managers of product development are faced with constructing a coherent set of decisions to provide the necessary environment for effective concurrent engineering. These decisions embrace diverse aspects such as reward policy, information technology, functional goal setting and organisational performance measurement.

Four perspectives were identified:

i. The characteristics of teamwork – Goal setting and social organisation
ii. Professional Engineers – The impact on future career paths of individuals

iii. Organisational culture – Developing the context for concurrent engineering.

iv. Transactions in concurrent working – Practical realities of interactions between people in large organisations

8.3 Scope for Innovation

Three main thrusts for innovation of the process were identified:

i. **Technology platform philosophy** - By decomposing the project workload in into major panel groups throughout the process chain the task of identifying consistent design practices and standards for panels and tools becomes manageable. Specialist teams can be developed around such work packages. The panel groupings can be aligned to RBP's "generics" strategy.

ii. **Solution to Problem Focus in Tool Design** - The engineering design methodology in tool engineering to be developed away from a dependence on synthesis by introducing engineering analysis of the metal forming process.

iii. **Concurrent Working** - A strong basis for concurrent engineering activity in the design process to be established. Priority areas are:

- Styling surface development
- Metal forming process specification
- Involvement of the press shop

A process analysis was conducted of a design methodology based on engineering methods, rather than post design synthesis testing. The resulting design process concept is shown in figure 8.17.

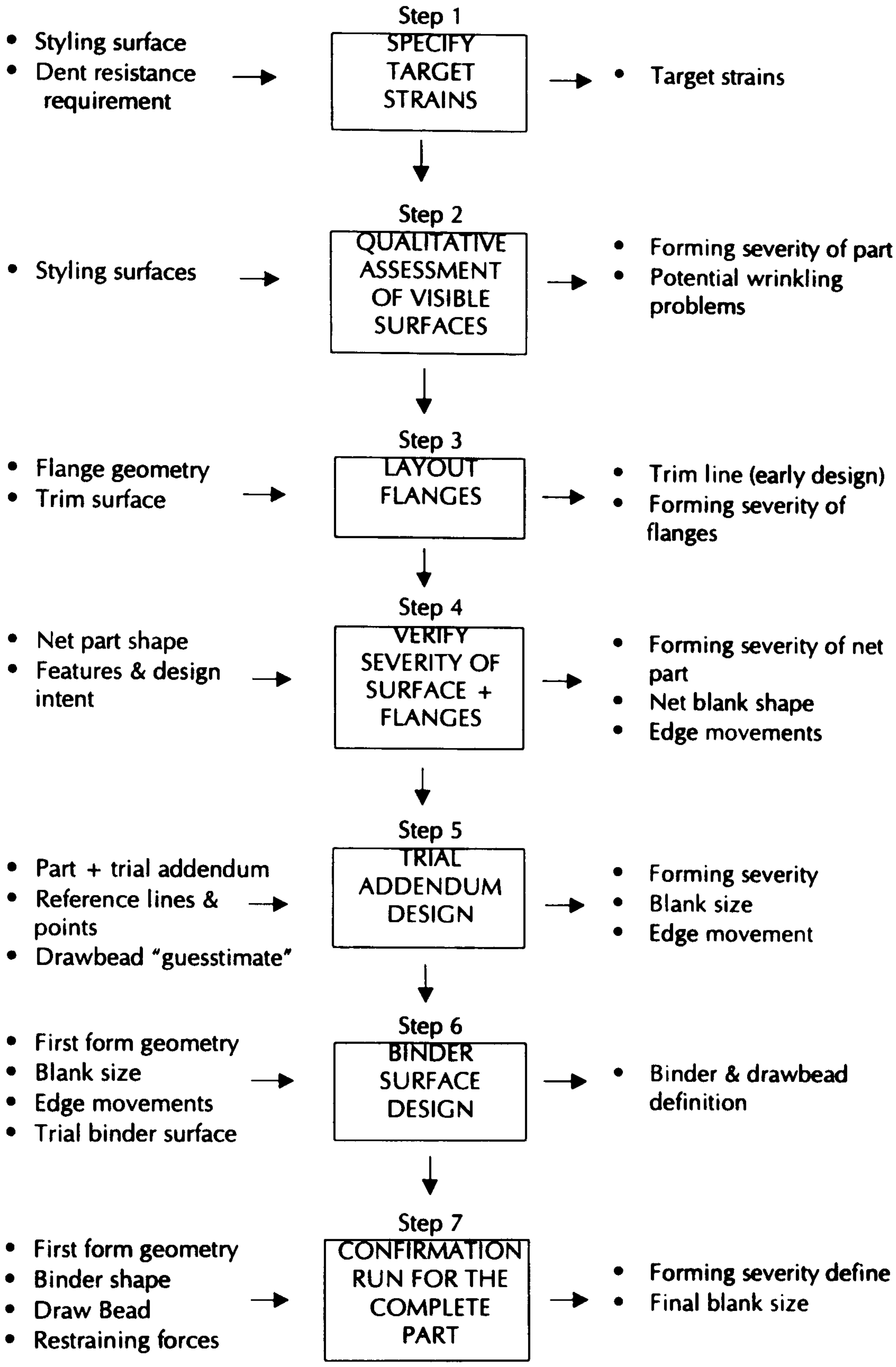


Figure 8.17: The "Design Based Approach" to Body Panel and Metal Forming Process Engineering

(source: T. Leverton, M. Smith, and M. Karima, A Concurrent Engineering Methodology for Styling, Body Design and Process Engineering of Automobile Stampings, Proceedings of IBEC '94)

8.4 Metal Forming Technology

Toyota first published a method to use forming technology in the die development process (Okamoto et al 1989). Karima et al (1989) introduced the concept of process signatures. Further Karima et al (1990) found that it was possible to model the forming process so as to predict the process signature for general features of components. Moreover the process signature responds predictably to changes in the major variables in the metal forming process system, e.g. friction, pressure and material characteristics.

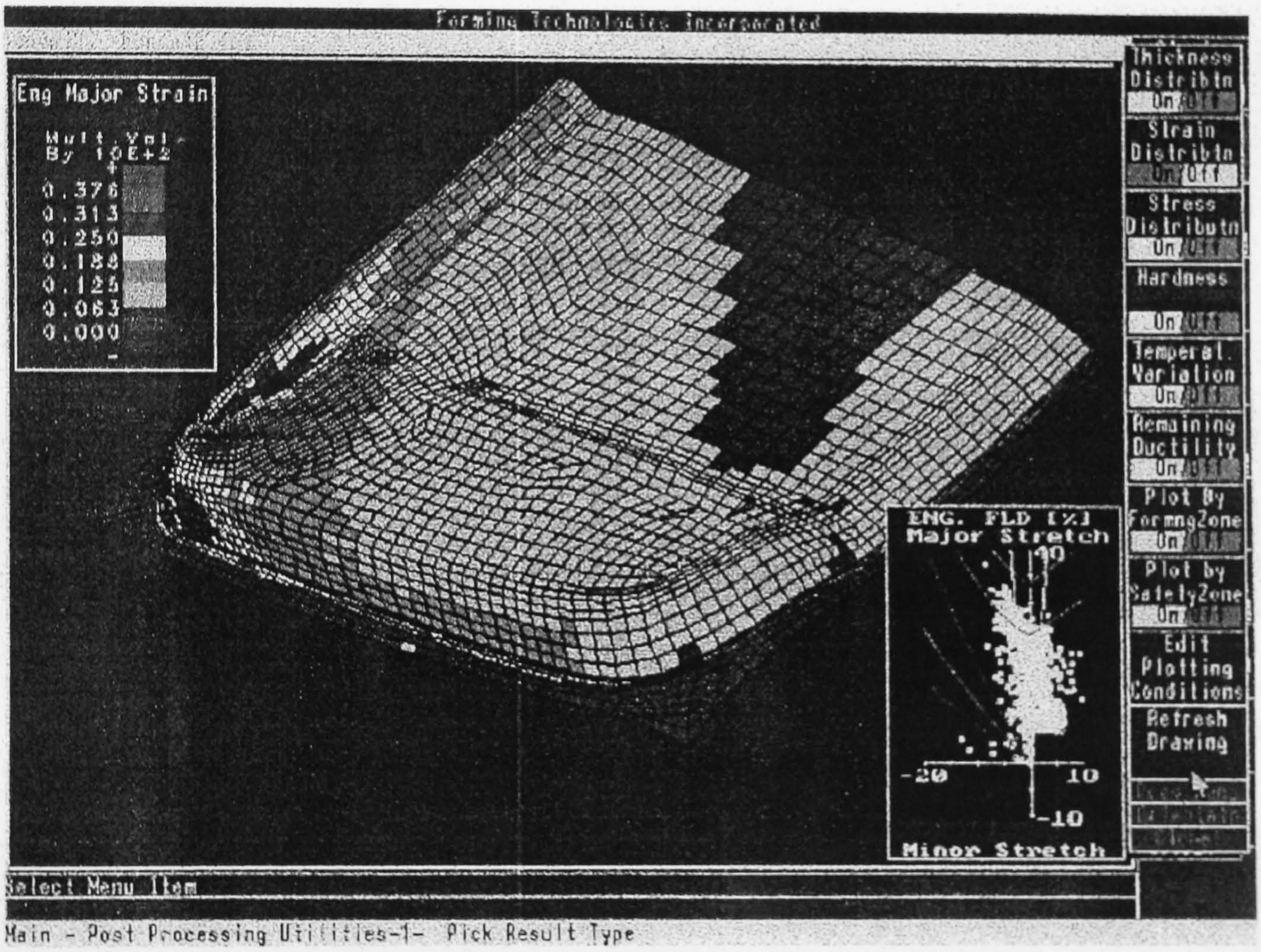


Figure 8.18: Example results report from FAST_3D for the CB40 Bonnet Outer Panel

Software applications have been developed that allow finely meshed finite element (FE) models to be subjected to analysis and the position of a specific element to be plotted on the FLD. Figure 8.18 shows an example of a results report from Forming Technologies Inc. FAST_3D ™

A strategic relationship was established at the end of 1993 between Rover and Forming Technologies Inc. (FTi), of Ontario, Canada. FTi are the only engineering consultancy in the world dedicated to metal forming technology research, training, and consultancy.

Table 8.5 shows a comparison between the traditional engineering approach and the new engineering approach integrating metal forming analysis techniques. Component sketches are included in Appendix 3.

PART	TRADITIONAL APPROACH		NEW APPROACH	
	CONCERN	PROBABLE OUTCOME	ACTION	OUTCOME
Bonnet Panel (see app. 3 figure 1)	- Ability to hold flat shallow panel with reverse form and no features lines	- After excessive expenditure, panel would always be slack and rework would probably be necessary for life	- Strain levels defined at outset New design approach used to define draw parameters required to achieve panel	- A good tight panel that required very little tryout. (Estimated cost avoidance - £150K at rework)
Tailgate Outer (see app. 3 figure 2)	- Consisted of 2 panels - Associated tooling costs - Quality of assembled part	- Simplified press tooling but, - Excessive piece and tooling costs - Possible long term assembly problems	- New design approach to prove pressing was possible as a single panel	- Skin panel with reduced costs. (Estimated cost savings - £100K)
Bonnet Inner (see app. 3 figure 3)	- Hinge areas identical to an existing panel that was a bad runner	- Duplication of existing slow running & high scrap rates - Excessive running costs	- Analyse existing condition using forming technology	- Bad running condition eliminated on new bonnet panel. (Est. cost saving - £100K per year scrap/rework)
Steering Housing (see app 3 figure 4)	- Certain batches splitting at top of piece	- Heavy lubrication - High scrap rates	- Provide alternatives with factual back-up - Analysis carried out to clearly define forming and material windows	- Careful control of parameters giving greatly reduced scrap withi part shape change. (Estimated cost saving - £80K scrap)

Table 8.5: Case data showing benefits of the Fti, RBP Engineering approach

(Source: Leverton, Smith & Karima 1994)

On the basis of the results of these pilot studies it was concluded that the metal forming simulation technology was a viable basis to complete the deployment of the new RBP product development strategy.

8.5 Conclusions from the Research

The conclusions arising from each area of research indicated that there was significant scope for innovation of the body and tool engineering process in RBP. These conclusions are outlined below.

i. The process configuration must enable integrity in the information flow both with the vehicle development programme, via PMP, and with RBP via EQAP.

ii. An organisational solution is needed which allows more formal concurrent working at the crucial stage of detail part and process engineering.

iii. Effective handling of the key integration design tasks (i.e. body assembly design, and die design) is a pre-requisite to stability of information flow downstream in the engineering process.

iv. An evaluation capability is needed to test new process designs prior to die design and build. Metal forming technology analysis is the basis to deliver this.

v. Information Technology trends suggest that increasing automation and simulation is possible within a reduced elapsed time than the existing processes.

vi. A change in culture reflecting problem oriented design supported by a common system of terminology across the business is needed to exploit knowledge and capture learning in the future.

vii. The realisation of a "Concurrent Engineer" as an individual qualified in both product and process design engineering appears to be possible based on the previous conclusions.

8.6 Proposed New Engineering Methodology

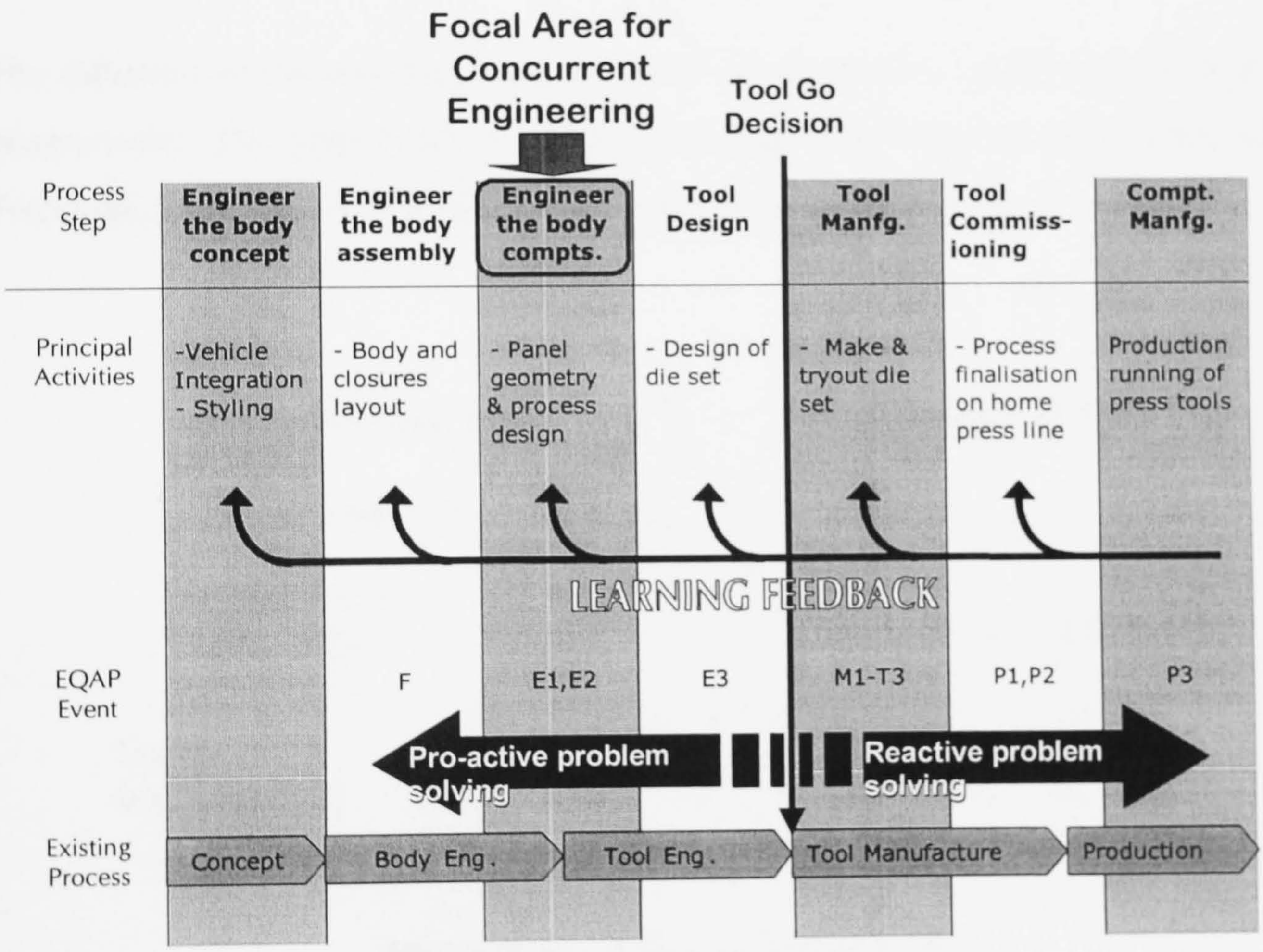


Figure 8.19: A proposed new engineering methodology for Body and Tool Engineering

The new methodology shown in figure 8.19 proposed an innovative decomposition of the traditional body and tool engineering process stream. By extending the involvement of metal forming engineers upstream, a new break point has emerged that lies within body engineering and within tool engineering. It was possible to build a new depart ment specialising in metal forming engineering.

Upstream, the press shop take greater responsibility for the process and quality maturation of the dies, as they approach start of production.

8.7 Change Implementation

8.7.1 Forming Technology

The diffusion of the required competencies was driven by a technical training programme. The programme extended to a large population at Rover Body and Pressings, from both Engineering and Manufacturing functions.

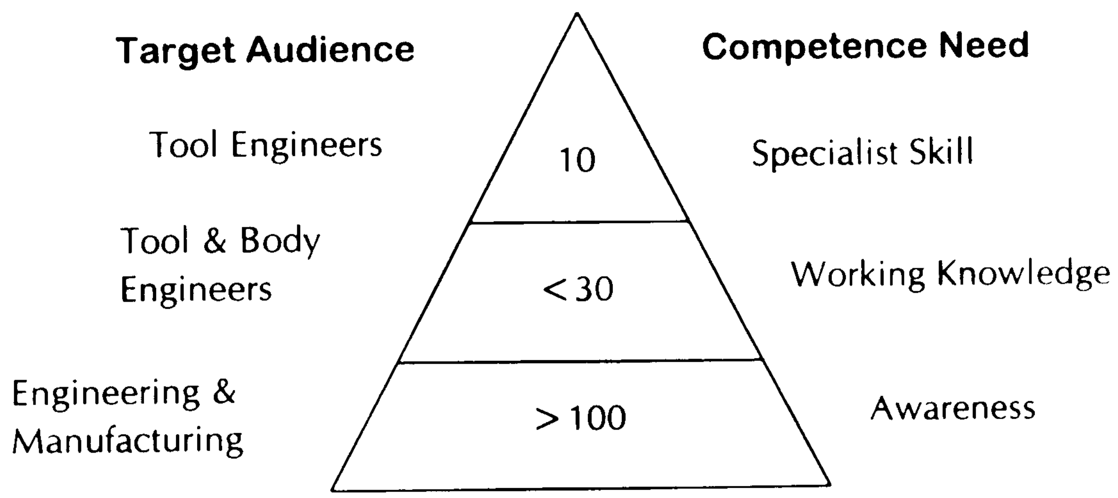


Figure 8.20 : Training Strategy for Metal Forming Technology in RBP

8.7.2 CAD Strategy

It was necessary to make adjustments the CAD straegy in order to improve the qulaity and timeliness of surface design information. Figure 8.21 shows the system architecture selected.

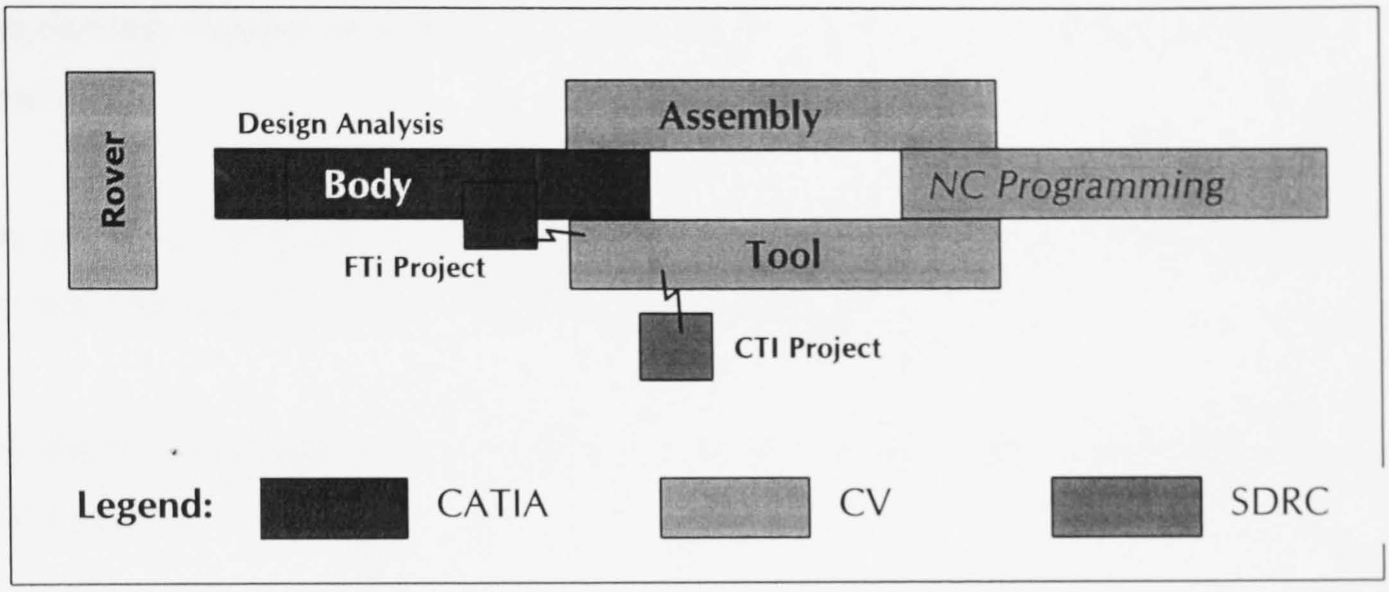


Fig 8.21: Strategic CAD system architecture for RBPE

8.7.3 Organisation Development

A four phase strategy was developed as follows:

i. Short term integration of Body and Tool Engineering functions under one Chief Engineer.

ii. Appointment of dedicated metal forming analysis team drawn from both body and tool engineering disciplines.

iii. Re-organisation of "Body and Tool Engineering Function" processes to promote integration across the two disciplines.

iv. Re-establishment of three functions, i.e. Body Engineering, Metal Forming Engineering and Tool Design.

8.7.4 New Model Effectivity

The new process methodology was partially applied to the R3 vehicle programme. A particular focus was the 3 door bodyside panels and door outer panels.

The target for CB40 was to have complete engineering of the outer skin panel content conducted using the proposed methodology.

This target was met and the full results achieved are reported in submission 6 of the portfolio.

9. The Effectiveness of the Product Development Strategy

9.1 Achievement of the Strategic Targets

9.1.1 Product Quality

Target: *Top quality component supply from transfer presses with RBPE manufactured tooling.*

Metric	RBPE 1993	Benchmark 1993	RBPE 1997	Benchmark 1997
Body Cosmetic Quality (QZ Score)	Not Available		1.48	<0.5
Body Accuracy (points ± 1.5 mm)	70%	90%+	90%	90%+
Component Supply Quality (ppm)	>5000	<300	540	<25
Unplanned Rectification (mins.)	0 to 480	0	0 to 10	0

Table 8.6: RBP Component Supply Quality Measures 1993 vs 1997

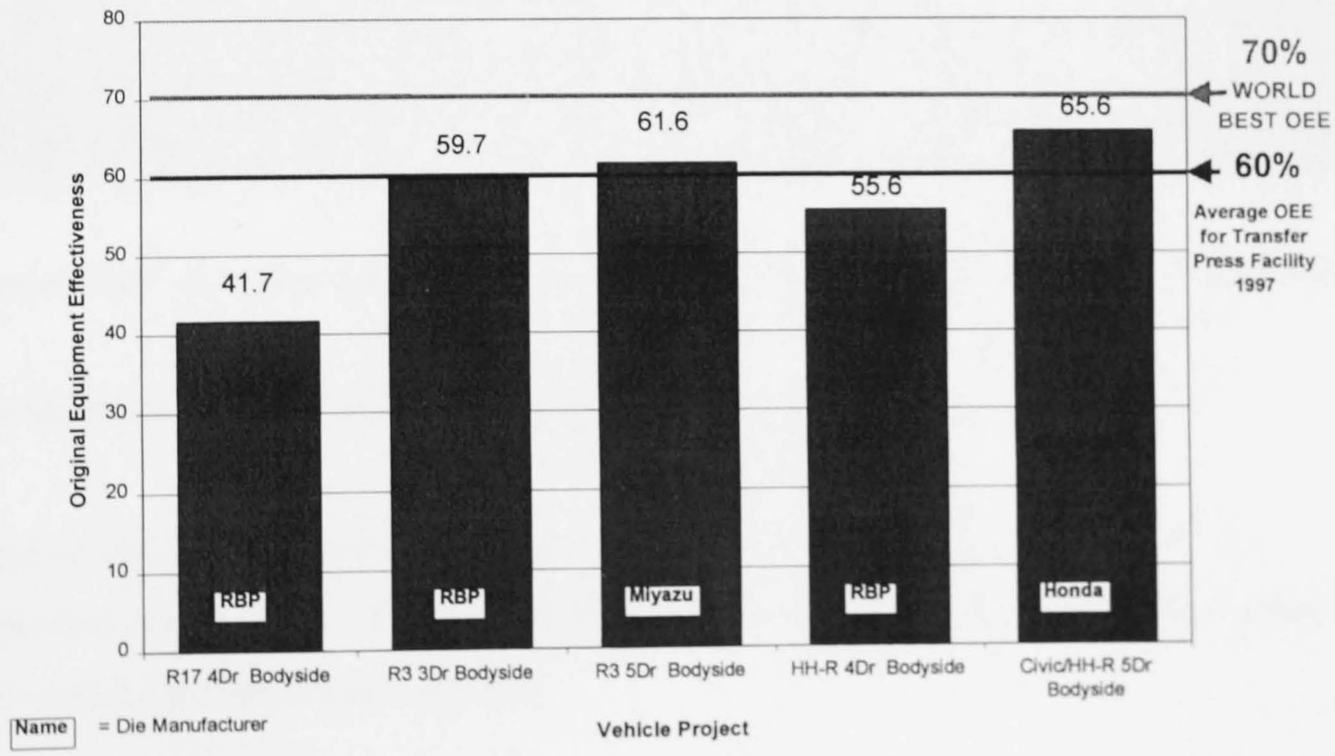


Figure 8.22: Average OEE Performance week 42/97 to week 8/98

For quality the strategic target has been met.

9.1.2 Lead Time

Target: *80 weeks from style fix to QP panels.*

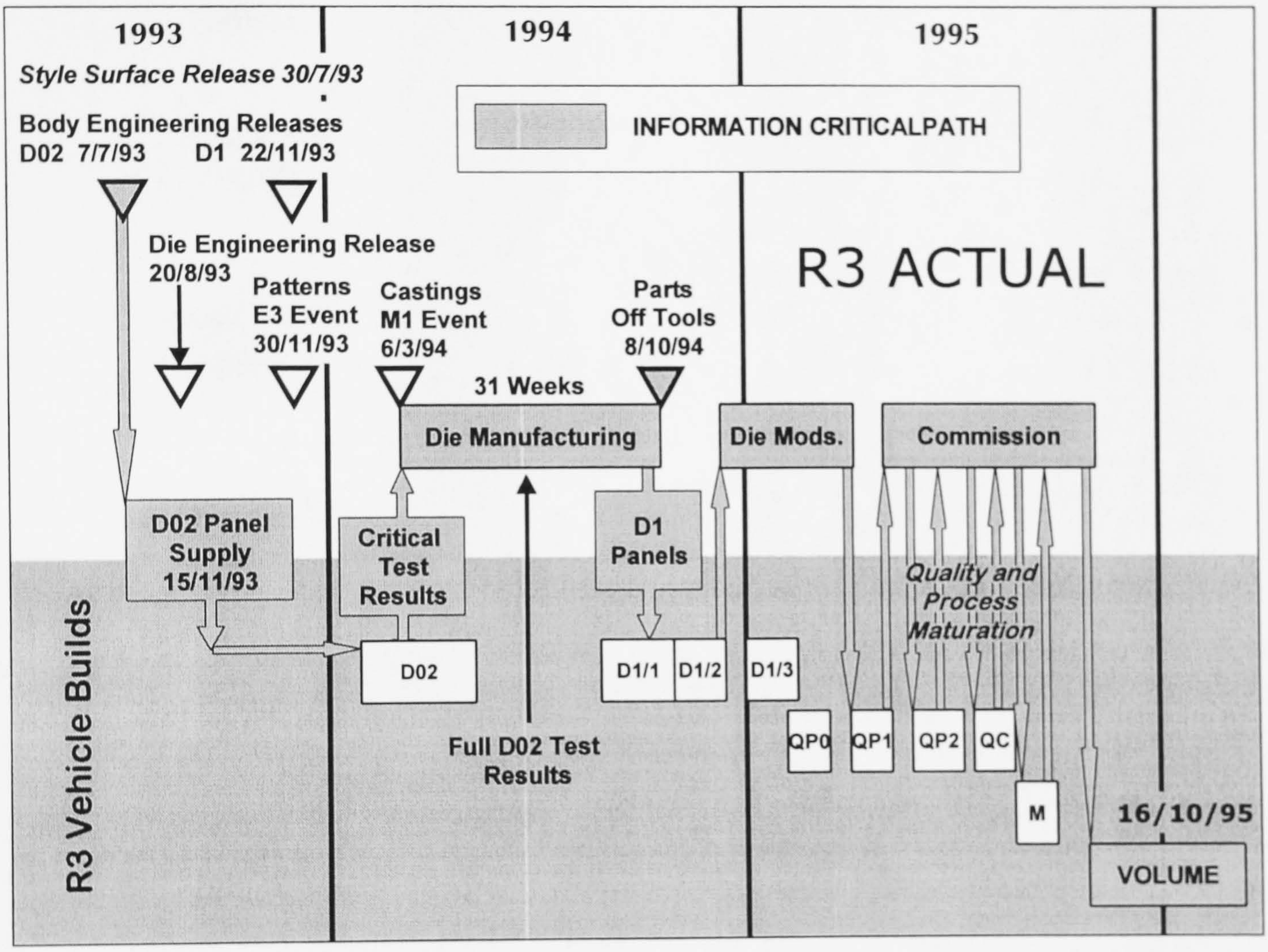
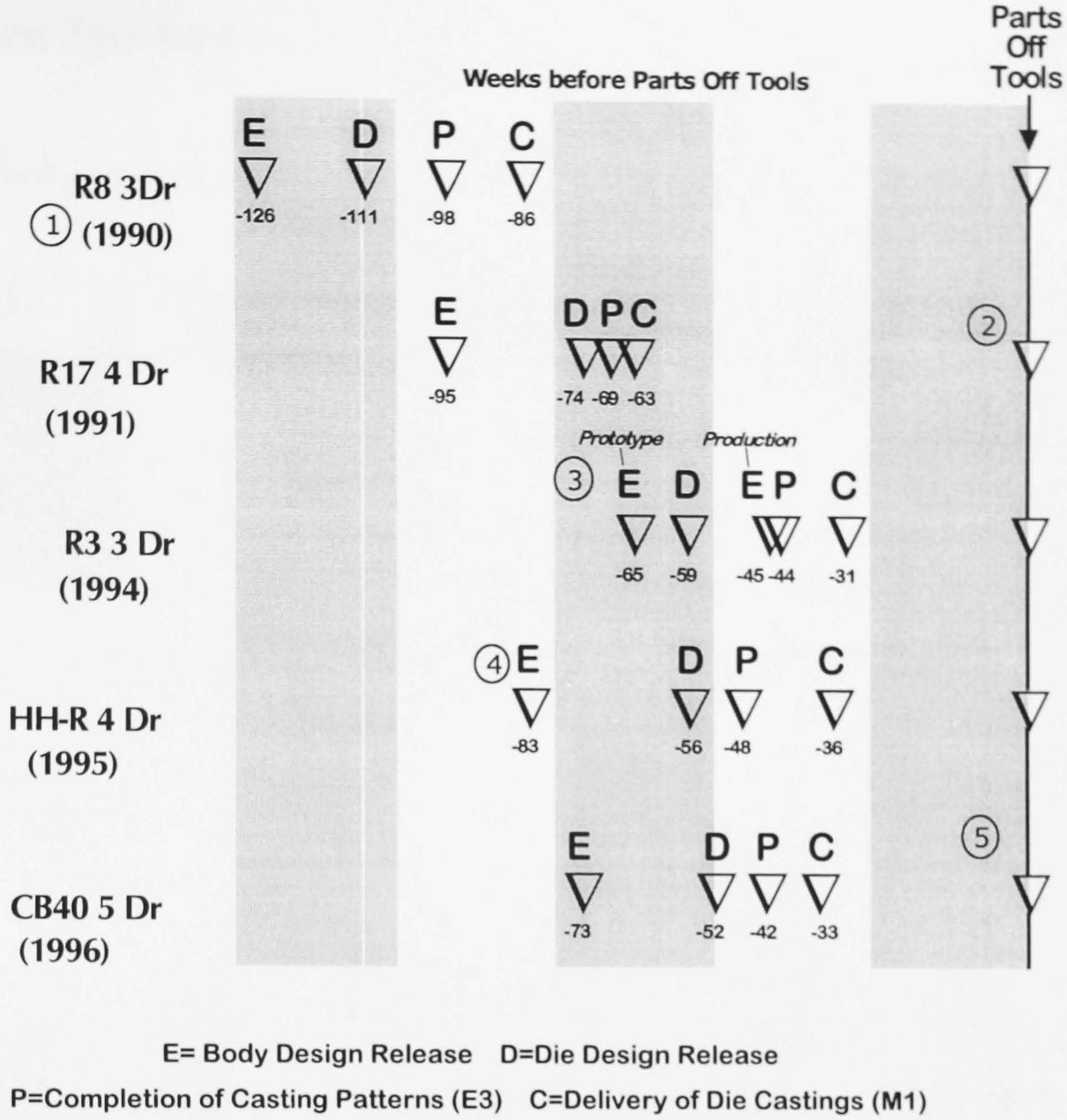


Figure 8.23: Actual Dates Achieved on the on the R3 3 Door Bodyside Programme

The strategic target of 80 weeks was met on the R3 project.

Figure 8.24 shows that the reduced die manufacturing lead times have been exploited on the later CB40 project to allow longer die process maturation time, with resulting higher parts quality.



1. Quality problems with the bodyside dies on R8 3Dr resulted in a 3 month delay to start of production.
2. R17 4Dr panel production was started with temporary operations in place for the first 90 days of production.
3. On the R3 3Dr project the prototype product engineering was used as the basis for the die planning and engineering. Final product engineering release was made after the release of die designs to Tool Manufacturing.
4. HH-R 4 Dr product engineering was available early as the bulk of the design was common with the HH-R 5 Dr bodyside, e.g. door apertures, and internal structure forward of the 'D' post.
5. For CB40, the T1 event represented the completion of die manufacture for all pressing operations. D1 panels were therefore fully off-tools.

Figure 8.24: Die Engineering and Manufacturing Lead Time Results

(source: Master Tool Schedules, RBP Tool Manufacturing

NB. source data included in Appendix 5)

9.1.3 Press Tool Cost

Target: *Press tool costs competitive with Japanese average die prices.*

Tool Class	RBPE 1993	Benchmark 1993	RBPE 1997	Benchmark 1997
Large Dies	100	75	100	85
Medium Dies	100	95	100	100
Small Dies	100	50-150	100	90-110

Table 8.7: Comparison of RBP Die Costs to External Benchmark Prices

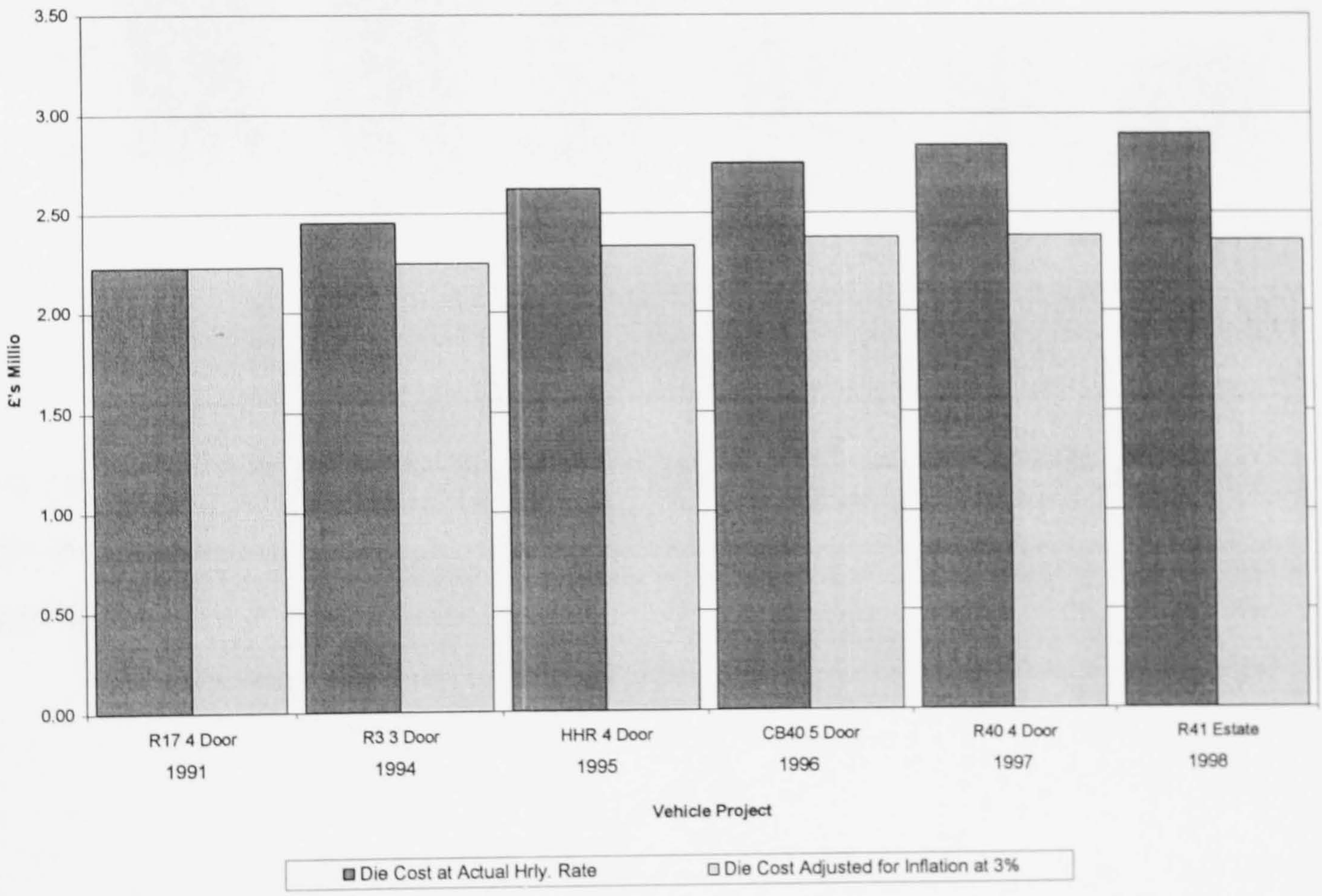


Figure 8.25: Absolute Bodyside Die Costs 1991 to 1998

This target was not met due to proportional increases in hourly charge rates offsetting reductions in required hours to manufacture.

9.1.4 Programme

Target: *Delivery to programme financial budget.*

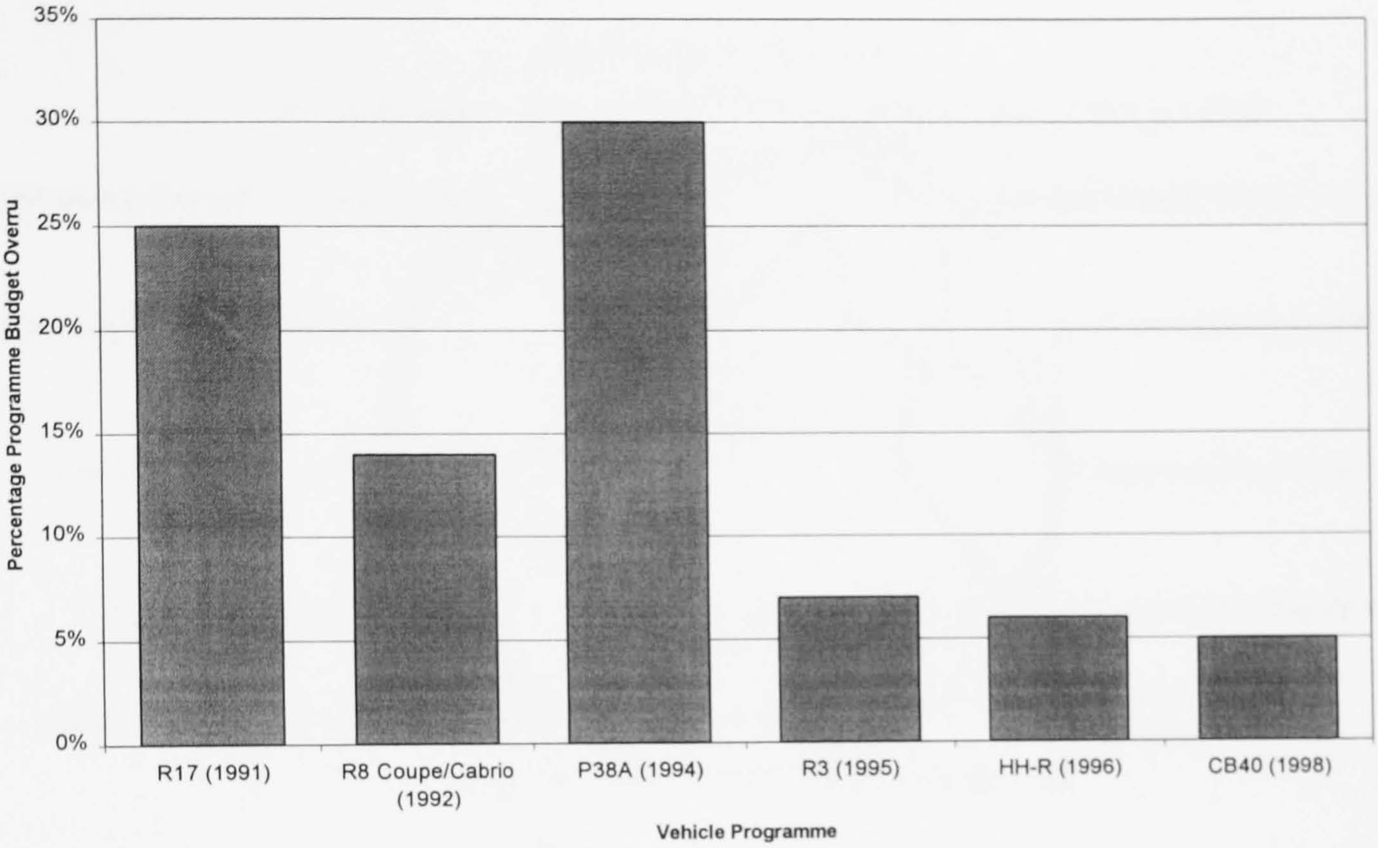


Figure 8.26: Performance to Programme Financial Budget

Figure 8.26 shows that there has been a step improvement in the delivery of the die programmes to committed budgets. However, the strategic target of zero overrun has not yet been met.

9.2 Comparison of RBP Performance to World Best

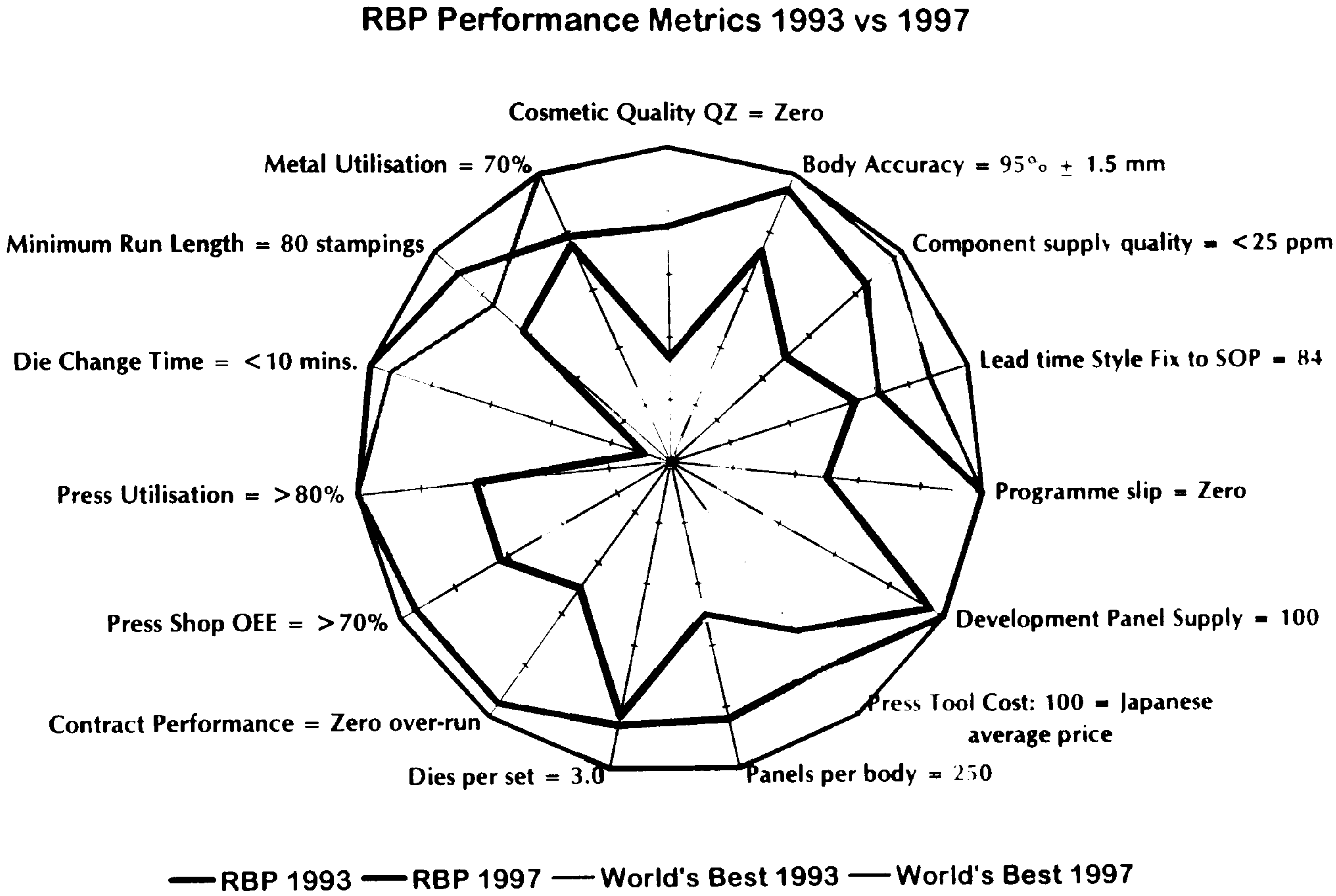


Figure 8.27: RBP Performance compared to World's Best September 1997

Rover Body and Pressings demonstrates a strong improvement in each dimension of product development performance. The position relative to world class in the press shop measures of die change time and overall equipment effectiveness are particularly relevant to this research as they depend on high levels of process capability in the dies.

10. The Reengineering of Product Development at Rover Group

The purpose of this case was to demonstrate that the innovation applied at Rover Body and Pressings could be transferred to wider context. The case study was the new product introduction process of the Rover Group.

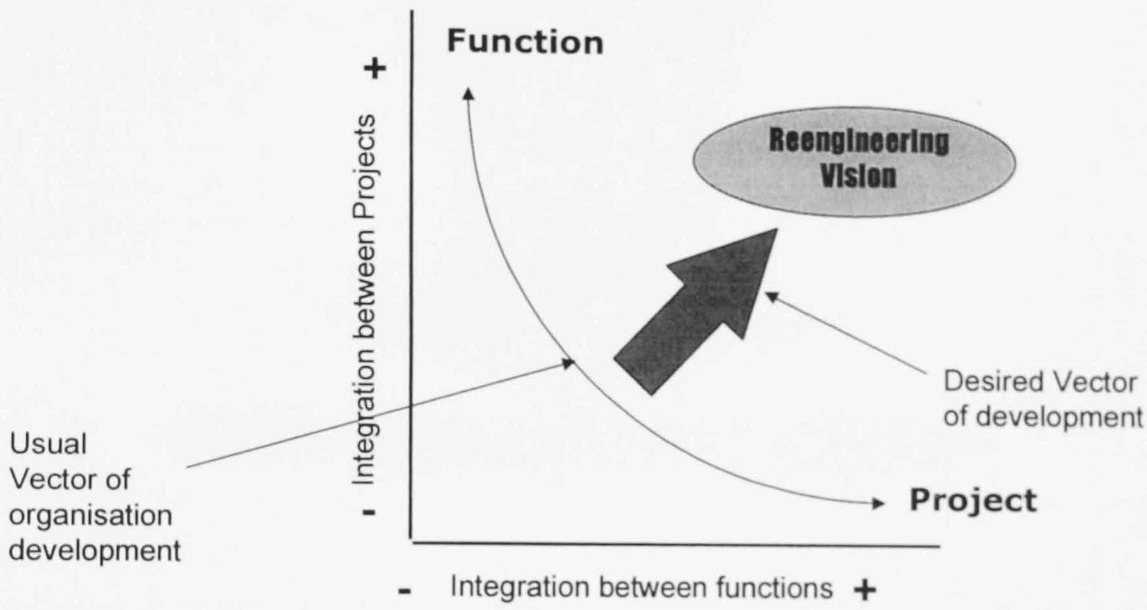


Figure 8.28: Organisation Development under Reengineering
(Adapted from Nobeoka 1993)

Rover have experienced both functional and project regimes of management in recent years. The usual vector of development reflects the time it takes for the organisational and business systems to adapt to changes.

The reengineering vision was to create a positive vector of improvement by smart use of technology to achieve integration across dispersed teams, and to support specialists to achieve higher engineering quality. There was a high degree of alignment between the concurrent engineering philosophy applied at Rover Body and Pressings and this case.

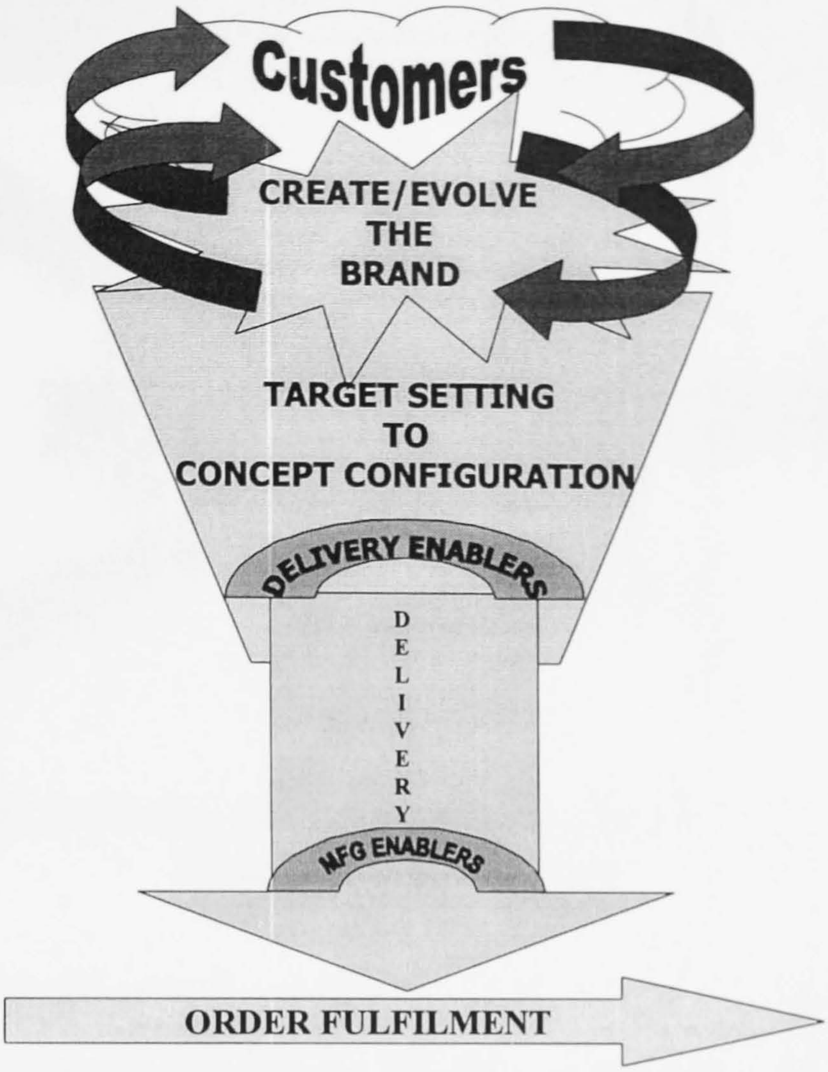


Figure 8.29: The Composition of Rover's Future Product Development Process
(source: Reengineering Steering Group)

Figure 8.29 showing the composition of Rover's future development process resembles closely the configuration of the RBP model

Figure 8.30 shows the proposed configuration of product development in the re-engineered environment. It resembles strongly the new model of body and tool development applied at Rover Body and Pressings.

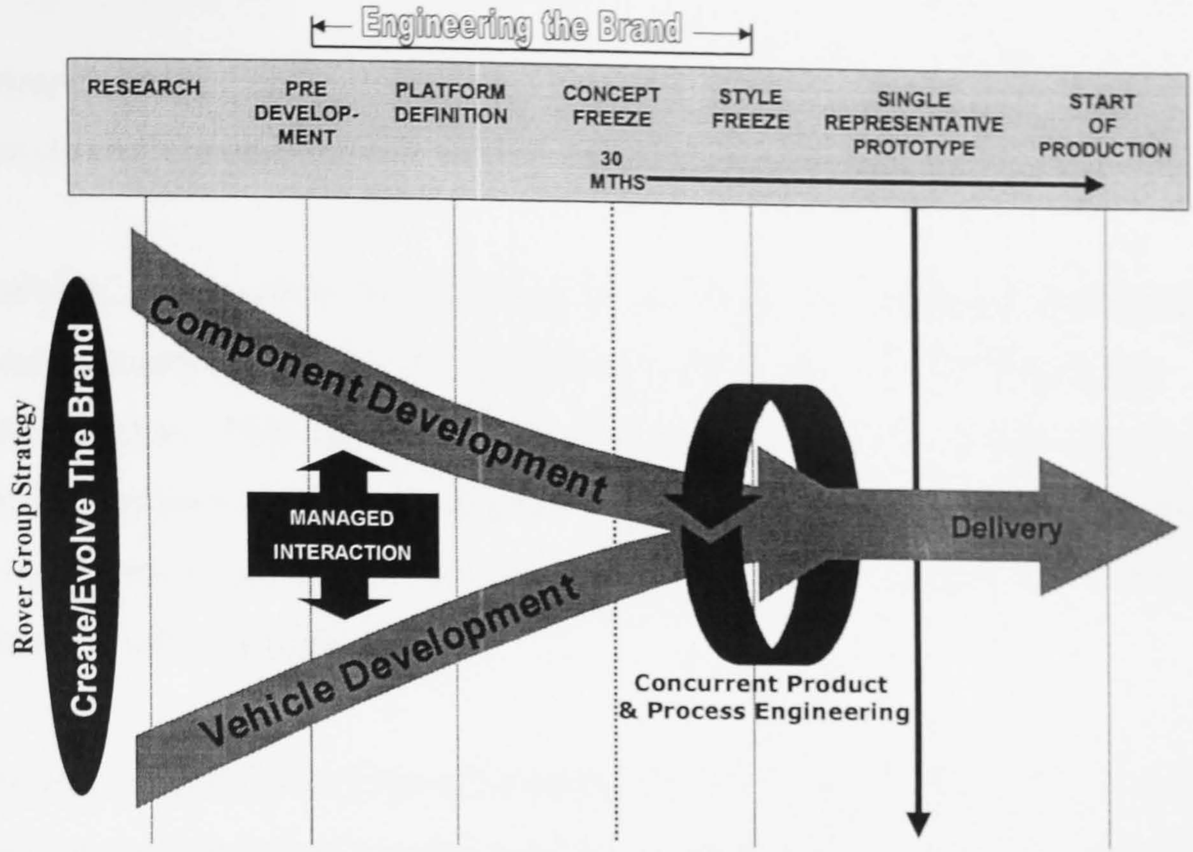


Figure 8.31: The Configuration of Product Development Process in a Reengineered Environment

Across the top of the diagram the sequence of activities and decision points appear. These begin with research and progress from left to right to conclude at start of production. Under concept freeze the lead time target for product delivery of 30 months is noted. The split arrow reflects the de-coupling of component and vehicle development during the early stages of a project life.

De-coupled component development means that the product development of strategic component systems is removed from the main product delivery phase. Instead, component systems are pre-developed for application to future vehicle projects. This pre-development is not pure research and development, but is more application oriented, and must be delivered against specific timing milestones.

De-coupled vehicle development reflects the need to explore more thoroughly all potential solutions for integrating the strategic component base of the company into new vehicle concepts.

A managed interaction between the two development streams implies that both are constrained by each other with a vehicle platform strategy.

The vehicle and component development activities converge as the concept definition improves, and finally synchronise at the point of the single skin prototype phase. The red arrow encircling the main process stream denotes a period of intensive concurrent engineering of product and process specification, prior to release of prototype engineering. This requires a policy of full electronic definition of all components.

On the left margin Rover Group Strategy, and the "Create/Evolve the Brand" process are positioned to signify that they drive the whole product development process.

Rover Group	Rover Body and Pressings
Establishment of Process	
3rd Generation Stage/Gate Concurrent Working	Disciplined Stage/Gate (EQAP) Concurrent Working
Separation of Engineering and Product Delivery phases	
Defined by single prototype design release	Defined by Metal Forming Process Sign-off (E3 Event)
Target Driven Engineering	
Targets emerge from identification of vehicle attributes from "Engineering the Brand" process	Targets defined by Metal Forming Limits
Focus on Core Competencies	
1.Brand related vehicle technologies 2. Vehicle Integration	Metal Forming Technology
Underpinned by Information Technology	
Electronic Product Definition	Metal Forming AnalysisTools

Table 8.8: Analogies in Product Development Strategy between Rover Group and Rover Body and Pressings

Table 8.8 draws out the analogies between the implementation of reengineering at Rover Group and the RBP case. It shows that the innovation applied at Rover Body and Pressings was transferred to the wider context.

SECTION 3:

Summary

11. Demonstration of Innovation

There are four innovative applications of engineering knowledge that were implemented during this research project. Each of these will be reviewed briefly to justify the claim for innovation.

11.1 The Process Model of Body And Tool Engineering.

The model which forms the basis for the product development strategy at Rover Body and Pressings provides an holistic view of the product creation system across the whole enterprise. This view of product development as a system led to a further three innovations at detail process level.

The claim is based on three dimensions.

Firstly, the literature is mostly partial in its treatment of product development problems. Either excessively managerial in emphasis, e.g. Clark and Fujimoto (1991), or excessively technology driven, e.g. Whitney (1995). This model seeks to balance these two valuable perspectives, and provides managers with the analytical basis to do that.

Secondly, the body of published research on concurrent engineering is still young. A glance through the references attached to this report show that much of the literature appeared in 1995 or 1996, after the date of the implementation reported here.

Thirdly, the organisational context for this research was unique in the automobile industry. No other industry executive had as broad a span of control of the body and tool engineering process as the Author enjoyed from 1991 to

1995. Indeed following BMW ownership my successors no longer gave this advantage.

Portfolio Report 6 presented evidence that the key elements of this innovation remain in place.

11.2 The Engineering Quality Assurance Procedure

EQAP represents the application of existing knowledge in a targeted way to support the strategic objectives of the whole product creation system.

The innovation claimed here is that the application of EQAP represented a radical shift in practice for Rover Body and Pressings. In the context of the first innovation EQAP has been exploited to directly support the concurrent engineering activities.

The EQAP procedures is now formally captured as ISO 9000 process EQ:0:PR:2:3, and is subject to external audit by VCA.

11.3 Focused Manufacturing Strategy for Die Manufacturing

Portfolio Report 4 outlines the content of this innovation in detail. The principles of focused manufacturing are well established. The claim of innovation is that it was a new application to RBP itself, and represented a step change in manufacturing management approach. Also, this approach appears to be rare in Europe. Toolrooms are generally managed as craft based enterprises, not as production systems.

In this respect the focused tool room restructuring represents the transfer of practices observed in Japan, to a western application.

11.3 Engineering Design Methodology

By embracing a scientific basis for the design of metal forming processes, it has been possible to intensify the application and capture of knowledge more effectively through the early engineering phases of development.

The innovation is not the technology itself but the innovative way in which it was deployed as an integrated element of the design methodology.

Since, 1993 both BMW and Toyota have become customers of FTi. However, in neither case are the tools applied within the design process but instead are used to test the design. There is little published research on applications of this sort which may be because of the need to protect the commercial advantage it represents.

In portfolio report 6 evidence of the continued application of this methodology was presented.

12. Conclusions

1. The practices associated with concurrent engineering are a relevant tool set to improve product development performance.

2. A system model for body and tool engineering was proposed which placed capable metal forming process specification at the heart of the process stream.

3. An Engineering Quality Assurance Procedure was established to create an environment for concurrent engineering activities, and measurement of target achievements.

4. A focused manufacturing strategy was implemented within die manufacturing. By simplifying the operational environment the development of specialist skills, and alignment of manufacturing technology policy with that of die engineering was made possible.

5. The engineering design methodology was changed to integrate a process step based on metal forming engineering science. Engineering analysis was applied to the creation of the metal forming process specification prior to die detail design.

6. There have been step changes in development performance in the dimensions of quality, lead time, and programme financial budget achievement.

7. Press tool costs have remained flat, in real terms, since the establishment of the new product development strategy.

8. The strategic targets for product development at Rover Body and Pressings, defined at the start of the case, have been met with respect to quality and lead time. Press tool cost and programme targets have not been met.

9. The five hypotheses stated for the Rover Body and Pressings case study were proven.

10. The system model of process strategy used at Rover Body and Pressings was transferred to the wider context of the Rover Group new product introduction process.

11. The philosophy of concurrent engineering deployed at Rover Body and Pressings, namely knowledge intensification of the upstream engineering processes followed by a rapid execution phase, and underpinned by information technology is generically applicable to product development.

13. Proposals for Further Work

During the research project the following areas were identified for potential future research projects.

13.1 Modeling and Simulation of the Press System

The level at which metal forming analysis is currently applied reflects the die as the system boundary. The die is assumed to be mounted to infinitely stiff mountings. In fact the die is an element of a larger system comprising the press equipment, and the press shop infrastructure itself.

Learning from Honda, RBP followed a direction in die design towards lightweight dies compared to typical European design practice. Implicit in this direction of development is that the die, particularly the lighter upper die, becomes more part of the press system and less a system in its own right. For example the tendency for the die to deform during the press cycle is increased. Other effects such as die bed wear impact on die set up.

The ability to fully model and simulate the press system, and exploit the structure of the press more directly in the design would enable a next level of concurrent engineering, and could support day to day management of the press shop processes.

13.2 Integration of Metal Forming into Die Design Tools

There remains a propensity, in 1997, to create the die geometry and then test it using the design analysis tools. It must be possible to integrate the metal forming analysis rules into the geometry design functionality in the future.

13.3 Real Time Concurrent Engineering

Both EQAP and the RBP project management policy are event driven management processes. This is essentially a batch processing of concurrent engineering activity, and reflects the current state of maturity of the organisation.

Research could be carried out into the factors needed to promote a more real time approach in the future relying on continuous communication between upstream and downstream factholders.

13.4 Application of the Design Structure Matrix

The design structure matrix is an information modeling technique used to distinguish the best sequencing for design process steps. Eppinger et al (1995) examined the application of this technique. The technique appears to be useful to support organisation and process design decisions.

A "real" test case of this technique would confirm its usefulness when these type of objective tool are becoming more important as engineering teams are more dispersed.

13.5 Application of the System Model of Process Strategy

The Author is currently engaged on the implementation of the reengineering project at Rover Group. This is a logical extension of the work reported in this research portfolio.

Technical Definitions of Metrics used in the Evaluation Model for Product Development Performance

Metric	Definition	Units	Benchmark	Data Source
Total Product Quality				
Initial Quality Survey (IQS)	Customer identified faults within 90 days of purchase	Faults per 100 vehicles	48 - Toyota Lexus Rover - 200	1997 JD Power Survey
Vehicle Warranty	Faults leading to claim on OEM warranty during first twelve months of	Faults per vehicle	0.8 - Toyota Rover = 2.5	1996 New Car Buyers Survey
QZ	Conformance to vehicle build specification	QZ points	2.5 - BMW 5 Series Rover = 10	BMW Quality Reports
Rectification	Proportion of vehicles requiring rectification after on line assembly	Percent	20% - Toyota Rover = 30%	Benchmark Visit to Toyota Burnaston UK
Development Lead Time				
Concept to Style Fix	Elapsed time from project initiation to exterior style fix	Months	7 mths - Toyota Rover = 12	Rover Body & Pressings 1997
Style Fix to SOP	Elapsed time from exterior style fix to start of production	Months	23 mths - Toyota Rover = 33	Rover Body & Pressings 1997
First Prototype to SOP	Elapsed time from first prototype build to start of production	Months	15 mths - Chrysler Rover = 24	Chrysler project timing synthetic
Concept to SOP	Elapsed time from project initiation to start of production	Months	30 mths - Toyota Rover = 35	Rover Body & Pressings 1997
Manufacturing Operating Performance				
Direct Labour Hours	Direct manpower consumed in BIW, paint, and final assembly	Hours per Vehicle	11 hrs - Nissan UK Rover = 15	Benchmark visit to Washington, UK
Material Margin	The ratio of production material cost and net sales revenue	Percent	45% - Ford Europe Land Rover =40+	Merril Lynch Analyst Report
Number of Assembly Parts	The total number of components required to build the vehicle at a	Number of Parts	1650 - Fiat Rover = 3000	Benchmarking Data
Lost Volume for New Model Change	Total production volume lost due to facility downtime, and rate of climb to full production rate due to a facility changeover to a new model	Number of Vehicles	0 - Honda Marysville, USA	Harbour 1996
Development Productivity				
Total Engineering Manhours	Engineering manhours consumed in the development of a new vehicle	Millions of Manhours	1.9M - Japanese Rover = 3.0M	Ellison et al 1995
Number of Prototypes	The number of prototype vehicles manufactured during the development programme	Vehicles	40 - Audi Rover = 200+	EUCAR 1996
Total Development Cost	Total cost of engineering manpower, prototype production material, and protoype tooling.	British Pounds	75M -Audi Rover = 120M	EUCAR 1996
Development Cost per Unit	Total expenditure on development divided by the volume of annual production	British Pounds per vehicle	£344/car - Chrysler Rover = £600/car	Harbour 1996

References for Table 2.2: Product Development Strategic Thrusts of Automobile Manufacturers

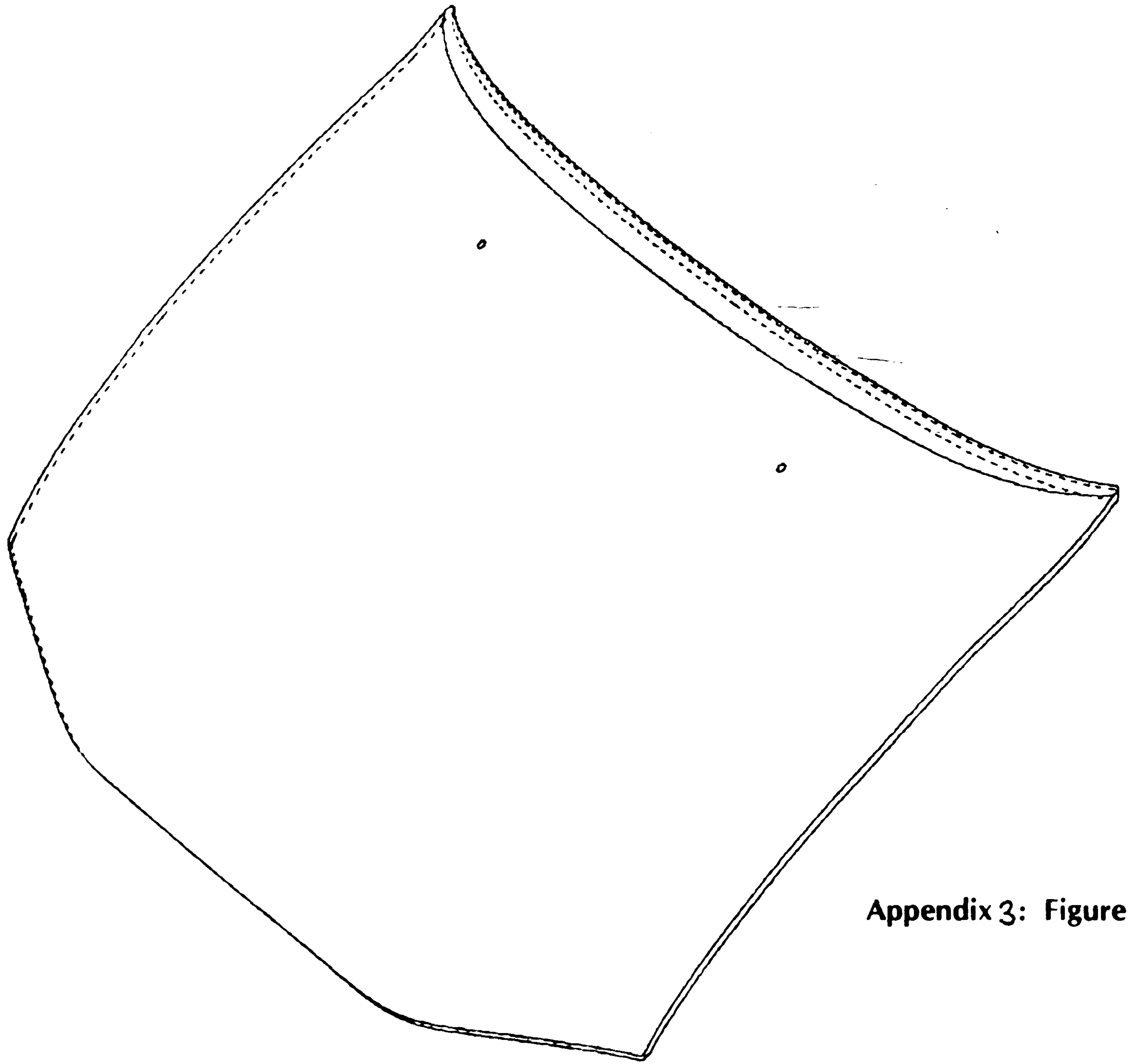
Strategy	Chrysler	Ford	Honda	Toyota	BMW	VW
Platform Organisation	Scott 1994a					
Balanced Matrix		Scott 1994b	Benchmark Information	Nobeoka 1995	Benchmark Information	EUCAR 1996 Benchmarking
Single Development Centre	Scott 1994a		Benchmark Information	Bremner 1997	Benchmark Information	
Globalisation of Development		Kidd 1997	Muffatto 1996	Toyota 1997		
Lead Time as a Key Driver	Thompson 1993	Scott 1994b		Jewett 1997	Reengineering Study	
Single CAD System	Brooke 1996		Honda R&D 1997			
Higher Supplier Integration	Public Domain		Muffatto 1996	Ward et al 1995		
Core Competence Models			Whitney 1995	Whitney 1995	Internal Documents	
Product Development Alliances		Scott 1994b				Minivan with Ford
Overt Platform Strategy	Yates 1996/ Public Domain	Scott 1994b/ Public Domain	Benchmark Information	Nobeoka 1995		Ericsson et al 1996
Single/Multi Brand	Public Domain	Public Domain	Public Domain	Public Domain	Public Domain	Public Domain

Note: All references for Rover Group taken from internal documents, and management communications.

Component Sketches from

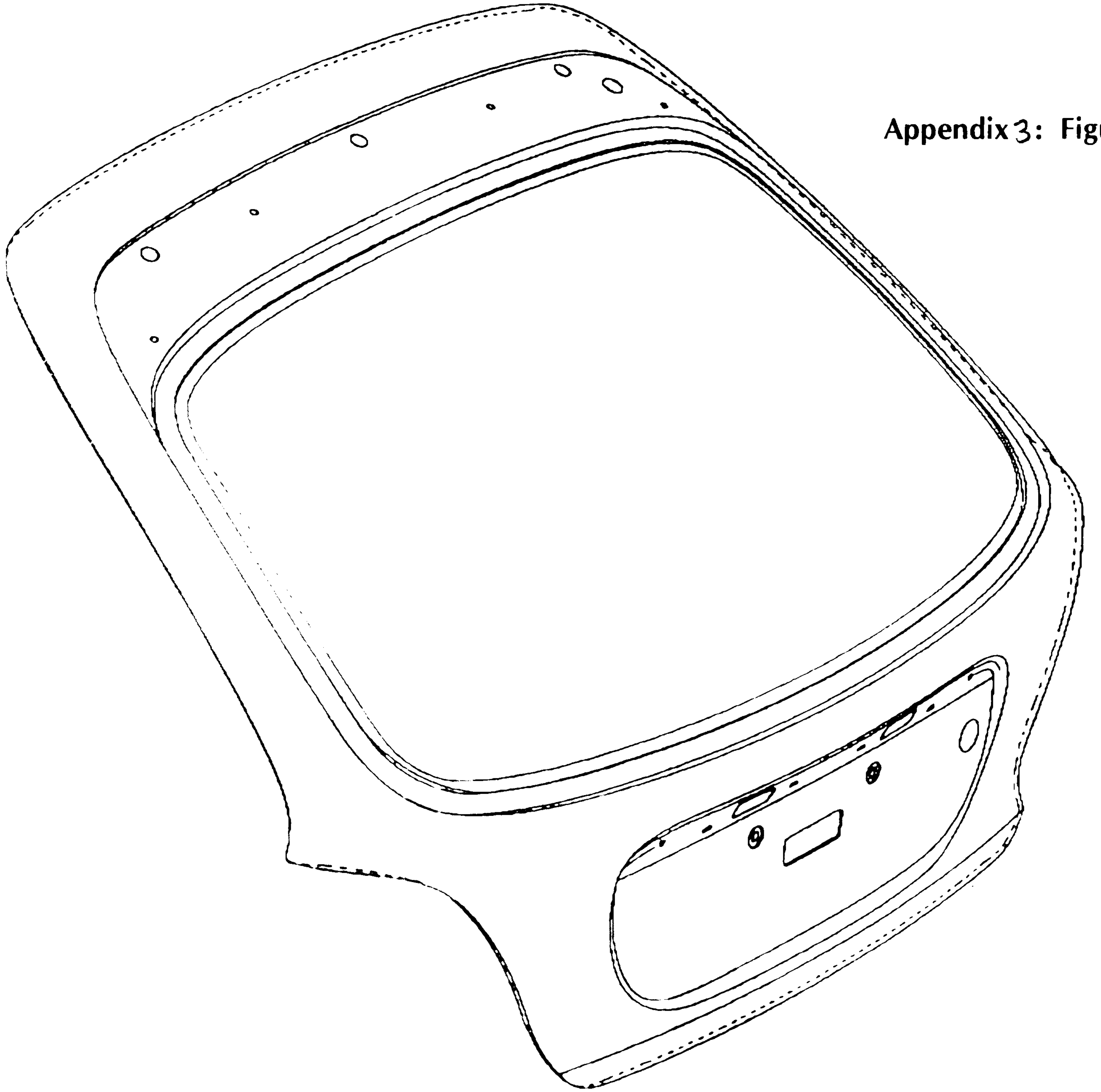
Metal Forming Technology

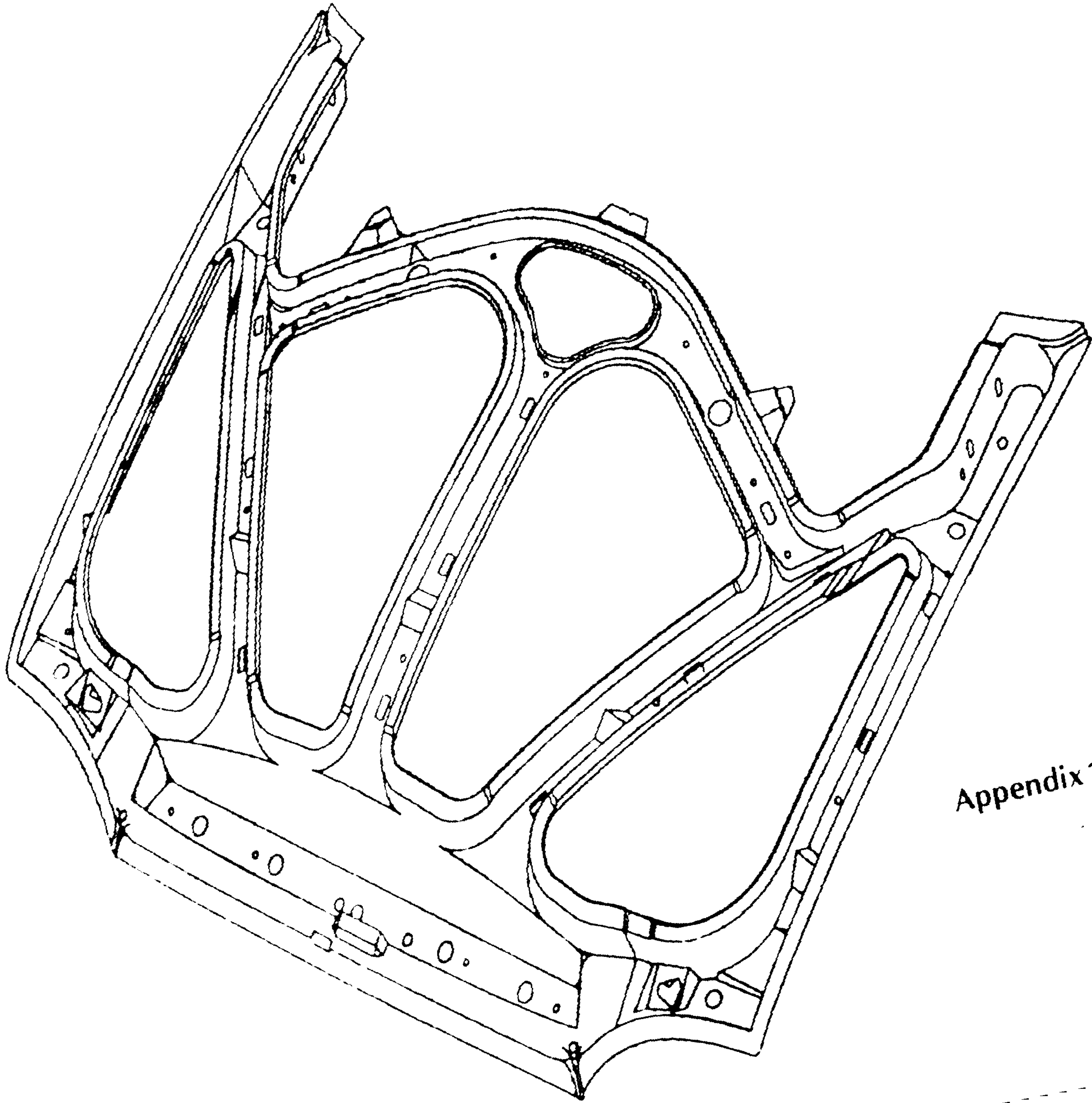
Pilot Studies at Rover Body & Pressings



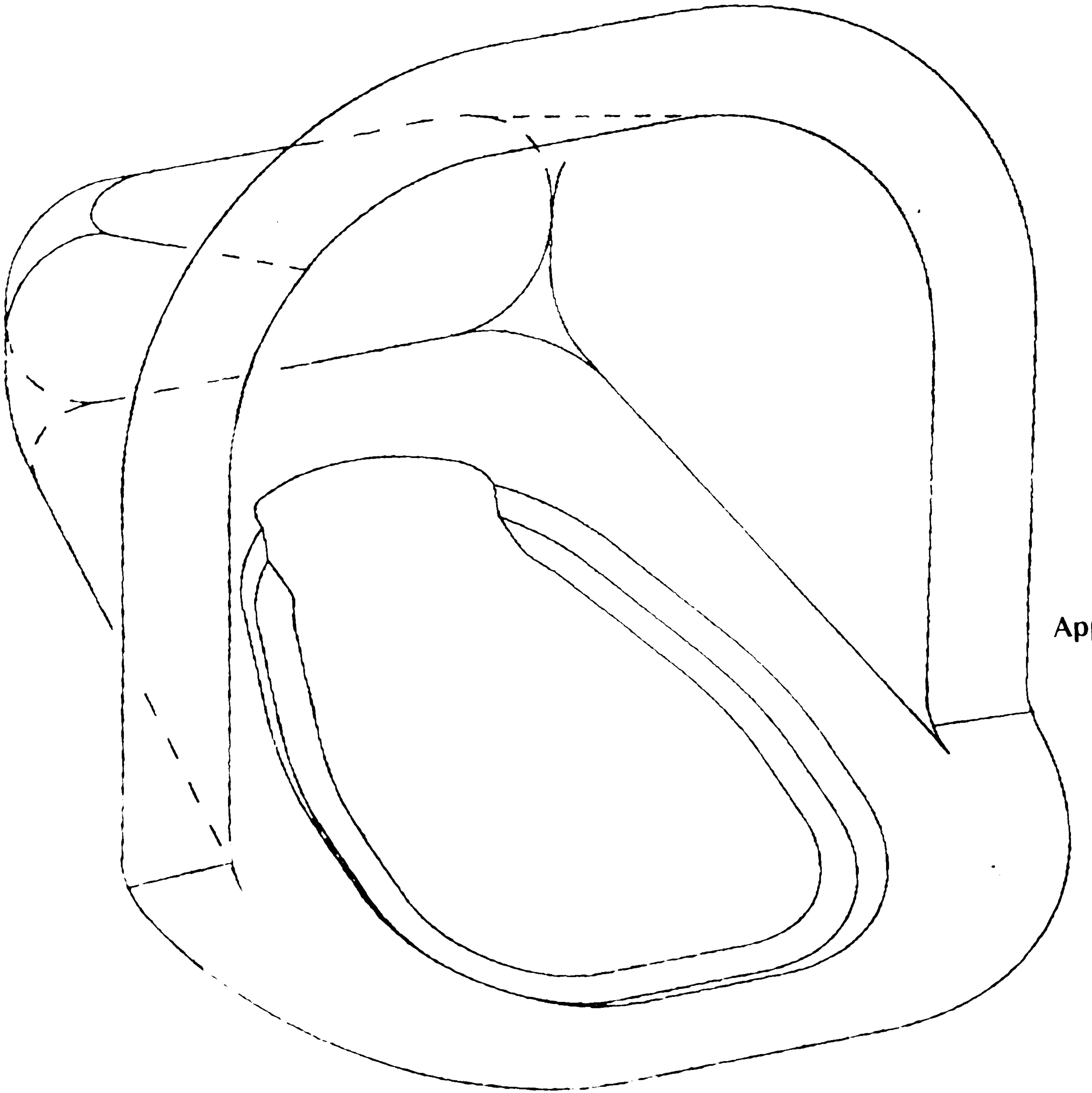
Appendix 3: Figure 1 Bonnet Outer

Appendix 3: Figure 2 Tailgate Outer





Appendix 3: Figure 3 Bonnet Inner



Appendix 3: Figure 4 Steering Housing

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