Determinants of Supply chain structure

by

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Thesis submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the School of Engineering at the University of Warwick.

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ABSTRACT

Title: **Determinants of supply chain structure**

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Degree: **Ph.D.**

Date: **April 2001**

This dissertation is a contribution to the study of manufacturing subcontracting, with particular reference to the European Automotive industrial sector. It takes as its central theme, the *structure* of supply chains – the way in which value addition is split amongst members of the chain. The thesis addresses a central question: What factors determine optimum structure and practice in modern-day industrial supply chains? This devolves into a number of derivative questions to which various parts of the study are addressed. With reference to 24 case study supply chains the investigation first tests whether existing theory can fully explain the changing structures. From the results of these tests a new model is postulated and then further work is carried out to validate the model. It was found that the concentration in existing theory on primarily dyadic relationships meant that when taken alone, current theory was insufficient to explain the changes in supply chain structure in the European automotive industry in the mid to late 1990s. It is felt that the work is novel in that it addresses the whole supply chain, and demonstrates the clear link between the physical structure and other determining success factors. Two methods for recording and systematically comparing both the structure and management practices in supply chains were developed – termed 'Fixed Reference Benchmark' and 'Hierarchical Structure Mapping'. These two models were tested, and used in the comparison of 24 European automotive supply chains. The results of this analysis showed the dominant factors that most heavily influenced the structure of supply chains in the European Automotive Industry to be: Criticality of component (which in turn affects the acceptability of risk), the level, and pace of development of technology for the component or system of the supply chain (which is strongly linked to bargaining power), the desire to reduce the complexity of logistics (which is also linked to acceptability of risk), the desire to reduce the cost of demand fluctuations, and the capital intensity of the production process.

It is felt that this study of supply chain structures is valuable in its contribution to new knowledge on three levels. At a theoretical level, it analyses the current theory, exposing gaps and anomalies. At an empirical level it presents contemporary data that in some parts simply substantiates and in others adds to the current theory. On a practical level it aims to present a picture which is of use to practitioners making decisions on the future of individual supply chains.

ACKNOWLEDGEMENTS

I would like to give particular thanks to the following people:

David Alexander for guidance, encouragement and much appreciated support especially during the later stages of data analysis and writing up. Gordon Brace for help and advice during the initial development of the study and throughout the field research. Keith Holmes and all at Bolton Institute of Higher Education who allowed time and resources to complete the study, as well as much needed encouragement. Lastly Anna Haywood, Jake Coleman and Josephine Coleman for being patient and supportive throughout the period of the study.

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Introduction

- **This chapter defines the research problem and approach used to carry out the study. An explanation of the structure of the thesis and a summary of the findings are also included.**

The topic area for this dissertation is supply chain 'structure'. It is concerned with the 'shape' of supply chains and why – for example - a car door for a German vehicle manufacturer arrives at the factory as approximately 100 discrete components[1], whereas for a similar French car, the components are assembled by suppliers, (the factory receives only a dozen main components). Is this an arbitrary choice, based on the individual preferences of the respective vehicle manufacturer? Is it the result of a mechanistic cost calculation? If it is purely cost, why are companies driven towards such vastly different strategies? Is it influenced by the ambitions of individual suppliers to provide a 'fuller service' to their customers? What are the economic, social and technological factors that drive supply chains in certain industries towards particular structures?

The thesis addresses a central question: What factors determine optimum structure and practice in modern day industrial supply chains? This devolves into a number of derivative questions to which various parts of the thesis are addressed.

Why does structure vary for different types of product and in different markets? Why do supply chains vary in certain economies and industries? Are supply chain structures influenced by certain determining factors? Do cultural aspects play a part (such as propensity for trust, diligence, and team working)? What about technological factors both in the design and manufacture of the product and expectations of customers in the product markets? Can transaction cost theory help to explain the way in which supply chains are developing? How is the structure of the supply chain affected by uncertainty? What is the role of information and how are supply chains affected by 'common access to knowledge' through developments in IT? What is the role of economics and how does this change the future of 'global sourcing'? Do technical aspects of the 'architecture' of the product drive the sourcing structure or vice-versa – (do the prevailing economics in the supply base shape the product architecture)? Does this vary for different product types[2]? How do these factors help to explain novel forms of sub-contracting such as the virtual enterprise, systems/modular purchasing, and strategic partnerships?

Is it possible to weigh up this set of factors to help determine an 'optimum' supply chain structure for a given set of circumstances?

The aim of this research is to answer some of the questions above. The outcome – the conclusions to the investigations - is a body of knowledge which can aid individuals who, by their actions, have an influence over the structure of individual supply chains (purchasing agents who make sourcing decisions, engineers who influence product architecture, supplier executives planning their company's core capabilities).

Put another way, the works seeks to set out the 'rule book' for a hypothetical 'supply chain designer'. The vehicle for concluding this rulebook is primarily an investigation into the changing supply structures in the European automotive industry, particularly the move towards 'systems' or 'modular' purchasing.

[1] An expansion of this example is given in Chapter 5 and written up in a paper "The transition from discrete component to systems supply" (Coleman, Brace, Kelly, Bhattacharya) presented at 28th International Symposium on Automotive Technology and Automation, September 1995.
[2] Chapter 5 will expand on this, using the theory set out in the 'Puttick four Quadrant grid'.

With reference to case study supply chains the investigation first tests whether existing theory can fully explain the changing structures. From the results of these tests a new model is postulated and then further work is carried out to validate the model.

There are a number of existing theories that address the subject of 'supply chain structure'. Some authors use the phrase 'value chain' (Porter 1985), others refer to the 'governance structure' (Powell 1990). The term 'supply chain structure' will be used throughout this thesis (see also section 1.2).

The first part of the thesis is devoted to reviewing existing works and summarising their conclusions. This part of the study (chapter 2), (together with an application of the theory to case study supply chains(Chapters 5 and 6)) contends that gaps exist. Unanswered questions as well as anomalies with present industrial developments are highlighted. No single body of work seems to be sufficient to explain the emerging supply structures.

The identification of unanswered questions, and the tentative postulation of a model was published in the paper "The structure conundrum" (Bhattacharya and Coleman, 1996)

The second part of the work develops a research methodology (Coleman and Bhattacharya, 1994), postulates a new model, then uses field and published data to fill in some of the gaps, enabling the final part of the thesis to conclude a set of answers. Interim results and conclusions were also published during the course of the study (Coleman and Ward; 1996; Coleman, 1998). It is hoped that a further publication will present the final conclusions from the research.

It is felt that this study of supply chain structures can be valuable on three levels. At a theoretical level, it analyses the current theory, exposing gaps and anomalies. At an empirical level it presents contemporary data that in some parts simply substantiate and in others add to the current theory. On a practical level it aims to present a picture which is of use to practitioners making decisions on the future of individual supply chains.

1.1 Definition of supply chains

A wide range of terms are used, sometimes inter-changeably, to describe the flow of goods from raw material suppliers to the end customer: Value chain, value addition chain, value stream, supply channel, supply network, extended enterprise, to name but a few.

Harland (1996), in his work on supply chain management, illustrates the situation as below.

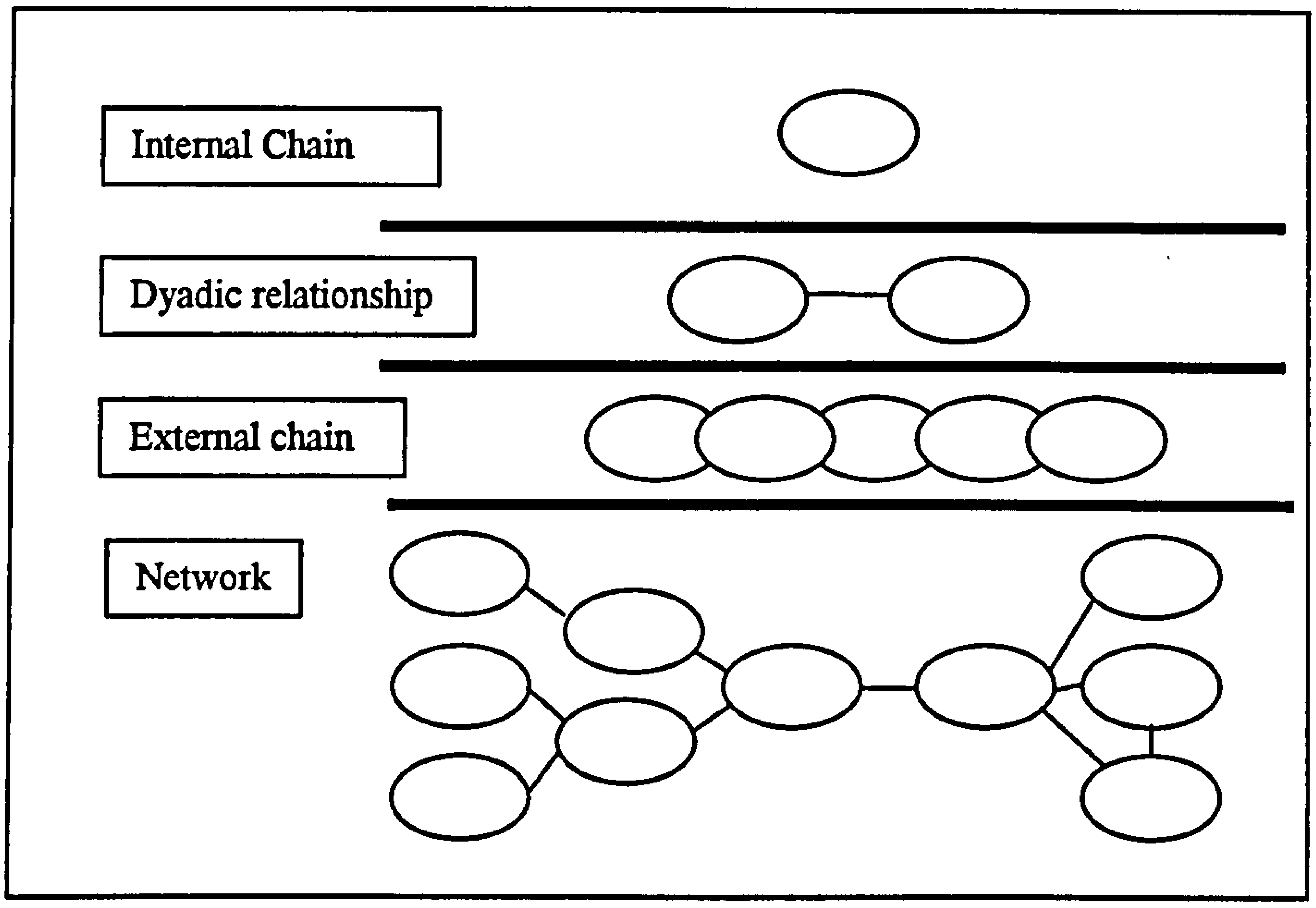


Figure 1.1 Supply relationships

Harland's illustration of supply relationships is, of course, a simplification of the actual arrangements in place. It fails to capture the true complexity of the many connections in modern supply networks.

In the current study, supply chain is taken to include all the interconnecting companies providing goods or services which contribute to the final 'product'. During the field research, 'final product' is not necessarily a saleable item. For example the supply chains for four similar 'car doors' for different vehicle manufacturers are studied. Here, the supply chain clearly fits within the broader supply chain, for the complete vehicle.

As such the definition of supply chain is similar to what Harland illustrates as 'supply network'. In other words supply chain is taken to be more than simply a linking set of dyadic relationships.

Figure 1.2, below illustrates an example supply chain, and shows the scope of supply chains as studied in this thesis.

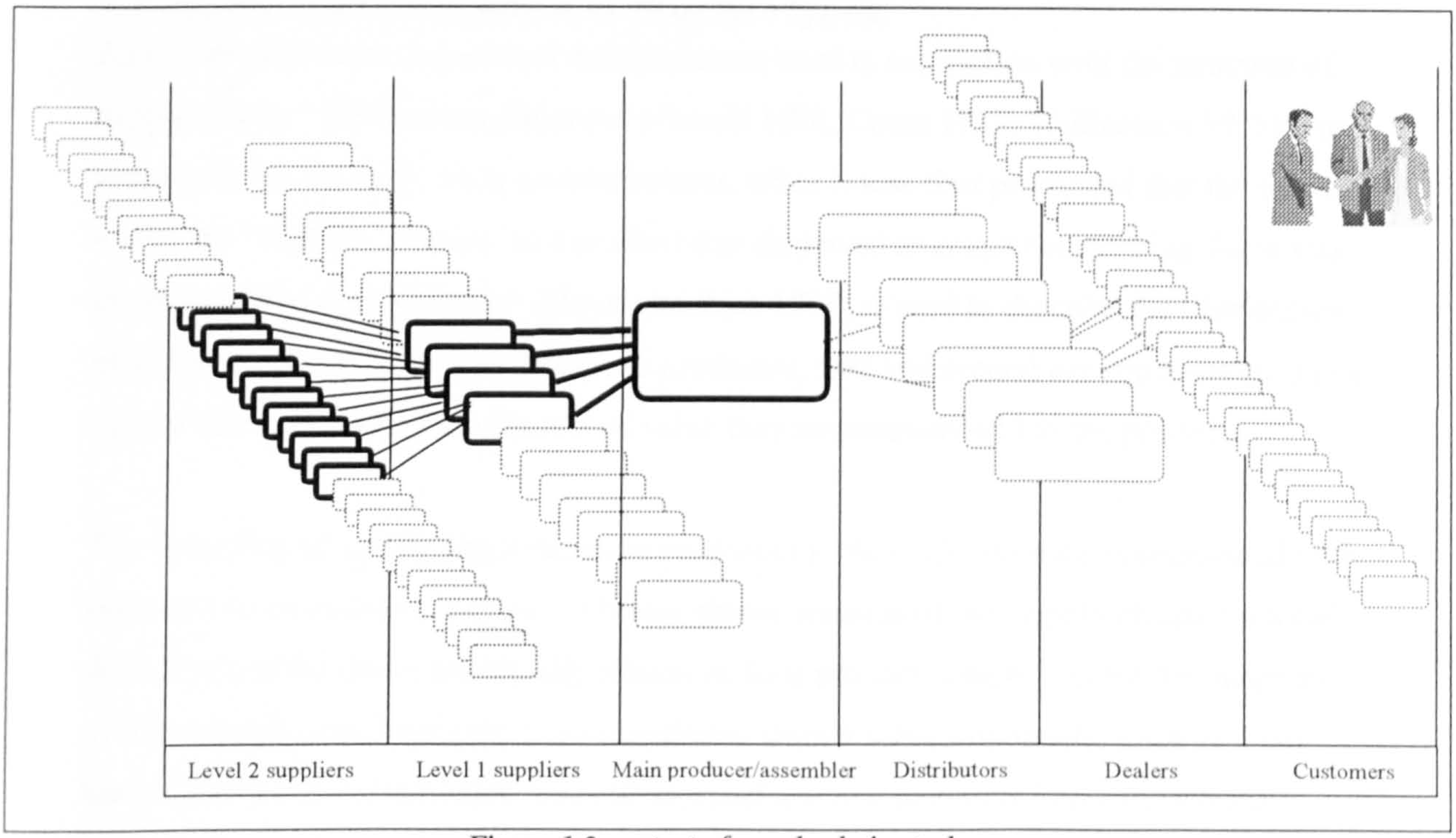


Figure 1.2 context of supply chain study

Taking an automotive example, the emboldened outline in figure 1.2 might represent the supply chain for the car door. The end point is a completed door, ready to assemble onto the vehicle. Some of the components (frequently the exterior panel(s)) will have been made 'in-house', and the majority bought from suppliers. In the figure four 'first level' suppliers are represented. In turn these are fed from level 2. In practice there is often a third and sometimes fourth level, tracing back to raw material production.

In this research, the extent of the supply chains studied will contain boundaries, in the sense that the 'whole' chain for the end product (e.g. the car) will be split into discrete

In this research, the extent of the supply chains studied will contain boundaries, in the sense that the 'whole' chain for the end product (e.g. the car) will be split into discrete

(and more manageable – in a research sense) chains, usually at component or 'module' level.

1.2 Supply chain structure and structure types.

Again, several terms and several definitions are used in connection with the structure of supply chains. 'Governance structure' (Powell 1990, Coase 1937, Williamson 1975) was termed during the early work on transactions, when it was first postulated that the way in which the 'addition of value' to a product was dispersed amongst contributing firms was important. 'Physical structure' (Hines and Rich 1997) is used to describe the distribution of various types of firm (Raw materials producers, first and second tier suppliers etc.) in a supply chain, as well as the amount of value they respectively add to the product.

The definition of supply chain structure pertinent to this study, is best communicated with reference to an example. Figure 1.3 below shows sections of two supply chains for a car door. Each of the doors are broadly similar in their product design, and for the purposes of the example are considered to be constituted from 9 sub-components. Each of them has a common set of activities required to transform raw materials into a completed product. However, the distribution of these activities amongst 'contributors' to the supply chain is different. The 'Structure' of the chain is different. Structure relates to the distribution of value adding activities amongst the firms in the chain. It is the way in which value addition is split.

So how can structure be portrayed and 'measured'. It can be seen that the supply chain on the left in figure 1.3 has an extra 'level' – there are a greater number of 'links' in the chain. The end customer choose to employ a supplier to integrate three of the sub-components into a sub-assembly. Therefore 'length'/ number of links/ number of levels is higher, and this is one measure of supply chain structure (sometimes referred to as number of echelons). Lamming and Harland (1998) state that:- ***"No research to date has***

Then there is the 'breadth' of the chain. This can be thought of as the number of contributors acting at each level. It can be seen that the chain on the left has greater breadth than that on the right in figure 1.3. This is partly because that on the left chooses to use multiple sources of component (or sub-assembly) 1.

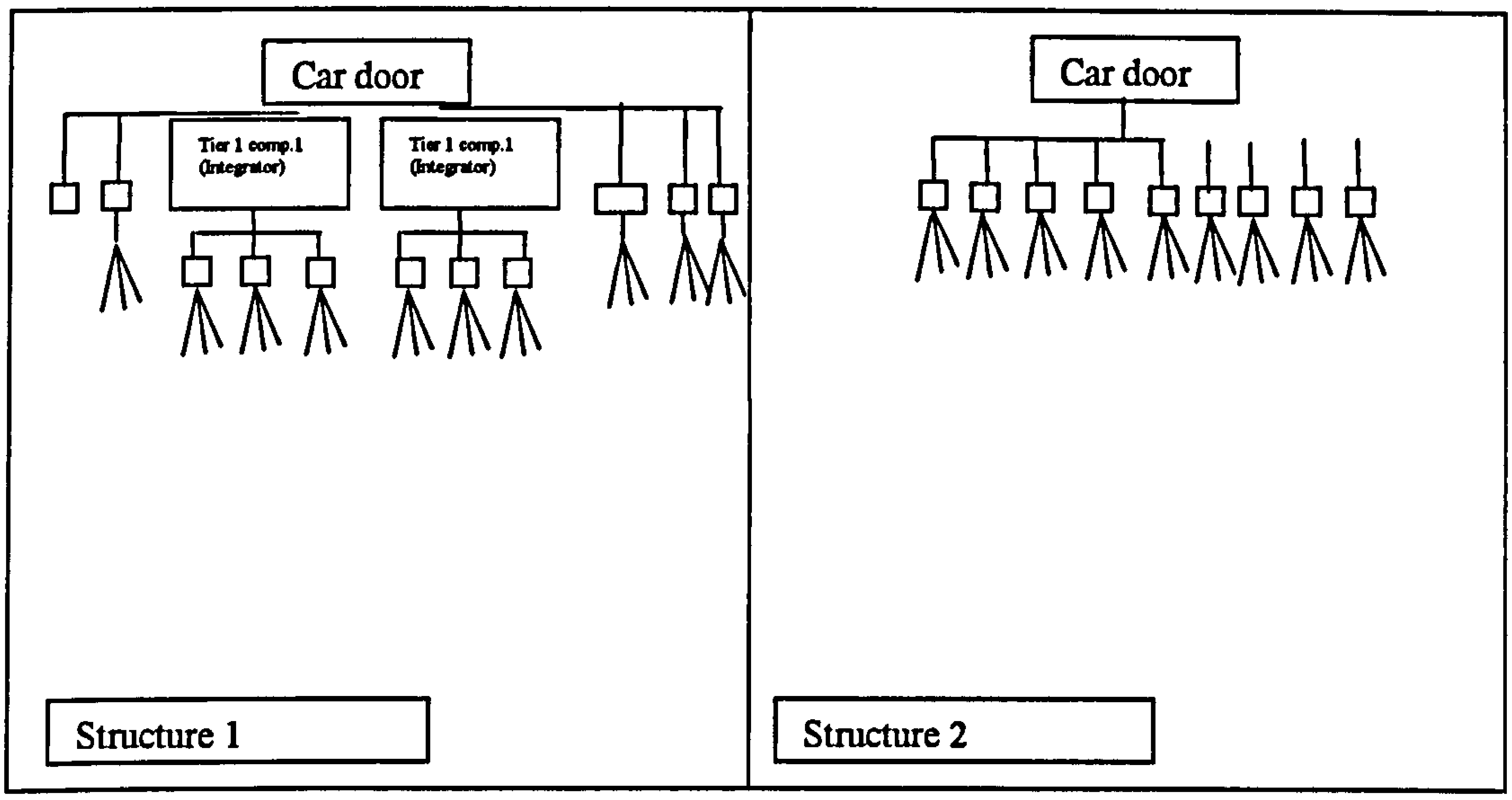


Figure 1.3 – Alternative sourcing structures

Nishiguchi (1987) reported on the trend in Japanese companies to reduce the breadth of their supply networks, whilst simultaneously increasing the tiering, i.e. the length. Traditionally, during the 1960's and 70's, the majority of Western companies used multi-sourcing. This trend seems to have come to an end, being replaced by a more Japanese approach, resulting in reliance on single or dual-sourcing strategies. The advantages and disadvantages of the breadth of supply structure has received some investigation, although mainly from a dyadic point of view rather than in the context of the structure of the chain as a whole (e.g. the IMP group, 1982; Lamming 1992; Nishiguchi 1987).

Then there is the way in which activities are grouped. Supplier 1 on the left of figure 1.3 performs a greater quantity (both in number and value) of value addition activities than any other contributor to the chain. Therefore a measure of the evenness of distribution amongst the chain maybe important. This again is a topic which seems to have received little attention.

The ***absolute number*** of firms in the chain maybe another relevant measure and is an issue which is addressed later in chapters 3 and 4.

1.3 Research method

The main aim of the dissertation is to answer its central question. The work proceeds by focussing on the specific questions that derive from this main concern. The first part of the work concentrates on a description and analysis of the main areas of published knowledge on the topic of supply chain structure. This is found to be lacking in its treatment of the supply chain as a homogenous single competitive entity. Much of the theory concentrates on optimising single transactions or single firms within the supply chain. The first investigative hypothesis put forward, therefore, was **that the existing theories - when applied to individual elements of supply chains and then these elements combined into the whole chain – could not fully explain the changes in structure taking place in the European Automotive industry.**

To establish the validity of this hypothesis, recourse was taken to field research, where twenty-four automotive supply chains were investigated, involving some 150 interviews at vehicle manufacturers and their suppliers[3].

A method for portraying the structure was developed (Coleman and Bhattacharya 1994), and this was used to compare theoretical predictions with the actual supply chains.

This part of the investigation established that the hypothesis could be accepted, and hence the aim of the next section was to verify the nature of the differences and whether a fuller theoretical framework could be generated.

[3] Appendix 1 includes a list of interviews and sites visited. (The publication referenced in footnote 1 also describes the interview process.)

Many of the departures from theory were concluded to be present when firms higher in the chain exercised greater control not only on their immediate 'neighbours' in the chain but also further up or downstream. Put another way, this first investigation showed that some firms were shown to be proactive in shaping greater sections of their supply chain, beyond their direct neighbours, a factor which does not seem to have featured highly in published research.

Two analysis methodologies, termed '**Fixed Reference Benchmark Model**' and '**hierarchical structure mapping tool**' were developed to investigate the structure, and the determinants of the structure at the 24 case study supply chains.

The core of the field research took place during 1994-1996 and includes discussions with some 65 interviewees at six European vehicle manufacturers, and 85 employees at 27 supplier companies. An 'agenda for analysis' was developed such that data for each supply chain could be both presented and analysed consistently across the sample of supply chains. Spreadsheets were used extensively for analysis.

It is felt that the field research and the conclusions from it are a particular strength of this study, adding contemporary data and shedding additional light on questions of relevance to industry as it moves into the next millennium.

1.4 Automotive Industry Field Research

The automotive industry field research focussed on twenty-four supply chains, comparing structure and practice across this sample. In order to achieve consistency, four components were chosen to represent a range of different technologies and sourcing strategies. Each of these four component supply chains was investigated at six vehicle manufacturers, making a total of twenty-four supply chains.

The four components were: Door, Instrument Panel, Electronic Control Unit and Wiring Harness.

Table 1.1 shows a typical breakdown of interviews for one automotive supply chain.

Door supply chain 1 (D1)					**Total number of interviewees**
Interviews at Vehicle manufacturer (No. of interviewees)	Designer (4)	Buyer (3)	Logisitics agent (2)	Logistics manager (1)	10
Interviews at first tier supplier (No. of interviewees)	Designer (2)	Commercial agent (1)	Logistics agent (1)		4
Second tier supplier (No. of interviewees)	Commercial agent (1)				1

Table 1.1. Typical interviews for case study supply chain.

1.5 Overview of findings – 'a new explanation of supply chain structure'.

1.5.1 Existing theories on supply chain structure

The existing theory related to the current study can be broken down into four areas or 'factors' affecting both the existence and structure of supply chains.

- Economic
- Social
- Technological
- Organisational

The areas of theory identified and summarised below each treat the four factors differently, but this researcher believes it is possible to identify these factors as common in all the related fields.

The areas of past and current academic work with a bearing on supply chain structure are listed below, and a summary of the literature presented in tabular form overleaf. Each contributes in part to the identified topic for this work and the first part of the thesis is devoted to bringing these theories together and using them to attempt to answer the questions posed. Gaps are identified to which the empirical works in part two are addressed.

Areas of relevant academic work are:-

> ***Transaction cost/obligational contracting; Trust/Cultural perspectives; Business strategy management; Networks; Dualism; logistics; Supply chain management; and Lean supply.***

The table below provides a brief overview of these areas of work, with reference to the main protagonists, their central contentions and key topic areas. This researcher has also suggested the way in which each area is linked to the current study.

Table 1.2 Principal theoretical frameworks with a bearing on supply chain structure.

	Networks	Trust	Transaction cost/ 'Obligational contracting'	Logistics	Lean supply	Supply chain management	Dualism	Business strategy Management
Main Proponents	Johanson Powell Hakanson Jamlo Snehota Reve	Helper Hirschman Sako Dore	Williamson	Bowersox Christopher Elram Towill	Womack, Jones, Lamming	Harland, Houlihan, Oliver, Nishiguchi, Slack	Piore, Sabel, Berger Edwards	Porter Skinner Puttick Chandler Mintzberg Pfeffer
Definitions	Model of organisation-evironment interface. Capabilites of individual firms dictated by interactions with small number of 'surrounding firms' in their network	Closer harmonious working relations with suppliers, based on trust and respect.	Seeks to explain the economic rationale of alternative forms of organisation, i.e. their relative efficiency.	Management of information flow 'up-stream' and materials flow 'down-stream' against business objectives	Collection of principles aiming at removing waste from product development and manufacturing processes.	Management of the 'value chain' Adding value faster than cost.	unequal treatment of economic agents located in different segments of the economy.	The generation and implementation of the pattern of activities which has an impact on the achievement of the organisational goals in relation to its environment.
Central concepts	Relationships develop with small number of external actors (e.g. customers, suppliers, competitors) which dictate the organisation of resources in the supply chain.	"Exit" or "Voice" as response to unsatisfactory supplier relations. Voice introduces the concept of mutual problem resolution rather than the threat of re-sourcing to another supplier.	Where transactions have highly uncertain outcomes, recur infrequently and require unique or transaction specific investment, they can be performed most efficiently with vertical integration – i.e less stratified supply chain.	Achieving the conditions for moving goods and information in a timely manner whilst achieving business objectives	Removal of waste Collaborative working with suppliers. Outsourcing greater value. Latterly 'value stream' applies theory to wider supply chain.	Relationship management. Sourcing policy. Logistics.	Dualists see inequality between the internal and external labour markets, between the primary and secondary sectors, or between the core and peripheral economies according to their own terminologies	"survival of the fittest" 'Best-Fit' between environment and organisation capabilities.
Gaps/Bearing on the work of the thesis	Supply chain structure results from the collective and connected intent of limited number of actors in the chain. Not tested against concepts such as modular supply/systems purchasing	Consensus agreement on boundaries in supply chain. Still only extends to diadic buyer-supplier relationship.	Seeks to link transaction type and cost to supply chain structure. Assumes opportunism as standard behaviour, no conclusive work to prove this in Euro. Auto Industry.	Change in structure assumed to have an effect on efficiency of logistics. Therefore assumed to be one determinant in choosing structure. Again, not tested with Supply Chain Structure as independent variable.	More to say about management of the chain rather than structure.	Goes some way to dealing with the supply chain as a single competitive entity, but focusses on management of chain rather than structure.	'Stratification' of the supply chain is dicated by cost differences between firms (e g relative cost of employment, land, buildings etc). Little work against recent changes in Euro. Auto. industry.	Individual strategies of the firms of the supply chain are based on their individual interpretation of the external environment. Individual strategies determine the structure. The supply chain 'fits itself' to its environment via the collective action of the firms in it.

1.5.2 Gaps and anomalies – development of research aims and hypotheses.

The point of departure for the novel work of this thesis is the casual observation by this researcher that the radical alteration of the structure of supply chains in the European automotive industry leading up to, and including the study period, is neither completely explained nor fully supported by existing theory.

Chapter 2 concludes that many of the applicable schools of theory in the study area are intrinsically intertwined and related, and three areas in particular can be viewed as especially pertinant to the field of study reported in this thesis. They are: Transcaction Cost theory combined with Trust/Cultural perspectives, Networks and Dualism.

The first investigative hypothesis is therefore that neither ***Transaction cost/obligational contracting combined with Trust/Cultural perspectives; Dualism; or Networks theory*** can satisfactorily explain all the changes in supply chain structure in the European passenger car manufacturing sector.

This hypothesis is found to hold true. Particularly because of the advent of 'partnership supply' and closer collaboration between suppliers and customers, the genesis of transaction cost theory, that the choice of market vs hierarchy is governed by the propensity of actors dealing with the transaction for 'opportunism' is found to no longer prevail. Field research also indicates that nominal 'partnership relationships' do not always engender mutual benefit to both customer and supplier, an assumption implicit in the theoretical construct of the 'Trust' school.

Much of the existing theory is aimed at individual transactions or at positioning individual firms in the supply chain. This researcher can find no evidence of these competing theoretical frameworks being applied across whole product supply chains or networks. Rather they focus on optimisation of individual elements, or dyadic buyer-supplier 'links' in the chain.

A method is proposed for addressing the whole of a product supply chain and mapping it's structure in a way that allows comparison between similar chains. This method is written up in the publication "Positioning in supply chains – a supplier's perspective" (Coleman and Bhattacharya, 1994)

This model is then used to compare the structure of supply chains predicted by the theory, against the practicalities of the 24 automotive supply chains featured in this study.

Important differences were found, particularly in instances where 'parents' in the supply chain had asserted some control beyond their immediate 'children' in the chain. This supported the view that in the case of business strategy management and transaction cost analysis, optimisation of individual elements does not necessarily result in optimisation of the supply chain when viewed as a single competitive entity.

A combination of the above research, and further study of the literature caused this researcher to believe that the effect of new product technology, creating new opportunities for changed 'product architecture' is an increasingly important factor in the determination of supply chain structure. Again this is an area which has not received significant academic investigation.

The current research supports the view that the nature of the technology and the criticality of the component or system has significant bearing on the structure and nature of the relationships. Confidentiality has a significant bearing, as does predictability of demand.

1.5.3 Summary of findings from field research.

The field research, and subsequent analysis brought forward the following findings:

- Network theory helps to explain the way in which structures evolve – driven primarily by management decisions taken by a relatively small number of actors in the links of the supply chain.

- Transaction cost theory is found to be useful in part, explaining the importance of bargaining power in the distribution of value addition in the chain, and helping to explain the emergence of a very strong 'Tier 1', and latterly 'Tier 0.5' in the automotive sector.
- Transaction cost theory does not fully account for 'win-win', or 'partnership' supply situations, characterised by joint working and mutual trust. Through consideration of the 'certainty of business retention' – a measure of trust in the relationship, the study highlighted instances where nominal partnership relationships belied a more honest assessment of the working practice, where opportunism and *lack of trust* were the dominant behaviour traits. The supply chains observed did not support the assumptions implicit in Williamsonian Transaction Cost Theory.
- The Porter 'Business Strategy Management' theory was found to be useful in explaining the emergence of the strong Tier 1 layer in the structure of the supply chains. However, it was found that the actual mechanics of 'determining' or 'driving' the structure towards a particular form or another was much more due to the individual decision making of actors in the chain, based primarily on cost, reduction of risk, and relative bargaining power.
- The structures were found to vary most greatly in the region of the VM to first tier 'links' in the chain. Value addition was found to be distributed quite differently in these layers, between the supply chains in the sample.
- The dominant factors in determining the structure were found to be: Criticality of component (which in turn affects the acceptability of risk), the level, and pace of development of technology for the component or system of the supply chain (which is strongly linked to bargaining power), the desire to reduce the complexity of logistics (which is also linked to acceptability of risk), the desire to reduce the cost of demand fluctuations,a nd the capital intensity of the production process.
- Novel forms of partnership which transcend the traditional dyadic relationships were found to exist, however it has not been possible to affect a direct comparison of performance.

1.6 Structure of the thesis

Chapter 1 defines the research problem and approach used to carry out the study. An explanation of the structure of the thesis and a summary of the findings are also included.

Chapter 2 provides a critical review of the most relevant areas of literature and draws conclusions on the current knowledge relating to supply chain structure. Areas for further investigation are identified from the original research questions.

Chapter 3 formalises the initial research hypothesis and details the development of the research method related to the first part of the investigation. An introduction to the field research is also included.

Chapter 4 describes the field research, including the analysis of data for the initial investigation. This section also presents the results and conclusions for the first phase of the research.

Chapter 5 develops the research method and describes how data was analysed.

Chapter 6 provides the results from the application of the research instruments developed in chapters 3 and 5.

Chapter 7 provides a discussion of the research carried out for this thesis including a review of the ways in which the work has addressed the questions originally posed. Follow-up work is also considered.

Chapter 8 Contains concluding remarks.

Chapter 2

Literature review

- **This chapter provides a critical review of the most relevant areas of literature and draws conclusions on the current knowledge relating to supply chain structure. Areas for further investigation are identified from the original research questions.**

Because of the diverse nature of the study, it has been found that many disciplines have a bearing on the supply chain structure. Some directly address the problem of supply chain or 'network' structure, others offer explanation for the positioning of individual firms within a network.

Principle bodies of work with relevance to 'supply chain structure' are identified as:

> **Transaction cost/obligational contracting; Trust/Cultural perspectives; Business Strategy Management; Networks; Dualism/industrial economics; logistics; Supply chain management; Lean supply.**

Included in this chapter is a critical review of these areas of theory. Later sections give greater detail on three areas chosen as the most pertinent to the research presented in this thesis. These areas are "Transaction cost economic theory, combined with Trust/cultural perspectives", "Network Theory" and "Dualism".

Transaction cost/obligational contracting (TC/OC) is a body of theory which seeks to establish which type of transaction is most efficient for a given set of circumstances. The theory primarily distinguishes between 'in-house' (termed 'Hierarchy' in TC/OC) and 'bought out' (termed 'Market').

Trust/Cultural perspective introduces the concept of "Exit" or "Voice" as opposing responses to unsatisfactory supplier relations. Voice refers to mutual problem resolution rather than the threat of re-sourcing (exit) to another supplier. Closer harmonious working relations with suppliers, based on trust and respect are at the centre of this body of work. Challenges the assumption of 'opportunism' being the pervading human characteristic which drives the cost of market transactions.

The notional importance of 'benevolence' is introduced. Defined as 'something shown in relations between unequals, by superior to inferior, the reciprocal of which is usually called loyalty'; or goodwill, which is more status-neutral and broader in its meaning defined as 'the sentiments of friendship and the sense of diffuse personal obligation which accrue between individuals engaged in recurring contractual economic exchange' (Dore 1987:170). Dore refutes the Williamsonian assumption of 'opportunism being a universal human trait' and associated assertion that trading relations are shaped by this.

Business Strategy Management is the study of the company's response to changing external conditions including the optimum positioning of the company in the supply chain.

'Networks' is a school of thought whose central contention is that a small number of 'actors' who most closely interact with the company mainly affects the 'shape' and 'management relationships' in supply chains. In other words business networks are

made up from individual companies (nodes) whose behaviour is most affected by the surrounding nodes.

Dualism suggest that supply chain structure is influenced by the unequal treatment of economic agents located in different segments of the economy. The distribution of activities in the supply chain is affected by such inequalities (an example would be differential employment costs against geographical location, or size of firm).

Applied to the language of supply chains, the formulae of dualism can be translated as follows: workers, often of a temporary status and/or in peripheral firms, in the external labour market (or the secondary sector) and small firms, frequently suppliers, in the peripheral economy do not receive what they are worth. That they do not earn what the market would dictate is built into the structure of dualism rather than due to the individual skill levels of the economic agent.

Logistics and Supply chain management are related areas of theory. At the core is the Management of information flow 'up-stream' and materials flow 'down-stream' against business objectives.

Lean supply is a Collection of principles aimed at removing waste from product development and manufacturing processes.

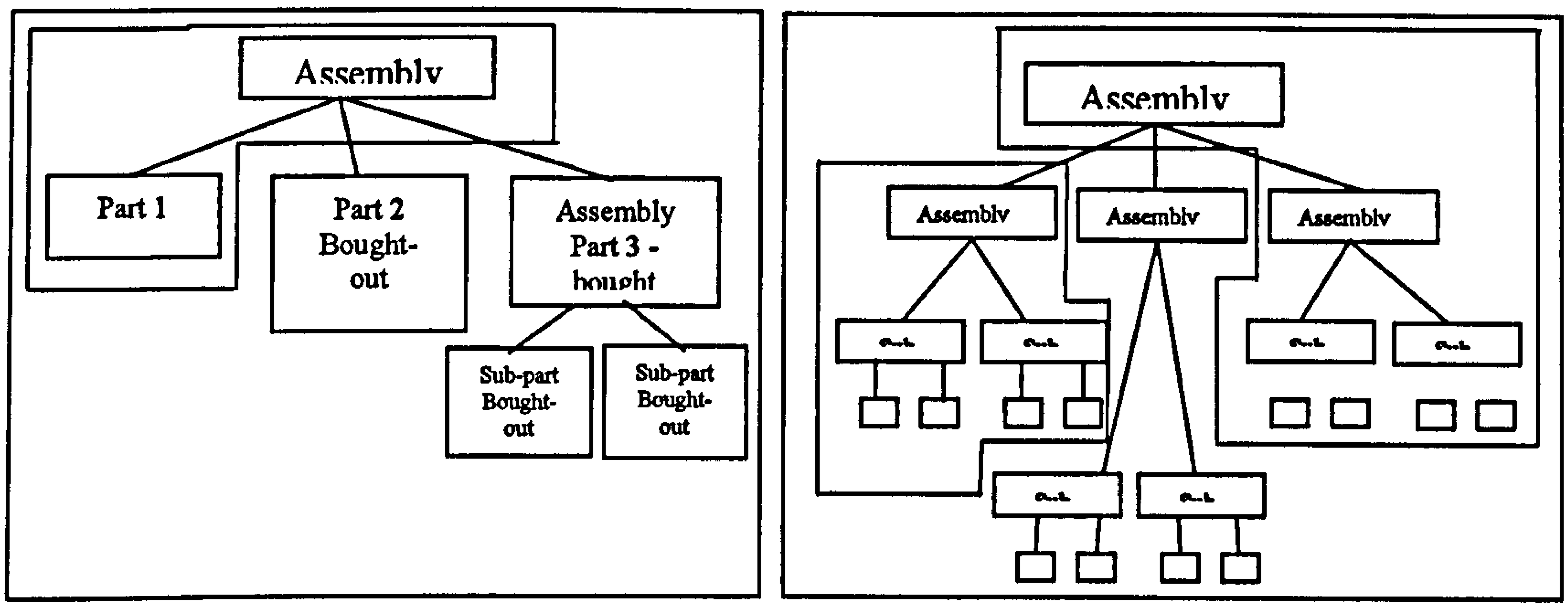
Table (2.1) on page 44 presents an overview of these subject areas.

2.1 Summary of principle areas.

Historical academic accounts of markets and firms accounted for the production of goods simply as a 'black box' function until the economist Ronald Coase (1937) conceived of the 'governance structure'. The key insight of Coase's work was that alternative arrangements for creating products existed with 'vertically integrated – single firms' at one end of a spectrum, and 'highly stratified supply chains using market transactions' providing the antithesis. In the former situation nearly all the value is added by a single company. With the stratified supply chain the value addition is split between any number of firms.

Williamson and other proponents of ***transaction cost economics*** in the 1970's took up this work. Transaction cost economics takes seriously the notion that organisational form matters a great deal. Williamson (1975; 1985) sought to establish which type of transaction was most efficiently carried out within a hierarchy (within the firm) and which are more suitable for completion using the market. For the purposes of this study, analysis of the transaction types required for a particular product could thus result in a theoretical optimum structure for the supply of that product. This would be in the form of a hierarchy of 'transactions', showing the theoretical optimum distribution of the product amongst firms in the supply chain. (Figure 2.1 illustrates this concept) A fuller discussion of transaction cost theory is undertaken in section 2.2 of this chapter.

Despite Williamson's empirical research, this work has been challenged in a number of studies. Powell (1990) points out that "...in many cases where transaction cost reasoning predicts internalisation; we find other kinds of governance structure, particularly networks." Macneil (1985, p.496) suggests that "the transaction cost approach is far too unrelational a starting point in analysing" relational forms of exchange. The premise for predicting transaction types in transaction cost economics is that all actors in the chain behave, and make decisions based on opportunism and 'bounded rationality'. This assumption has again been challenged. (Perrow, C. 1986)



Optimum structure following analysis of transaction Costs
SCENARIO 1

Optimum structure following analysis of transaction costs
SCENARIO 2

Figure 2.1. showing alternative structures for same products, given differing transaction costs.

Porter (1985) first suggested the concept of production as a chain of activities in which value is added. The question then is: 'which activity does a firm chose to perform internally and which activities are outsourced to members of a network who presumably can carry them out more effectively?' He points to the benefits of specialisation, focus and size as the providers of impetus for companies to use sub-contractors. Porter developed these concepts into his seminal work on ***competitive strategy***, generating a set of principles to aid companies in organising themselves into the best 'position' in the supply chain for their own competitive advantage. Porter's principles are again based on extensive empirical research and many subsequent studies have tested the results against individual firms. Porter's work typifies and is included in the 'school' of ***business strategy management'.***

The dominant idea in the conceptual core of business strategy research has been partly derived from biology ("survival of the fittest"). The effectiveness of the organisation, (its potential for accumulating resources), is assumed to be a function of matching the characteristics of the environment with the capabilities of the organisation. The idea of 'fit' between capabilities of the organization and the characteristics of the environment is a key re-occurring theme.

The strong implication for supply chains is that structure evolves, as individual firms react to their environment, positioning themselves in the best place in the supply chain to suit external and internal conditions.

There exists a large and growing body of contributors, building a body of knowledge based on the overriding principle set out above. Represented are such groups as industrial economists (Chandler 1962; Porter 1980, 1985), organisational theorists (Hall and Saias, 1980; Miles and Snow, 1984; Mintzberg, 1987; Pfeffer, 1987) and management theorists and consultants (Ansoff, 1965; Hoffer and Schendel, 1978; Henderson, 1979; Ohmae, 1982; Puttick)

The concept of business strategy has many definitions. The content assigned to the concept also varies from one author to another. The essence of many definitions converges in the concept of strategy as "the pattern in the stream of decisions and activities...(Mintzberg and McHugh, 1985, p6)...that characterises the match an organisation achieves with its environment...and that is determinant for the attainment of its goals..."(Hoffer and Schendel, 1978, p.25).

A strategy is therefore a plan of the pattern of activities, which has an impact on the achievement of the organisational goals in relation to its environment.

The business strategy school usually assumes that the criterion of effectiveness in the case of business organisations is the accumulation of monetary wealth over time.

The fit with the environment is assumed good if the organisation out-performs other organisations in competing for the resources held by other entities in the environment. (Customers-suppliers etc)

Three assumptions are made: first the environment of an organisation is faceless, atomistic and beyond the influence of control of the organisation . The organisation can exploit opportunities that exist in the environment. The environment exists with or without the organisation.

Second assumption is that the strategy results from the deployment of resources controlled hierarchically by the organisation. In the supposedly competitive and "non-controllable" environment, the effectiveness or exchange potential of an organisation will depend on its relative efficiency in combining resources. Internal resources can be reallocated in order to adapt to environmental conditions, thus enhancing effectiveness.

Thirdly, environmental conditions change continuously, so that frequent if not continuous adaptation is required in the organisation. There is a group of individuals in the organisation, which is concerned by definition with managing organisational effectiveness. It is assumed that this group can and does interpret environmental conditions after which it formulates and implements a future strategy. It decides and crafts the pattern of activities to be executed by the organisation.

These assumptions have all been challenged over time. Hannan and Freeman (1977) concept of collective dependence of organisations. Pfeffer and Salancik (1978) who talk about the resource dependence of organisations.

Porter (1985) has set out possibly the most complete and widely accepted framework, and this is summarised in the following section, with additions and adaptations as are seen fit from other authors in the area.

More recently what has become known as the ***network model*** for 'organisation-environment interface' has sought to explain the way in which networks form. The onus of this model is that the small and finite number of 'contacting' or corresponding actors surrounding them influences 'actors' in the network.

The network model stems originally from casual observations that business organisations often do operate in environments which include only a limited number of identifiable organisational entities (or actors – e.g. customers, suppliers, legal or professional bodies)

(Hagg and Johanson, 1982; Mattson 1985; Ford *et al*, 1986). As a result of the organisation's interactions, over time, a set of relationships develop that link the resources and activities of one party with those of another. With respect to the European automotive industry under study in this thesis, the network model would explain the drastic change in supply chain structure in terms of close working relationships between supplier and vehicle manufacturer resulting in a mutual decision for the supplier to expand his activities to include system assembly. A more recent body of work in the area of networks is that carried out at the University of Bath under the auspices of 'The Interorganisational Networking Project'. This work has helped to establish a generic set of networking activities related to the process of establishing and operating supply hetworks (Johnsen, Wynstra, Zheng, Harland and Lamming, 2000). The strategy management doctrine, above, would suggest the supplier changing his role as a result of his, or his customers review of external conditions (the economy, developments in technology etc.) concluding in favour of this change. (Section 2.4 of this chapter describes the network school of thought in more detail) This researcher feels that the network school comes closest to addressing the problems posed in this PhD thesis (see chapters 6 and 7). Again, however, the isolation of 'structure' as an important variable in network performance is viewed to have been overlooked.

One of the criticisms of Williamson and other's work on Transaction costs is that it fails to address the real possibility that if a market relationship breaks down, then they might be improved by negotiation and mutual problem solving. As an alternative to Williamson's approach, Hirschman (1970) formulated a theory of 'responses of decline in firm's organisations' in terms of ***'exit'*** to a better alternative and ***'voice'*** as any attempt to change rather than escape from a problem. His work can be seen as an early move towards partnership relationships, as opposed to more short-term transactional approaches to co-operation between buyers and suppliers. Much later, Hines (1996) termed the study of this trend the ***'Trust School'***. Helper (1990), Sako (1992) and Dore (1987) further developed the work of Hirschman.

From the point of view of this study, the trust school helps to explain the evolution of the structure of individual 'links' in the chain, but says little about the overall chain, and how this may be viewed as a homogenous competitive entity. The 'trust school' is more fully reported later in this chapter.

The *logistics* discipline has its origins in the Second World War (Slack *et al.*, 1991, p529). At the heart of logistics is the 'horseshoe model' showing an information flow from customers to suppliers and a flow of materials going in the opposite direction (Bowersox *et al*, 1986).

Until recently logistics has been seen as focussing on the internal or to some extent dyadic customer-supplier relationships. Persson (1989), however, argues for the need to broaden the internal perspective due to changing logistical technologies, control systems and forms of organisation. Christopher (1992) describes logistics as an 'integrated concept spanning the entire supply chain from raw material through to the point of consumption'.

In the view of this researcher, logistics makes a contribution to the current study because changes in the structure of the supply chain cannot help but have an effect on the efficiency of the logistics of that chain. Towill (1987), for example, uses the concept of 'Industrial Dynamics' to measure the effect of changing network structure on the amount of stock held in the 'pipeline'.

In a similar way to logistics ***Supply chain management (SCM)*** is concerned with both the internal and external flow of materials and information. The focus is on managing the chain towards adding value faster than costs. Value is seen from the customers' point of view i.e. the focus is on how suppliers can satisfy the customer. Value is therefore defined in terms of perceived value. Supply chain management is seen by some as a progression of logistics, attempting to cover, as it does, the extended chain of activities beyond the first level customer-supplier relationship.

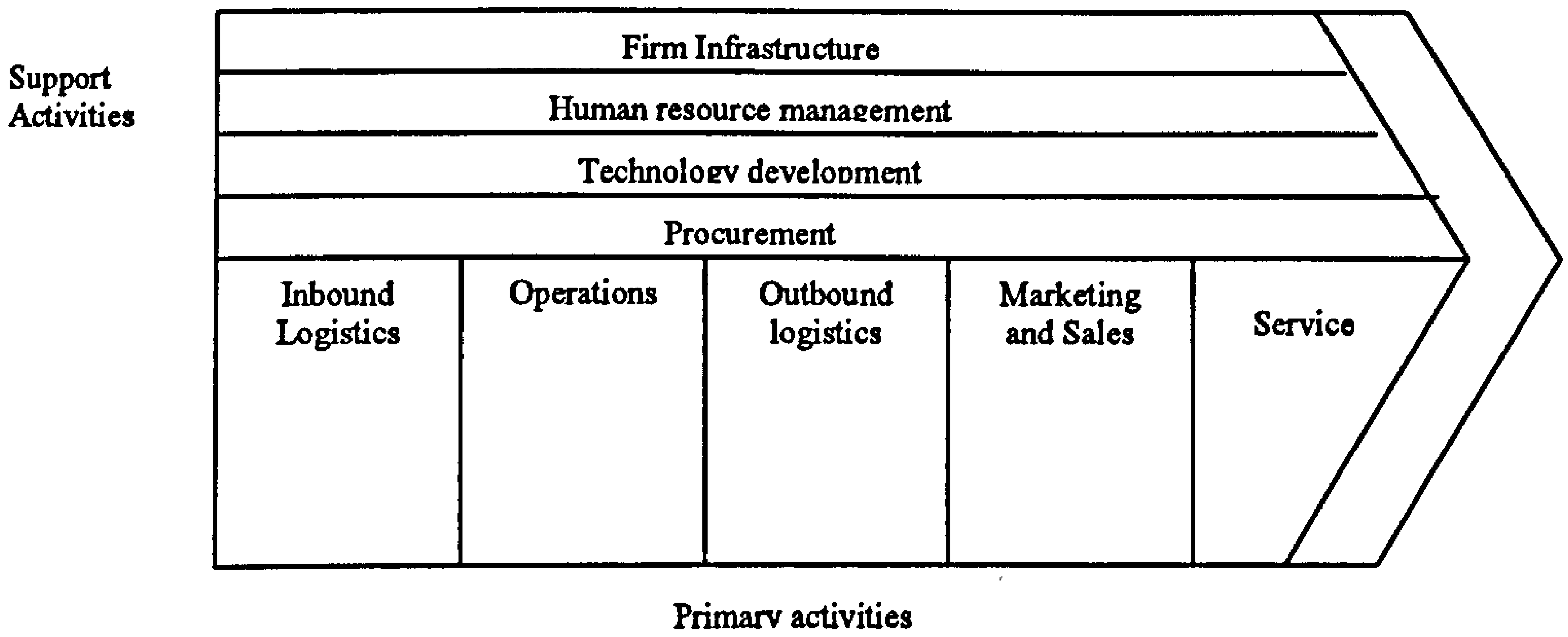


Figure 2.2 The Value Chain Source: Porter (1985)

Similar to Porter (1985) in strategic management, many authors in the supply chain management field use the concept of the value chain. Interestingly, Hayes and Wheelright (1984) discussed the 'commercial chain', externalising their work on operations management to include links both up and downstream of the main organisation.

Two aspects appear to differentiate supply chain management from Porter's work. The first is that SCM is a field largely grounded in the theory of logistics and operations management. In other word SCM is less strategic and more operational.

Secondly SCM has made use of principles from the field of industrial dynamics to model the behaviour of production-distribution chains. The original industrial dynamics work carried out by Forrester (1961) has been taken up and developed by Towill (1987) and the Cardiff University Logistics Systems Dynamics Group, where networks including those in the automotive, electronics and construction sectors have been modelled. The models then allow experimentation with certain operating variables from which effects on performance can be evaluated.

This work is seen to be extremely valuable to the current study but unfortunately from this researcher's perspective does not include examples where the actual *structure* of the network is one of the tested variables.

Further work of relevance in the SCM field is that carried out by Nishiguchi (1989) who analysed the organisation of Japanese companies (most notably Toyota) and their organisation into 'tiers'.

More recently the concept of 'Entreprise logistics' has been developed (Greis and Kasarda, 1997) as a tool for integrating the logisitcs activities both within and between the strategically aligned organisations in the extended entreprise. Of particular relevance to the body of work in this thesis has been the exploration of the fit between an organisation's entreprise logistics capabilities and its supply chain structure (Stock, Greis, Kasarda, 2000). Results from this study indicate that 'entreprise logistics – the ability to co-ordinate logistics between and across entreprises – is a neccesary tool for the coordination of supply chain operations that are geographically dispersed around the world.

A recent theory closely linked to SCM and logistics is that of ***Lean Supply.*** The terminology was spawned from the *International Motor Vehicle Project* (IMVP), a worldwide benchmarking of practice in the automotive industry, coordinated by the Massachusetts Institute of Technology (MIT). In this study, and described in the resulting book '*The machine that changed the world'*, Authors Womack, Jones and Roos (1990) demonstrated that the worlds best (mainly Far Eastern) automotive companies were designing and assembling vehicles with less that half the resources than typical Western mass production companies.

Part of this difference in performance, they suggested is down to the way in which the Japanese managed their supply base.

Unfortunately this work stopped short of discussing in much detail the way in which the supply chains were structured, concentrating instead on the way in which suppliers were managed.

Womack and Jones later developed their ideas to encompass up and down the value chain to form a 'continuous value stream' (1997) Again, little emphasis is placed on the structure of the supply chain.

The final field of theory of particular relevance to this study is that of ***Dualism***. The core of the theory is that there is unequal treatment of economic agents located in different segments of the economy - regardless of their objective worth. The segments can be labour markets (Kerr 1954; Doeringer and Piore, 1971; Piore, 1975; Wilkinson et al 1981) or dual economies (Averitt, 1968). The economic agents may be workers or firms.

Dualists see inequality between the internal and external labour markets, between the primary and secondary sectors, or between the core and peripheral economies according to their own terminologies.

The structure of supply chains – they argue – is driven by organisations seeking to take advantage of these inequalities. For example a large multi-national organisation may choose to outsource assembly of its products to a lower cost sector of the economy, or indeed to a lower cost economy.

Of particular relevance to the aims and objectives of this thesis is the work carried out in the School of Business at Georgetown University, Washington DC (Ernst, Kamrad and McDonough, 2000). Like the current research, this work spans many of the theoretical constructs discussed above, and seeks to view supply structures in the context of a 'best fit' between operating circumstances and supply structure type. The work introduces a taxonomy and corresponding framework for four 'supply structure types'; rigid, postponed, modularized, and flexible. The dependant variables in the selection of structure type are 'postponement' (the degree to which the product can be 'customised' (i.e. changed from a standard sub-product to produce a 'new' end product) at a late stage in the production process, and 'modularity' (the extent to which the product can be broken into standard modules). This work is of great relevance to the current thesis, and is referred to later in chapter 4. It does not, however seek to empirically measure structure, relying instead on a classification into four basic types.

The above summary seeks to briefly describe the contributing areas of existing work related to this study.

The following sections review the most germane topic areas in greater depth, and include this researcher's commentary on the links to the current thesis. In the exploration of links to the current thesis, three areas of theory emerge as the most relevant, containing some fascinating empirical questions with both relevance to supply chain structure, and which do not appear to have been investigated. These are identified in the text, and addressed later in this thesis (chapters 5 and 6). The three areas are "Transaction cost economic theory, combined with cultural/trust perspectives", "Network theory" and "Dualism", which form the subject of the following sections.

2.2 *Transaction cost/ 'Obligational contracting'*

The main proponent of transaction cost economics is Oliver E. Williamson. His work is summarised into two books, **"Markets and Hierarchies." (1975) and "The Economic Institutions of Capitalism:Firms, Markets, Relational contracting (1985)**

Commenting on transaction cost theory, Lazerson (1990) states that "... from the standpoint of traditional economics, the option of vertical integration is a simple matter of calculus...". Coase, in his original work on the subject, stated this formula in terms of the decision to rely on the market occurring when 'the cost of organising an extra transaction within the firm becomes equal to the costs of carrying out the same transaction by means of an exchange in the open market or the cost of organising in another firm' (1937)

Williamson set out the drivers of this cost equation, seeking to explain the circumstances under which the cost of an external transaction is likely to exceed those of carrying out the work internally.

Williamson proposes that where transactions have highly uncertain outcomes, recur infrequently, and require unique or transaction-specific investment, they can be performed most efficiently internally - within a hierarchy (vertical integration).

In a perfect market, transactions are carried out without transaction costs. Information is freely available, decision making is rational, there are always alternative suppliers and buyers, and there are no carry-over effects from one period to the other of a specific transaction between two parties in the market. When these conditions do not prevail, transaction costs emerge because there is a need to devote efforts to organising, carrying out and controlling transactions among interdependent actors.

The transaction-cost approach first of all recognises the phenomena of these costs, then seeks to explain the governance structure (institutional form) – market, hierarchy or intermediate form – which would minimise the costs, according to the circumstances of the transaction.

Williamson perceived vertical integration as the favourable option in certain circumstances, because one party in an independent (market) relationship is bound to behave **opportunistically**, due to asset specificity (1975). Asset specificity is the notion of specific investment in resources for that one transaction. An example would be a supplier purchasing plant and equipment specifically to produce components for a particular customer. Williamson's argument is based on the notion that this specificity provides the supplier with an opportunity to artificially boost the price to the customer and, he argues, the supplier will take advantage of that opportunity. In this situation he argues in favour of vertical integration. He suggests that when there is 'bilateral dependency' in a relationship (the customer is dependent on the supplier and/or vice versa) then the transaction cost will increase beyond that encountered with vertical integration.

So, the human characteristic of 'opportunism' is a key assumption in Williamson's transaction cost logic. A second assumption is that of **'bounded rationality'**. This is defined as the inability to predict and therefore solve problems above a certain level of complexity. *"The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behaviour in the real world"* (H.Simon, 1957) As will be explained later this refers to neurophysiological limits on the one hand and language limits on the other.

If the effect of 'opportunism' is to be contained in a market transaction then the contractual agreement must cover every circumstance that may occur in the lifetime of the contract. In many situations, Williamson argues, this is not possible because of 'bounded rationality'. (The contract cannot cover every eventuality when the situation contains a large number of unknown factors.) This phenomenon becomes a stronger determinant of structure as the complexity of the potential contract (level of uncertainty) increases. New or untried technology (both product and process) and components which are critical to the competitive advantage of a product would both be examples of situations where the complexity of a contract would be very great. Williamson argues that the phenomenon of 'bounded rationality' means that these types of transactions can be carried out more efficiently internally.

"Opportunism" and "bounded rationality" are the two key human characteristics at the heart of Williamson's model for determining governance structure. The other variables are to do with the type of environment in which the potential transaction is to take place. Williamson terms these the 'objective properties of the market'. Again two key properties are postulated. "**Uncertainty**" refers to the level of possible future contingencies in a contract, and the consequences of failure. "**Small numbers exchange relationships**" refers to the number of qualified alternative suppliers of the product or service. Thus a '**small numbers exchange condition**' refers to a situation in which very few sources of supply exist.

It is the pairing of the human characteristics on the one hand and the properties of the market on the other that is at the heart of transaction cost theory. ...the cost of writing and executing complex contracts across a market *vary with the characteristics of the human decision makers who are involved with the transaction and the objective properties of the market on the other.* (Williamson, 1975 p8, emphasis in original)

The pairing of bounded rationality and uncertainty is considered first. If, in consideration of the limits of bounded rationality, it is very costly or impossible to identify future contingencies and specify, beforehand, agreed responses, then long-term external contracts may be avoided, in favour of vertical integration. Rather than attempt to anticipate all possible contingencies from the outset, the future is permitted to unfold. Situations are managed internally as they occur.

The relation between opportunism and a small numbers exchange relation will be explained more fully later in the section (this is necessary because the theory will be tested against case study supply chains in chapter 5) By way of introduction, Williamson states that:

1. *"opportunism refers to a lack of candor or honesty in transactions, to include self-interest seeking with guile";*
2. *"opportunistic inclinations pose little risk as long as competitive (large numbers) exchange relations obtain;*
3. *"many transactions that at the outset involve a large number of qualified bidders are transformed in the process of contract execution, so that a small numbers supply condition effectively obtains at the contract renewal interval; and*
4. *"recurrent short-term contracting is costly and risky when opportunism and transactions of this latter kind are joined.*

   (Williamson 1975, pp9-10)

Williamson provides an operational model of his transaction cost theory, in the form of his 'organisational failures framework'. Figure 2.3 gives a diagramatical representation of the model.

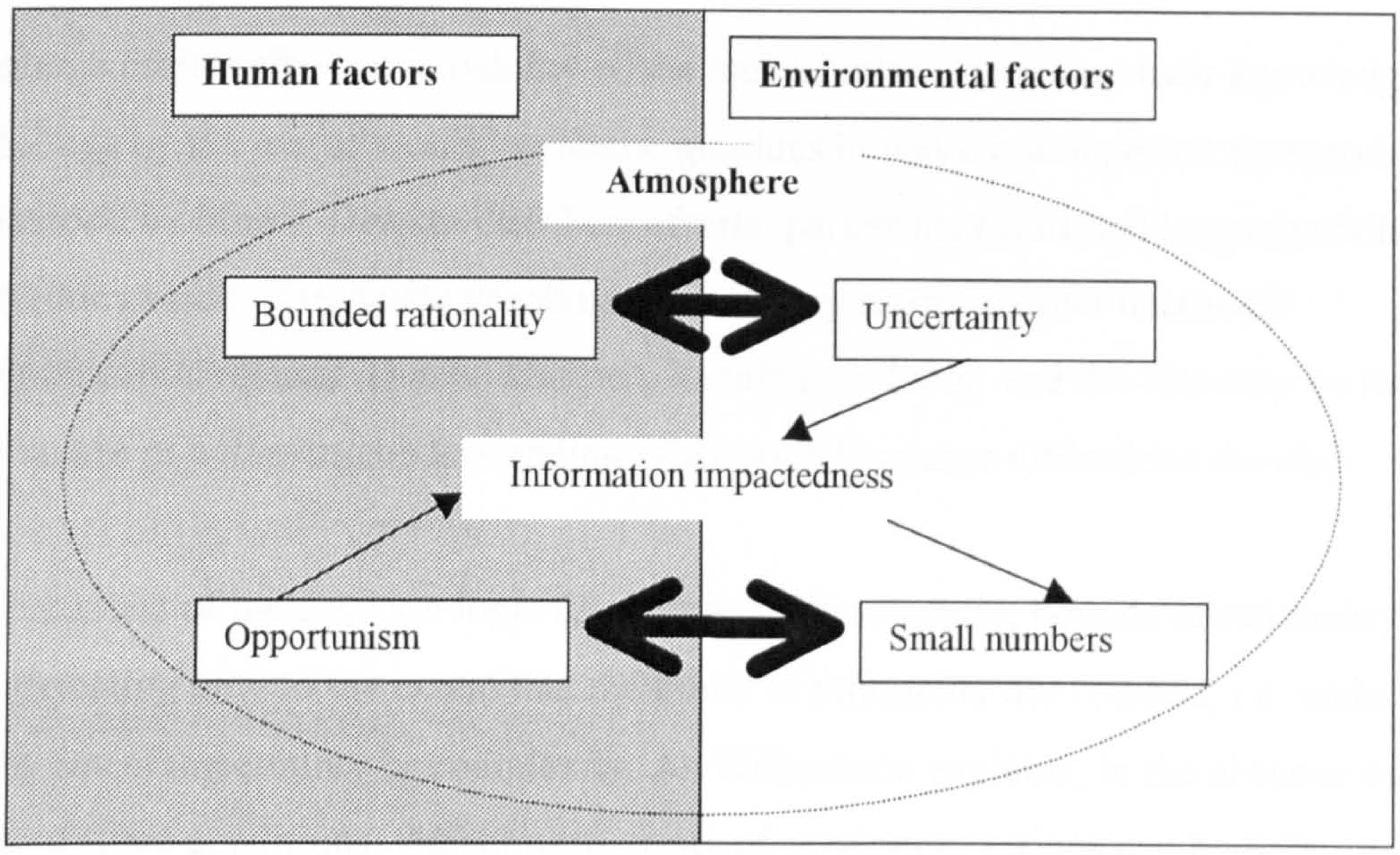


Figure 2.3 Williamson (1975) Organisational failures framework.

The following section explains the organisational failures framework in greater detail, and as such is picked up in the following chapter where case study supply chains are tested against leading theoretical frameworks.

Bounded rationality and complexity/uncertainty

Bounded rationality refers to human behaviour that is "intendedly rational but only limitedly so" (Simon, 1961, pxxiv). Williamson suggests that although it is widely appreciated that human decision-makers are not rapid calculators, the implications for economic organisation has received very little research (1975, p 23). He expands on his description of bounded rationality, explaining that it involves neurophysical limits on the one hand, and language limits on the other. The physical limits take the form of rate and storage limits on the powers of individuals to receive, store, retrieve and process information without error. Again he quotes from the work of Simon (1957, p. 199) …"it is only because individual human beings are limited in knowledge, foresight, skill and time that organisations are useful instruments for the achievement of human purpose"

Language limits refer to the inability of the individuals to articulate their knowledge or feelings by the use of words, numbers, graphics in ways which permit them to be understood by others. Despite their best efforts, parties may find that language fails them (due to lack of requisite vocabulary), and they resort to other means of communication instead. Demonstrations, learning by doing, and the like may be the only means of achieving understanding when such language difficulties develop.

In the context of the decision logic for supply chain structure, bounds of rationality are interesting only to the extent that the limits of rationality are reached, i.e. under conditions of uncertainty or complexity. As Williamson explains, in the absence of either of these conditions, the appropriate set of contingent actions can be fully specified at the outset. Thus it is the relationship between bounded rationality and the environment of the transaction which creates the basis for rules of 'structural logic'. Given a sufficiently simple environment bounded rationality constraints are not reached, and governance structure choices are not posed.

Williamson further differentiates the transaction environment, for the purposes of analysis. He explains the difference between complexity and uncertainty with reference to several 'gaming' problems. Whereas the decision tree for a simple game such as 'noughts and crosses' can be constructed with relative ease, a more complex problem such as chess is theoretically possible, but very time consuming and costly. Most decision problems, unlike board games, are not deterministic but involve decision-making under uncertainty. For these, the comprehensive decision tree is "not apt even to be feasible" (Williamson, 1975):

> "What may be referred to as "uncertainty" in chess is "uncertainty introduced into a perfectly certain environment by inability – computational inability – to ascertain the structure of the environment." (Simon, 1972, p 170) But the result of the uncertainty, whatever its source, is the same: approximation must replace exactness in reaching a decision"

The level of 'computational inability' is of course transient, and advances in knowledge as well as available computing power push the boundaries of what might be termed 'uncertain'. Examples of relevance to supply chain structure are the ability to more accurately predict future demand, as well as reduction in time-scale for proving new technology and designing new products.

Opportunism and small numbers

Williamson contends that opportunism – "self seeking with guile" - has profound implications for choosing between alternative forms of supply chain structure.

He distinguishes opportunistic behaviour from both "stewardship behaviour" and "instrumental behaviour". Opportunism involves making "false or empty, that is self-disbeleived, threats and promises" in the expectation that individual advantage will thereby be realized (Goffman, 1969. P 105.)

Stewardship behaviour, on the other hand involves a trust relationship in which the word of a party can be taken as his bond. Instrumental behaviour is defined as more neutral, more innocent, in which there is no self awareness that the interests of a party can be furthered through the use of deliberate stratagems.

Williamson makes a number of interesting points concerning opportunism which will be of importance in the ensuing research. First, adavntages that are due to pre-existing or fully disclosed productive conditions (such as unique geographical location or differential skill/quality level) that obtain from the outset of the contract should not be considered opportunistic. Rather, parties are simply realisinbg returns to which they are entitled. These should be distinguished from either (a) selective or distorted information disclosure or (b) self-disbelieved promises regarding future conduct.

The second point of note concerns 'small numbers' trading situations. This is felt to be especially important in the European Automotive industry. At the outset of a contract –

for example during sourcing for a new component for a new vehicle, a large numbers condition will appear to obtain – in other words there are a relatively large number of alternative qualified sources for the component. However, as the contract progresses, and certainly by the time it is up for renewal, the large numbers situation may no longer pertain. *This is especially true when capital and/or research and development has been invested by the first supplier* – a situation of great relevance to the European automotive industry.

Information impactedness

Information impactedness arises mainly because of uncertainty and opportunism. It is the situation where the true circumstances of the transaction are known to one or more parties but cannot be costlessly discerned by or displayed for others. That is to say, it is to do with the disparity of information between parties in the transaction.

Atmosphere

Atmosphere is referred to in the model as recognition that economic transactions are not simply cold clinical dealings unaffected by the environment in which they take place. For example, a firm who are seeking to establish more open and honest relationships with their suppliers may have made presentations, invited suppliers to briefing sessions and so on to try establish better relationships. This atmosphere may also affect the choice of structure.

Asset specificity

In his later work, Williamson proposes asset specificity as the most critical dimension for describing transactions (1985, p30 & 83) He presents a seemingly water tight argument, which is particularly germane to the present study of supply chain structure.

Asset specificity refers to durable investments that are undertaken in support of particular transactions (ibid. , p55). Four types of asset specificity are distinguished: site, physical, human and dedicated specificity. Site specificity refers to the situation whereby – for example, a supplier sites his assembly or manufacturing site in close proximity to his main customer so as to economise on inventory and transportation expenses. The fact that setup and/or relocation costs are great is apt to dictate the maintenance of the relationship for the useful life of the assets between the parties.

Physical specificty is characterised by mobile and physical features of assets such as specific dies, moulds and tooling for the manufacture of a component. Lock-in problems are avoided if, as is often the case in the west, the ownership for the assets is concentrated on the purchaser (as in the case where a purchaser of plastic mouldings owns the moulds even though they are deployed at the supplier's plant). In such instances the purchaser can reclaim the assets and reopen the bidding in case of contractual trouble. Human asset specificity arises in a learning-by-doing fashion through long-standing customer-specific operations. Dedicated asset specificity is when a discrete and/or additional investment in generalised production capacity in the expectation of a significant amount of sale of product to a particular customer.

Chapter 5, details the investigation of transaction cost theory using empirical data from the case study supply chains.

2.3 Trust / cultural perspective

In contrast to the Williamsonian analysis of contracting structure choice, which primarily relates the level of obligation between customer and supplier to the extent of 'asset specificity' in the transaction (in other words the level to which the supplier has invested in specific assets for this particular transaction), Dore (Dore, 1987) provides a much more cultural explanation. In work based in the Japanese economy, he finds that the level of obligation cannot be explained by asset specificity alone. Rather, an extra economic factor particularly strong in Japanese culture is assumed to be responsible for the continuation and prevalence of high levels of market transactions. (which in terms of supply chain structure means high levels of outsourcing, and longer supply chains with more 'links'.) the extra economic factor Dore suggests can be termed benevolence, defined as 'something shown in relations between unequals, by superior to inferior, the reciprocal of which is usually called loyalty'; or goodwill, which is more status-neutral and broader in its meaning defined as 'the sentiments of friendship and the sense of diffuse personal obligation which accrue between individuals engaged in recurring contractual economic exchange' (Dore 1987:170). He refutes the Williamsonian assumption of 'opportunism being a universal human trait' and associated assertion that trading relations are shaped by this – thus:-

> *...Here is another of those timeless generalisations concerning 'capitalist economies' about which Japan gives pause. Transaction costs for large Japanese firms may well be lower than elsewhere. 'Opportunism' may be a lesser danger in Japan because of the explicit encouragement, and actual prevalence, in the Japanese economy of what one might call moralised trading relationships of mutual goodwill (ibid., p.173)*

The cultural disposition of the Japanese are further assumed to have four significant connected factors: collective risk-sharing and long-term advantage, dutifulness, freindliness, and economic efficiency.

Having formulated this cultural explanation of the greater prevalence of relational contracting in Japan, Dore then asks; how uniquely Japanese is it? The answer given is that, although the Japanese are assumed to have an unusual preference for relational contracting, they are not uniquely susceptible to it. Referring to some British evidence in the Civil, construction, textile and retail industries that demonstrates the existence of a similar mode of contracting in the U.K., he further hypothesises that relational contracting is a phenomenon of affluence. When well-off consumers become more quality than price conscious, relational contracting is held to come into its own. It does so for two reasons. First because quality assurance demanded by affluent customers, has to depend largely on trust. Second, when affluence reduces price pressures, tendencies to prefer stable and friendly relationships to an adverse bargaining one emerge. Having referred to a stronger emphasis on quality

In a similar vein, Mari Sako in her seminal work, "Price, Quality and Trust – Inter-firm relations in Britain and Japan" (Sako, 1992) Contrasts approaches of close long term trading relationships with arm's length adversarial commercial bargaining. This work uses organisational efficiency as the independent variable, whilst measuring the effect of a spectrum of relationship practices and supports the view that high levels of trust in general produces greater effectiveness and translates into higher levels of quality at favourable cost.

2.4 Network theory

Network theory recognises the difference in perspective between 'organisational theory' which tends to conclude that individual organisations are embedded in their environment and that thus behaviour is greatly constrained, and Strategy Management which is concerned with the opportunities for directing and managing the behaviour of the individual organisation, consequently assuming that the organisation possesses a certain degree of freedom of choice.

Network theorists describe industrial networks as 'sets of connected exchange relationships between actors controlling industrial activities'

J.Carlos Jarillo, in "Strategic Networks", (Jarillo, 1993) defines strategic networks thus:

> "Strategic networks are long term, purposeful arrangements among distinct but related for profit organisations that allow those firms in them to gain or sustain competitive advantage vis-à-vis their competitors outside the network, by optimising activity costs and minimising co-ordination costs … Trust is at the very core of what a strategic network is, for it is the mechanism that lowers transaction costs, thus making the network viable economically"

Most work on network structure tends to focus primarily on inter-organisational relations rather than networks (Human and Provan, 1977). Organisational theory, like Transaction

Cost Economics has been used to explain aspects of networking, such as governance or inter-organisational power and resource acquisition.

One of the most obvious structural issues here, is concerned with network boundary – what is defined as within, and without the governance of individual actors in the network. A related issue is size of network in terms of number of network connections or number of direct and indirect relationships. In the vocabulary of this thesis, these concepts are referred to as the 'length'and 'breadth' of the supply chain, and the 'distribution of value addition activties' amongst the network.

Another issue relates to the types of relationship, which in turn is related to ownership and control of the network. Types of relationship in the spectrum include vertical integration, joint venture/strategic alliance, networking/multiple partnerships, licensing/franchising, single and dual source, preferred suppliers and arms' length contracts. Cox (1996) developed a typology of internal and external contractual relationships. It is argued that the effective boundaries of the firm will be based on analysing types of relationship competencies. Core skills and competencies tend to be controlled through internal contract. Complementary skills of medium asset specificity are more likely to be outsourced through various forms of co-operation. In contrast, low asset specificity skills which have residual competence will be outsourced through arms' length contracts.

In essence, the Network School views the system of firms engaged in production, distribution and use of goods and services as a network of relationships (Johanson and Mattsson, 1987). There is a division of work in a network that means that firms are dependent on each other. Therefore their activities need to be coordinated. Coordination is not achieved through a central plan or an organisational hierarchy, nor does it take place through the price mechanism, as in the traditional market model. Instead, coordination takes place through interaction among firms in the network, in which price is just one of the several influencing conditions. The firms are free to choose counterparts, and thus market forces are at play. To gain access to external resources, however, and to make it possible to sell products, exchange relationships have to be established with other firms. Such relationships take time and effort to develop, which constrains the firms' possibilities to change counterparts. The need for adjustments among the interdependent firms concerning the quantity, and quality of goods exchanged, or the timing of such exchanges call for more or less explicit coordination through joint planning, or through power exercised by one party over the other. Each firm in the network has relationships with customers, distributors, suppliers, etc., plus indirect relations, via those firms, with the suppliers and customers of them.

In the context of the current PhD thesis, the concept of relationship exchanges can be said to extend as far a specifying the nature of the goods to be exchanged, and hence to directly influence the structure of the network, in terms of who in the network is responsible for supplying which bits of the product. This however is a part of the concept which has received little attention.

Some very interesting work has been carried out by Reve and Cox, which in utilises notions inherent in business strategy management, network theory, and to an extent Transaction cost economics. In 'The firm as a nexus of internal and external contracts' Reve (1990) makes an important conceptual development of the efficient boundary of the firm from a strategic management point of view. Firstly Reve suggests firms should focus on unique resources (core competencies and skills) to respond to the requirements of an ever-changing environment. Only these unique resources should be governed within the firm. Secondly firms should outsource complementary skills through close external contracts, as core skills need to be complemented by complementary skills. Thus, the properties of the transaction determine what constitutes the efficient boundary of the firm (Reve, 1990, p.144) Thirdly this efficient boundary should be assessed on a continuous basis. Inspired by Reve, Cox (Cox 1996) discussed which types of external contractual relationships firms ought to adopt under what circumstances. The basic argument is that firms should adopt an internal governance structure for core skills which are high in asset specificity.

Hence, for different reasons, Reve and Cox identify assett specificity as being an important determinant in the structure of the industrial network.

More recent work at the University of Bath has established a classification of supply networks (Johnsen, Zheng, Harland, Lamming, 1998, 1997), considered useful in establishing a generic set of networking skills required in the establishment and operation of supply networks.

2.5 Dualism

The core of the theory is that there is unequal treatment of economic agents located in different segments of the economy regardless of their objective worth. The segments can be labour markets (Kerr 1954; Doeringer and Piore, 1971; Piore, 1975; Wilkinson et al 1981) or dual economies (Averitt, 1968). The economic agents may be workers or firms.

Dualists see inequality between the internal and external labour markets, between the primary and secondary sectors, or between the core and peripheral economies.

Applied to the language of supply chains, their theory can be translated as follows: workers, often of a temporary status and/or in peripheral firms, in the external labour market (or the secondary sector) and small firms – often suppliers, in the peripheral economy don't receive what they are worth. That they do not earn what the market would dictate is built into the structure of dualism rather than due to the individual skill levels of the economic agent.

Screening thresholds called the 'points of entrance' (Kerr 1954 p 101) or the 'ports of entry and exit' (Doeringer and Piore, 1971:2) at the boundary of the two labour markets effectively outsiders from insiders. Internal workers are promoted according to administrative rules along clearly defined mobility clusters. They are largely protected from external shocks through stabilising institutional arrangements. Their wages are relatively high and well defined by length of service based wage scales. Amenities and fringe benefits are ample. Working environments are generally good. Job security is substantial.

By contrast the direct inverse applies to the conditions of the external workers. Similarly, small firms in the peripheral economy are seriously discriminated against in terms of access to technologies, capital and human resources readily available to large firms in the core economy.

Furthermore, workers and firms in the external and/or peripheral sectors are largely subject to laissez-faire competition of the market. When the economy is booming, they are used extensively. When it contracts, they are the first to be forced out of economic activities.

Berger and Piore (1980) propose a dynamic theory of dualism in which the strategic use of subcontracting through the substantial shift of productive capacity – and therefore risks – to the secondary sector helps large firms survive successfully in the world of uncertainty and flux. They cite French and Italian cases in which the origins of this strategy are seen in a corporate response to a massive wave of strikes in the late 1960s in both countries that seriously halted production and rigidified labour contracts in the primary sector through subsequent labour legislation. Flexible recourse to subcontracting is seen to have usefully resolved the problem.

With reference to the current study, dualist theory would seek to explain the different distributions of value addition in product supply chains for ostensibly similar products with reference to economic inequalities which are realised as cost differences, so atracting more value addition to lower cost sectors of the economy. In other words, to those where the cost is least, the value addition will migrate.

Table 2.1, overleaf seeks to summarise, and discuss the most relevant areas of work, along with their links to the current PhD study.

Table 2.1 Principal theoretical frameworks with a bearing on supply chain structure.

	Networks	Trust	Transaction cost/ 'Obligational contracting'	Logistics	Lean supply	Supply chain management	Dualism	Business strategy Management
Main Proponents	Johanson Powell Hakanson Jarrilo Snehota Reve	Helper Hirschman Sako Dore	Williamson	Bowersox Christopher Elram Towill	Womack, Jones, Lamming	Harland, Houlihan, Oliver, Nishiguchi, Slack	Piore, Sabel, Berger Edwards	Porter Skinner Puttick Chandler Mintzberg Pfeffer
Definitions	Model of organisation-evironment interface. Capabilites of individual firms dictated by interactions with small number of 'surrounding firms' in their network	Closer harmonious working relations with suppliers, based on trust and respect.	Seeks to explain the economic rationale of alternative forms of organisation, i.e. their relative efficiency.	Management of information flow 'up-stream' and materials flow 'down-stream' against business objectives	Collection of principles aiming at removing waste from product development and manufacturing processes.	Management of the 'value chain' Adding value faster than cost.	unequal treatment of economic agents located in different segments of the economy.	The generation and implementation of the pattern of activities which has an impact on the achievement of the organisational goals in relation to its environment.
Central concepts	Relationships develop with small number of external actors (e g. customers, suppliers, competitors) which dictate the organisation of resources in the supply chain.	"Exit" or "Voice" as response to unsatisfactory supplier relations. Voice introduces the concept of mutual problem resolution rather than the threat of re-sourcing to another supplier.	Where transactions have highly uncertain outcomes, recur infrequently and require unique or transaction specific investment, they can be performed most efficiently with vertical integration – i.e. less stratified supply chain.	Achieving the conditions for moving goods and information in a timely manner whilst achieving business objectives	Removal of waste Collaborative working with suppliers. Outsourcing greater value. Latterly 'value stream' applies theory to wider supply chain.	Relationship management. Sourcing policy. Logistics.	Dualists see inequality between the internal and external labour markets, between the primary and secondary sectors, or between the core and peripheral economies according to their own terminologies	"survival of the fittest" 'Best-Fit' between environment and organisation capabilities.
Gaps/Bearing on the work of the thesis	Supply chain structure results from the collective and connected intent of limited number of actors in the chain. Not tested against concepts such as modular supply/systems purchasing	Consensus agreement on boundaries in supply chain. Still only extends to diadic buyer-supplier relationship.	Seeks to link transaction type and cost to supply chain structure. Assumes opportunism as standard behaviour, no conclusive work to prove this in Euro. Auto Industry.	Change in structure assumed to have an effect on efficiency of logistics. Therefore assumed to be one determinant in choosing structure. Again, not tested with Supply Chain Structure as independent variable.	More to say about management of the chain rather than structure.	Goes some way to dealing with the supply chain as a single competitive entity, but focusses on management of chain rather than structure.	'Stratification' of the supply chain is dicated by cost differences between firms (e g relative cost of employment, land, buildings etc). Little work against recent changes in Euro. Auto. industry.	Individual strategies of the firms of the supply chain are based on their individual interpretation of the external environment. Individual strategies determine the structure. The supply chain 'fits itself' to its environment via the collective action of the firms in it.

Chapter 3

Research method

- **This chapter formalises the research hypothesis and details the development of the research methods related to this investigation. An introduction to the field research is included, which links with a more detailed account of this subject in the following chapter.**

The previous chapter has reviewed relevant areas of theory relating to supply chain structure, and indicated areas in which the particular set of circumstances in Western Europe has led to changes in structure which are not fully explicable with recourse to existing theory alone.

As detailed in chapter 1 of the thesis, the primary aim is concerned with seeking a new explanation of the determinants of supply chain structure. The method by which this will be sought is to model known case study supply chains, and compare their structures against that predicted by already existing 'structure' theory. This method is shown diagrammatically in figure 3.1, overleaf.

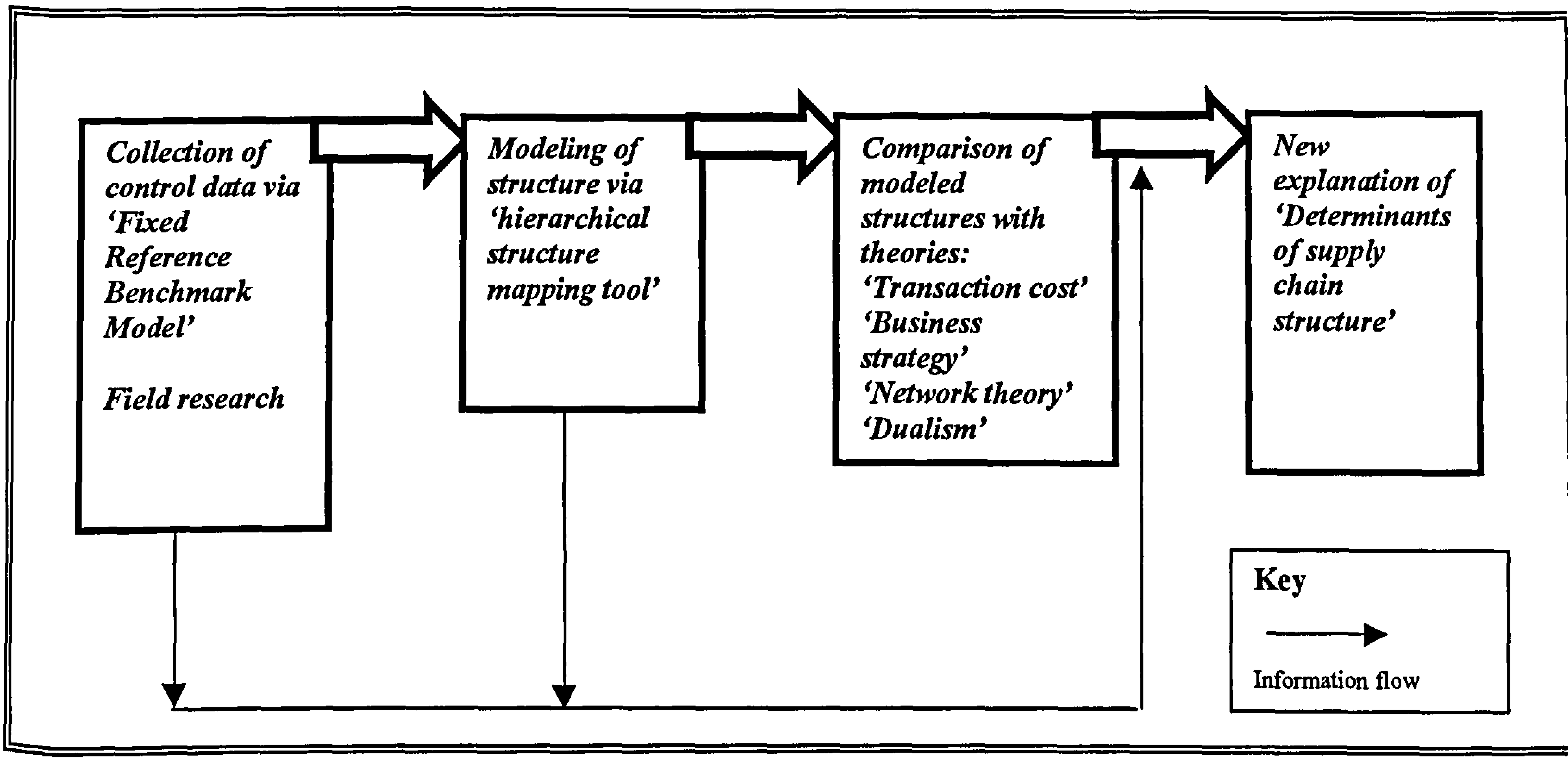


Figure 3.1 Research method

The first part of the 'novel' research work presented in this thesis is concerned with reviewing the three areas of existing theory – Transactional cost economics, Business Strategy Management, Network theory and Dualism, with respect to **case study supply chains**.

The particular chains chosen to compare 'theory with practice' are automotive components or systems. These have been chosen in such a way as to represent a cross section of European Automotive practice, in the family car sector, in the mid to late 1990's. Ostensibly common components were selected across six European vehicle manufacturers' (VMs') supply chains[1], in order to maintain consistency of findings.

Section 1 of this chapter presents details of the content and rationale for the 'phantom benchmark' modelling tool – a tool developed to collect and compare background information on the chains in order to isolate the effect of 'structure'.

[1] Much of the initial field research data was collected during the author's involvement in the Brite EuRam II project; Future Working Structures, in which six partner vehicle manufacturers co-operated.

The following, second section develops the 'hierarchical structure mapping tool' – a method of presenting and comparing the structure of the supply chains under study.

3.1 Development of 'phantom benchmark' modeling method

The first requirement was to ensure that the supply chains selected would provide a meaningful and academically rigorous sample.

When it came to selecting case study supply chains, each Vehicle Manufacturer in the study offered broadly similar models from within its product range from which to select the components. Beyond these qualifying similarities, however lay a mesmeric number of variations, nuances and quirks within and across the supply chains. This is to be expected, as the supply chains have evolved over many years, through consecutive model cycles, in different economies and as a result of different company strategies. Consequently, anything short of rigorously isolating and then defining common elemental activities, independent of the supply chain's particular environment, would have produced flawed results when attempting a supposed direct 'comparison' with established theory.

It was recognised that:

a) a true cross sectional analysis of enough relevant supply chains in the sector was not feasible, and, more importantly;
b) the sample chosen could only be used rigorously if the variable of 'structure' could be isolated effectively from other variable features of the supply chains in the sample.

From this line of reasoning, came the idea to compare each of the supply chains against a fixed comparator or non-varying reference point – the 'phantom benchmark'.

The comparator consists of those 'other' variables in the supply chains which it is felt should be measured to enable the effect of structure to be investigated. The 'phantom benchmark' therefore was a synthesised embodiment of the distinct elements at work in an hypothetical optimal practice product supply chain.

The idea of a fixed reference point was developed into a theoretical model of optimal or best-practice supply chain management. The model as shown below is not original in its constituent aspects. Taken as a whole though the author believes it gives form to the concept of various novel forms of supply chain such as are developing in the European Automotive industry.

3.1.1The elements of the Fixed Reference Benchmark Model

The choice of appropriate elements for the phantom benchmark is governed by the desire to describe those features of a supply chain which have an effect on its performance, but are independent of its physical structure (see chapter 1, section 1.2 for definition of 'structure')

The starting point for the development of the elements is the core processes at work in the supply chain.

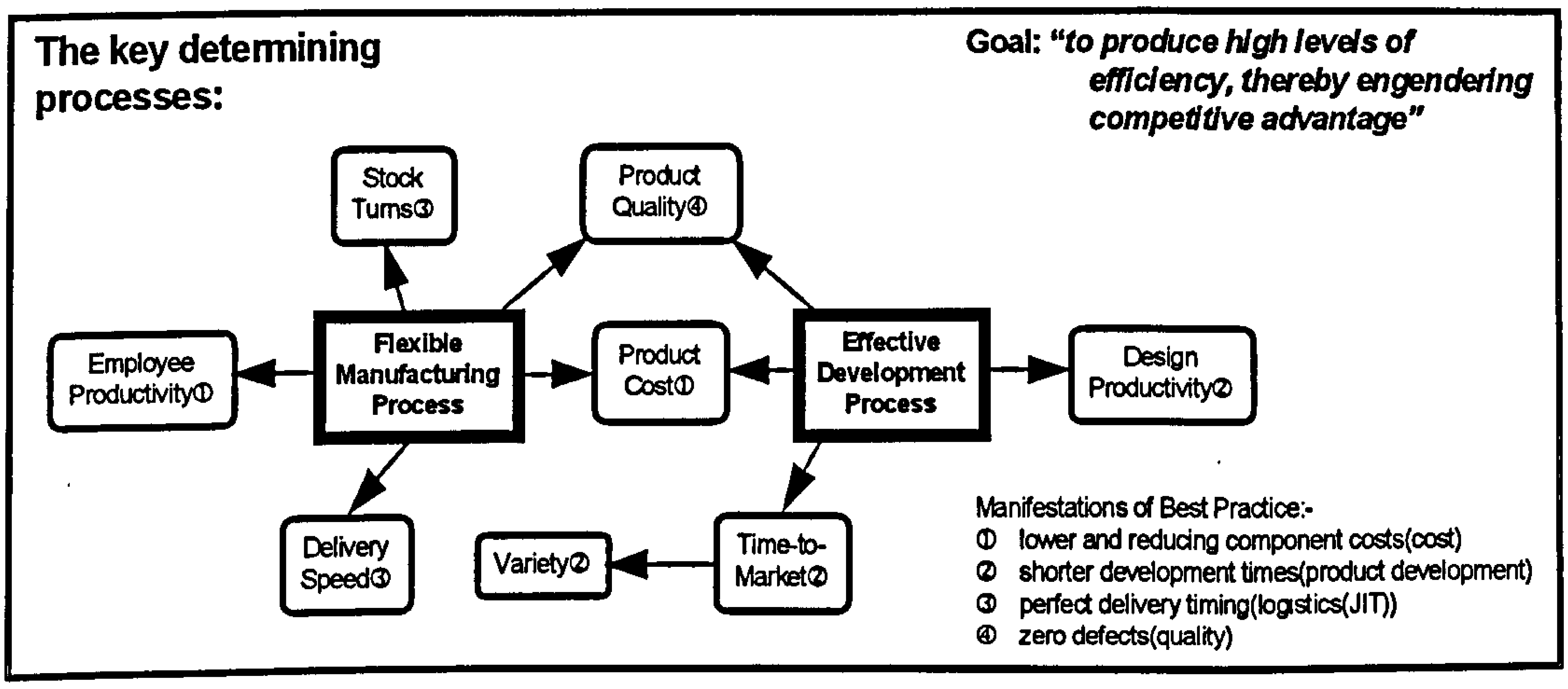


Figure 3.2 Key determining processes and performance indicators

Figure 3.2 above depicts the key processes of manufacturing and development, and also indicates measures against which the performance of the processes may be assessed.

The Fixed Reference Benchmark Model needs to include those features – both physical and behavioural – which affect, in some way, the operation and/or performance of the two determining processes.

One of the important features, this thesis postulates, is the structure of the chain. The Fixed Reference Benchmark Model needs to provide a way of collecting information on the other influences, in order that their affect may be considered during the structural analysis. In itself the model represents hypothetical optimum practice. It is a point of reference. Not necessarily realistic, or even a desirable target, rather it allows the reality of the case study supply chains to be recorded in a consistent way, and in a way which enables the isolation of the effect of their structure.

The following sections set out the elements of the model, indicating the reason for their inclusion. The method for gauging a particular supply chain's 'fit' to the benchmark model is also indicated. The approach taken was to expand each of the main constituent elements of the model, by giving considered definitions of often contentious aspects such as: 'single sourcing' and 'tiered supply base'. And detailing those practices that again are considered to manifest 'best practice'. A later chapter (5) develops the elements further to provide numerical measures to indicate the fit with the model.

So what elements should be included?

Tiered supply base

The physical routing of communication in the chain and the extent to which the chain is orchestrated as a whole is considered to be important. For use in the model these concepts are grouped under the element 'tiered supply base'.

The benefits of the tiered model can be traced to the traditional Japanese Keiretsu supply base in which benefits were gained from a high level of dedication - a shared destiny relationship where the supplier relied on the success of its one main customer, and vice versa. Here, long-term business plans were normally shared between the partners. In addition the roles of the partners were very focussed (Nishiguchi, 1993). There was a high degree of stability in the supply base, and each partner had deliberately orchestrated narrowly focussed processes and resources to satisfy only one main customer. Another contributing beneficial factor was that collaboration between partners - both vertically (up and down the supply chain), and horizontally to supply chains of interfacing components and systems - was usually strong, well established over successive model cycles, and managed externally without the need for involvement of the assembler/customer (Lamming,1994). Lamming talks of 'tiering' of the supply base coming about when suppliers on the same horizontal level are encouraged to communicate directly with each other, rather than indirectly via their common customer.

This is considered useful on two levels. First, their respective components or systems may eventually end up adjacent, or connected in the final product. Direct communication about the interface between the two is clearly more beneficially carried out directly rather than the traditional case of the mutual customer acting as an intermediary in the discussion. The second form of 'horizontal' communication or collaboration is when a group of suppliers at the same level in a chain get together to discuss issues of common interest to-do with the supply chain. Examples often quoted (Lamming 1990, Jones 1992) are schedule stability, packaging requirements and transportation problems. Often this comes about when supplier clubs, or discussion groups are formed. Figure 3.3 illustrates the benefits to the supply chain of forming into more self-managing 'tiers'.

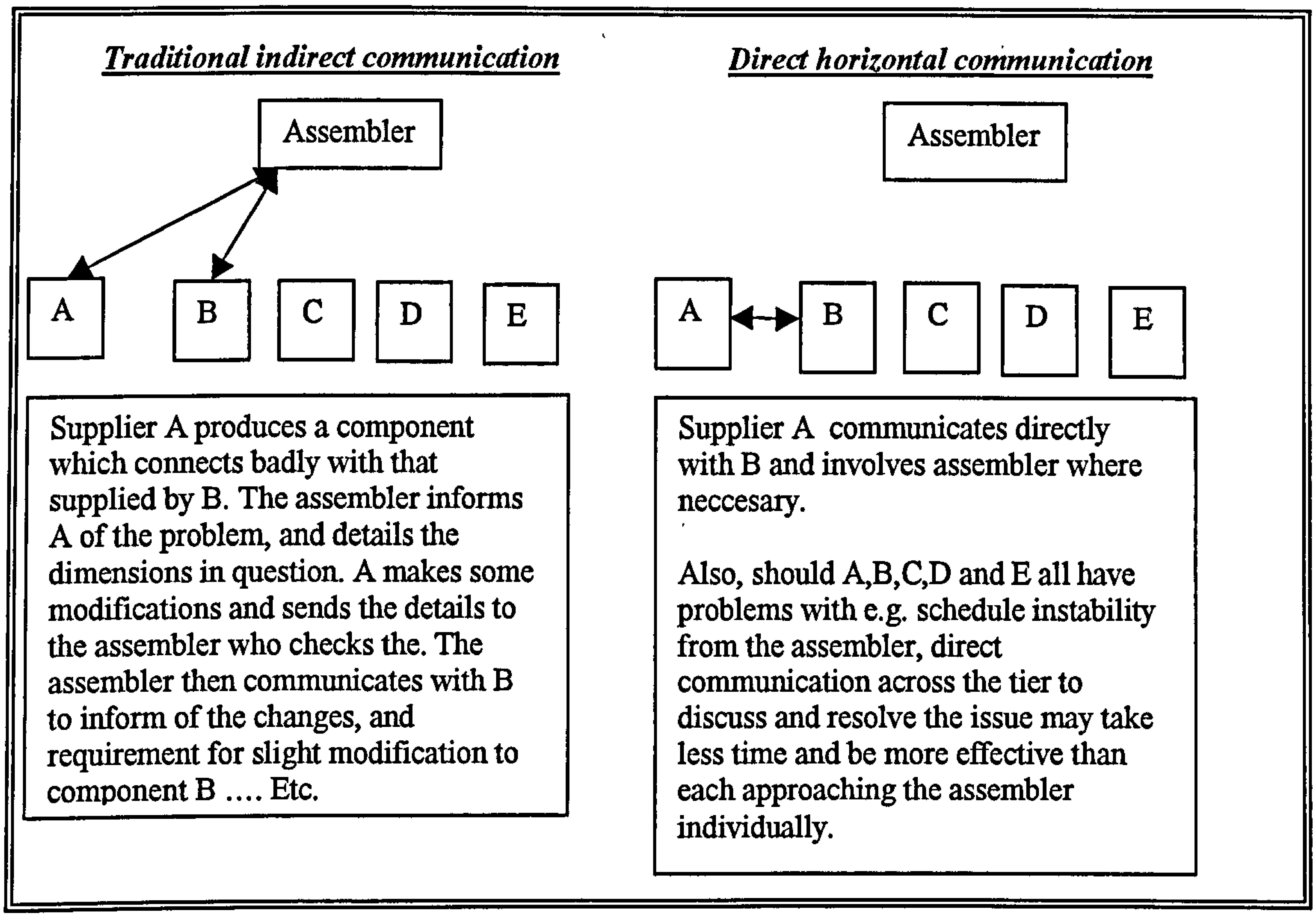


Figure 3.3 horizontal collaboration in supply chains

The tiered model (at least in the sense of the 70's and 80's Japanese keiretsu based supply chains) had some success in achieving a dedicated supply chain, without the unwieldiness of vertical integration (Womack and Jones, 1990).

The definition - used for the fixed reference 'Fixed Reference Benchmark Model', therefore consisted of three aspects:

- The degree of **integrity** of the supply chain to the customer;
- The degree of **demarcation** or **"focusedness"** of the supplier in terms of the different products it supplies to its customer(s);
- The amount of **direct horizontal collaboration** between adjacent suppliers in the same tier.

figure 3.4 aspects of tiering.

To establish a numerical rating of the case study supply chains against the phantom benchmark, proxy measures were developed against each of the three aspects above. Details of the numerical calculation method are given in Chapter 5.

Outsourcing

It was considered important to measure the overall level of outsourcing in the chain, defined as the amount of value added by the assembler related to that added by the rest of the supply chain.

The positive effect of an assembler outsourcing non-core activities can be traced to a number of determining factors. First, costs such as wages and overheads are generally appreciably lower in the supply base (Lamming, Jones, Nishiguchi). In addition, as the assemblers increasingly outsource, so suppliers' volumes grow tending to drive down costs further due to economies of scale (Perrow 1989). This effect is heightened when the first tier supplier is located in an advantageously lower cost area, or where the majority of the manufacture is carried out in a low cost area with final assembly in a closely located satellite plant, with delivery in-line with a broadcast assembly sequence from the assembler (Anderson 1985). Cost is a factor that applies for the outsourcing of *manufacture*, as well as for the *design* of the component and *research and development.* Other determining factors in the outsourcing of both assembly and development work is related to the desire on the part of the assembler to reduce the complexity of managing his operations and sharing the risk capital out amongst members of the value chain.

The level of outsourcing for both processes - manufacture and development – was considered in the 'Fixed Reference Benchmark Model'. A high level was viewed as positive (Womack and Jones 1990, Boston consulting Group 1994). Here, as for the other two elements of supply chain structure, 'component' is taken to imply the maximum logical level of integration, in other words the 'end point' *assembly* for the component. For example in measuring the level of outsourcing for "door supply chain", the 'complete door' was defined as the highest level of integration for door components, and outsourcing measured with reference to 100% of the assembly.

The aspects of outsourcing were defined as:

Manufacturing : The proportion of value external to the VM as a percentage of the completed assembly's value; Development: The proportion of discrete component development and component to component integration undertaken externally to the VM by its supply base as a percentage of the total requisite development activities.

figure 3.5 aspects of outsourcing.

Again, details of the numerical calculation method are given in Chapter 5.

Systems purchasing

The benefit of outsourcing the *manufacture* of **systems** is traced to the reduction in logistics and assembly costs. The VM is able to receive in sequence higher level assemblies with minimum levels of stock. Logistics complexity inside the VM is reduced in proportion to the reduction in direct external suppliers.

In addition to systems manufacture (sometimes termed *logistics integration*) the other option in **systems purchasing** is to delegate the *design,* or *development* of the system to the supply base. Here the advantages are traced to the delegation of the 'interface management' - the management of the integration of the discrete components into a system - and with this the shedding of responsibility for managing the interaction beween the developers of individual constituents of the system.

The measure for systems purchasing consists of two aspects:

Manufacturing: The ratio of significant components in the system to the number of direct external suppliers; Development: The ratio of the maximum possible component to component interfaces for the system against the number managed externally by the supply base.

figure 3.6 aspects of systems purchasing

Here again the measure utilises a fixed 'end point' definition of the 'system'. In the case of car doors for example this is represented by the whole door. Chapter 5 shows the breakdown of a door (one of the case study components), and a list of 16 significant sub-components. The maximum score for the systems purchase measure would be reached if a supply chain developed and manufactured the whole door externally to the VM. Here the ratio for **Manufacturing** would have unity as the numerator (one external supplier for the whole 'system'). The opposite extreme would be the case of the VM assembling the door in-house, where the numerator would be 16. (All 16 components received individually from direct external suppliers). The ratio for **development** shows progress towards the VM delegating the integration of the system. Here the proportion of neccesary interfaces delegated to the supply base is represented. *"Full service supply"* (sometimes termed - *full function*) describes a relationship in which the supply base is responsible for the development, manufacture and assembly of the system. In the 'Fixed Reference Benchmark Model' "Full services supply" of the defined 'end point' system by a single supplier would score 100%.

Single sourcing

The virtue of a single source of supply has been advocated using a number of different points of logic. First from a quality point of view (Deming 1988), and also from a cost perspective - a single set of tools and development work, for example. In addition the comparativley higher volume may enable the supplier to invest into more dedicated facilities. Finally, developing a deeper long lasting relationship with a single supplier can have intrinsic benefits for improvement of the manufacturing and development process (Macbeth 1993).

Sourcing policy in the 'Fixed Reference Benchmark Model' was scored by placing the policy into one of the following categories:

Single sourced by **range**: a single supplier for a particular component type for the entire model range;

Single sourced by **model**: different suppliers retained in the assemblers portfolio, but a single source selected for each model (e.g. single supplier for all window regulators for a particular model line.);

Single sourced by **part number**: a single source for each unique part number reference (could include for example different suppliers for front and rear regulators, but single source for all front manual regulators.);

Dual or Multi-sourced by part number: More than one supplier for a unique part number reference.

figure 3.7 aspects of single sourcing

The measure takes due account of the realistic proviso that commodity items with no 'customer specific design content' would be expected to follow a purely contractual relationship with spot purchases from a range of commodity suppliers. Conversely, proprietary items with technology owned uniquely by one supplier would normally imply single source by range. The 'rating' of sourcing policy takes place with regard to the nature of the component.

Again, the calculation of the numerical rating is explained in chapter 5 where it is also used against the case study supply chains.

Design and development delegation

The effectiveness of the development phase in which the assembler and supplier overlap or hand over responsibility for component development is addressed in this element. The well defined roles of assembler and supplier inherent in the traditional

relationships of either 'manufacture to drawing' or commodity type item, have moved towards 'co-development' - 50:50 responsibility for development. The move towards less well-defined roles increases the potential for lost efficiency.
Here factors such as the compatibility of the partners' development processes, and early involvement of the supplier are developed into a proxy measure for the efficiency of 'Design and development delegation'. The aspects are:

Percentage of **development delegated** - the split of work;
Efficiency of the work sharing;
Point of **first involvement.**

figure 3.8 aspects of design and development delegation

The weighting of the second and third aspects are affected by the first factor, in that as the percentage of responsibility moves away from either the VM or the supplier being fully responsible, towards a more collaborative typical 50:50 share of development responsibility - so the importance of 'efficient work sharing' and 'early involvement' become accentuated. Hence the calculation of scores, (set out in chapter 5) contains a weighting calculation for factors two and three, based on factor one.

Long-term contracts

The positive effects of changes in trading relationship from purely contractual 'arm's length' fixed-term, short duration contracts to more 'obligational' partnership relationships can be traced to the degree of certainty to both parties that the trading relationship is 'in it for the long game' (Sabel, Piore, 1992) - an elastic response from the customer to price differential, where the customers first response to a more competitive bid from an alternative source is to support the existing supplier rather than re-source the work.

Here, the nominal contract duration - the explicit overt contract length is measured, and in addition a "Certainty of business retention" index has been developed to measure the less overt effect of confidence in retaining the business - the propensity of the customer to resource the work faced with a hypothetical more competitive bid from an alternative source. The measure is set out in chapter 5.

Customer focus

The main aspect measured here is the degree to which the supplier has organised his resources to be specific to the customer, related to the portion of revenue he receives from that particular customer of his total revenue. A supply chain/trading relationship with high resource specificity and comparatively small revenue portion would be scored more highly than one with an equally high specificity but in which the customer represents a large proportion of the suppliers business.

To apply the 'Fixed Reference Benchmark Model' to the case study supply chains, the internal structures at suppliers were analysed to find the split between resources oriented 'vertically' around the customer i.e. specific to that customer, and those which span horizontally across all customers, centred around the product. Resource specificity was measured in two constituent parts - resources for manufacture and resources for development. Rather than a detailed decomposition of the two processes into individual activities followed by direct measurement of specific and non-specific resources - the present methodology involves measuring resource specificity via a judicious selection of the key elements of the two main processes. The details of this method are contained in chapter 5. The final score is conditioned by reducing or increasing the resource specificity score according to the relative size of the customer account.

Open book costing

The advantage of open-book costing is seen first as enabling the VM to audit the viability of the tender, to protect himself against unrealistic bids. Second is the potential for achieving the best-cost position in the long run for the mutual benefit of both trading partners.

The benchmark measure consists of two aspects:

The **extent** of shared information.
The **compatibility** of format of the information.

figure 3.9 aspects of open-book costing

The second measure is used as a proxy for the amount of extra effort expended by the supplier to convert his information into the format convenient for analysis within the VM, or vice versa, for the VM to convert the suppliers information into his own cost structure format.

Once again, the numerical measure is explained in a following chapter.

Mutual relationship development

Here, progress towards improving mutually problematic factors is assessed as a proxy to mutual development of the trading relationship.

Mutual development in terms of truly significant collaboration between VM and suppliers to solve perennial problems such as schedule instability has not been seen to date . One example of collaboration which has yielded benefits for both supplier and VM is the introduction of self-billing systems. The VM benefits from the opportunity to reduce headcount to carry out invoicing (for example a reduction of 100 to 10 heads at one VM). The suppliers receive more prompt and more reliable payment

Open Systems

The measure here is designed to gauge progress towards integrated communication systems - linking the VM and supplier's commercial/administration systems by EDI or on-line access (for example, use of the internet and/or joint planning systems such as DMRP or SAP).

The following aspects were used to calculate the overall score for this element:

Communication by EDI or other electronic means (e.g. Internet, SAP, DMRP) of :

Information	Score
Planning schedules	20
Delivery schedules	20
Invoice submission	20
Invoice payment (E.F.T.)	20
Purchase orders	20
	100

table 3.1. open systems -(i) general rating system

JIT deliveries

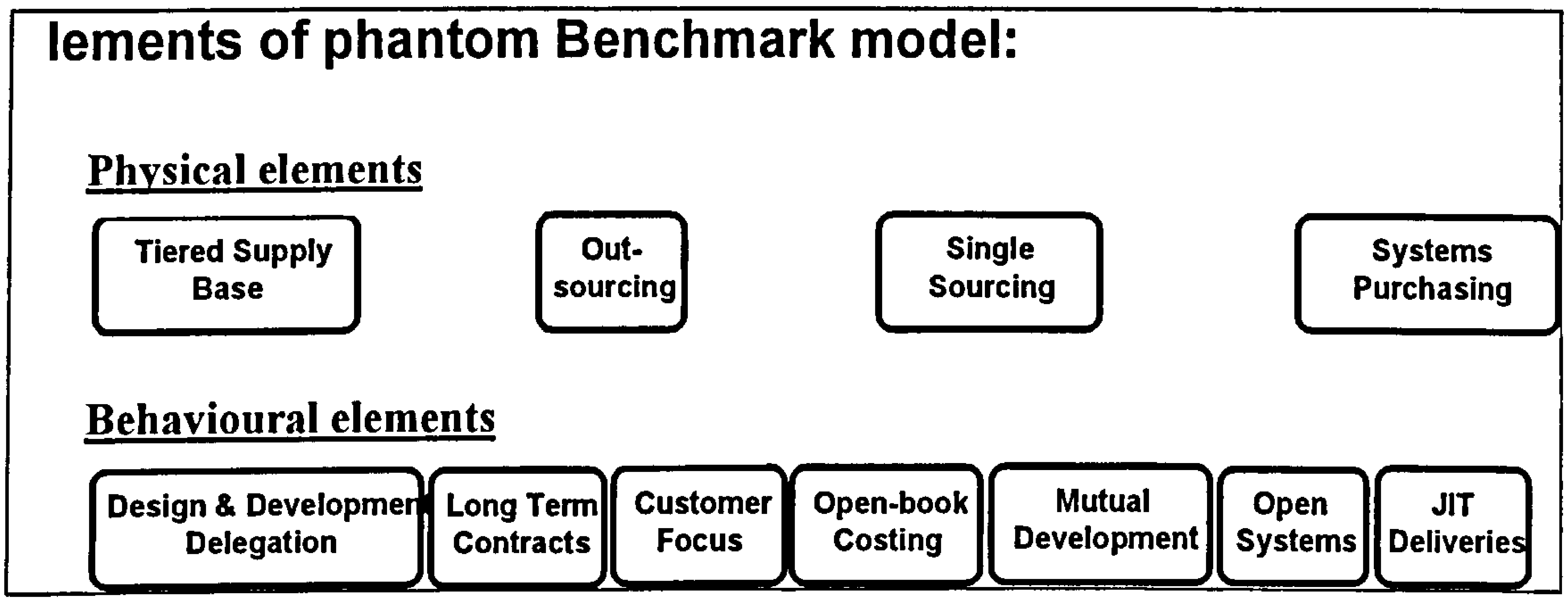
The basis for the measure of JIT would be a comparison of the optimal 'true JIT' pipeline stock level i.e. for ideal sequenced manufacture and delivery in-line with vehicle build, with actual pipeline inventory. This measure is not available, and the following is based on observation during field data gathering.

A distinction can be made here between 'JIT delivery' and true 'lean supply' which involves JIT manufacture and delivery throughout the supply chain (Lamming, 1992).

Although little information on JIT deliveries related to the case study supply chains was collected during field research, the investigation has made use of published data related to the companies in the study (Anderson,1993)

3.1.2 Summary of Fixed Reference Benchmark Model and its use.

Once the elements had been established, (section 3.1.1 above sets out rationale for the elements, and figure 3.10. shows these diagrammatically) - next came the consideration of the actual mechanics of comparing a studied supply chain with the 'phantom benchmark'.



Element	*expanded definition*
Tiered Supply Base	focussed relationship with clearly defined and delegated responsibilities Horizontal collaboration on new product development/systems integration role.
Outsourcing	core activities focus.
Systems Purchasing	retention of product authorship.
Single Sourcing	per model range.
Design&Development Delegation	total service supply – concept to production capability/project management; redistribution of engineering resource.
Long-term Contracts	model life contracts; incentive sharing of productivity gains.
Customer Focus	shared vision on ultimate customer.
Open-book Costing	cost transparency; compatible accounting systems.
Mutual Development	relationship/joint assessment; shared learning programmes.
Open Systems	computer supported collaborative work using integrated broadband communications.
JIT Deliveries	schedule stability/responsiveness; variety reduction; standardised, reusable containers; logistics partner alliance; local manufacture.

Figure 3.10 Main constituent model elements expanded

The definitions of each element in the current model were developed further to provide a numerate ways of measuring for example the 'extent of tiering' in a particular supply chain. As previously mentioned, the full workings of the elements, and scoring of the aspect therein are set out in chapter 5.

The idea of presenting this information using "Radar" diagrams was developed into working methods for calculating the position of actual practice relative to the fixed model. Provision in the calculation was also made for gauging the rate of progress towards better if not best practice from the current position where known, based on future plans information gathered at interviews.

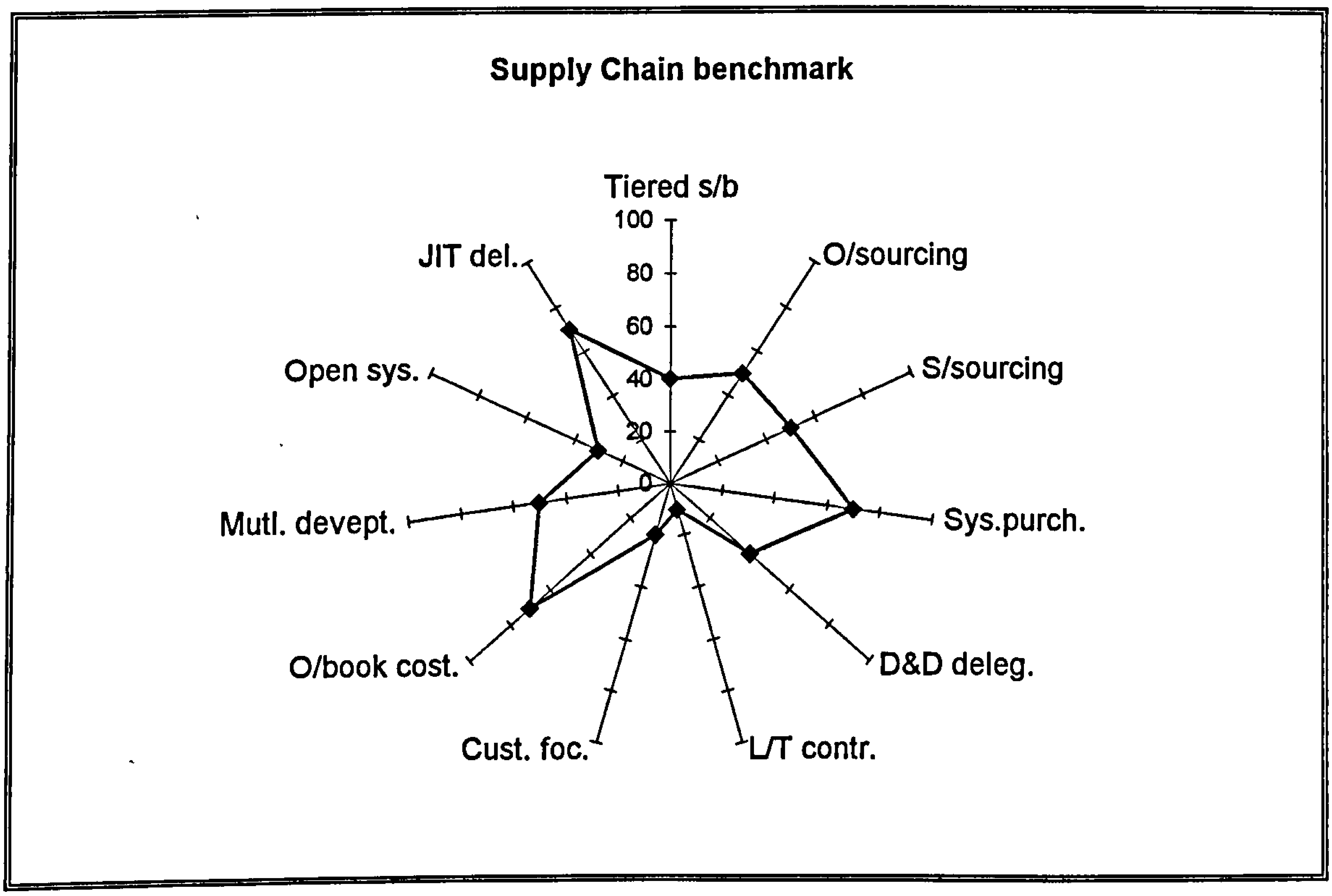


figure 3.11 Radar diagram presentation of practice against the 'phantom' benchmark model

Once the majority if not every supply chains' information had been entered, they formed a database of 'descriptions' of broader aspects of practice in the supply chain was created. The purpose of this phase of the research was to ensure that an objective comparison method for the supply chains was possible, and that the structure of the chain could be isolated from the many other factors affecting its behaviour.

Fraunhoffer Institut für Arbeitswirtschaft und Organisation

The elements of practice that form the Fixed Reference Benchmark Model have their basis in historical theory as outlined in Chapter 2 of this thesis. When viewed together, the set of elements also gives representation to many of the aspects of practice in which change is taking place. It thus provides a conceptual framework for assessing the extent to which supply chains are adopting new practices and new value stream structures. Figure 3.10 above outlines the elements of the Fixed Reference Benchmark model, with a brief description of the measurable 'aspects' that constitute each element. An interesting comparison between the model elements as shown in this diagram can be made to those suggested by Dr K Thaler, in his work with the Fraunhoffer Institute. Figure 3.12 (overleaf) (Thaler 1995) shows eight factors, six of which have direct similarity with elements in the Fixed Reference Benchmark Model. The Fraunhoffer Institut make use of their model as a depiction of the areas of expertise in which their (mainly action based) research can be carried out for client companies. As such the diagram is used to demonstrate competence across (all) the 'currently important developments' (Thaler 1995) in modern European Automotive Supply Chains. Although the Fraunhoffer and the Fixed Reference Benchmark Models differ in the nomenclature of certain of their elements, when the definitions set out in an earlier section of this chapter are understood, the parallels in the two independently developed pieces of work is clear to see. In the context of this thesis, it is seen as important that the set of practices measured with the Fixed Reference Benchmark model correlate with those identified by the internationally recognised work of the Fraunhoffer Institut.

Further, the Fraunhoffer model does not purport to exist as a fully functioning instrument for research (as can be said for the Fixed Reference Benchmark Model) – the elements are not defined, neither are methods for gauging progress towards the aspects of practice contained therein.

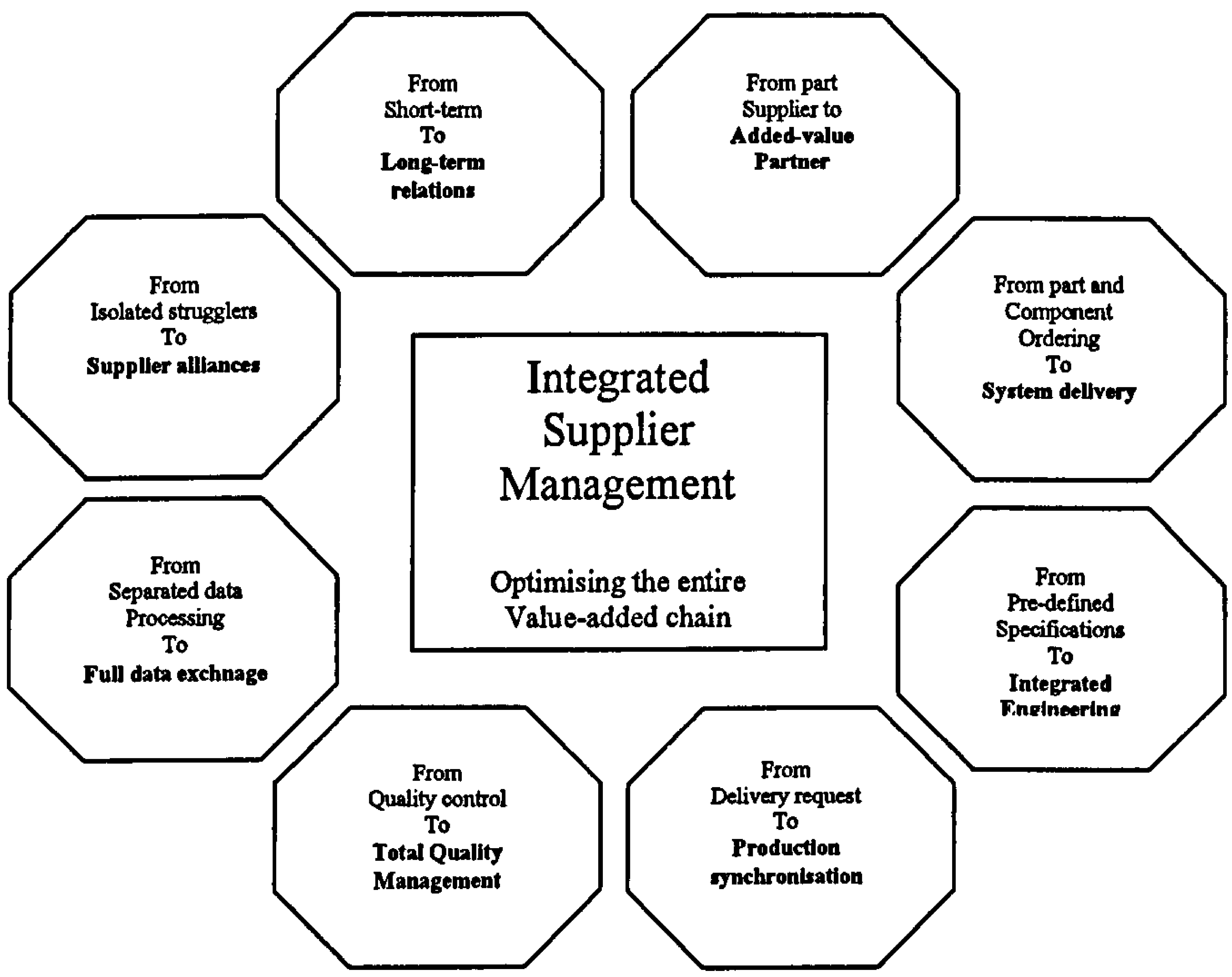


Figure 3.12 - The need for "partnering" (source Thaler op. Cit.)

Table 3.1.1 presents a match between elements of the Fraunhoffer model and the Fixed Reference Benchmark model.

Fraunhoffer Model elements	*Fixed Reference Benchmark Model elements*
Production synchronisation	JIT Deliveries
Integrated Engineering	Design and Development delegation
System delivery	Systems purchasing
Added-value Partner	Mutual Development
Long-term relations	Long Term contracts

Supplier alliances	Tiered Supply base
Full data exchnage	Open systems, Open Book Costing
Total Quality Management	Single Sourcing, Customer Focus.

Table 3.1.1 Comparing elements between Fraunhoffer and Fixed Reference Benchmark models

In summary, the Fixed Reference Benchmark Model presented in this chapter and completed in chapter 5 gives quantitative expression to some of the descriptive concepts to which European Automotive Supply Chains (as far as it has been possible to derive consensus) aspire. In addition it facilitates the measurement of progress of individual chains towards these goals.

3.2 Development of "Hierarchical Structure Mapping tool"

The next section outlines the second research instrument developed for the study – the 'Hierarchical Structure Mapping Tool'. The purpose behind this tool is to allow the portrayal of actual structure of the chains investigated. The synthesis of information portrayed in the 'Fixed Reference Benchmark Model' and the 'Hierarchical Structure Mapping Tool', together with comparison with existing theory, is designed to generate the main findings of the study (see figure 3.1 for diagramatic representation of methodology).

The benchmark model allows comparison of various elements of supply chains to be investigated, and moreover creates a database of information about the chains, with which the affect of 'structure' can be isolated.

In order to carry out the review, a method for portraying and comparing the actual structure a – "Hierarchical Structure Mapping Tool" - has been developed. This enables structures to be compared, one with another, and in the first instance allows actual structures to be compared with those 'predicted' by existing theory.

3.2.1. Review of existing supply chain modelling techniques

A preliminary task was to check that a suitable method did not already exist.

Much work has been carried out into modeling various aspects of supply chains. Hines and Rich (1997) present a number of 'value stream mapping tools', some of which have been created by themselves, and others which already existed. Table 3.2 below shows the tools, along with an indication of their use.

	Mapping tool						
Wastes/structure	Process activity mapping	Supply chain response matrix	Production variety funnel	Quality filter mapping	Demand amplification mapping	Decision point analysis	Physical structure (a) volume (b) Value
Overproduction	L	M		L	M	M	
Waiting	H	H	L		M	M	
Transportation	H					L	
Inappropriate processing	H		M	L		L	
Unnecessary inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Defects	L			H			
Overall structure	L	L	M	L	H	M	H
Key	H = High correlation and usefulness M = Medium correlation and usefulness L = Low correlation and usefulness						

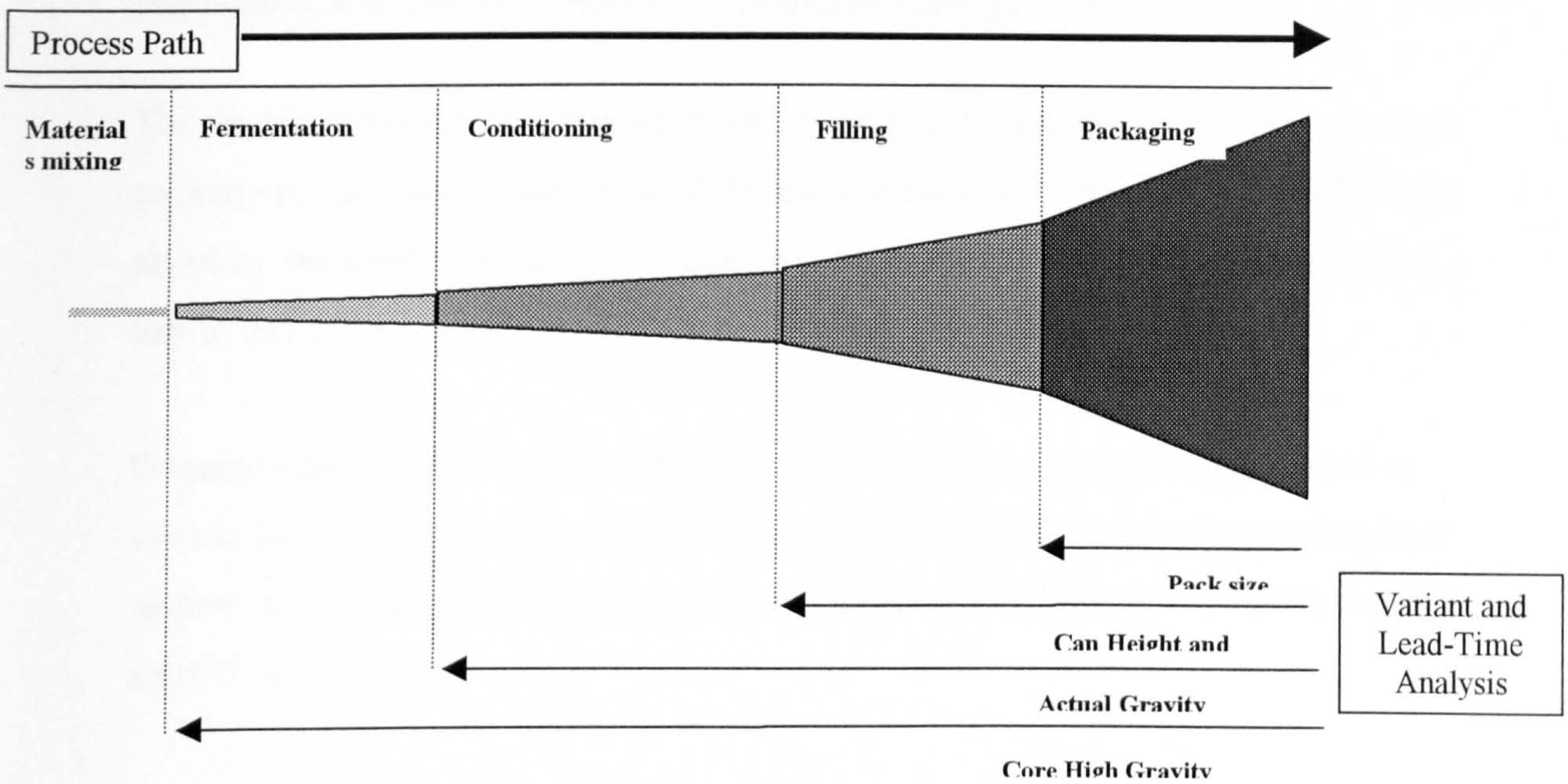
Table 3.2 Seven Value stream mapping tools (Hines and Rich 1997)

Process activity mapping has it's origins in industrial engineering and involves studying the activities carried out during the process of supply. Activities are split into several categories: first, transformation is any part of the manufacturing process itself (e.g. cutting metal, forming, casting etc.) Secondly, transport activities (here, distance and time are also recorded), Inspection, storage and delays are also recorded, and a simple flow chart constructed depicting the activities of the supply chain for a particular product or component. This system is useful for analysing and improving the production process, and the structure of the supply chain could be superimposed on the flow chart to show 'who' in the supply chain carried out each part of the process. It has traditionally been used as a tool to remove excess delays, and measure transport and processing time, rather comparing and portraying structure. The new method developed for the investigation of structure, and described later in this section has it's base in process activity mapping, but places greater emphasis on measuring the distribution of activities amongst the firms making up the supply chain.

The **Supply Chain Response Matrix** portrays the activities in the supply chain against time. The method was developed in the logistics movement. New (1993) and Forza (1993) used a similar method in textile supply chains, whilst Beesley (1994) reported the development and use of "time based process mapping" in automotive, aerospace and construction supply chains. The methodology has similarities to the traditional project planning, or Gantt chart presentation, where activities are presented as bars, the length of the bar in a horizontal sense, shows the duration of activities. In the supply chain response matrix reported in Hines and Rich (1997), the height of the bar is used to represent the amount of inventory held at each stage in the process. In the context of the current investigation into structure, the Supply Chain Response Matrix is useful only in the sense of a way of comparing the performance of case study supply chains. In itself, the method does not portray the structure. Therefore if it is to be used, the structure must be portrayed first, then the Matrix used to compare relative performance.

The **Production Variety Funnel** offers a way of presenting the build up of product variants at various stages in the production process of products. In addition, critical lead times are measured. Figure 3.13. shows an example of a production variety funnel for a brewing process.

The production variety funnel allows the researcher to understand both the way in which the supply chain operates, and the level of complexity that has to be managed. It allows the similarities and differences between supply chains to be compared.



In the context of the current 'structure' study, the method is useful in providing background information on the chains under study.

Figure 3.13 Production variety funnel, brewing industry

The **Quality Filter Mapping** approach is a tool designed to identify where quality problems exist in the supply chain. Three different types of quality defect, product, service and internal scrap are identified, and levels mapped against the different stages in the supply chain.

Demand amplification mapping is based on the Forrester and Burbidge effects defined in the systems dynamics movement. At each inventory or order point in a supply chain, variations in demand are apt to be distorted because of prevailing stock control policy, and poor decision making. For example, a temporary increase in demand from an end producer may be interpreted as a general increase in demand by a supplier, who may in turn pass on an even greater demand to sub-suppliers. The 'Burbidge effect' is linked to the 'law of industrial dynamics' which states:

> ...if demand is transmitted along a series of inventories using stock control ordering, then the amplification of demand will increase with each transfer (Burbidge, 1970)

The upshot of the effect is that although on average, supply chains may have enough capacity to adequately meet demand, because of the huge peaks and troughs brought about by the amplification effects, they may be unable to produce enough goods on a day to day basis.

Demand amplification mapping involves plotting demand changes against time at various points in the supply chain. In essence this provides a way of measuring how responsive the supply chain is to changes in demand, and how susceptible it is to the amplification effects.

For the current structure study, this provides another way of measuring a 'performance' aspect of supply chains. Supply chains with various forms of structure could be compared with respect to their propensity to amplify demand.

Decision point analysis involves determining the point in the supply chain at which goods begin to be produced – or distributed, specifically for customer demand, rather than against forecasts. Clearly a 'purchase and make to order' supply chain would have a decision point much closer to the raw material end of the supply chain than for example a supply chain producing consumer goods for a national distribution network.

Hines and Rich (1997) developed a method entitled **"Physical structure mapping"** which they use to present an overview of supply chains at industry level. The tool is illustrated below and portrays information against two criteria, namely: volume structure and cost structure. The first diagram shows the structure of the industry according to the various tiers that exist in both the supplier and distribution chains, with the assembler situated at the middle point. The supplier area is shown to include raw material sources and other support suppliers (such as tooling, capital equipment and consumables). These two sets of firms are not given a tier level as they can be seen to interact with the assembler as well as with other supplier tiers. The area of each part of the diagram is proportional to the number of firms in each set.

The second diagram maps the industry in a similar way with the same sets of organisations. However, instead of linking the area of the diagram to the number of firms involved, it is directly linked to the value adding process. As can be seen in the diagram example, the major value adding occurs in the raw material firms, the first tier and the assembler.

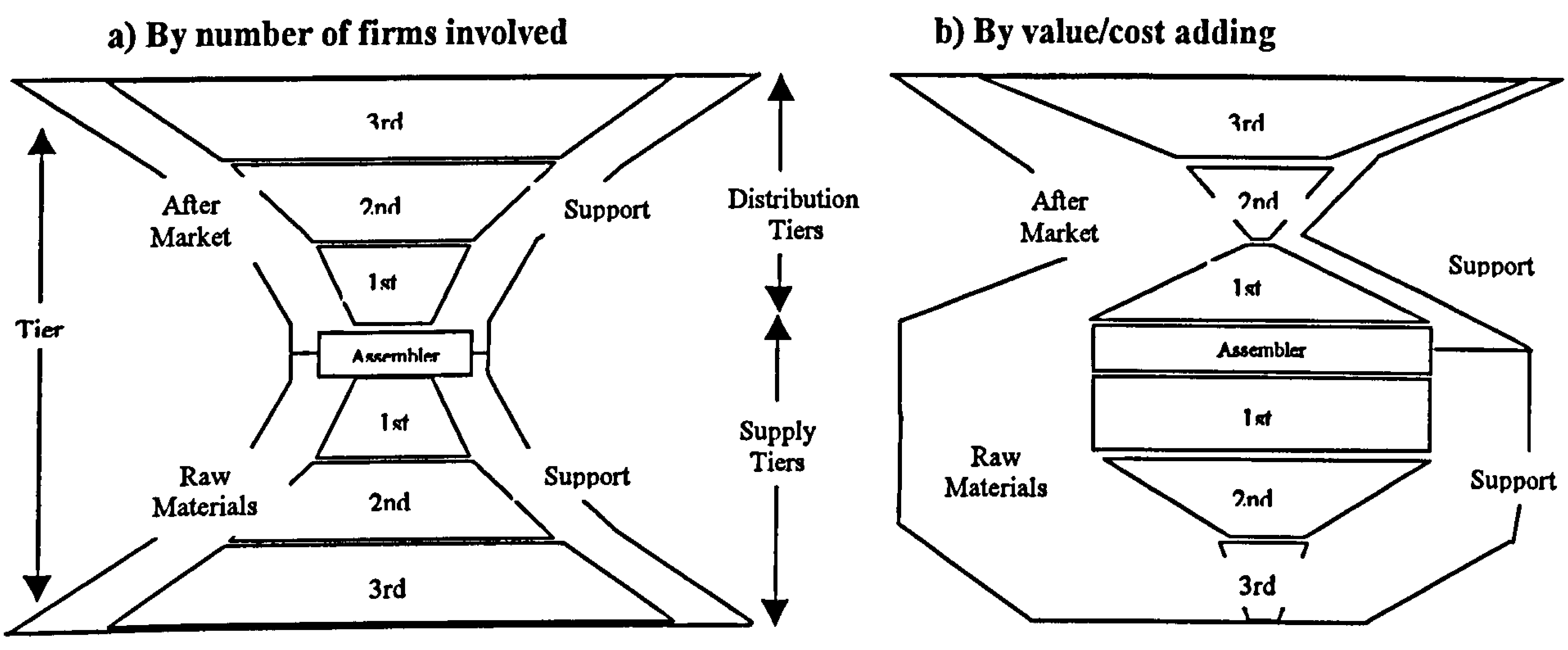


Fig 3.14. Physical structure mapping (source: Hines and Rich 1997)

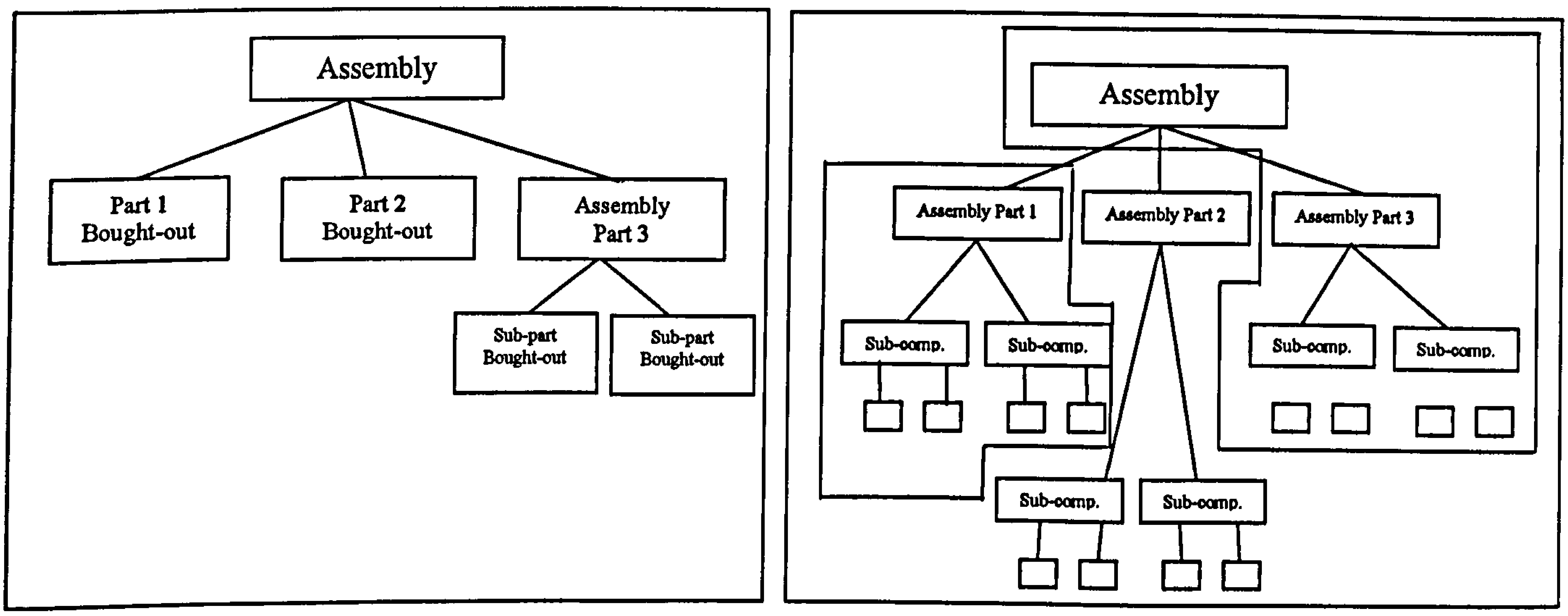
3.2.2 Development of new "Hierarchical Structure mapping tool"

As can be seen from the summary above, a number of different mapping tools exist, each portraying different features and aspects of supply chains and each having their own individual merits.

The requirements of a mapping method for carrying out the investigation proposed in this thesis are such that it is felt that a new method is required. The major requirement is that the mapping tool should portray the distribution of value adding activities in the supply chain as well as identifying the boundaries of the firms contributing to the chain.

The basis of the hierarchical mapping tool has been published in the International Journal of Logistics Management (Coleman and Bhattacharya, 1995).

It is based on portraying the way in which value-addition activities are distributed amongst firms in the supply chain. At the heart of the method is the consideration of the production bill of materials (BOM) for the product. Rather than considering the BOM in the limited sense of that part produced by any one firm, the method requires the full BOM for the product irrespective of who produces any one part.



Traditional purchase BOM relating to activities of 1 company ***Integrated Supply chain BOM showing distribution of value addition activities***

figure 3.15 Traditional and integrated BOM

A simple example can be used to illustrate the basis for the modelling method.

Considering the supply chain to produce a car door: two extremes of 'supply chain structure' can be envisaged.

First, consider the car-maker who keeps most of the value adding activities for the production of the door in-house.

Consider the full set of value adding activities, from production of components, combination of components into sub-assemblies, and final assembly of the door. It may be that the structure of the chain is such that raw material production and some 'sub-components' manufacture (fixings etc.) is carried out by suppliers, but all the remaining tasks (value addition activities) are carried out by the assembler. To see exactly which value addition activities are carried out by who we list all the constituent value addition activities for the door, down to a level of, say, sub-components. We then map which activities each company carries out for that particular chain.

Modelling method

So, the method allows the supply chain to be modelled in terms of the set of value-addition activities required to produce the product. Once the complete set of activities has been identified, the ownership of each step can be superimposed to form a model of the ownership structure.

As an aside to this thesis, in a 'supply chain re-engineering initiative', such a method could be used to model different profiles of ownership. For a supplier who contributes to the chain, a model of the re-engineered structure would provide useful information to guide capability acquisition and hence successful positioning. Figure 3.16 shows the methodology steps.

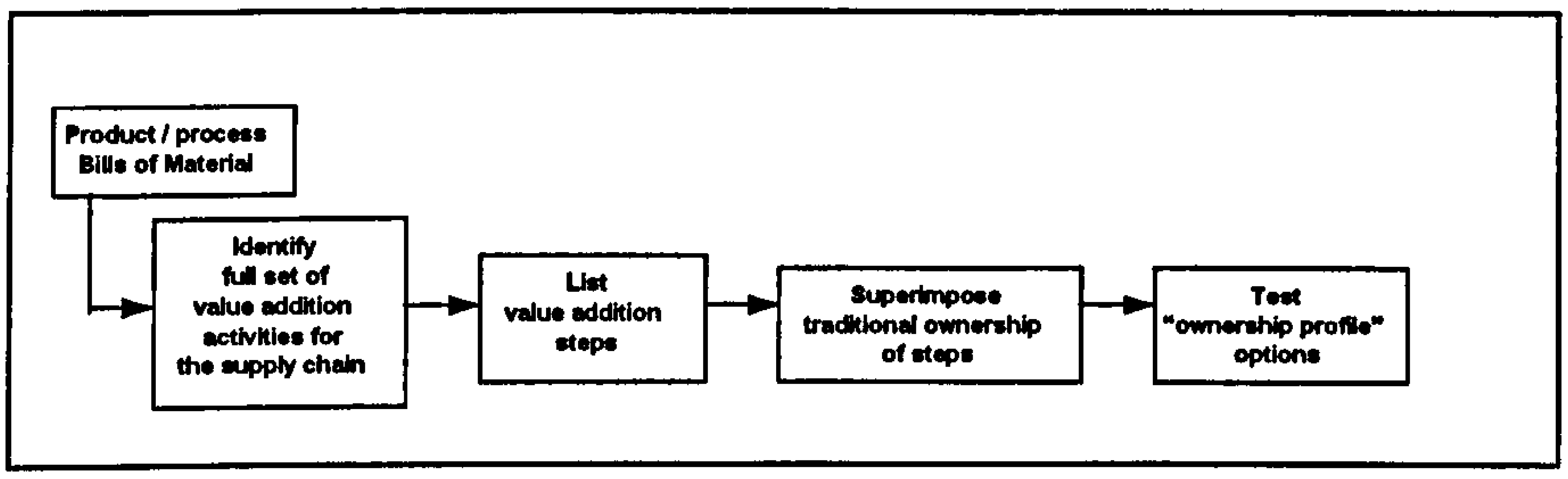


Figure ** : Steps in Re-engineering Methodology

For the purposes of this thesis, the method is used as shown below, in figure 3.17 below.

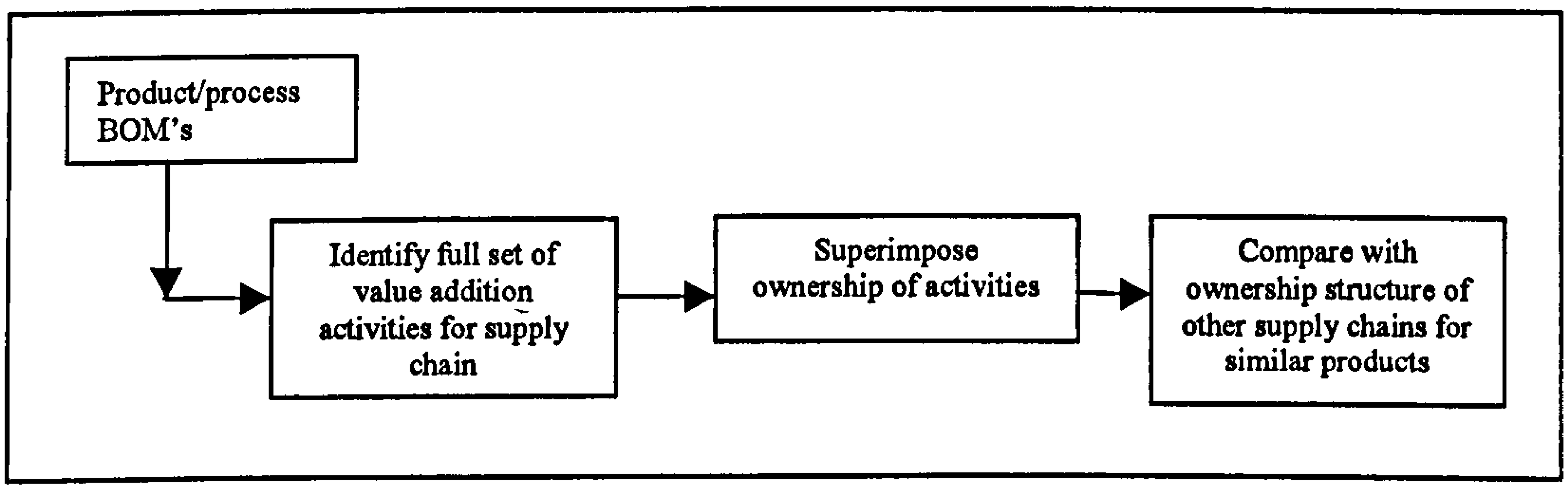


Figure 3.17 Using Hierarchical Structure Mapping in research investigation

Figure 3.18. illustrates the use of the technique in the automotive industry. The supply chain in question is that for car door window-winding mechanisms. The first column represents the set of value additions to bring the door "to the customer". Subsequent columns show different configurations of ownership. Option 1 represents the traditional state where much of the ownership of the design and assembly of the door and its components lay with the vehicle manufacturer. Subsequent columns show the changing ownership, as the supply chain is re-engineered.

value addition	*Value addition ownership* *Option 1 : Traditional ownership*	*Value addition ownership* *Re-engineered Phase 1*	*Value addition ownership* *Re-engineered Phase 2*	*Value addition ownership* *Re-engineered Phase 3*
assemble door to vehicle	Vm	vm	vm	vm
design door	Vm	vm	vm	vm
fit audio equipment to door	Vm	vm	vm	vm
fit trim to door	Vm	vm	vm	vm
fit regulator	Vm	vm	SUPPLIER 1	SUPPLIER 1
fit motor	Vm	vm	SUPPLIER 1	SUPPLIER 1
fit glass	Vm	vm	SUPPLIER 1	SUPPLIER 1
fit cabling	Vm	vm	SUPPLIER 1	SUPPLIER 1
paint door	Vm	vm	vm	vm
fit door handle	Vm	vm	SUPPLIER 1	SUPPLIER 1
fit locks	Vm	vm	SUPPLIER 1	SUPPLIER 1
manufacture regulator	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1
design regulator	Vm	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1
manufacture motor	Supplier 2	supplier 2	supplier 2	supplier 2
design motor	Supplier 2	supplier 2	supplier 2	Supplier 2
manufacture pressings	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1	Supplier 3
design pressings		SUPPLIER 1	SUPPLIER 1	SUPPLIER 1

Figure 3.18 – Use of technique for door component

Level and Range of Capabilities

The supplier in question has moved from option 1 through phase 1 to into Phase 2. In this movement up the value chain, the supplier increased both level and range of value addition activities in moving from phase 1 to 2. However, not all customers moved to Phase 2 type out-sourcing for the same supply chain (window winding systems). Thus this supplier found himself operating in all the three versions of the same supply chain (Option 1, Phases 1&2) for different customers, achieving what could be called an 'elastic capability range'.

3.2.3 Use of the model in the study

The modelling method was developed further during the course of the study in order that more meaningful comparison of the chains could take place.

Figure 3.19 shows an example of a door supply chain using the completed 'Hierarchical Structure Mapping Tool'.

Figure 3.19 - Hierarchical Structure Mapping tool

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 5	Supplier 6	Supplier 7	Supplier 8	Supplier 9	Supplier 10	Supplier 11	Supplier 12	Supplier 13	Supplier 14	Supplier 15	Supplier 16	Supplier 17	Supplier 18
Fit door to car	■																			
Final assembly of door	■																			
Fit Loudspeaker to mounting	■																			
Fit Glass seals to door	■																			
Fit door seals	■																			
Manufacture outer panels	■																			
Assemble Outer panels	■																			
Fit Interior trim panel complete	■																			
Fit Door check strap	■																			
Fit Door hinges	■																			
Fit Glass pane	■																			
Fit Exterior mirror	■																			
Fit Exterior door handle	■																			
Fit Side Impact Restraint System	■																			
Fit regulator to mounting		■																		
Assemble Regulator		■																		
Pressings for Regulator		■																		
Fit Latch/central locking to mounting		■																		
Assemble Latch/central locking		■																		
Fit Window lift switches to mounting		■																		
Fit wiring harness to mounting brackets		■																		
Fit glass channels to mounting bracket		■																		
Assemble Wiring harness			■																	
Looming for wiring harness			■																	
Assemble Loudspeaker				■																
Manufacture main sub-components Loudspeaker				■																
Assemble window lift switches					■															
Manufacture main sub-components window lift switches						■														
Manufacture glass channels							■													
Manufacture glass seals								■												
Manufacture door seals									■											
Assemble Interior trim panel complete										■										
Manufacture sub-components Interior trim panel complete											■									
Manufacture Door check strap												■								
Manufacture Door hinges													■							
Manufacture Glass pane														■						
Manufacture Exterior mirror															■					
Manufacture main sub-components Exterior mirror																■				
Manufacture Exterior door handle																	■			
Assemble Side Impact Restraint System																		■		
Manufacture main sub-components Side Impact Restraint System																			■	
Manufacture main sub-components Latch/central locking																				■

From the figure, the following points of interest can be observed:

- The value addition activities in the left column are ostensibly generic across similar car doors, allowing cross comparison between chains to highlight differences in supply chain structure.
- The value addition activities represent the full set of activities for the door down to sub-sub-component level.
- In the example shown, supplier 1 is the manufacturer of the 'window regulator' but has also taken responsibility for assembling other parts of the mechanism into a 'door module'.
- The shaded portions give a rough indication of the level of value added by each contributor to the chain. At this stage the value for each generic activity is assumed to be equivalent, hence in the example shown, the vehicle assembler and supplier 1 contribute the greatest value.
- If access to component values and assembly costs were available, the model could be developed further so that the area of shaded block could represent more accurately the amount of value added.

So, after data collection via the field research exercise had been carried out, and the information input via the two research instruments, a set of results for each supply chain was achieved. The results consisted of three sections for each chain.

1) Results from the 'Fixed Reference Benchmark Model'
2) Results from the 'hierarchical structure mapping tool'
3) Comparison of actual structure with existing 'structure theory'

Chapter 5 shows the analysis carried out to achieve these results, whilst Chapter 6 summarises the results themselves. Before this, the following chapter describes the sample of supply chains chosen and the collection of data.

Chapter 4

Field Research

- **This chapter describes the information gathering process for the study. It covers direct data, via structured interviews and questionnaires at six European vehicle manufacturers and twenty-two suppliers, as well as indirect data via publicly available data sources.**

4.1 Introduction

As discussed in previous chapters, The automotive industry field research focussed on twenty-four supply chains, comparing structure and practice across this sample. In order to achieve consistency, four components were chosen to represent a range of different technologies and sourcing strategies. Each of these four component supply chains was investigated at six vehicle manufacturers, making a total of twenty-four supply chains.

The four components were; **Door, Instrument Panel, Electronic Control Unit** and **Wiring Harness.**

Table 1.1 shows a typical breakdown of interviews for *one* automotive supply chain.

Door supply chain 1 (D1)					Total number of interviewees
Interviews at Vehicle manufacturer (No. of interviewees)	Designer (4)	Buyer (3)	Logisitics agent (2)	Logistics manager (1)	10
Interviews at first tier supplier (No. of interviewees)	Designer (2)	Commercial agent (1)	Logistics agent (1)		4
Second tier supplier (No. of interviewees)	Commercial agent (1)				**1**

Table 4.1 interviews for Door Supply chain 1, showing 15 persons interviewed.

During the first period of field research, data collection instruments were devised in the form of four questionnaires which were intended to be completed at structured face to face interviews with respect to each of four persons connected with the components:-

1) **DESIGNER** - The person in the vehicle manufacturer who is/was mainly responsible for the specification of the component.

2) **BUYER** - The person in the vehicle manufacturer who is/was mainly responsible for calling up supplies of this component.

3) **LOGISTICS CONTROLLER** - The person in the vehicle manufacturer who is/was mainly responsible for calling up supplies of this component for use.

4) **SUPPLIER** - The person in the supplier who nurtures the relationship with this manufacturer.

In addition to the questionnaires three data collection forms were designed to acquire information about the three processes of **design/development, manufacturing** and **buying/selling.** Two versions of each form were produced in order that both the vehicle manufacturer's and the supplier's contribution to the processes could be recorded.

'Information packs' were produced to send in advance to each of the interviewees. Each contained an introduction to the project, a summary of the structure of the proposed interview as well as the questionnaire and process flow chart data collection forms.

Data collection interviews commenced in January 1994 at Rover Group. It was immediately found that in addition to the four planned interviews for each component, further meetings would be required. An example of the increase in data collection interviews was for the **'Door Process Chain'.** At Rover this is assembled 'in-house' from many purchased components and in order to gain a broader understanding of the door supply chain, at least two sub-components needed to be studied. In the case of **'Instrument Panel'** the same situation applies, and two sub-components were chosen for study. Subsequent to the first round of interviews validation, clarification and in some instances additional data were sought from the respondent. This also required extra meetings.

Supplier interviews began in June 1994, and it was found that the detailed information sought on logistics and development issues required that the supplier's designer and logistics expert, as well as the commercial representative were interviewed. In addition separate follow up interviews were often required.

Data collection at the five other partner companies and their suppliers was carried out between June 1994 and June 1996. Some 150 interviews were carried out at the VM partner companies and 22 supplier companies. Table 4.2 shows the supply chains from which data was gathered.

Supply chain	***Component***	***Supply chain***	***Component***
1) Rover/Motorola	ECU	13) Renault/UTA - MAI	Wiring Harness
2) Rover/Lucas Rists	Wiring Harness	14) Renault/Rockwell	Door process chain - Door cassette
3) Rover/Brose	Door process chain – Door cassette	15) Renault/Alibert	Instrument panel - Facia moulding
4) Rover/Kigass	Door process chain - Door handle	16) BMW/Siemens	ECU
5) Rover/Marley	Instrument panel - Facia moulding	17) BMW/Reinshagen	Wiring harness
6) Rover/Merit	Instrument panel - Light switch	18) BMW/Brose	Door process chain - Door cassette
7) PSA/Bosch	ECU	19) BMW/EDSCHA	Door process chain - Door hinge
8) PSA/Maducher	Door process chain - Door handle	20) BMW/Sparte Kunststoff	Instrument panel - Facia moulding
9) PSA/Rockwell	Door process chain - Window regulator	21) Ford/EEO	ECU
10) PSA/Treves	Door process chain - Interior door trim	22) Ford/Britax Wingard	Door process chain - Door mirror
11) PSA/Valeo Electronique	Instrument panel - Stalk switches	23) Ford/Fico or Happich	Sunvisor
12) PSA/Valeo Thermique	Instrument panel - HVAC equipment	24) Mercedes-Benz/Brose	Door process chain - Window regulator

Table 4.2 investigated supply chains.

The following sections describe the sample of components, the questionnaires and other forms of data gathering.

4.2 The components

The object in selecting the components was to achieve a cross section of purchasing practice, such that findings from the investigation could be held to be true across as broad a cross section of the automotive industry as possible. It is clearly understood (Lamming 1992, Womack and Jones 1990) that purchasing practice differs depending on the nature of the component. Generally 'commodity' items (raw materials, standard fastenings etc.)

are treated by purchasers as 'spot transactions' (Nishiguchi 1989) the trading relationship between buyer and supplier is 'arms length' (Sako 1992) and lasts for the duration of a particular purchase. As components become more specific to individual customers, the design content increases, the need for closer communication is apparent, and both buyer and supplier invest greater time and money into each transaction. This type of arrangement often leads to more 'obligational contracting' (Sako 1992) where there is vested interest for both customer and supplier to make the trading relationship close and long term.

In the current investigation it was felt important that a range of components representing different levels of trading relationship were included.

Thus, the following four components were selected for study; door, wiring harness, Electronic Control Unit (ECU), and dashboard.

The door and the dashboard have some similarity, in that they are both fairly complex assemblies comprising up to 150 sub-components. Traditionally vehicle manufacturers have purchased discrete components from the supply base and assembled the door and dashboard in-house. The current trend has been that a greater proportion of assembly is carried out in the supply base. In the case of the dashboard, the logical end-point is a 'fully assembled vehicle cockpit', comprising interior mouldings, instrument pack, heating and ventilation system, wiring, switches, pedal box and steering wheel. This is manufactured and fully assembled within the supply base and delivered complete to the vehicle manufacturer for assembly into the vehicle.

The ECU is interesting because of the fast pace at which the technology for vehicle electronics is developing. New electronic systems such as driving/handling management, and engine management have determined that significant investment in research and development is necessary for this component. The other driving force is changing legislation for example in the area of emissions, which require the ECU to be updated.

The wiring harness is interesting in that the looming (bundling together the right length and combination of wire to make up the harness) is extremely labour intensive. Wiring harnesses are also significant because they demand a vast variety of finished part numbers. The individual customer specification of the vehicle in the form of engine type, optional extra's, as well as the level of electronic equipment in the car mean that thousands of end configuration of wiring harness exist to cover one vehicle range.

4.2.1 Door

The supply chain was considered to start at the point of sub-sub components (e.g. pressings for the window winder), and end at the fully completed door. Clearly some vehicle manufacturers choose to carry out the majority of door assembly in-house, whereas others buy in semi (or in one case fully) completed doors. As such the structure of the supply chains varies quite markedly from one VM to another and the door is considered to be a useful example to study because of this.

Table 4.3 below shows the major activities and components involved in producing a car door.

(Next page)

Fit door to car
Final assembly of door
Fit Loudspeaker to mounting
Fit Glass seals to door
Fit door seals
Manufacture outer panels
Assemble Outer panels
Fit Interior trim panel complete
Fit Door check strap
Fit Door hinges
Fit Glass pane
Fit Exterior mirror
Fit Exterior door handle
Fit Side Impact Restraint System
Fit regulator to mounting
Assemble Regulator
Pressings for Regulator
Fit Latch/central locking to mounting
Assemble Latch/central locking
Fit Window lift switches to mounting
Fit wiring harness to mounting brackets
Fit glass channels to mounting bracket
Assemble Wiring harness
Looming for wiring harness
Assemble Loudspeaker
Manufacture main sub-components Loudspeaker
Assemble window lift switches
Manufacture main sub-components window lift switches
Manufacture glass channels
Manufacture glass seals
Manufacture door seals
Assemble Interior trim panel complete
Manufacture sub-components Interior trim panel complete
Manufacture Door check strap
Manufacture Door hinges
Manufacture Glass pane
Manufacture Exterior mirror
Manufacture main sub-components Exterior mirror
Manufacture Exterior door handle
Assemble Side Impact Restraint System
Manufacture main sub-components Side Impact Restraint System
Manufacture main sub-components Latch/central locking

Table 4.3 main activities and components in door production

The doors studied were from the following vehicles: Rover R17(800) Coupe, Renault Laguna, BMW E36 (3 Series), Ford Various models, PSA Citroen Xanthia, Mercedes Benz E class.

4.2.2 Instrument panel

Here, the supply chain was considered to start at the sub-sub component level (e.g. components for lighting switch), and end at the fully assembled dashboard. Again this gave the possibility for great variation in the structure of the chain to supply the end point assembly.

The level of technology for this component is not great in terms of its sophistication or complexity. However, advances have been made in the material and process for manufacturing the mouldings.

The fact that the completed dashboard is bulky to both store and transport is also considered to be of interest when considering the optimum structure of the supply chain.

Although many of the sub-components are can be standardised, the number of end configurations is great, influenced by trim levels, optional extras, Left hand and right hand drive, etc. Table 4.4 below shows the major components and activities in the dashboard supply chain.

Fit dashboard to car
Final assembly of dashboard
Fit Instrument binnacle to mounting
Final stage wiring connections
Fit wiring harness to dashbooard
Looming for wiring harness
Manufacture outer moulding
Manufacture inner moulding
Fit mouldings together
Fit glove box moulding inner
Fit glove box door moulding
Manufacture glove box mouldings
Fit HEVAC switches
Manufacture HEVAC switches
Fit passenger side airbag
Assemble passenger side airbag assembly
Manufacture main airbag components
Fit ducting
Manufacture ducting
Fit ICE system
Manufacture ICE system
Fit secondary switches
Manufacture secondary switches
Fit column switch assembly
Assemble column switch assembly
Manufacture main components for column switch assembly
Fit steering column
Manufacture steering column
Fit Steering Wheel
Manufacture steering wheel
Fit final trim
Manufacture final trim

Table 4.4 main activities and components, dashboard supply chain

4.2.3 Wiring harness

The wiring harness is a simple component in terms of the number of different sub-components. However it is made up from hundreds of different wires, each with a specific functionality, length and routing. Standardisation of connection and junction points has taken place to some extent across the industry, but a mesmeric quantity of different permutations of wire/connection types is typical in a range of harnesses.

For the purposes of the current study, the wiring harness is interesting because it represents a simple technology level, but complex logistics. It is also faced with eventual substitution by a new technology, the Vehicle Network, which will enable connection of the vehicle's entire electronic system by a single 'backbone' network.

Table 4.5 below shows the main components and activities in the wiring harness supply chain.

Fit harness to vehicle
Final assembly of harness
Manufacture of looms
Manufacture of connectors
Fit looms to connectors
Sheathing of loom assemblies
Manufacture of sheathing

Table 4.5 main components and activities in wiring harness supply chain

The wiring harnesses studied were from the following vehicles: Rover R17(800) Coupe, Renault Laguna, BMW E36 (3 Series), Ford Various models, PSA Citroen Xanthia, Mercedes Benz E class.

4.2.4 Electronic control Unit

The electronic control unit form the central data processing point for the vehicle. It is the hub of the electronic system, connecting electronic and elctro/mechanical systems in the vehicle, and providing computing power for engine management and other processes.

The units are not overly complex in their manufacture – they have relatively few main sub-components. However the design of the hardware, and particularly the software is highly complex. The environment in which the unit operates is subject to extremes in temperature and often has to withstand the ingress of both moisture and dirt.

In addition the pace of development in electronic systems is such that constant up-dating and redesign is necessary.

The supply chains involve the sourcing of microchips, an activity at risk from the vagaries of the global commodity markets.

When taken together, it is thought that the set of components provide a sample which is representative of a broad range of purchasing practice.

4.3 Questionnaires

The four questionnaires for designer, buyer, logistics agent and supplier respectively provide questions both on the structure and practices carried out in the case study supply chains. They were intended as a repository for information, and as a guide of structure for the interviews.

The objectives in developing the questionnaires were as follows:

- to provide data to populate Fixed Reference Benchmark Model;
- to provide structure for hierarchical structure mapping tool; and
- to collect data to allow comparison between actual structure and practice, and existing theory.

Some *examples* from the questionaire, and the reasons for their inclusion are given in table 4.6 below.

Example questions	Use of question in study
14. What proportion of your total take of this part is made by this supplier? (a) <30% (b) 30-60% (b) 60<100% (d) 100% **a b c d**	To measure level of dependence on supplier. This data is used in benchmark measure of 'Single sourcing' and in the comparison against 'Transaction cost' theory.
16. Would you describe your relationship with this supplier by any of the following words? (a) partnership (b) preferred supplier (c) established supplier (d) None of the above **a b c d**	Important in 'Network theory' comparison.
1. What is the duration of the contract with this supplier? (a) open ended (b) to the end of the life of this model (c) one year (d) more than one year(specify) **a b c d**	Used in the 'phantom benchmark' element – Long Term Contracts, as well as comparison with Transaction cost theory.
18. Did this supplier contribute to the design of the component? (a) not at all (b) with minor modifications (c) with significant design input (d) 100% supplier designed **a b c d**	Design and Development phantom benchmark element.
70. At what stage of the development process was first contact with the supplier(for the supply of this part) made? (a) concept design (b) detail specification (c) design manufacture **a b c**	Important for Design and Development element, and in considering trust in the relationship.
52. If you monitor suppliers by a formal vendor rating system: (a) is it a common system applied to all suppliers? (b) if there is a different system for foreign suppliers, does this supplier count as domestic? (c) or does it count as foreign? (d) or is this supplier subject to unique monitoring?	Used in comparing with 'Transaction cost' theory.

a b c d	
63. The last time this supplier suggested some improvement/amendment to the product was? (a) within the last week (b) within the last month (c) within the last 3 months (d) within the last 6 months (e) longer ago than 6 months **a b c d e**	Used in comparing to Network theory.
65. As a principle do you believe that "Co-makership" i.e. the shared responsibility, capital and inventiveness, for creating and supplying your products is a viable strategy? **Yes No**	Used in comparing to Network theory, and in the design/development benchmark element
71. How was the price for this component negotiated? (a) target price set by you (b) target range set by you (c) competitive tender bids set by suppliers **a b c**	Used in comparing actual structure with Transaction cost theory.
78. Does this supplier provide you with open book costing information and, if so, how much information are they prepared to provide? (a) does not operate open book (b) provides bill of material breakdown only (c) provides material and labour breakdown (d) provides full access to material, labour, overhead and profit **a b c d**	Network and Transaction Cost theory, and Fixed Reference Benchmark Model element.
79. Is open book costing a significant factor in sourcing with suppliers? (a) crucial (b) an important consideration (c) a marginal influence (d) not a serious factor **a b c**	Network and Transaction Cost theory, and Fixed Reference Benchmark Model element.
86. Does your relationship with this supplier extend to sharing with them your commodity strategy for this component? (a) not at all (b) only where it specifically affects sourcing agreements (c) open book **a b c**	Network and Transaction Cost theory.
88. To what extent are your long term marketing	Network and Transaction Cost theory, and

and/or manufacturing strategies shared with this suppliers? (a) not at all (b) formally presented (c) open book **a b c**	Business Strategy Management.
94. What is the method of communication with second and third line suppliers, for, (i) routine production matters, (ii) supersessions? (a) solely via this supplier (b) mainly via this supplier (c) mainly directly to 2nd and 3rd line (d) solely directly to 2nd and 3rd line **i) a b c d** **ii) a b c d**	'Open systems' Fixed Reference Benchmark Model element.
99. Do you find this company capable of and willing to design vehicle systems comprising more than one component? **Yes No**	Used in calculating 'Systems purchasing' benchmark element.
85. Is the relationship with this supplier affected by a "component/commodity strategy", and if so, what sort of effect does it have? (a) not affected (b) provides guidance on supplier (c) sets out guidelines on level of co-makership and delivery requirements (d) others(specify) **a b c d**	Used in comparing Business Strategy Management theory, and Network Theory.
45. Do you provide dedicated resources to manufacture the components for this customer? a) Yes, dedicated factory b) Yes, dedicated component and final assembly line c) Yes, dedicated final assembly d) No	Used in the determination of asset specificity, for phantom benchmark, and comparison with transaction cost theory.

A full copy of the main questionnaire is included as appendix 2 of the thesis.

Indirect data

In addition to the collection of data directly from the automotive supply chains, certain parts of the research investigation required independent data which was gathered from publicly available sources.

For example, in the comparison between actual supply chain structure, and that predicted by the Dualist theory, a breakdown of regional labour, land and building costs is required. This was sought from Government statistics, and helped to show that whilst cost of manufacture is a significant factor in the sourcing strategy of major VM's, it didn't influence directly the choice of supply chain structure. (See Chapter 5)

Recourse was taken to Government and Auto. industry data at several points during the investigation, to supplement the direct data.

4.4 Treatment of ongoing changes in the European Automotive Industry

During the period of research for this thesis the industry has been continually changing, reacting to new technological factors, as well as social, economic, political and competitive opportunities and threats. During the development of the research methodology and subsequent application through field research, the overiding aim was to create a research instrument which is outwith progressive changes in business practice, and rather that it strikes at the key generic activities required in the supply chain processes of product development and product manufacture. For example, the communication of schedule information is considered a key activity in the supply chain process (it will be required irrespective of the the means of communicating that information) and so forms one of the aspects of the Fixed Reference Benchmark Model "Open systems" element. The means by which the communication is performed can then be recorded against that element. It happens that business practices in this area have changed during the course of this research, migrating towards joint planning systems where supplier and customer share access to common 'end customer requirements' in real time. (Systems such as Distributed Materials Requirements Planning (DMRP) and the commercially available software package SAP)

The means by which these activities are achieved are nevertheless viewed as important but it is the fact that the postulated benchmark model focuses on key generic ***process related*** activities which allows it to remain relevant despite changing business practices.

Examples of major changes in the industry, of relevance to this thesis are: ***E-business*** (use of Internet based communication to conduct customer to supplier business (Callaghan and Pie, 1998)); ***Sequenced In-Line Supply (SIS)*** (The harmonisation of end-product and component manufacturing sequence(Bessant and Kaplinsky, 1998)); and ***Mass Customisation*** (fast response manufacture of make-to-order customer specific product (Alford and Sackett, 2000)).

Let us look at how these three key business practice changes are tracked by the proposed benchmark model.

E-Business

Out of the eleven proposed elements measured by the benchmarking tool, the one which best captures practice in the area of E-business is that entitled "Open Systems". Section 3.1.1., page 59 sets out the definition of this element, and it can be seen that progression towards using shared planning information in real time receives positive scoring . Hence increased acceptance and more common use of E-business in the supply chain would be reflected in the model by higher scores on this particular leg, and hence contribute to higher scores overall for the supply chain.

Sequenced In-line supply and Mass Customisation

The model measures progression of the supply chain towards 'true Just In Time' (Lamming, 1992). True Just-In-Time is defined as sequenced manufacture of components, in-line with vehicle build. Two distinctions can be made, and are scored to reflect progression towards optimal practice. Firstly JIT *manufacture* rather than JIT *delivery* – where components are delivered from pipeline inventory is scored more highly. Secondly the 'distance up-stream' in the supply chain to which JIT manufacture is carried out is also measured. For example, in a hypothetical case where raw material is extracted from the ground JIT to be processed, JIT to be formed into components, JIT to be sub-assembled, JIT to be assembled onto the vehicle, JIT to be sold to a customer – this scenario would score a maximum rating. In other words, true sequenced manufacture and delivery from raw material to end customer.

Again the benchmark model allows for reflection on the progress of each surveyed supply chain towards this optimum practice. As discussed in chapter 3, although the measure for this element was developed during the study, collection of data to populate this element of the model has not been possible in the time period.

This measure also reflects on the ability of the supply chain to deliver mass customisation. If the supply chain possesses the flexibility to manufacture and deliver in line with vehicle build sequence, then ensuring that the vehicle build sequence is in line with actual customer demand is – in the terms of the model – another step up the continuum of practice. Again this can be measured and reflected in the benchmark score.

Next chapter

This chapter has outlined the methods and sources of data gathering. The following chapter describes how the data, and the research methodology from Chapter 3, were put together to generate the findings of the study.

Chapter 5

Analysis

- **This chapter explains first how the data was used to populate the Fixed Reference Benchmark Model. It then shows the analysis involved in modeling the structure of the supply chains via the Hierarchical Structure Mapping tool. Finally it explains how the actual structure was compared with that predicted by the leading structure theories set out in chapter 2.**

5.1 Introduction

Chapter 3 described the research method, in terms of the elements of the Fixed Reference Benchmark Model, and how these are used in conjunction with the Hierarchical Structure Mapping tool to generate findings on the determinants of supply chain structure.

The first part of this chapter shows how numerical ratings for the benchmark model elements were achieved. It also describes the results of one set of supply chains – in order to aid presentation of the rating scheme.

Data analysis using the structure mapping tool is described in the second part of this chapter.

The penultimate section describes how actual structure is related to existing structure theory, and lastly the process of generating the results is presented. Chapter 6 deals with the full set of results.

5.2 Achieving numerical ratings for Fixed Reference Benchmark Model elements.

Each element of the model described in chapter 3 is given a 'maximum' score of 100. It is useful to reiterate that a high score does not necessarily correspond to an assertion of better practice. The rating scheme merely allows rigorous comparison of the supply chains, against a fixed reference.

Each element is split into multiple 'aspects', which in turn are derived. From the derivation, measurable factors either direct or by proxy are used to give a numerical 'score' to the 'aspect'. The scoring system is routed in the derivation of often-contentious aspects such as 'tiered supply base'. In the development of the scoring system, recourse has been taken to established theory, and/or factors which are accepted in the industry as true indicators of certain aspects of the elements being measured by the benchmark model. In many cases the weightings of the factors have been given a linear distribution, in other words equal weighting to all factors. In others, a somewhat subjective judgment as to the weighting has been made, based on qualitative definitions from the literature, and the researcher's own experience of the market in which the supply chains operate. The score for each element is calculated by summing the score of the aspects.

5.2.1) Element 1 - Tiered Supply Base

Degree of **dedication** of the supply chain to the customer max. = 25 + Amount of **demarcation** of roles within the supply chain max. = 50 + Amount of **direct collaboration** between suppliers involved with the assembly max. = 25

Table 5.1. Three Aspects of Tiered Supply Base showing the weighting ascribed to each aspect.

Explanatory notes:

The positive effect of a tiered supply base is traced to the Japanese desire to achieve the *dedication* of vertical integration - a focused and flexible supply base - without the unwieldiness of direct ownership (Lamming 1989, Monden 1983). This effect is measured, and ratings allocated, by considering three aspects. First the number of main customers contributing 80% of the supplier's total business (sales volume) is measured as a proxy for dedication. Marks are allocated on a pro-rata basis assuming that the maximum likely spread of customers would be 21 (This being equal to the number of significant vehicle producers purchasing in Europe as set out in table 5.2 below).

Volume producers:

- VW Group:
  1. VW
- GM Group:
  2. Opel
  3. Vauxhall
- PSA Group:
  4. Peugeot
  5. Citroen
- Ford Group:
  6. Ford
- Fiat Group:
  7. Fiat
- Japanese Transplants:
  8. Nissan
  9. Toyota
  10. Honda
  11. Mitsubishi
  12. Renault

Lower volume or specialist producers:

- VW Group:
  13. Audi
  14. Seat
  15. Skoda
- Ford Group:
  16. Jaguar
- GM Group
  17. Saab
- BMW Group
  18. BMW
  19. Rover
- 20. Mercedes-Benz
- 21. Volvo

Table 5.2 21 European Vehicle customers

The rating is calculated as follows. (Maximum available mark = 25)

$$\textbf{Rating=} \left[100-\left((\alpha-1)\times\frac{100}{20}\right)\right]\times 0.25$$

Where:

α = Number of customers contributing to 80% of supplier's sales volume (data collected via questionnaire)

The second aspect of tiering included in the measure is the extent to which the supplier has a clear and stable role in the supply chain - termed *demarcation.* This aspect relates to the achievement in traditional Japanese supply bases of a minimum overlapping of scarce and finite resources because of a disciplined orchestrated distribution of roles (Nishiguchi 1990, Nakamura 1981). If the supplier is 'unfocused' in the sense of supplying discrete components for some customers but more complex systems for others - then a low rating would be attributed. This part of the index gives a measure of the 'range' of complexities handled, as a proxy to the level of sub-optimisation of resource utilisation. The aspect is split into two constituents - a measure of the demarcation of roles in:

a) The Manufacturing process, and
b) The Development process.

a) The 'unfocusedness' of the manufacturing process is indicated by the range of different complexities the system deals with, which is indicated by the differential* in piece part prices e.g. a supplier who manufactures window regulators, priced at £10 and also 'modules' priced at £85 would have a differential ratio of 1:8.5. On the other hand a supplier who only supplied regulators might have a much lower differential. The rating is calculated as follows. (Maximum available mark = 25)

$$\textbf{Rating=} \left[100-\left(\left(\frac{\beta}{\gamma}-1\right)\times\frac{100}{24*}\right)\right]\times 0.25$$

Where:

β = Maximum value component or system produced
γ = Minimum value component or system produced

*greatest possible differential is assumed to be 1 to 25, e.g. £10 component least value, £250 maximum value.

Note : A representative overall measure of the unfocusedness of the supply base for the complete assembly (e.g. door) would require this analysis to be completed for all major constituent sub-components for the assembly.

b) The 'range' of complexities handled by a supplier's New Product Introduction process is indicated by the range of different project lead times**. e.g. for doors, if the supplier develops regulators (lead time typically 18 months) as well as modules (lead time typically 36 months) the differential would be 1:2. The rating is calculated as follows. (Maximum available mark = 12.5%)

$$\textbf{Rating}= \left[100-\left(\left(\frac{\delta}{\varepsilon}-1\right)\times\frac{100}{4**}\right)\right]\times 0.25$$

Where:

δ = Maximum lead time component or system designed.

ε = Minimum lead time component or system designed.

**greatest possible differential assumed to be 1 to 5, from study sample shortest lead time component = 12 months, longest lead time = 60 months.

The third aspect of tiering included in the measure is the amount of horizontal collaboration directly between suppliers rather than indirectly through the vehicle manufacturer. This is measured by the ratio of number of interfaces at which direct communication occurs as a percentage of total number of possible *beneficial* direct interfaces. Determination of the measure relies on first establishing the highest logical integration level (e.g. for door components - the 'whole door' - see chapter 3) and identifying the significant major components within the system. Next the quantity of *potential* direct interfaces is measured. Finally - for the supply chain under study - the *actual* number of interfaces at which direct communication occurs is measured. A component 'interface grid' is used to identify the total number of interfaces. An example 'interface grid' is illustrated for the door assembly.

	Component-to-component interfaces	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Re	La	Lo	Wi	Wi	Gl	Gl	Do	Int	O	Do	Do	Gl	In	Ex	Ex	Si
1	Regulator																	
2	Latch/central locking																	
3	Loudspeaker																	
4	Window lift switches	1																
5	Wiring harness	1	1	1	1													
6	Glass channels	1																
7	Glass seals	1					1											
8	Door seals																	
9	Outer panel			1	1													
10	Interior trim panel complete	1		1			1	1	1	1								
11	Door check strap																	
12	Door hinges								1			1						
13	Glass pane	1					1	1			1							
14	Inner panel	1	1	1		1	1	1	1	1	1	1	1					
15	Exterior mirror					1					1							
16	Exterior door handle		1		1	1					1							
17	Side Impact Restraint System					1				1	1				1			
																		Total = 43

Table 5.3 Component to component interfaces, indicating interfaces where direct supplier to supplier collaboration would be beneficial

The table above shows 43 interfaces where components either adjoin or are physically connected to each other in the car door. These interfaces are considered as points where direct supplier to supplier collaboration would remove the detrimental effect of communication via a third party, i.e. the common VM customer. The detrimental effect of such a method of communication is seen first as the extra time required to relay enquiries through the VM engineer, to the supplier engineer and back again, and also because of the greater potential for distortion and inaccuracies because of the double handling of information.

Therefore the greater number of interfaces at which direct supplier to supplier communication is allowed to happen, the greater will be the score for this aspect of the overall 'tiered supply base' element.

The rating is calculated as follows. (Maximum available mark = 25)

$$\textbf{Rating} = \left(\left(\frac{\zeta}{\eta}\right) \times 100\right) \times 0.25$$

Where:

ζ = Interfaces managed externally to the VM

η = Total possible interfaces

Together the two aspects represent the balance of manufacturing and development responsibility for the assembly between the VM and its supply base.

5.2.3) Element 3 - Systems Purchasing

Manufacturing Logistics integration and pre-assembly in the supply base. max.= 50 + **Development** Horizontal interface management by the supply base. max. = 50

Table 5.5 Aspects of systems purchasing, showing weightings

Explanatory notes:

The measure employed here utilises the fixed end point definition of the logical limit of systems integration for the component, as set out in table 5.2. The measure compares the theoretical end point for systems integration (both assembly integration and 'design and development integration') with the actual practice observed in the supply chain. For manufacturing the ratio of significant major components to number of direct external suppliers is calculated, thereby giving a measure of the amount of logistics integration carried out in the supply base. The rating is calculated as follows. (Maximum available mark = 50)

$$\textbf{Rating=} \quad \left[100-\left((\theta-1)\times\frac{100}{(\kappa-1)}\right)\right]\times 0.5$$

Where:

$\theta =$ Number of direct external suppliers for the complete assembly
$\kappa =$ Number of significant constituent components in the assembly

The second aspect of systems supply measures the amount of 'development integration' carried out in the supply base. Here the benefits of delegating the development of the system to the supply base are traced to the ability of the VM to delegate the management of the integration of the discrete components into the higher level assembly. Thus a measure of the number of component to component interfaces managed directly by the supply base compared to the total number of interfaces for the 'end point system' (e.g. the whole door represents the 'end point system' for door components), gives a measure of the design/development aspect of systems supply. The rating is calculated as follows. (Maximum available mark = 50)

$$\textbf{Rating} = \left(\frac{\lambda}{\mu} \times 100\right) \times 0.5$$

Where:

λ = Interfaces managed externally to the VM

μ = Total possible interfaces

5.2.4) Element 4 - Single Sourcing

Single sourced by range	= 100
Single sourced by model	= 75
Single sourced by part number	= 50
Dual sourced by part number	= 25
Multi-sourced by part number	= 0

Table 5.6 Showing rating scale for single sourcing element

Explanatory notes

Proprietary items with technology owned uniquely by one supplier would imply single source across VM's product range e.g. breakthrough technology.

Commodity item with no specific design content (e.g. fixings) - a purely contractual arrangement would be expected, with multiple sources for a given part number.

5.2.5) Element 5 - Design and Development delegation

Critical:

Efficiency of work sharing
Max. = 50
+
Point of first involvement (relative to start of VM concept phase)
Max = 50

Non-critical:

Percentage of development delegated
Max.= 33
+
Efficacy of delegation
Max. = 33
+
Point of first involvement
Max. = 33

Table 5.7 Aspects of Design and Development Delegation showing weightings, and differentiating between 'critical' and 'non-critical' components.

Explanatory notes:

Consideration is taken of the heterogeneous nature of the components in the study, by assessing the nature of the component and placing it within the range for critical to non-critical. This position predicates the parameters of the desired relationship. In practice the sub-totals of the aspects under critical and non-critical are scaled according to the criticality/non-criticality of the component. The current positioning method, whilst based on consistently applied definitions of criticality and non-criticality could be evaluated and further developed.

Assessment of critical component trading relationship:

The assessment the relationship is reflective of the necessity for collaborative working for critical component development: joint development where the supplier holds knowledge of the component technology, and the VM has knowledge of the application requirement. Here, the first most important parameter of the working relationship is that the VM and supplier 'mesh' efficiently (Dore 1987), hence "Efficiency of work sharing". Secondly that the supplier is involved early enough in the vehicle development such that the overall design can be optimised - the supplier is not constrained by parameters already fixed by the VM (Womack and Jones 1990) - and the full potential of the technology can be realised.

Efficiency of work sharing

Assessment of the efficiency of work sharing is carried out by proxy, by examination of key features of the work sharing practices:

i) (10 marks) Do the VM and supplier use compatible CAD systems ?.

ii) (20 marks) Is there a direct link between CAD systems - ability to download, work on and up load each others CAD files ?.

iii) (30 marks) Dedicated product development teams permanently working for this customer ?

iv) (10 marks) Use of guest Engineers ?

v) (30 marks) Supplier's development team an integral part of the VM New Product Development team?

Point of first involvement (relative to pre-concept):

The second aspect measured in the relationship for critical component development is the involvement period of the supplier (supplier commitment point to volume production) relative to the vehicle development time (pre-concept to volume production). Here the ratio is raised to a power (four) such that situations of higher involvement time are positively rewarded disproportionately as involvement time approaches the vehicle project duration.

$$\text{Rating} = \left(\frac{\pi}{\xi}\right)^4 \times 100$$

Where:

ξ = VM project lead time (pre-concept to volume production)

π = Supplier involvement period (supplier commitment point to volume production)

Sub-total for 'critical component development' is obtained by combining both elements, then scaling according to the nature of the component. (Entirely critical=x1, entirely non-critical = x0).

Assessment of non-critical component trading relationship:

For less, or non-critical components the relationship is characterised more by delegation than by work sharing. The amount of delegation and the efficacy of delegation form two sub-aspects in this part of the measure. Point of first involvement is still felt to be important, but this time is measured relative to the start of concept phase, taking consideration of the innaplicability of involving a non-critical component supplier during the concept definition phase.

Amount of delegation

This is measured directly out of 100 and multiplied by 1/3 - to combine with the other two sub-aspects for 'non-critical'.

$$\text{Rating} = \rho \times \frac{1}{3}$$

Where:

ρ = Supplier share of development

Efficacy of delegation:

The second sub-aspect measures the practices which are likely to achieve or detract from the successful realisation of the benefits of delegation. Namely reducing the involvement of the VM, which pre-requires also clearly set out 'hand over' of responsibilities to the supplier. This sub-aspect is further split into:

Dealing with sub-supply
and
Role clarity

Dealing with sub-supply:

The total number of sub-components is studied, and the proportion thereof which the supplier sources with a freehand is expressed. A further sophistication takes satisfactory account of disproportionately costly individual sub-components e.g. electric motor in electric window regulator. Therefore the first ratio can be multiplied by the cost/value of the sub-components dictated by the VM as a proportion of the total value of the component. This sophistication is not included in the current calculation.

$$\text{Rating} = \left(\frac{\sigma}{\tau}\right) \times \frac{1}{3}$$

Where:

σ = Number of significant sub-components dictated by the VM
and
τ = Total number of significant sub-components dictated by the VM

Role clarity in delegation:

Role clarity refers to the division of responsibility between the Vm and supplier, and the extent to which the working relationship succeeds in achieving un-equivocal and non-overlapping work packages. The current rating method involves a subjective review from the field research.

ν = role clarity in delegation

Point of first involvement (relative to concept phase):

The involvement period of the supplier is measured relative to the start of the VM's concept design stage.

$$\text{Rating}=\left(\frac{\pi}{\phi}\right)\times 100$$

Where:

π = Number of significant sub-components dictated by the VM

and

ϕ = Total number of significant sub-components

Scores for Amount of delegation, Efficacy of delegation, and Point of first involvement are combined for the sub-total for 'non-critical component trading relationship'. The sub-total is scaled according to the nature of the component.

5.2.6) Element 6 - Long-term Contracts

Nominal length of the contract max. = 50 + Certainty of business retention on the part of the supplier max. = 50

Table 5.8 Aspects of Long Term Contracts Element showing weightings

Explanatory notes:

The first aspect measured here is the nominal contract length. The logic here is that the longer the contract duration, the greater the confidence in the trading relationship. The stated contract duration is compared relative to the duration of the model life of the vehicle.

$$\textbf{Rating} = \left(\left(\frac{\chi}{\psi}\right) \times 100\right) \times 0.5$$

Where:

χ = Nominal contract length

and

φ = duration of model life

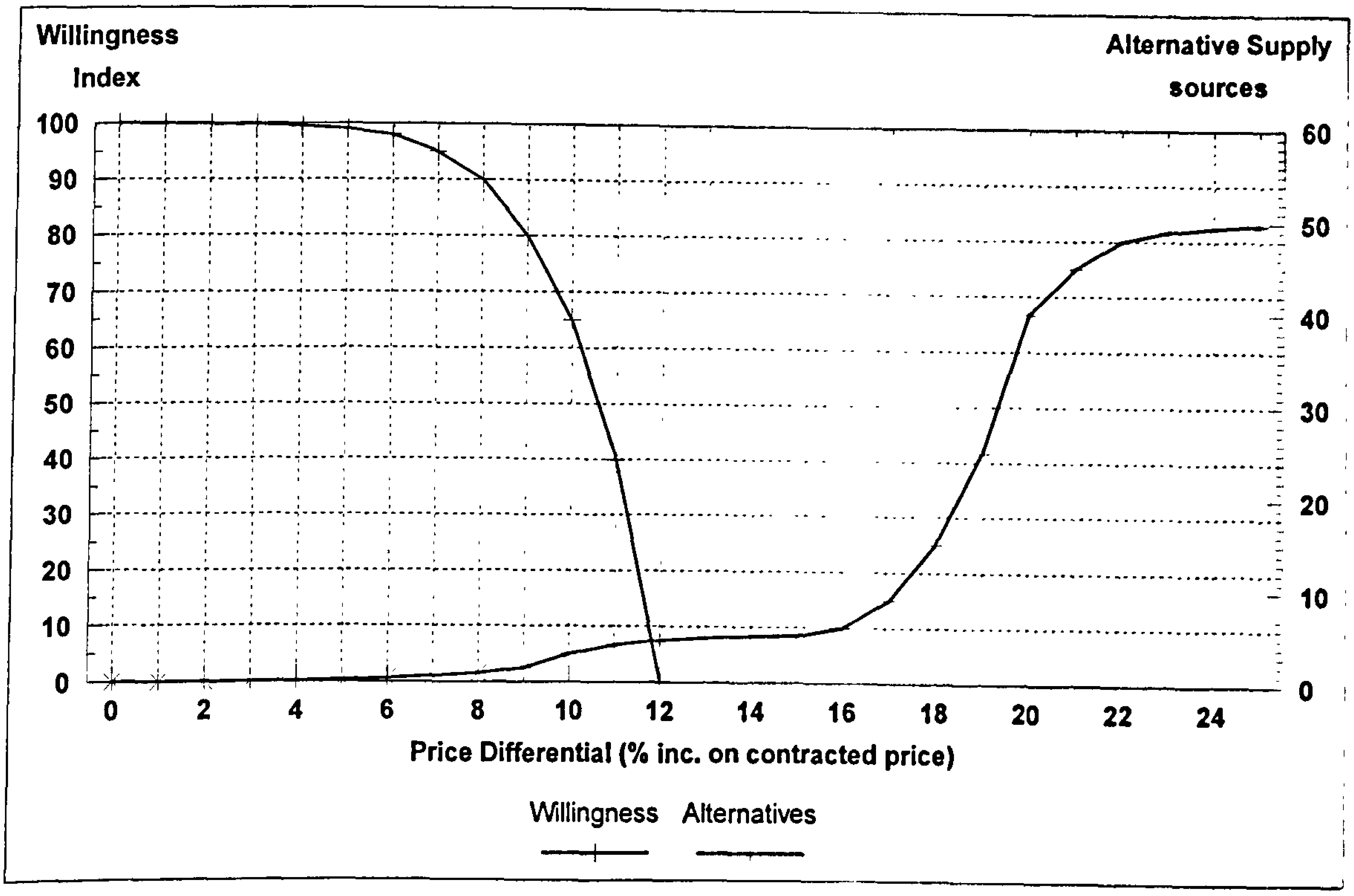
The premise for having a second determinant of this element is to assess the actual or real length as opposed to the nominal length of Contract. This is done by way of analysing the trading relationship *between* the two actors i.e. Vehicle Manufacturer and Supplier(direct), rather than discrete assessment of the responses from the two actors. This way affords an objectivity in the assessment necessarily lacking in the prima facie acceptance of the public responses from the actors' representatives, given during the interview data collection phase of this study.

Now that we have established the qualitative shift inherent in this way of assessment it is necessary to recall why a longer-term contract is necessarily desirous? It is generally accepted that the Supplier will benefit from the assurance of a more permanent revenue stream from the Customer than is conventional (Sako 1992, Helper 1990, Lamming 1989). Realisable benefit is typically derived from enhanced: integrity of planning, level of investment, scale of production. If so realised there is at least the potential for the Customer to benefit in turn. That is, a contract whose duration is significantly longer than is conventional practice, for example for the duration of a model rather than subject to annual renewal, affords mutual advantage in the trading relationship. The same principle may of course be employed in the less visible but nonetheless important, because of the significant value added as a proportion of the total, trading relationships upstream in a typical automotive supply chain.
Given the above, we may now state that in order to assess the length of contract we will actually be analysing the trading relationship to gauge the degree of assurance the Supplier can realistically expect to have, in parallel to the nominal length declared by the Customer. It would be incorrect for the reader to infer here, that the Customer acts deceitfully and the degree of assurance the Supplier has is in all instances to be less than the nominal length.

The basis for the analysis of the trading relationship is to depict the interplay between two factors. The first factor is the willingness of the Customer's representative i.e. the Buyer, to continue to honour the original contract irrespective of the declared duration. It takes as its hypothesis that a move to a policy of long-term contracts by a VM requires a greater tolerance of episodes of relative uncompetitiveness by its chosen Supplier, and that it will positively help the Supplier during these episodes to secure long-term mutual competitive advantage, rather than resort to short-term opportunistic re-sourcing.

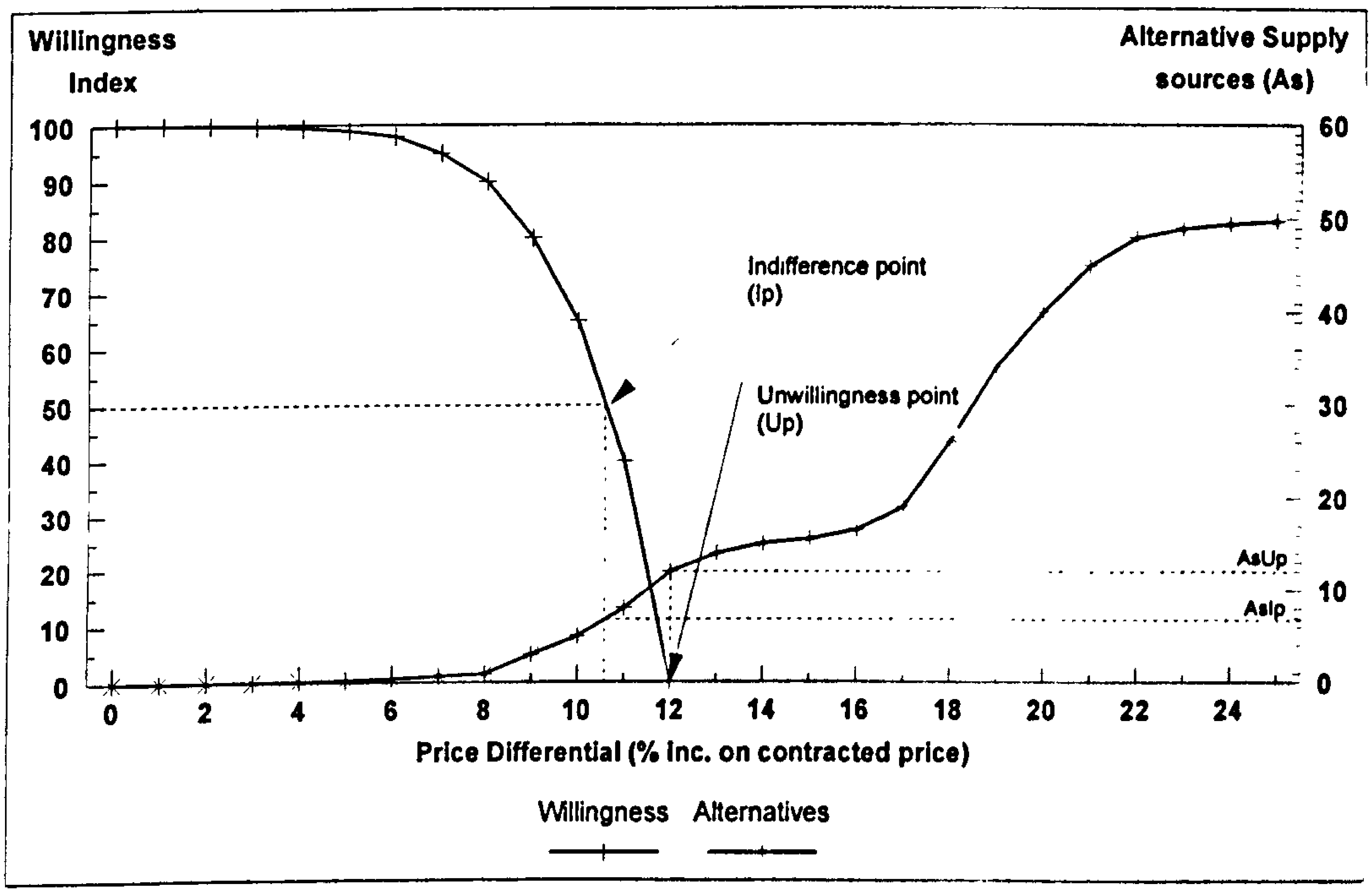
The Customer's representative is asked to quantify his continued willingness to honour the contract for a range of increasing uncompetitiveness by his existing Supplier; he is instructed not to condition his response by conscious regard to actual knowledge of viable alternatives. Essentially, we wish quantify his propensity to re-source the contract directly from his innate behaviour, in turn, influenced by company internal nurturing factors. The measure of uncompetitiveness is taken to be price: an increasingly unfavourable price differential compared to the originally contracted price. It is acknowledged that uncompetitveness is more complex than the piece part price simply, including quality, delivery and technical ability also.

The second factor is the number of alternative competing sources as a function of price. The relevant range of prices is that commencing with the contract price with the existing Supplier, up to an absolute price in excess of the price differential which returns a minimum willingness by the Customer's representative to continue to honour the contract. The relationship between the number of alternative competing sources and price is principally determined in each case by the degree of differentiation of the component being traded. Differentiation can be non-existent i.e. a pure commodity component or complete i.e. unique, a proprietary component. This may be not just the product itself, but also process and combined know-how. This range of product differentiation is closely aligned to perfect competition and monopoly or at least monopolistic competition in the market, for commodity and proprietary components respectively. Further, small price increases for commodity type components can induce large amounts of extra supply, whilst proprietary components tend to present high barriers to entry to potential alternative competing sources. Final determination of the path of the curve traced by alternative competing sources for the relevant range of positive price differential to contract price is secured by specific market circumstances information from the Supplier concerned plus the researchers own evaluation of the general market circumstances for the generic component studied gained from studying parallel supply chains. A general plot of the two factors on a common price differential axis for an intermediate type component is shown below.



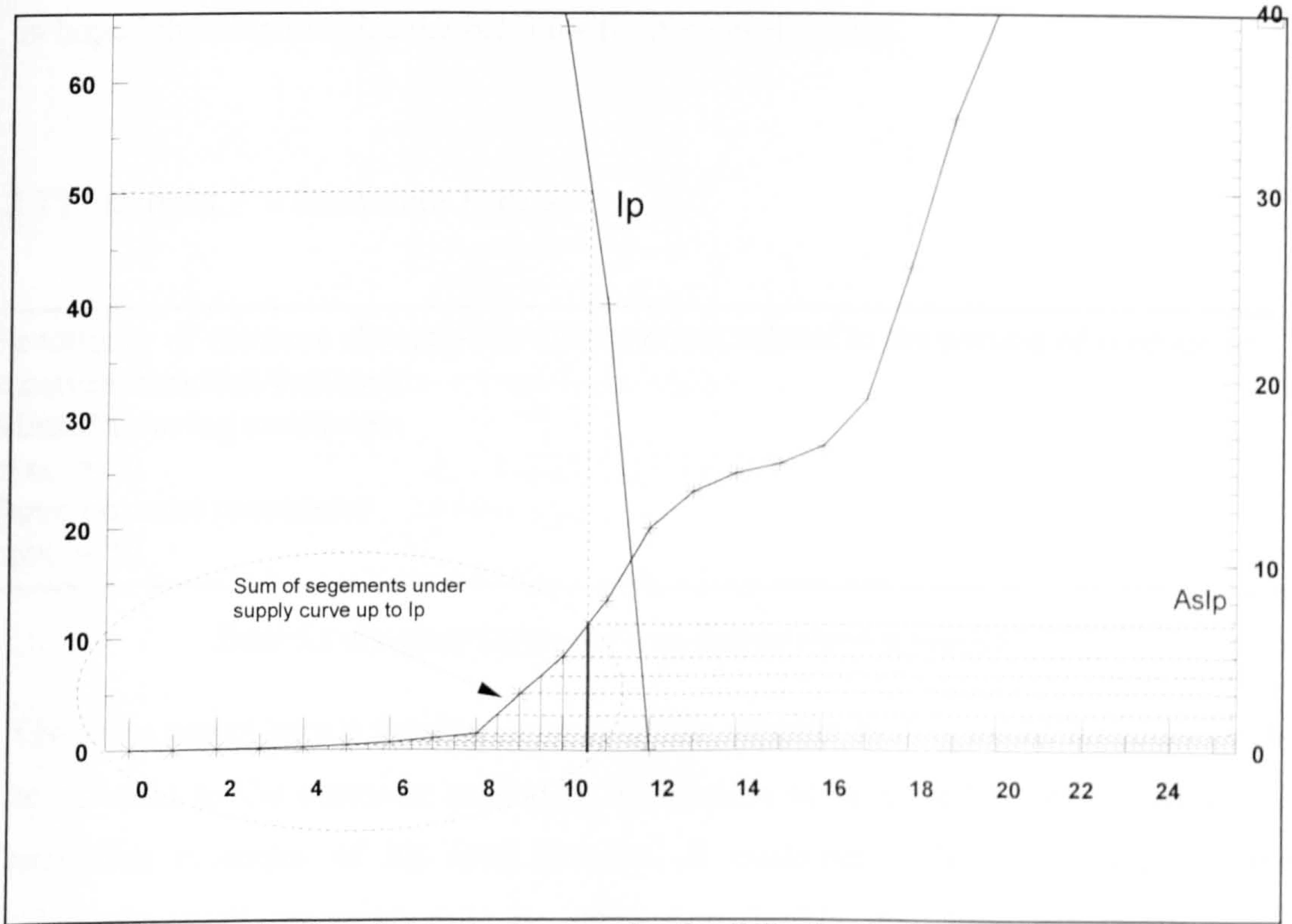
Graph. 5.1 A general depiction of interplay of factors within the trading relationship

With the depiction of the interplay of the two factors achieved, the analysis of the trading relationship is taken one stage further by concentrating on two critical points on the Willingness Index plot. The first point is the particular price differential at which the Customer's representative becomes indifferent to the existing Supplier. That is, the price differential at which he is on the cusp of moving from a marginally positive willingness to continue to honour the contract with his existing Supplier, to a marginally positive unwillingness to continue to honour this contract. This is by definition the price differential on the plot that equates to 50. We term this point the Indifference point. The Indifference point's crucial significance is that it defines the degree of uncompetitiveness of the existing Supplier, as represented by the factor of price, at which the Customer's representative begins earnestly looking for alternatives. However, the difference between his desire to actively re-source the contract and the feasibility of doing so is determined by the number of alternative supply sources available at that price differential level i.e. an absolutely higher price level. The second point is the particular price differential at which the Customer's representative is to all intent wholly unwilling to continue to honour the contract. This point is significant in that it affords the comparison of the number of alternative supply sources available to the Customer's representative when he is in no doubt of his desire to re-source the contract. We term this point the Unwillingness point. If for example the Customer's representative has initially declared a conventionally short-term contract length and then finds the Supplier to be uncompetitive to a point in excess of any residual willingness to continue sourcing with this Supplier, he may also find that the actuality of re-sourcing is not feasible due to the non-existence of alternative supply sources. These two points are highlighted in the figure below.



Graph. 5.2 A general representation of the two critical points and associated alternative supply sources

The last stage of the analysis and thence to the measurement of the actual length of contract is to quantify the feasibility of re-sourcing the contract by the Customer's representative at his Indifference point. The feasibility is not simply the associated number of alternative supply sources(AsIp). It is only the last or marginal supply source who is willing to offer its supply in the market at the price differential that equates to the Indifference point. As the price differential reduces each supply source in turn will withdraw its offer of supply. Therefore, the Customer's representative's actual re-sourcing feasibility quantity is the sum of the number of alternative supply sources at each increment of price differential working back from the Indifference point price differential to zero price differential i.e. the contract price with existing Supplier. This is represented in the figure below.



Graph. 5.3 Quantification of the actual re-sourcing feasibility for the Customer's representative

An integration of the area under the alternative supply sources curve, bounded by the origin i.e. contract price and the perpendicular from the Indifference point provides a statistical measure of actual re-sourcing feasibility. Thus we can state as a formula:

$$\int \frac{dA_s}{dP_d} =$$

Conversely, we can state that the inverse of the Customer's representatives actual re-sourcing feasibility is the assurety the existing Supplier can have for his contract retention, set aside from the nominal length declared by the Customer's representative.

Important note: having set out the premise for the determination of a theoretical 'true length of contract' aside from the 'nominal contract length' articulated formally between supplier and customer, it must be noted that it has been beyond the scope of this study to either fully develop, test and use the method to produce useable results. It is hoped that this remains the basis for further development.

5.2.7) Element 7 - Customer Focus

Specificity of resource allocation to the customer, related to the portion of revenue he receives from that customer:- **Manufacturing resources:** max. = 50 **Development resources:** max. = 50

Table 5.9 Aspects of Customer Focus element showing weightings

The main aspect here is the degree to which the supplier has organised his resources to be specific to the customer related to the portion of revenue he receives from that particular customer of his total revenue. A customer with high specificity and relatively small account would be rated more highly than high specificity and a customer who represents a large proportion of the supplier's business.

Resource specificity (Ford et al, 1985) is measured in two constituent parts, corresponding to the two main processes of manufacture and design/development. Rather than a detailed decomposition of the two processes into individual activities followed by direct measurement of specific and non-specific resources - the present methodology involves measuring resource specificity via a judicious selection of the key elements of the two main processes. The elements of the two main processes are shown in the table below. Should a process element be dedicated to that customer, the maximum available rating would be awarded for that part of the process. Should the resources be split between more than one customer, then marks are awarded pro-rata according to the proportion of customers using the resource (e.g. if the supplier serves 10 customers in total, 2 customers using a particular resource would correspond to 80% specificity - 10 customers is defined as 0% specificity)

Table 5.10 Manufacturing process resource specificity - maximum rating 100

Process element	Maximum rating (dedicated to single customer)
In-bound logistics	16
Material processing	16
Component manufacture	16
Sub-assembly	16
Final assembly	20
Despatch	16
	100

Table 5.11 Development process resource specificity - maximum rating 100

Process element	Maximum rating (dedicated to single customer)
Advanced R&D	16
CAD facilities	16
Prototype manufacture	16
Testing	16
Product development	20
Manufacturing engineering	16
	100

The final rating for 'customer focus' is conditioned by a multiplication factor related to the proportion of the supplier's total sales volume represented by this customer. The conditioned rating is calculated as follows, for the:

Manufacturing process

$$\text{Rating}_{cm} = Log_{10}\left[\left[R_m \times \left(\frac{R_m}{\omega}\right)\right] \times 0.1\right] \times 0.5$$

and

Development process:

$$\text{Rating}_{cd} = Log_{10}\left[\left[R_d \times \left(\frac{R_d}{\omega}\right)\right] \times 0.1\right] \times 0.5$$

Where:

R_m = Rating actual for Manufacturing process
R_d = Rating actual for Development process
ω = Percentage of suppliers' turnover

5.2.8) Element 8 - Open-book Costing

Extent of information sharing max. = 80 + Compatibility of format max. = 20

Table 5.12 Aspects of Open Book Costing

Explanatory notes

The advantage of open-book costing is seen first as enabling the VM to audit the viability of the tender, to protect himself against unrealistic bids. Second is the potential for achieving the best-cost position in the long run for the mutual benefit of both trading partners.

The first aspect of the benchmark measure is to check progress towards this optimal position, is the amount of information provided by the supplier. Maximum rating here is 80.

Extent of information sharing	Rating
Closed book	0
Materials	20
Materials & labour	40
Materials & Labour & overheads	60
Full access	80

The second aspect measured is the compatibility of the format of the information - providing a measure of the harmonisation of the standards between supply chain members - as a proxy to the extent of common interpretation of the information. An additional 20 is awarded if the first tier and VM have adopted a common cost standard.

5.2.9) Element 9 - Mutual Development

Progress towards improving mutually beneficial relationship factors max. = 100

Table 5.13 Mutual Development Measurement

Explanatory notes:

Here joint working on mutually problematic factors is assessed, as a proxy to mutual development.

Factor	Rating
Schedule variability	14.7
Pallet control	14.7
Standardisation	14.7
Upfront development funding	14.7
Late design changes	14.7
Early involvement	14.7
Late feedback on supplier suggestions	14.7

5.2.10) Element 11 - Open Systems

Links between VM and Supplier of their commercial systems. max. = 100

Explanatory notes:

Here communication is assessed and rated as to whether or not direct EDI links exist for the following information.

Factor	Rating
Planning schedules	20
Delivery schedules	20
Invoice submission	20
Invoice payment	20
Purchase orders	20

5.2.11) Element 11 - JIT Deliveries

Pipeline stock level relative to 'True JIT'(sequenced manufacture) stock level. max. = 100

Explanatory notes:

The measure of JIT used here is a comparison of optimal 'make to order' sequenced manufacture stock levels, compared to actual pipeline stock.

This measure is not available for this study and published figures (Anderson 1993) were used for the purposes of the thesis.

5.3) Populating the Fixed Reference Benchmark Model

Once the numerical grading system had been established the work proceeded by allocating data to the various equations and weighting systems, such that each supply chains' scores could be calculated.

From the equations, the following list of data points have been extracted and placed in tabular form. Each data point could then be extracted from the data base of data collected during field research (see table 5.18)

Data points				
No.	Variable	Description	Unit	Value
1	α=	number of customers contributing to 80% of Suppliers sales volume	No.	
2	β=	maximum value component or system produced by the Supplier	Ecu	
3	γ=	minimum value component or system produced by the Supplier	Ecu	
4	δ=	maximum lead time component or system designed by the Supplier	Yr.	
5	ε=	minimum lead time component or system designed by the Supplier	Yr.	
6	ζ=	interfaces managed externally to the VM	No.	
7	η=	total possible interfaces	No.	
8	θ=	number of direct external suppliers for the complete assembly	No.	
9	κ=	number of significant constituent components in the assembly	No.	
10	λ=	interfaces managed externally to the VM (NB.intermediate status)	No.	
11	μ=	total possible interfaces (NB. Intermediate status)	No.	
12		compatible CAD systems	No.	
13		direct CAD link	Y/N	
14		dedicated development teams	Y/N	
15		guest engineers	Y/N	
16		integral development teams	Y/N	
17	ξ=	VM project lead time (pre-concept to volume production)	Yr.	
18	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	
19	ρ=	Supplier share of development	%	
20	σ=	number of significant sub-components dictated by VM	No.	
21	τ=	total number of significant sub-components in component	No.	
22	υ=	role clarity in delegation	%	
23	φ=	VM project lead time (concept to volume production)	Yr.	
24	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	
25	χ=	nominal contract length	Yr.	
26	ψ=	duration of model life	Yr.	
27	Rm(1)=	in-bound logistics (number of customers using the resource)	No.	
28	Rm(2)=	material processing (number of customers using the resource)	No.	
29	Rm(3)=	component manufacture (number of customers using the resource)	No.	
30	Rm(4)=	sub-assembly (number of customers using the resource)	No.	
31	Rm(5)=	final assembly (number of customers using the resource)	No.	
32	Rm(6)=	despatch (number of customers using the resource)	No.	
33	Rd(1)=	advanced R&D (number of customers using the resource)	No.	
34	Rd(2)=	CAD facilities (number of customers using the resource)	No.	
35	Rd(3)=	prototype manufacture (number of customers using the resource)	No.	
36	Rd(4)=	testing (number of customers using the resource)	No.	
37	Rd(5)=	product development (number of customers using the resource)	No.	
38	Rd(6)=	manufacturing engineering (number of customers using the resource)	No.	
39		total number of customers of relevant plant	No.	
40	ω=	percentage of supplier's turnover	%	

Table 5.18- Data to populate Fixed Reference Benchmark Model

The table above was input into an Excell spreadsheet, and data from each supply chain placed in subsequent columns, to form the database of raw data for the study.

An analysis spreadsheet was created, to take the raw data and perform calculations in line with the equations set out previously in this chapter.

Tables 5.19 and 5. 20 shows the 'front sheet' for the analysis spreadsheet for one of the supply chains, the Rover/Brose R17 coupe door module.

Rover – Brose (R17 coupé)

Element	Aspect	Factors	Max.	Act.	Element Total
Tiered supply base	Dedication of supply Chain	No. of customers for 80% of sales * 1.1	25	18	
	Role demarcation	Manufacturing differential *1.2	25	14	
		Development differential *1.2	25	10	
	Horizontal collaboration	Direct communication at interfaces *1.3	25	4	(max 100) 46
Outsourcing	Level of outsourcing	Manufacturing process *2.1	50	40	
		Development process *2.2	50	40	(max 100) 80
Systems purchasing	Degree of sytems purchasing	Manufacturing process *3.1	50	17	
		Development process *3.2	50	8	(max 100) 25
		Total (Max 300)			151

Numbers show 'Element and Aspect' reference system e.g. 3.1 = Element 3 (Systems purchasing), aspect 1 (Manufacturing process)

Table 5.19 Rover R17 Coupe, scoring for elements 1-3

Element	Aspect	Factors	Max.	Act.	Element Total
Single sourcing	Sourcing policy	By range,or	100		
		By Model,or	75		
		By part No.,or	50	50	
		Dual by p.No.,or	25		(Max 100)
		Multi by p.No.	0		50
Design and development delegation	Percentage of Development delegated *5.3	Split of work VM to supplier *5.3	45	43	
	Eficiency of work Sharing (Max.score weighted with relation to factor 3 *5.1)	Compatible CAD (*5.1)	1	0	
		Direct link (*5.1)	2	0	
		Dedicated prod. Devt.	3	3	
		Guest engineers	1	1	
		Integral prod.devt.	3	0	
	10				
	Point of first involvement *5.2	Ratio of new product lead time against length of supplier involvement *5.2	45	36	(Max 100) 83
Long term contracts	Nominal length of Contract	Percentage of model life *6.1	50	7	
	Certainty of business Retention	(not available) *6.2	50		(max 100) 14
Customer focus	Specificity of resource Allocation	Manufacturing resources	50		
		Development resources	50		
	Relative size of Customer's account	Percentage of supplier's business	*1-10	3	(max 100) 3
Open-book costing	Extent of information Sharing *8.1	Closed book, or	0		
		Materials, or	20		
		Materials & Labour, or	40		
		Materials, labour and o'heads, or	60		
		Full access	80	80	
	Compatibility of format	Standard cost breakdown adopted *8.2	20	0	(max 100) 80
Mutual development	Progress towards Improvement of Muually beneficial Factors	* 9.1	100	39	(max 100) 39
Open systems			100	60	(max 100) 60
JIT deliveries			100		(max 100) N/A
		Total (Max 700)			329

Total structure and relationship management rating = **480**
max. = 1000

Table 5.20 Rover R17 Coupe, showing scores for elements 4-11

The analysis of the data progressed by plotting each of the supply chains' scores on a radar chart, as shown below.

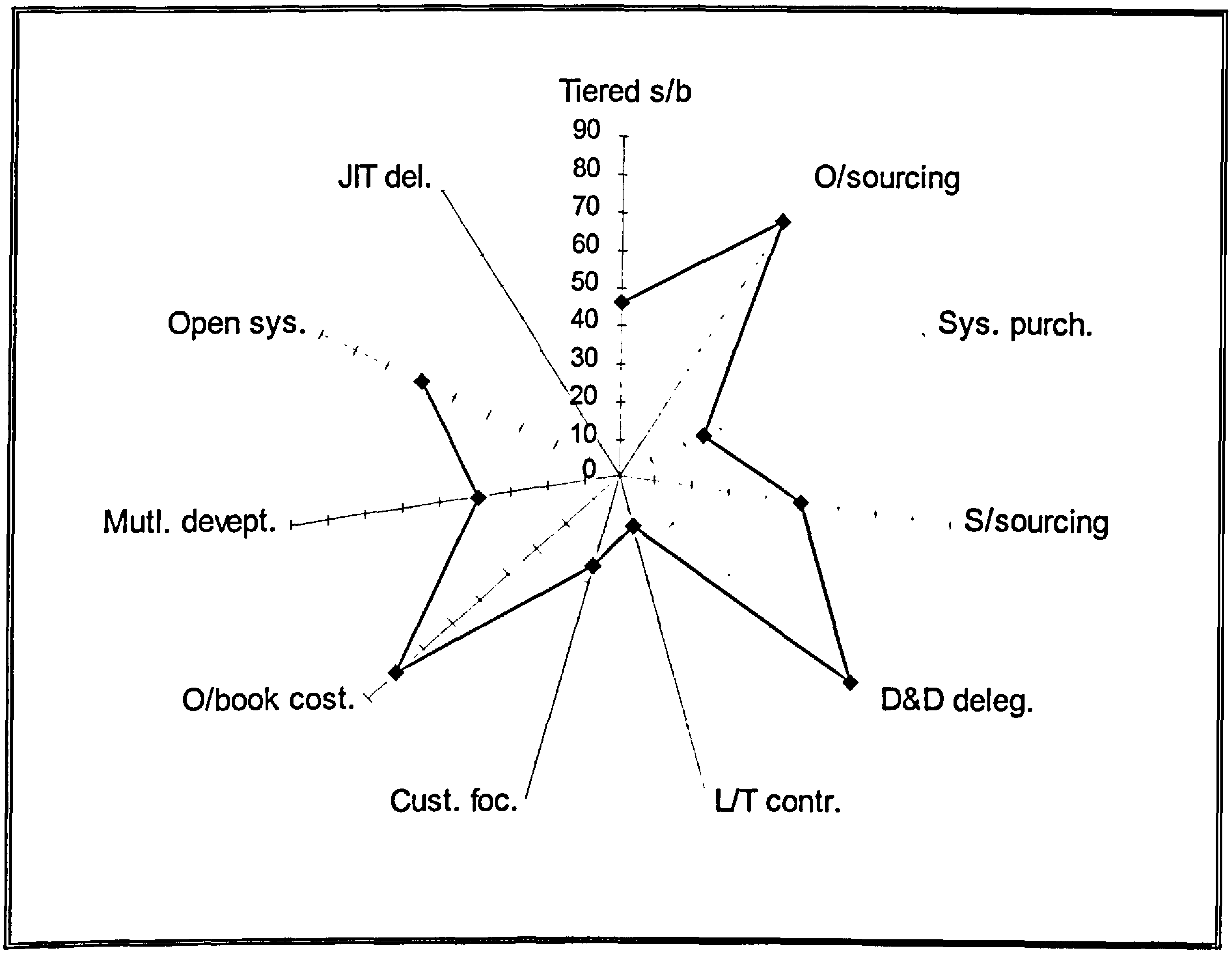


Figure 5.4 Radar plot showing scores for R17 Coupe/Brose GMbH supply chain

5.4 Populating the Hierarchical Structure Mapping model

Once the benchmark scores had been calculated for the supply chains, the next step in the research method was to match this with a representation of the structure of the supply chain by means of the Hierarchical Mapping model.

Populating this model was a relatively simple task, involving generating a generic list of value addition activities for the component. In other words the steps in producing the end product which would not vary from chain to chain. Next the distribution of the 'ownership' of the value addition steps (In other words which company performed which step?) was superimposed (see chapter 3 for methodology)

The structure of the Rover/Brose R17 coupe door module supply chain is shown below.

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 5	Supplier 6	Supplier 7	Supplier 8	Supplier 9	Supplier 10	Supplier 11	Supplier 12	Supplier 13	Supplier 14	Supplier 15	Supplier 16	Supplier 17	Supplier 18
Fit door to car	■																			
Final assembly of door	■																			
Fit Glass seals to door	■																			
Fit door seals	■																			
Manufacture outer panels	■																			
Assemble Outer panels	■																			
Fit Interior trim panel complete	■																			
Fit Door check strap	■																			
Fit Door hinges	■																			
Fit Exterior mirror	■																			
Fit Exterior door handle	■																			
Fit Side Impact Restraint System	■																			
Fit Loudspeaker to mounting		■																		
Fit Glass pane		■																		
Fit regulator to mounting		■																		
Assemble Regulator		■																		
Pressings for Regulator		■																		
Fit Latch/central locking to mounting		■																		
Assemble Latch/central locking		■																		
Fit Window lift switches to mounting		■																		
Fit wiring harness to mounting brackets		■																		
Fit glass channels to mounting bracket		■																		
Assemble Wiring harness			■																	
Looming for wiring harness			■																	
Assemble Loudspeaker				■																
Manufacture main sub-components Loudspeaker				■																
Assemble window lift switches					■															
Manufacture main sub-components window lift switches						■														
Manufacture glass channels							■													
Manufacture glass seals								■												
Manufacture door seals									■											
Assemble Interior trim panel complete										■										
Manufacture sub-components Interior trim panel complete											■									
Manufacture Door check strap												■								
Manufacture Door hinges													■							
Manufacture Glass pane														■						
Manufacture Exterior mirror															■					
Manufacture main sub-components Exterior mirror																■				
Manufacture Exterior door handle																	■			
Assemble Side Impact Restraint System																		■		
Manufacture main sub-components Side Impact Restraint System																			■	
Manufacture main sub-components Latch/central locking																				■
Total No. of value addition steps performed by each	12	10	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	

5.5 Comparison with Existing theories

As described in chapters 2 and 3 of this thesis, one of the novel approaches for the work is to attempt to relate existing structure theory to actual supply chains in the European Automotive industry. The premise for this work is the hypothesis that the latest developments in actual structure are not fully explained with recourse to existing theory alone.

Consequently part of the results presented in the following chapter will relate to the three theories selected in chapter 2 – Transaction cost theory, Network theory and Dualism – and attempt to justify the hypothesis set out above.

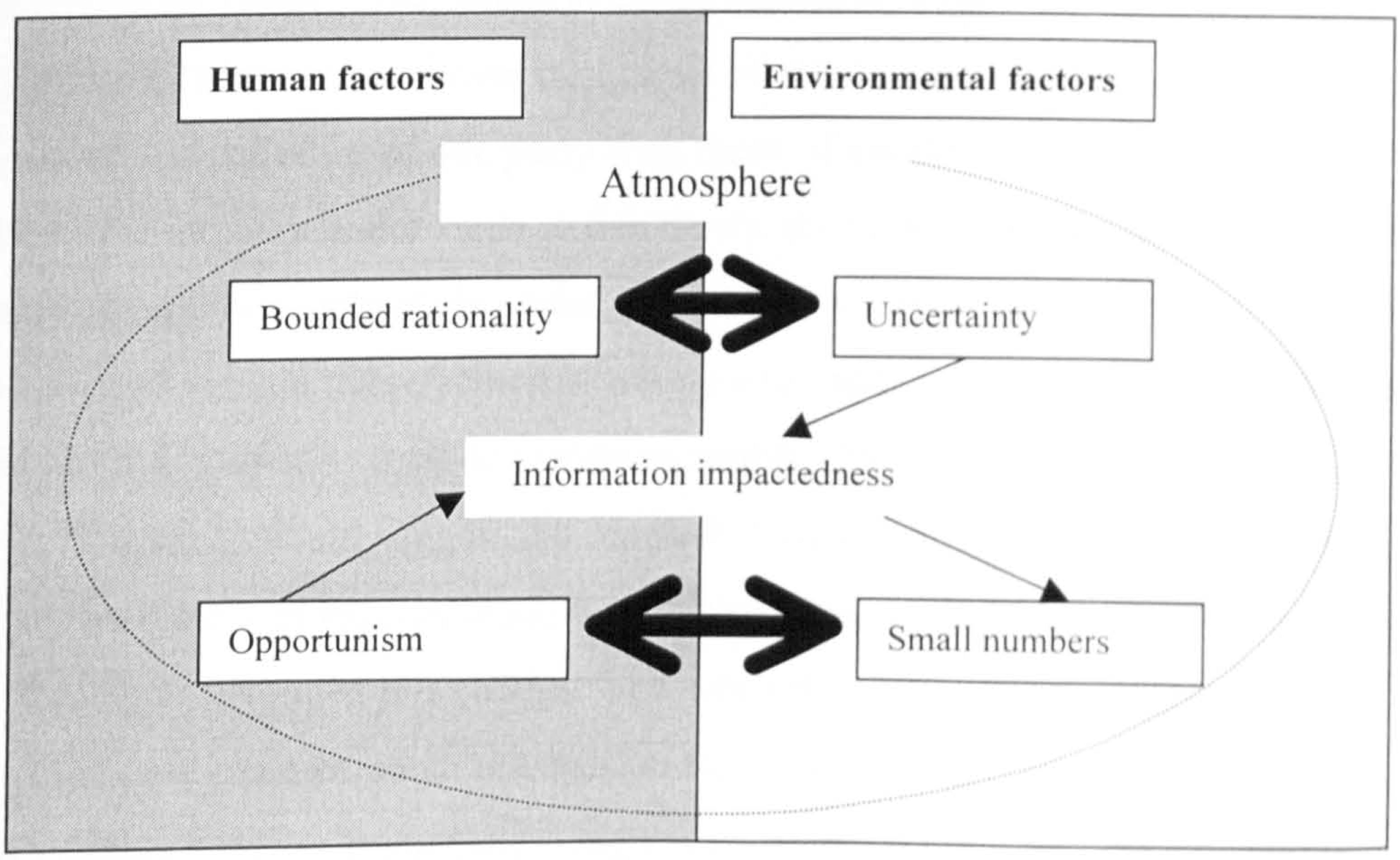
For such an undertaking to be considered rigorous, and for the justification or otherwise of the hypothesis to be valid, a course of analysis is required to relate theory to actual structure on the ground.

To do this, the genesis of each theory has been reduced – from the literature - to a number of key assertions. These assertions are then tested, using data from the 24 supply chains, using appropriate statistical analysis techniques, in order to assess the validity or otherwise of the main hypothesis.

5.5.1 Transaction cost theory

As set out in chapter 2, transaction cost theory explains the supply chain structure (or Governance structure) with reference to a set of factors for each possible transaction and hence sought to establish which types of transaction was most efficiently carried out within a hierarchy (within the firm) and which are more suitable for completion using the market. Analysis of the transaction types required for a particular product could thus result in a theoretical optimum structure for the supply of that product.

Figure 5.6 below (first shown in Chapter 2) sets out these factors.



The following assertions can be drawn from the theory (set out in Chapter 2).

Where 'asset specificity' is high, and combined with small numbers (little competition), a market type transaction is unlikely.

The converse – where asset specificity is low, and competition is wide, a market transaction is likely.

Where uncertainty is high, and combined with bounded rationality, a market transaction is unlikely.

The converse – where uncertainty is low, and combined with bounded rationality, a market transaction is likely.

Section 6.5. of chapter 6 presents the results of this analysis.

5.5.2 Network theory

The network model stems originally from casual observations that business organisations often do operate in environments which include only a limited number of identifiable organisational entities (or actors – e.g. customers, suppliers, legal or professional bodies) (Hagg and Johanson, 1982; Mattson 1985; Ford *et al*, 1986). As a result of the organisation's interactions, over time, a set of relationships develop that link the resources and activities of one party with those of another. With respect to the European automotive industry under study in this thesis, the network model would explain the drastic change in supply chain structure in terms of close working relationships between supplier and vehicle manufacturer resulting in a mutual decision for the supplier to expand his activities to include system assembly. The strategy management doctrine, set out in chapter 2, would suggest the supplier changing his role as a result of his, or his customers review of external conditions (the economy, developments in technology etc.) concluding in favour of this change. The network model suggests a less structured, more pragmatic and more personal mechanism for change, based on the individual relationships between immediate 'neighbours' in the supply network.

The main assertion drawn from 'network theory', and tested in this thesis is:

> *The distribution of value addition activities amongst firms in a supply chain is determined more by the individual interactions of 'close neighbours' in the supply chain than it is by planned reviews of external economic, social and technological climate.*

Section 6.5. of chapter 6 presents the results from this analysis.

5.5.3 Dualism

Dualists see inequality between the internal and external labour markets, between the primary and secondary sectors, or between the core and peripheral economies according to their own terminologies.

The structure of supply chains – they argue – is driven by organisations seeking to take advantage of these inequalities. For example a large multi-national organisation may choose to outsource assembly of its products to a lower cost sector of the economy, or indeed to a lower cost economy.

The main declaration drawn from Dualist theory, and tested in this thesis is:-

> *Variations in cost between different economic actors in the European Industry drive the structure of supply chains to take one form or another.*

Section 6.5. of chapter 6 presents the results from this analysis.

5.5 Next chapter

Chapter 6 presents the results accrued from the application of the various research instruments used in the study.

Chapter 6

Results

- **This chapter presents the results accrued from the application of the various research instruments used in the study.**

6.1 Introduction

The research instruments and their systematic use in this study have been discussed in chapter 3 "Research method" and chapter 5 "Analysis". This chapter presents the results sub-divided into the following sections.

- Phantom benchmark scores and Hierarchical structure maps for 24 supply chains.
- Comparison of supply chains one with another, using phantom benchmark model.
- Comparison of supply chain structures using hierarchical structure mapping.
- Validation of hypotheses 'Actual structure Vs theory'.

6.2. Phantom Benchmark scores and Hierarchical Structure Maps for 24 chains.

1. Rover R17 - door

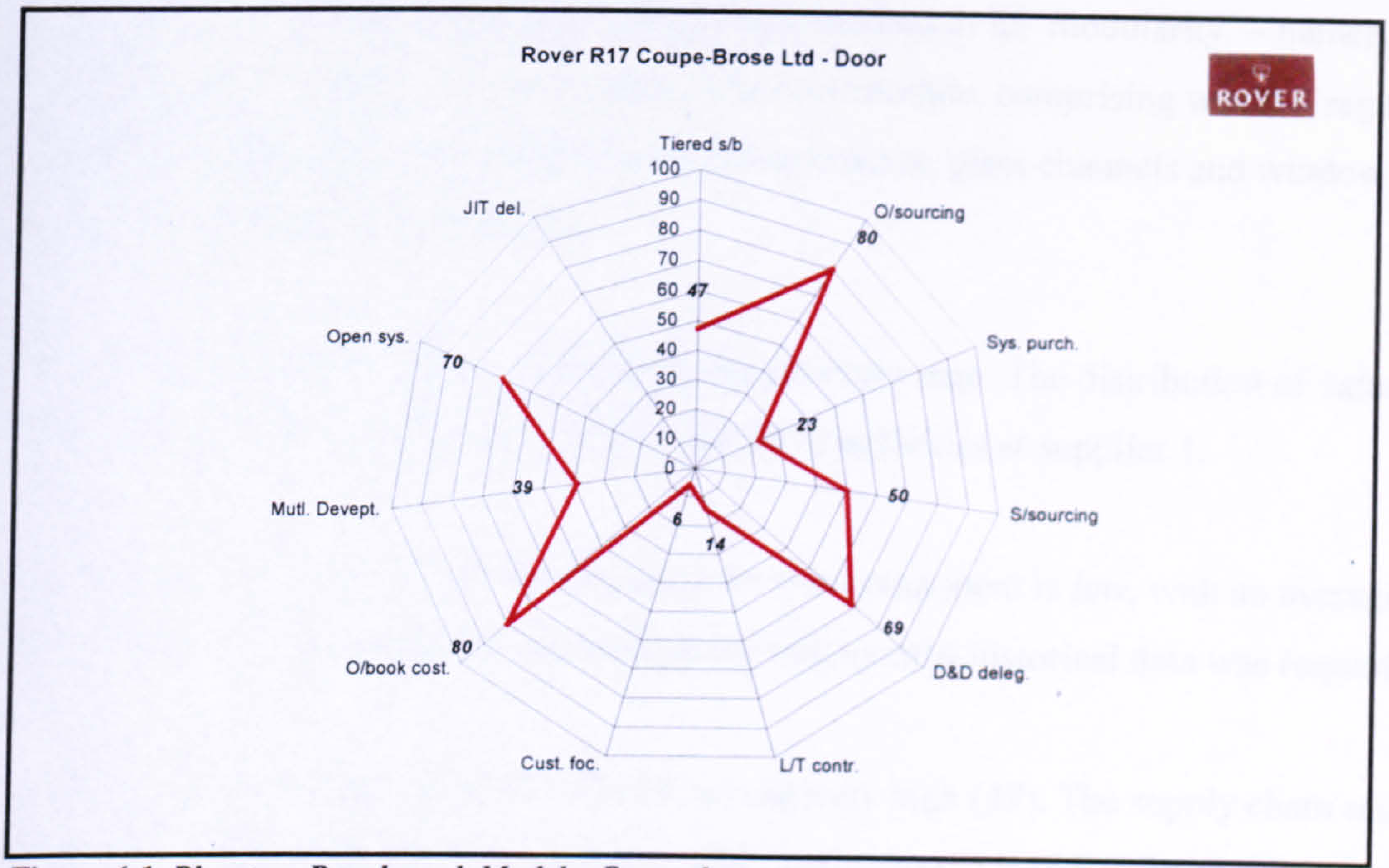


Figure 6.1. Phantom Benchmark Model – Rover door

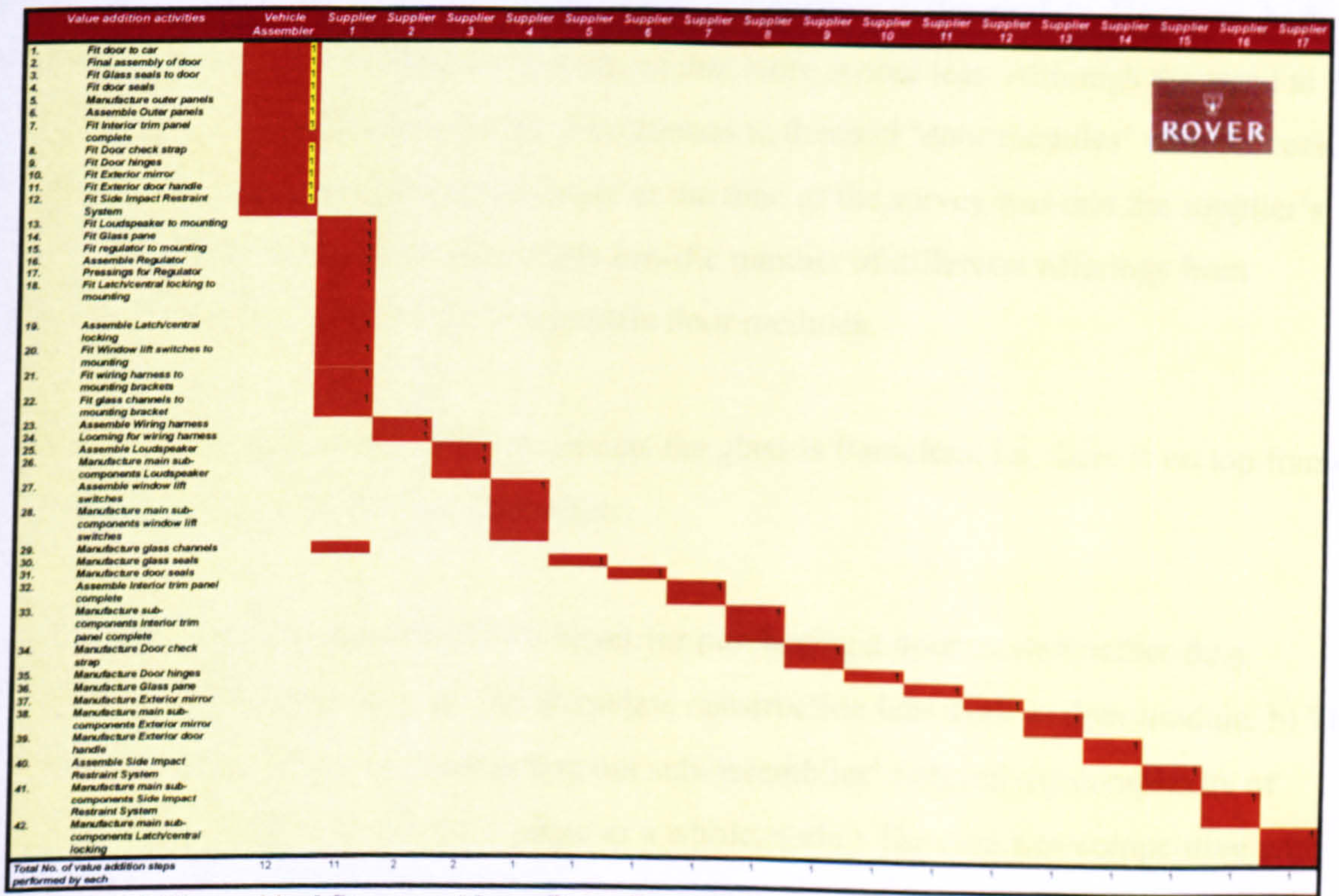


Figure 6.2 Hierarchical Structure Map – Rover Door

Commentary on Rover R17 door supply chain

The door supply chain studied for Rover Group - a modular door for the Rover 800 (Rover's code is R17) Coupé- scored highly for OUTSOURCING and relatively highly for SYSTEMS PURCHASING. This can be attributed to its 'modularity' – namely, the use of a 'door module' for this vehicle. The door module, comprising window regulator, locking mechanism, wiring harness, mounting bracket, glass channels and window glass is fully assembled at the supplier.

The structure of the chain is reflected in the structure map. The distribution of value addition activities can be seen, with 11 out of 41 activities at supplier 1.

It is significant that the volume of supply for this component is *low*, with an average of just 15 per month during the research period (six months historical data was requested)

The score for TIERED SUPPLY BASE is relatively high (47). The supply chain scored highly for 'collaboration external to the VM', owing to the lead supplier (of the door module) coordinating the supply of the sub-components in the module. However, both 'demarcation' and 'dedication' aspects of this score scored less. Although the trend at the supplier was for greater numbers of customers to demand 'door modules' with successive new vehicle programmes, the situation at the time of the survey was that the supplier's product range included an injuriously prolific number of differemt offerings from discrete components through to complete door modules.

The door is unusual in that for the coupe, the glass is frameless, i.e. there is no top frame against which the top of the glass abuts.

The stated reasons from the VM's buyer for purchasing a door module rather than discrete components were a) The frameless construction lent itself to door module. b) The coupe is low volume, so 'contracting out sub-assemblies' reduced the complexity of organising logistics for the R17 range as a whole, and c) The cost was competitive with other methods such as using discrete components.

2. Mercedes Benz E-Class – door

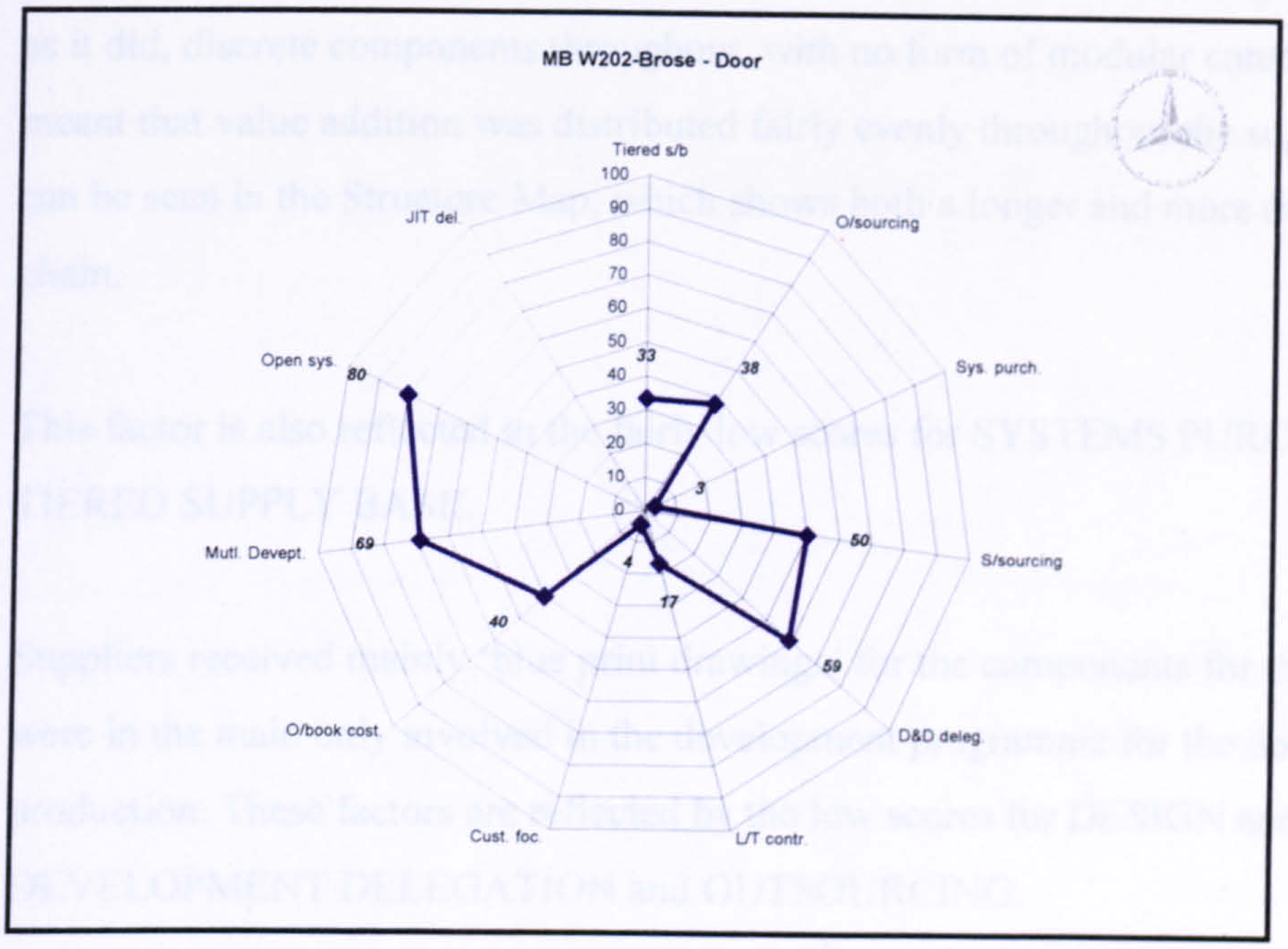


Figure 6.3 Phantom Benchmark Model – MB door

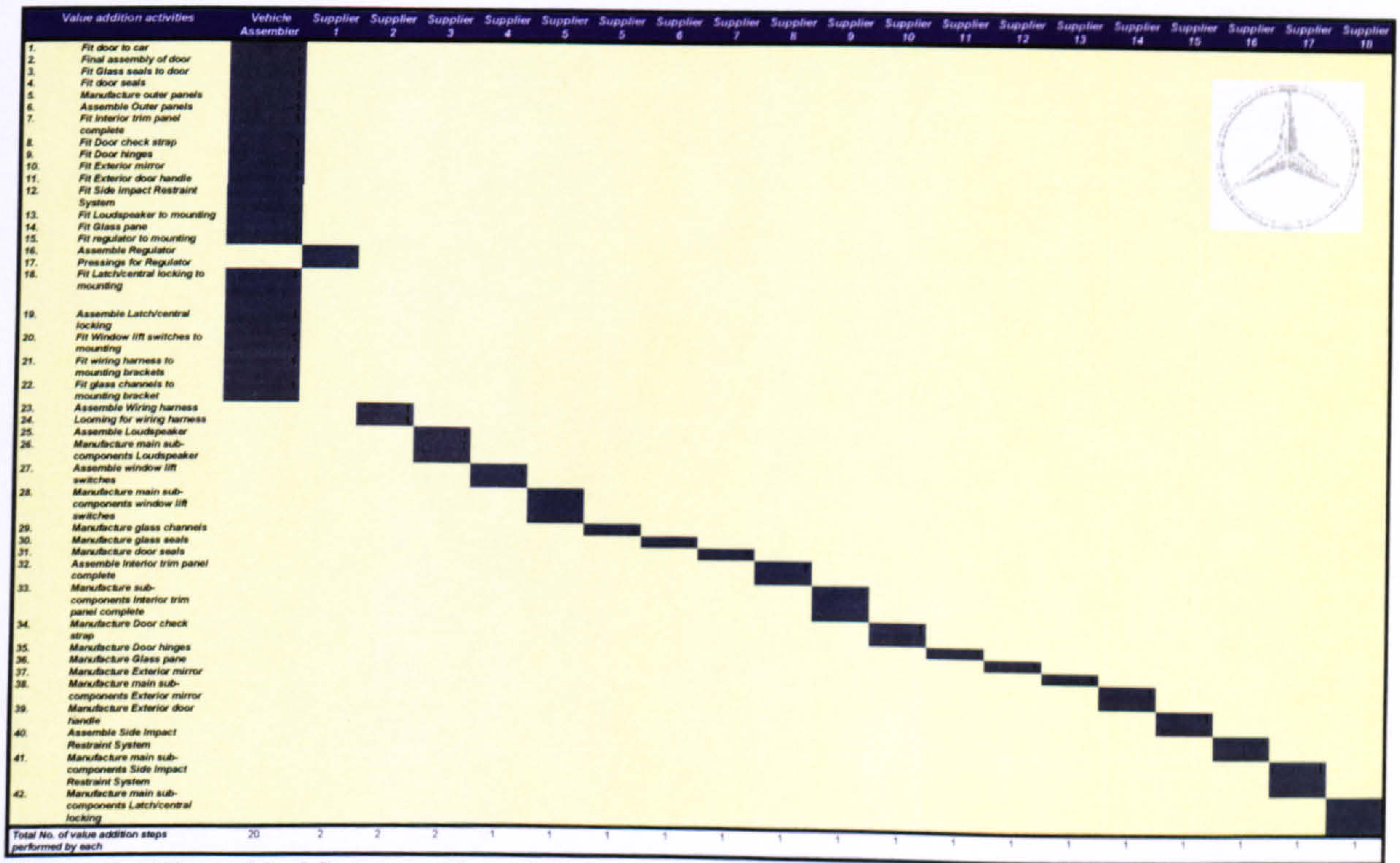


Figure 6.4 Hierarchical Structure Map – MB door

Commentary on Mercedes Benz E Class door supply chain

The door studied at Mercedes Benz was fairly traditional in its sourcing structure, using as it did, discrete components throughout, with no form of modular construction. This meant that value addition was distributed fairly evenly throughout the supply chain. This can be seen in the Structure Map, which shows both a longer and more distributed supply chain.

This factor is also reflected in the fairly low scores for SYSTEMS PURCHASING and TIERED SUPPLY BASE.

Suppliers received mainly 'blue print drawings' for the components for the door, and were in the main only involved in the development programme for the door fairly close to production. These factors are reflected by the low scores for DESIGN and DEVELOPMENT DELEGATION and OUTSOURCING.

3. Peugeot 106 – door

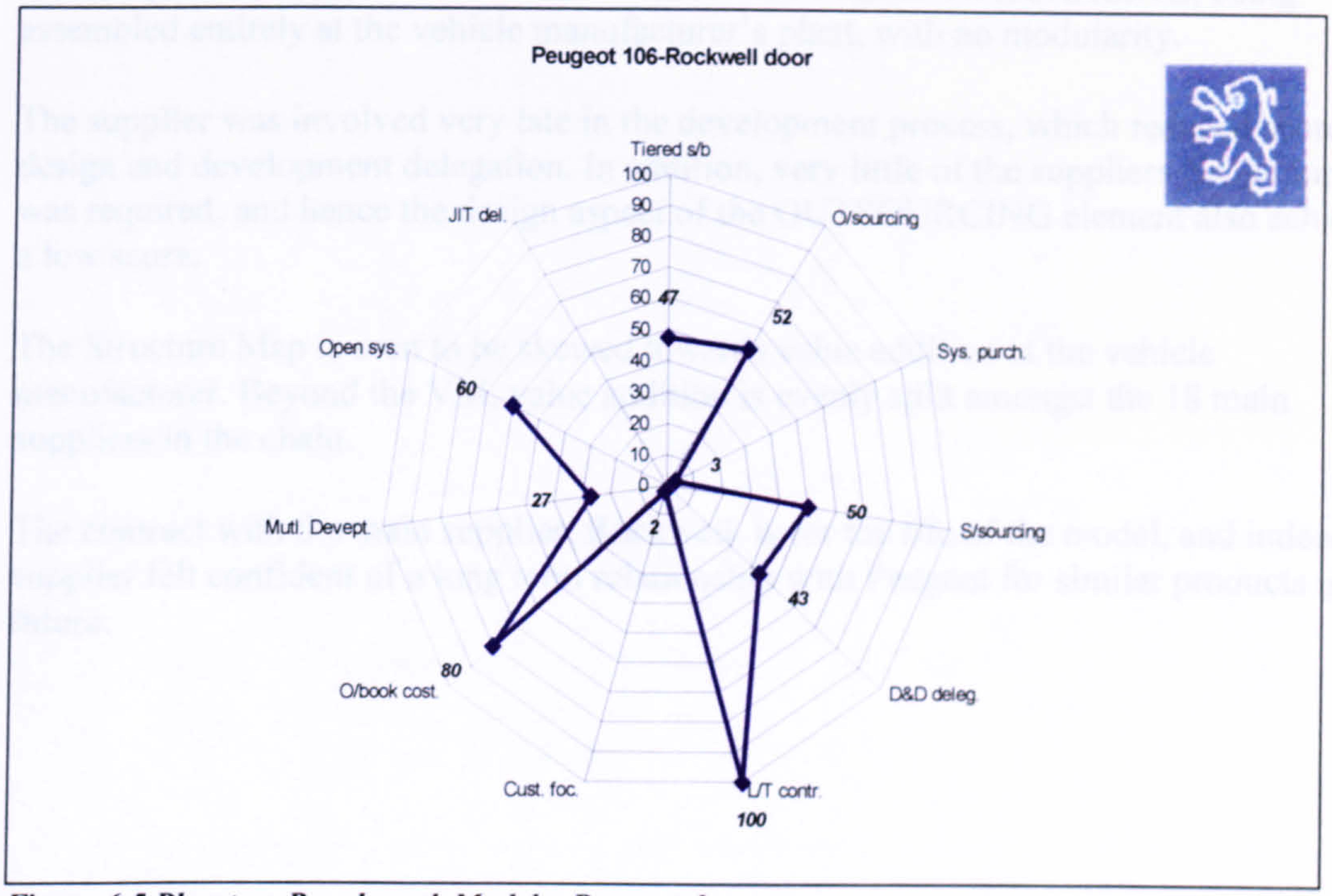


Figure 6.5 Phantom Benchmark Model – Peugeot door

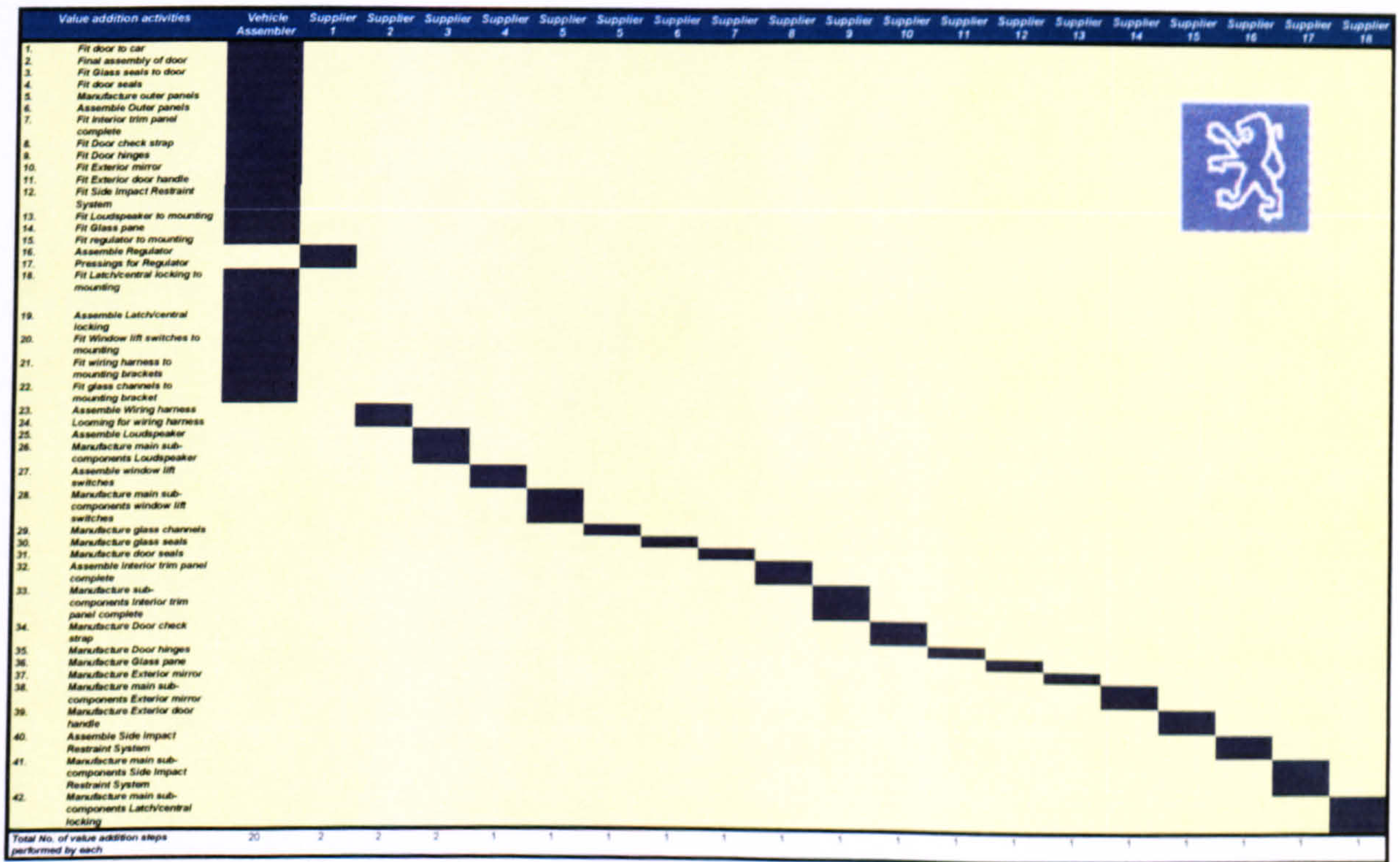


Figure 6.6 Hierarchical Structure Map – Peugeot door

Commentary on Peugeot 106 door supply chain

The Peugeot 106 door achieved a low score for SYSTEMS PURCHASING, being assembled entirely at the vehicle manufacturer's plant, with no modularity.

The supplier was involved very late in the development process, which reduced scores for design and development delegation. In addition, very little of the suppliers design input was required, and hence the design aspect of the OUTSOURCING element also achieved a low score.

The Structure Map is seen to be skewed towards value addition at the vehicle manufacturer. Beyond the VM, value addition is evenly split amongst the 18 main suppliers in the chain.

The contract with the main supplier, Rockwell, is for the life of the model, and indeed the supplier felt confident of a long term relationship with Peugeot for similar products in the future.

4. Renault Laguna – door

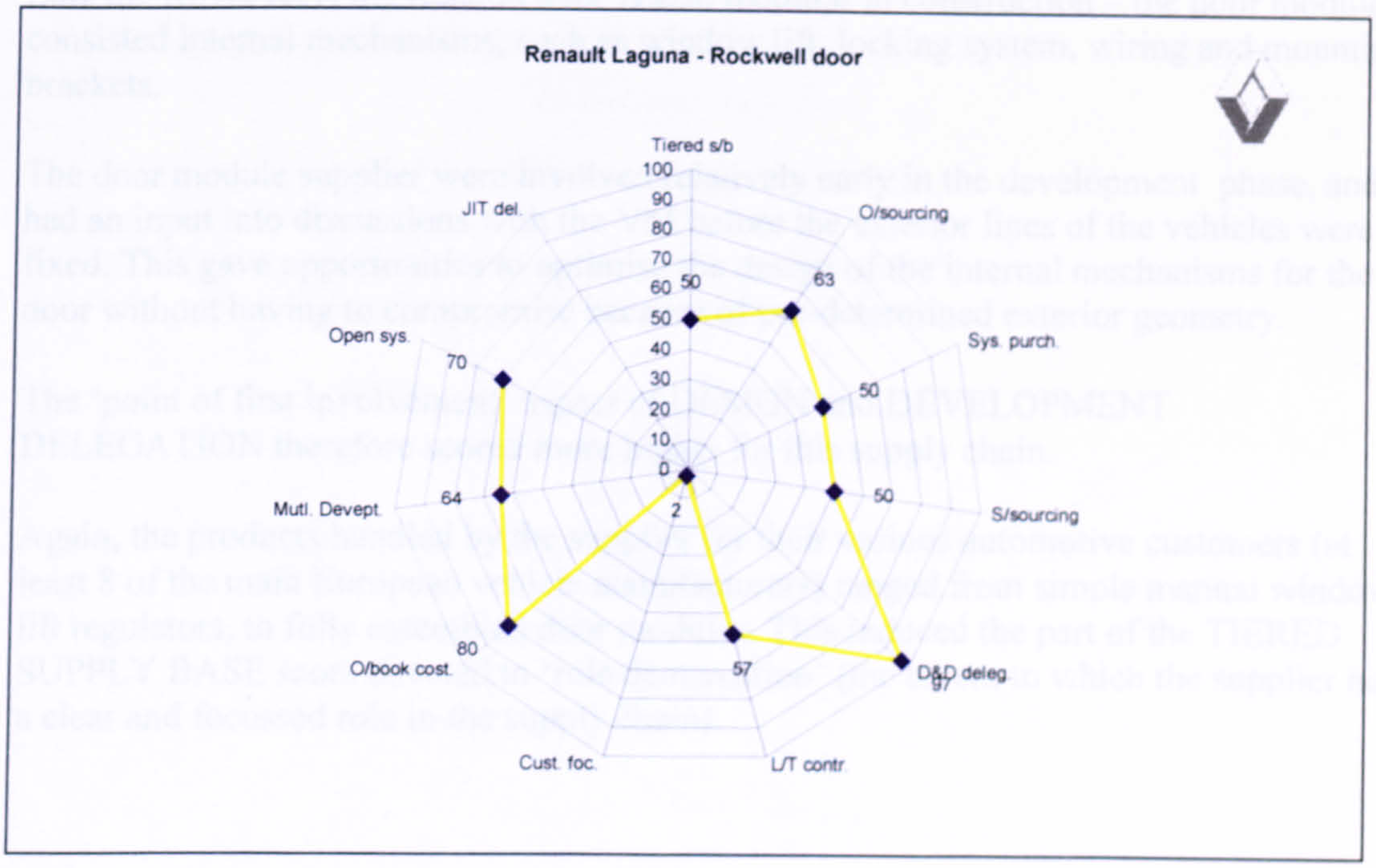


Figure 6.7. Phantom Benchmark Model – Renault door

	Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Supplier 7	Supplier 8	Supplier 9	Supplier 10	Supplier 11	Supplier 12	Supplier 13	Supplier 14	Supplier 15	Supplier 16	Supplier 17	Supplier 18
1.	Fit door to car	1																		
2.	Final assembly of door	1																		
3.	Fit Glass seals to door	1																		
4.	Fit door seals	1																		
5.	Manufacture outer panels	1																		
6.	Assemble Outer panels	1																		
7.	Fit interior trim panel complete	1																		
8.	Fit Door check strap	1																		
9.	Fit Door hinges	1																		
10.	Fit Exterior mirror	1																		
11.	Fit Exterior door handle	1																		
12.	Fit Side Impact Restraint System	1																		
13.	Fit Loudspeaker to mounting		1																	
14.	Fit Glass pane	1																		
15.	Fit regulator to mounting		1																	
16.	Assemble Regulator		1																	
17.	Pressings for Regulator		1																	
18.	Fit Latch/central locking to mounting		1																	
19.	Assemble Latch/central locking		1																	
20.	Fit Window lift switches to mounting		1																	
21.	Fit wiring harness to mounting brackets		1																	
22.	Fit glass channels to mounting bracket	1																		
23.	Assemble Wiring harness			1																
24.	Looming for wiring harness			1																
25.	Assemble Loudspeaker				1															
26.	Manufacture main sub-components Loudspeaker				1															
27.	Assemble window lift switches					1														
28.	Manufacture main sub-components window lift switches					1														
29.	Manufacture glass channels						1													
30.	Manufacture glass seals							1												
31.	Manufacture door seals								1											
32.	Assemble interior trim panel complete									1										
33.	Manufacture sub-components Interior trim panel complete										1									
34.	Manufacture Door check strap											1								
35.	Manufacture Door hinges												1							
36.	Manufacture Glass pane													1						
37.	Manufacture Exterior mirror														1					
38.	Manufacture main sub-components Exterior mirror															1				
39.	Manufacture Exterior door handle																1			
40.	Assemble Side Impact Restraint System																	1		
41.	Manufacture main sub-components Side Impact Restraint System																		1	
42.	Manufacture main sub-components Latch/central locking																			1
	Total No. of value addition steps performed by each	14	8	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 6.8. Phantom Benchmark Model – Renault door

Commentary on Renault Laguna door supply chain
Like the Rover R17, the Renault door is also modular in construction – the door module consisted internal mechanisms, such as window lift, locking system, wiring and mounting brackets.

The door module supplier were involved relatively early in the development phase, and had an input into discussions with the VM before the exterior lines of the vehicles were fixed. This gave opportunities to optimise the design of the internal mechanisms for the door without having to compromise because of pre-determined exterior geometry.

The 'point of first involvement' aspect of DESIGN and DEVELOPMENT DELEGATION therefore scored more highly for this supply chain.

Again, the products handled by the supplier for their various automotive customers (at least 8 of the main European vehicle manufacturers) ranged from simple manual window lift regulators, to fully assembled door modules. This reduced the part of the TIERED SUPPLY BASE score devoted to 'role demarcation' (the extent to which the supplier had a clear and focussed role in the supply chain).

5. Citroen Xanthia – door

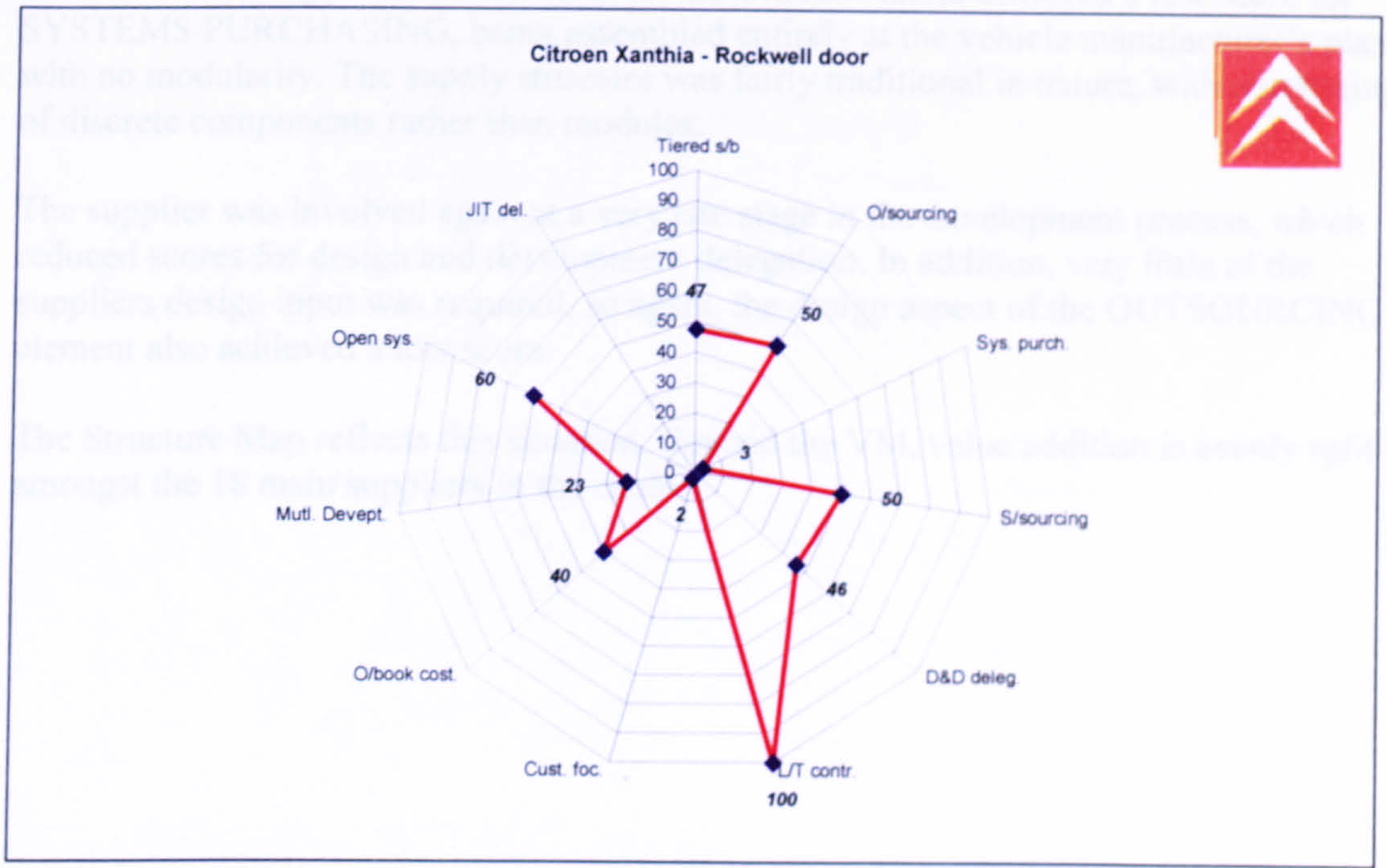


Figure 6.9. Phantom Benchmark Model, Citroen door

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Supplier 7	Supplier 8	Supplier 9	Supplier 10	Supplier 11	Supplier 12	Supplier 13	Supplier 14	Supplier 15	Supplier 16	Supplier 17
1. Fit door to car	1																	
2. Final assembly of door	1																	
3. Fit Glass seals to door	1																	
4. Fit door seals	1																	
5. Manufacture outer panels	1																	
6. Assemble Outer panels	1																	
7. Fit interior trim panel complete	1																	
8. Fit Door check strap	1																	
9. Fit Door hinges	1																	
10. Fit Exterior mirror	1																	
11. Fit Exterior door handle	1																	
12. Fit Side Impact Restraint System	1																	
13. Fit Loudspeaker to mounting	1																	
14. Fit Glass pane	1																	
15. Fit regulator to mounting	1																	
16. Assemble Regulator		1																
17. Pressings for Regulator		1																
18. Fit Latch/central locking to mounting	1																	
19. Assemble Latch/central locking		1																
20. Fit Window lift switches to mounting	1																	
21. Fit wiring harness to mounting brackets	1																	
22. Fit glass channels to mounting bracket	1																	
23. Assemble Wiring harness	1																	
24. Looming for wiring harness	1																	
25. Assemble Loudspeaker			1															
26. Manufacture main sub-components Loudspeaker			1															
27. Assemble window lift switches				1														
28. Manufacture main sub-components window lift switches				1														
29. Manufacture glass channels					1													
30. Manufacture glass seals						1												
31. Manufacture door seals							1											
32. Assemble interior trim panel complete								1										
33. Manufacture sub-components interior trim panel complete									1									
34. Manufacture Door check strap										1								
35. Manufacture Door hinges											1							
36. Manufacture Glass pane												1						
37. Manufacture Exterior mirror													1					
38. Manufacture main sub-components Exterior mirror														1				
39. Manufacture Exterior door handle															1			
40. Assemble Side Impact Restraint System																1		
41. Manufacture main sub-components Side Impact Restraint System																	1	
42. Manufacture main sub-components Latch/central locking																		1
Total No. of value addition steps performed by each	21	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 6.10 – Hierarchical Structure Map – Citroen door

Commentary on Citroen Xantia door supply chain

Similar to the Peugeot 106, and MB door, the Citroen Xantia achieved a low score for SYSTEMS PURCHASING, being assembled entirely at the vehicle manufacturer's plant, with no modularity. The supply structure was fairly traditional in nature, with purchasing of discrete components rather than modules.

The supplier was involved again at a very late stage in the development process, which reduced scores for design and development delegation. In addition, very little of the suppliers design input was required, so again, the design aspect of the OUTSOURCING element also achieved a low score.

The Structure Map reflects this situation. Beyond the VM, value addition is evenly split amongst the 18 main suppliers in the chain.

6. BMW E36 - door

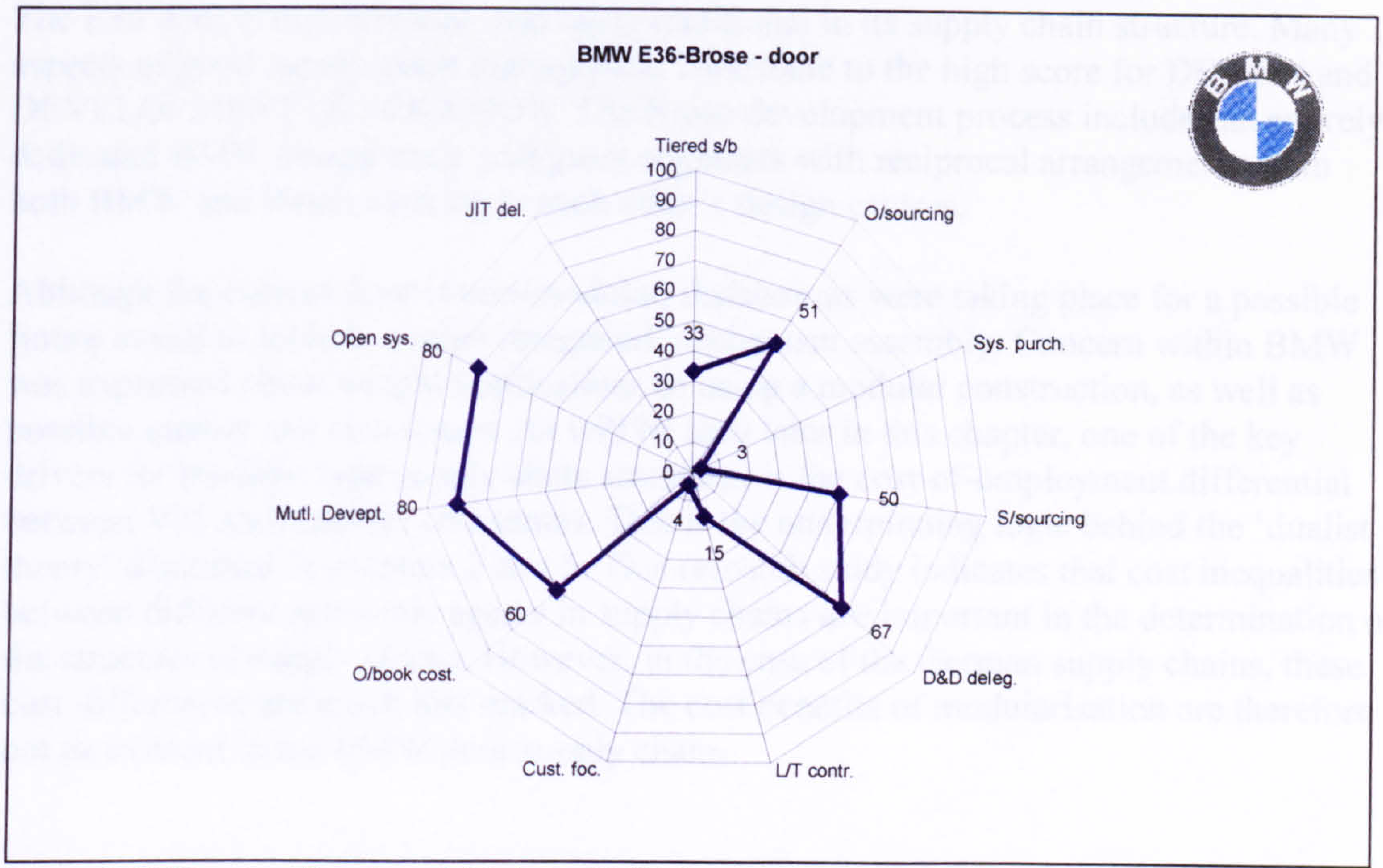


Figure 6.11 Phantom Benchmark Model – BMW door

	Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Supplier 7	Supplier 8	Supplier 9	Supplier 10	Supplier 11	Supplier 12	Supplier 13	Supplier 14	Supplier 15	Supplier 16	Supplier 17
1.	Fit door to car	1																	
2.	Final assembly of door	1																	
3.	Fit Glass seals to door	1																	
4.	Fit door seals	1																	
5.	Manufacture outer panels	1																	
6.	Assemble Outer panels	1																	
7.	Fit interior trim panel complete	1																	
8.	Fit Door check strap	1																	
9.	Fit Door hinges	1																	
10.	Fit Exterior mirror	1																	
11.	Fit Exterior door handle	1																	
12.	Fit Side Impact Restraint System	1																	
13.	Fit Loudspeaker to mounting	1																	
14.	Fit Glass pane	1																	
15.	Fit regulator to mounting	1																	
16.	Assemble Regulator		1																
17.	Pressings for Regulator		1																
18.	Fit Latch/central locking to mounting	1																	
19.	Assemble Latch/central locking		1																
20.	Fit Window lift switches to mounting	1																	
21.	Fit wiring harness to mounting brackets	1																	
22.	Fit glass channels to mounting bracket	1																	
23.	Assemble Wiring harness	1																	
24.	Looming for wiring harness	1																	
25.	Assemble Loudspeaker			1															
26.	Manufacture main sub-components Loudspeaker			1															
27.	Assemble window lift switches				1														
28.	Manufacture main sub-components window lift switches				1														
29.	Manufacture glass channels					1													
30.	Manufacture glass seals						1												
31.	Manufacture door seals							1											
32.	Assemble Interior trim panel complete								1										
33.	Manufacture sub-components Interior trim panel complete									1									
34.	Manufacture Door check strap										1								
35.	Manufacture Door hinges											1							
36.	Manufacture Glass pane												1						
37.	Manufacture Exterior mirror													1					
38.	Manufacture main sub-components Exterior mirror														1				
39.	Manufacture Exterior door handle															1			
40.	Assemble Side Impact Restraint System																1		
41.	Manufacture main sub-components Side Impact Restraint System																	1	
42.	Manufacture main sub-components Latch/central locking																		1
Total No. of value addition steps performed by each		21	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 6.12 Hierarchical Structure Map – BMW door

Commentary on BMW E36 door supply chain

The E36 door is non-modular, and fairly traditional in its supply chain structure. Many aspects of good supply chain management contribute to the high score for DESIGN and DEVELOPMENT DELEGATION. The Brose development process includes an entirely dedicated BMW design team, and guest engineers with reciprocal arrangements from both BMW and Brose working at each other's design centres.

Although the current door is non-modular, discussions were taking place for a possible future model to include a more integrated mechanism assembly. Concern within BMW was expressed about weight implications of using a modular construction, as well as possible quality and cost issues. As will be seen later in this chapter, one of the key drivers for modular type supply chain structures is the cost-of-employment differential between VM and supplier companies. This is the underpinning logic behind the 'dualist theory' discussed in chapters 2 and 5. This research study indicates that cost inequalities between different economic agents in supply chains ***are*** important in the determination of the structure of supply chains. However, in the case of the German supply chains, these cost differences are much less marked. The cost benefits of modularisation are therefore not as existent in the BMW door supply chain.

7. Rover R17 - wiring harness

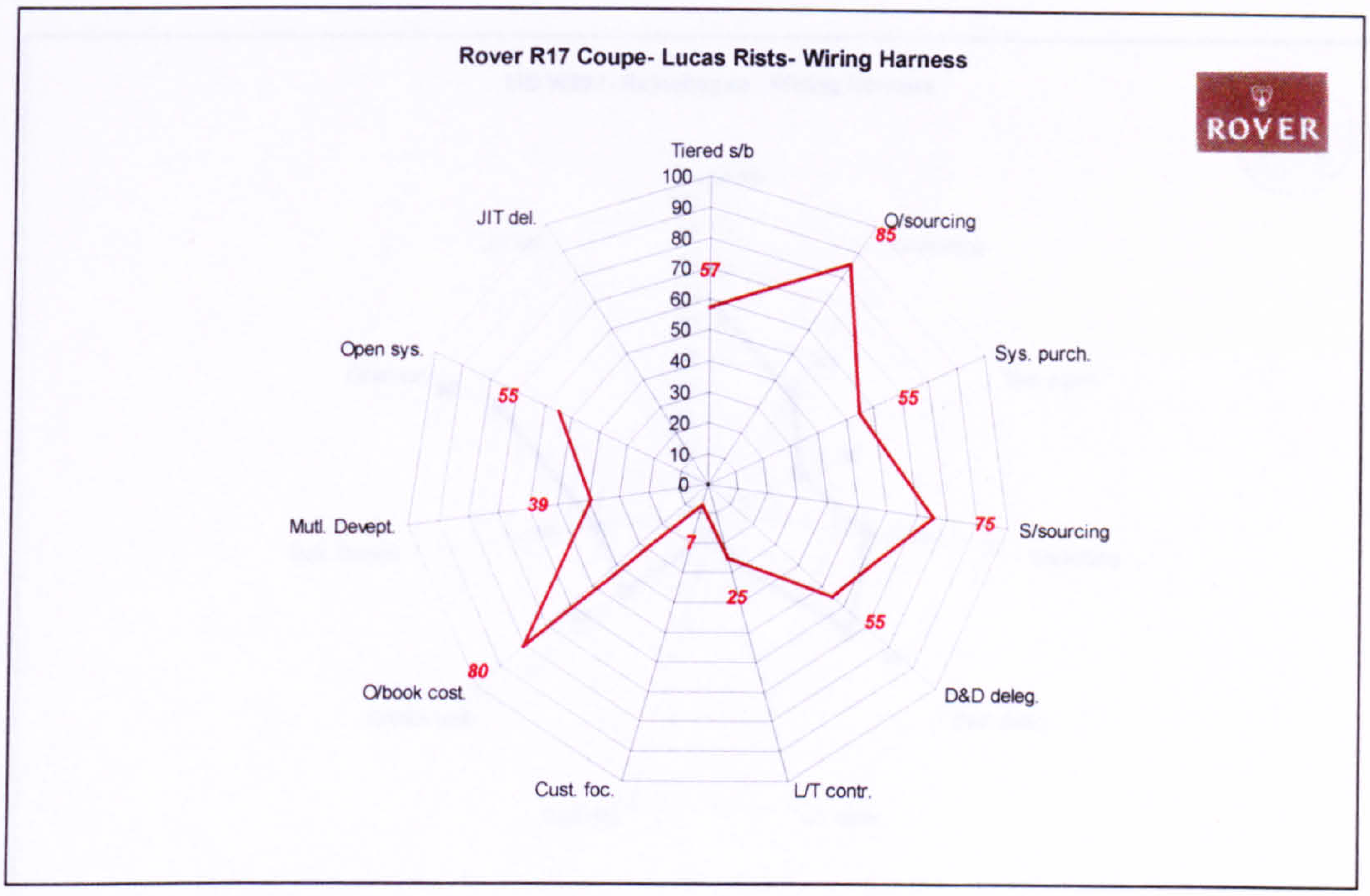


Figure 6.13. Phantom Benchmark Model – Rover Wiring harness

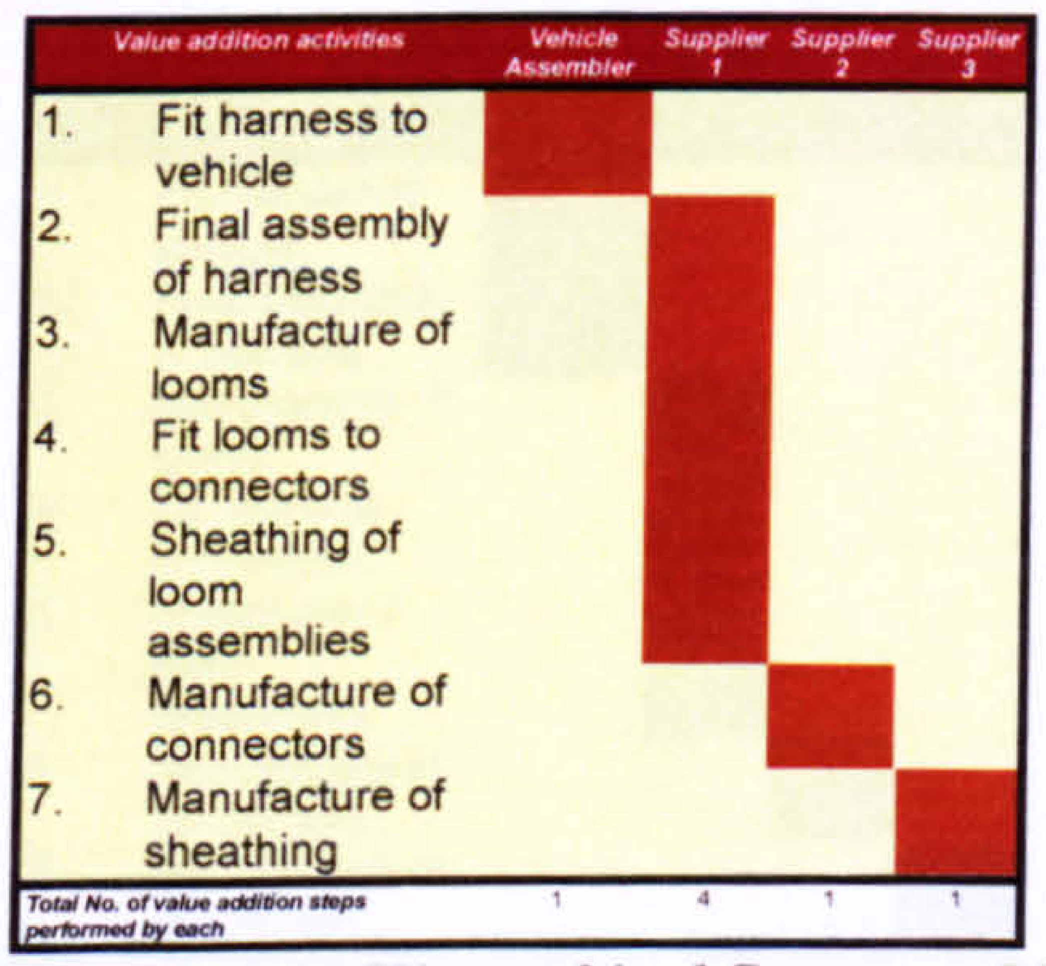


Figure 6.14 Hierarchical Structure Map – Rover Wiring harness

Commentary on Rover R17 wiring harness

Most of the value addition in the wiring harness supply chain is carried out at the first tier supplier. The looming operation is both labour and material intensive. The Rover chain scores fairly highly for both SYSTEMS PURCHASING and OUTSOURCING. This is primarily due to the fact that Rover have delegated the task of configuring the various harnesses into 'vehicle kits' to the supplier.

8. Mercedes Benz E-Class – wiring harness

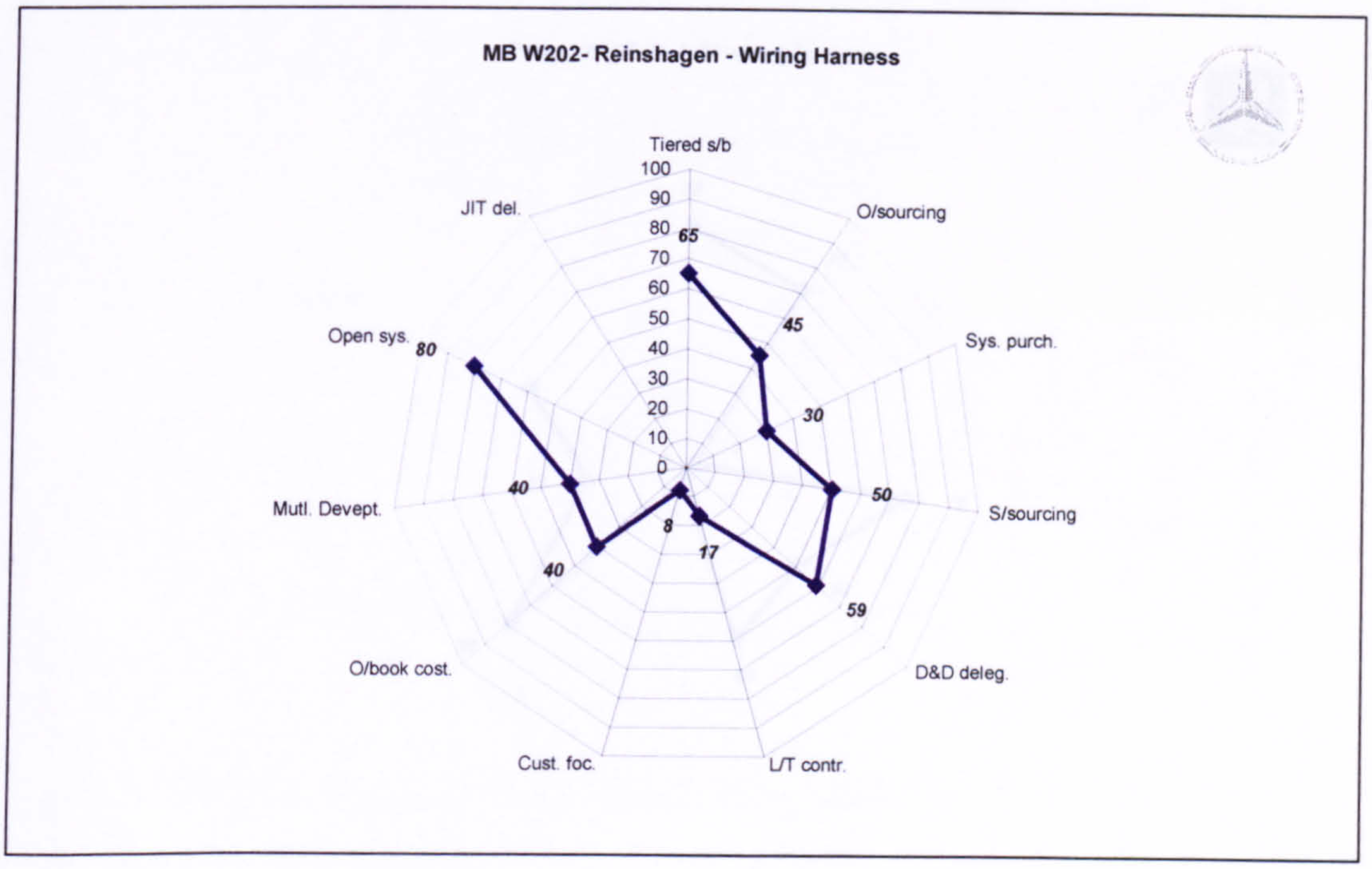


Figure 6.15 Phantom Benchmark Model – MB Wiring harness

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3
1. Fit harness to vehicle				
2. Final assembly of harness				
3. Manufacture of looms				
4. Fit looms to connectors				
5. Sheathing of loom assemblies				
6. Manufacture of connectors				
7. Manufacture of sheathing				
Total No. of value addition steps performed by each	2	3	1	1

Figure 6.16 Hierarchical Structure Map – MB Wiring harness

Commentary on MB E-class wiring harness

Again, most of the value addition is carried out by the first tier supplier. In this case, however the supplier does not carry out the selection of harnesses and configuration into vehicle kits.

9. Peugeot 106 – wiring harness

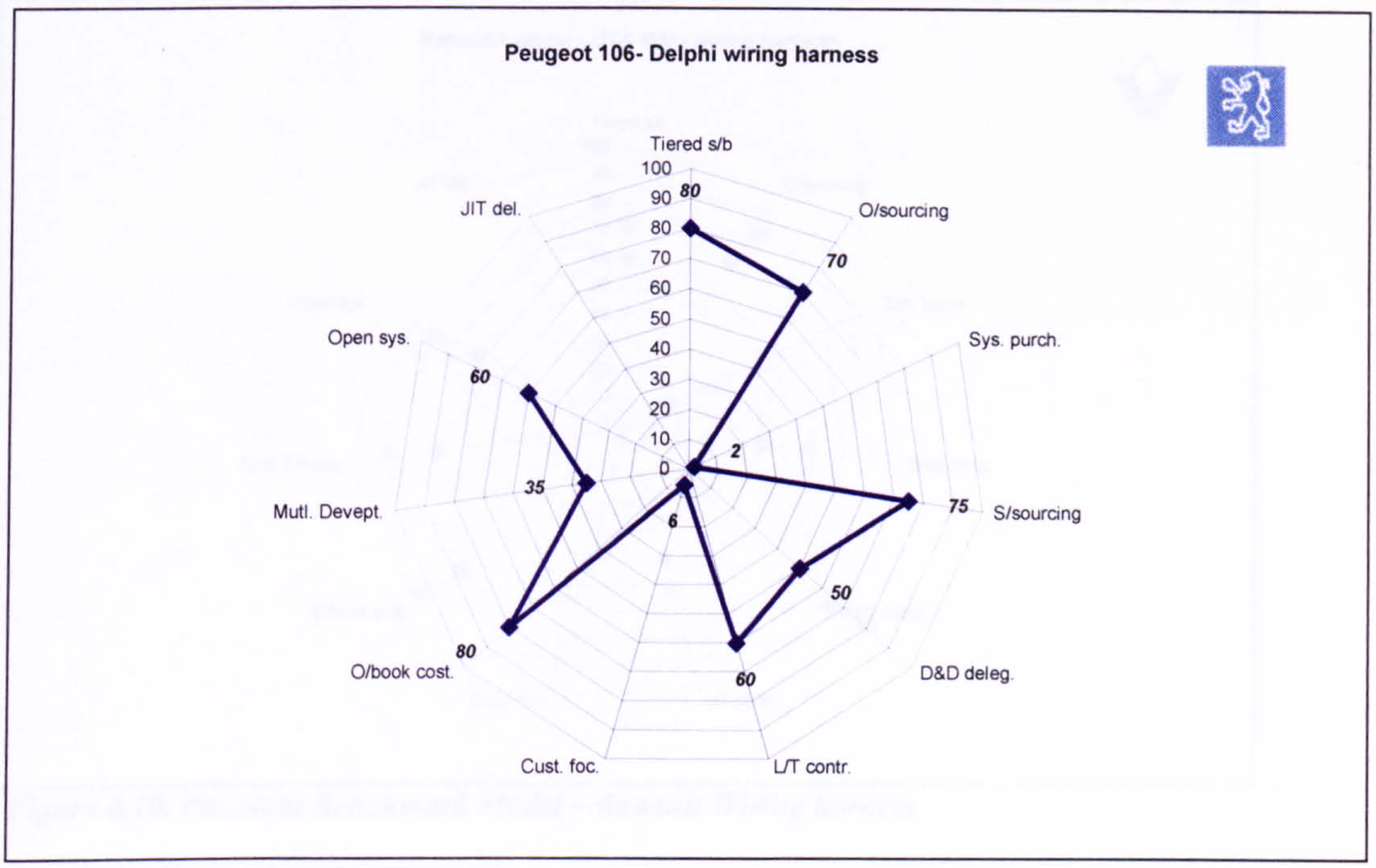


Figure 6.17 Phantom Benchmark Model – Peugeot Wiring harness

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2
1. Fit harness to vehicle			
2. Final assembly of harness			
3. Manufacture of looms			
4. Fit looms to connectors			
5. Sheathing of loom assemblies			
6. Manufacture of connectors			
7. Manufacture of sheathing			
Total No. of value addition steps performed by each	2	4	1

Figure 6.18 Hierarchical Structure Map – Peugeot Wiring harness

Commentary on Peugeot 106 wiring harness.

The supply chain here is fairly typical, with the VM looking after final configuration. PSA manufacture wiring harnesses themselves for some vehicles, but the 106 was outsourced, due to a more competitive bid from Delphi, during the vehicel development phase.

10 . Renault Laguna – wiring harness

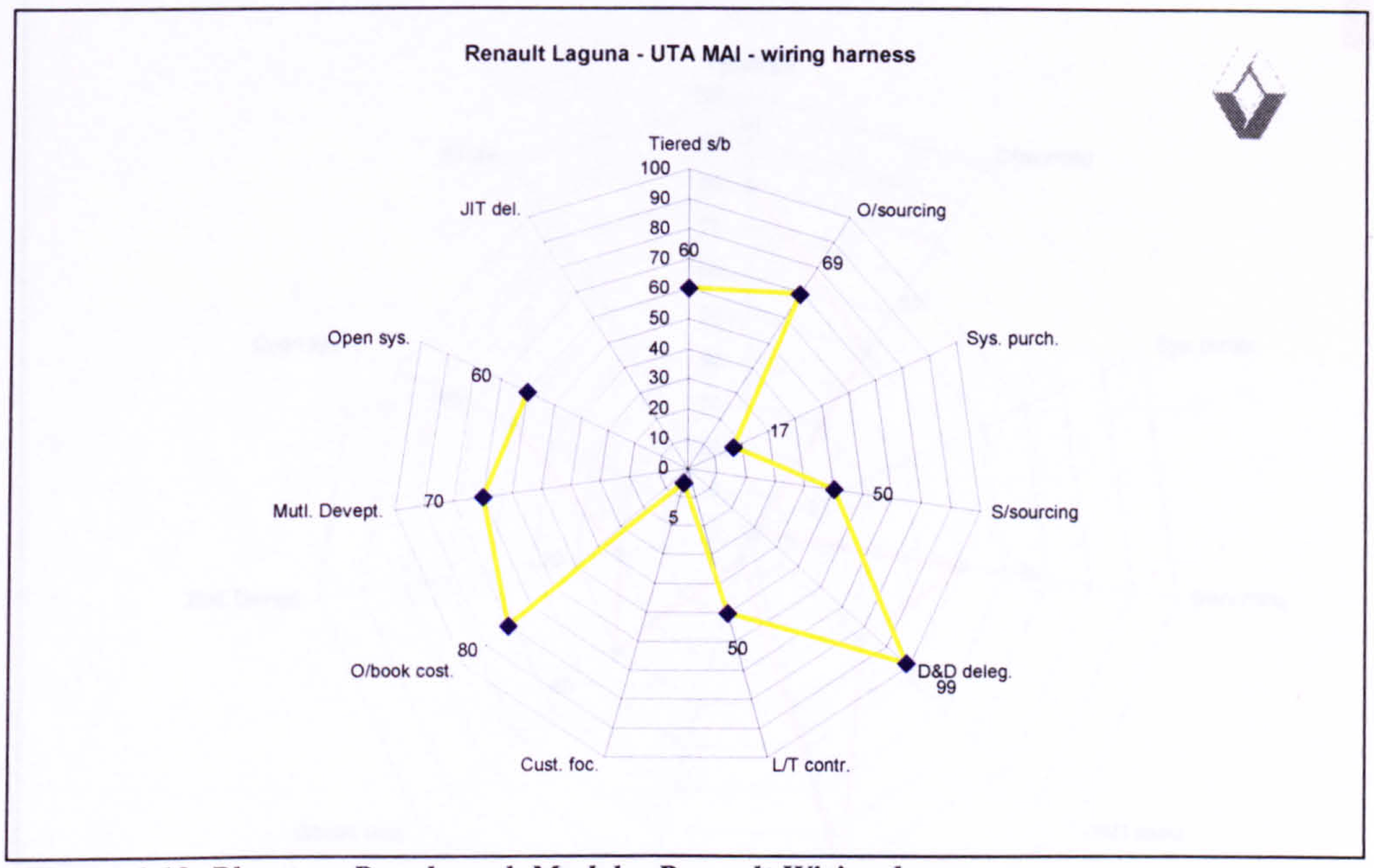


Figure 6.19. Phantom Benchmark Model – Renault Wiring harness

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3
1. Fit harness to vehicle				
2. Final assembly of harness				
3. Manufacture of looms				
4. Fit looms to connectors				
5. Sheathing of loom assemblies				
6. Manufacture of connectors				
7. Manufacture of sheathing				
Total No. of value addition steps performed by each	2	3	1	1

Figure 6.20. Phantom Benchmark Model – Renault Wiring harness

Commentary on Renault wiring harness

Renault have an interesting and innovative working relationship with their harness suppliers UTA MAI . The biggest challenge in the supply of harnesses is keeping control of the colossal array of variants in the range. Renault have set up a three way 'team approach', involving themselves, the supplier, and the supplier of connectors, in order to address this problem specifically . This means that the supplier are involved right at the conception of new products. The 'efficiency of worksharing' aspect of DESIGN and DEVELOPMENT DELEGATION gained a high score, as did the development aspect of OUTSOURCING.

11. Citroen Xanthia – wiring harness

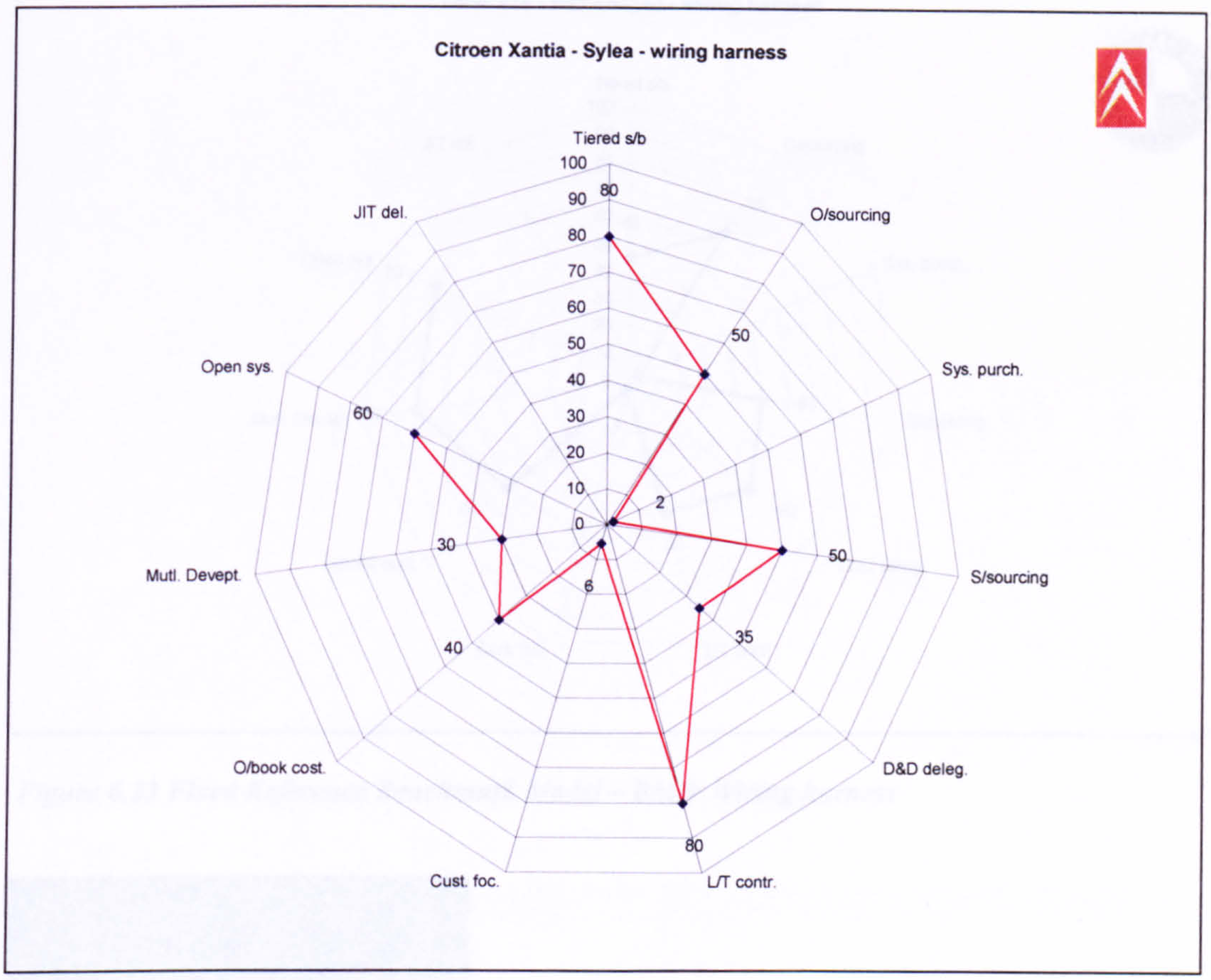


Figure 6.21. Fixed Reference Benchmark Model, Citroen Wiring harness

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2
1. Fit harness to vehicle			
2. Final assembly of harness			
3. Manufacture of looms			
4. Fit looms to connectors			
5. Sheathing of loom assemblies			
6. Manufacture of connectors			
7. Manufacture of sheathing			
Total No. of value addition steps performed by each	5	1	1

Figure 6.22 – Hierarchical Structure Map – Citroen Wiring harness

Commentary on Citroen Xantia wiring harness

The major difference with this supply chain is that the looming and assembly of the wiring harnesses are carried out in-house, by a PSA subsidiary company. Hence the relatively lower scores for OUTSOURCING and SYSTEMS PURCHASING.

12. BMW E36 - wiring harness

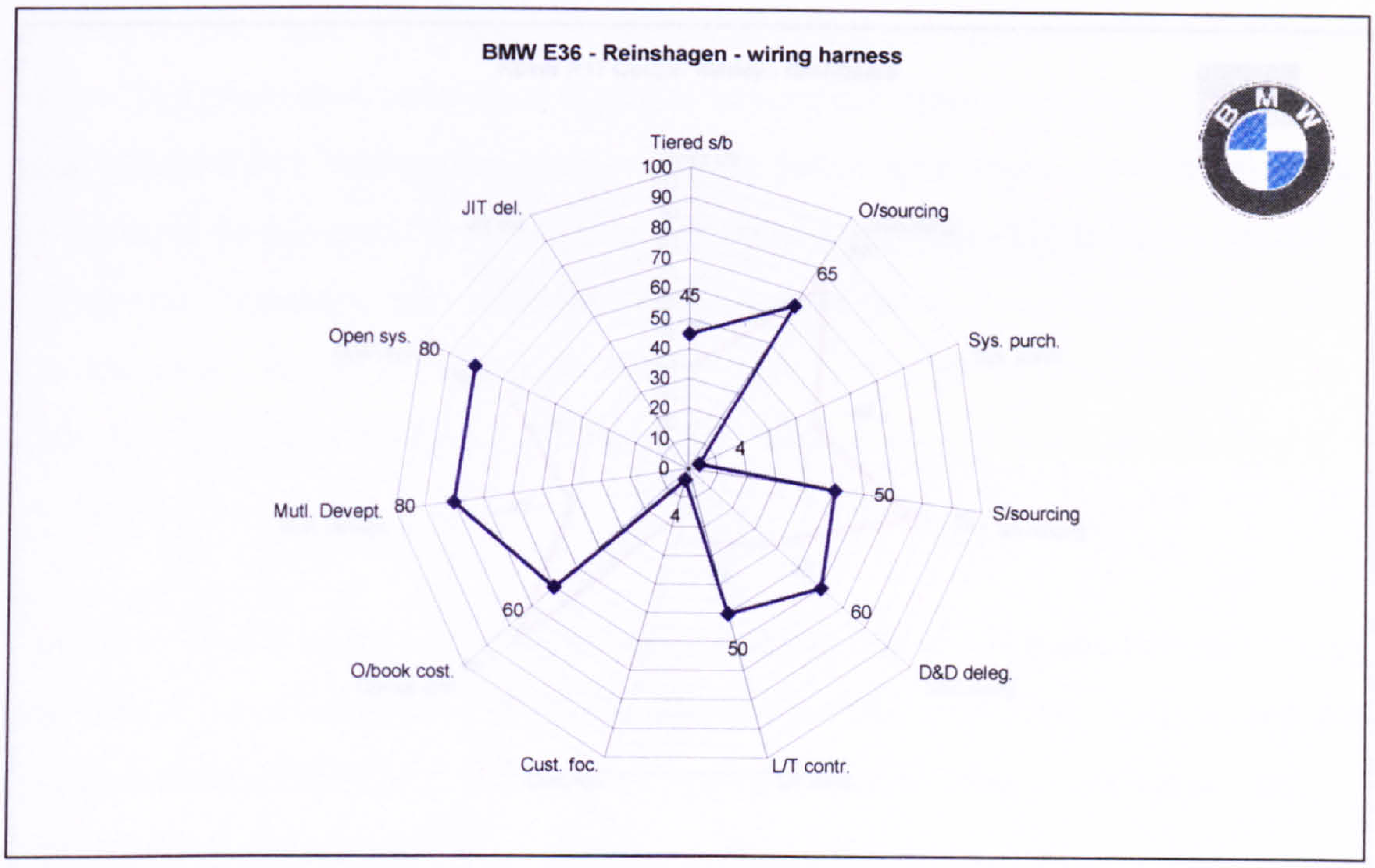


Figure 6.23 Fixed Reference Benchmark Model – BMW Wiring harness

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3
1. Fit harness to vehicle				
2. Final assembly of harness				
3. Manufacture of looms				
4. Fit looms to connectors				
5. Sheathing of loom assemblies				
6. Manufacture of connectors				
7. Manufacture of sheathing				
Total No. of value addition steps performed by each	1	4	1	1

Figure 6.24 Hierarchical Structure Map – BMW Wiring harness

Commentary on BMW E36 wiring harness

The E36 wiring harness supply chain is fairly typical in its structure. Again, BMW score highly for DESIGN and DEVELOPMENT DELEGATION, and MUTUAL DEVELOPMENT. This is mainly due to the practice of guest engineers, and other methods employed to build the working relationships between the VM and the supplier.

13. Rover R17 - dashboard

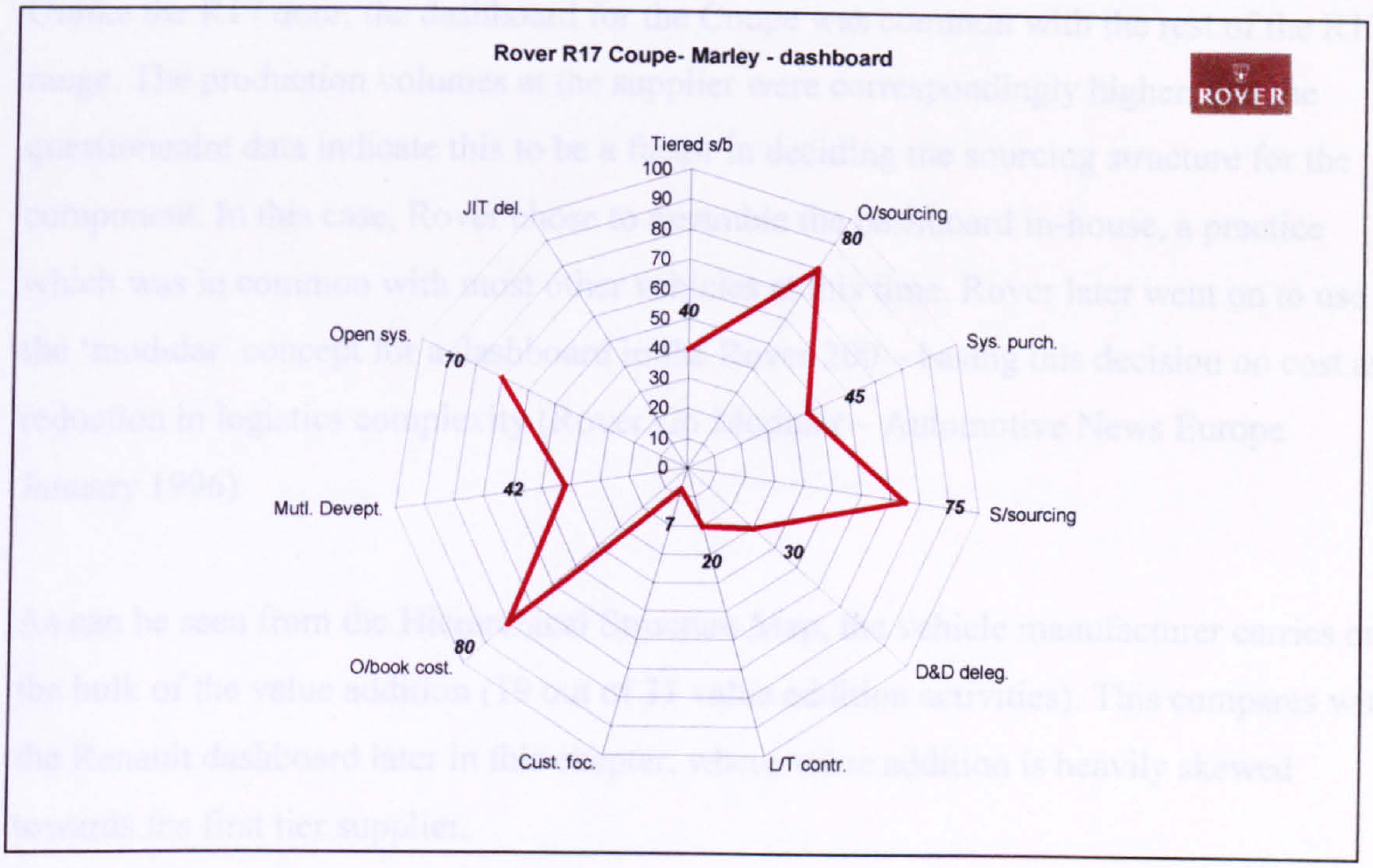


Figure 6.25. Fixed Reference Benchmark Model – Rover Dashboard

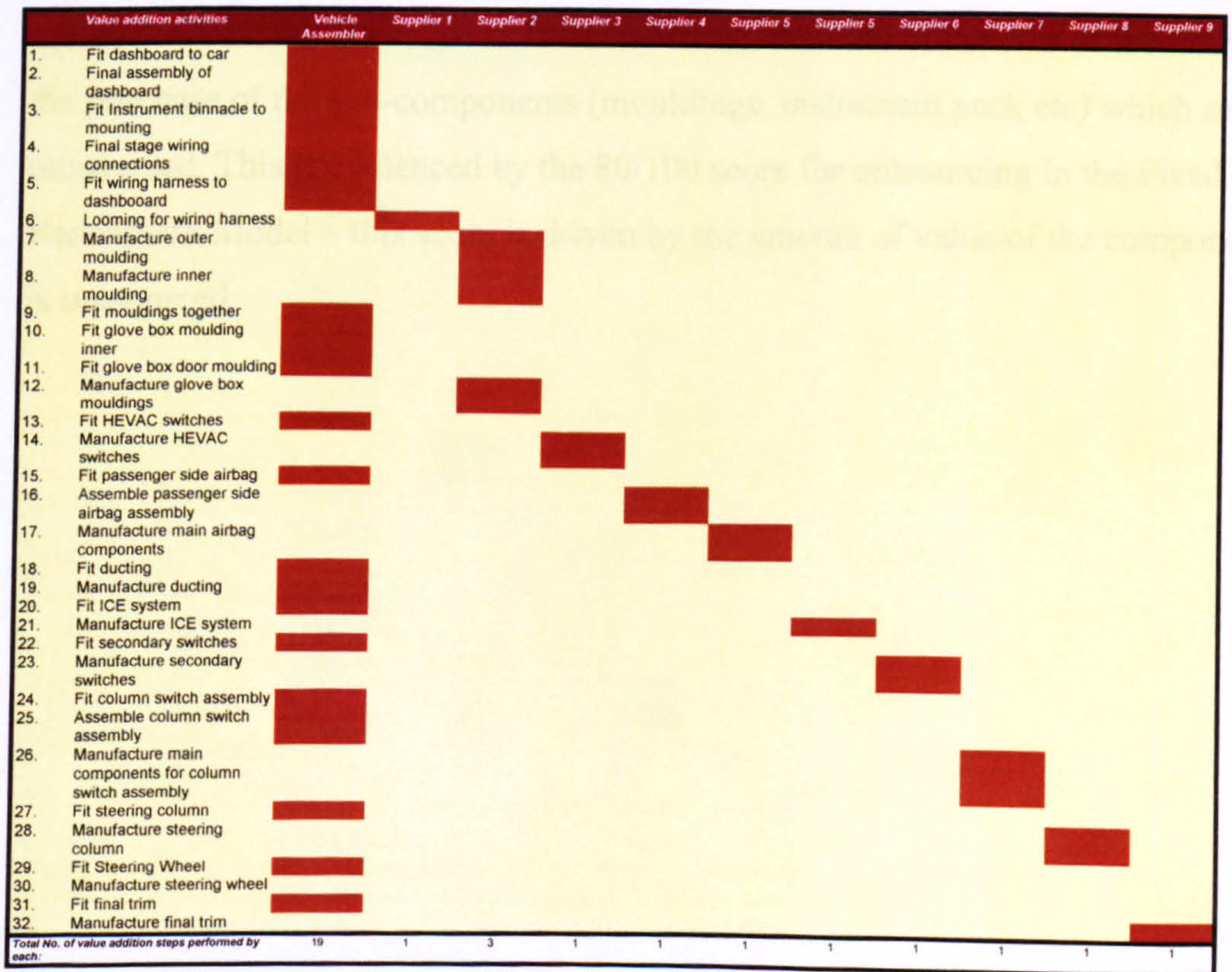


Figure 6.26 Hierarchical Structure Map – Rover Dashboard

Commentary on Rover R17 dashboard

Unlike the R17 door, the dashboard for the Coupe was common with the rest of the R17 range. The production volumes at the supplier were correspondingly higher, and the questionnaire data indicate this to be a factor in deciding the sourcing structure for the component. In this case, Rover chose to assemble the dashboard in-house, a practice which was in common with most other vehicles at this time. Rover later went on to use the 'modular' concept for a dashboard in the Rover 200 – basing this decision on cost and reduction in logistics complexity (Rover Go Modular – Automotive News Europe January 1996)

As can be seen from the Hierarchical Structure Map, the vehicle manufacturer carries out the bulk of the value addition (19 out of 31 value addition activities). This compares with the Renault dashboard later in this chapter, where value addition is heavily skewed towards the first tier supplier.

It is interesting to note that although the bulk of the value addition *activities* are carried out by the VM, when viewed in financial terms, the bulk of the *cost* of the dashboard is in the purchase of the sub-components (mouldings, instrument pack etc) which are outsourced. This is evidenced by the 80/100 score for outsourcing in the Fixed Reference Benchmark Model – this score is driven by the amount of value of the component which is outsourced.

14. Mercedes Benz E-Class – dashboard

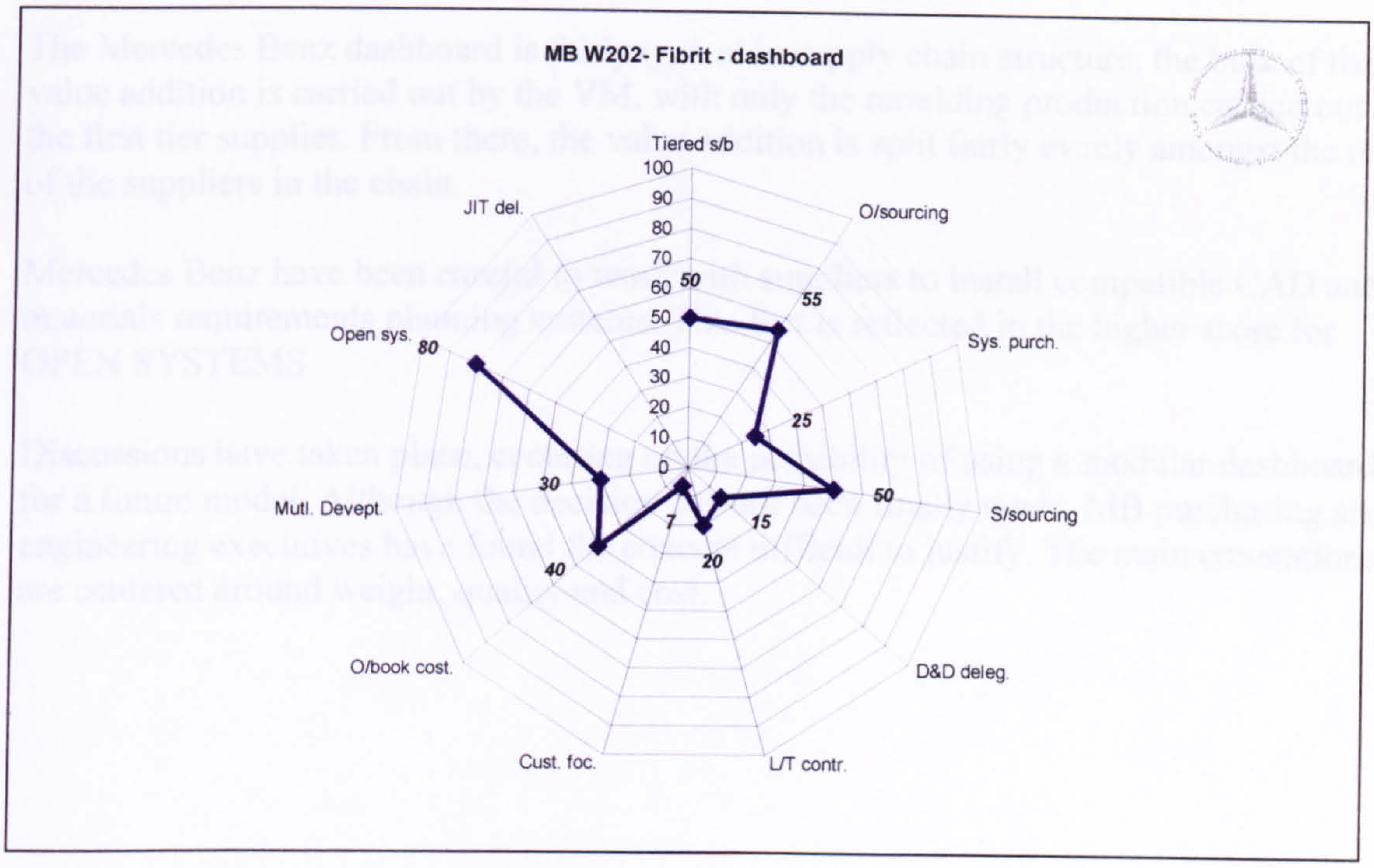


Figure 6.27 Fixed Reference Benchmark Model – MB dashboard

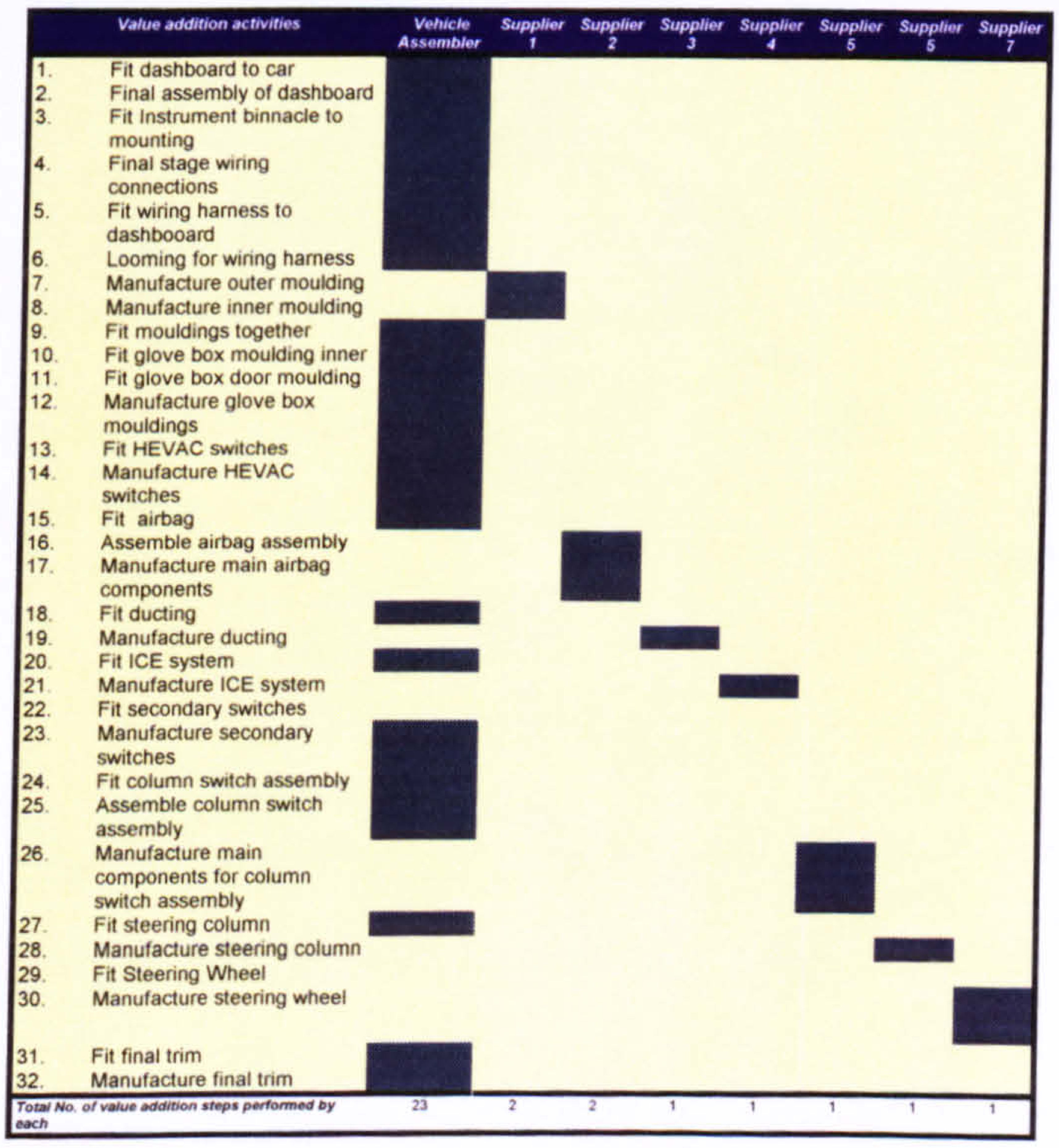


Figure 6.28 Hierarchical Structure Map – MB dashboard

Commentary on MB E-Class dashboard

The Mercedes Benz dashboard is fairly typical in supply chain structure, the bulk of the value addition is carried out by the VM, with only the moulding production carried out by the first tier supplier. From there, the value addition is split fairly evenly amongst the rest of the suppliers in the chain.

Mercedes Benz have been careful to work with suppliers to install compatible CAD and materials requirements planning systems. This fact is reflected in the higher score for OPEN SYSTEMS.

Discussions have taken place, centering on the possibility of using a modular dashboard for a future model. Although the decision has not been finally made, MB purchasing and engineering executives have found the concept difficult to justify. The main contentions are centered around weight, quality and cost.

15. Peugeot 106 – dashboard

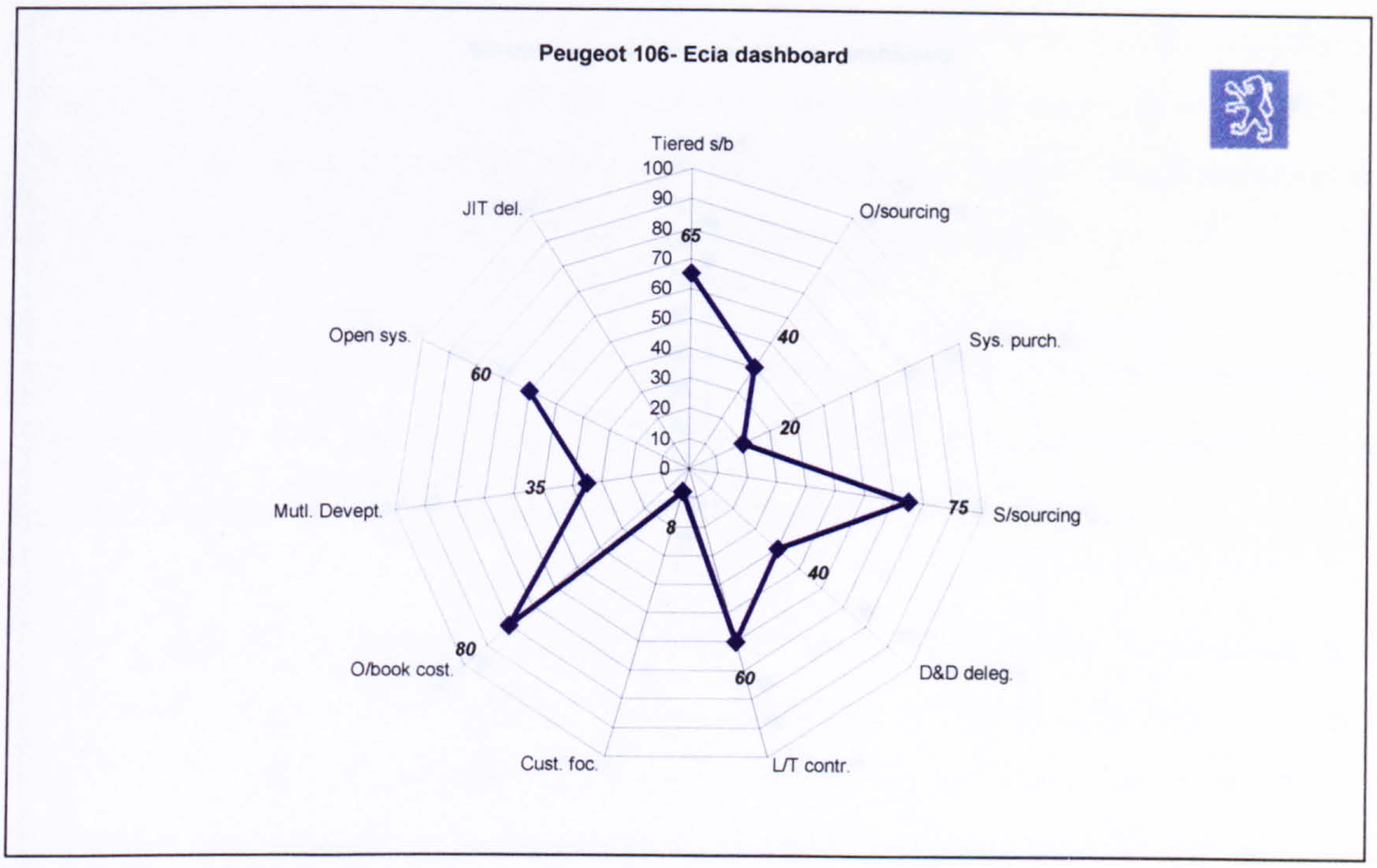


Figure 6.29 Fixed Reference Benchmark Model – Peugeot dashboard

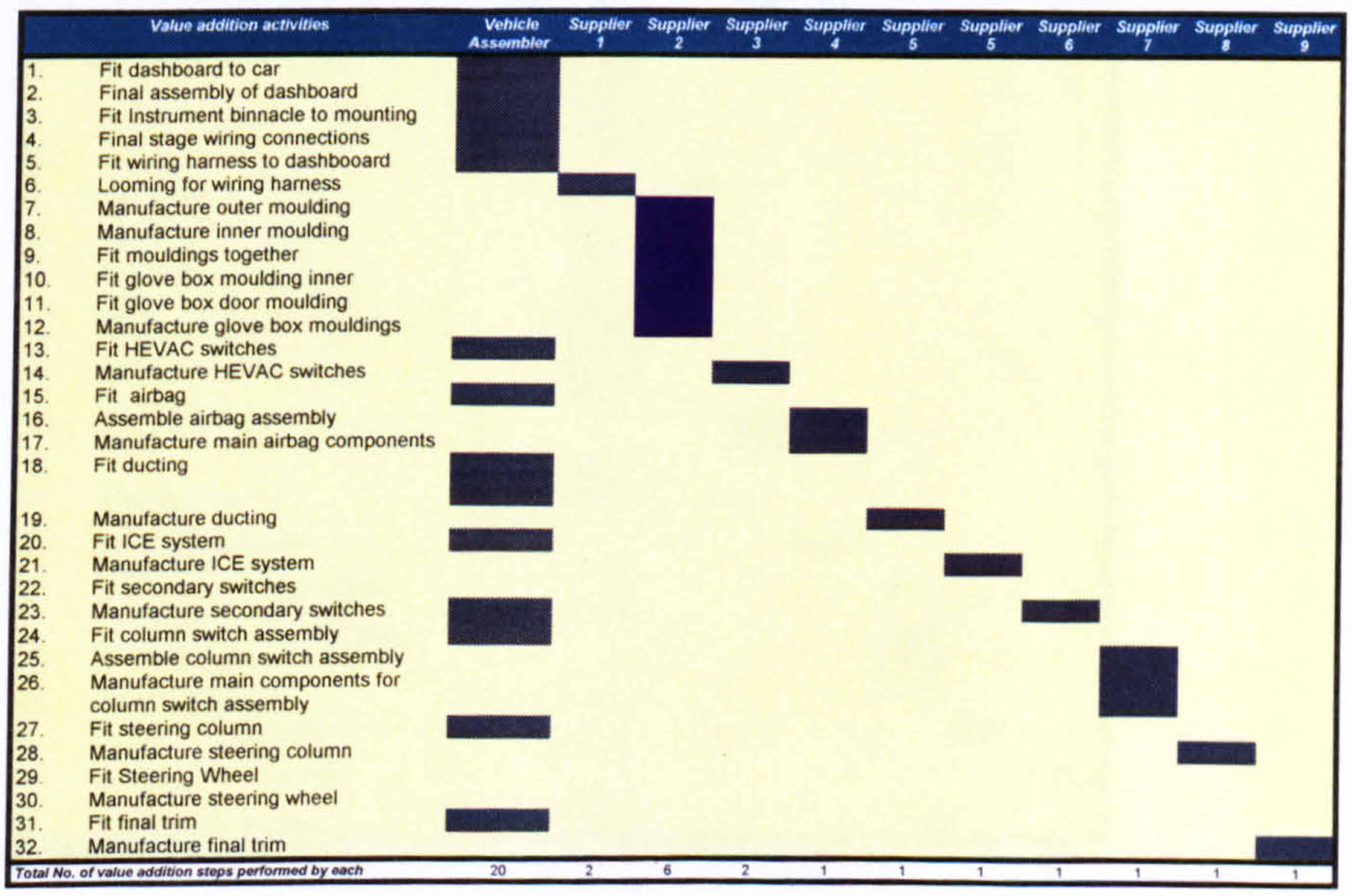


Figure 6.30 Hierarchical Structure Map – Peugeot dashboard

16. Renault Laguna – dashboard

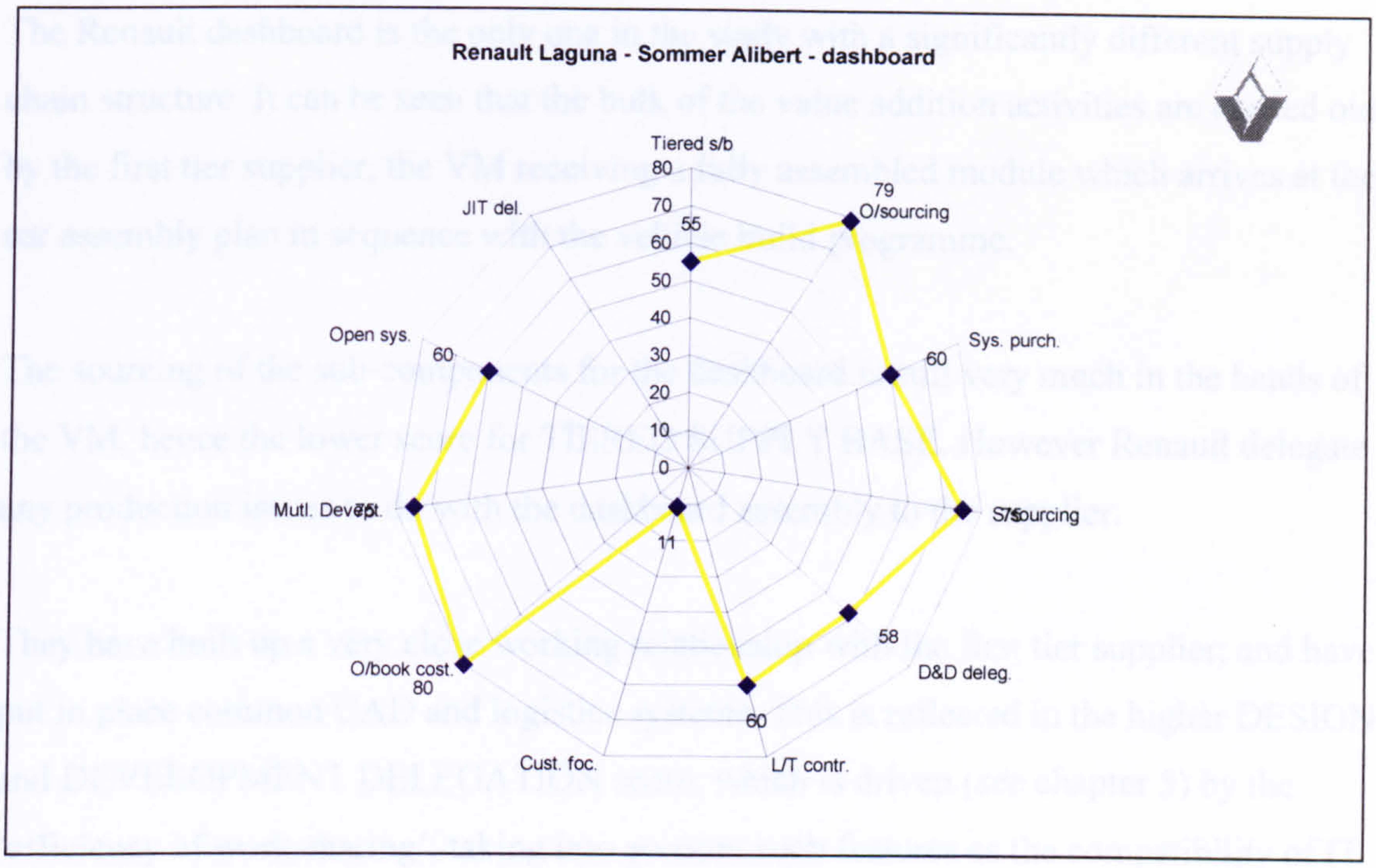


Figure 6.31. Fixed Reference Benchmark Model – Renault dashboard

Value addition activities		Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Supplier 7
1.	Fit dashboard to car	■	■						
2.	Final assembly of dashboard		■						
3.	Fit Instrument binnacle to mounting		■						
4.	Final stage wiring connections		■						
5.	Fit wiring harness to dashbooard		■						
6.	Looming for wiring harness			■					
7.	Manufacture outer moulding		■						
8.	Manufacture inner moulding		■						
9.	Fit mouldings together		■						
10.	Fit glove box moulding inner		■						
11.	Fit glove box door moulding		■						
12.	Manufacture glove box mouldings		■						
13.	Fit HEVAC switches		■						
14.	Manufacture HEVAC switches		■						
15.	Fit airbag		■						
16.	Assemble airbag assembly				■				
17.	Manufacture main airbag components				■				
18.	Fit ducting		■						
19.	Manufacture ducting		■						
20.	Fit ICE system	■							
21.	Manufacture ICE system					■			
22.	Fit secondary switches		■						
23.	Manufacture secondary switches						■		
24.	Fit column switch assembly		■						
25.	Assemble column switch assembly						■		
26.	Manufacture main components for column switch assembly						■		
27.	Fit steering column		■						
28.	Manufacture steering column							■	
29.	Fit Steering Wheel		■						
30.	Manufacture steering wheel								■
31.	Fit final trim		■						
32.	Manufacture final trim		■						
Total No. of value addition steps performed by each:		2	21	1	2	1	3	1	1

Figure 6.32. Fixed Reference Benchmark Model – Renault dashboard

Commentary on Renault Laguna dashboard

The Renault dashboard is the only one in the study with a significantly different supply chain structure. It can be seen that the bulk of the value addition activities are carried out by the first tier supplier, the VM receiving a fully assembled module which arrives at the car assembly plan in sequence with the vehicle build programme.

The sourcing of the sub-components for the dashboard is still very much in the hands of the VM, hence the lower score for TIERED SUPPLY BASE. However Renault delegate any production issues to do with the dashboard assembly to the supplier.

They have built up a very close working relationship with the first tier supplier, and have put in place common CAD and logistics systems. This is reflected in the higher DESIGN and DEVELOPMENT DELEGATION score, which is driven (see chapter 5) by the 'efficiency of work sharing', taking into account such features as the compatibility of IT systems.

17. Citroen Xanthia – dashboard

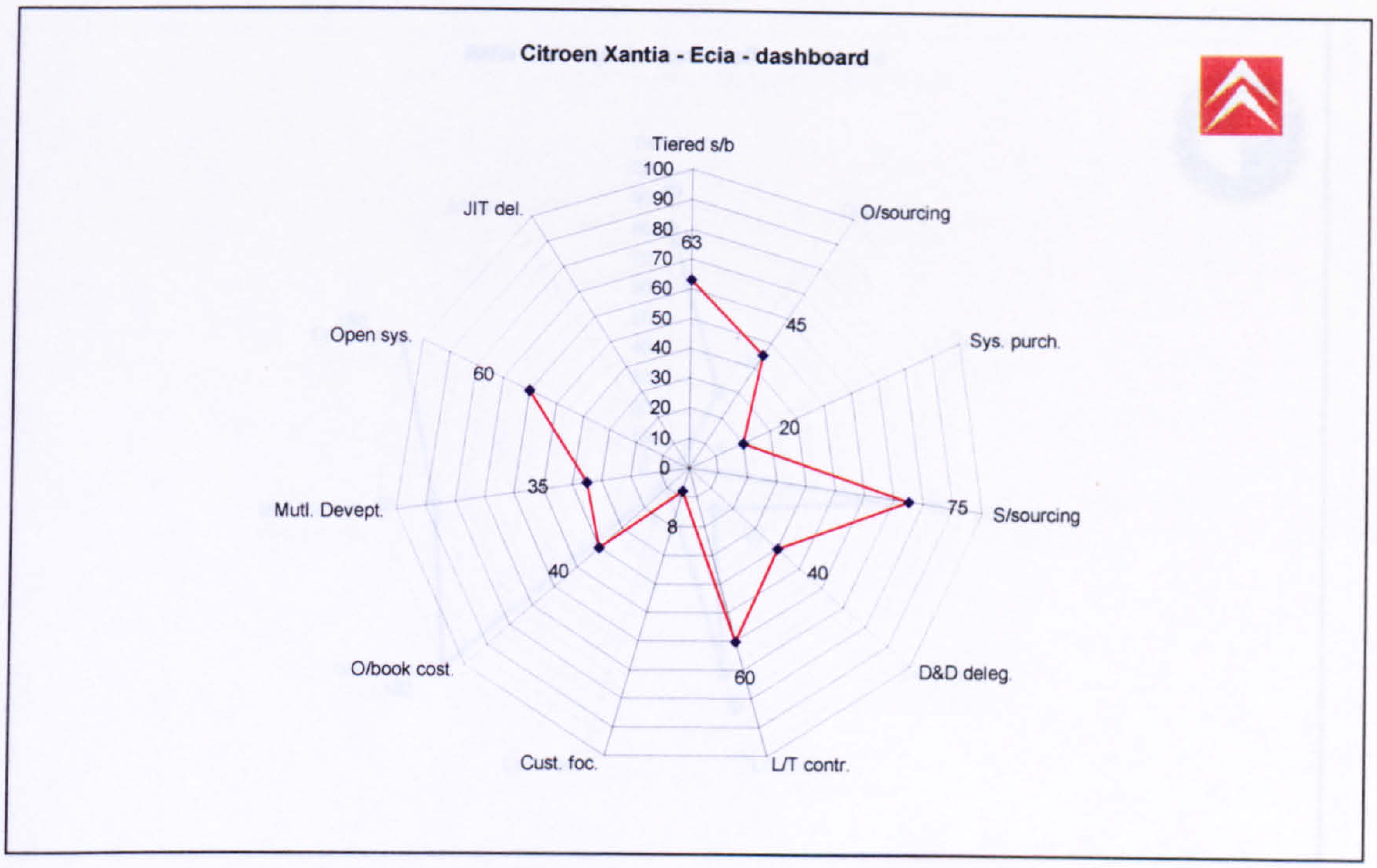


Figure 6.33. Fixed Reference Benchmark Model, Citroen dashboard

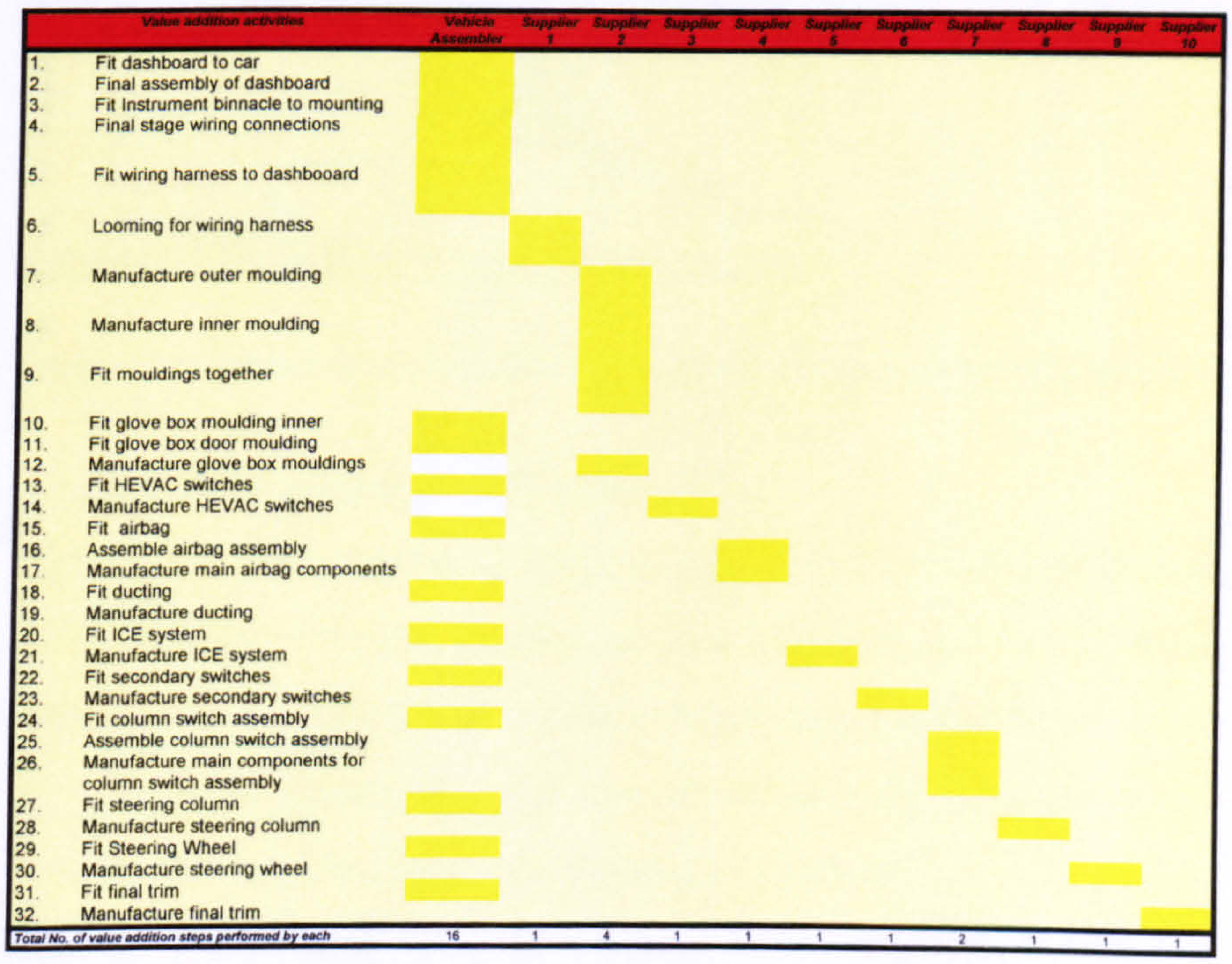


Figure 6.34 – Hierarchical Structure Map – Citroen dashboard

18. BMW E36 dashboard

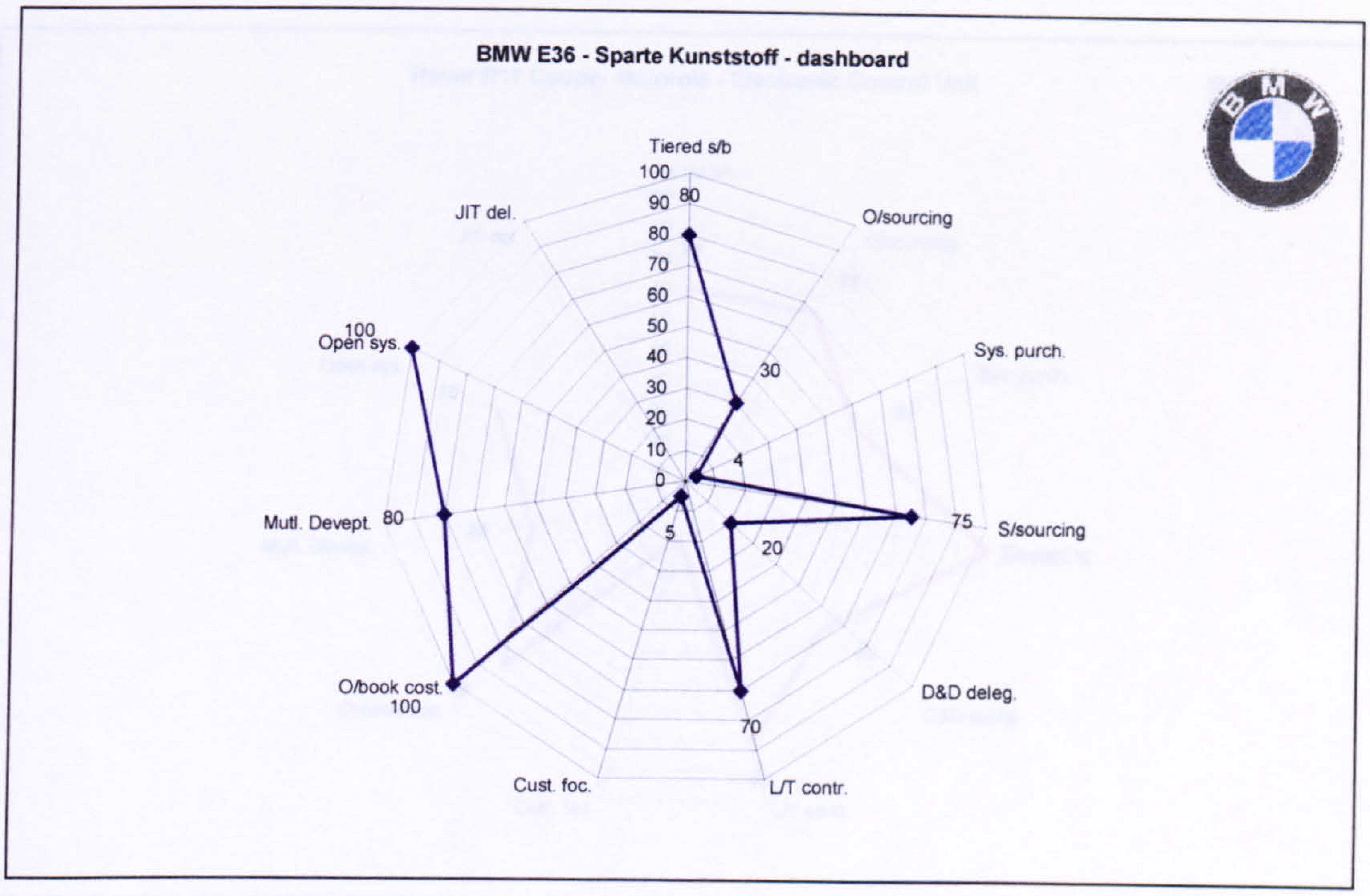


Figure 6.35 Fixed Reference Benchmark Model – BMW dashboard

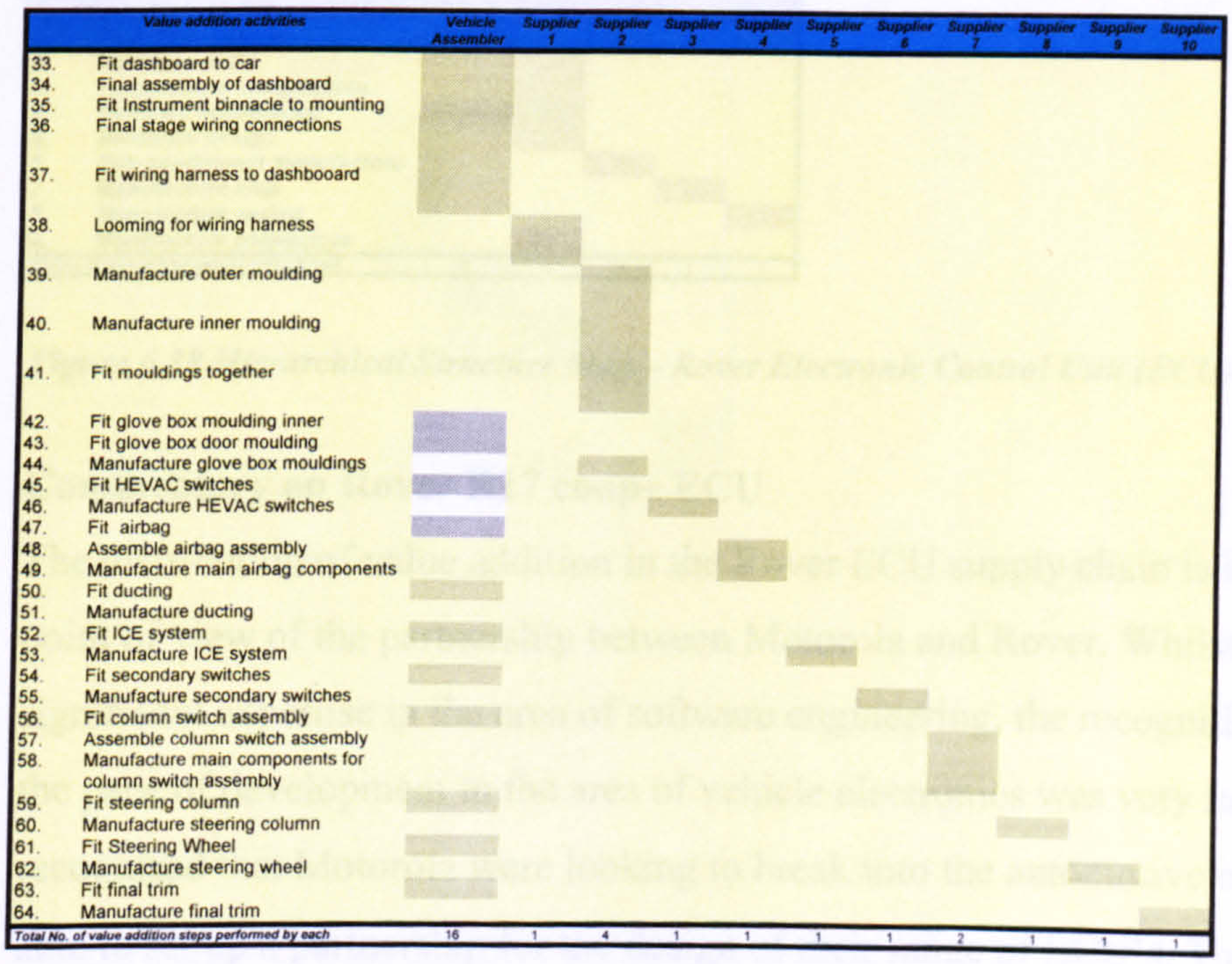


Figure 6.36 Hierarchical Structure Map – BMW dashboard

19. Rover R17 - Electronic Control Unit (ECU)

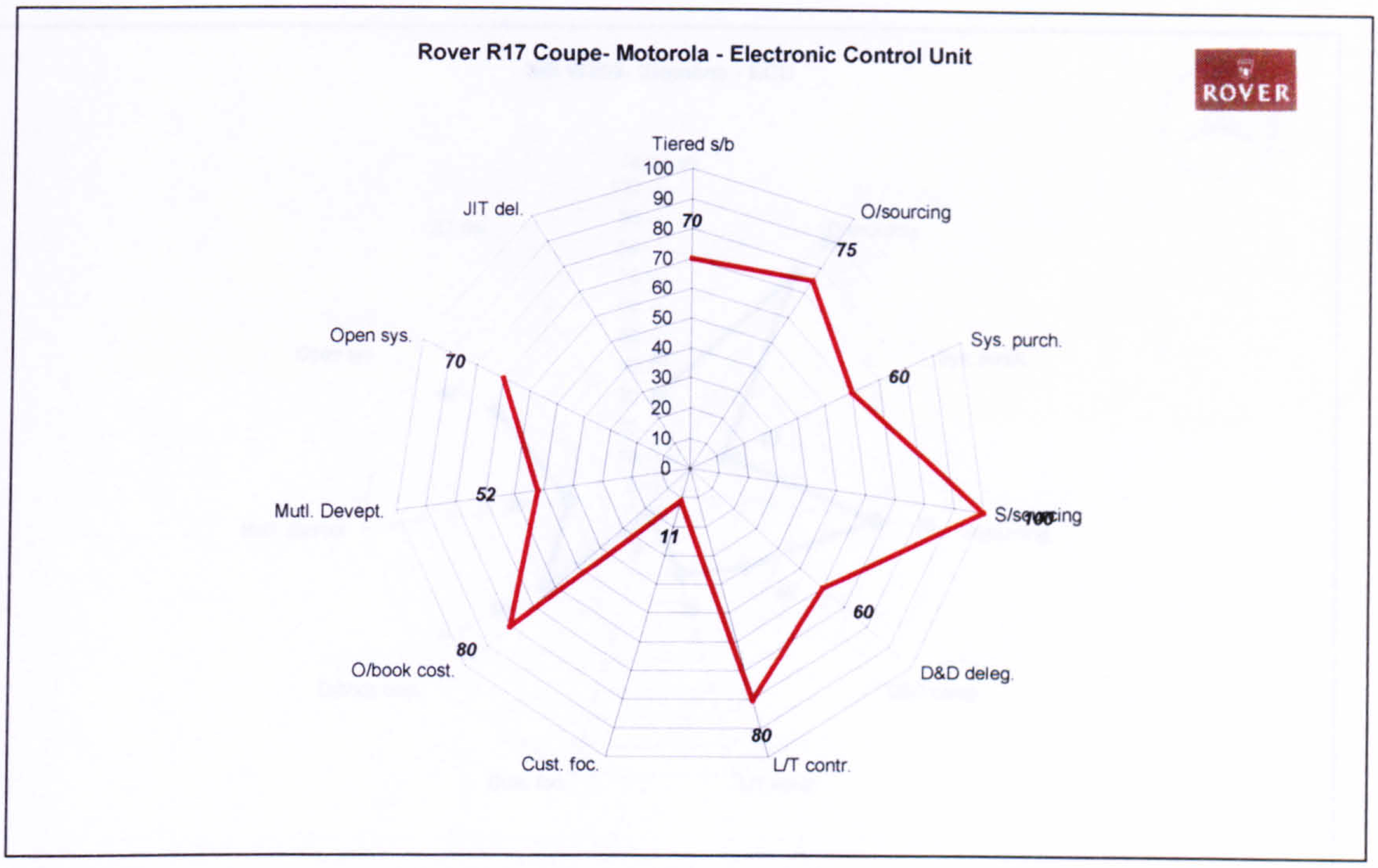


Figure 6.37. Fixed Reference Benchmark Model – Rover Electronic Control Unit (ECU)

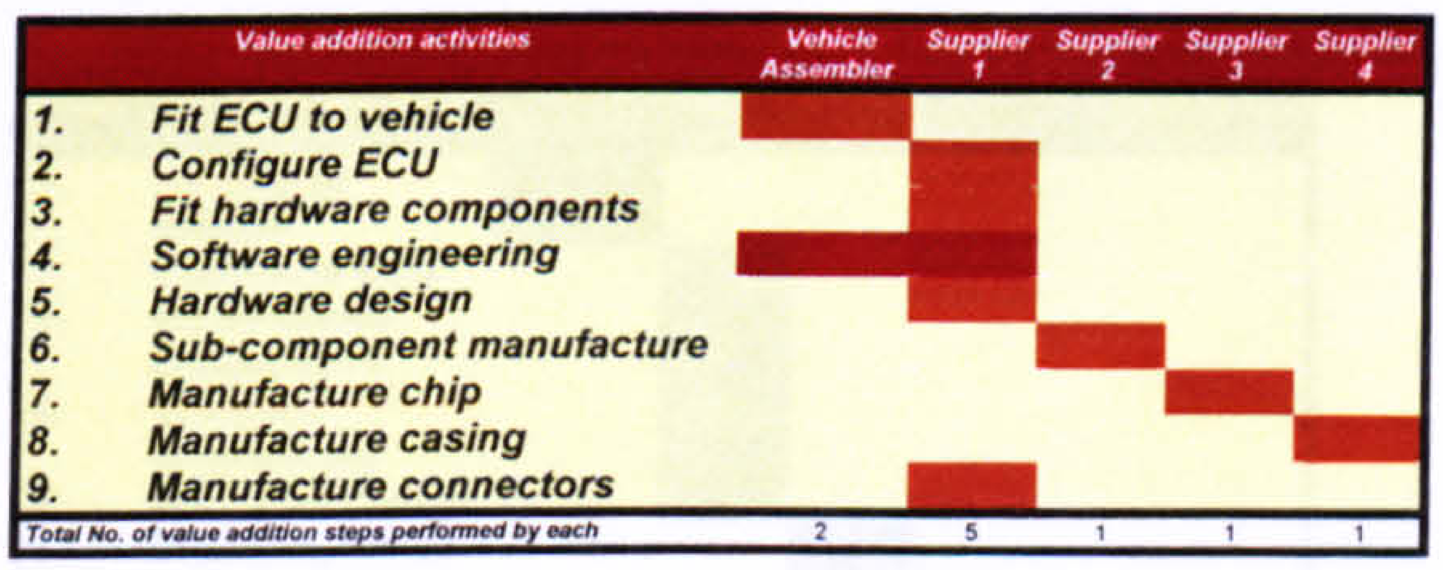


Figure 6.38 Hierarchical Structure Map – Rover Electronic Control Unit (ECU)

Commentary on Rover R17 coupe ECU

The distribution of value addition in the Rover ECU supply chain is interesting from the point of view of the partnership between Motorola and Rover. Whilst Rover retain significant expertise in the area of software engineering, the recognition was made that the pace of development in the area of vehicle electronics was very fast. Rover recognised that Motorola were looking to break into the automotive market, and were able to set up a partnership for the design of their range of ECU's. The supply chain scores highly for TIERED SUPPLY BASE – significant here is the fact that the Motorola design and production facilities were dedicated to Rover as their only customer.

20. Mercedes Benz E-Class – Electronic Control Unit (ECU)

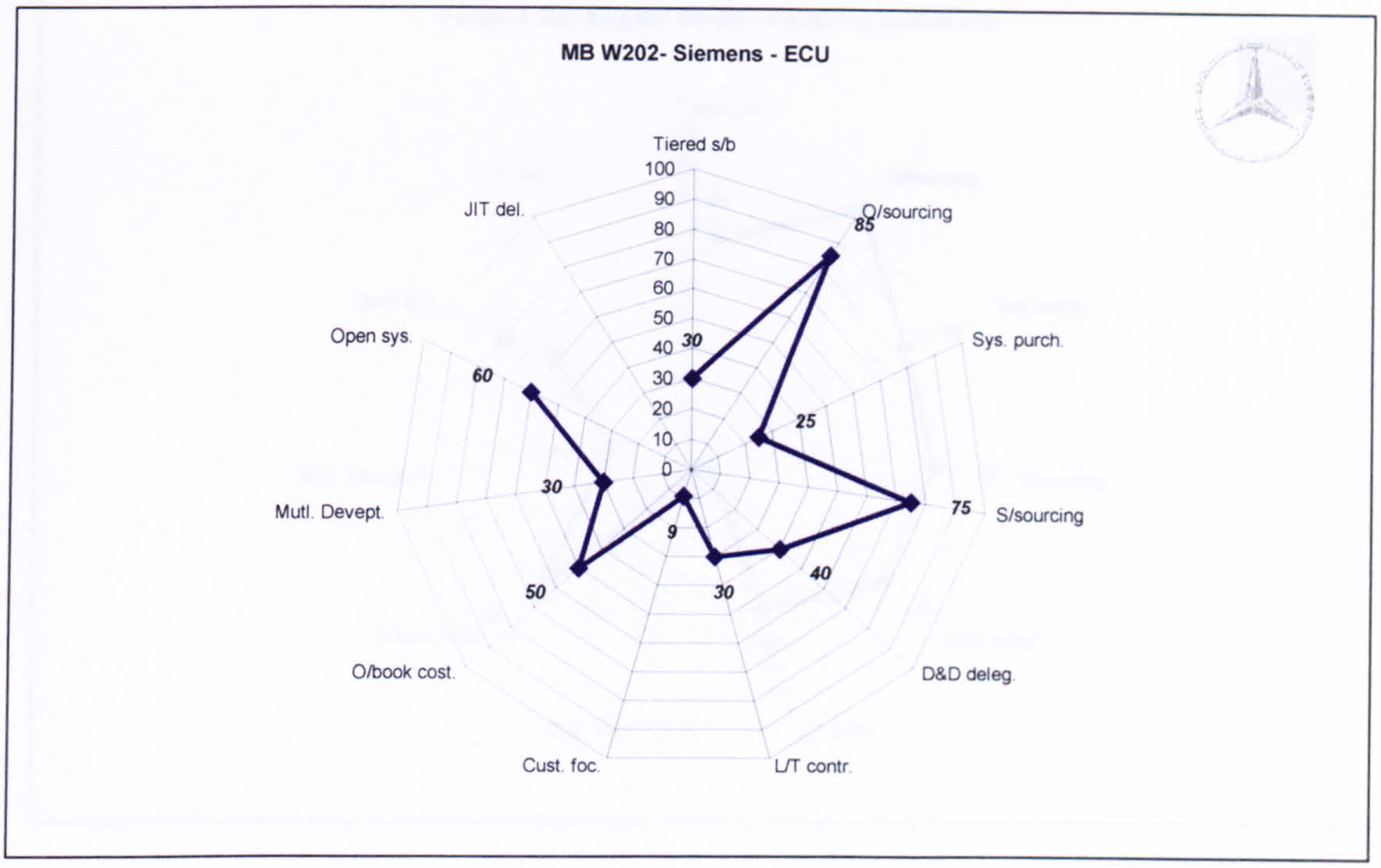


Figure 6.39 Fixed Reference Benchmark Model – MB Electronic Control Unit (ECU)

Value addit++++ioc6tttt6 g ybbbbb n activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
1. Fit ECU to vehicle						
2. Configure ECU						
3. Fit hardware components						
4. Software engineering						
5. Hardware design						
6. Sub-component manufacture						
7. Manufacture chip						
8. Manufacture casing						
9. Manufacture connectors						
Total No. of value addition steps performed by each	1	4	1	1	1	1

Figure 6.40 Hierarchical Structure Map – MB Electronic Control Unit (ECU)

21. Peugeot 106 – Electronic Control Unit (ECU)

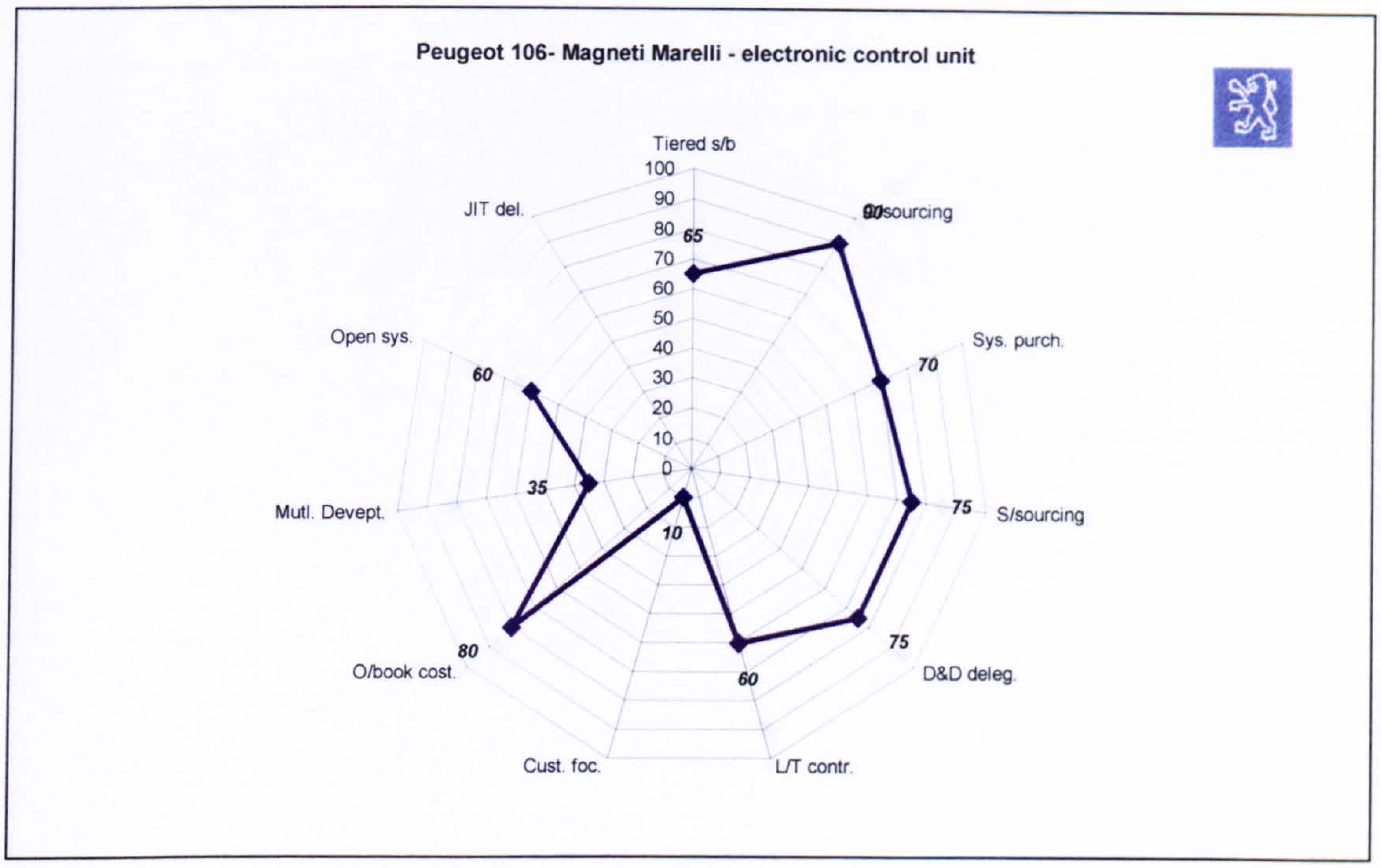


Figure 6.41 Fixed Reference Benchmark Model – Peugeot Electronic Control Unit (ECU)

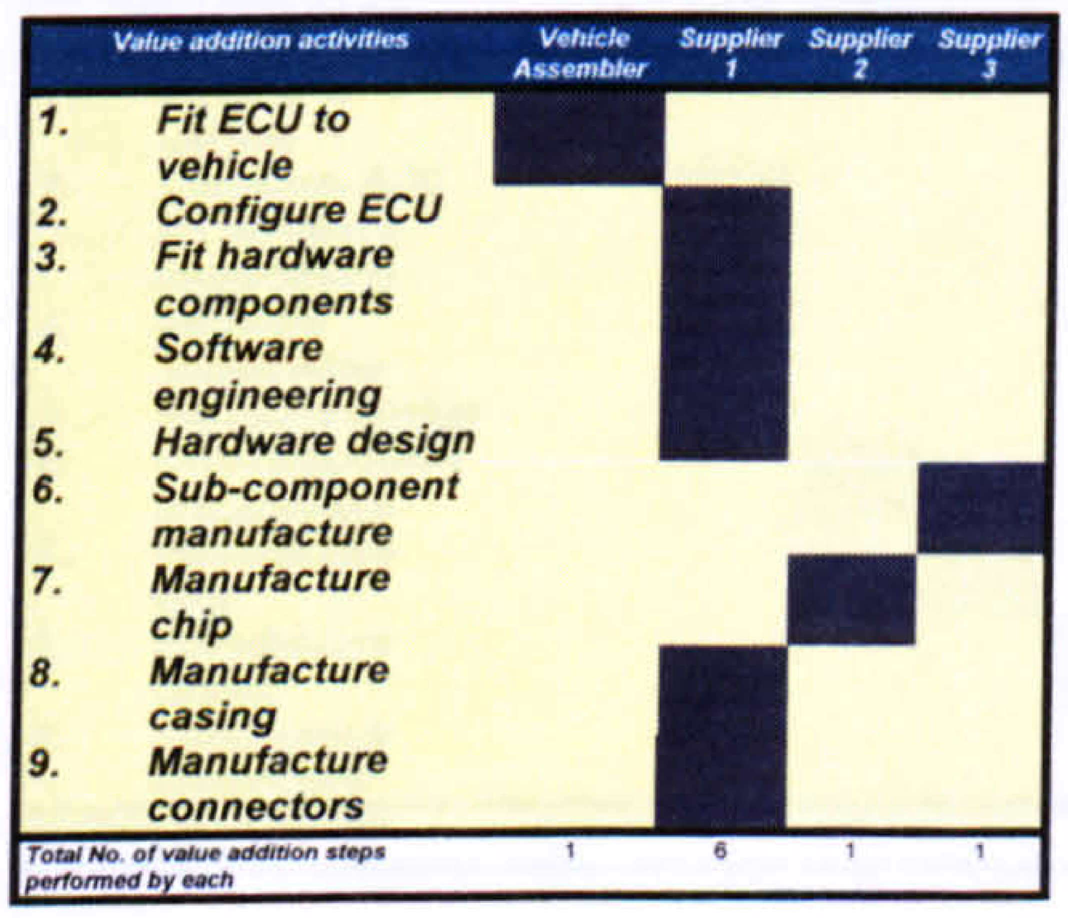


Figure 6.42 Hierarchical Structure Map – Peugeot Electronic Control Unit (ECU)

22. Renault Laguna – Electronic Control Unit (ECU)

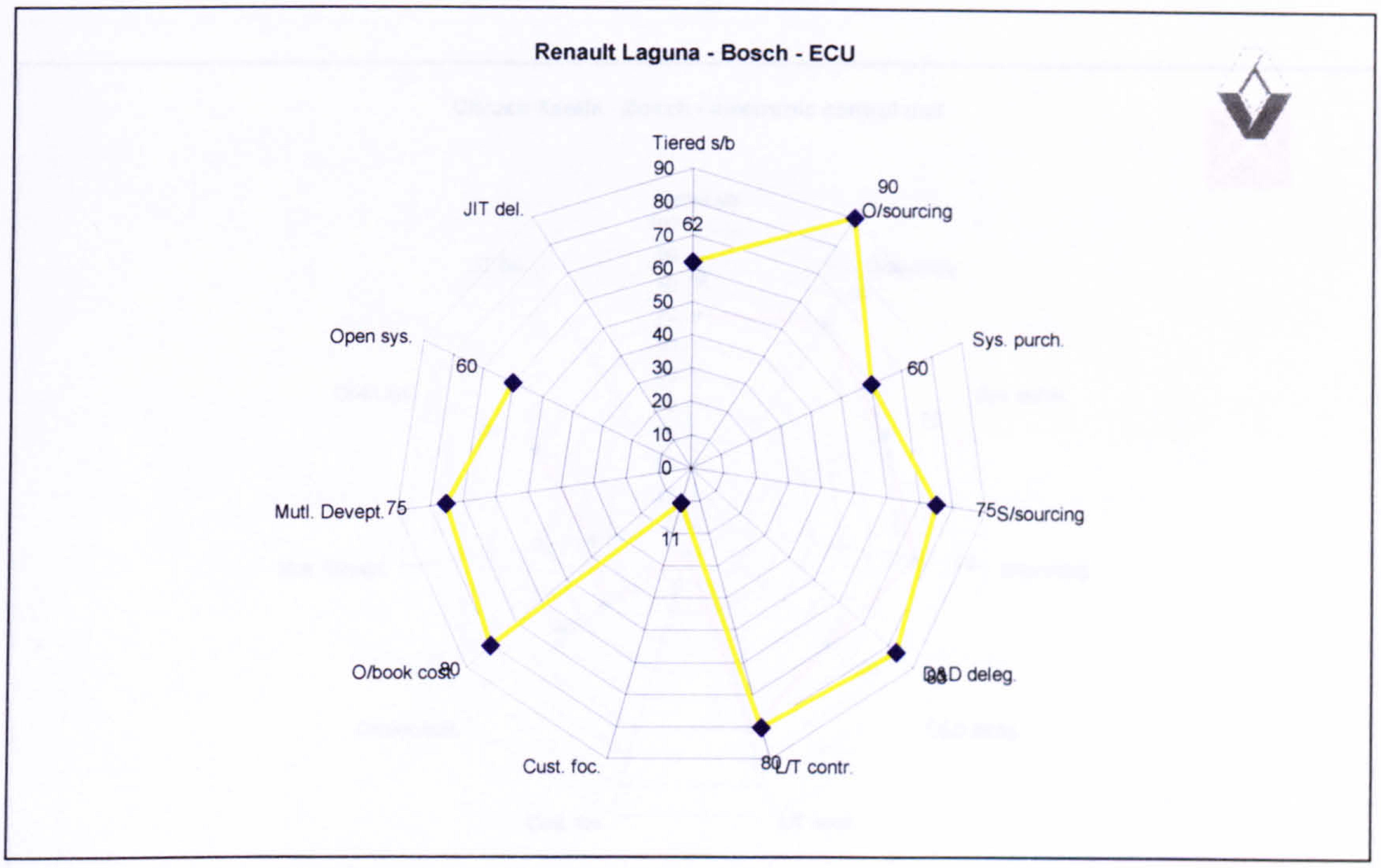


Figure 6.43. Fixed Reference Benchmark Model – Renault Electronic Control Unit (ECU)

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
1. Fit ECU to vehicle						
2. Configure ECU						
3. Fit hardware components						
4. Software engineering						
5. Hardware design						
6. Sub-component manufacture						
7. Manufacture chip						
8. Manufacture casing						
9. Manufacture connectors						
Total No. of value addition steps performed by each	1	4	1	1	1	1

Figure 6.44. Fixed Reference Benchmark Model – Renault Electronic Control Unit (ECU)

23. Citroen Xanthia – Electronic Control Unit (ECU)

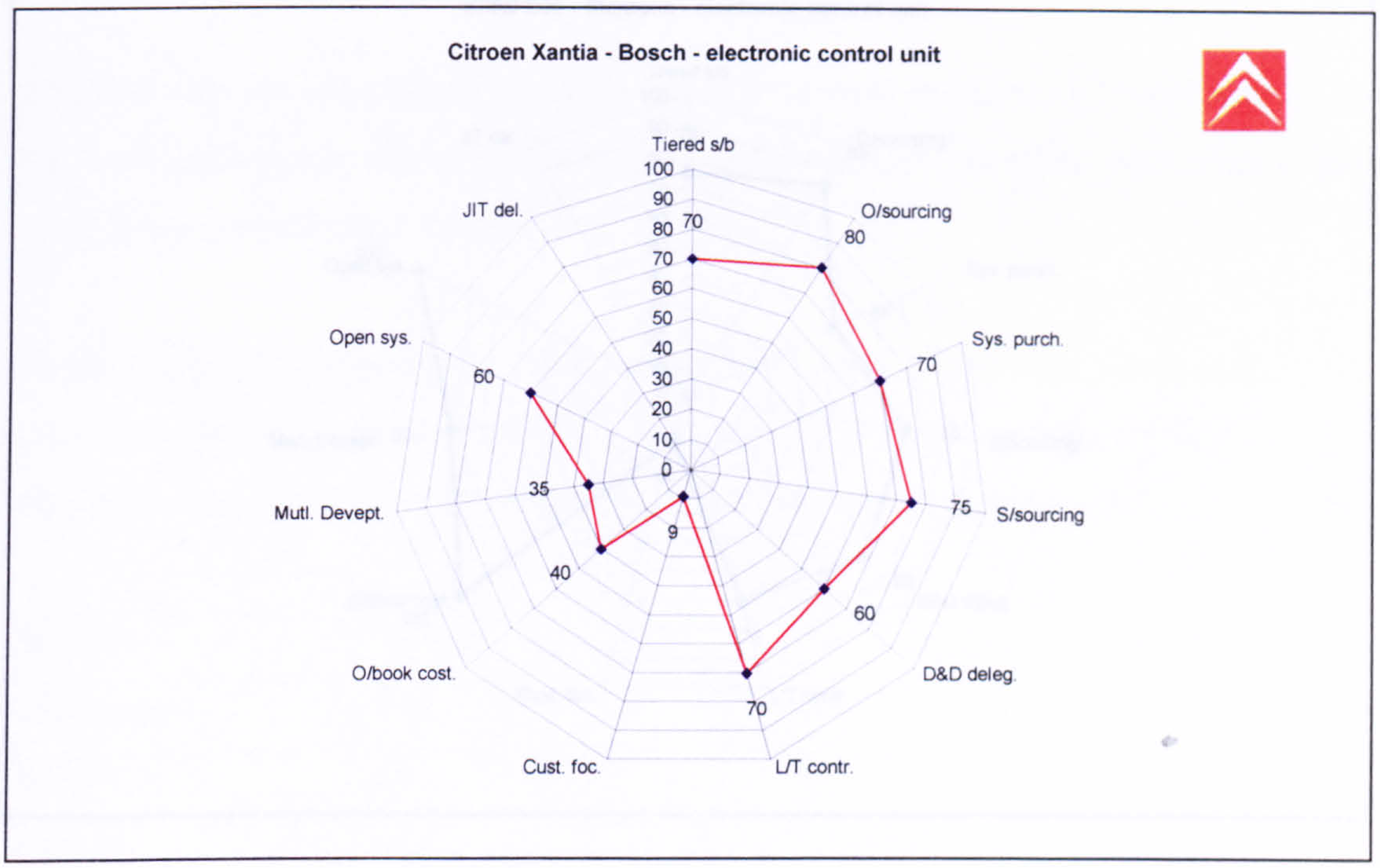


Figure 6.45. Fixed Reference Benchmark Model, Citroen Electronic Control Unit (ECU)

Value addition activities	Vehicle Assembler	Supplier 1	Supplier 2	Supplier 3	Supplie 4	Supplier 5
1. Fit ECU to vehicle						
2. Configure ECU						
3. Fit hardware components						
4. Software engineering						
5. Hardware design						
6. Sub-component manufacture						
7. Manufacture chip						
8. Manufacture casing						
9. Manufacture connectors						
Total No. of value addition steps performed by each	1	4	1	1	1	1

Figure 6.46 – Hierarchical Structure Map – Citroen Electronic Control Unit (ECU)

24. BMW E36 Electronic Control Unit (ECU)

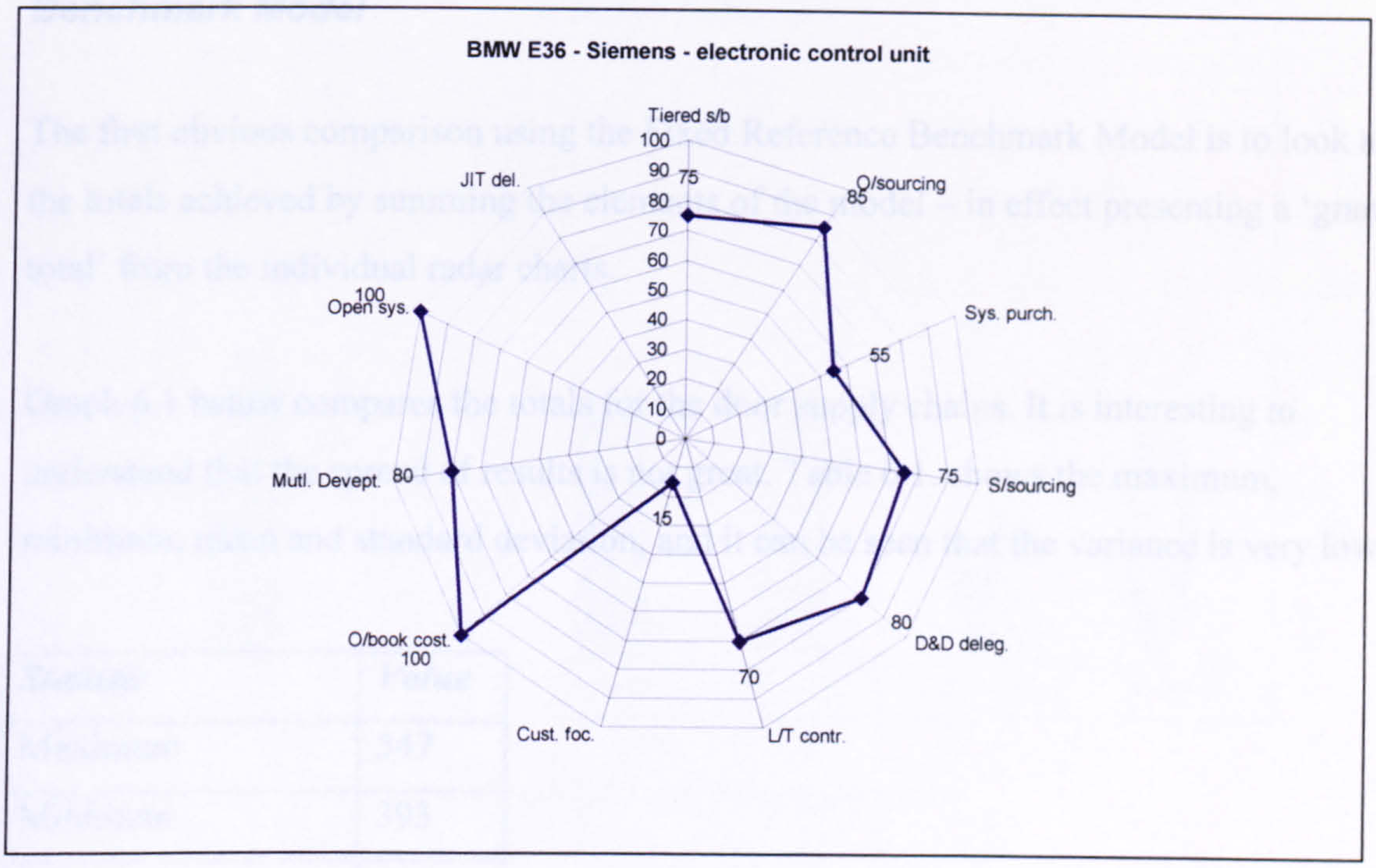


Figure 6.47 Fixed Reference Benchmark Model – BMW Electronic Control Unit (ECU)

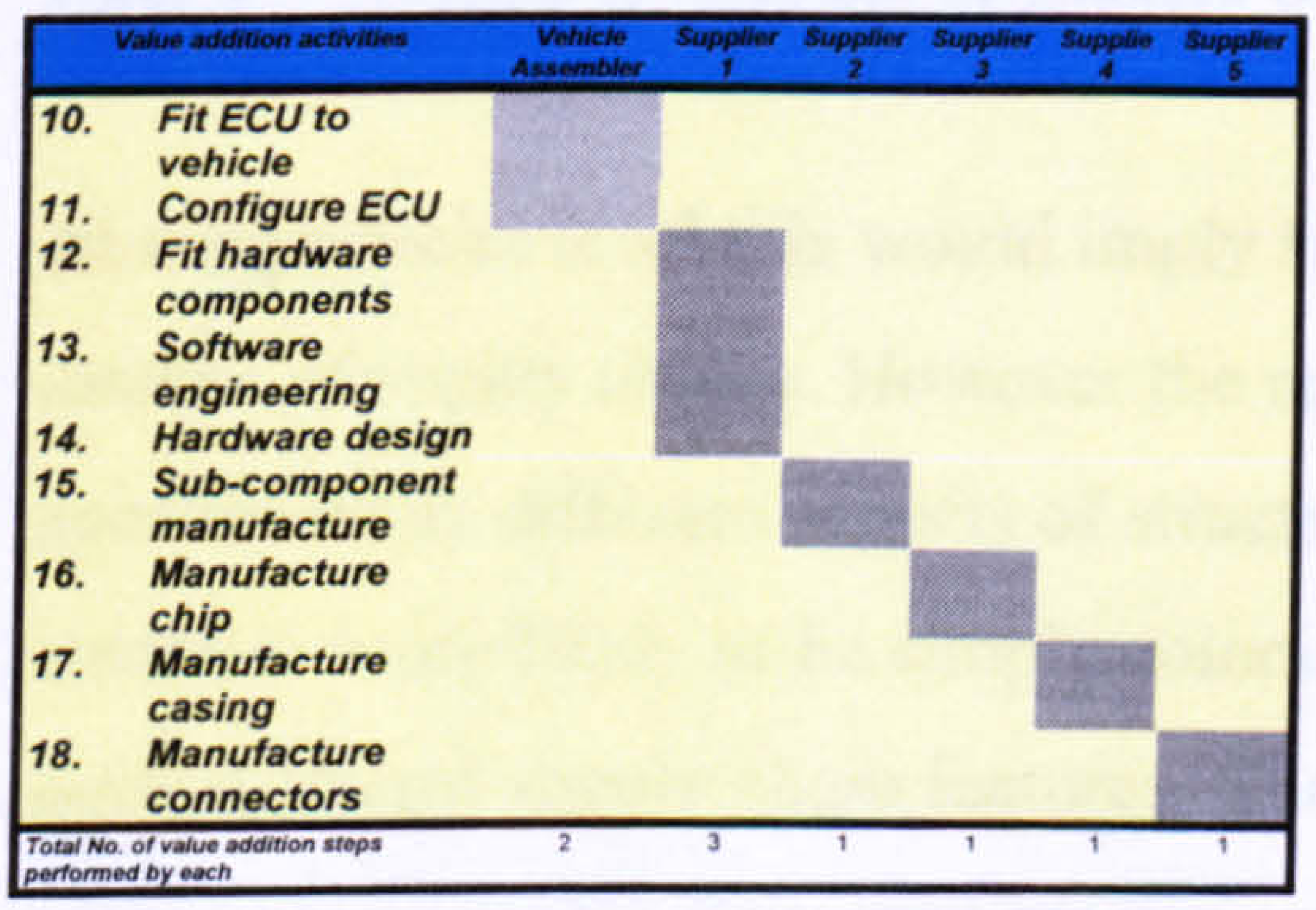


Figure 6.48 Hierarchical Structure Map – BMW Electronic Control Unit (ECU)

6.3 Comparison of supply chains one with another, using Fixed Reference Benchmark Model

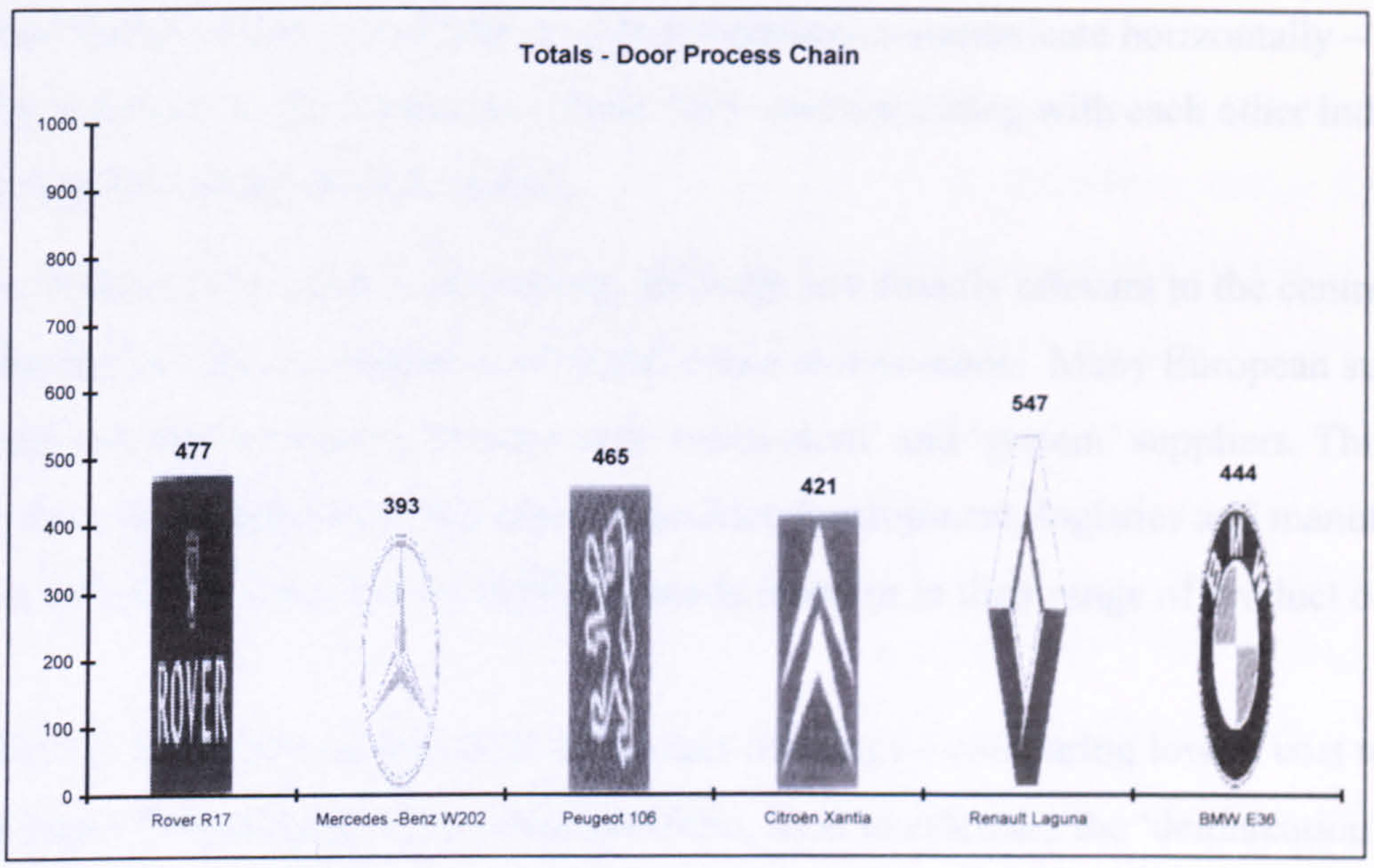
The first obvious comparison using the Fixed Reference Benchmark Model is to look at the totals achieved by summing the elements of the model – in effect presenting a 'grand total' from the individual radar charts.

Graph 6.1 below compares the totals for the door supply chains. It is interesting to understand that the spread of results is not great. Table 6.1. shows the maximum, minimum, mean and standard deviation, and it can be seen that the variance is very low.

Statistic	*Value*
Maximum	547
Minimum	393
Mean	457
Standard Deviation	53

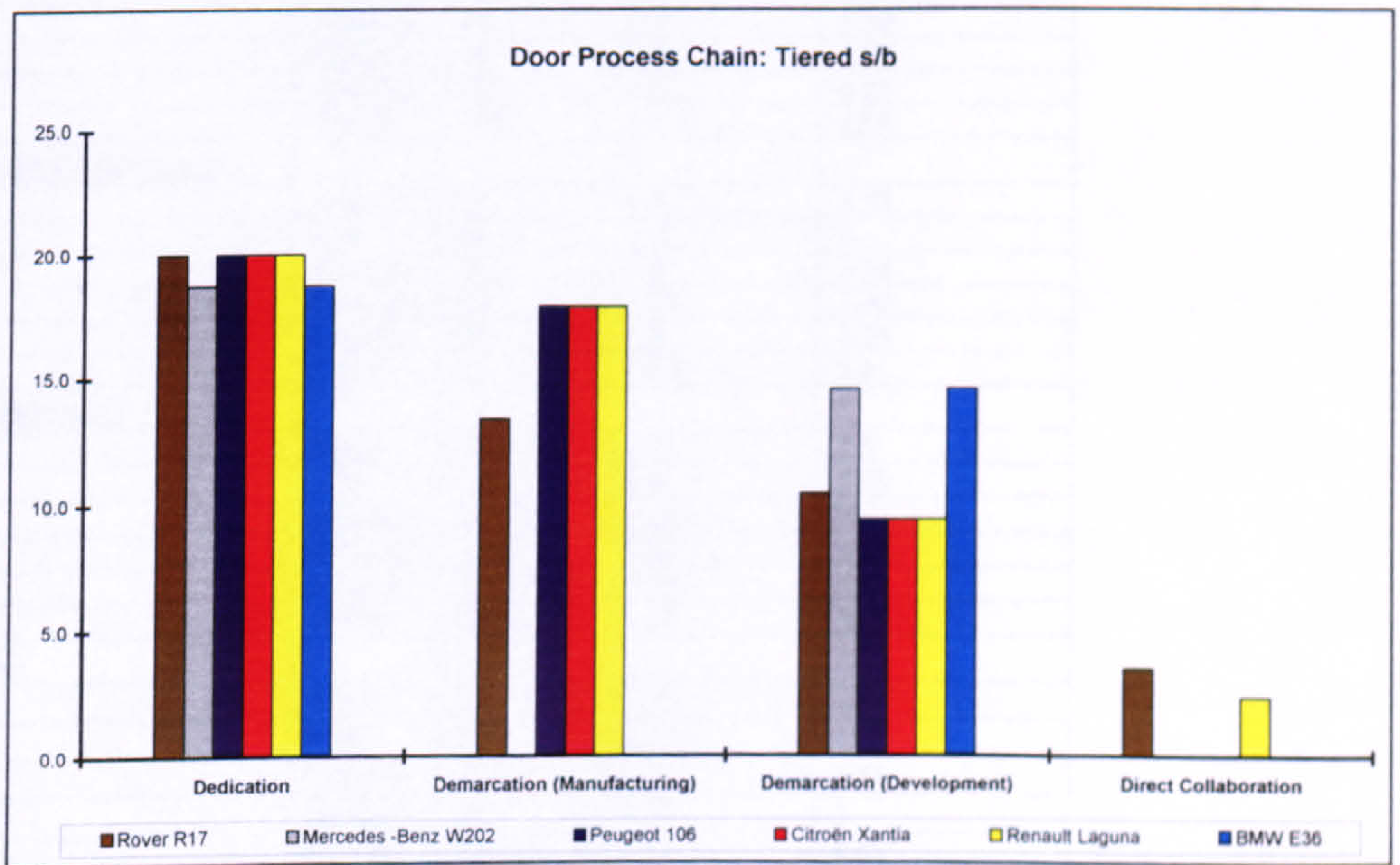
Table 6.1. Analysis of Phantom Benchmark Grand Totals

At a superficial level this would imply similar practices and similar structures across the sample of supply chains. However the reality is that because the scoring system takes into account many different aspects of structure and practice, an identical score for two supply chains is more likely to be simply coincidence. Equality in the grand totals hide some quite different supply chain features. Comparing individual element scores can draw more valuable inferences, and greater conclusions still can be found when comparing individual 'aspects' of the element totals.



Graph 6.1 Totals door supply chains

Graph 6.2, below shows the analysed chain scores for TIERED SUPPLY BASE. The results can be seen to be more revealing when split into aspects.



Graph 6.2 Scores for TIERED SUPPLY BASE, split by aspect

From the graph above it can be seen that the main differences between the supply chains are in the varying degrees of 'demarcation' (the extent to which the supplier has a clear and focussed role in the supply chain – see chapter 3 and 4 for fuller definition) and 'direct collaboration' (the extent to which suppliers communicate horizontally – with other suppliers on the same tier – rather than communicating with each other indirectly with the VM acting as intermediary.

The 'demarcation' issue is interesting, although not directly relevant to the central theme of the thesis – the investigation of *supply chain determinants.* Many European suppliers of main components are at present both 'component' and 'system' suppliers. This means that their competencies, in the areas of product development, logistics and manufacturing must be broad to cater for the differing needs inherent in their range of product offering.

Table 6.2. below shows the ratios of product offerings – comparing lowest cost to highest cost items in each suppliers product portfolio, used to calculate the 'demarcation' aspect of TIERED SUPPLY BASE.

Component		Highest cost component (ECU)	Lowest cost component (ECU)	Ratio Highest/lowest (demarcation index)
Door				
	Rover	102	15	6.80
	MB	150	8	18.75
	Peugeot	55	6	9.20
	Renault	44	6	7.33
	Citroen	60	9	6.67
	BMW	108	8	13.5
Wiring Harnesss				
	Rover	25	9	2.78
	MB	45	9	5
	Peugeot	27	8	3.34
	Renault	39	10	3.90
	Citroen	26	8	3.25
	BMW	32	10	3.2
Dashboard				
	Rover	25	10	2.5
	MB	30	8	3.75
	Peugeot	40	20	2
	Renault	185	20	9.25
	Citroen	35	10	3.5
	BMW	205	10	20.5
ECU				
	Rover	80	75	1.07
	MB	65	55	1.18
	Peugeot	70	45	1.55
	Renault	70	35	2
	Citroen	60	9	6.68
	BMW	65	55	1.18

Table 6.2. Ratios of value addition between first two tiers

The higher ratios correspond mainly to supply chains with a 'modular' structure, in other words, those where high proportions of value addition are carried out in the first tier of supply. Examples are: doors made with door modules; fully assembled dashboard (sometimes termed cockpit module). In these cases the 'demarcation' score is low (between 10 and 15 out of 50), indicating that these suppliers are dealing with a broad range of product offerings from discrete components to fully integrated systems or modules.

This is a feature of the European first tier of supply which seems in stark contrast to the structure adopted in the Japanese automotive industry (Cusumano 1989, Nishiguchi 1993) where sharply demarcated, clear and focussed roles for the supplier are a feature. The implication here, is that the less focussed, or the broader the spectrum of product offerings the supplier has to deal with, the more difficult it is to optimise resources.

The next point of interest is the aspect 'direct collaboration'. This refers to the delegation of the 'integration role' traditionally carried out by the vehicle manufacturer. For the dashboard, for example, to integrate the heating system with the wiring harness, the mouldings with the instrument binnacle etc., the vehicle manufacturer would be in overall control.

However, for supply chains in which the first tier supplier assembles components into complete systems– the opportunity is there for the supplier to carry out this integration role, and for suppliers of adjacent components to communicate directly one with another, rather than using the VM as intermediary. The low scores for direct collaboration are reflective of the fact that in practice the VM often retains control of this integration so that a three way communication system develops. An anecdotal point of evidence serves to illustrate the way this works. The wiring harness supplier involved in the dashboard supply chain for Renault needed to confirm the details of the connectors required to connect the harness to the heating control system. Instead of communicating directly with the supplier of the heating control, they first contacted the first tier supplier responsible for the dashboard assembly. This supplier was unable to supply the information, because the VM had carried out all the negotiations with the heating control supplier. Instead of a direct 'horizontal' communication between the two suppliers of adjacent components, a much more complicated and indirect 'vertical' communication had to take place.

Looking at this issue across the sample of supply chains in the study, 8 supply chains had this 'modular' structure, where significant portions of the value addition is carried out by first tier supplier, and hence the opportunity for delegating the integration role exists. Out of the 8, only two showed evidence of direct communication externally to the VM. In the Fixed Reference Benchmark Model, this phenomenon is measured as the proportion of 'component to component interfaces' where direct communication takes place, relative to the total number of component to component interfaces.

This fact is interesting from the point of view of supply chain structure determinants. Using the same 8 supply chains, in which the structure is significantly different (the value addition is heavily skewed towards first tier supplier) the questionnaire data (see chapter 4) shows one of the dominant factors for choosing this structure to be the desire at the VM to reduce both logistics and product development complexity. The key way in which this might be achieved is delegating the orchestration of the supply of the complete system to the first tier supplier, and yet in practice this control, or orchestration function is often being carried out by the VM. Although VM executives state this as a desired output from the change in supply chain structure, in practice it doesn't often seem to be achieved. Rather, a fairly complex network of control, with the VM delegating some responsibilities, but retaining control of others, is often the result.

The questionnaire analysis also showed that suppliers would find it helpful to gain more control over both the choice, and the management of sub-suppliers.

A further convolution of the straightforward structure is seen when second level suppliers sell directly to the VM for some components, and via a first level 'integrator' for others.

Choice of second level suppliers and control of the relationship with second level was often found to be retained by the VM. As an example for door systems, when quality problems with the window glass were experienced by the first level supplier the VM had to be involved in the solution. The existing relationship was stronger between the VM and second level glass supplier than between first tier integrator and second level. Again a more complete set of analysis using the developed method should show up this phenomenon in a more rigorous way - measured by aspect three of tiering - 'direct horizontal collaboration'.

A further point of interest is the way in which the transition to the new structure in Europe is taking place. Tiering in the Japanese industry took place in the 1960s where the prime driving force was a period of rapid expansion of output volume and increase in product variety (Cusumano, 1989). At this time the involvement of suppliers acted to increase rapidly the capacity, and help to manage product variety. The formation of tiers could be said to be more by default than by design, as a result of outsourcing for cost reduction and greater integration.

In contrast the transition in Europe seems to be more evolutionary in nature. This may be affected by the fact that large capable suppliers already exist in Europe for most vehicle systems. Whatever the driver, this study shows a resulting highly un-focussed supply base with many suppliers capable of both direct and indirect supply, and both low and high levels of integration.

The following section presents the results, with commentary from some of the other Fixed Reference Benchmark Model elements. In this section, one supply chain in particular is featured (The Rover R17 coupe) and the detail of this chain is used as comparison for observations from other chains:

outsourcing

Results are shown in table 6.3 for the Rover R17 coupé door.

Aspect	Factor	Maximum	Actual
Manufacturing	Discrete component	70	65
	Assembly	30	15
Development	Discrete component	70	70
	Integration	30	10
		200	160
	Score for outsourcing		80

Table 6.3 Outsourcing - R17 coupé door

The outsourcing levels on the Rover R17 Coupé door are affected by a highly integrated door module supplied by Brose UK Ltd (Coventry) which combines window regulator, latch/central locking, wiring harness, glass channels, and glass - mounted on a common base plate. Hence the outsourcing level for 'assembly' and 'component to component integration' scores more highly than would have been the case for a traditional door method where the VM is responsible for integrating and assembling the discrete components.

Observations from other supply chains

The difference in level of outsourcing across different supply chains was found, in the main to be affected most heavily by the assembly and integration elements of the measure. This suggests that the set of discrete components which are manufactured and designed externally to the VM remains constant across the supply chains, but that some VMs are beginning to experiment with increased levels of integration.

The risks under consideration at the vehicle manufacturers are those of losing competitive product differentiation as more and more key systems are outsourced to suppliers who, typically, sell to several automotive customers.

The challenge for the VMs is perceived to be striking a judicious balance between a reluctance to go outside for core skills which might differentiate the product with subsequent loss of those skills (as they are given away to the supply base), and the economic cost of manufacturing, researching and developing the products in-house both now and as the technology advances in the future.

Systems purchasing

The Rover R17 coupé door has a level of systems purchasing such that 6 of the 16 constituent components were combined into the 'high level asembly (door module) supplied by Brose. Out of the remaining components, all were supplied individually for assembly at the VM. Similarly for development the higher level assembly at Brose represented delegation of 6 out of a possible 39 interfaces. Table 6.4 shows systems purchasing index for this supply chain.

Apsect	Factor	Maximum	Actual
Manufacturing	Ratio (m)	50	17
Development	Ratio (D)	50	8
	Score for systems purchasing		**25**

Table 6.4 Systems purchasing - R17 coupé door

Observations from other supply chains

1. Instrument panel - The most common level of integration for components in the study is the case of the facia moulding and exterior skin being combined with moulded plastic ventilation grilles, fixing and strengthening brackets. This again contrasts with the method adopted by Ford for an American model and the new Ford/VW multi purpose

vehicle (MPV) where the 'cockpit' is assembled and delivered as a unit combining facia, instruments, steering column, air bag, climate control and in-car entertainment.

2. ECU - In at least one case, all functions of the highest specification vehicle were included in one standardly configured ECU to cover the whole vehicle range, offering greater stability of schedule and less complex logistics, at the expense of some redundant functionality when the unit is used on lower specification vehicles.

The degree of implementation of systems purchasing is normally increased with each new model. The possibility of introducing the practice for components during the life of the model is greatly reduced.

Single sourcing

Sourcing policy for Rover R17 is to single source by part number. Rockwell are the preferred supplier for window regulators, and utilised for other part numbers on the R17 range except for the Coupé (the component studied) which was sourced from Brose. The Coupé requires a frameless door - a design with which Brose had had previous experience with Audi. From the scale set out in appendix 1, this supply chain gains 75% for this element.

A number of '*hybrid*' sourcing arrangements were identified. from the other supply chains. The VM in the study with the greatest level of global manufacture and sourcing describes three such sophistications. Components for a 'global car' were either:

(1) sourced from one supplier with a single production facility from which the parts were shipped around the world;
(2) sourced from a single commercial entity but from different manufacturing plants local to vehicle assembly; or,
(3) dual sourced with separate suppliers for European and North American production, but with a commonly developed set of tools and one set of component development work.

Other 'hybrid' sourcing arrangements exist where for example vehicle manufacturers operate 'development contracts' with a *lead supplier* developing the component and manufacturing a percentage of the production volume, the remainder being sourced from a different supplier using the same blueprint drawings and tool design as the primary source.

The following description of the Audi process, from published literature (Morgan, Cooke and Price) was found to be representative of current practice.

> "... In practice the new relationship with first tier suppliers will take the following form. At the concept phase Audi will consult with two or 3 potential suppliers, certainly no more because of the time and cost involved in evaluation. depending on the complexity of the module or system this conceptual phase could take up to six months. At the final design phase Audi will select just one of these to be its partner and a strict division of labour will be agreed so as not to engineer the work more than once. Once this stage has been reached Audi believes it is impossible to change the partner. However, to insure itself against any shortcomings on the part of its partner, Audi reserves the right to select a new partner at the production phase. In theory at least, the whole process is meant to involve a judicious balance of competition and co-operation."

Design and development delegation

The development of the door module for the Rover R17 coupé was weighted towards a high level of responsibility given to the supplier. Brose had developed a similar module for Audi, and hence some 90% of the development was carried out independent of the VM. The breakdown of factors for this supply chain is shown in table 6.5.

Apsects	Factor	Maximum	Actual
Percentage of development delegated.	90:10 split supplier to VM	45	43
Efficiency of work sharing	CAD compatibility	3	0
	Integration of product development teams	7	4
Point of first involvement	Ratio of project lead time to supplier involvement time.	45	36
Score for Design and development delegation			**83**

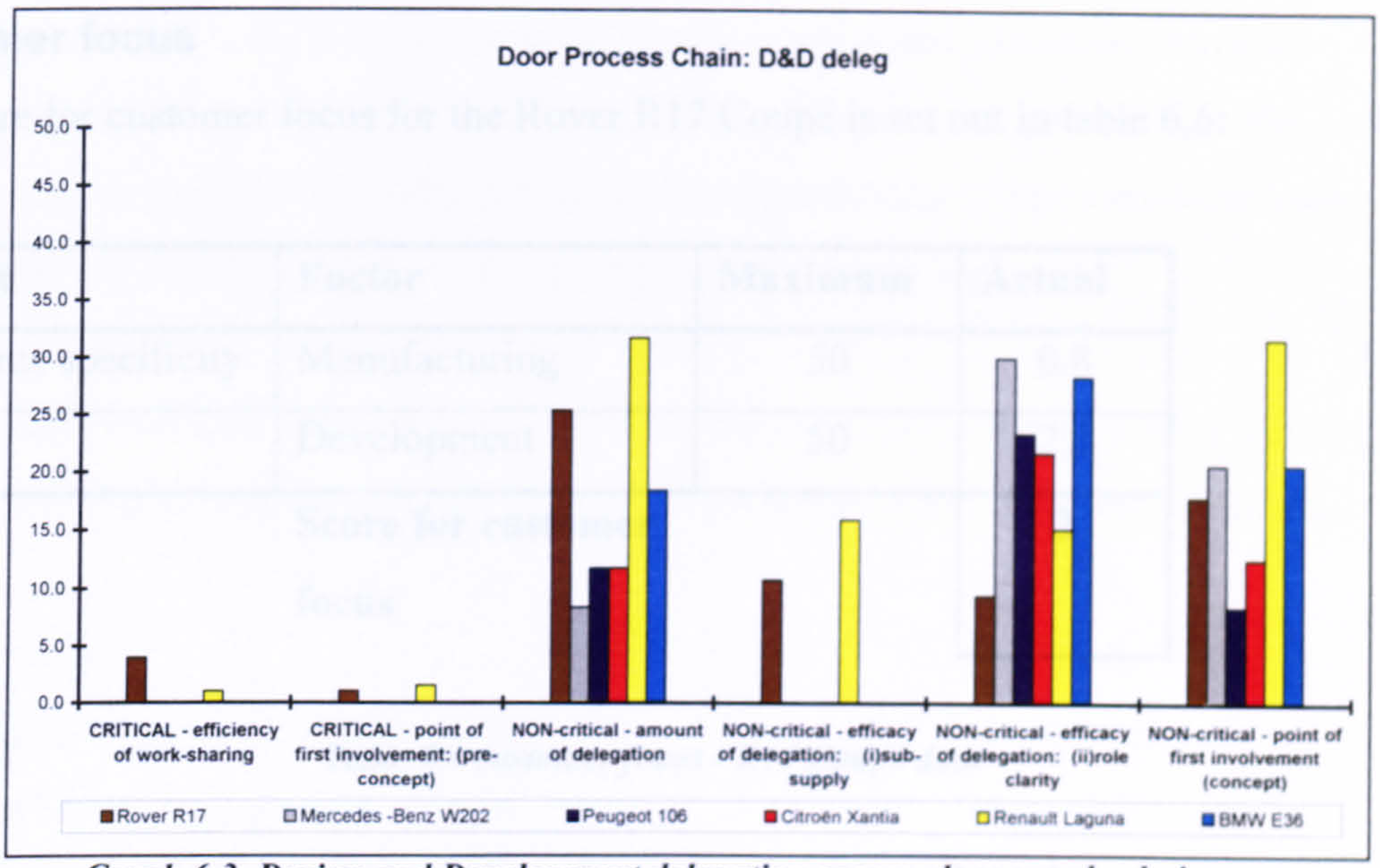
Table 6.5 design and development delegation - R17 coupé door

Observations from other supply chains

All the supply chains investigated are classified as supplying either classical 'black box' or 'grey box' components, probably by virtue of the components being key to the vehicle.

The extreme is represented by the ECU which is a classical black box component except in the case of two VMs, one of which retains design and manufacture in-house, the second has responsibility for design of the software with a close partner for hardware design and manufacture.

In one door supply chain, the supplier voiced a desire to be involved earlier in the process, in order to have the opportunity to enter into negotiation before the exterior lines of the vehicle are fixed. Because these affect the requirements of the window lift mechanism, slight changes, at the request of the supplier might allow optimisation of the mechanism design with consequent cost savings. In another supply chain the VM does allow such involvement and the feedback of the supplier at an early stage has on occasion led to minor modifications of the styling of the vehicle.



Graph 6.3. Design and Development delegation scores, door supply chains

The graph above reflects the fact that the door componentry is viewed by the VM as being non-critical. This correlates with a high propensity for outsourcing these parts.

Long term contracts

The norm for current purchasing policy at the VMs for which data has been analysed is for contracts covering the life of the model. An opt out clause for either party within the model life period is common.

The data in this instance is skewed by the age of the model for the component under study. Older models tend to have fixed length contracts for typically perhaps twelve months.

The exception to this policy would be based on common sense decisions on whether the component is key or commodity. For common items - fasteners and raw materials for example - the VM retains choice of several suppliers and shorter-term contracts. The change to longer-term contracts for the model life of the vehicle is more recent.

Customer focus

The score for customer focus for the Rover R17 Coupé is set out in table 6.6:

Aspect	Factor	Maximum	Actual
Resource specificity	Manufacturing	50	0.8
	Development	50	2.2
	Score for customer focus		**3**

Table 6.6 customer focus - R17 Coupé door

Here, the top end of the scale is set by a theoretical position of maximum resource specificity and a customer representing only 10% of the supplier's business. Hence the score achieved must be viewed against this, and a logarithmic scale would be appropriate on which to plot the supply chains under study.

For this element, analysis of further supply chains will include, for example satellite plants and customer specific development resources.

Open book costing

For the Rover R17 Coupé, full access to materials, labour overheads and profit is given by Brose to Rover. The two companies do not have compatible cost standards. Therefore the score here for the open book costing element is 80%.

Observations from other supply chains

It is true to say that most VMs insist on full cost data from the suppliers, especially in the case of key systems. At least one VM has a high profile cost reduction programme involving open tabling of cost information, aimed at reducing costs rather than the supplier's margin.

At some suppliers the request for full cost information is viewed as intrusive. Others feel that full account of one-off investments in capital is not given in a statement which concentrates on costs directly attributable to the product. In addition, whilst some areas of cost are seen as indisputable, others, such as the apportioning of overheads are not as precise and can lead to time consuming discussion to reach agreement.

For suppliers with many automotive customers the incompatibility of costing systems can cause additional processing in order to provide the information in the agreed format to the VM.

Mutual development

Rover R17 coupé are given in table 6.7:

Factor	Maximum	Actual
Schedule variability	12.5	8
Pallet control	12.5	8
Standardisation	12.5	0
Up front development funding	12.5	0
Late design changes	12.5	0
Early involvement	12.5	8
Late feedback on suggestions	12.5	3
Level of innovation	12.5	12
Score for Mutual Development		39

Table 6.7 Mutual development - R17 Coupé door

Observations from other supply chains

In the main supplier evaluation is carried out using audit processes developed by the VM to evaluate various aspects of the supplier's business. One feature of European component supply is that evaluation methods normally differ from VM to VM, both in terms of the evaluation criteria, data collection methods, and frequency of audit.

In Germany and in France, the federations of manufacturers of vehicle equipment, the VDA and the FIEV play a proactive role in for example engineering strategic alliances between suppliers, and facilitating joint agreements on the common Quality Audit system.

Results - Open systems

Rover R17 Coupé results are shown in table 6.8.

Information	Score (max)	Score (actual)
Planning Schedules	20	20
Delivery Schedules	20	20
Invoice submission	20	20
Invoice payment (EFT)	20	0
Purchase orders	20	0
Score for Open systems	**100**	**60**

Table 6.8 - Open systems -(ii) Rover R17 coupé

JIT deliveries

The basis for the measure of JIT would be a comparison of the optimal 'true JIT' pipeline stock level i.e. for ideal sequenced manufacture and delivery in-line with vehicle build, with actual pipeline inventory. This measure was not developed fully for this study, and the following is based on observation during field data gathering.

A distinction can be made here between 'JIT delivery' and true 'lean supply' which involves JIT manufacture and delivery throughout the supply chain.

The problem for the studied chains appears to be not so much achieving regular deliveries to the plant and to line-side, but more, achieving this without reliance on 'non-lean' buffer stock elsewhere in the supply chain.

It has been of particular interest to observe suppliers with contracts both to the Japanese transplant operations and the chains studied, who can perform markedly better for the Japanese, with less finished goods stock, in-process inventory and raw materials.

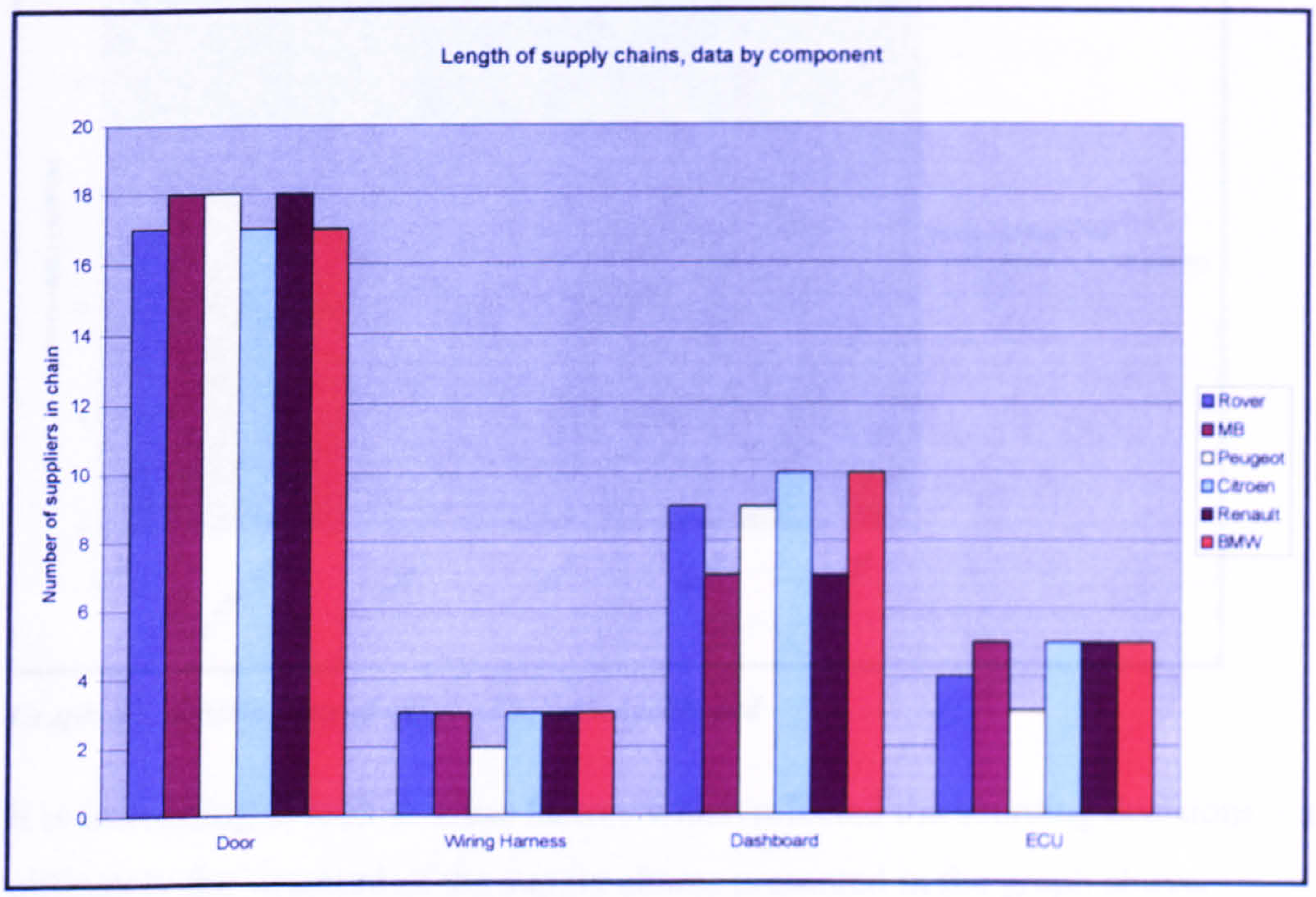
The phrase 'apparent JIT' was coined by Lamming (1993) to describe the western practice which relies too heavily on pipeline inventory to achieve JIT delivery to the vehicle assembly plant.

At this stage the cause for this is deduced to be schedule instability, with fluctuations both either in total volume or mix requirements, and late variation between actual and forecast delivery. Some supply chains were found to have fairly regular variations of as much as +/- 30% from planned delivery requirements with as little as two days notice to react to the change. The high variety of a particular component to cover a model range is also thought to be a contributory factor.

Most of the VMs profess a move towards a greater proportion of part numbers delivered in sequence Just-In-Time for final assembly.

6.4 Comparison of supply chain structures using hierarchical structure mapping.

It can be seen that the structure of the chains differs quite considerably, even within the same component group. The two measures of 'length' of supply chain, and 'distribution of value addition activities' are useful in the interpretation of these results. Taking the dashboard component group as an example, it can be seen that the 'shortest' supply chain has just 7 suppliers to carry out the generic set of value addition activities (32 in total), whilst the longest has 10 suppliers.



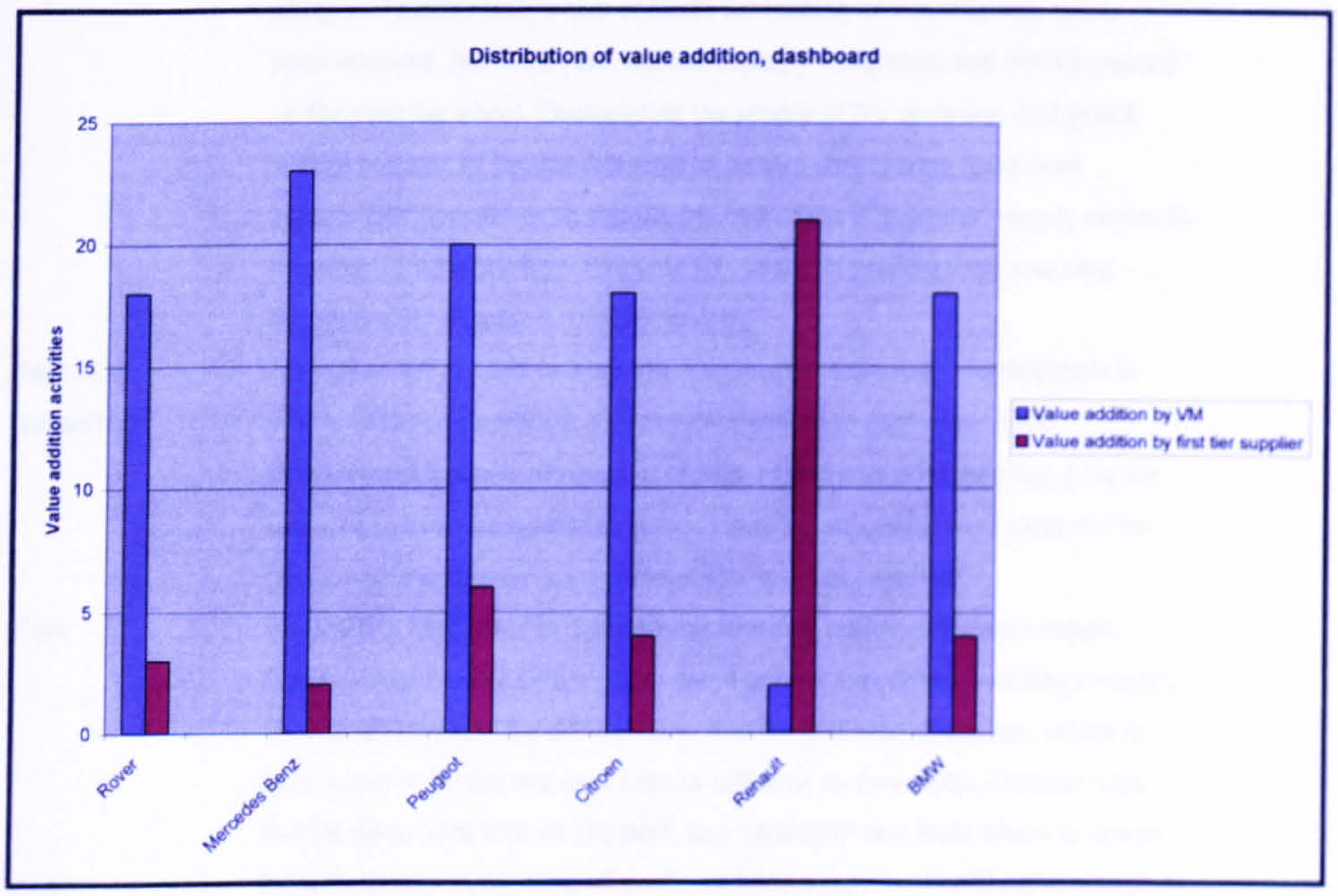
Graph 6.4. Length of supply chains, data by component.

When the 'tail' of the supply chain is included the structures of the supply chains look reasonably similar (this is evident from the Structure Maps presented earlier in this chapter). This however, hides some important inferences, and it is more useful to look at the value distribution amongst firms in the first and second tiers.

The distribution of activities can most usefully be measured between the Vehicle Manufacturer, and first tier supplier. In the shortest dashboard supply chain

(Renault/Sommer Alibert), 21 out of the 32 activities (0.65 of the value addition) is carried out by the tier 1 supplier, whilst only 2 activities (0.06 of the value addition) are taken care of by the VM. The differential between value added by VM and Tier 1 supplier is therefore 0.59, or 59% of the value.

Graph 6.5. below shows the differential in value addition between supply chains in the *dashboard* component group. It can be seen that the variation here is much greater.



Graph 6.5. Distribution of value addition - dashboard

It is interesting to look at some factors which affected the sourcing decisions – and ultimately the structure of the supply chains presented in the graph above.

Table 6.9 below lists possible factors which may have driven the supply chain towards one structure or another.

Factor	Comment
Production volume	In this case, the production volumes are within a similar range. The vehicles in the sample (apart from Rover R17 coupe) are all relatively high volume models, and the dashboard for R17 coupe is common with other R17 models – boosting the dashboard volume* Hence the factor of Volume is not significant for this component group. Production volume was not important in Renaults decision to adopt a modular approach.
Level of Technology	Outsourcing the assembly of the dashboard to avoid the VM having to keep abreast of rapidly evolving technology is another possible driver. However, in this case the assembly technology is neither complex, nor rapidly changing. One possible logic for the modular dashboard is the increasing use of integrated electronics, where controls for heating and ventilation, in-car entertainment, indicators etc. are increasingly integrated, and often mounted on the steering wheel. Outsourcing the supply of the complete dashboard system because of the combination of previously separate functional components appears to be significant. Out of the 8 'modular' supply chains in the study, 6 attached importance to this factor in making their sourcing decision. (See chapter 4 – questionnaire)
Pace of technology	As well as the level of technology, the pace of technology development is also considered important. Rover were inclined to ourtsource ECU development because the pace of change in this area of technology (due for example to new emissions legislation) made it unjustifiable to carry out in-house with the relatively low production volumes involved.
Cost	Evidently a key factor in determining sourcing policy, and hence supply structure is cost. Looking in more detail at how cost drives sourcing structure, we can see that it is the difference in cost for different structures, which in turn is driven by the true cost base in different sectors of the economy (see dualist discussion later in chpater), and 'strategic' cost base which is driven by such factors as the level of profit (or loss) a supplier is willing to accept on a product, the price that the end customer is prepared to pay for the convenience of outsourcing assembly tasks. This 'strategic' cost can be demonstrated to be driven by such factors as the relative bargaining power within the various possible trading relationships in the supply chain. Looking at the dashboard example, the Renault chain is vastly different from any of the others, being much more skewed towards the first tier supplier. Several cost factors are found to be at play in the determinastion of this sourcing structure. First, the wage gradient (governed by the difference in

* European Sales Volumes 1995 (Source Automotive News Europe)

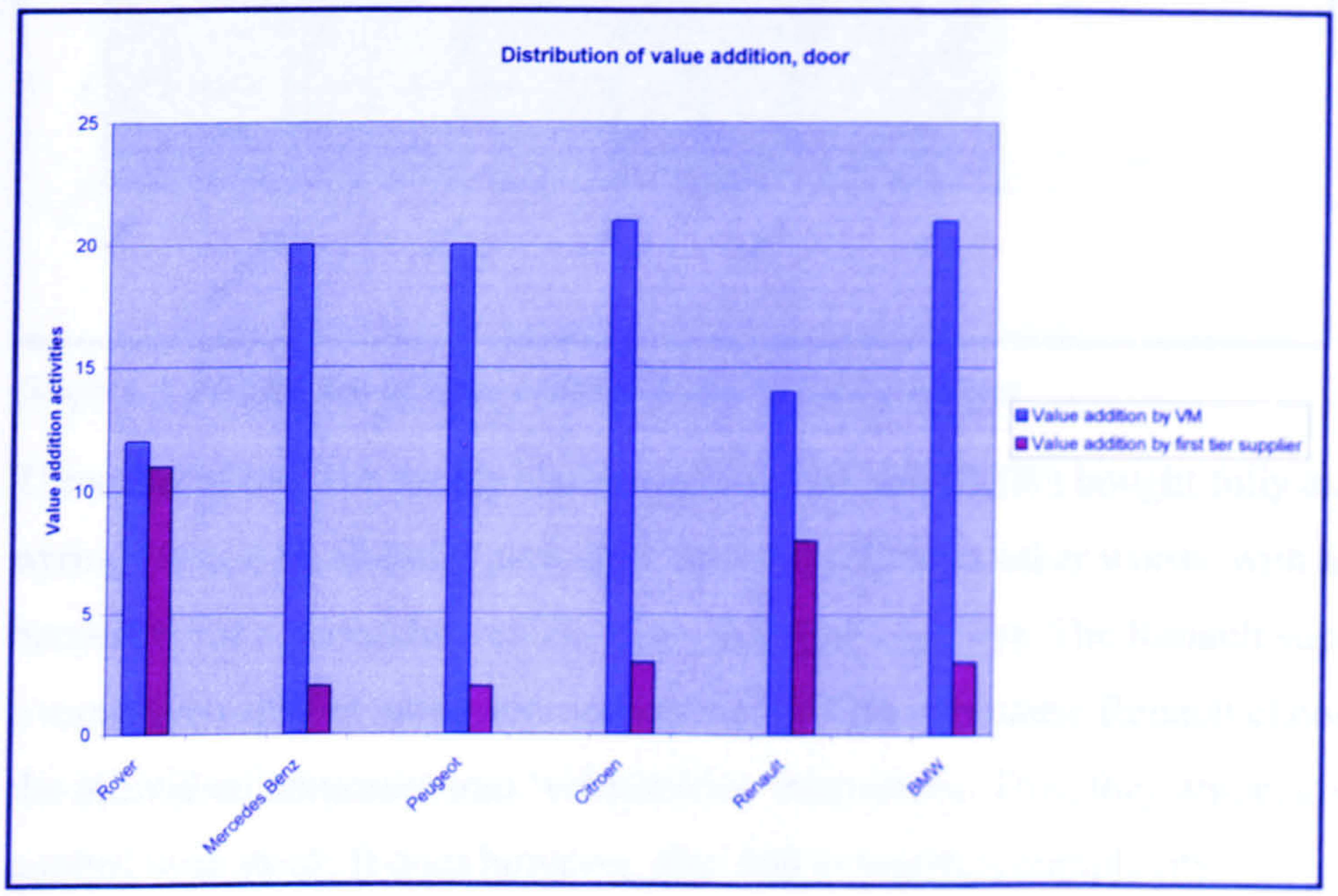
Model	Sales volume
Rover R17	52,000
BMW E36	190,000
Citroen Xantia	137,000
PSA 106	271,000
MB E-Class	170,000
Renault Laguna	156,000

	employment costs between different types of firms) is seen to be relatively steep in the French economy (Nichiguchi, 1990). Secondly the supplier was willing to accept a very small profit margin in order to 'break into' the 'fully assembled dashboard' market, and hence decided to offer a good price for this service. This also fitted with Renaults desire to simplify their logistics, and free up space beside the Laguna assembly line. Hence these factors came together to determine the supply structure.
Trust	Another key driver for outsourcing, discussed in Chapter 2 under 'Transaction Cost Economics' is the issue of Trust. It was felt that under conditions of little choice of supply, and resource specificity (specific resources dedicated to the component transaction) that a supplier would be apt to be 'opportunistic' in its pricing. Hence, under these conditions the transaction would be driven 'in-house'. In the dashboard example the 'transaction' is the pre-assembly of the dashboard. Many possible sources of supply exist for this transaction (Assembly is not specialised) It does require specific resources. As will be seen later in this chapter the notions behind Transaction Cost Economics can be challenged on the grounds of greater trust through partnership working and practices such as Open Book Costing.
Lack of space	The desire to save space in an existing assembly plant, either because greater volumes are being sought, or because the new vehicle needs more space, can drive the sourcing decision towards greater amounts of value being outsourced. In the dashboard case, questionnaire analysis showed this not to be a significant factor, except in the case of Renault.
Lack of facilities	Another driver might be lack of facilities. This is particularly strong where the manufacturing process is particularly novel or specialised. This factor was not significant in the dashboard case.
Lack of capacity	Again this factor was not significant for dashboards.
Reduction in management complexity	Tis was seen to be a key factor for Renault, who wished to reduce the complexity of their logistics. The target was 20% reduction in part count with each successive new model introcution. Clearly modular supply chains is a good way to achieve this.
Reduction in risk	This featured highly in all the outsourcing decisions. The VM desired to close off, or increase supply of components at short notice, and with little financial penalty.

Table 6.9. Main determinants of supply chain structure - dashboard

The table above summarises the main determinants of supply chain structure, of relevance in the dashboard case studies, and explains their significance with respect to the structures encountered in this research.

Considering the DOOR components, many of the factors apply in the same way. Both the Rover and Renault doors are modular. Graph 6.6 below indicates a much more even split of value addition in these two than the other supply chains in the study. It can be seen, however that the difference is not as extreme as with the dashboard. Vehicle manufacturers have not yet reached the extreme of purchasing a complete door from suppiers, ready for assembly to the vehicle. (Although it is known that for at least one vehicle, outside of this study, produced by Mazda in Japan, this has been tried (Boston Consulting Group, 1994)



Graph 6.6 Distribution of value addition – door supply chains

Considering graph 6.6, the main difference in sourcing structure between the wiring harness supply chains is brought about because the PSA wiring harnesses are assembled in-house. Although this doesn't add too much to the argument for supply chain determinants, it is interesting to note that PSA justify this strategy purely on a cost basis, and that discussions are underway for a new vehicle to buy harnesses from suppliers. The other interesting point for harnesses is that in the future, Multiplexing, and Vehicle Network technology is likely to supercedes the traditional wiring harness. The determinants suggested in this thesis would indicate again that the value addition for

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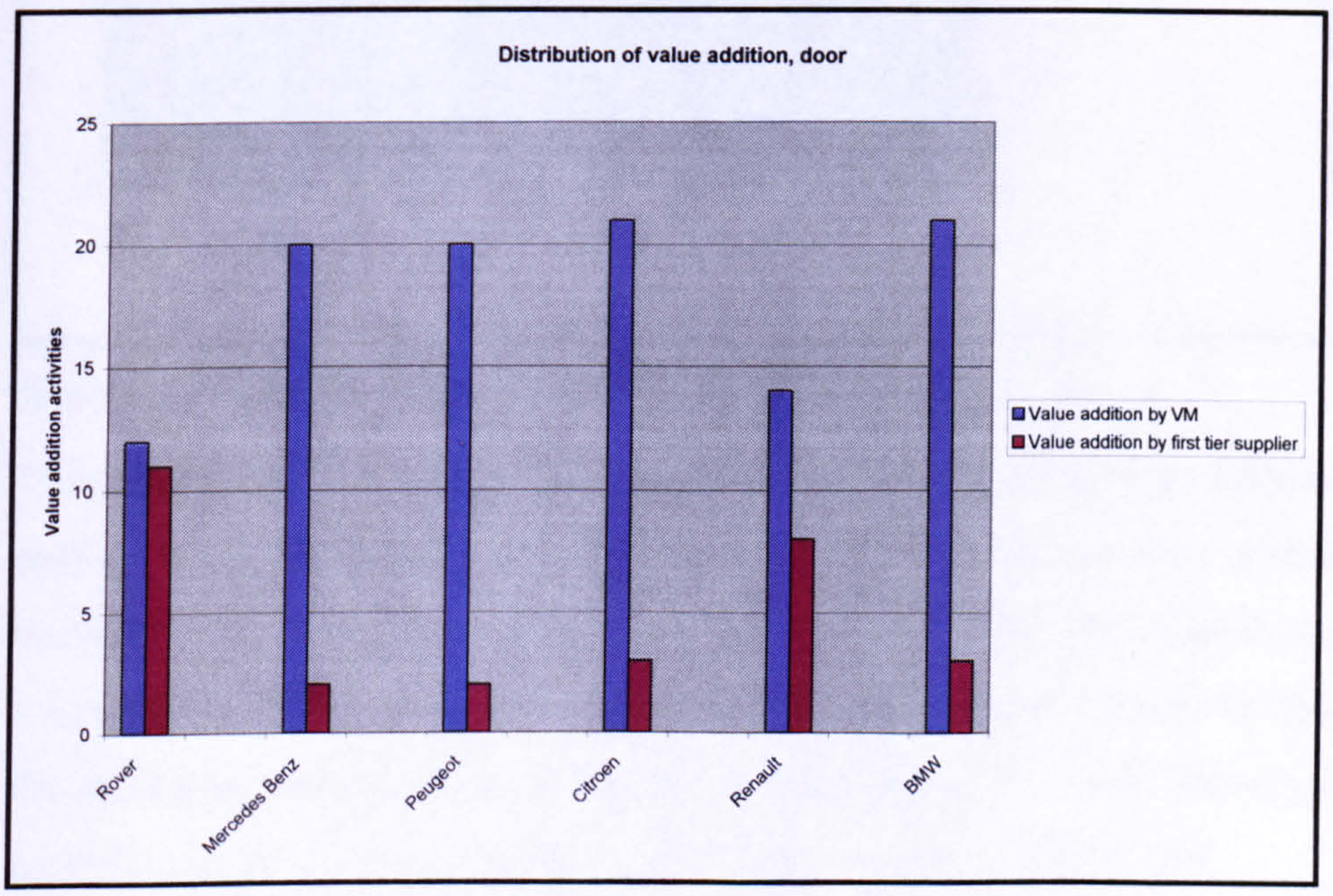

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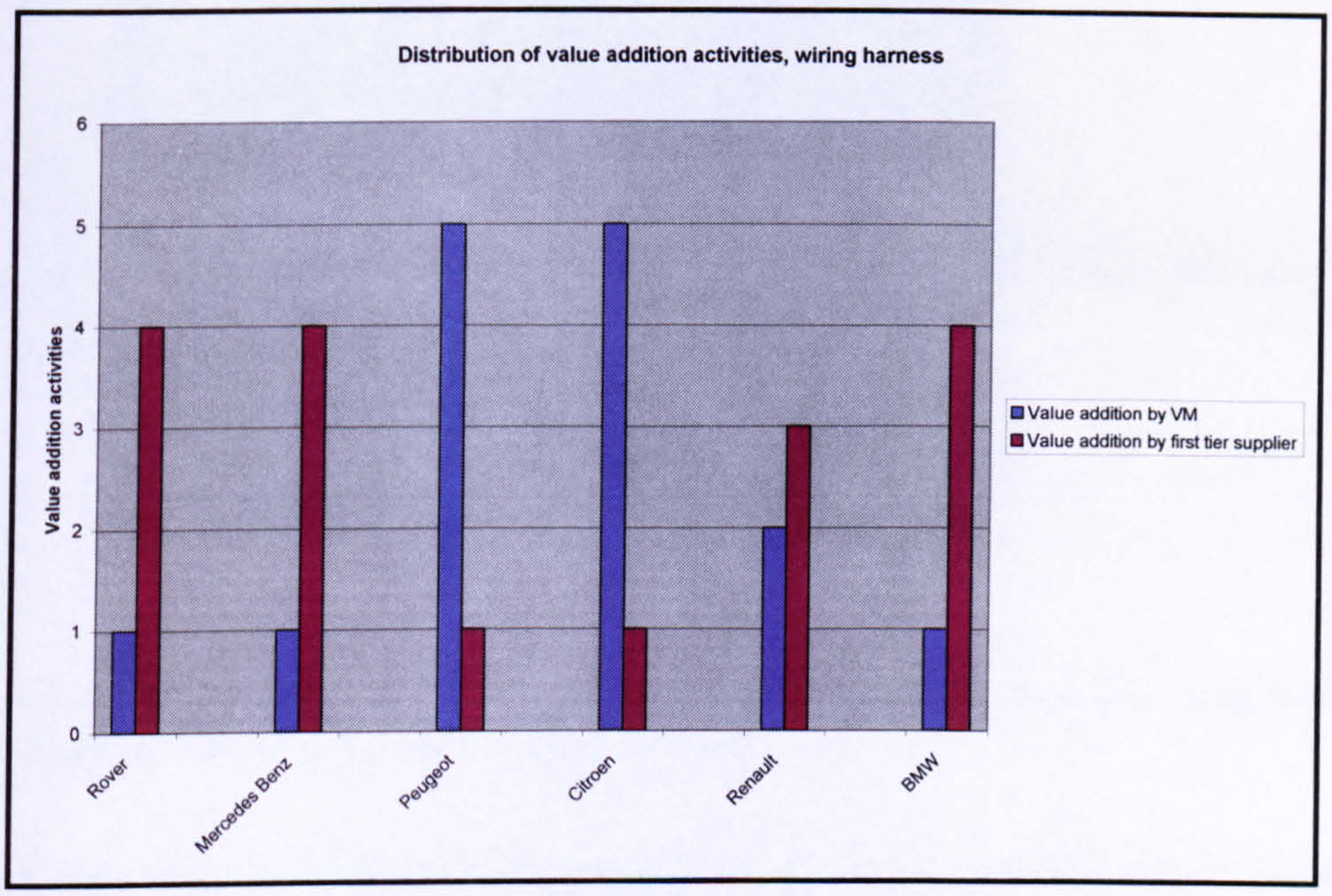
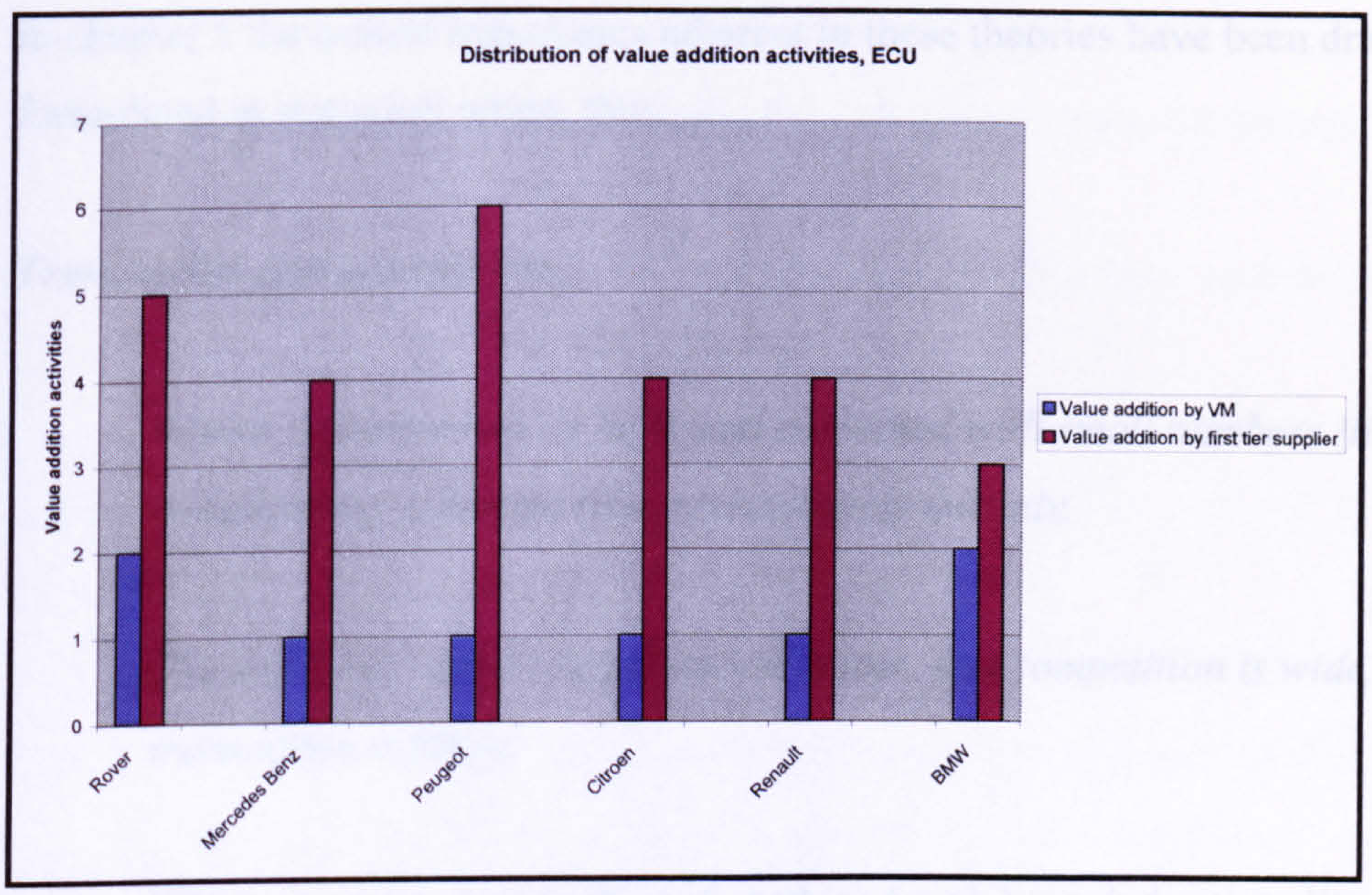


Graph 6.7. Distribution of value addition activities, wiring harness

Three out of the five supply chains (Rover, MB and BMW) bought fully assembled wiring harnesses, already 'packaged' as vehicle kits (in other words, with all the right harnesses for a particular vehicle type packaged together). The Renault supply chain has a more even split of value addition activities. This is because Renault choose to configure the individual harnesses into 'vehicle kits' themselves. This, they argue, gives them more control over stock. It does however, also add to logistics complexity.



Graph 6.8. Distribution of value addition - ECU

Value addition distribution in the ECU supply chains differed only in degree. All chains were dominated by the first tier supplier. The main determinant here is the level and pace of technology. Very few vehicle manufacturers – on their own – could justify the investment in R and D to keep at the forefront of electronic vehicle control.

A summary discussion of the determinants, relating them to the actual structures mapped in this study appears in the next chapter.

6.5 *Validation of hypotheses 'Actual structure Vs theory'.*

In chapter 2, the existing theory was reviewed, and the following areas have been found to be most applicable:

> **'Transaction Cost Economics' (Coase, 1937; Williamson, 1975 and 1985) 'Trust and Cultural Perspectives' (Dore, 1987; Sako, 1992), 'Business Strategy Management' (Porter, 1985), 'Network theory' (Jarillo, 1993; Johanson and Mattsson, 1987) and 'Dualism' (Berger and Piore, 1980; Edwards, 1979).**

In chapter 5 the central hypotheses inherent in these theories have been drawn out and formulated in statistical terms, thus:

Transaction cost economics:

> *Where 'opportunism' is high, and combined with small numbers (little competition), a market type transaction is unlikely.*
>
> *The converse – where opportunism is low, and competition is wide, a market transaction is likely.*
>
> *Where uncertainty is high, and combined with bounded rationality, a market transaction is unlikely.*
>
> *The converse – where uncertainty is low, and combined with bounded rationality, a market transaction is likely.*

Network theory:

> *The distribution of value addition activities amongst firms in a supply chain is determined more by the individual interactions of 'close neighbours' in the supply chain than it is by planned reviews of external economic, social and technological climate.*

Dualist theory:

> *Variations in cost between different economic actors in the European Industry drive the structure of supply chains to take one form or another.*

In order for the validity of these hypotheses to be tested they must be stated in statistical terms:

Transaction cost economics

Taking the above hypothesis, and stating it in statistical terms, the emerges:

> *There is a negative correlation between asset specificity combined with small numbers, and market transactions.*

Network theory:

In statistical terms, the hypothesis becomes:

> *The most significant influence on decisions made which affect the structure of the chain result from interaction with actors from close neighbours in the chain.*

Dualist theory:

One of the key variables which define the dual economy described in this theory is the cost of employment, whose difference between actors can be measured with reference to publicly available figures for Wage Gradient (Nishiguchi, 1993) Wage gradient defines the level of difference in wage costs between – for example large and small firms.

The dualist hypothesis, tested in this thesis can be stated in statistical terms thus:

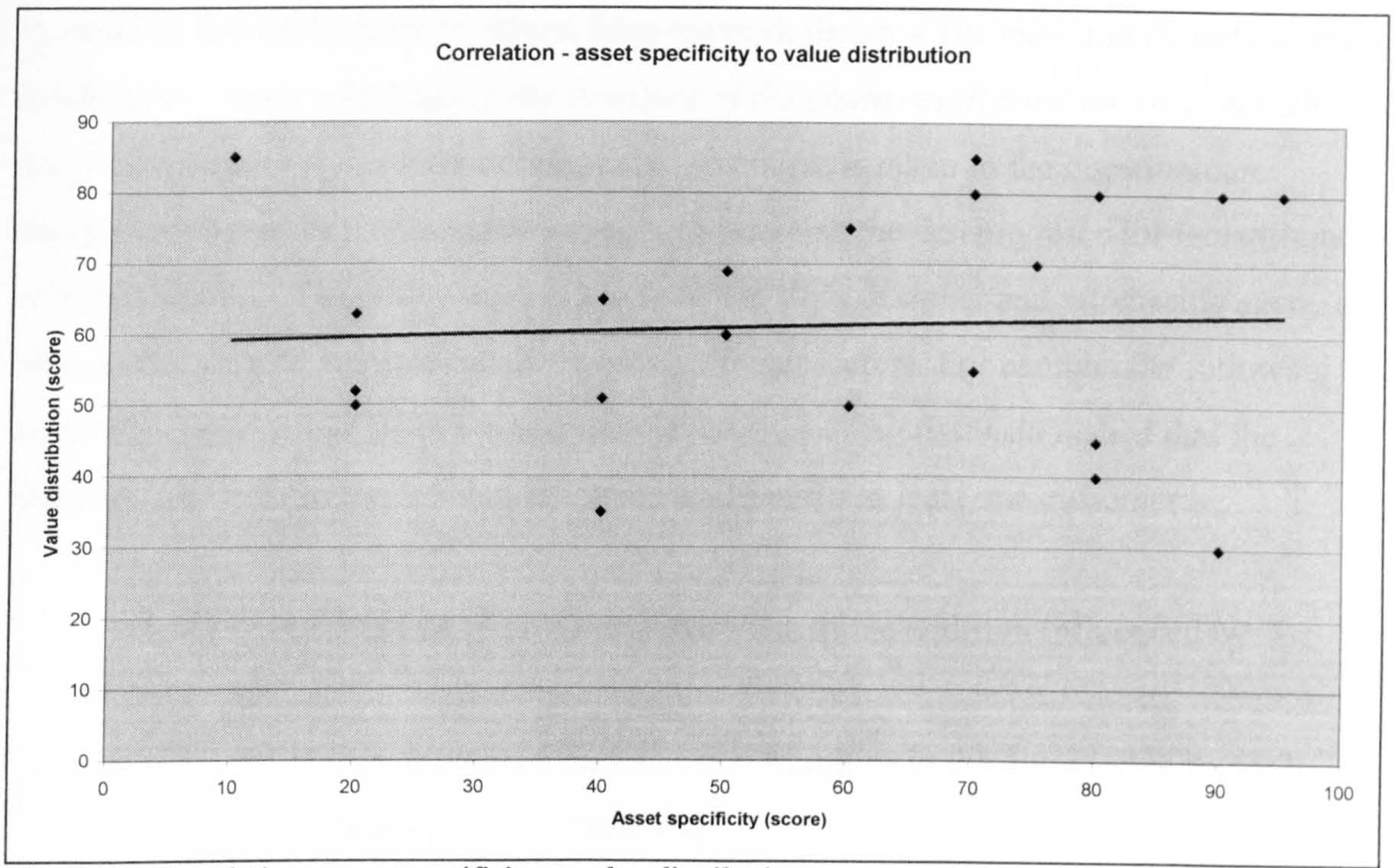
> *There is a positive correlation between wage gradient, and dispersal of value addition activities into the supply chain.*

6.4.1 Hypothesis testing

Transaction Cost Economics

In order to test the Transaction Cost Theory hypothesis it is neccesary to place definitions on the variables in the calculation. The measure of asset specificity already described in the formulation of the Fixed Reference Benchmark Model (see section 5.2.7 – CUSTOMER FOCUS) is used, where the manufacturing and design processes are assessed for the specificity of resources required in their execution.

This is then graphed against the OUTSOUCING benchmark score, which measures the percentage of the product put out to the market. In this way the first hypothesis can be tested.



Graph 6.9 Correlation – asset specificity to value distribution

Once the individual supply chain scores are plotted, a linear trendline can be added to indicate any correlation. In this case calculating the least squares fit for a line represented by the following equation plots a linear trendline:

$$Y = mx + b$$

where m is the slope and b is the intercept.

As can be seen from the plot, there is a clear trend, but showing a *positive* correlation between asset specificity and value distribution to the supply chain. This supports the earlier observation that the VM, in many cases, seeks to outsource those parts of value addition where risk and uncertainty is high.

For the 24 automotive supply chains under question, the first hypothesis drawn from Transaction Cost Economics is therefore rejected.

Network theory

In order to test the hypothesis drawn from network theory - *The most significant influence on decisions made which affect the structure of the chain result from interaction with actors from close neighbours in the chain.* – recourse is taken to the questionnaire analysis where one set of questions sought to establish the driving force for redistribution of value addition. Questions were put to both the VMs designer and purchasing agent, as well as the supplier to establish the most significant factors. For eample, the following question related to the suppliers commercial agent, having first established that the supplier has changed the level of his value addition for at least one customer:

Q. Was your practice of providing more/less value addition influenced by:

i) Your own review of business opportunities in the automotive sector? (marginally - heavily)

ii) Direct request from your customer? (marginally - heavily)

iii) Because you see it as a way of increasing your turnover? (marginally - heavily)

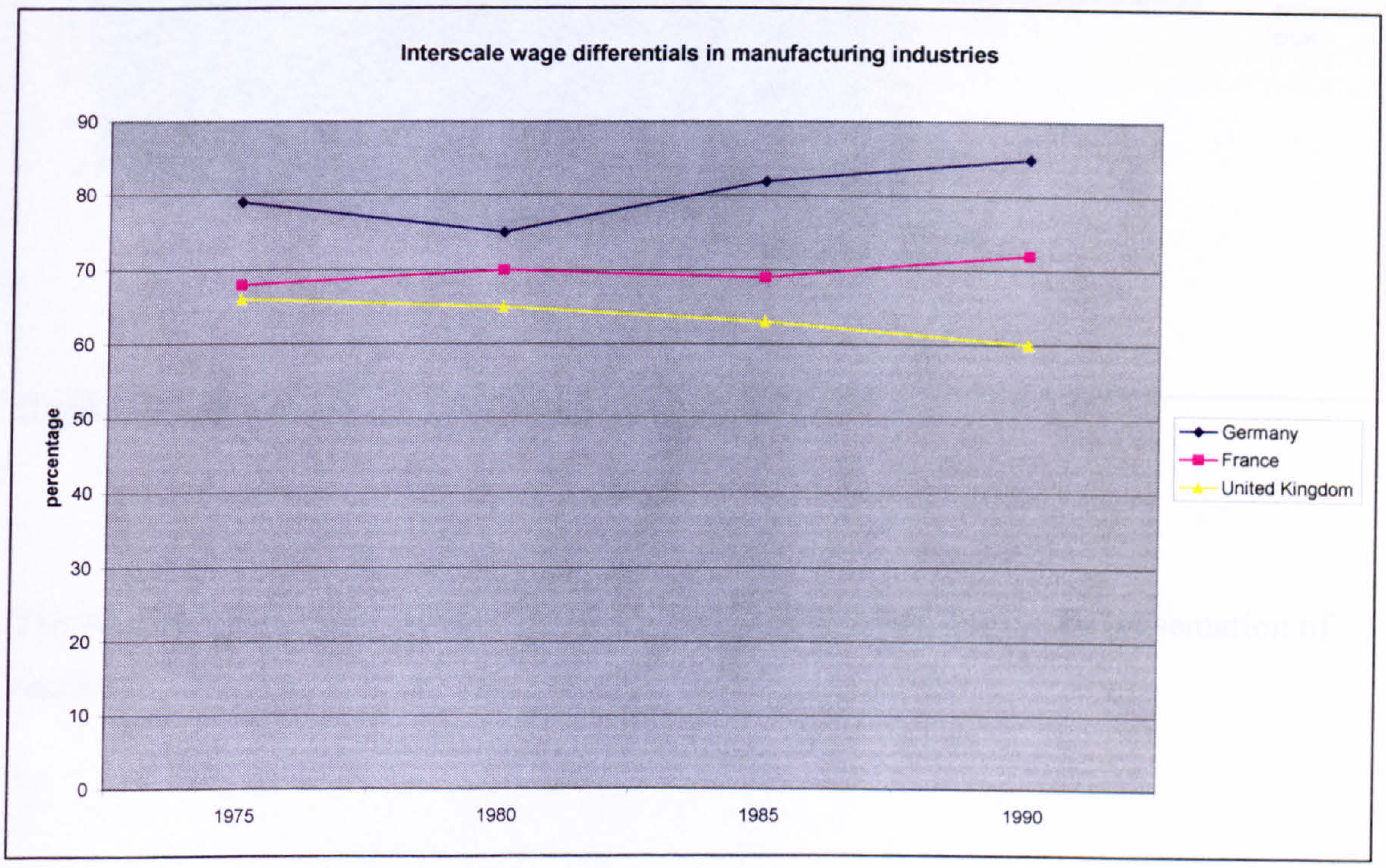
iv) In discussion with the purchasing agent from the VM customer? (marginally - heavily)

Similar questions were asked at the customer, and together, the responses can be analysed to generate the most significant factors influencing re-distribution of value addition.

In this case, 19 out of the 24 supply chains (79%) were found to have the most significant factor as "Direct communication with customer/supplier". Hence for the supply chains tested, the 'Network theory' hypothesis is accepted.

Dualism

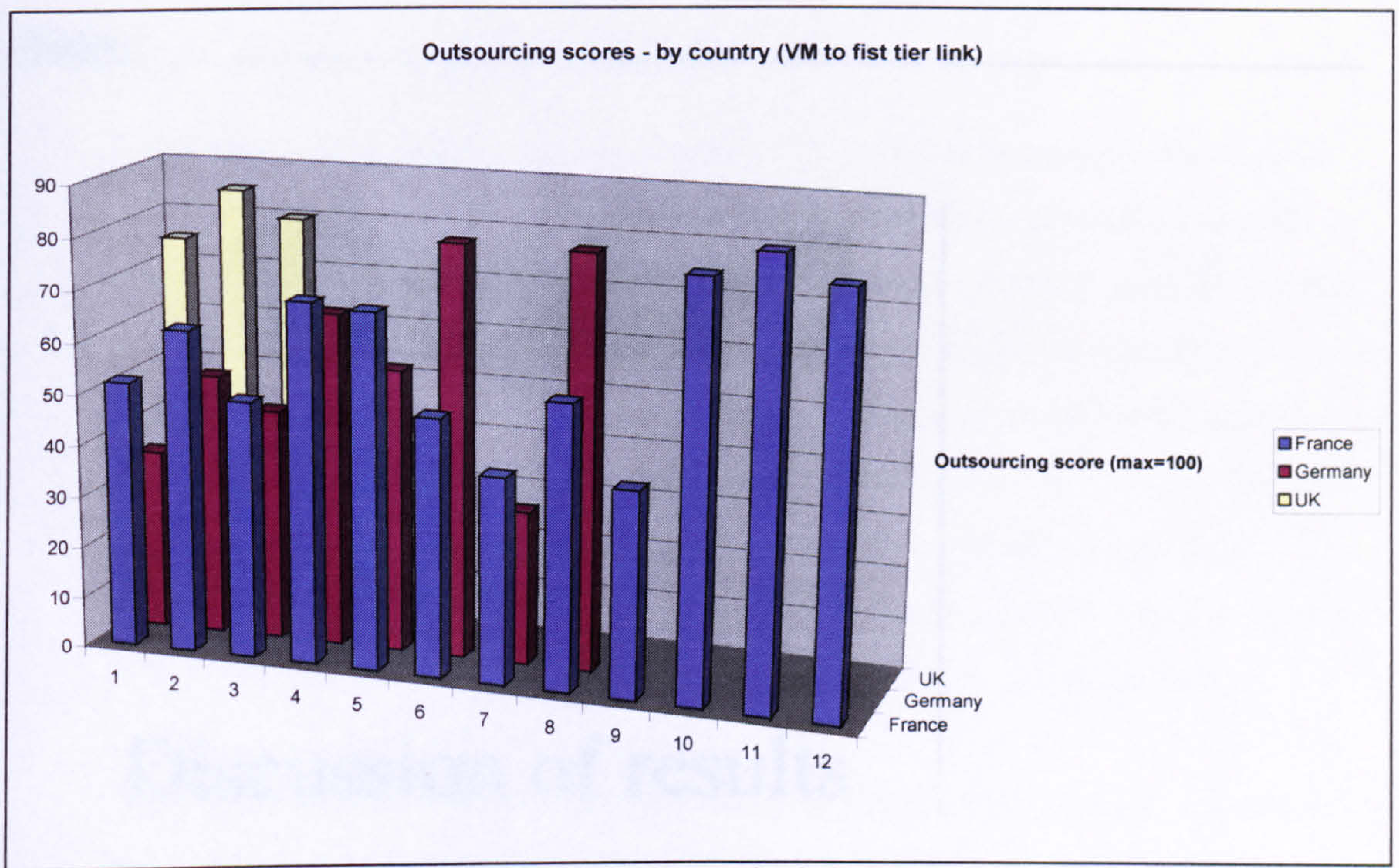
In testing the dualism hypothesis, recourse is taken to publicly available data on wage gradient. As can be seen from the table, wage gradients are seen to be significantly lower in Germany than in both the UK and France. This relates to positively to the levels of outsourcing in the respective countries, showing that the higher the wage gradient, the higher the level of outsourcing. Therefore, the dualist hypothesis is also accepted.



Graph 6.10 Interscale wage differentials in manufacturing industries

Source: EC statistics report – Basic Statistical Research on Wage Structure

Note – percentages refer to the average regular salary for males at firms with 50-150 employees as opposed to the same at firms with 1000 or more employees.



Graph 6.11 – Outsourcing scores by country for 24 supply chains

The next chapter brings together the discussion points raised during the presentation of results.

Chapter 7

Discussion of results

- The first part of this chapter undertakes some general discussion of points raised by the Fixed Reference Benchmark Model analysis, and the use of the structure maps. This is aimed at drawing out factors that consistently affect the structure of the chains. Next the question of existing theory, and how this relates to the results is discussed. The method used will be discussed, indicating particular points that are felt to be unique. Finally, a comparison with the original objectives of the thesis, and recommendations for further work will is made.

7.1 Discussion of results from the phantom benchmark exercise

7.1.1 Tiered supply base

Evidence from the supply chains in the study shows there to be an emergence of tiering. The evolution is in its early stages. The current situation is characterised by predominantly direct suppliers of components. Re-positioning is taking place with some suppliers becoming 'system integrator' or 'first tier', buying components from other suppliers who previously sold directly to the VM. Most VMs and suppliers are in the 'transition phase'.

What is emerging in Europe is a structure with some differences to the Japanese model. For example one of the suppliers of door latches is currently a 'second tier' or indirect supplier for one model, and yet supplies direct to the VM for other models. A supplier of window winding mechanisms supplies individual components for some customers, and door modules or 'systems' for others. It is unclear at the moment whether these type of differences are as a result of the early stage in the change to tiering, or whether they will be a lasting feature of the European structure. This situation is indicated in the Fixed Reference Benchmark Model by low scores for the 'demarcation aspect' of Tiered Supply Base.

One feature which will probably be a lasting difference for Europe in the medium term is the 'sharing' of first tier 'key players' for major components, between VMs. One of the trends in Europe is the rationalisation of suppliers. The eventual outcome, as predicted by the BCG report (Boston consulting Group, 1994), is 2-6 key players for each component group. The implication for VMs is that for systems such as fuel, electronic control, brakes etc. the chosen supplier will also supply many of its competitors. This is quite different from the Japanese structure which favours 'dedicated' suppliers of key systems, with cross share holding. The phanotm benchmark model allows recognition of this phenomenon via the 'dedication aspect' of the element score.

In summary, the emerging structure contains differences as compared to the Japanese model. Some of these differences appear to be 'here to stay'. Others may be a function of the transition phase.

With respect to the central area of concern of the study – the drivers or determinants of supply chain structure, the results show several factors to be at play. First there are the factors driving the 'low' scores in the 'dedication aspect'. These are driven mainly by the fact that most European suppliers maintain contracts with between 6 and 13 Vehicle Manufacturer customers. This in turn is driven by the historical make-up of the industry which in the past saw national producers supporting national markets, resulting in the far more vehicle producers, each with smaller volumes, than say North America whose market is dominated by 'the big three' – General Motors, Ford and Chrysler. This situation in Europe is rapidly changing, with mergers and take-over reducing the number of customers in the market and hence increasing the volume per producer. The affect on the number of customers per supplier has also seen a reduction. A quick recalculation of the 'dedication aspect' for the BMW E36 door supply chain, for the 'dedication' aspect shows the score to have increased from 9 (out of total of 25) to 16, because of the reduction in main auto customers supplied by Brose, the first tier supplier. Brose now supply less part numbers, but with a higher volume per part number.

The second factor which is concerned primarily with the 'demarcation aspect' of the score is the fact that in many areas of their operations, vehicle manufacturers are seeking to reduce risk and complexity. For operations in which ***the process technology is relatively non-technical*** (such as the pre-assembly of dashboards, or car doors, or seats), transposing the operation from the Vehicle manufacturers factory to the supplier is low risk, it removes the burden of volume flexibility from the vehicle manufacturer, and it is an operation to which the supplier can easily adapt. In many cases the cost is the same if not less for the VM and a great deal of risk, as well as logistics complexity is removed from the operation. An important enabler in this respect is the availability of suppliers both willing and able to take on the new 'integrator' role. In the European industry competition amongst suppliers is fierce, capacity exceeds demand, and this also drives suppliers to adapt and change to new roles in the supply chain, adding more or less value to their components as the vehicle manufacturer requests.

The situation for components where either the product or process technology is ***complex,*** where either the level or pace of development is high, is rather different. In the present study, the ECU supply chains fit into this category. Here, the supplier has more power, and to some extent it is they who dictate the distribution of value addition in the chain. For example, both Bosch and Siemens supply a 'black box' package. The reason given for Motorola sharing the development of the Rover ECU – supplying a so-called 'grey box' component was because at the time they were seeking to break into the automotive electronics sector, and Rover were a willing partner.

In conclusion, the move towards tiering in the supply base is being driven by the reduction in automotive customers (and suppliers) through merger and take-over, and the desire at the VM to delegate complexity and risk. The move is checked in instances where the supplier asseverates higher levels of bargaining power in the relationship, usually through knowledge of specialist automotive electronics technology.

7.1.2. Outsourcing

Evidence from the study indicates the trend to be moving towards more outsourcing and more focus on core activities. The move towards outsourcing 'systems' is likely to have the greatest effect on the redistribution of value addition in the supply chain.

7.1.3. Single sourcing

Evidence from the study indicates that most Vms are pursuing a policy of moving towards single sourcing across individual model ranges.

Similarly to the way in which mergers and takeovers are reducing the number of customer contracts held at suppliers, and increasing the volume of each contract, the move towards single sourcing is achieving the same result.

In a different way, it is also allowing the VM and supplier to invest more time in the relationship inherent in each contract. This is evidenced by the positive correlation in the research between single-sourcing and a high score for DESIGN and DEVELOPMENT DELEGATION. The main influence on this high scorre is the 'meshing index', a measure of the effort put into joint working.

A significant minority of Vms maintain multiple sourcing, either of identical components, or for left hand drive and right hand drive variants, and front and rear bumpers, and left and right door mirrors.

The reasons for dual sourcing were given as; extra price leverage, insurance against interruption of supply, and historical allegiances from pre-merger supply.

One comment from a supplier of door components sumarises some of the arguments foro single sourcing:

"If we were confident of supplying the total volume of the part it would be easier to justify investing in dedicated facilities and even co-location"...

7.1.4 Systems purchasing

This practice is becoming more common, as evidenced by the more recent product offerings from Rover, Renault and BMW, where the concept is being used for example on door components. In this example, rather than buying the window regulator, handles, locks and bracketry separately - manufacturers have chosen to source a 'door cassette' combining many of the components.

Based on the supply chains studied, the evidence shows a gradual up-take of the systems concept.

Speed of implementation seems to be governed by factors both at the VM and supplier. Vehicle manufacturers are considering the feasibility and justification for introducing the concept across a wider spectrum of components on the next generation models. The implications for vehicle manufacturers, on the down side, are a loss of systems skills to the supplier and all the knock on effects of running down their own engineeering resource. They also face the risk of 'hollowing out' the vehicle or loosing knowledge of all but the basic architecture of the vehicle and its sub-systems. Differentiation through product alone is seen as a marketing strategy which is more difficult to use with so much of the vehicle outsourced. On the 'up-side'of the equation, vehicle manufacturers stand to gain the benefits of cost reduction through running down their own resource for design and assembly of the systems and also the task of managing the logistics. Benefits here can be traced back to economies due to focus and because of generally lower costs at suppliers.

For the suppliers the implications again are wide. On the one hand an opportunity exists to expand the business to take on more of the design and manufacture of the vehicle. On the other hand this requires a build up of engineering resource, design asssembly and supply chain management capabilities. It also requires taking over the relationship of suppliers who traditionally supplied to the VM. There is a distinct difference for such suppliers, requiring investment in people and technology. Our research suggests that margins are no higher on 'systems' than 'individual components'. Systems capability is becoming a qualifying criteria for suppliers, at the behest of the VMs.

Evidence from the study shows that some suppliers are running two separate systems to cope with individual components for older models and systems for current and future vehicles. Another feature of the 'transition' is the retention of choice of second tier suppliers on the part of the VM. This has caused problems, for example when 'first tier' experience quality problems, they need to involve the VM to solve such problems because of the traditional relationship.

In summary, systems supply is being increasingly used. The speed of take up is affected mainly by the VM who currently hold most of the engineering resource for the design and assembly of such systems. This is changing, and the onus seems to be on the supplier to build up capability independent of the VM.

7.1.5 Summary of phantom benchmark discussion

In summary, the Phantom Benchmark Analysis has shown that:

- There *are* differences in both structure and relationship management in supply chains at partner companies in the project. There are significant changes taking place with each successive new model. These changes are more marked in certain supply chains, with individual practices receiving more or less emphasis at the individual companies. The speed of change is primarily governed by the VM, especially in supply chains where the level or pace of technology is relatively low.

- To bring about a tiered structure with systems supply, there remains a considerable requirement for redistribution of capabilities amongst partners in the supply chains.

- Suppliers are becoming proactive in *gaining* the capabilities for systems supply but our findings show that the development is normally carried out independantly from the vehicle manufacturers, who are the current holders of the required capability.

- Strategic confidentiality, partnership development, and product differentiation are found to be affected by a supply industry *structure* characterised by 'first line' suppliers of major vehicle systems selling to 'multi-customer' bases.

- Relationships between organisations in the supply chain were found to fall short of true partnerships - there are constraining factors, both cultural and technical in nature, which restrict progress towards co-operative relationships.

- The tiering structure emerging in the European industry is different in one important respect, to the structure in Japan. First tier suppliers, rather than being dedicated primarily to one customer (as is the case for example with

Toyota and Nippon Denso for Electronic Control Units) in Europe supply to a range of automotive customers. This makes the important requirements of trust, strategic partnership and joint planning more difficult to achieve. Component rationalisation would remove in part this barrier. Rationalisation, mergers and collaborations amongst VMs would also allow supply structures closer to the Keiretsus of Japan. This study supports the view that the Keiretsu structure is important for the Virtual Enterprise.

7.2 Discussion of theoretical comparison with case study supply chains

- Network theory helps to explain the way in which structures evolve – driven primarily by management decisions taken by a relatively small number of actors in the links of the supply chain.

- Transaction cost theory is found to be useful in part, explaining the importance of bargaining power in the distribution of value addition in the chain, and helping to explain the emergence of a very strong 'Tier 1', and latterly 'Tier 0.5' (Lewis and Wright 1999) in the automotive sector.

- Transaction cost theory does not fully account for 'win-win', or 'partnership' supply situations, characterised by joint working and mutual trust. Through consideration of the 'certainty of business retention' – a measure of trust in the relationship, the study highlighted instances where nominal partnership relationships belied a more honest assessment of the working practice, where opportunism and *lack of trust* were the dominant behaviour traits. The supply chains observed did not support the assumptions implicit in Williamsonian Transaction Cost Theory.

- Transaction cost no longer covers all possibilities – there exists a much wider and more sophisticated range of working practices where both suppliers and VMs roles are more blurred.

- Practices such as 'Open Book Costing' remove the Transaction Cost Economic logic for keeping transactions with high asset specificity, or the situation of low numbers of qualified potential suppliers in-house.

- The Porter 'Business Strategy Management' theory was found to be useful in explaining the emergence of the strong Tier 1 layer in the structure of the supply chains. However, it was found that the actual mechanics of 'determining' or 'driving' the structure towards a particular form or another was much more due to the individual decision making of actors in the chain, based primarily on cost, reduction of risk, and relative bargaining power.

- The Porter 'Business Strategy Management' theory was also found to be useful in explaining the level of mergers and take-overs occurring in the industry.

- The structures were found to vary most greatly in the region of the VM to first tier 'links' in the chain. Value addition was found to be distributed quite differently in these layers, between the supply chains in the sample.

- The positive correlation between wage gradients, and higher levels of outsourcing shows that the dualist hypothesis is found to be significant in the European Automotive industry. In Germany, for example, it is not as advantageous to outcource assembly, as it is in the UK or France. Wage gradients are steeper in these two countries, and this correlates positively with greater levels of value dispersed into the supply base.

- The dominant factors in determining the structure were found to be: Criticality of component (which in turn affects the acceptability of risk), the level, and pace of development of technology for the component or system of the supply chain (which is strongly linked to bargaining power), the desire to reduce the complexity of logistics (which is also linked to acceptability of risk), the desire to reduce the cost of demand fluctuations, and the capital intensity of the production process.

- Novel forms of partnership which transcend the traditional dyadic relationships were found to exist, however it has not been possible to affect a direct comparison of performance.

- Structure determined by criticality of component. Complexity of managing development and production of component – simplicity and economies of scale paramount.

- Last, the questionnaire analysis points to the desire on the part of the VM to reduce risk. This, coupled with increased power of first tier suppliers who own the knowledge capital for a large number of more recent vehicle innovations means that the supplier are both able, and willing to take on more significant roles in the supply chains. Chains where the *VM* have taken a risk and invested in the innovation (for example Rover ECU) tend to be shorter, more skewed to in-house value addition, but also under threat because of the higher level of risk.

7.3 Noteworthy points of supply chain methods developed within the study

The methodology developed in the study, notably the use of the 'Fixed Reference Benchmark Model' to compare supply chains, both with each other, and with their structure via the Mapping Tool is considered to be novel in that:

In general:

- it addresses supplier relationships in their entirety drawing together the two processes of product development and manufacture, meaningfully quantifying the elements of both the relationship management and the supply chain's structure

- it permits flexibility in its deployment; conscious of and takes consideration of heterogeneous nature of automotive components which themselves predicate the parameters of the desired supply relationship (for example in the assessment of criticality Vs non-criticality of the component)

- it is sufficiently robust to be used in non-automotive industry supplier relationship studies - especially those sectors which rely upon suppliers/sub-contractors for the majority of final value added

- it highlights the operating tensions in the multi-customer first tier European suppliers i.e. plurality of input versus single minded dedication to any one customer's needs through asset specificity; enables a view to taken of the supplier's ability to reconcile these forces through economy of scale in the production of sub- components in cost advantageous locations and final configuration in proximity to the customer.

In particular, the following points are considered novel in the approach:

- the ability to measure and quantify 'system purchasing' by way of describing an end point for component integration, which is then used as the reference for the degree of integration and vehicle manufacturer externalised development interfaces achieved by the supplier base on behalf of this customer, through the scoring system.

- with regard to the Delegation of Development element, it is innovative to predicate an assessment of the relationship by the nature of the component - within the range from critical to non-critical - which then moderates the assessment of optimal practice i.e.

from the utmost importance of efficient work sharing in the former case to the utmost importance of efficacious delegation in the latter case

- with regard to length of contract awarded by the vehicle manufacturer innovative to assess the supplier's certainty of business retention in parallel to the declared duration by the vm's buyer. This is arrived at by plotting a customer's 'willingness to honour the contract' index, and a market alternative supply curve against a scale of increasing supplier uncompetitveness as judged by adverse unit price. The interplay of these curves is used to quantify the customer's actual commitment to the original contract and the supplier's assurance of not being subjected to re-sourcing.

7.4 Comparison with original objectives

The central question posed at the start of this thesis concerned the structure of European Automotive supply chains. It sought an explanation as to why, for example, the assembly of a car door for a German manufacturer was dispersed amongst many suppliers in the chain, and only comes together at the VM for final assembly, whereas for a similar French car door, much more of the assembly is carried out in the supply base by fewer contributing suppliers.

In many ways, the main point of inquiry has been successfully concluded.

Existing theory has been shown to give some of the answers: Asset specificity is still important. Various ways to achieve equity in the relationship under conditions of high asset specificity have been investigated, (open book costing, satellite 'customer dedicated' assembly plants, open communication systems etc) but ultimately it has been shown that suppliers hold the power in these situations, and this still drives the production of certain key components in-house. However, rather than the Transaction Cost Economic (TCE) theory assertion of this applying as a general rule, this research has shown that for many components it does not hold. The concept of 'Criticality' of component is investigated, and TCE is found to be supported only for components considered 'critical' by the VM (i.e. those considered key in the defense of the competitive position). Components outside this range are handled either through partnership, with open book costing and dedicated customer design and manufacture teams at the supply partner, or are simply purchased on the open market.

Ultimately the structure of the supply chains studied is determined by a small number of executives in the immediate 'network' of trading relationships. In no cases was the supply chain viewed as a whole, and a 'Porteristic' analysis of that chain's environment carried out resulting in a holistic strategy for the chain. Rather, the structure evolves as a result of individual decisions taken, in consultation with a low number of actors in the particular links of a chain. In this respect, the research supports the change mechanism postulated in the Industrial Network School of theory.

With regard to the factors influencing the decisions made by those actors; it can first be said that they are legion. It is thought that this research has identified some of the important causal links, but as the next section will indicate, there is further work to be done in this area.

The dominant factors in determining the structure were found to be: Criticality of component (which in turn affects the acceptability of risk), the level, and pace of development of technology for the component or system of the supply chain (which is strongly linked to bargaining power), the desire to reduce the complexity of logistics (which is also linked to acceptability of risk), the desire to reduce the cost of demand fluctuations, and the capital intensity of the production process.

7.4 Further work

During the course of this study, many questions have been raised. Some of these have been answered with recourse to existing theory, and others through the process of research described in this thesis. However, others still remain unanswered.

Trust

Chapter 5 begins to develop a method of measuring trust in a buyer/supplier relationship. The link between criticality of component and the requirement for non-opportunistic behaviour is key here. The way that in which this trust manifests itselfwas explored and the notion of the 'certainty of business retention' (rather than the notional contract length) has been discussed (chapter 5). However, a robust way in which to measure this phenomena has not been fully developed, and it is felt that more work in this area would be interesting and beneficial.

This work would centre on defining a way of quantifying the willingness of the Customer's representative i.e. the Buyer, to continue to honour the original contract irrespective of the declared duration. It would take as its hypothesis that a move to a policy of long-term contracts by a VM requires a greater tolerance of episodes of relative uncompetitiveness by its chosen Supplier, and that it would positively help the Supplier during these episodes to secure long-term mutual competitive advantage, rather than resort to short-term opportunistic re-sourcing.

The Customer's representative could be asked to quantify his continued willingness to honour the contract for a range of increasing uncompetitiveness by his existing Supplier; he would be instructed not to condition his response by conscious regard to actual knowledge of viable alternatives. Essentially, this work would seek to quantify the buyers propensity to re-source the contract directly from his innate behaviour, in turn, influenced by company internal nurturing factors. The measure of uncompetitiveness could be taken to be price. Hence an increasingly unfavourable price differential compared to the originally contracted price. It is acknowledged that uncompetitveness is more complex than the piece part price simply, including quality, delivery and technical ability also, and this could be built into the quantification method. As explained in chapter 5, a curve linking the buyers willingness to remain with the supplier against a range of 'short term uncompetitiveness' could be plotted, indicating 'real' as opposed to 'nominal' trustful behaviour on the part of the buyer. The second part of the analyis could then introduce the notion that willingness to resource is also conditioned by the number of available alternative sources of supply.

The second factor, therefore, that could be measured is the number of alternative competing sources *as a function of price*. In other words this work would seek to establish a way of measuring the number of alternative sources willing/capable to supply the given component at: - first a price below the current contract price, and then for a range of prices of varying degrees of competitiveness. The relevant range of prices is that commencing just below the contract price with the existing Supplier, up to an absolute price in excess of the price differential which returns a minimum willingness (with reference to the first proposed factor above) by the Customer's representative to continue to honour the contract. Here the notion of component type would need to be considered. The relationship between the number of alternative competing sources and price is principally determined by the degree of differentiation of the component being traded. Differentiation can be non-existent i.e. a pure commodity component or complete i.e. unique, a proprietary component. This may be not just the product itself, but also process and combined know-how. For example, small price increases for commodity type components can induce large amounts of extra supply, whilst proprietary components tend to present high barriers to entry to potential alternative competing sources.

In summary, this exploration of the measurement of 'real' trust in the relationship centers on the measurement of the buyer's willingness to remain with a particular supplier in the face of:- a) a range of levels of short term un-competitive practice, and b) a range of numbers of possible alternative sources of supply.

Empirical measurement of value addition

The Hierarchical Structure Mapping method could be further developed by assigning a measure of value to each step, rather than assuming equal value, and simply analysing the number of steps and how these are distributed in the chain. This could be based on the collection of real cost data based on a breakdown of the Bill Of Materials for the product in question, or alternatively based on a standard cost estimation system and work measurement.

Graphical representation of the distribution of 'actual value addition' in the supply chain could be achieved by scaling the grid squares on the structure map according to the actual value addition performed at each company in the chain.

This then would allow a greater level of certainty in the conclusions drawn against supply chains with differing distribution of value.

Development of 'cause and effect links' into decision support tool

Many of the cause and effect links in the determination of supply chain structure have either been described from existing theory, or investigated during the research. A useful, aim would be to put these together into an 'expert system' model. It is felt that this PhD thesis has investigated and validated some of the 'missing' links. But it has stopped short of putting the links together into a predictive tool.

Derived from the findings presented in chapter 6 and discussed in this chapter, Figure 7.1 presents a 'first working model' for such an tool. It shows pressure to outsource value against pressure to retain in-house versus the set of factors that have been identified as critical to the design of supply structures, through the work contained in the thesis.

Further work in this area could center on the validation of such a model, including investigating the validity of using a quantitative system for measuring pressure to outsource.

The factors represented on the diagram can be split into the three categories of 'Product related" (criticality of component, production volume, Capital intensity, Knowledge intensity, Rate of change of technology development, demand fluctuation, Relationship related" (Trust) and "Market/economy related" (Number of available sources of supply, cost differential supplier Vs assembler)

Factor	***Explanation***
Criticality of component in terms of product differentiation	For components considered to give competitive edge, assemblers become immediately desirous to keep in-house, and only outsource when other factors outweigh this desire.
Capital/Knowledge intensity/pace of technology development	Components where the level of technology is high, or the pace of change of technology is high, assemblers tend to outsource, taking advantage of economies of scale and greater supplier specialism.
Demand fluctuation	Again, components with greater demand uncertainty are often preferred to be outsourced.
Trust	The higher the trust, the greater mutual benefit for customer/supplier, hence lower pressure to keep in-house.
Number of competitive sources of supply	Assemblers tend to shy away from monopoly or near monopoly supply relationships, and hence greater pressure to make in-house in these situations.
Cost differential	Where cost advantages can be gained through exploiting duality in the economy, this will tend to increase pressure to outsource.

Development and validation of a predictive tool along the lines discussed would require the researcher to first of all develop a quantitative method of measuring pressure to outsource. This could perhaps be based on the notion of a scalar system, ranging from the extreme position of the assembler being unwilling to outsource at all costs, through to the opposite extreme of (for example) the supplier being the holder of worldwide patents for the component.

In validating the proposed curves represented in figure 7.1, it is necessary to isolate the effect of one variable from another. For example engines at a low volume sports car manufacturer might be viewed as highly critical in terms of differentiating the product, and so high pressure to keep in-house may be present. However, low production volume, high knowledge intensity, fast pace of technology development, and high capital intensity would create opposite, and perhaps overbearing pressure to outsource. The research would need to concentrate on defining in isolation the effects of the variables, in order that when the model is being applied, the net effect of all factors can be assessed.

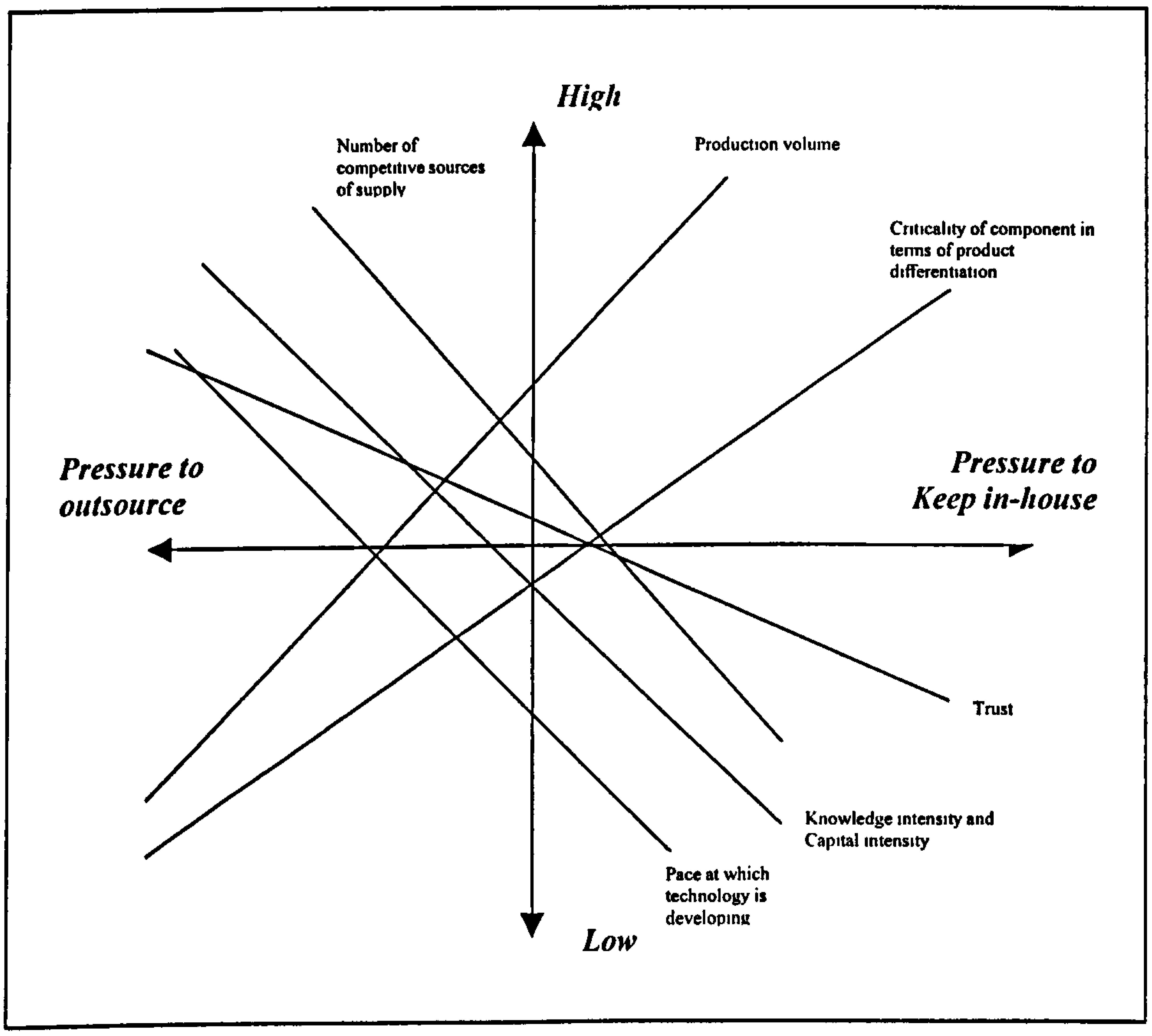


Figure 7.1. Initial model for "Structure design tool"

Chapter 8

Conclusions

The principal objective of this study has been to determine the factors that affect the structure of supply chains in the European Automotive industry. This central question is devolved into a number of derivative questions to which various parts of the study have been addressed.

The first course of research action has the been the quest for suitable answers from existing theory. Because of the cross-functional nature of the question posed, many areas of theory were found to be relevant in some form or another. Those which are reviewed in chapter 2 are listed below.

> **Transaction cost/obligational contracting; Trust/Cultural perspectives; Business Strategy Management; Networks; Dualism/industrial economics; logistics; Supply chain management; Lean supply.**

Although all the areas listed above are found to have some relevance, the most applicable are found to be 'Transaction Cost Economics' (Coase, 1937; Williamson, 1975 and 1985) 'Trust and Cultural Perspectives' (Dore, 1987; Sako, 1992), 'Business Strategy Management' (Porter, 1985), 'Network theory' (Jarillo, 1993; Johanson and Mattsson, 1987) and 'Dualism' (Berger and Piore, 1980; Edwards, 1979).

The central hypotheses inherent in each of the theories have been drawn out and formulated in statistical terms. The hypotheses have then been tested against a sample of 24 European Automotive supply chains from a spectrum of the main vehicle producers. The data was collected via some 150 field interviews, over a period of 18 months. The conclusions from this hypotheses testing can be presented thus:

- Network theory helps to explain the way in which structures evolve – driven primarily by management decisions taken by a relatively small number of actors in the links of the supply chain.
- Transaction cost theory is found to be useful in part, explaining the importance of bargaining power in the distribution of value addition in the chain, and helping to explain the emergence of a very strong 'Tier 1', and latterly 'Tier 0.5' in the automotive sector.
- Transaction cost theory does not fully account for 'win-win', or 'partnership' supply situations, characterised by joint working and mutual trust. Through consideration of the 'certainty of business retention' – a measure of trust in the relationship, the study highlighted instances where nominal partnership relationships belied a more honest assessment of the working practice, where opportunism and *lack of trust* were the dominant behaviour traits. The supply chains observed did not support the assumptions implicit in Williamsonian Transaction Cost Theory.
- The Porter 'Business Strategy Management' theory was found to be useful in explaining the emergence of the strong Tier 1 layer in the structure of the supply chains. However, it was found that the actual mechanics of 'determining' or 'driving' the structure towards a particular form or another

was much more due to the individual decision making of actors in the chain, based primarily on cost, reduction of risk, and relative bargaining power.

- The dualist hypothesis that cost differentials in the supply base are at least responsible in part for shaping supply chains is supported, when tested against the case study supply chains.

In summary, some of the answer to the thesis' central question has been gleaned from existing theory. In addition the hypotheses testing has added useful empirical findings in support or dispute of those theories under review.

The second course of action has been to develop a quantified system for recording the structure and relationship management within a supply chain. Again, the model has been tested against the sample 24 supply chains. The model – the 'Phantom Benchmark', together with a second research instrument developed – the 'Hierarchical Structure Mapping Tool', are used to compare supply chains one with another, isolating the variable of *structure*, and thereby shedding new light on which other factors are important in the determination of structure.

The dominant factors in determining the structure were found to be: Criticality of component (which in turn affects the acceptability of risk), the level, and pace of development of technology for the component or system of the supply chain (which is strongly linked to bargaining power), the desire to reduce the complexity of logistics (which is also linked to acceptability of risk), the desire to reduce the cost of demand fluctuations, and the capital intensity of the production process (which also affects the consequence of demand shifts).

As discussed in the previous chapter, many questions have been raised in this thesis. Some of these have been answered with recourse to existing theory, and others through the process of research described in this thesis. However, others still remain unanswered.

More light has been shed on the effect of trust in the relationship. The link between criticality of component and the requirement for non-opportunistic behaviour is key here.

The way that in which this trust manifests itself has also been explored and the notion of the 'certainty of business retention' (rather than the notional contract length) has been discussed (chapter 5). However, a robust way in which to measure this phenomena has not been fully developed, and it is felt that more work in this area would be interesting and beneficial.

The Hierarchical Structure Mapping method could be further developed by assigning a measure of value to each step, rather than assuming equal value, and simply analysing the number of steps and how these are distributed in the chain.

Many of the cause and effect links in the determination of supply chain structure have either been described from existing theory, or investigated during the research. A useful, aim would be to put these together into an 'expert system' model. It is felt that this PhD thesis has been useful in investigating and validating some of the 'missing' links. But it has stopped short of putting the links together into a predictive model.

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APPENDICES

1. PAPER – SUPPLY CHAIN RE-ENGINEERING: A SUPPLIERS PERSPECTIVE

2. SAMPLE QUESTIONNAIRE

3. SPREADSHEET ANALYSIS

TEXT BOUND INTO

THE SPINE

Supply Chain Reengineering: A Supplier's Perspective

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One of the more significant structural changes in Western manufacturing industry is the redistribution of "value addition activities" in product supply chains. Final assemblers are often choosing to subcontract the design and manufacture of large sections of their products in an attempt to focus their effort. In turn suppliers take on more of the design and assembly of the end product and may also choose to delegate some of their own activities to second line suppliers [1].

These changes require that the profile of capabilities necessary to design and manufacture the product is also redistributed among the partners in the chain. Competition between suppliers is fierce, particularly in view of the fact that the changing structure favors fewer sources [2]. The suppliers which survive will probably be those who successfully position themselves in terms of appropriate value adding capabilities and differentiation through high levels of customer service[3][4][5].

The term "supply chain reengineering" (SCR) has recently been used [6][7] to describe how a company can go about improving its supply chain processes. The concept does not usually consider the possibility of a redistribution of ownership of parts of the processes. This article considers industry restructuring as a part of SCR as well as the role of the supplier in "implementing" SCR. The paper presents a way in which a supplier can model the reengineered structure and become more proactive in positioning himself with appropriate capabilities.

he reallocation of addition activities rmally requires a redistribution of bilities among the ners in the chain.

Current trends in manufacturing are giving rise to a change in structure of the supply industry. In many industrial sectors the end assembler is reconsidering the whole process of designing and manufacturing its products with a view to deciding on the logical proportions of "value addition activities" which should be split between itself and its suppliers. In turn, some suppliers are choosing to delegate some of their own activities to second line suppliers [8]. One result is a reallocation of the value addition activities between the partners in the supply chain.

Normally the assembler decides to retain those activities which it considers "core" to its success and outsources those which it feels are more appropriately carried out by suppliers. Outsourced activities increasingly include both the design and manufacture of subassemblies for the end product. The assembler prefers to buy-in a smaller quantity of complete systems or modules. For example, a European car assembler states that the number of separate components which it has to manage logistically per vehicle has dropped from typically 5000 in 1990 to 4500 in 1994. This figure is even more significant when viewed against an increase in overall parts because of extra safety requirements and more sophisticated technological features.

The reallocation of value addition activities normally requires a redistribution of capabilities among the partners in the chain. For example, traditionally, assemblers have designed each individual component and sourced them from separate suppliers (who have manufactured from the assemblers drawing). Increasingly the assembler prefers to give "functional" specifications, and allow the supplier to carry out the detailed design. Later the assembler may prefer to ask a chosen supplier to combine many of the components into a subassembly and sell them a "system". Both of these instances require the supplier to acquire new capabilities. On the one hand design, on the other assembly and program management.

But what is the mechanism for bringing about such change? Recently, the idea that supply chains can be proactively redesigned has been formalized under the heading of "Supply Chain Reengineering"[9][10].

Supply Chain Reengineering

Eckler and Katz explain the concept thus:

"The concept, then, is to define core processes and related structures that extend from suppliers through to customers – further, to examine the value added role of those processes and structures, independent of organizational role in the supply chain."

In our approach the reengineering project is taken as starting from scratch, and ownership of the value addition steps is not treated as a given at this stage.

The issue of leadership in supply chain reengineering is open to question. Process improvement is often "led" by the end assembler, but can be viewed as a supply chain wide activity. It is open to any partner to assess the supply chains to which he contributes and proactively acquire or shed capability in order to fit into the new and more logical structure. The premise of this paper is that restructuring is more effectively achievable if partners in the chain are proactive in this respect. This assertion is explored in the paper using case study examples showing both proactive, and "reactive" restructuring.

The redistribution of value-addition activities is both a threat and an opportunity for supply chain partners. It is a threat in the sense that if the supplier does not take proactive steps he might at best remain at his present "level" of value addition and at worst get dropped from the supply chain. It is an opportunity in the sense that it allows proactive suppliers to "poach" the value addition opportunities through developing and matching its capabilities and thus increasing its share of "ownership" in the supply chain.

"Level" of Value Addition a Supplier Should Pitch For?

Let us consider a typical supply chain without any "ownership" boundaries. If we exclude the primary metal processors and final product distributors, the supply chain would consist of raw material, such as casting, or component suppliers at the lowest level and the final product assembler or the "product owner" at the highest end, with a number of value addition levels in between. The entire set of value addition levels would constitute the range for such a supply chain.

If we now put ownership boundaries on this supply chain, then each supplier can measure their current and future contribution to the value created in the supply chain in terms of the two dimensions of *level* and *range*. Thus each company would be operating at a defined *level* of value addition activities which equates to the "level" in the supply chain at which the company is operating – raw material extraction and processing would therefore correspond to the lower *levels*, and assembling the final end product would be highest *level*.

Such a supplier could undertake a very limited *range* of activities, for example, a metal coating specialist in an automotive supply chain who chooses only to receive components from a first line supplier, coat them and send them back. Alternatively the supplier could choose to contribute a broad *range* of value addition activities, for example as in the case of a first line automotive "systems supplier" who contributes research and development, whole system design and assembly and perhaps subcomponent design and manufacture. In this case the *range* of activities contributed, from the total "raw materials to finished product set", is broad.

Level and range is explained in Figure 1 as applicable to a part of the bill of material (BOM) structure. Thus a supplier who is at level A can plan for level B or level C. This "level increase" automatically increases the "range", if the current level(s) remains as part of the supplier's business.

The redistribution of value-addition activities is both a threat and an opportunity for supply chain partners.

Thus, if a supplier presently at level A of value addition starts supplying sub-assemblies, he has increased the level as well as the range of value addition.

This level and range of value addition options becomes available to a supplier only if the final assembler moves from a purchase BOM shown in Figure 2, to the BOM shown in Figure 1. Many times the supplier may have to take proactive steps to move the final assembler from Figure 2 to Figure 1 BOM for his supply chain.

Companies can therefore choose to operate at a higher or lower *level* with either

Figure 1
"Level" and "Range" of Value Addition in a Supply Chain

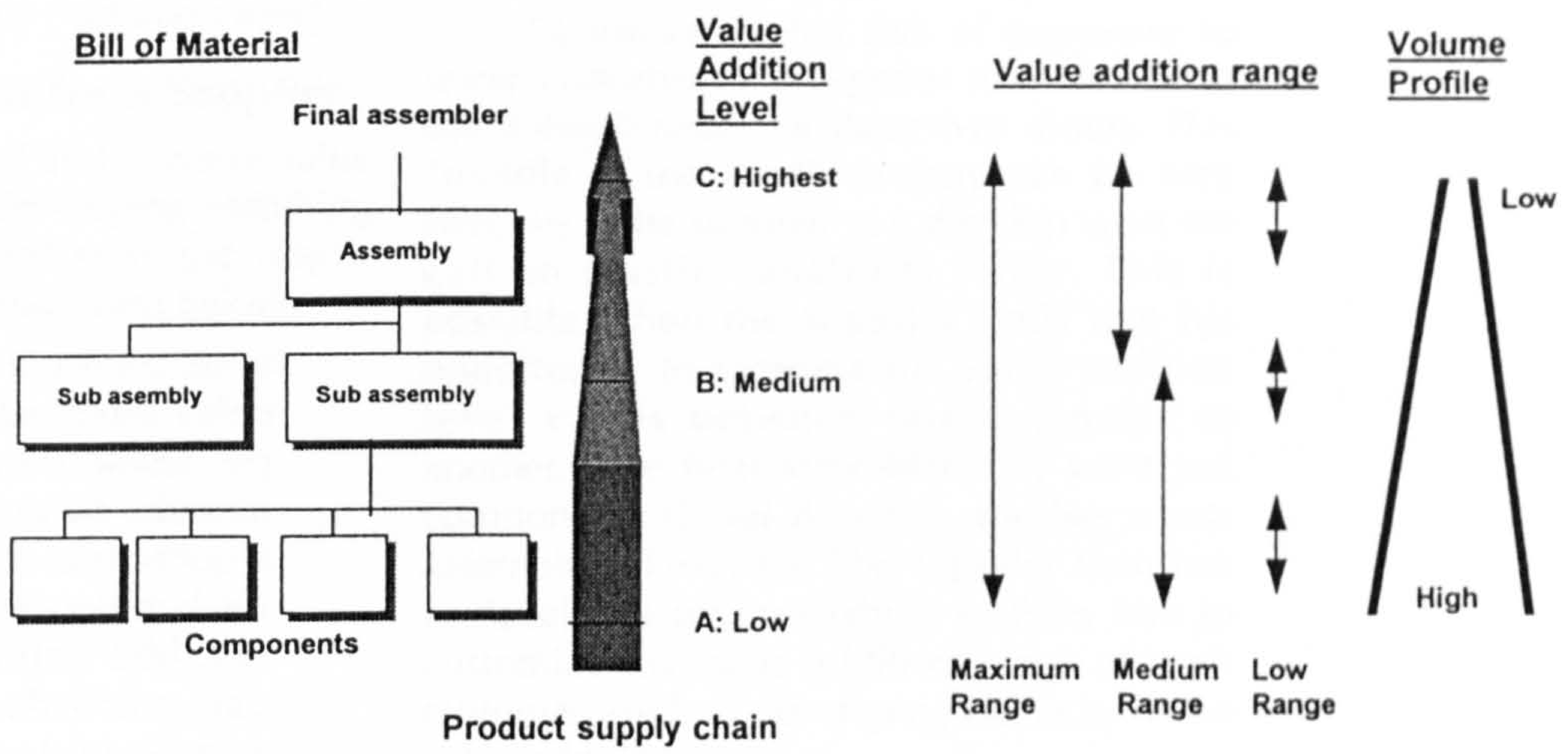
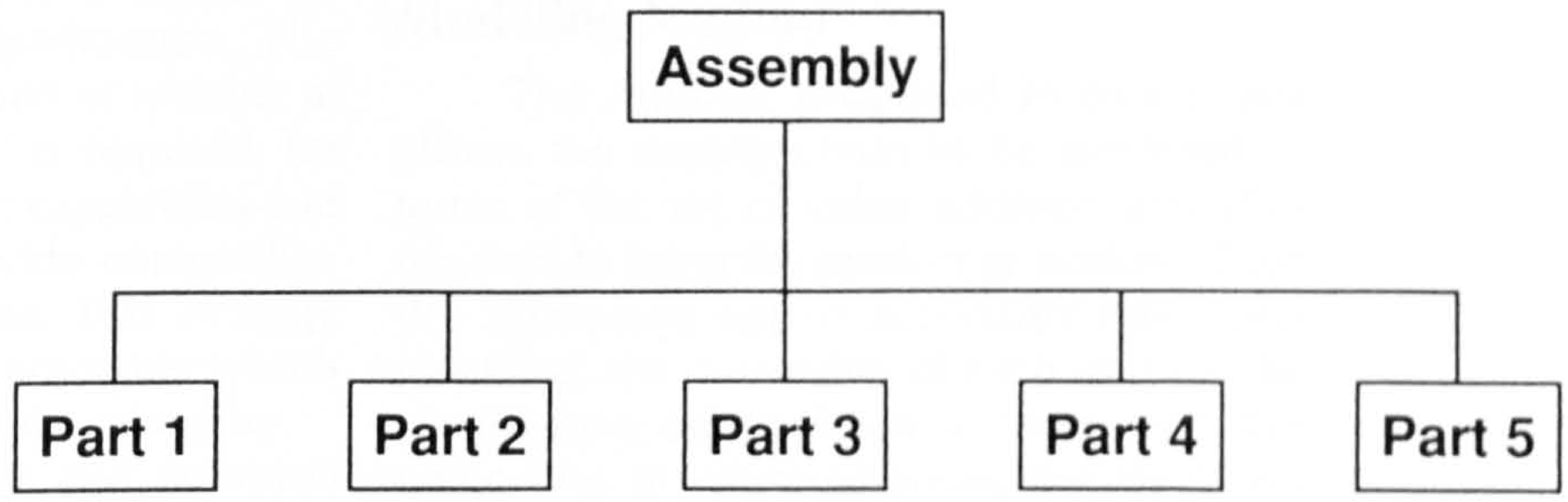


Figure 2
Traditional Purchase BOM



a broader or narrower *range*. For example, a highly vertically integrated company could be said to own a very broad range of value addition activities from the highest level, for example final assembly, to the lowest. A move from BOM 2 to 1 allows a supplier to pitch for a different level and/or increase his range of value addition activities in conjunction with similar repositioning [11] by other members in the supply chain, and this leads to supply chain reengineering.

Matching Value Addition Profile with Capability Profile

The dimensions of *level* and *range* are critical because they define the *amount* and *type* of capability required for a supplier to successfully achieve his desired position in the supply chain. Thus a higher level and broader range of value addition would require different types and range of capabilities than a supplier operating at a lower level with a narrower range. The guiding logic which has helped suppliers in the automotive sector to choose specific "levels and ranges" at which to operate will be discussed later in this paper.

There is another dimension to this match between value profile and capability profile. As a supplier moves from level A to level C (refer to Figure 1), the degree of customization for a particular final assembler increases. That is to say at level A parts which are common or very similar in design and technology may be used for different final assemblers. At level C the picture may be quite the opposite with little commonality between assemblies used in final assemblies by different final assemblers.

Thus, at level A the same capability can supply to more than one customer, while at level C, more than one capability may be needed to supply to more than one customer. This implies that a supplier can have access to larger volumes at level A than at level C. This we call the "volume funnel."

Strategic Implications for a Supplier

The concept of level and range of value addition activities and developing matching capabilities have several strategic implications for a supplier as discussed below.

Depth of range vs. focus: As a supplier incorporates more value addition levels in his business, the increased range of value addition requires the supplier to develop a range of capabilities needed for each additional value addition level. These capabilities may range from "black/grey box design", supplier management, project planning and control, assembly equipment and expertise, and system testing expertise.

Managing such a diverse range of capability may not be easy and can dilute the effectiveness of the organization. The supplier has to ask the question of whether at this stage "capability focus" is required, for example, to shed some of the capabilities and keep only those which provide competitive edge and/or highest margins. This strategy might lead to outsourcing activities which were earlier key activities for the company.

Capability risk analysis and premium on capability: As a supplier moves up the value chain the complexity and number of capabilities required increases which calls for greater investment in their development. However, the volume funnel implies that as the supplier moves up the value chain, correspondingly, his level of risk also increases, since he becomes more closely tied with the final assembler. In an ideal situation, it would be worthwhile for him only if the premium on the increased capability outweighs the risk, or if he is faced with the risk of losing existing business if he does not make this transition. (What happens in practice is discussed later).

The above analysis suggests that a supplier is faced with two choices to achieve turnover growth:

- the *volume* route to growth whereby the supplier decides to stay at his existing value addition *level* (for example level A) and grows by increasing the number of supply chains of which he is a part.
- the *value* route to growth by moving to level C for the existing or fewer supply chains.

To minimize his risk of exposure to fewer customers the supplier may decide to use a combination of these two routes. This "middle of the road" strategy can be very effective if the supplier can develop what we call an elastic capability range. This is possible when the supplier finds that his opportunity to increase his value addition level varies between one customer to another. One final assembler may want just components (Level A) while another wants assemblies (Level C). The supplier then has to develop a process which enables him to customize his value addition range to each customer, such as developing elasticity in the value addition range.

The following section presents a modeling method which can be used to analyze the options available to suppliers and illustrates the above concepts using a case study company.

Modeling Method

The method proposed in this paper allows the supply chain to be modeled in terms of the set of value addition activities required to bring the product to market. Once the complete set of activities has been identified, the ownership of each step can be superimposed to form a model of the ownership structure (showing the level and range of value addition activities for all partners in the chain). In a reengineering "initiative", such a method could be used to model different profiles of ownership. For a supplier who contributes to the chain, a model of the reengineered structure would provide useful information to guide capability acquisition and hence successful positioning. Figure 3 shows the methodology steps.

Table 1 illustrates the use of the technique in the automotive industry. The supply chain in question is that for car door window winding mechanisms. The first column represents the set of value additions to bring the door "to the customer." Subsequent columns show different configurations of ownership. Option 1 represents the traditional state where much of the ownership of the design and assembly of the door and its components lay with the vehicle manufacturer. Subsequent columns show the changing ownership as the supply chain is reengineered.

As a supplier moves up the value chain the complexity and number of capabilities required increases which calls for greater investment in their development.

Figure 3
Steps in Reengineering Methodology

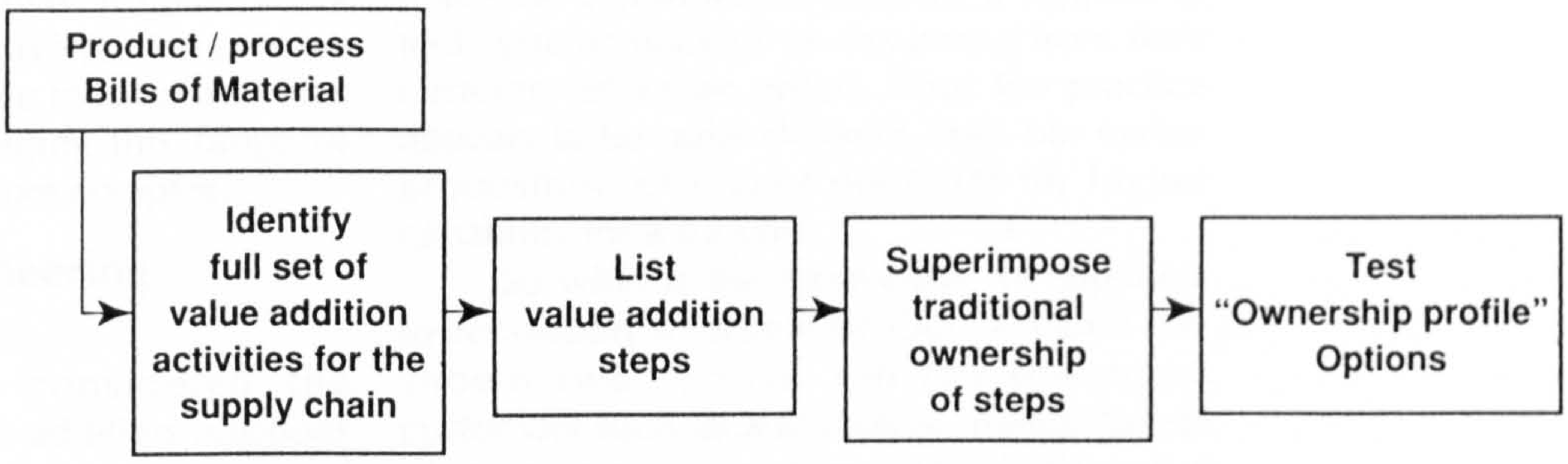


Table 1
Value Addition Ownership Model – Automotive Component

Value addition	*Value addition ownership* *Option 1: Traditional ownership*	*Value addition ownership* *Reengineered Phase 1*	*Value addition ownership* *Reengineered Phase 2*	*Value addition ownership* *Reengineered Phase 3*
assemble door to vehicle	vm	vm	vm	vm
design door	vm	vm	vm	vm
fit audio equipment to door	vm	vm	vm	vm
fit to trim to door	vm	vm	vm	vm
fit regulator	vm	vm	SUPPLIER 1	SUPPLIER 1
fit motor	vm	vm	SUPPLIER 1	SUPPLIER 1
fit glass	vm	vm	SUPPLIER 1	SUPPLIER 1
fit cabling	vm	vm	SUPPLIER 1	SUPPLIER 1
paint door	vm	vm	vm	vm
fit door handle	vm	vm	SUPPLIER 1	SUPPLIER 1
fit locks	vm	vm	SUPPLIER 1	SUPPLIER 1
manufacture regulator	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1
design regulator	vm	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1
manufacture motor	supplier 2	supplier 2	supplier 2	supplier 2
design motor	supplier 2	supplier 2	supplier 2	supplier 2
manufacture pressings	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1	supplier 3
design pressings	vm	SUPPLIER 1	SUPPLIER 1	SUPPLIER 1

The supplier in question has moved from Option 1 through Phase 1 into Phase 2. In this movement up the value chain, the supplier increased both level and range of value addition activities in moving from Phase 1 to 2. However, not all customers required Phase 2 type outsourcing for window winding systems. Thus this supplier found himself operating in all the three versions of the same supply chain (Option 1, Phases 1&2) for different customers, achieving what we had earlier called an "elastic capability range".

The move to Phase 3 is planned for the ure and represents a reduction in range, the company decides to outsource the nufacture of pressings (which traditionally s been their main activity). This range uction represents a desire to focus activities the company as managing this range of pabilities has become more complex.

pply Chain Reengineering Practice

So far we have considered the ppliers' choice of value addition *positions* terms of level and range as a series of *tions* for partners in the supply chain. But hat are the benefits and trade-offs for tners in the supply chain to adopting one tion over another, and what are the entry d exit barriers for such reengineering? is section discusses some of the practical ues involved in achieving such a istribution of value addition activities in supply chain.

First of all, what guides a supplier vards a strategy of taking on more (or less) the value addition? The basic objective of y such reengineering exercise is to deliver eater value to the final customer. The nefits can be traced to three factors at the ppliers; economies of scale (in many cases supplier produces similar components for her customers), increased potential for novation (ideas are often carried over from er customers or generated at the supplier cause of a more in depth understanding of component). The third and perhaps most nificant source of benefit is derived from fact that generally wage costs are found be lower at suppliers.

Our research in the European tomotive industry (where this type of tructuring is already taking place [12]), gests that the beneficiaries of the *actual t savings* resulting from the reengineering the final assemblers or the product ners. For example a vehicle manufacturer one instance was able to redeploy some % of engineering resources for one set of nponents as a result of the redistribution ctivities to the supplier.

A supplier who takes on more of the sign and manufacture of vehicles by evating" himself to "systems" supplier, for ample, increasing both *level* and *range*, n expect no higher margins on his ducts. In fact, many suppliers have found re pressure on profitability because of the d to increase engineering and R&D resources. We found some suppliers, such as a manufacturer of fuel tanks for the automotive industry, are very reluctant to make the investment to become a supplier of fuel systems without an assurance from their customer of future orders. Thus the practice appears to be quite different from our earlier proposition of higher premium for higher capability for a supplier.

So what is the motivation for suppliers to reposition themselves? Our research has shown two factors. On the one hand customers such as automotive manufacturers almost *require* systems capability as a "given" for first tier suppliers. A supplier who is not proactive in this respect fears being dropped from the customers' preferred supplier list or gets pushed down the supply chain. A real motivation is therefore survival. Allied to this is the limitation of volume route to growth imposed on suppliers by supplier rationalization process undertaken by most big assemblers. Finding new customers is proving to be difficult. This leaves, in many instances, the value route as the only way to turnover growth. There is also the increased "Kudos" of becoming a first tier supplier.

The "chosen or reengineered structure" for the supply chain with redistributed value addition activities can be seen to be primarily dictated by the more "powerful" end assemblers at the top end of the supply chain.

Considering the benefits of redistributing value addition, it can be seen that they are primarily cost related, and ultimately should deliver greater value for money to the end customer. Therefore the motivation for reengineering, and guiding logic as to the choice of the structure, particularly from the final assemblers perspective, is based on cost. There are however other considerations. There are risks for those both "shedding" value addition activities and gaining them. On the one hand, assemblers fear loosing control over the design of some of their key components. Our research shows this to be the case particularly for strategic components such as the "electronic control unit" (ECU)[13]. The second fear legitimately held by "assemblers" higher up the supply chain who are considering delegating design and manufacture is that the suppliers run the risk of simply not being able to build up the necessary capability fast enough to design and manufacture sometimes complex systems to tight time scales. A supplier of fuel tanks was asked by the "assembler" to present his plans for developing and manufacturing a

Considering the benefits of redistributing value addition, it can be seen that they are primarily cost related, and ultimately should deliver greater value for money to the end customer.

fuel system, comprising fuel tank, filler pipes, pressure release valves, fuel pump and so on. At the end of the presentation it became apparent that the supplier had not yet even looked at the full bill of materials or working drawings for the system. A more proactive approach on part of the supplier would have allayed the assembler's fears [14].

For the example of door systems given earlier in this paper, where the supplier was proactive and anticipated the capability requirements and built up expertise in advance of the customers requirement, the risks for both supplier and assembler were minimized. In this instance three main factors contributed to the company successfully becoming a supplier of systems. First, the company very accurately identified the capabilities required to be developed to move from Option 1 through Phases 1, 2 & 3 as part of their strategic plan (the modeling method put forward in the paper can help suppliers to carry out this step). Second, they were willing to invest in compatible CAD equipment, assembly equipment, training and other resource to achieve the capability. Finally, the company followed a policy of moving project managers between projects for different customers so that the learning from the first company requiring a "system" was passed on to subsequent projects.

However, our research suggests that few companies, be they final assemblers or suppliers, have developed a systematic logical methodology to select the "least" cost reengineering option. As one representative of a large automobile company told us, the current "fashion" is towards "systems" supply and that is why we are moving in that direction. In this company there were instances when a supply chain was reengineered through buying-in a system because this fitted in with purchasing policy and subsequently economic justification was found difficult to prove.

...om a supplier's ...tive, capability ...ment to match ...d positioning is ...utionary rather ...a revolutionary process.

From a supplier's perspective, capability development to match the desired positioning is an evolutionary rather than a revolutionary process. The goal post is usually determined by the final assembler in the form of the final shape of the reengineered supply chain. Thus, the question for the supplier is not "what" but "how". The example of the failure of the supplier of fuel tanks quoted earlier shows, a proactive approach using the modeling method presented in this paper enables a supplier to be better prepared to respond not only to any reengineering but sometimes influence the shape of the reengineered supply chain. But the reengineering process in not a "one-way" street. A supplier requires reassurance and a commitment from customer(s) before a commitment can be made.

Conclusions

Supply chain reengineering as described in this paper is no longer just a possibility. It is happening today. Discussions with suppliers seem to suggest that many of them are unhappy that while they have remained at Level A their competitors have moved to Levels B and C (refer to Figure 1). In the process they have been pushed down the supply chain ladder in that they have become supplier to another supplier who has developed the capability of systems integration, instead of dealing directly with the final customer.

Redistribution of value addition activities is resulting in the slimming down of engineering resources at large "product assembler" companies, increased delegation of design activities to suppliers, and corresponding cost reductions which are starting to be passed on to end customers in the form of value for money. A topical example is the new Mercedes Benz / SMH "micro car" will be based on the principle of systems supply, with a view to achieving drastically lower costs and "highly competitive prices."

Those suppliers who are proactive in their approach have been able to take advantage of the opportunities which open up in this restructuring. As the case described in this paper shows, such a proactive approach to charting the value addition capability profiles can be extremely useful for the supplier in planning capability acquisition in the medium to long term. It can also enable the supplier to match the capabilities needed to meet the customized requirements of each of his customers. And finally, for many suppliers, "value" route to growth is no more a matter of choice, it has become a necessity.

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BUYER'S INFORMATION PACK

1. INTRODUCTION

2. QUESTIONNAIRE

3. PROCESS CHARTING

1. Introduction

Buyer's Interview:

Warwick Manufacturing Group have been asked by Rover Group to carry out some research to map out the supply chain processes of: Component development, Sourcing and Manufacture, for a number of representative components.

The researcher will carry out a similar activity at BMW, Renault, PSA Group,Ford of Europe, and Daimler-Benz. The intention is to compare the processes and determine best practice.

In this interview we wish to find out how the Buyer contributes to the processes given above.

Interview format:

Part 1

Questionnaire: Approximately ½hour to talk through the enclosed questionnaire(attachment 1). We would also be very grateful if you could supply any supporting documents you feel would reinforce the questionnaire survey.

Part 2

Process mapping: Approximately ½hour to complete a flow chart of the process your are involved with. As a start, we would be most grateful if you could construct a flow chart similar to the example in attachment 2.

Your assistance in this research will be greatly appreciated.

This structured interview is intended for completion by the investigator in the presence of the responding company. It is not a questionnaire for distribution by post.

Interview Structure(Buyer's):

Date of Interview	
1. COMPANY	
2. RESPONDENT	
3. PART	
4. MODEL	
5. SUPPLIER	
6. NAME & ADDRESS OF CONTACT	Tel.:

7. VALUE OF BUSINESS IN TOTAL WITH SUPPLIER

8. VALUE OF THIS PART

1991	1992	1993

9. DATE WHEN STARTED BUSINESS WITH THIS COMPANY

10. DATE WHEN FIRST DELIVERIES OF THIS PART STARTED

11. TAKE IN UNITS(LAST TWELVE MONTHS)

12. Is your contract with this supplier limited to this part number? Yes No

13. How many suppliers supply this part number? 1 2 3

14. What proportion of your total take of this part is made by this supplier? a b c d
(a) <30% (b) 30-60%
(b) 60<100% (d) 100%

15. If you place other business with this supplier is it a b
(a) other models of this component?
(b) other types of this component?

16. Would you describe your relationship with this supplier by any of the following words? a b c d
(a) partnership
(b) preferred supplier
(c) established supplier
(d) None of the above

17. What is the duration of the contract with this supplier? a b c d
(a) open ended
(b) to the end of the life of this model
(c) one year
(d) more than one year(specify)

18. Did this supplier contribute to the design of the component? a b c d
(a) not at all
(b) with minor modifications
(c) with significant design input
(d) 100% supplier designed

19. Would you use this supplier again? Yes No

20. What was the main drive in selecting this supplier(quality capability being a "given") a b c d e
(a) previous satisfactory relationship
(b) some design/process advantage
(c) available capacity
(d) promptness of response
(e) price

21 How important was the relative value of a b c d

currencies in making this sourcing decision?
(a) crucial
(b) an important consideration
(c) a marginal influence
(d) not a serious factor

22. Since the sourcing decision was made, has currency fluctuation caused a re-appraisal of similar sourcing decisions in the future? a b c d
(a) positively Yes
(b) very probably
(c) possibly
(d) No

23. Is the price fixed in a b
(a) your currency?
(b) his currency?

24. Do you buy currency forward? Yes No

25. Is the price a b c
(a) factory gate?
(b) F.O.B.?
(c) delivered?

26. When negotiating price do you and the supplier allow exchange rates to influence the deal? For example have you ever quoted exchange rates as a reason for price reduction? Yes No
Has this supplier ever pleaded exchange rates as a reason for price adjustment? Yes No

27. Do you believe that a fixed exchange rate or single currency would materially affect your sourcing decisions? Yes No

28. When the sourcing decision was made, did the difference in language between the companies have an effect? a b c
(a) a significant retarder
(b) a marginal inconvenience
(c) no effect whatsoever

29. Since operating with this supplier, has it been found that difference in language causes any problems? a b c
(a)significant miscarriage of important information
(b) noticeable delays/re-transmission
(c) no effect at all

30. Has your company any arrangements in place to teach key staff the language of this supplier? Yes No

31. Has this supplier any arrangements in place to teach his key staff your language? (DK = Don't Know) Yes No DK

32. Have you ever discussed the problem of language with this supplier? Yes No

33. If yes to Q.32, in what context? a b c d
(a) you wished him to improve competence in your language
(b) you or he attributed a failure to language
(c) you were agreeing a glossary of terms
(d) other(specify)

34. When you select a supplier, does his proximity to your plant influence your decision? a b c
(a) heavily
(b) marginally
(c) not at all

35. In operating with this supplier, has his remoteness from your plant ever caused interruption of supply? a b c d
(a) several times
(b) more than once
(c) once
(d) no

36. In operating with this supplier has his remoteness from your plant caused difficulties which are important enough for you to consider alternatives? Yes No

37. Were the difficulties in Q.36 a b c d
(a) time consumed in visits?
(b) cost of visiting?
(c) difficulties of transport?

(d) level of stock needed?

38. Have you ever considered requiring this supplier to set up manufacturing facilities in your own country? Yes No

39. Have you required this supplier to maintain stocks in your own country? Yes No

40. If yes to either Q.38 or 39, does your policy towards this supplier differ from that towards comparable suppliers from your own nationality? Yes No

41. Please indicate which systems of exchanging data exist between your companies a b c d e f
(a) hard copy by post or courier
(b) fax
(c) electronic medium(tape, disk etc.) by post or courier
(d) electronic mail box
(e) EDI
(f) EDI & on-line enquiry access to database

42. How do you exchange engineering drawings and/or modifications to these? a b c
(a) hard copy by post/courier
(b) electronic medium by post/courier
(c)EDI

43. Do you find electronic communication with this supplier any different from similar communication with suppliers in your own country? a b c d e
(a) technically not achievable to adequate standard
(b) more time consuming
(c) less reliable
(d) significantly more expensive
(e) OK - none of these things

44. Has the 1993 single market conditions improved the ease of trading with this supplier in your view? Yes No

45. Does the difference in VAT rates and VAT procedures affect your cash flow when trading with this supplier? a b c
(a) adversely

(b) favourably
(c) neutral(c.f. internal trading)

46. Are you conscious of any trading culture differences when dealing with this supplier any if so, do these relate to — a b c d e
(a) expectations of settlement dates?
(b) expectations of information?
(c) attitude to schedules
(d) reaction times
(e) other(specify)

47. Has your organisation learned any useful lessons? — a b c
(a) directly from this supplier
(b) as a result of trading with this supplier
(c) not in the context of this supplier

48. As compared with an "overseas" (i.e. non-EC) supplier, which if any of the following statements apply? — a b c d e
(a) documentation is easier
(b) shipping/duty/tax costs less
(c) communication is easier
(d) transport is easier
(e) legal arrangements are more clear or are easier to administer

49. If any of Q.48 above applies, which if any would be the most significant factor in preferring an EC supplier to a non-EC supplier — a b c d e

50. Of your company's bought-in material can you say approximately the proportions which are sourced, respectively
Own country /other EC / Beyond EC
(a) Value
(b) Component part numbers

	O	**E**	**B**
V			
C			

51. Does your current sourcing activity change this proportion? — a b c d
(a) towards more global sourcing
(b) towards more EC sourcing
(c) towards more local sourcing
(d) no discernible effect

52. If you monitor suppliers by a formal vendor rating system: a b c d
(a) is it a common system applied to all suppliers?
(b) if there is a different system for foreign suppliers, does this supplier count as domestic?
(c) or does it count as foreign?
(d) or is this supplier subject to unique monitoring?

53. The last monitoring report on this supplier in your possession is dated: a b c d e
(a) within the last month
(b) 1 to 3 months ago
(c) 3 to 6 months ago
(d) 6 to 12 months ago
(e) more than 12 months ago

54. On the last report this supplier was rated
(a) excellent
(b) good
(c) satisfactory
(d) needing improvement
(e) unacceptable
under the following headings(if rated)

QUALITY	a	b	c	d	e
SCHEDULE ADHERENCE	a	b	c	d	e
JIT PERFORMANCE	a	b	c	d	e
FLEXIBILITY	a	b	c	d	e
INNOVATION/DESIGN	a	b	c	d	e
PRODUCTIVITY	a	b	c	d	e
PRICE REDUCTIONS	a	b	c	d	e
OTHER(specify)	a	b	c	d	e

55. A representative of this supplier last called at your premises? a b c d e
(a) within the last week
(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

56. A commercial executive of your company last called on this supplier? a b c d e
(a) within the last week
(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

57. One of your engineering executives last called on this supplier? a b c d e
(a) within the last week
(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

58. The last formal progress meeting with this supplier was? a b c d e
(a) within the last week
(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

59. Not including routine schedules, statements or invoices, the last written communication with this supplier was? a b c d e
(a) within the last week
(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

60. The last time you disputed an invoice from this supplier was? a b c d e
(a) within the last week
(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

61. The last time this supplier reminded you that payment was overdue was? a b c d e
(a) within the last week

(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

62. The last time anything this supplier provided was sent back or had to be re-worked was? a b c d e
(a) within the last week
(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

63. The last time this supplier suggested some improvement/amendment to the product was? a b c d e
(a) within the last week
(b) within the last month
(c) within the last 3 months
(d) within the last 6 months
(e) longer ago than 6 months

64. If you could change some aspect of this supplier's performance, behaviour or attitude what would it be? ____________________

65. As a principle do you believe that "Co-makership" i.e. the shared responsibility, capital and inventiveness, for creating and supplying your products is a viable strategy? Yes No

66. Is there any difference for this component between makers of your own nation, as against this particular maker, which changes your assessment of this viability? Is so what?

____

67. In your view what are the main barriers which remain to be overcome to make this particular link in your supply chain as effective as any other link in the world? ____________________

68. What is your benchmark? ____________________

69. How are you addressing the issue of achieving world class performance of this link? ____________________

70. At what stage of the development process was first contact with the supplier(for the supply a b c

of this part) made?
(a) concept design
(b) detail specification
(c) design manufacture

71. How was the price for this component negotiated? a b c
(a) target price set by you
(b) target range set by you
(c) competitive tender bids set by suppliers

72. Are there any differences in delivery agreement with this supplier, as against a similar supplier in your own country? Yes No

73. If yes to Q.72, are the differences concerned with
(a) delivery frequency? i ii
 (i) more frequent
 (ii) less frequent
(b) volume flexibility? i ii
 (i) more flexibility
 (ii) less flexibility
(c) firm/tentative planning horizons? i ii
 (i) longer
 (ii) shorter
(d) call off procedure? Yes No

74. Do you see any of the following as difficulties in creating the delivery arrangements you desire with suppliers in other EC countries? a b c d e
(a) distance
(b) communication methods
(c) organisational culture
(d) language
(e) differences in trading contracts

75. To initiate the development of the component at the suppliers, were your specifications a b c d
(a) functional
(b) detailed
(c) fully detailed
(d) other

76. Was the interaction between you and the supplier during negotiations for this a b c

component led by:
(a) Purchasing
(b) Engineering/Design
(c) Product Development

77. Was the interaction with the supplier carried out by a team from your plant   a   b   c   d   e
(a) at all stages of the negotiation?
(b) during component specifications?
(c) during price negotiation?
(d) during delivery agreement negotiation?
(e) at any other stage of negotiations?

78. Does this supplier provide you with open book costing information and, if so, how much information are they prepared to provide?   a   b   c   d
(a) does not operate open book
(b) provides bill of material breakdown only
(c) provides material and labour breakdown
(d) provides full access to material, labour, overhead and profit

79. Is open book costing a significant factor in sourcing with suppliers?   a   b   c   d
(a) crucial
(b) an important consideration
(c) a marginal influence
(d) not a serious factor

80. Do you operate a plan to use third party accreditation, such as ISO9000 through an approved agency, as a method of assessing supplier quality?   Yes   No

81. Do you receive guest engineer support on this product?   Yes   No

82. If yes to Q.81, does this include the following stages in product development and productive stages?   a   b   c
(a) initial concept design
(b) pre-volume launch support
(c) post-volume problem solving

83. Do you operate a rate of exchange/currency   Yes   No

escalator agreement with your supplier?

84. If yes to Q.83, are these legally binding agreements based on a formal mechanism? Yes No

85. Is the relationship with this supplier affected by a "component/commodity strategy", and if so, what sort of effect does it have? a b c d
(a) not affected
(b) provides guidance on supplier
(c) sets out guidelines on level of co-makership and delivery requirements
(d) others(specify)

86. Does your relationship with this supplier extend to sharing with them your commodity strategy for this component? a b c
(a) not at all
(b) only where it specifically affects sourcing agreements
(c) open book

87. In your view, to what extent is your commodity strategy linked to your company's long term marketing/manufacturing strategies?
(a) not at all
(b) not directly
(c) influenced by
(d) heavily affected
how is it linked? ________________

88. To what extent are your long term marketing and/or manufacturing strategies shared with this suppliers?
(a) not at all
(b) formally presented
(c) open book

89. To what extent does this suppliers share their long term business plans and strategies? a b c d
a) not at all
(b) formally presented
(c) open book

(d) other(specify)

90. At what stage was manufacturing method/tooling design initiated? a b c d e f
(a) after first product drawing
(b) after second product drawing
(c) after the final drawing
(d) after the first prototype fabrication
(e) after second prototype fabrication
(f) any other phase

91. How would you classify the process of the manufacturing tooling? a b c d
(a) a large number of changes took place and each change was recorded before tool designers took it up
(b) a large number of changes were made but could not be implemented without a detailed review system
(c) a small number of changes took place each rigorously reviewed
(d) a small number of changes took place and could be implemented informally

92. Which of the following functions has an ongoing scheduling/ordering/improving responsibilities relating to this component? a b c d
(a) Purchasing
(b) Logistics
(c) Design/Development
(d) Manufacturing

93. Is the supplier interface by (i) each individual function or (ii) a unified team? If (ii), which function in Q.92 takes the lead?
i ii
a b c d

94. What is the method of communication with second and third line suppliers, for, (i) routine production matters, (ii) supersessions?
i a b c d
ii a b c d
(a) solely via this supplier
(b) mainly via this supplier
(c) mainly directly to 2nd and 3rd line
(d) solely directly to 2nd and 3rd line

99. Do you find this company capable of and willing to design vehicle systems comprising more than one component? Yes No

100. When you last agreed a component design with this supplier what was the delay before they had the manufacturing capability available? a b c d
(a) less than 2 weeks
(b) less than a month
(c) 1-3 months
(d) more than 3 months

101. Does the documentation of this component show adequate use by the supplier of FMEA or other appropriate analytical techniques? Yes No

102. Has this supplier suggested an improved use of material(i.e. change of specification or method of economy)? a b c d e
(a) during the last 3 months
(b) during the last year
(c) during the last 2 years
(d) long ago
(e) never in memory

103. Has this supplier built acceptable prototypes? a b c d e
(a) for all recent components
(b) on every occasion they have been required
(c) on some occasions successfully but has failed in other cases
(d) cannot produce prototypes
(e) has never been asked for prototypes

ROVER - DOOR

No.	Element	Aspect	process	Variable		Rating sub.	Rating total
1	**Tiered s/b**	Dedication		α=	5.0	20.0	
		Demarcation		β=	102.0		
			manufacturing	γ=	8.4	13.4	
				δ=	5.0		
			development	ε=	1.5	10.4	
		Direct Collaboration		ζ=	6.0		
				η=	43.0	3.5	47
2	**O/sourcing**		manufacturing			40	
			development			40	80
3	**Sys. purch.**		manufacturing	θ=	12.0		
			(goto name="supply_points_for_complete_door")	κ=	17.0	16	
			development	λ=	6.0		
				μ=	43.0	7	23
4	**S/sourcing**					50	50
5	**D&D deleg.**	Nature of Component					
		split:	critical:				
			efficiency of work-sharing(meshing rating)			20	
			(goto name="efficiency_of_work_sharing")				
			point of first involvement(pre-concept)	ξ=	3.5		
				π=	2.0	5	
		critical =	20			5	
			non-critical:				
			amount of delegation	ρ=	95.0	32	
			efficacy of delegation:				
			(i) sub-supply	σ=	1.0		
				τ=	6.0	14	
			(ii) role clarity	υ=	70.0	12	
						26	
			point of first involvement(concept)	ϕ=	3.0		
				π=	2.0	22	
		non-critical =	80			64	69
6	**L/T contr.**	Nominal Contract		χ=	1.0		
		Length	percentage of model-life	ψ=	7.0	7	
		Certainty of Business					
		Retention	data not available				14
7	**Cust. foc.**	Specificity of Resource					
		Allocation	manufacturing	Rm=	36	2.6	
			(goto name="Manufacturing_process_resource_specificity")				
			development	Rd=	41	3.3	
			(goto name="Development_process_resource_specificity")				
		Relative size of customer's account	fraction of supplier's turnover	ω=	0.25		6
8	**O/book cost.**	Extent of information sharing	(goto name="Extent_of_information_sharing")		100	80	
		Compatibility of Format			0	0	80
9	**Mutl. Devept.**		(goto name="Progress_in_mutual_development")		39		39
10	**Open sys.**		(goto name="Links_of_commercial_systems")		70		70
11	**JIT del.**						n/a
							478

Phantom Benchmark Model

Variables				
No.	Variable	Description	Unit	Value
1	α=	number of customers contributing to 80% of Suppliers sales volume		5
2	β=	maximum value component or system produced by the Supplier	Ecu	102.0
3	γ=	minimum value component or system produced by the Supplier	Ecu	8.4
4	δ=	maximum lead time component or system designed by the Supplier	Yr.	5.0
5	ε=	minimum lead time component or system designed by the Supplier	Yr.	1.5
6	ζ=	interfaces managed externally to the VM		6
7	η=	total possible interfaces		43
8	θ=	number of direct external suppliers for the complete assembly		12
9	κ=	number of significant constituent components in the assembly		17
10	λ=	interfaces managed externally to the VM (NB.intermediate status)		6
11	μ=	total possible interfaces (NB. intermediate status)		43
12		compatible CAD systems		No
13		direct CAD link		No
14		dedicated development teams		Yes
15		guest engineers		Yes
16		integral development teams		No
17	ξ=	VM project lead time (pre-concept to volume production)	Yr.	3.5
18	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	2.0
19	ρ=	Supplier share of development	%	95.0
20	σ=	number of significant sub-components dictated by VM		1
21	τ=	total number of significant sub-components in component		6
22	υ=	role clarity in delegation	%	70.0
23	ϕ=	VM project lead time (concept to volume production)	Yr.	3.0
24	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	2.0
25	χ=	nominal contract length	Yr.	1.0
26	ψ=	duration of model life	Yr.	7.0
27	Rm(1)=	in-bound logistics (number of customers using the resource)		8
28	Rm(2)=	material processing (number of customers using the resource)		8
29	Rm(3)=	component manufacture (number of customers using the resource)		8
30	Rm(4)=	sub-assembly (number of customers using the resource)		1
31	Rm(5)=	final assembly (number of customers using the resource)		1
32	Rm(6)=	despatch (number of customers using the resource)		8
33	Rd(1)=	advanced R&D (number of customers using the resource)		8
34	Rd(2)=	CAD facilities (number of customers using the resource)		3
35	Rd(3)=	prototype manufacture (number of customers using the resource)		8
36	Rd(4)=	testing (number of customers using the resource)		8
37	Rd(5)=	product development (number of customers using the resource)		1
38	Rd(6)=	manufacturing engineering (number of customers using the resource)		4
39		total number of customers of relevant plant		8
40	ω=	percentage of supplier's turnover		25%

Phantom Benchmark Model

Turnover breakdown by customer			
No.	Customer	%	Cum.
1	Rover Group	25	25
2	Ford Motor Co.	25	50
3	Volvo B.V.	15	65
4	Vauxhall Motors	10	75
5	Jaguar Cars	10	85
6	Toyota M.M.E.	5	90
7	Honda U.M.	5	95
8	others	5	100
9		0	100
10		0	100
11		0	100
12		0	100
13		0	100
14		0	100
15		0	100
16		0	100
17		0	100
18		0	100
19		0	100
20		0	100

Component-to-component interfaces

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Re	Lat	Lo	Wi	Wi	Gl	Gl	Do	Int	Ou	Do	Do	Gl	Inn	Ex	Ex	Si
1	Regulator																	
2	Latch/central locking																	
3	Loudspeaker																	
4	Window lift switches	1																
5	Wiring harness	1	1	1	1													
6	Glass channels	1																
7	Glass seals	1					1											
8	Door seals																	
9	Outer panel			1	1													
10	Interior trim panel complete	1		1			1	1	1	1								
11	Door check strap																	
12	Door hinges								1			1						
13	Glass pane	1					1	1			1							
14	Inner panel	1	1	1		1	1	1	1	1	1	1	1					
15	Exterior mirror					1					1							
16	Exterior door handle		1		1	1					1							
17	Side Impact Restraint System					1				1	1				1			

total = 43

Component-to-component interfaces managed externally to the VM

		1	2	5	6	13	14
		Re	Lat	Wi	Gl	Gl	Inn
1	Regulator						
2	Latch/central locking						
5	Wiring harness	✓	✗				
6	Glass channels	✓					
13	Glass pane	✗			✗		
14	Inner panel	✓	✓	✓	✓		
	total=						6

phantom benchmark model

MB - Door

No.	Element	Aspect	process	Variable		Rating sub.	total
1	**Tiered s/b**	Dedication		α=	6.0	19	
		Demarcation		β=	150.0		
			manufacturing	γ=	6.0	0	
				δ=	4.0		
			development	ε=	1.5	15	
		Direct Collaboration		ζ=	0.0		
				η=	43.0	0	33
2	**O/sourcing**		manufacturing			29	
			development			9	38
3	**Sys. purch.**		manufacturing	θ=	16.0		
			(goto name="supply_points_for_complete_door")	κ=	17.0	3	
			development	λ=	0.0		
				μ=	43.0	0	3
4	**S/sourcing**					50	50
5	**D&D deleg.**	Nature of Component					
		split:	critical:				
			efficiency of work-sharing(meshing rating)			15	
			(goto name="efficiency_of_work_sharing")				
			point of first involvement(pre-concept)	ξ=	4.8		
				π=	2.6	4	
		critical =	0			0	
			non-critical:				
			amount of delegation	ρ=	25.0	8	
			efficacy of delegation:				
			(i) sub-supply	σ=	1.0		
				τ=	1.0	0	
			(ii) role clarity	υ=	90.0	30	
						30	
			point of first involvement(concept)	ϕ=	4.2		
				π=	2.6	21	
		non-critical =	100			59	59
6	**L/T contr.**	Nominal Contract		χ=	1.0		
		Length	percentage of model-life	ψ=	6.0	8	
		Certainty of Business					
		Retention	data not available				17
7	**Cust. foc.**	Specificity of Resource					
		Allocation	manufacturing	Rm=	36	4.3	
			(goto name="Manufacturing_process_resource_specificity")				
			development	Rd=	0	0.0	
			(goto name="Development_process_resource_specificity")				
		Relative size of					
		customer's account	fraction of supplier's turnover	ω=	0.15		4
8	**O/book cost.**	Extent of information sharing	(goto name="Extent_of_information_sharing")		25	20	
		Compatibility of Format			100	20	40
9	**Mutl. Devept.**		(goto name="Progress_in_mutual_development")		69		69
10	**Open sys.**		(goto name="Links_of_commercial_systems")		80		80
11	**JIT del.**						n/a
							393

phantom benchmark model

Turnover breakdown by customer			
No.	Customer	%	Cum.
1	VW	20	20
2	BMW	15	35
3	Mercedes-Benz	15	50
4	Audi	10	60
5	Ford-Werke	10	70
6	Adam Opel	10	80
7	Peugeot	5	85
8	Others (7 in total)	15	100
9		0	100
10		0	100
11		0	100
12		0	100
13		0	100
14		0	100
15		0	100
16		0	100
17		0	100
18		0	100
19		0	100
20		0	100

phantom benchmark model

Component-to-component interfaces

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Re	La	Lo	Wi	Wi	Gl	Gl	Do	Int	Ou	Do	Do	Gl	In	Ex	Ex	Si
1	Regulator																	
2	Latch/central locking																	
3	Loudspeaker																	
4	Window lift switches	1																
5	Wiring harness	1	1	1	1													
6	Glass channels	1																
7	Glass seals	1					1											
8	Door seals																	
9	Outer panel			1	1													
10	Interior trim panel complete	1		1			1	1	1	1								
11	Door check strap																	
12	Door hinges								1			1						
13	Glass pane	1					1	1			1							
14	Inner panel	1	1	1		1	1	1	1	1	1	1	1					
15	Exterior mirror					1					1							
16	Exterior door handle		1		1	1					1							
17	Side Impact Restraint System					1				1	1				1			

total = 43

phantom benchmark model

Variables				
No.	Variable	Description	Unit	Value
1	α=	number of customers contributing to 80% of Suppliers sales volume		6
2	β=	maximum value component or system produced by the Supplier	Ecu	150.0
3	γ=	minimum value component or system produced by the Supplier	Ecu	6.0
4	δ=	maximum lead time component or system designed by the Supplier	Yr.	4.0
5	ε=	minimum lead time component or system designed by the Supplier	Yr.	1.5
6	ζ=	interfaces managed externally to the VM		0
7	η=	total possible interfaces		43
8	θ=	number of direct external suppliers for the complete assembly		16
9	κ=	number of significant constituent components in the assembly		17
10	λ=	interfaces managed externally to the VM (NB.intermediate status)		0
11	μ=	total possible interfaces (NB. intermediate status)		43
12		compatible CAD systems		yes
13		direct CAD link		yes
14		dedicated development teams		no
15		guest engineers		no
16		integral development teams		no
17	ξ=	VM project lead time (pre-concept to volume production)	Yr.	4.8
18	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	2.6
19	ρ=	Supplier share of development	%	25.0
20	σ=	number of significant sub-components dictated by VM		1
21	τ=	total number of significant sub-components in component		1
22	υ=	role clarity in delegation	%	90.0
23	φ=	VM project lead time (concept to volume production)	Yr.	4.2
24	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	2.6
25	χ=	nominal contract length	Yr.	1.0
26	ψ=	duration of model life	Yr.	6.0
27	Rm(1)=	in-bound logistics (number of customers using the resource)		14
28	Rm(2)=	material processing (number of customers using the resource)		14
29	Rm(3)=	component manufacture (number of customers using the resource)		14
30	Rm(4)=	sub-assembly (number of customers using the resource)		1
31	Rm(5)=	final assembly (number of customers using the resource)		1
32	Rm(6)=	despatch (number of customers using the resource)		14
33	Rd(1)=	advanced R&D (number of customers using the resource)		14
34	Rd(2)=	CAD facilities (number of customers using the resource)		14
35	Rd(3)=	prototype manufacture (number of customers using the resource)		14
36	Rd(4)=	testing (number of customers using the resource)		14
37	Rd(5)=	product development (number of customers using the resource)		14
38	Rd(6)=	manufacturing engineering (number of customers using the resource)		14
39		total number of customers of relevant plant		14
40	ω=	percentage of supplier's turnover		15%

phantom Benchmark Model

Renault - Door

No.	Element	Aspect	process	Variable		Rating sub.	total
1	**Tiered s/b**	Dedication		$\alpha=$	5.0	20	
		Demarcation		$\beta=$	53.7		
			manufacturing	$\gamma=$	6.9	18	
				$\delta=$	3.5		
			development	$\varepsilon=$	1.0	9	
		Direct Collaboration		$\zeta=$	4.0		
				$\eta=$	43.0	2	50
2	**O/sourcing**		manufacturing			37	
			development			26	63
3	**Sys. purch.**		manufacturing	$\theta=$	7.0		
			(goto name="supply_points_for_complete_door")	$\kappa=$	17.0	31	
			development	$\lambda=$	16.0		
				$\mu=$	43.0	19	50
4	**S/sourcing**					50	50
5	**D&D deleg.**	Nature of Component					
		split:	critical:				
			efficiency of work-sharing(meshing rating)			20	
			(goto name="efficiency_of_work_sharing")				
			point of first involvement(pre-concept)	$\xi=$	4.5		
				$\pi=$	4.0	31	
		critical =	5			3	
			non-critical:				
			amount of delegation	$\rho=$	100.0	33	
			efficacy of delegation:				
			(i) sub-supply	$\sigma=$	0.0		
				$\tau=$	4.0	17	
			(ii) role clarity	$\upsilon=$	95.0	16	
						33	
			point of first involvement(concept)	$\phi=$	3.5		
				$\pi=$	4.0	33	
		non-critical =	95			94	97
6	**L/T contr.**	Nominal Contract		$\chi=$	4.0		
		Length	percentage of model-life	$\psi=$	7.0	29	
		Certainty of Business					
		Retention	data not available				57
7	**Cust. foc.**	Specificity of Resource					
		Allocation	manufacturing	Rm=	0	0.0	
			(goto name="Manufacturing_process_resource_specificity")				
			development	Rd=	36	2.2	
			(goto name="Development_process_resource_specificity")				
		Relative size of					
		customer's account	fraction of supplier's turnover	$\omega=$	0.30		2
8	**O/book cost.**	Extent of information sharing	(goto name="Extent_of_information_sharing")		100	80	
		Compatibility of Format			0	0	80
9	**Mutl. Devept.**		(goto name="Progress_in_mutual_development")		64		64
10	**Open sys.**		(goto name="Links_of_commercial_systems")		70		70
11	**JIT del.**						n/a
							583

phantom Benchmark Model

Variables				
No.	Variable	Description	Unit	Value
1	α=	number of customers contributing to 80% of Suppliers sales volume		5
2	β=	maximum value component or system produced by the Supplier	Ecu	53.7
3	γ=	minimum value component or system produced by the Supplier	Ecu	6.9
4	δ=	maximum lead time component or system designed by the Supplier	Yr.	3.5
5	ε=	minimum lead time component or system designed by the Supplier	Yr.	1.0
6	ζ=	interfaces managed externally to the VM		4
7	η=	total possible interfaces		43
8	θ=	number of direct external suppliers for the complete assembly		7
9	κ=	number of significant constituent components in the assembly		17
10	λ=	interfaces managed externally to the VM (NB.intermediate status)		16
11	μ=	total possible interfaces (NB. intermediate status)		43
12		compatible CAD systems		no
13		direct CAD link		no
14		dedicated development teams		yes
15		guest engineers		yes
16		integral development teams		no
17	ξ=	VM project lead time (pre-concept to volume production)	Yr.	4.5
18	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	4.0
19	ρ=	Supplier share of development	%	100.0
20	σ=	number of significant sub-components dictated by VM		0
21	τ=	total number of significant sub-components in component		4
22	υ=	role clarity in delegation	%	95.0
23	ϕ=	VM project lead time (concept to volume production)	Yr.	3.5
24	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	4.0
25	χ=	nominal contract length	Yr.	4.0
26	ψ=	duration of model life	Yr.	7.0
27	Rm(1)=	in-bound logistics (number of customers using the resource)		11
28	Rm(2)=	material processing (number of customers using the resource)		11
29	Rm(3)=	component manufacture (number of customers using the resource)		11
30	Rm(4)=	sub-assembly (number of customers using the resource)		11
31	Rm(5)=	final assembly (number of customers using the resource)		11
32	Rm(6)=	despatch (number of customers using the resource)		11
33	Rd(1)=	advanced R&D (number of customers using the resource)		11
34	Rd(2)=	CAD facilities (number of customers using the resource)		1
35	Rd(3)=	prototype manufacture (number of customers using the resource)		11
36	Rd(4)=	testing (number of customers using the resource)		11
37	Rd(5)=	product development (number of customers using the resource)		1
38	Rd(6)=	manufacturing engineering (number of customers using the resource)		11
39		total number of customers of relevant plant		11
40	ω=	percentage of supplier's turnover		30%

phantom Benchmark Model

Turnover breakdown by customer			
No.	Customer	%	Cum.
1	Peugeot S.A.	30	30
2	Renault	30	60
3	VW Group	10	70
4	Rover Group	9	79
5	Fiat Group	8	86
6	Nissan M.M.(UK)	4	90
7	IBC Vehicle	1	91
8	Ford of Europe	1	92
9	Adam Opel	1	93
10	Mercedes-Benz	0	93
11	Others	7	100
12		0	100
13		0	100
14		0	100
15		0	100
16		0	100
17		0	100
18		0	100
19		0	100
20		0	100

Component-to-component interfaces

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Re	La	Lo	Wi	Wi	Gl	Gl	Do	Int	Ou	Do	Do	Gl	In	Ex	Ex	Si
1	Regulator																	
2	Latch/central locking																	
3	Loudspeaker																	
4	Window lift switches	1																
5	Wiring harness	1	1	1	1													
6	Glass channels	1																
7	Glass seals	1					1											
8	Door seals																	
9	Outer panel			1	1													
10	Interior trim panel complete	1		1			1	1	1	1								
11	Door check strap																	
12	Door hinges								1			1						
13	Glass pane	1					1	1			1							
14	Inner panel	1	1	1		1	1	1	1	1	1	1	1					
15	Exterior mirror					1					1							
16	Exterior door handle		1		1	1					1							
17	Side Impact Restraint System					1				1	1				1			

total = 43

Component-to-component interfaces managed externally to the VM

		1	2	5	14
		Re	La	Wi	In
1	Regulator				
2	Latch/central locking				
5	Wiring harness	✓	✗		
14	Inner panel	✓	✓	✓	
	total=				4

Phantom benchmark Model

Peugeot - Door

No.	Element	Aspect	process	Variable		Rating sub.	Rating total
1	**Tiered s/b**	Dedication		$\alpha=$	5.0	20	
		Demarcation		$\beta=$	53.7		
			manufacturing	$\gamma=$	6.9	18	
				$\delta=$	3.5		
			development	$\varepsilon=$	1.0	9	
		Direct Collaboration		$\zeta=$	0.0		
				$\eta=$	43.0	0	47
2	**O/sourcing**		manufacturing			32	
			development			20	52
3	**Sys. purch.**		manufacturing	$\theta=$	16.0		
			(goto name="supply_points_for_complete_door")	$\kappa=$	17.0	3	
			development	$\lambda=$	0.0		
				$\mu=$	43.0	0	3
4	**S/sourcing**					50	50
5	**D&D deleg.**	Nature of Component					
		split:	critical:				
			efficiency of work-sharing(meshing rating)			35	
			(goto name="efficiency_of_work_sharing")				
			point of first involvement(pre-concept)	$\xi=$	4.6		
				$\pi=$	1.0	0	
		critical =	0			0	
			non-critical:				
			amount of delegation	$\rho=$	35.0	12	
			efficacy of delegation:				
			(i) sub-supply	$\sigma=$	1.0		
				$\tau=$	1.0	0	
			(ii) role clarity	$\upsilon=$	70.0	23	
						23	
			point of first involvement(concept)	$\phi=$	4.0		
				$\pi=$	1.0	8	
		non-critical =	100			43	43
6	**L/T contr.**	Nominal Contract		$\chi=$	7.0		
		Length	percentage of model-life	$\psi=$	7.0	50	
		Certainty of Business					
		Retention	data not available				100
7	**Cust. foc.**	Specificity of Resource					
		Allocation	manufacturing	Rm=	0	0.0	
			(goto name="Manufacturing_process_resource_specificity")				
			development	Rd=	36	2.2	
			(goto name="Development_process_resource_specificity")				
		Relative size of					
		customer's account	fraction of supplier's turnover	$\omega=$	0.30		2
8	**O/book cost.**	Extent of information sharing	(goto name="Extent_of_information_sharing")		100	80	
		Compatibility of Format			0	0	80
9	**Mutl. Devept.**		(goto name="Progress_in_mutual_development")		27		27
10	**Open sys.**		(goto name="Links_of_commercial_systems")		60		60
11	**JIT del.**						n/a
							465

Phantom benchmark Model

Turnover breakdown by customer			
No.	Customer	%	Cum.
1	Peugeot S.A.	30	30
2	Renault	30	60
3	VW Group	10	70
4	Rover Group	9	79
5	Fiat Group	8	86
6	Nissan M.M.(UK)	4	90
7	IBC Vehicle	1	91
8	Ford of Europe	1	92
9	Adam Opel	1	93
10	Mercedes-Benz	0	93
11	Others	7	100
12		0	100
13		0	100
14		0	100
15		0	100
16		0	100
17		0	100
18		0	100
19		0	100
20		0	100

Phantom benchmark Model

Component-to-component interfaces

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Re	La	Lo	Wi	Wi	Gl	Gl	Do	Int	Ou	Do	Do	Gl	In	Ex	Ex	Si
1	Regulator																	
2	Latch/central locking																	
3	Loudspeaker																	
4	Window lift switches	1																
5	Wiring harness	1	1	1	1													
6	Glass channels	1																
7	Glass seals	1					1											
8	Door seals																	
9	Outer panel			1	1													
10	Interior trim panel complete	1		1			1	1	1	1								
11	Door check strap																	
12	Door hinges								1			1						
13	Glass pane	1					1	1			1							
14	Inner panel	1	1	1		1	1	1	1	1	1	1	1					
15	Exterior mirror					1					1							
16	Exterior door handle		1		1	1					1							
17	Side Impact Restraint System					1				1	1				1			

total = 43

Phantom benchmark Model

Variables				
No.	Variable	Description	Unit	Value
1	α=	number of customers contributing to 80% of Suppliers sales volume		5
2	β=	maximum value component or system produced by the Supplier	Ecu	53.7
3	γ=	minimum value component or system produced by the Supplier	Ecu	6.9
4	δ=	maximum lead time component or system designed by the Supplier	Yr.	3.5
5	ε=	minimum lead time component or system designed by the Supplier	Yr.	1.0
6	ζ=	interfaces managed externally to the VM		0
7	η=	total possible interfaces		43
8	θ=	number of direct external suppliers for the complete assembly		16
9	κ=	number of significant constituent components in the assembly		17
10	λ=	interfaces managed externally to the VM (NB.intermediate status)		0
11	μ=	total possible interfaces (NB. intermediate status)		43
12		compatible CAD systems		yes
13		direct CAD link		yes
14		dedicated development teams		yes
15		guest engineers		yes
16		integral development teams		no
17	ξ=	VM project lead time (pre-concept to volume production)	Yr.	4.6
18	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	1.0
19	ρ=	Supplier share of development	%	35.0
20	σ=	number of significant sub-components dictated by VM		1
21	τ=	total number of significant sub-components in component		1
22	υ=	role clarity in delegation	%	70.0
23	ϕ=	VM project lead time (concept to volume production)	Yr.	4.0
24	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	1.0
25	χ=	nominal contract length	Yr.	7.0
26	ψ=	duration of model life	Yr.	7.0
27	Rm(1)=	in-bound logistics (number of customers using the resource)		11
28	Rm(2)=	material processing (number of customers using the resource)		11
29	Rm(3)=	component manufacture (number of customers using the resource)		11
30	Rm(4)=	sub-assembly (number of customers using the resource)		11
31	Rm(5)=	final assembly (number of customers using the resource)		11
32	Rm(6)=	despatch (number of customers using the resource)		11
33	Rd(1)=	advanced R&D (number of customers using the resource)		11
34	Rd(2)=	CAD facilities (number of customers using the resource)		1
35	Rd(3)=	prototype manufacture (number of customers using the resource)		11
36	Rd(4)=	testing (number of customers using the resource)		11
37	Rd(5)=	product development (number of customers using the resource)		1
38	Rd(6)=	manufacturing engineering (number of customers using the resource)		11
39		total number of customers of relevant plant		11
40	ω=	percentage of supplier's turnover		30%

phantom benchmark model

Citroen - door

No.	Element	Aspect	process	Variable		Rating sub.	Rating total
1	**Tiered s/b**	Dedication		$\alpha=$	5.0	20	
		Demarcation		$\beta=$	53.7		
			manufacturing	$\gamma=$	6.9	18	
				$\delta=$	3.5		
			development	$\varepsilon=$	1.0	9	
		Direct Collaboration		$\zeta=$	0.0		
				$\eta=$	43.0	0	47
2	**O/sourcing**		manufacturing			30	
			development			20	50
3	**Sys. purch.**		manufacturing	$\theta=$	16.0		
			(goto name="supply_points_for_complete_door")	$\kappa=$	17.0	3	
			development	$\lambda=$	0.0		
				$\mu=$	43.0	0	3
4	**S/sourcing**					50	50
5	**D&D deleg.**	Nature of Component					
		split:	critical:				
			efficiency of work-sharing(meshing rating)			35	
			(goto name="efficiency_of_work_sharing")				
			point of first involvement(pre-concept)	$\xi=$	4.6		
				$\pi=$	1.5	1	
		critical =	0			0	
			non-critical:				
			amount of delegation	$\rho=$	35.0	12	
			efficacy of delegation:				
			(i) sub-supply	$\sigma=$	1.0		
				$\tau=$	1.0	0	
			(ii) role clarity	$\upsilon=$	65.0	22	
						22	
			point of first involvement(concept)	$\phi=$	4.0		
				$\pi=$	1.5	13	
		non-critical =	100			46	46
6	**L/T contr.**	Nominal Contract		$\chi=$	7.0		
		Length	percentage of model-life	$\psi=$	7.0	50	
		Certainty of Business					
		Retention	data not available				100
7	**Cust. foc.**	Specificity of Resource					
		Allocation	manufacturing	Rm=	0	0.0	
			(goto name="Manufacturing_process_resource_ specificity")				
			development	Rd=	36	2.2	
			(goto name="Development_process_resource_ specificity")				
		Relative size of					
		customer's account	fraction of supplier's turnover	$\omega=$	0.30		2
8	**O/book cost.**	Extent of information sharing	(goto name="Extent_of_information_sharing")		50	40	
		Compatibility of Format			0	0	40
9	**Mutl. Devept.**		(goto name="Progress_in_mutual_development")		23		23
10	**Open sys.**		(goto name="Links_of_commercial_systems")		60		60
11	**JIT del.**						n/a
							421

phantom benchmark model

Turnover breakdown by customer			
No.	Customer	%	Cum.
1	Peugeot S.A.	30	30
2	Renault	30	60
3	VW Group	10	70
4	Rover Group	9	79
5	Fiat Group	8	86
6	Nissan M.M.(UK)	4	90
7	IBC Vehicle	1	91
8	Ford of Europe	1	92
9	Adam Opel	1	93
10	Mercedes-Benz	0	93
11	Others	7	100
12		0	100
13		0	100
14		0	100
15		0	100
16		0	100
17		0	100
18		0	100
19		0	100
20		0	100

Component-to-component interfaces

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Re	La	Lo	Wi	Wi	Gl	Gl	Do	Int	Ou	Do	Do	Gl	In	Ex	Ex	Si
1	Regulator																	
2	Latch/central locking																	
3	Loudspeaker																	
4	Window lift switches	1																
5	Wiring harness	1	1	1	1													
6	Glass channels	1																
7	Glass seals	1					1											
8	Door seals																	
9	Outer panel			1	1													
10	Interior trim panel complete	1		1			1	1	1	1								
11	Door check strap																	
12	Door hinges								1			1						
13	Glass pane	1					1	1			1							
14	Inner panel	1	1	1		1	1	1	1	1	1	1	1					
15	Exterior mirror					1					1							
16	Exterior door handle		1		1	1					1							
17	Side Impact Restraint System					1				1	1				1			

total = 43

phantom benchmark model

Variables				
No.	Variable	Description	Unit	Value
1	α=	number of customers contributing to 80% of Suppliers sales volume		5
2	β=	maximum value component or system produced by the Supplier	Ecu	53.7
3	γ=	minimum value component or system produced by the Supplier	Ecu	6.9
4	δ=	maximum lead time component or system designed by the Supplier	Yr.	3.5
5	ε=	minimum lead time component or system designed by the Supplier	Yr.	1.0
6	ζ=	interfaces managed externally to the VM		0
7	η=	total possible interfaces		43
8	θ=	number of direct external suppliers for the complete assembly		16
9	κ=	number of significant constituent components in the assembly		17
10	λ=	interfaces managed externally to the VM (NB.intermediate status)		0
11	μ=	total possible interfaces (NB. intermediate status)		43
12		compatible CAD systems		yes
13		direct CAD link		yes
14		dedicated development teams		yes
15		guest engineers		yes
16		integral development teams		no
17	ξ=	VM project lead time (pre-concept to volume production)	Yr.	4.6
18	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	1.5
19	ρ=	Supplier share of development	%	35.0
20	σ=	number of significant sub-components dictated by VM		1
21	τ=	total number of significant sub-components in component		1
22	υ=	role clarity in delegation	%	65.0
23	ϕ=	VM project lead time (concept to volume production)	Yr.	4.0
24	π=	Supplier involvement period (supplier commitment point to volume production)	Yr.	1.5
25	χ=	nominal contract length	Yr.	7.0
26	ψ=	duration of model life	Yr.	7.0
27	Rm(1)=	in-bound logistics (number of customers using the resource)		11
28	Rm(2)=	material processing (number of customers using the resource)		11
29	Rm(3)=	component manufacture (number of customers using the resource)		11
30	Rm(4)=	sub-assembly (number of customers using the resource)		11
31	Rm(5)=	final assembly (number of customers using the resource)		11
32	Rm(6)=	despatch (number of customers using the resource)		11
33	Rd(1)=	advanced R&D (number of customers using the resource)		11
34	Rd(2)=	CAD facilities (number of customers using the resource)		1
35	Rd(3)=	prototype manufacture (number of customers using the resource)		11
36	Rd(4)=	testing (number of customers using the resource)		11
37	Rd(5)=	product development (number of customers using the resource)		1
38	Rd(6)=	manufacturing engineering (number of customers using the resource)		11
39		total number of customers of relevant plant		11
40	ω=	percentage of supplier's turnover		30%

BMW - door

No.	Element	Aspect	process	Variable		Rating sub.	Rating total
1	**Tiered s/b**	Dedication		α=	6.0	19	
		Demarcation		β=	150.0		
			manufacturing	γ=	6.0	0	
				δ=	4.0		
			development	ε=	1.5	15	
		Direct Collaboration		ζ=	0.0		
				η=	43.0	0	33
2	**O/sourcing**		manufacturing			31	
			development			20	51
3	**Sys. purch.**		manufacturing	θ=	16.0		
			(goto name="supply_points_for_complete_door")	κ=	17.0	3	
			development	λ=	0.0		
				μ=	43.0	0	3
4	**S/sourcing**					50	50
5	**D&D deleg.**	Nature of Component					
		split:	critical:				
			efficiency of work-sharing(meshing rating)			5	
			(goto name="efficiency_of_work_sharing")				
			point of first involvement(pre-concept)	ξ=	5.0		
				π=	2.6	4	
		critical =	0			0	
			non-critical:				
			amount of delegation	ρ=	55.0	18	
			efficacy of delegation:				
			(i) sub-supply	σ=	1.0		
				τ=	1.0	0	
			(ii) role clarity	υ=	85.0	28	
						28	
			point of first involvement(concept)	ϕ=	4.2		
				π=	2.6	21	
		non-critical =	100			67	67
6	**L/T contr.**	Nominal Contract		χ=	1.0		
		Length	percentage of model-life	ψ=	6.5	8	
		Certainty of Business					
		Retention	data not available				15
7	**Cust. foc.**	Specificity of Resource					
		Allocation	manufacturing	Rm=	36	4.3	
			(goto name="Manufacturing_process_resource_specificity")				
			development	Rd=	0	0.0	
			(goto name="Development_process_resource_specificity")				
		Relative size of					
		customer's account	fraction of supplier's turnover	ω=	0.15		4
8	**O/book cost.**	Extent of information sharing	(goto name="Extent_of_information_sharing")		50	40	
		Compatibility of Format			100	20	60
9	**Mutl. Devept.**		(goto name="Progress_in_mutual_development")		80		80
10	**Open sys.**		(goto name="Links_of_commercial_systems")		80		80
11	**JIT del.**						n/a
							444

Phantom benchmark model

Turnover breakdown by customer			
No.	Customer	%	Cum.
1	VW	20	20
2	BMW	15	35
3	Mercedes-Benz	15	50
4	Audi	10	60
5	Ford-Werke	10	70
6	Adam Opel	10	80
7	Peugeot	5	85
8	Others (7 in total)	15	100
9		0	100
10		0	100
11		0	100
12		0	100
13		0	100
14		0	100
15		0	100
16		0	100
17		0	100
18		0	100
19		0	100
20		0	100

Phantom benchmark model

Component-to-component interfaces

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Re	La	Lo	Wi	Wi	Gl	Gl	Do	Int	Ou	Do	Do	Gl	In	Ex	Ex	Si
1	Regulator																	
2	Latch/central locking																	
3	Loudspeaker																	
4	Window lift switches	1																
5	Wiring harness	1	1	1	1													
6	Glass channels	1																
7	Glass seals	1					1											
8	Door seals																	
9	Outer panel			1	1													
10	Interior trim panel complete	1		1			1	1	1	1								
11	Door check strap																	
12	Door hinges								1			1						
13	Glass pane	1					1	1			1							
14	Inner panel	1	1	1		1	1	1	1	1	1	1	1					
15	Exterior mirror					1					1							
16	Exterior door handle		1		1	1					1							
17	Side Impact Restraint System					1				1	1				1			

total = 43

Phantom benchmark model

Variables				
No.	Variable	Description	Unit	Value
1	$\alpha=$	number of customers contributing to 80% of Suppliers sales volume		6
2	$\beta=$	maximum value component or system produced by the Supplier	Ecu	150.0
3	$\gamma=$	minimum value component or system produced by the Supplier	Ecu	6.0
4	$\delta=$	maximum lead time component or system designed by the Supplier	Yr.	4.0
5	$\varepsilon=$	minimum lead time component or system designed by the Supplier	Yr.	1.5
6	$\zeta=$	interfaces managed externally to the VM		0
7	$\eta=$	total possible interfaces		43
8	$\theta=$	number of direct external suppliers for the complete assembly		16
9	$\kappa=$	number of significant constituent components in the assembly		17
10	$\lambda=$	interfaces managed externally to the VM (NB.intermediate status)		0
11	$\mu=$	total possible interfaces (NB. intermediate status)		43
12		compatible CAD systems		yes
13		direct CAD link		no
14		dedicated development teams		no
15		guest engineers		no
16		integral development teams		no
17	$\xi=$	VM project lead time (pre-concept to volume production)	Yr.	5.0
18	$\pi=$	Supplier involvement period (supplier commitment point to volume production)	Yr.	2.6
19	$\rho=$	Supplier share of development	%	55.0
20	$\sigma=$	number of significant sub-components dictated by VM		1
21	$\tau=$	total number of significant sub-components in component		1
22	$\upsilon=$	role clarity in delegation	%	85.0
23	$\phi=$	VM project lead time (concept to volume production)	Yr.	4.2
24	$\pi=$	Supplier involvement period (supplier commitment point to volume production)	Yr.	2.6
25	$\chi=$	nominal contract length	Yr.	1.0
26	$\psi=$	duration of model life	Yr.	6.5
27	Rm(1)=	in-bound logistics (number of customers using the resource)		14
28	Rm(2)=	material processing (number of customers using the resource)		14
29	Rm(3)=	component manufacture (number of customers using the resource)		14
30	Rm(4)=	sub-assembly (number of customers using the resource)		1
31	Rm(5)=	final assembly (number of customers using the resource)		1
32	Rm(6)=	despatch (number of customers using the resource)		14
33	Rd(1)=	advanced R&D (number of customers using the resource)		14
34	Rd(2)=	CAD facilities (number of customers using the resource)		14
35	Rd(3)=	prototype manufacture (number of customers using the resource)		14
36	Rd(4)=	testing (number of customers using the resource)		14
37	Rd(5)=	product development (number of customers using the resource)		14
38	Rd(6)=	manufacturing engineering (number of customers using the resource)		14
39		total number of customers of relevant plant		14
40	$\omega=$	percentage of supplier's turnover		15%