THE IMPACT OF PRODUCT VISUAL ASPECTS ON DEVELOPMENT PROCESSES AND SUCCESS IN THE COMPONENT SUPPLY INDUSTRY

A thesis submitted for the degree of Doctor of Philosophy

by

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0 Preface

0.1 Abstract

The study describes how product visual aspects affect development processes and success in the component supply industry.

Past research has demonstrated the importance of the product development function to component supply companies. Previous publications have also shown that visual and aesthetic properties are important for the success of manufactured products.

The objective of the study was firstly, to establish on a general level how supply companies control the development process and whether supplier involvement in component development affects their business success. The second stage was to examine more specifically whether visual aspects of products affect development control and business success in the supply industry.

The thesis is presented as six chapters. Chapter 1 provides an introduction. Chapter 2 sets up a model of product development in the supply industry, conducts a series of case studies in industry and develops three hypotheses predicting the impact of product visuals on the development process and success in the component supply industry. In chapter 3 develops a research method for an extensive survey. Chapter 4 plots the data collected in the survey. Chapter 5 discusses the plots examining the three hypotheses.

It was shown that supplier control in the development of component visuals decreased with the visual significance of the component in the final product. Furthermore, component profits for supply companies increased with the visual significance of the component in the final product.

Finally in chapter 6 conclusions are made.

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0.5 Acknowledgements

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3. The intellectual support of Dr Thomas Inns from the DRC
4. The support of Professor Eric Billett & Professor Peter Isherwood in allowing this research to be carried out from Germany and within the Department of Design, Brunel University

0.6 Glossary of terms

term	explanation
component	Manufactured products usually consist of different components. The PC mouse in figure 0.1 consists of a cable, a chip and a plastic moulding.
lead manufacturer	A company that buys components and assembles or builds them into complete products. The lead manufacturer in figure 0.1 assembles the components into a PC- mouse.
supplier	A company that sells component(s) to a lead manufacturer.
visible element	A part of a component that is visible to the user once the component has become part of the final product. The elements in the diagram which are visible to the user are the parts of the cable outside the moulding and likewise the external surface of the moulding.
non-visible element	A part of a component that is not visible to the user once the component has become part of the final product. The non-visible elements in the diagram are the micro-chip, the part of the cable inside the moulding and the parts of the moulding which are hidden from the eye of the user.
visual significance of a component in the final product	Manufactured products consist of different components. Some components are visually more significant to the overall product than others. To the visual function of the PC mouse, the moulding in figure 0.1 is probably more significant than the cable.
share in visible surface	On of the measures to analyse visual significance. The visual significance of components in final products is measured by ranking components in terms of their share in the visible surface, usually expressed by size. The moulding of the PC mouse in figure 0.1 has a higher share in the visible surface than the cable.
customisation	A customised component is designed specifically for one lead manufacturer. Other lead manufacturers cannot use the component as part of their product. In figure 0.1, the moulding and the chip are customised. The cable is not customised. It is sold to other lead manufacturers as well.

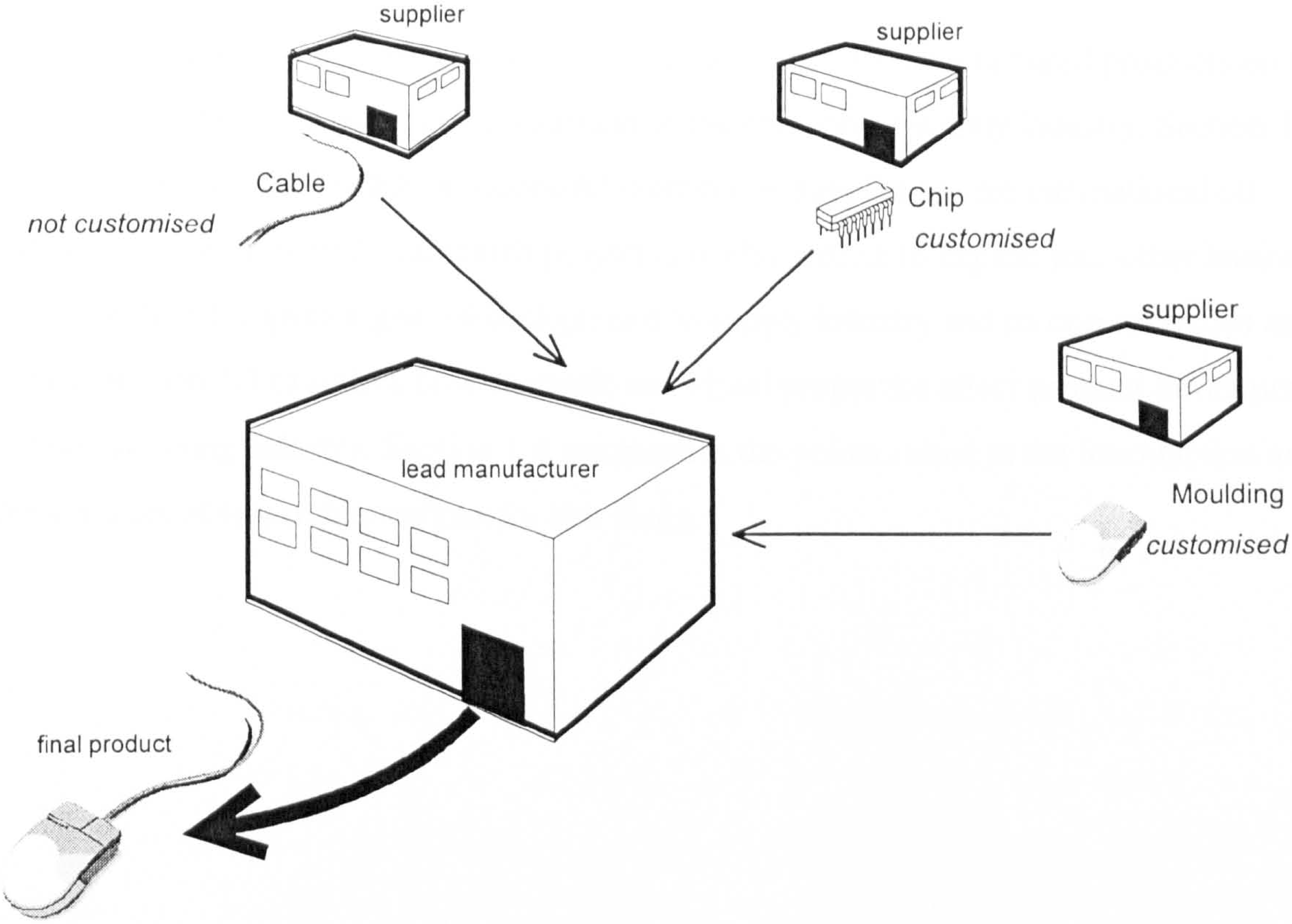

figure 0.1 diagram showing the supply chain for the manufacture of a computer mouse

1 Introduction

The following thesis examines the impact of visual aspects of manufactured products on the development processes and business success in the component supply industry. Section 1.1 introduces HIBY-ELAFLEX, a successful component supplier for the international oil industry who sponsored this research project and who wishes to expand into other business areas. Section 1.2 gives a general background to supply industry and its current trends and issues. Section 1.3 examines how aesthetic and visual properties affect product development in manufacturing industry. Section 1.4 summarises the points raised in the introduction and derives a set of research questions for this study.

1.1 Background to study

The author of this study graduated in Industrial Design from Brunel University in June 1995 and began his first employment in the design department at HIBY/ ELAFLEX in Germany. HIBY Plettenberg together with its trading company ELAFLEX Hamburg have a staff of about 350 people generating an annual turnover of 50m Euro. The companies specialise in the design, production and distribution of valves, fittings and hoses for automotive refuelling (see figure 1.1). The company's most profitable product line is the ZVA nozzle series for the refuelling of motorcars at service stations. 95% of all petrol stations in Europe and 50% of all service stations in Asia are equipped with ZVA nozzles of which HIBY produces more than 300.000 every year.

Marketing departments in oil companies consider nozzles important because they are the only device which customers touch and operate on their sites. When drawing up supply tenders for petrol dispensers, oil companies specify to the dispenser manufacturers which type of nozzle they require on their pumps. If oil companies specify ZVA, dispenser manufactures will buy and assemble HIBY/ ELAFLEX products.

In recent years, the management of HIBY/ ELAFLEX decided to diversify and expand its activities as a component supplier to industry. As part of this diversification strategy, the company offered the author sponsorship for a comprehensive study on product development in the supply industry. In 1996, Dr Tom Inns from the Design Research Centre at Brunel University agreed to supervise the project. The author and the Design Research Centre have a strong background in Industrial Design and HIBY-ELAFLEX's initial idea was to diversify into new markets by copying the function of existing components based on technologies available in the company, but improve their visual qualities. The management of HIBY-ELAFLEX therefore asked the author to investigate opportunities for exploiting product visual aspects in the component supply industry. After some initial research, the author and the DRC laid out the objectives for the study. The first stage was to establish on a general level how supply companies control the development process and whether supplier involvement in component development affects their business success. The second stage was to examine more specifically whether visual aspects of products affect development control and business success in the supply industry.

figure 1.1 picture of ZVA nozzle

1.2 Component supply industry

HIBY-ELAFLEX is a typical component supplier for international oil companies. Component suppliers can be found in many different sectors of industry. Complex products like household appliances, motorcars, aeroplanes, machine-tools, computers etc. consist of many, sometimes thousands of different components. Components can be defined as sub-systems, assemblies or units which lead manufacturers buy from suppliers and build into their products. Components are part of the final product and leave the factory of the lead manufacturer after final assembly (see Engelhardt and Günter, 1981 [1]).

The purchasing of components has become a key function in many manufacturing organisations. Germany's largest corporation, DaimlerChrysler AG, has an annual purchasing volume worth 52 billion Euro which is about 45% of the company's total revenues (see Jackson, 1998 [2]). In a survey of CEOs, 66% of executives felt that purchasing is more important than all other activities, except marketing and finance (see McKeefry, 1993 [3]).

1.2.1 Levels of supply relationships

Companies that manufacture complex products can, in principle, choose between two forms of organising the production of their components: They can either produce components in-house or buy components from suppliers. Buying components on an open supply market represents the most basic form of industrial organisation. Early capitalist theory regarded market sourcing as the result of a radical division of labour ensuring optimum productivity (see Adam Smith, 1776 [[4]])

The correct mix between the integration of in-house production and market sourcing of components has been subject of industrial research and analysis for many years (see Culliton, 1942 [[5]] and Rasch, 1968 [[6]]). In modern business literature the subject is often found under the terms *production depth*, *vertical integration*, *make-or-buy decision* and numerous researchers have explored the issue from various angles. Siebert, 1990 [[7]] divided studies on the subject into four major groups:

1. studies analysing the make-or-buy decision process
2. studies analysing the classical motives for vertical integration
3. studies describing the success of integration strategies
4. studies analysing the determinants of production depth and its change

As described above, market sourcing and in-house production represent the most basic forms of industrial organisation. A third option for lead manufacturers and suppliers is to form strategic alliances or cooperations. According to Siebert, 1990 [[7]] the difference between cooperations and market sourcing relationships is that lead manufacturers and suppliers are committed longer term giving each other a certain amount of security concerning their future business behaviour. Co-operation can take on different legal forms:

- joint ventures
- minority ownership
- license agreements
- supply contracts

1.2.2 Recent trends in supply industry

In section 1.2.1 three basic types of industrial organisation were introduced. In many industries, lead manufacturers developed their entire final products before asking suppliers to produce individual components to precise specifications. In recent years, many industrial organisations have changed their supply strategy from simple component buying to supply chain optimisation (see Dumond, 1995 [[8]]). Lead manufacturers have also shifted responsibility for component development and design to suppliers (see Hayes and Wheelwright, 1984 [[9]]; Womack, Jones and Roos, 1990 [[10]]; Clark and Fujimoto, 1991 [[11]]; OECD, 1992 [[12]]). Motor manufacturers, for example, are reducing their in-house production depth asking suppliers to design and produce increasingly complex modules and system solutions like complete cockpit assemblies with instrument panels, air-conditioning or steering systems with integrated air-bags. Werner Mischke, head of development at Audi AG, estimated that 50% of his company's design and development work is now done by suppliers (see Ostle, 1999 [[13]]).

The transfer of development responsibilities form lead manufacturers to component suppliers has had important consequences on how supply companies acquire new business. The chamber of industry and commerce for Munich and Upper Bavaria advises supply companies in setting up in-house product development capabilities (see Stelzer, 1998 [[14]]). For the development of new BMW 3-series launched in spring 1998, the motor manufacturer defined 20 component modules. Forty months before the car was launched, BMW held design competitions among leading suppliers. For each module a group of three to seven suppliers was given design briefs. The suppliers had three months to develop ideas and present their concepts to BMW. The best concepts were chosen and only the winning suppliers were accepted on the product development team (see Chew, [[15]]).

Similar trends also exist in the aerospace industry where component or sub-system suppliers are becoming responsible for providing full technical solutions to complex problems (see Paliwoda and Bonnaccorsi, 1994 [[16]]). Hibbert, 1997 [[17]] described the development of the *Global Express Jet* by the Canadian aircraft manufacturer Bombardier. The company selected component and system suppliers, specified requirements and general system characteristics. The suppliers were responsible for developing, testing, integrating, flight-testing and certifying their components. They were also in charge of selecting and co-operating with their own, second-tier suppliers. Bombardier kept authority on certification of the final aircraft.

Motives behind integrating suppliers in development

By giving component development responsibilities to suppliers, lead manufacturers have obtained a number of benefits including reduced costs and business risks as well as an improved development process.

reduced cost and business risks

The Chicago-based management consultancy AT Kearney conducted an extensive industrial study and found that the best companies had reduced their costs by 12% as a result of advanced purchasing practices (see Burton, 1997 [[18]]). Bonnaccorsi and Lipparni, 1994 [[19]] conducted a survey amongst industrial managers in Italy and identified some of the reasons behind this cost-saving potential. Respondents explained that suppliers who were active in component development helped their business to reduce costs because:

- Suppliers encouraged component standardisation.
- The cost/ performance trade-off became more visible because lead manufacturers were able to compare several concepts from different suppliers
- Consistency between product design and the suppliers' manufacturing capabilities was improved.
- Less engineering changes were necessary at late stages of the development.
- Contracts ensured component target prices.

Paliwoda, 1994 [[16]], 1993 [[20]] found that aircraft manufacturers have reduced their own business risks if they make suppliers responsible for developing and integrating entire components or sub-systems. In case of component failure, lead manufacturers can simply pass product liability on to their suppliers.

improvement of development process

AT Kearney's study on industry practices showed that by involving suppliers in development, the best companies reduced their new product development lead times by more than 60%. Bonnaccorsi and Lipparni found that supplier integration accelerates product development because:

- Suppliers and lead manufacturer establish concurrent engineering between their teams.
- Technical problems are identified earlier.

- Suppliers can plan component manufacturing more effectively.

1.3 *Product visual aspects*

Section 1.1 introduced HIBY-ELAFLEX a successful component supplier for the international oil industry which wants to diversify its supply business into other sectors. The author and supervisor of this study were trained in Industrial Design and have an interest in the aesthetic and visual aspects of manufactured products. The management of HIBY-ELAFLEX asked the author to investigate opportunities for exploiting visual aspects in the supply industry.

Section 1.2 gave a brief introduction to component supply industry. It was found that relationships between suppliers and lead manufacturers can operate on different levels. Trends indicate that many large manufacturing organisations have reduced their technology depth and have given more development responsibility to suppliers thereby reducing costs, business risks and improving development processes. For many supply companies, development skills have become an important competitive asset.

The following section reviews the importance of visual appearance, style and aesthetics for product design and product development in manufacturing industry.

1.3.1 Product technology vs. Product aesthetics

Manufactured products have many functions. One of them is a visual function. Product designers, marketing people and R&D engineers often argue about the value of product visual aspects, aesthetics and style in relation to a product's technical functions and physical performance.

Pugh, 1991 [[21]] took an extreme stance advising product engineers that visual performance always comes before technical performance:

> "Never forget, whatever the product, that the customer *sees* it first, before he buys it - the physical performance comes later. The visual performance is always first."

According to Harada (published by Burr, 1989 [[22]]), consumer perception of a product's technical properties is often strongly influenced by its visual appearance:

> "By merely looking at a product, the consumer will form a hypothetical image of many properties besides shape and appearance: they will assume knowledge about functional properties, for instance the engine power and driving characteristics of a car passing by or the sound recording quality of a cassette tape in a shop window."

Ulrich and Eppinger, 1995 [[23]] also followed the argument that customers do not evaluate products merely on technical properties:

> "Companies would... market the product on the merits of its technology alone, although customers certainly evaluate a product using more holistic judgements, including ergonomics and style."

Gustafsson and Granbom, 1993 [[24]] found that many consumers do not admit or are not aware of the fact that aesthetic properties affect their preference for certain products. The researchers developed a number of design variations of a domestic heat level sensor which is used to adjust room temperatures. The design variations were shown to potential consumers to test their preference for certain technical as well as aesthetic attributes. Before the test, most consumers had claimed that product visual characteristics were unimportant and would not affect their choice. Gustafsson and Granbom found that if consumers considered the technical functions of two design variations equal, it was likely that consumers chose the product with the shape they found most appealing.

To resolve the conflict between aesthetic properties and technical properties and the argument which of the two are more important for products, Ulrich and Eppinger distinguished between technology-driven and user-driven products:

> "The primary characteristic of a *technology-driven* product is that its core benefit is based on its technology, or its ability to accomplish a specific technical task. While such a product may still have important aesthetic or ergonomic requirements, consumers will most likely purchase the product primarily for its technical performance...The core benefit of a *user-driven* product is derived form the functionality of its interface and/ or its aesthetic appeal...while these products may be technically sophisticated, the technology does not differentiate the product...rarely does a product fit exactly into a given category. Instead, most products fall somewhere along the continuum."

Ulrich and Eppinger also emphasised that aesthetic aspects become more important if product technology matures:

> "One example is the Sony Walkman. The core benefit of the first Walkman model was its technology (miniature tape player). As competition entered this market, however, Sony relied heavily on ID to create aesthetic appeal and enhanced utility, adding to the technical advantages of subsequent models."

Desbarats, 1998 [[25]] also underlined the commercial value of aesthetics for products whose technology is mature:

> "In any market with modest technical maturity, design and brand ownership will deliver far higher margins than any direct form of manufacturing."

1.3.2 Product and Corporate Identity

Section 1.3.1 explained that visual aspects are important for manufactured products because consumers judge products mainly on the basis of their appearance. Visual characteristics are increasingly important if products are user-driven and if underlying technology is mature.

The growing significance of corporate identity in the business world also indicates that visual qualities are of key strategic importance to many companies. The MORI research company conducted a survey in 1992 amongst chairmen of some of Europe's biggest corporations. The results were both interesting and significant. Corporate identity emerged as one of the main concerns in the minds of the people who ran these companies.

According to Ollins, 1995 [[26]] product is an important part of a corporate identity:

> "The fundamental idea behind an identity programme is that everything the organisation does, everything it owns, and everything it produces should project a clear idea of what it is and what its aims are. The most significant way in which this can be done is by making everything in and around the organisation - its products, buildings, communications and behaviour -consistent in purpose and performance and, where this is appropriate, in appearance too."

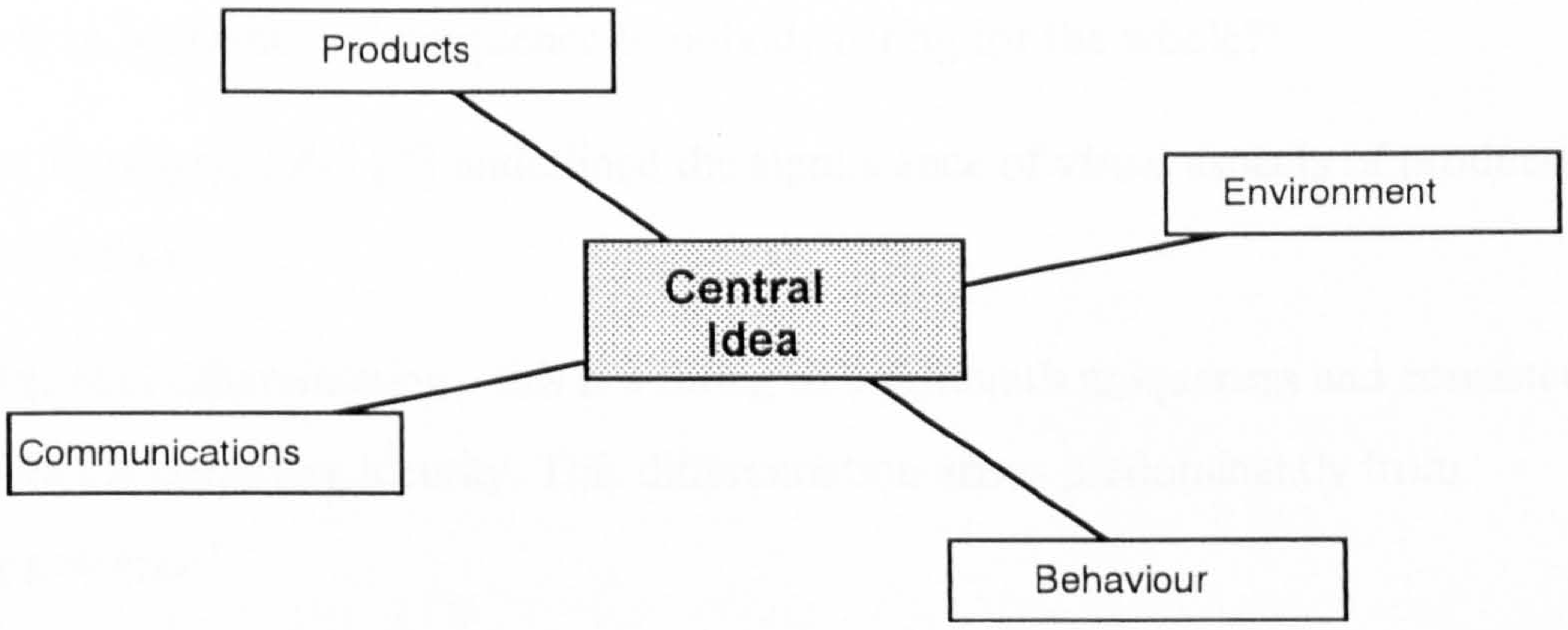

figure 1.2 model of corporate identity by Ollins

Ollins created a model of corporate identity shown in figure 1.2.

Although product is only one element in Ollins' identity mix, the author stresses that for some companies, product can be the most important element:

> "In a product-based company, it is the product that is the most significant element in the identity mix. The most important single factor in creating the identity of, say, the Jaguar company is the car itself...The same holds true for Parker, Seaffer or Lamy in

the writing-instruments business...each company's product has a different image, largely conditioned by its appearance and price." (Ollins, 1989 [27])

"Many organisations deliberately design their products / services with their identity in mind. Sony's identity is based around the products it designs and makes." (Ollins, 1995 [26])

Grinyer, 1998 [28] explained that products have become so critical for corporate identity that the design decision process is shifting from R&D to Marketing departments:

"And yet design is increasingly commissioned by marketing people rather than engineering or research and development departments as it is understood that the product is the most powerful and best communicator of brand value and corporate differentiation."

To implement corporate identity through product design, Ollins, 1989 [27] suggested product audits:

"Do the products that the company makes and sells have consistent style and quality? Or, on the contrary, is there no connection between one product range and the next? And if there is no consistency, is this intentional, because of branding - or is it an accident, a consequence of nobody caring for the whole?"

Ulrich and Eppinger, 1995 [23] underlined the significance of visual aspects of products for corporate identity:

"Product differentiation - this is a rating of a product's uniqueness and consistency with the corporate identity. This differentiation arises predominantly from appearance"

1.3.3 Product visual aspects and consumer culture

Section 1.3.1 explained that visual aspects are important for manufactured products because consumers judge products largely on the basis of their appearance. Visual characteristics are increasingly important if products are user-driven and if underlying technology is mature.

Section 1.3.2 suggested that product visual aspects are important for companies as they are a strong element of corporate identity.

The following section summarises views which consider visual design a means for influencing buyer behaviour.

Ruiz, 1996 [[29]] described how product visual characteristics appeal to the senses:

> "The fantasy value of a product is a subliminal element that makes the buyer feel good about purchasing a certain product that is not a necessity but appeals to the senses. In many cases, the design packaging greatly contributes to the fantasy value development of a product."

Moberly, 1996 [[30]] describes design as a form of visual seduction:

> "...at one level, design is a form of visual seduction. Think of the market food stalls in France with their mouth-wateringly attractive, tactile displays of fruits and vegetables. Anita Roddick is right when she says: *The first bite is taken with the eye.*"

Killip, 1997 [[31]] advocates visual design to guide customer choice:

> "Strong and memorable branding will guide your customer to making the right choice when faced with the inevitable barrage of repeat purchase options. Colour, shape, brand image, functionality and product satisfaction all play a role in guiding the right choice."

Walker, 1989 [[32]] argued that the central purpose of design, fashion, shopping and consumption is to create pleasure:

> "The pleasure derived from owning and using an object is bound up with the pleasure of its desire, the act of purchase and the perception that others have of the consumer by virtue of that ownership. Design should therefore aim to enhance the pleasure derived from each of these sources..."

Table 1.1 shows the sources of pleasure together with the contribution that design makes to each of them as adapted from Walker.

table 1.1 list of design pleasure principles according to Walker

Sources of pleasure	Design contribution
Desire	Conceiving and expressing the myth or fantasy Advertising
Purchase	Packaging Display Retail environment
The object	Qualities of newness Tactile qualities Aesthetic appeal
Use	Performance Ergonomics Ease of use
Perception by others	Symbolic value

A number of researchers have identified a shift away from price-led consumption satisfying fundamental needs towards a consumption driven by style and image. Cooper and Press, 1995 [[33]] wrote:

> "Sign value therefore begins to erode price as a factor considered important by consumers."

Japanese automotive designer Naoki Sakai argued that this is leading towards what he describes as the conceptual economy:

> "In this economy value is imaginary. There need be no relation between sales price and production cost. Instead in this system of artificial value, the psychological nature of the product is what determines its desirability and hence its cost. It's the sort of mechanism in operation in the world of fashion." (see also Platt, 1991 [[34]])

In this context, the expression 'lifestyle' is often used:

> "An important concept in consumer culture is lifestyle: self-expression and the assertion of individuality through the consumption of distinctive styles of goods and services." (see Featherstone, 1987 [[35]])

In a report published in 1988, the Japanese Ministry of International Trade and Industry (MITI) advised companies to adjust their product development strategies accordingly:

> "People no longer base their decisions for purchase only on the fundamental criteria such as function, economy and safety. Now there is a growing tendency to select on the basis of secondary criteria... The future of design would seem to indicate greater individualism and design diversification, possibly leading to an inordinate variety of products." (see Pilditch, 1989 [[36]])

The greater individualism, design diversification and inordinate variety of products predicted by the Japanese MITI in 1988, can today be observed when looking at the ever-increasing visual variety in products like kitchen appliances, mobile phones or motorcars, complex products which are often based on fewer technical platforms. This was clearly demonstrated during the development of the Rover 600, an offspring of the Honda Accord. By keeping as many common components as possible between the Accord and the 600, the two car companies minimised the development and production costs of their new cars. Jones, 1997 [[37]] describes how this strategy was put into practice:

> "Whilst adopting this approach, there was the need to differentiate the two vehicles and, from Rover's perspective, to add the necessary styling features to position the 600 as a distinctive, prestigious and aspirational product. Whereas in the past, the Rover models which had arisen from the partnership had mainly been re-badged versions of Honda vehicles, with this project it was felt that a more recognisable differentiation was necessary. In achieving this, the major problem which faced the Rover design team was that the body structure and dynamics of the two vehicles were to remain identical - the same transmission, electronics and suspension were all incorporated in the same body. The only components which were eligible for redesign were therefore those which formed either the exterior or interior surfaces of the product."

Many car companies are following the Rover/ Honda example and are now creating a wider range of models basing them on fewer standardised platforms. The Ford Motor company wants to reduce its platforms from 32 down to 16 by the year 2004. Nissan has currently got 30 global platforms and wants to cut that number down to 10. Renault has 5 platforms and will have only 3 platforms by the year 2000. Successors of the Laguna, Safrane and

Espace will all be based on one common platform. Volkswagen is wishing to expand its VW, Seat, Skoda, Audi brands on just 4 different platforms (see Weernink, 1997 [[38]]).

Michael Treschow, chief executive of Electrolux, the world's largest household appliance group, is following the automotive example and announced the development of a series of common global platforms for its products, including refrigerators, vacuum cleaners and freezers. Following an unsuccessful attempt by US-rival Whirlpool to produce a world washer which failed to take account of differing regional tastes, Electrolux wants to cut cost by producing a basic oven platform for Europe but changing particular visual features in certain markets and strengthening the identity of its Zanussi and AEG brand names (see Burt, 1999 [[39]]).

Capital Products

One might argue that visual aspects play an important role in consumer products, but are less crucial in the design of capital products whose purchase is not driven by personal style and emotional values. Yamaoto and Lambert, 1994 [[40]] investigated the impact of product aesthetics on the evaluation of industrial products and found that performance and price are indeed critical, but aesthetically pleasing properties appear to have a positive influence upon the preference of industrial buyers.

Lorenz, 1986 [[41]] published a case study on the farming equipment company John Deere. Apart form high quality manufacture, innovation and a strong dealer network, the company's management is convinced that industrial design has played a key part in Deere's rise to become America's largest maker of agricultural equipment dominating the tractor and harvester market.

1.4 Objectives of research

Chapter 1 laid out the background to this study. The reader was introduced to the subject of component supply industry and to the importance of visual aspects for product development in manufacturing industry.

Section 1.1 introduced HIBY-ELAFLEX a successful component supplier for the international oil industry which wants to diversify its supply business into other sectors. The author and supervisor of this study were trained in Industrial Design and have an interest in the aesthetic and visual aspects of manufactured products. The management of HIBY-ELAFLEX asked the author to investigate opportunities for exploiting product visual characteristics in the supply industry.

Section 1.2 gave a brief introduction to component supply industry. It was found that relationships between suppliers and lead manufacturers can operate on different levels. Trends indicate that many large manufacturing organisations have reduced their technology depth and have given more development responsibility to suppliers thereby reducing costs, business risks and improving development processes. For many supply companies, development skills have become an important competitive asset.

The first objective of this study was to establish on a general level how supply companies control the development process and whether supplier involvement in component development affects their business success:

1. How is product development controlled in supply relationships ?
2. What are the effects and drivers behind the different levels of control?
3. What success strategies can suppliers follow?
4. Are success strategies driven by control

The second objective of this study was to examine the role of product visual aspects in supply industry.

Section 1.3 dealt with the significance of visual appearance, style and aesthetics for product development in today's manufacturing industry. It was found that visual aspects of manufactured products are important for various reasons:

Consumers judge products on their appearance, particularly if products are user-driven and if underlying technology is mature.

Product visual aspects are a critical element of company's corporate identity.

Product visual aspects influence consumer buying behaviour, they create consumer pleasure and communicate personal style.

The following questions were set to examine whether visual aspects of products affect development control and business success in the supply industry:

How are product visual aspects controlled in supply relationships?
What drives different levels of control in visual development?
How can suppliers exploit visual aspects for their company's success?
Will suppliers be more successful if they control more of the visual development?

The model in figure 1.3 shows how the research questions relate to each other.

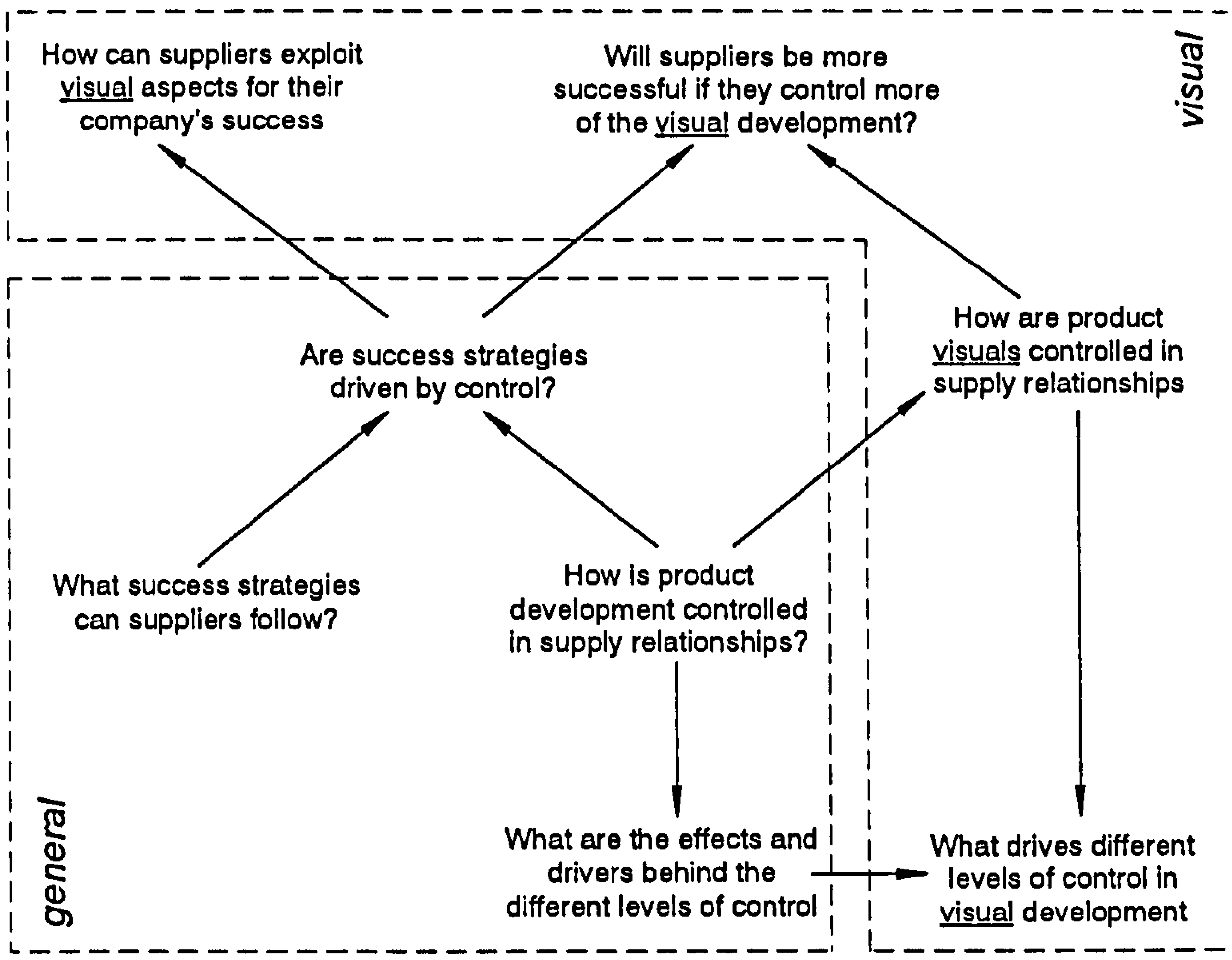

figure 1.3 questions on supply company control, success and impact of product visual aspects on component development

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2 Hypotheses Development

2.1 Introduction

In chapter 1 the reader was introduced to trends and issues in the component supply industry. It was noted that many industrial companies have reduced their production depth and have given more development responsibility to component suppliers. As a consequence, the product development function has become an important competitive asset for many suppliers. In order to establish how supply companies control the development process and whether supplier control in component development affects business success, four research questions were derived.

Chapter 1 also demonstrated that visual and aesthetic properties are important for manufactured products. Companies can systematically control and plan their products' visual qualities. Another four research questions were put forward to establish the effect product visuals have on supplier development control and supplier success.

The following chapter picked up the questions developed in chapter 1. The general questions could be answered with a review of past literature. The specific questions on how product visuals affect development control and product success in the supply industry could not be answered with past literature. Therefore a series of case studies were conducted. The findings led to three hypotheses which could later be tested on a larger scale to answer the specific questions.

2.2 Objectives

The objectives of chapter 2 were to:

1. explore issues of development control and strategies for business success in the component supply industry on a general level,
2. derive hypotheses that predict how product visuals affect development control and product success in the supply industry .

2.3 Method

These objectives were achieved in three sections.

Section 2.4 picked up the general questions on development control, effects and drivers and reviewed past literature. The findings were summarised in a model of product development in the supply industry.

Section 2.5 picked up the general questions on success strategies of component suppliers and reviewed past literature. In order to identify whether success is driven by control, the strategies were compared against the model of product development.

Section 2.6 used the model of product development and the success strategies identified in the previous sections to conduct a series of case studies in industry. Based on the findings, a number of hypotheses were developed predicting the impact of product visuals on development control and product success in the supply industry. To find answers to the specific questions, the hypotheses could later be tested on a larger scale.

The model in figure 2.1 summarises how the research questions were dealt with in the sections.

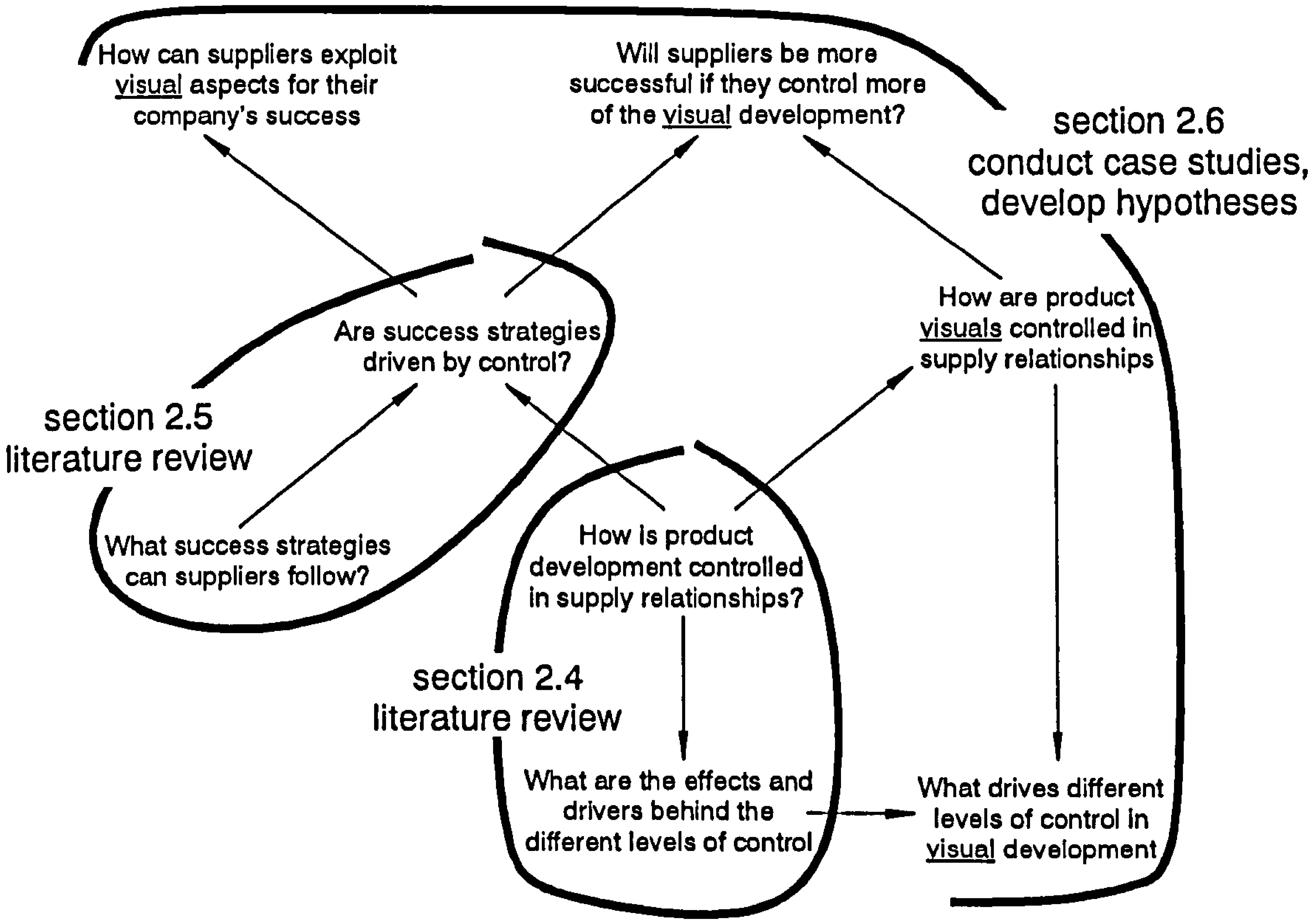


figure 2.1 model showing how the research questions were dealt with in the sections

2.4 Model of Product Development

Chapter 1 demonstrated that supply relationships are complex and occur on different organisational levels (see also Knuf and Inns, 1997 [46]). The following section picked up general questions on development control, their drivers and effects and summarises the findings in a model of product development in the supply industry.

2.4.1 Objectives

The objective of the following section was to:

1. establish how product development is controlled in supply relationships,
2. identify the drivers and effects behind the different levels of control.

2.4.2 Method

In order to achieve these objectives, nine studies on product development in the supply industry were reviewed:

1. establish the different forms of organising product development in supply relationships,
2. identify the drivers behind the different forms of organisations,
3. identify the effects on how suppliers design their components,
4. summarise the findings in a simple model.

Figure 2.2 sets up the model of product development showing the basic relationship between drivers, organisation and effects.

figure 2.2 model of product development in the supply industry

To structure key issues and terms of each study, a template was developed shown in table 2.1.

table 2.1 template for structuring studies on product development in supply industry

Author	Name of the author and year of publication
Background	Brief description of the study and its background
Development organisation in Supply Relationships	How the author classifies different forms of development organisation in supply relationships.
Drivers	What are the drivers, i.e. the strategic considerations, business and technology factors behind these forms of organisation.
Effects	How do the different forms of organisation affect supplier operations and design.

2.4.3 Results

Nine studies on product development in supply situations were reviewed and processed using the template format shown in table 2.1. The results are presented in tables 2.2.-2.6.

table 2.2 literature review on product development in supply industry (a)

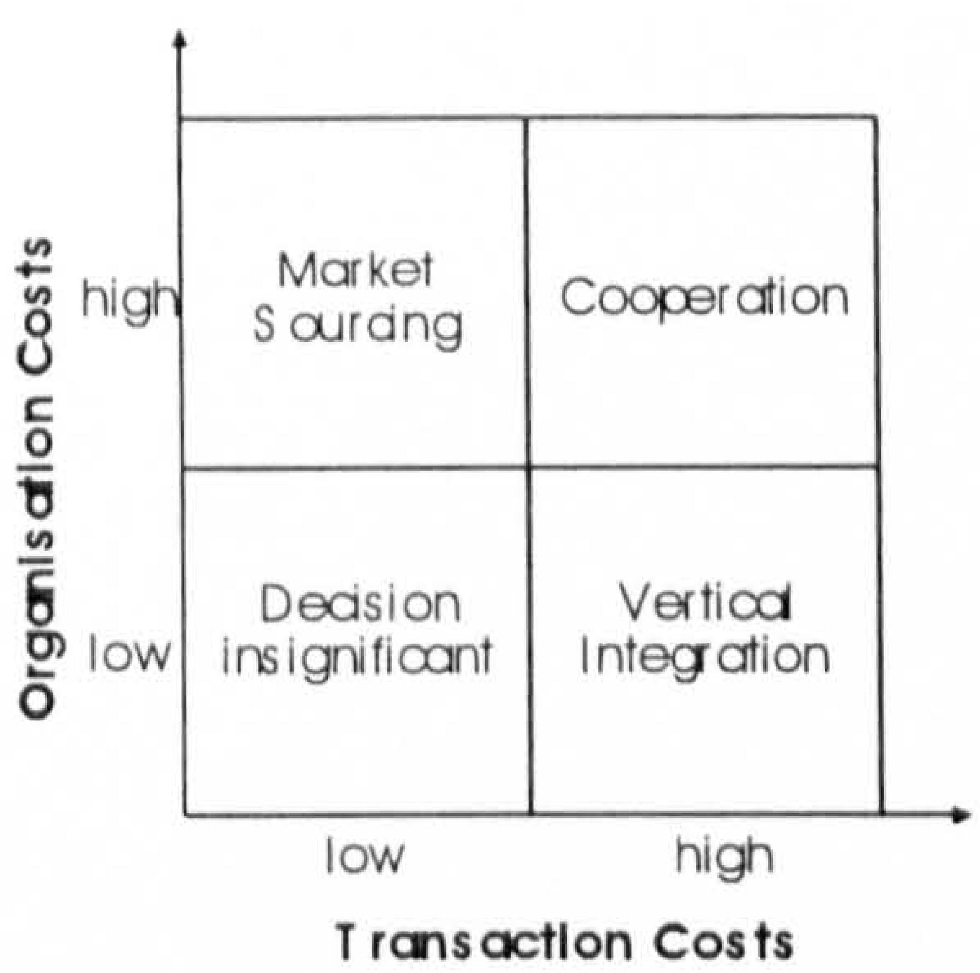
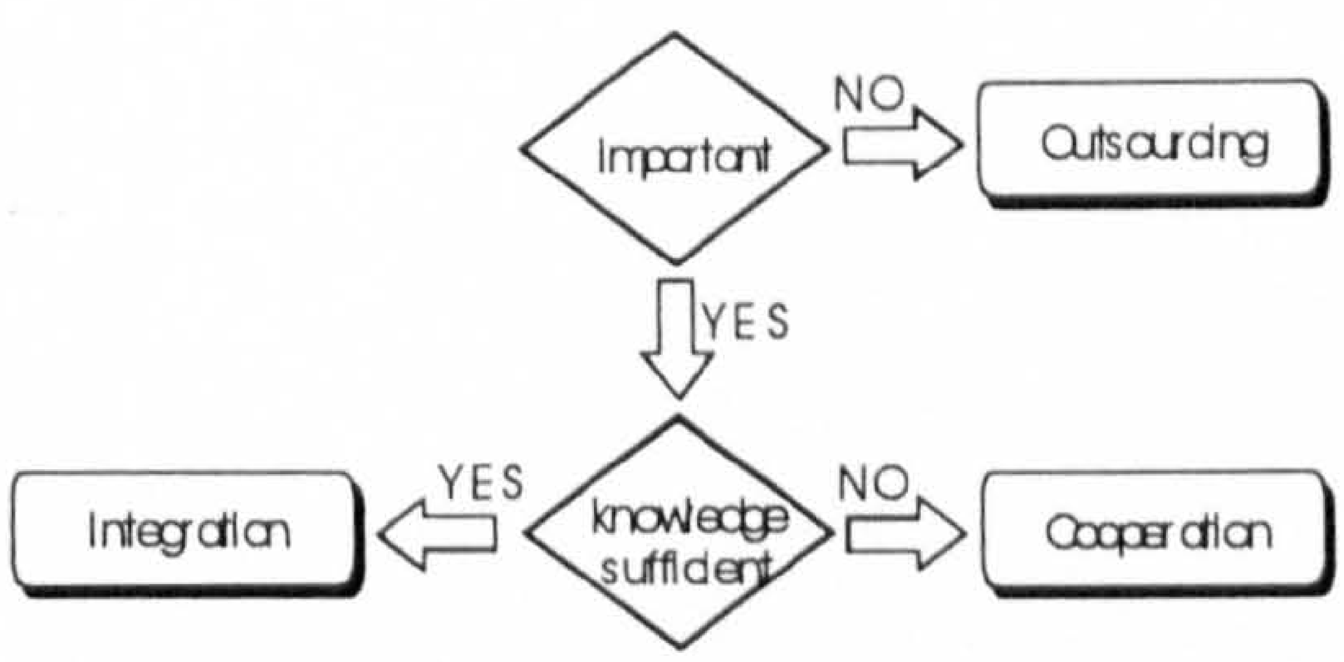
Author	Siebert, 1990 [7]	Hermes, 1992 [47]
Background	Portfolio model based on Transaction Cost Theory helping lead manufacturers to select appropriate product development strategy.	Portfolio model based on 'core competence approach'. The model helps lead manufacturers to select appropriate R&D strategy;
Development organisation in supply relationships	• Vertical Integration • Cooperation • Market sourcing	• Integration • Cooperation • Outsourcing
Drivers	To achieve maximum profitability companies have to optimise their Transaction cost and Organisation cost structure and choose the right integration/ outsourcing mix. 	The decision whether a company should develop a certain technology inside its organisation or give the development to suppliers depends on : • whether the technology is important for the lead manufacturer's competitiveness • whether the lead manufacturer's knowledge of the technology is sufficient 
Effects	--	--

table 2.3 literature review on product development in supply industry (b)

Author	Bongardt, 1990 [48]	Wynstra,1996 [49]
Background	Relationship model explaining different levels of lead manufacturer control over the development process.	Portfolio model explaining the relationship between purchasing and development
Development organisation in supply relationships	--	• supplied, supplier is servant • shared, supplier is partner • sourced, supplier is creator
Drivers	Lead manufacturer control over the development process increases with: • component importance for the differentiation of the final product • component importance for system integration	The extent and content of co-operation depends on • knowledge difference between customer and supplier • functional importance of the component for the performance of the final product • financial importance of the component for the cost of the final product
Effects	--	--

table 2.4 literature review on product development in supply industry (c)

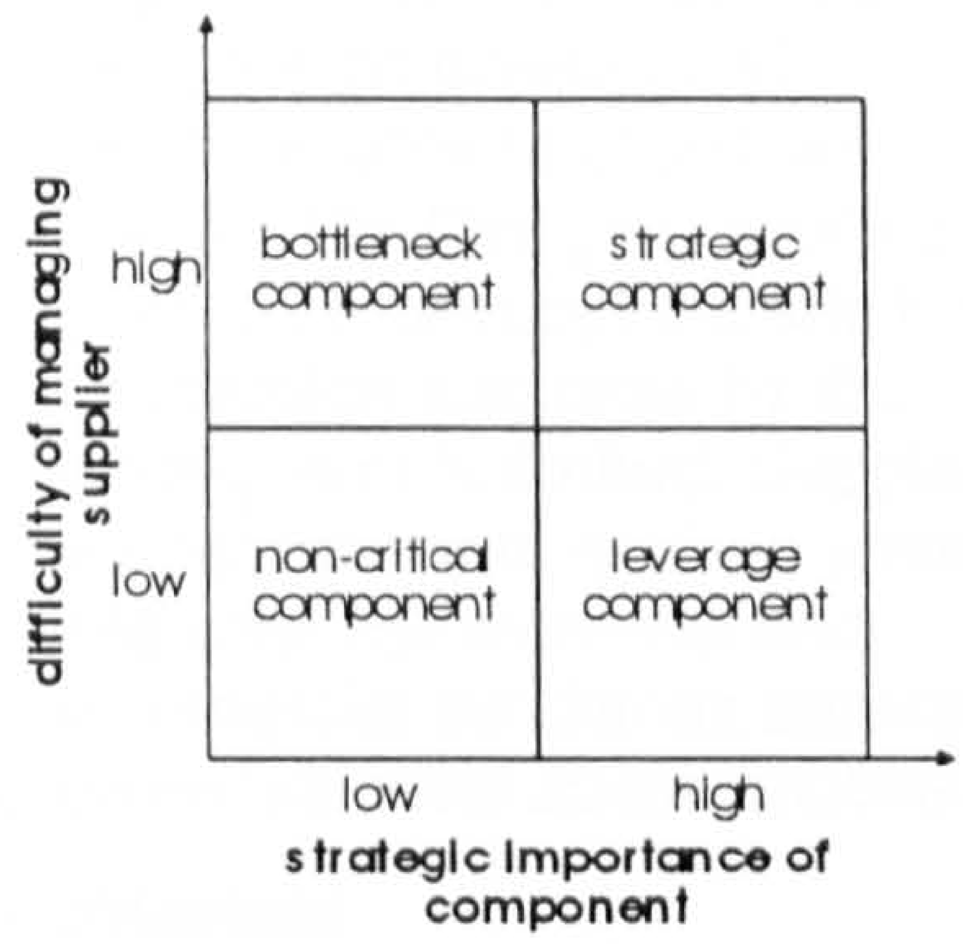
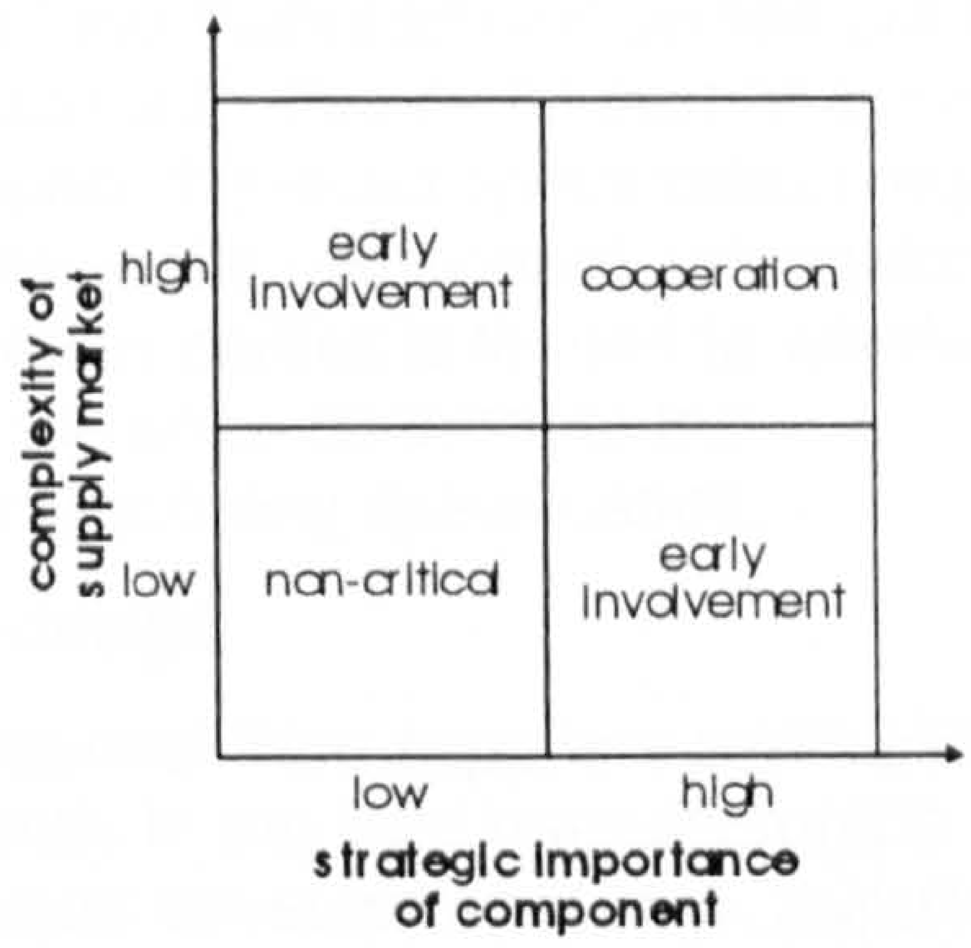
Author	Fiocca, 1982 [50]	Kraljic, 1983 [51]
Background	Portfolio model for purchasing to identify priority components	Portfolio model for choosing an appropriate purchasing strategy
Development organisation in supply relationships	• bottleneck components • strategic components • leverage components	• non-critical • early involvement • co-development
Drivers	Factors determining the component type • component strategic importance • difficulty of managing supplier  	Factors determining the relationship type • component importance for purchasing • complexity of supply market 
Effects	--	--

table 2.5 literature review on product development in supply industry (d)

Author	Bonnaccorsi and Lipparni, 1994 [19]	Muffatto and Pannizzolo, 1996 [52]
Background	Study analysing how firms involve their suppliers in innovation.	Study comparing the structure of Italian and Japanese motorcycle industry. One aspect was supply relationships.
Development organisation in supply relationships	• Traditional • Japanese	• traditional supply relationships • co-design partnerships • autonomous suppliers
Drivers	--	--
Effects	Traditional Suppliers are involved after the design is completed and technical specifications are issued. The Design process is a black-box for suppliers and the information disclosed by the leading firm is limited. Suppliers are requested to quote a price and offer full technical and commercial conditions against given technical specifications. Japanese Involvement of suppliers normally takes place in the concept stage before the design of the new product. This is true especially for first-tier suppliers responsible for design, development and sometimes assembly of integrated parts and systems.	Traditional The lead manufacturer carries out all design activities on its own and gives the supplier the exact specification required to make the component. Interaction between parties is limited to whether or not the parts conform to the manufacturing specification. Co-design Personnel from suppliers participates directly in the lead manufacturer's product development team. Suppliers are involved from an early stage in the development process and responsible for specific sub-projects or components. They offer a series of possible alternatives that influence the final design result. Autonomous suppliers Suppliers autonomously both design and produce components. A producer uses the component in the assembly of its product.

table 2.6 literature review on product development in component supply industry (e)

Author	Calderini and Cantamessa, 1997 [53]
Background	A survey amongst supply companies located in the area surrounding Turin in north western Italy.
Development organisation in supply relationships	• Type A • Type B • Type C
Drivers	--
Effects	Type A Companies design products first and market them later. Design specifications are based upon own market analysis techniques and are not related to a specific tender. The focus of development is the product itself. Companies offer standardised products through catalogues. Type B Companies compete through tenders which are related to a specific product. The supplier operates upon an engineer-to-order basis and design activities unfold at the same time as sales transactions. Companies offer customised products on an engineer-to-order basis. Type C Companies receive detailed drawings from their customers for customised products. Their main concern is to provide manufacturing processes and facilities.

2.4.4 Discussion

The information found in the nine studies had been summarised and structured in tables 2.2-2.6. The following section discusses differences and similarities in the studies.

Development organisation

A variety of models has been forwarded defining different forms of development organisation in supply relationships. The different forms of organisation determine how product development is controlled in supply relationships. Despite the differences in terminology, most studies have used a three-fold classification:

1. **integration** by the lead manufacturer: suppliers are only responsible for component manufacturing and have no control in component development,
2. **collaboration:** lead manufacturers and suppliers jointly develop components,
3. **autonomous** supplier: suppliers are in complete control of component development and lead manufacturers are simply market-sourcing components.

Based on this result, the three forms of development organisation were added to the basic model of product development (see figure 2.3).

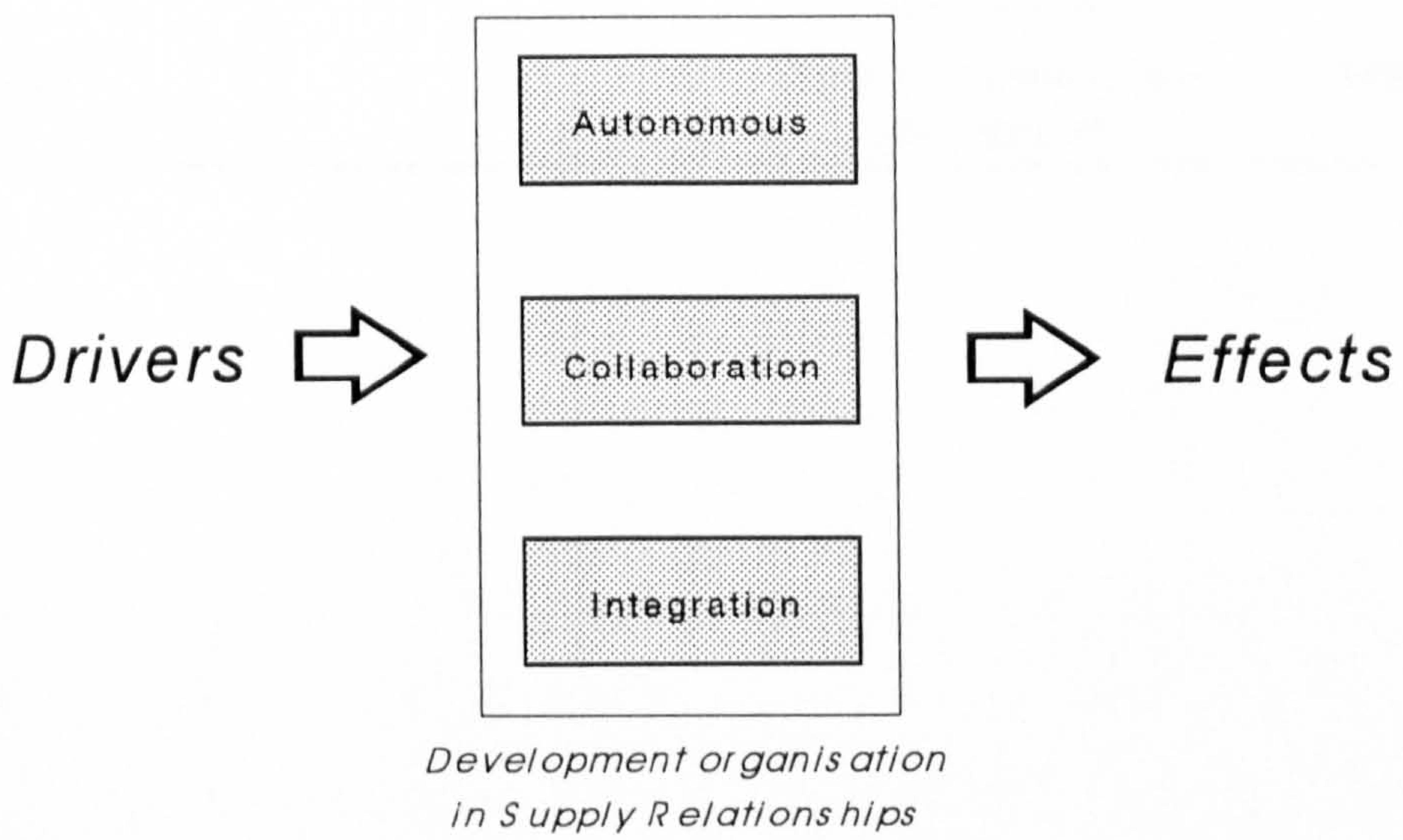


figure 2.3 model of product development with forms of development organisation added

Table 2.7 shows the variety of terms found in the studies. The first column lists the names of authors and the year of publication of the study. The 2nd column lists the terms that can be classified as 'integration' by lead manufacturer. The 3rd column lists the terms used to describe 'collaboration'. The 4th column contains the terms used by each author for 'autonomous supplier'.

table 2.7 terms used in literature: development organisation in supply relationships

author	Integration	Collaboration	Autonomous
Siebert,1990	Integration	Cooperation	Market Sourcing
Hermes, 1992	Integration	Cooperation	Outsourcing
Bongardt, 1990			
Bonnaccorsi, 1994	Traditional	Japanese	
Muffatto, 1996	Traditional	Co-design	Autonomous supplier
Calderini, 1997	Type C	Type B	Type A
Wynstra, 1996	Design supplied	Design shared	Design sourced
Fiocca, 1982		Strategic/ Leverage components	Bottleneck components
Kralijc, 1983		Early invovlement/ co-development	Non-critical

Drivers

The previous section explained the three-fold classification system which most researchers have used to describe different types of development organisation in supply relationships. The forms of organisation, i.e. integration, collaboration and autonomous, determine how product development is controlled in supply relationships. Some authors have specifically examined the factors driving a lead manufacturer's decision to select one of these levels. The subject backgrounds and approaches vary quite considerably. It is therefore difficult to identify common themes.

Siebert developed a portfolio model with which lead manufacturers can select an appropriate form of supply organisation. He based his approach on *Transaction Cost Economics.* This school of thought argues that lead manufacturers delegate work to suppliers in order to optimise their cost structure. The main contributors to *Transaction Cost Economics* are Coase, 1937 [[54]], Williamson, 1975 [[55]] and Teece, 1976 [[56]].

Hermes and Bongardt based their models on the *Core Competence* approach which business literature introduced in the early 1990's (see Prahalad and Hamel, 1990 [[57]]). The *Core Competence* approach promoted the view that companies must concentrate their in-house resources on developing a unique combination of technologies, skills and knowledge in order to be competitive. This implies that technologies and skills which are not core to the business should be left to suppliers.

Siebert, Hermes, Bongardt, Bonnaccorsi, Muffatto and Calderini examined product development processes in supply relationships. The studies of Wynstra, Fiocca and Kralijc originated from the field of industrial purchasing. Their objective was to develop tools with which industrial buyers can optimise their supply portfolio.

Despite the differences in emphasis and subject backgrounds, most authors suggested that lead manufacturers should consider *component importance for the final product* before choosing the development organisation. Wynstra expressed component importance in terms of its functional, performance and financial significance for the final product. Hermes argued that component importance depends on its technological significance for the company's competitiveness. Bongardt pointed out that component importance is determined by how it contributes to the differentiation of the final product and to the integration of the core technology. Fiocca and Kralijc used the general terms 'component strategic importance' and 'component importance for the purchasing function'.

Hermes and Wynstra identified *knowledge of lead manufacturer* as a further driver which determines organisation in supply relationships. If lead manufacturer knowledge is insufficient they rely on suppliers to support the development project.

Other factors mentioned in the literature like difficulty of managing the supply account, customer attractiveness, strength of the relationship and complexity of supply market stem from the field of industrial purchasing and are less relevant to the product development function.

Table 2.8 summarises the variety of drivers found in the studies.

table 2.8 terms used in literature: drivers behind development organisation

author	drivers behind product development organisation
Siebert,1990	
Hermes, 1992	component importance for the competitiveness, lead manufacturer knowledge of component technology
Bongardt, 1990	component importance for the differentiation of the final product
Bonnaccorsi, 1994	
Muffatto, 1996	
Calderini, 1997	
Wynstra, 1996	importance for function, performance, cost of final product, knowledge of lead manufacturer
Fiocca, 1982	strategic importance
Kralijc, 1983	importance for purchasing

Based on the results of the literature review, the drivers *component importance for final product* and *product knowledge of lead manufacturer* were added to the model (see figure 2.4).

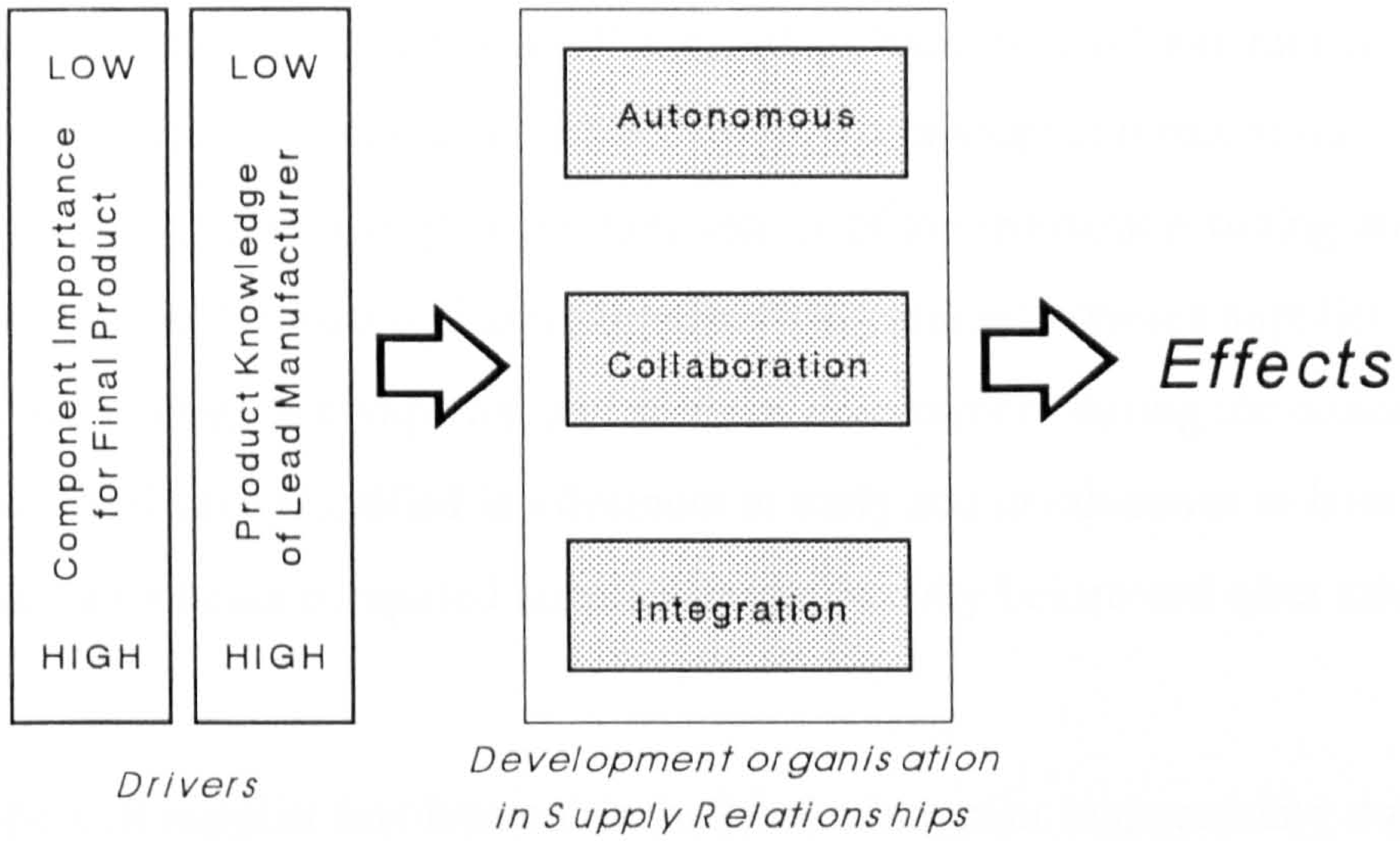


figure 2.4 drivers behind different forms of development organisation

Effects

The previous sections described three basic forms of development organisation in supply relationships and its drivers. The following section examined how the different forms of organisation affect supply company operations and product design.

Bonnaccorsi and Lipparni, Muffatto and Pannizzolo, Calderini and Cantamessa suggested that the different forms of organisation affect supply companies in terms of their involvement in the development process. One aspect of involvement is timing during the development process. Bonnaccorsi and Lipparni differentiated between supplier involvement after design is completed and supplier involvement during the concept stage. Muffatto and Pannizzolo classified involvement at early and involvement at later stages. Calderini and Cantamessa compared supplier design activity before and after sales transaction.

A further aspect of supplier involvement is the level of supplier responsibility during the development process: Bonnaccorsi and Muffatto pointed out that suppliers are merely responsible for component production and have no responsibility for development in traditional relationships. Suppliers and lead manufacturers take design decisions jointly in collaborations. Supplier responsibility is highest when they develop components autonomously without lead manufacturers.

The effect different supply relationships have on product design were described by Calderini and Cantamessa: Components become customised if lead manufacturers integrate development or collaborate with suppliers. Design is less customised if suppliers develop components autonomously. Table 2.9 summarise the variety of effects identified in the studies.

table 2.9 terms used in literature: effects of development organisation

author	effects of product development organisation
Siebert,1990	
Hermes, 1992	
Bongardt, 1990	
Bonnaccorsi, 1994	timing of invovlement, responsibility during invovlement
Muffatto, 1996	invovlement from early or late stage, amount of design entrusted to supplier
Calderini, 1997	design activity in relation to sales transaction, customisation of component
Wynstra, 1996	
Fiocca, 1982	
Kralijc, 1983	

Based on the results of the literature review, the effects *supplier involvement* and *component customisation* were added to the model.

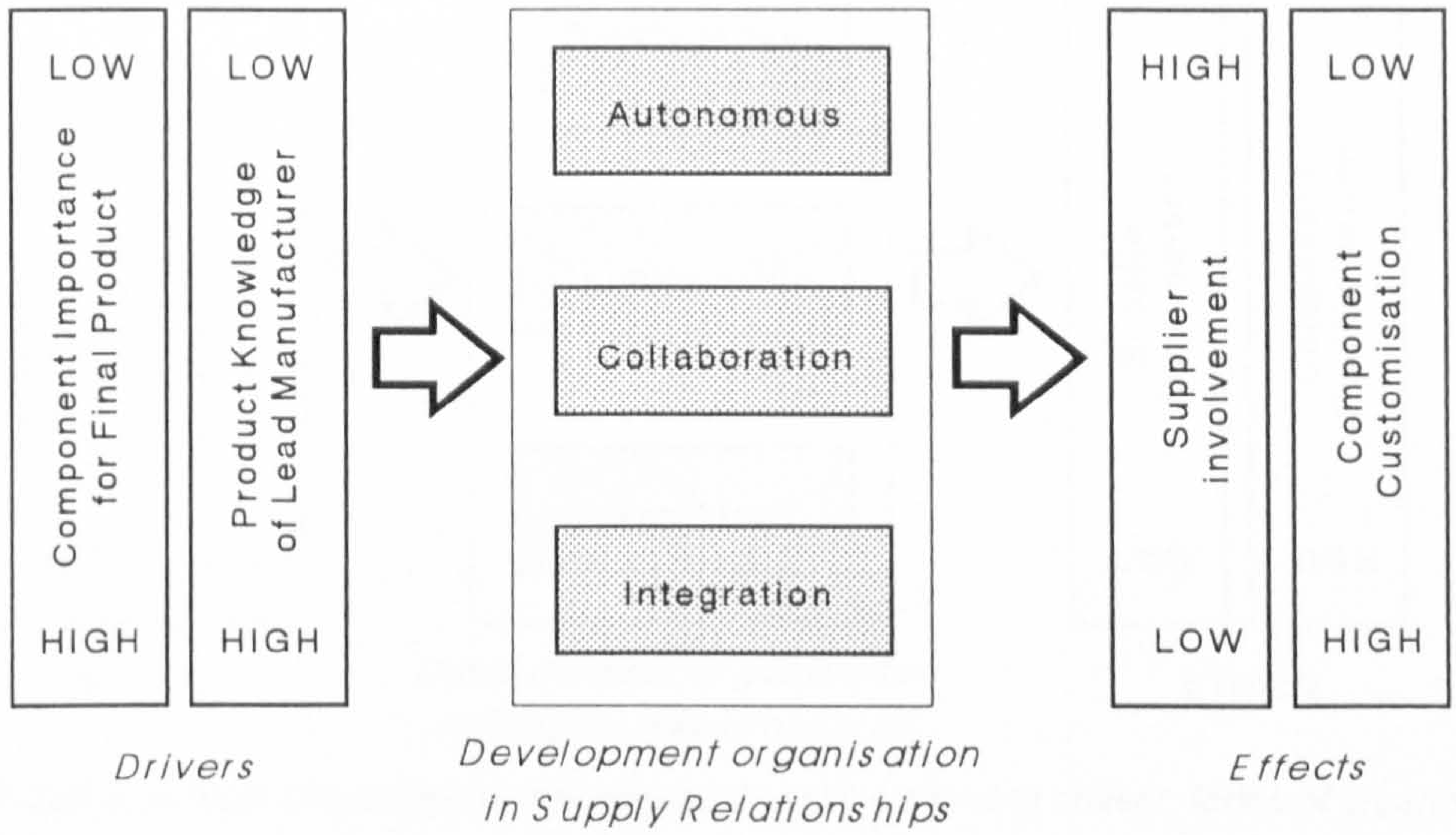


figure 2.5 model of product development with effects added

2.4.5 Conclusions

The objective of section 2.4 was to:

1. establish how product development is controlled in supply relationships,

2. identify the drivers and effects behind the different levels of control.

Different forms of development organisation determine how product development is controlled in supply relationships.

integration: component development is controlled by lead manufacturers, suppliers have no control and are only responsible for production;

collaboration: lead manufacturers and suppliers jointly develop components;

autonomous: suppliers are in complete control of component development;

The different levels of control are largely driven by the importance of the component in the final product and product knowledge of lead manufacturer. They affect supplier involvement in the development process and the degree of component customisation (see figure 2.6).

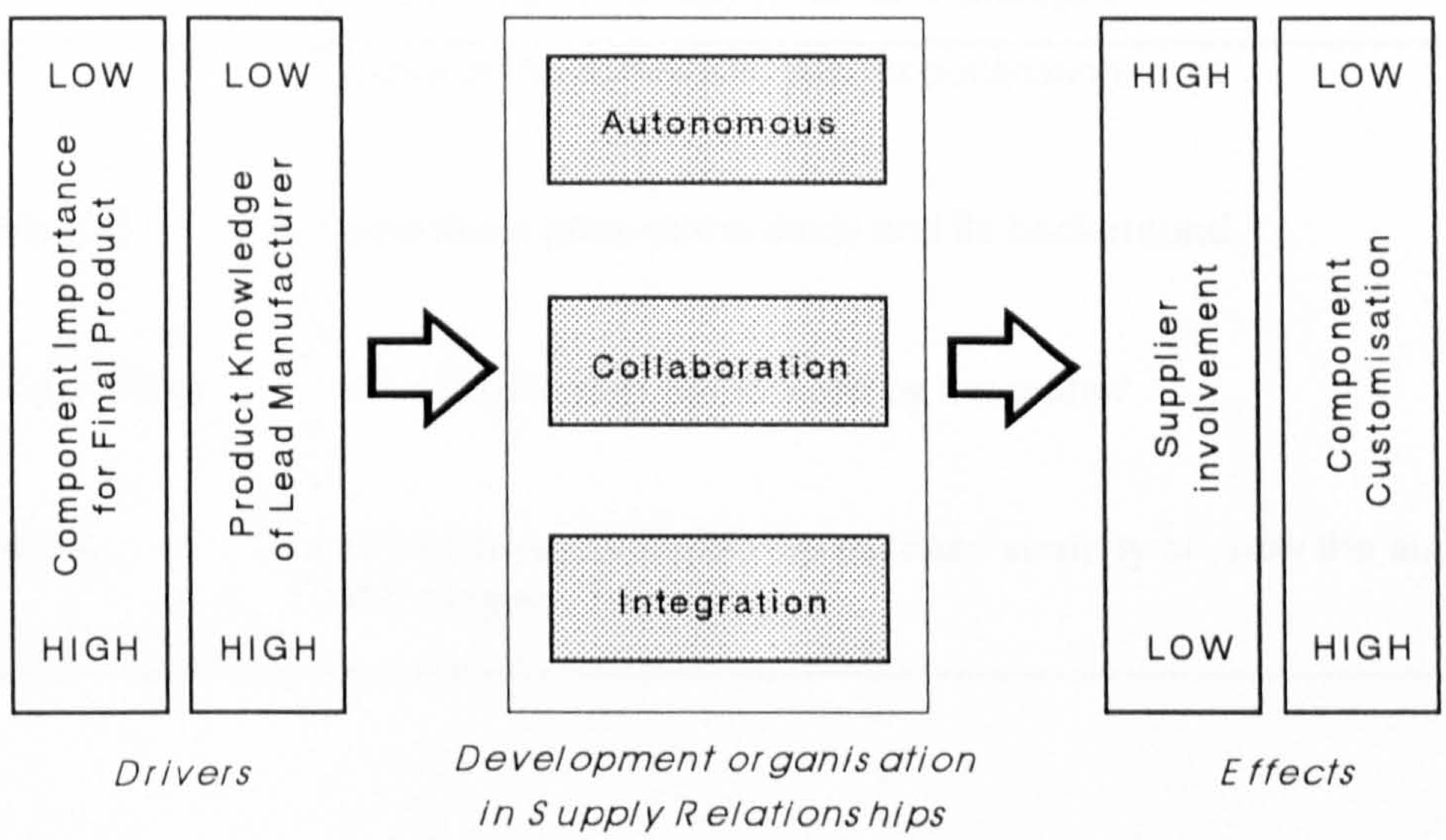


figure 2.6 model of product development in supply relationships showing drivers, forms of organisation and effects

2.5 supply company success

Section 2.4 reviewed past literature for information on development control, its drivers and effects in the component supply industry. The findings were summarised in a model of product development organisation in supply relationships. The following section picked up the general questions on success strategies of supply companies.

2.5.1 Objectives

The objectives of the following section were to:

1. review success strategies for supply companies,
2. examine whether the success strategies depend on supplier control in product development.

2.5.2 Method

In order to achieve these objective, four studies on success strategies in the supply industry were reviewed. Each study was structured using the template shown in table 2.10. The success strategies were then compared against the model of product development of section 2.4.

table 2.10 template for structuring literature on supplier success strategies

Author	name of the author and year of publication
ac ground	brief description of the study and its background
uccess strateg	success strategy put forward by the author
easoning	what the author based the success strategy on, how the author justified the suggested strategy.

2.5.3 Results

Four studies on success strategies in the supply industry were reviewed and structured using the template format shown in table 2.10. The results are shown in tables 2.11- 2.13.

table 2.11 literature on success strategies in supply industry (a)

Author	Paliwoda, 1994 [16], 1993 [20]	Müller, 1994 [58]
Background	The authors analysed supply relationships in the European aerospace industry and examined the role of suppliers in the writing of design specifications.	The author examined marketing strategies of supply companies.
Success strategy	Suppliers should develop complex and customised components. They should become involved very early during the development process, preferably at the specification stage.	Suppliers that cannot compete on price should differentiate their components. Supplier involvement in development is key to a differentiation strategy.
Reasoning	Suppliers of highly complex customised 'system-solutions' were more successful than suppliers of standard components. Suppliers of standard components could easily be replaced by cheaper suppliers at any time. Suppliers of highly complex, customised components had a more stable market. If suppliers were involved early at the specification stage, they could tailor specifications towards their offer. After such specifications were released, other suppliers were unable to enter the market.	The author based his suggestion on Porter's of basic competitive strategies: price leadership differentiation

table 2.12 literature on success strategies in supply industry (b)

Author	Inns and Hands, 1998 [66]	SM&P Unternehmensberatung, 1993 [59]
Background	The Design Research Centre published a case study on a supply company to Land Rover.	The management consultancy examined recent changes in the European automotive supply industry.
Success strategy	Suppliers should offer a design service and build stronger partnerships with their customers.	Suppliers should invest in R&D.
Reasoning	In-house design capabilities allowed the company to become a black-box supplier to Land-Rover adding high value to its products.	SM&P argued that global sourcing policies of large auto manufacturers and increasing competition from companies in countries with low labour costs has put many suppliers in Western Europe under severe price pressures. Suppliers should therefore pursue a differentiation strategy and create innovative components which ensure higher prices and protect against low-cost competition.

table 2.13 literature on success strategies in supply industry

Author	Backhaus, 1992 [60]
Background	The author suggested emancipation strategies with which supply companies can become less dependent on their lead manufacturers.
Success strategy	Backhaus suggested a strategy called Mehrstufiges Marketing (multistage marketing): Suppliers should differentiate components and make them identifiable and important for the quality and perceived quality of the final product.
Reasoning	Lead manufacturers are less likely to substitute a supplier's component if the component has a positive effect upon the end-user's purchasing decision.

2.5.4 Discussion of results

The success strategies put forward by the authors are all based on Porter's basic competitive strategies. Porter, 1980 [[61]] recommended that companies must choose between two basic strategies if their business is to be successful. Companies can either offer the lowest price along with acceptable quality or they must provide highest quality or the most differentiated offer.

Interestingly, all studies in the literature review are biased towards differentiation. This may partly be due to the fact that differentiation is often considered the superior strategy generating higher revenues than price leadership (see Buzzel and Gale, 1987 [[62]]; Ughanwana and Baker, 1989 [[63]]).

All studies in the review emphasised that suppliers require substantial control in development if they decide to pursue a differentiation strategy.

Paliwoda and Bonnaccorsi discovered that by being involved early during the writing of specifications, aerospace suppliers created lock-in effects for their lead manufacturer. Suppliers tailored system specifications to their component design so that aircraft manufacturers were unable to change to other suppliers during production.

Backhaus argued that suppliers who are in control of the development process can create components which are identifiable to the end-user and important for the quality or quality image of the final product. Suppliers will become less dependent on lead manufacturers if such components generate a demand pull from end-users.

Inns and Hands suggested that suppliers may use their design skills to create components which add high value to the final product thereby building strong partnerships with lead manufacturers.

SM&P Unternehmensberatung and Müller simply recommended that suppliers should invest in R&D in order to differentiate their components from the competition.

Supplier control in the development is critical in all success strategies put forward. Suppliers should therefore work on the autonomous or the collaboration level. These two levels have been marked on the model as shown in figure 2.7.

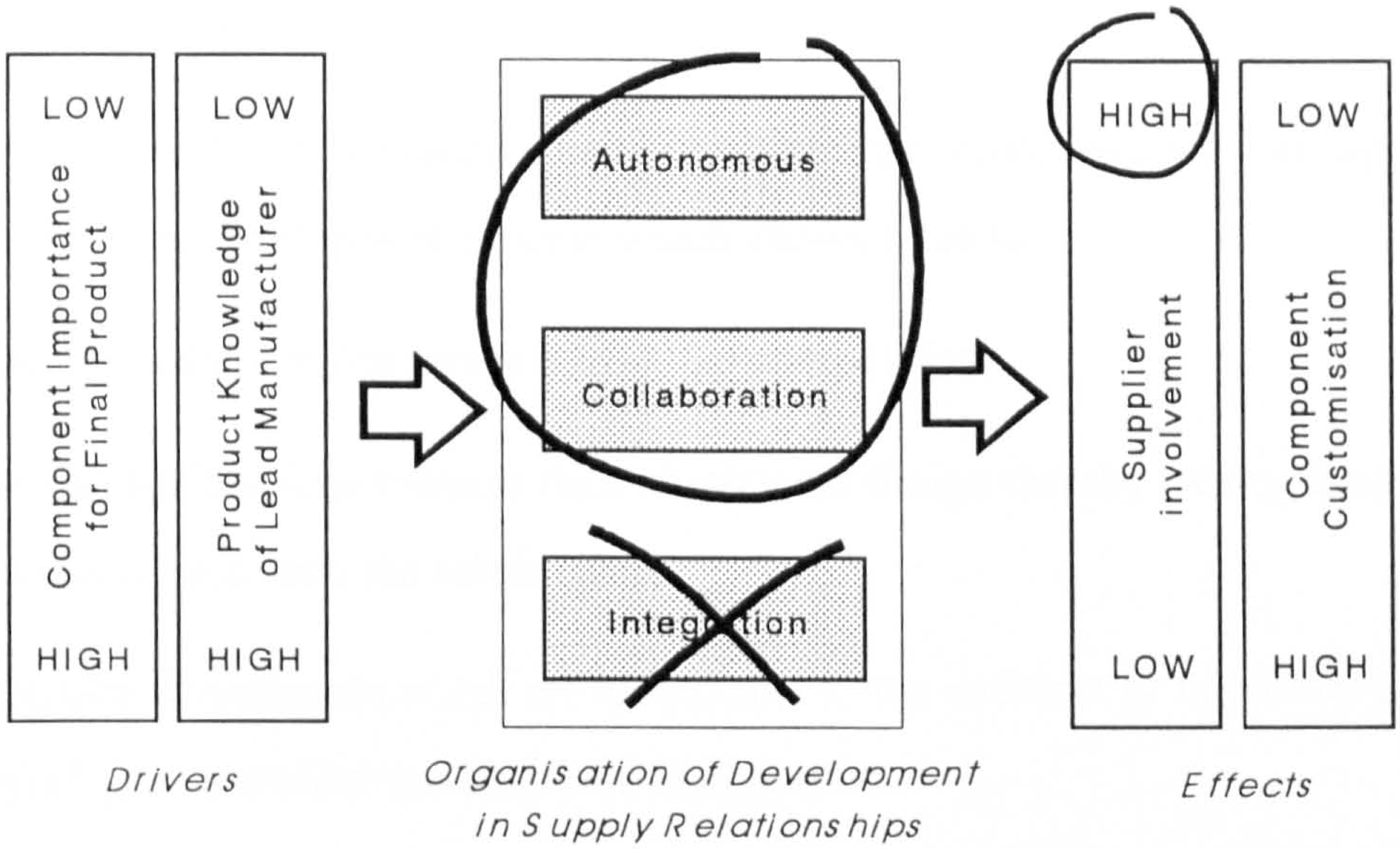


figure 2.7 model showing the two forms of development organisation which have been shown to bring success to suppliers

2.5.5 Conclusions

The objectives of section 2.5 were to:

1. review success strategies for supply companies,
2. examine whether the success strategies depend on supplier control in product development.

Based upon Porter's differentiation approach, researchers recommended that suppliers should control the development process which allows them to:

- differentiate their components from the competition,
- tailor specifications towards their component design thereby locking lead manufacturers into the relationship,
- develop components which are identifiable to the end-user or important for the quality or perceived quality of the final product.

In order to implement these strategies, suppliers should work on the autonomous or collaboration level.

2.6 Product visuals in supply industry

Section 2.4 reviewed past literature for information on development control, its drivers and effects in the component supply industry. The findings were summarised in a model of product development organisation in supply relationships.

Section 2.5 picked up the general questions on success strategies of supply companies, identified strategies and found that supplier control in product development is critical for their implementation.

The specific questions on how product visuals affect development control and product success in the supply industry could not be answered on the basis of past literature. Therefore a series of case studies were conducted. The findings of these case studies led to three hypotheses which predict the impact of product visuals on supplier control and product success. Testing the hypotheses on a larger scale would help to establish:

1. How product visuals are controlled in supply relationships
2. What drives different levels of control in visual development.
3. Whether suppliers can benefit from visual aspects of final products
4. Whether suppliers can benefit from controlling visual development.

2.6.1 Objectives

The objective of the following section is to develop a series of hypotheses which predict the impact of product visuals on supplier control in development and on product success.

2.6.2 Method

Information on product development and supply relationships was analysed in seven industrial case studies. The method was based on the analytical induction technique as suggested by Johnson, 1997 [64]. Table 2.14 shows the Johnson method. Table 2.15 lists how the technique was applied in this study.

table 2.14 list of phases of analytical induction suggested by Johnson, 1997

phase I	Gain access to the phenomenon of interest.
phase II	Define phenomenon whose variation is to be explained and identify variations. Categorise those variations in terms of shared characteristics and differences.e.g. case category A, B, C
phase III	Create a provisional list of case features common to each identified category. Review for any deviant cases of the phenomenon which lack case features common to cases initially put in the same category. Explain variations.

table 2.15 list of phases, applying analytical induction for this study

phase I	*Gain access to the phenomenon of interest* 1. Gain access to industrial companies and obtain information on product development in supply relationships.
phase II	*Define phenomenon whose variation is to be explained and identify variations.* 1. Review the supply model developed in section 2.4. 2. List the model features of the categories. 3. develop qualitative questions (what-, why- how- questions) using the model features. 4. Design an analysis template based on the qualitative questions. *Categorise those variations in terms of shared characteristics and differences.* 5. Structure the case study information acquired in phase I using the analysis template.
phase III	*Create a provisional list of case features common to each identified category* 1. Review the structured information. 2. Compile a component list out of 'what' information. 3. Decide whether component contains visible elements or not. 4. Extract 'why and how' information for each component and determine the form of development organisation (integration, collaboration, autonomous). *Review for any deviant cases.* 5. Discuss the findings and define component categories. *Explain variations* 6. Examine to what degree suppliers have controlled visual development and whether visuals have affected product success in the supply industry. 7. Develop hypotheses which predict the impact of product visuals on development control and on product success in the supply industry.

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Esso Retail

Esso Retail is part of Exxon-Mobil Corp., the world's largest integrated oil company. The author had approached the head of Esso's *Retail Engineering Services* Office for Central Europe during Esso's visit to the HIBY-ELAFLEX production facilities in summer 1996. The head of Retail Engineering invited the author to Esso's Central European office in Hamburg and to the international headquarters in Brussels.

Although HIBY-ELAFLEX and Esso have had a good relationship for more than 30 years, it proved very difficult to get detailed information out of Esso's technical staff. The oil company had just rearranged its international management structure and staff had been told to build more formal relationships with suppliers. Over the past decades national managers had developed close personal ties with a number of key supply companies. It was now Esso's intention to crack regional networks in order to cut costs and optimise the global supply chain. Prime experts in every national office had been made redundant. They were replaced with staff from other divisions like refining, exploration.

Table 2.16 gives general background information on Esso. The case study can be found in Appendix I.1.

table 2.16 summary of general information on Esso

background	company visited	Esso Retail Engineering
	address	Brussels, Belgium
	ownership	Esso Retail engineering is part of Exxon-Mobil which is listed on the New York Stock Exchange.
size	turnover p.a.	Exxon-Mobil Corp. 182 billion US$
	employees	Exxon-Mobil Corp., 123,000 world wide
	structure	Exxon is the world's largest integrated oil company and divided into a multitude of companies or business groups. The largest is Exxon Company International (ECI) which is responsible for business outside North America.
business	main activities	The majority of the group's income stems from oil exploration and petrochemicals. Only 20% of Exxon's business is refining and fuel retail. About 30% of the company's requirement for crude oil stems from own sources. The rest is bought on the world market. Exxon has strong interests in exploration, refining, retailing and petrochemicals. In-house R&D activities focus on technologies for geoscientific oilfield analysis which help to increase the chances of successful drilling. Another important area for research is lubricants and petrochemicals which generate high profit margins.
	markets	Exxon-Mobil sells its products and services in almost every country around the world.
	strategy	Exxon assumes that competitive assets such as capital, resources and knowledge are equally accessible and available to all multinational oil companies. Corporate management has therefore decided to follow a price leadership strategy. Exxon (or under its European brand name Esso) aims to provide the same products and services as any other competitors, but at a lower cost. The key performance figure for Exxon is return on investment (ROI).

BP Oil Retail

The contact with BP retail engineering (part of BP Amoco, the world's third largest integrated oil company) was arranged through the managing director of HIBY-ELAFLEX who had known senior technical staff at BP for over 20 years. The interview partners at BP were very experienced in the planning and development of fuel retail sites.

Table 2.17 gives general background information on BP. Figure 2.8 shows a picture of a modern BP retail site in east Germany. The case study can be found in Appendix I.2.

figure 2.8 picture of BP retail site in east Germany

table 2.17 summary of general information on BP

background	company visited	BP Amoco PLC
	address	BP OiL Retail, Hamburg, Germany
	ownership	The company is listed at the London Stock Exchange
size	turnover p.a.	BP Amoco PLC 104 billion US$
	no of employees	
business	main activities	BP Amoco concentrates its resources on oilfield research. Much of the off-shore exploration is given to Schlumberger oilfield services. A technology gap in lubricants and polymers was closed by cooperating with Mobil Oil.
	markets	BP's main markets are in Europe and Asia. Amoco's main markets are in North and South America.
	strategy	The company has identified shareholder value as its performance indicator. To maximise profitability, BP is pursuing a rigorous policy of corporate downsizing, outsourcing to service providers and focus on core competences and economies of scale. Staff development at BP Oil Deutschland, one of the corporations largest subsidiaries, illustrates the effect of corporate downsizing. While profitability has increased since the 1970s, BP Deutschland staff has fallen from 11,500 to 1,500 today. A further reduction down to 250 people is planned. The recently announced take-over of Atlantic Richfield (ARCO) will make BP Amoco the world's largest oil company. Growing competition from hypermarkets is forcing oil companies like BP to restructure their petrol station networks. In terms of throughput, British hypermarkets achieved close to 7 million litres per site compared to under 2 million litres per BP site in 1997. The high volume throughputs at hypermarkets translate into extremely low unit costs, estimated to be over $0.04/l less than those of major oil company sites. The result of this is that hypermarket service stations are able to sell fuel below the normal market price while still achieving profitable operations. In order to keep up with competition, BP has closed smaller petrol stations concentrating fuel sales at large or very large sites thereby reducing unit costs. Since the 1970s, the number of retail outlets has fallen by 70%. Half of the cost for a new service station consists of labour costs for construction. The other half are cost for equipment. Traditionally 70% of equipment cost was spent on fuel dispensing and only 30% on convenience shop facilities. During the late 1980s and early 1990s convenience shop business has grown rapidly and has become very important for site profitability. Its share of total investment has risen to about 50% and further increases are expected.

ERCO Leuchten

ERCO specialises in the design and manufacture of upmarket lights for architectural applications. The contact with ERCO was also arranged through HIBY-ELAFLEX. The husband of the managing director's secretary works as a senior lab technician at ERCO's technical centre in Lüdenscheid. He persuaded the head of mechanical design to invite the author to the company and explain ERCO's product structure, ERCO's technical and business strategy and how ERCO involves suppliers in the development of products. Figure 2.9 shows a picture of ERCO products. Table 2.18 gives general background information on ERCO. The case study can be found in Appendix I.3.

figure 2.9 picture of ERCO products

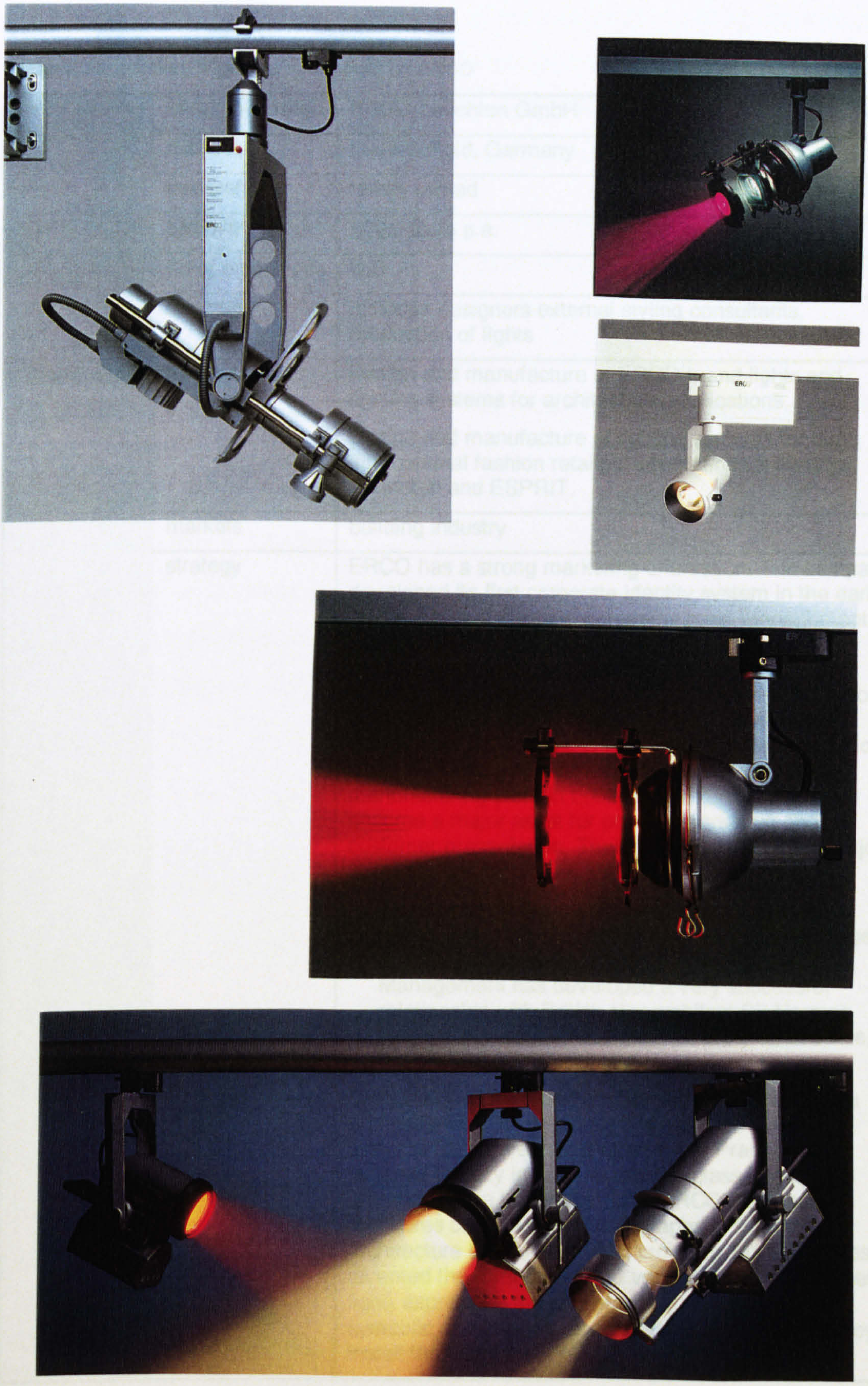


table 2.18 summary of general information on ERCO

background	company visited	ERCO Leuchten GmbH
	address	Lüdenscheid, Germany
	ownership	family owned
size	turnover	100m Euro p.a.
	no of employees	850
	structure	in house designers external styling consultants, production of lights
business	main activities	Design and manufacture of ERCO brand lights and lighting systems for architectural applications, Design and manufacture of lighting systems for large international fashion retailers like Hennes & Mauritz, Benneton and ESPRIT.
	markets	building industry
	strategy	ERCO has a strong marketing orientation. The company developed its first corporate identity system in the early 1970s. Style and image determine most management decisions. Quality and efficiency of products and processes are of secondary interest. Factory architecture, arrangement, colour and shapes of office equipment, machines, tools, furniture, desktop computers, paper, files, coffee mugs, pencils etc. follow strict aesthetic guidelines. ERCO's head offices and manufacturing plant in Lüdenscheid (Germany) have become a major asset for product marketing and customer presentation. The company follows two major strategies for promoting ERCO products: 1. The company has developed partnerships with a number of leading international architects who use ERCO lighting systems for all their projects. Management has developed a very successful relationship with British star architect Sir Norman Foster who has also designed ERCO's head office, factory and family mansion. ERCO targets the world's most famous art museums and galleries. The company has supplied lighting systems for the Vatican museum, the Prado, the National Gallery in London and the glass pyramid entrance of the Louvre in Paris. ERCO's company brochures contain more photographs of famous architecture then of their own products. Marketing has invented the formula: *ERCO verkauft Licht* (ERCO sells light) expressing the company's quest to appear as symbolic and glamorous as the buildings in which they install their lights.

Philips-Alessi jugless kettle.

Philips Hastings together with the Italian company Alessi introduced a range of upmarket kitchen appliances. One product is a green jugless kettle made out of injection moulded plastic. The following case study describes the development of the kettle body involving designers from Philips in Hastings, Alessi and a supply company specialising in tooling and production of plastic components for household appliances.

A friend of the author's is a senior marketing manager at a company which produces small kitchen appliances. This company works very closely with Riedel Entformungstechnik GmbH which develops and manufactures complicated plastic components for household appliances like Siemens vacuum cleaners. The owner and managing director of Riedel Entformungstechnik had recently completed the kettle project for the domestic appliance division of Philips and granted the author access to the entire project files. They included prototype models, engineering drawings, sketches, memos and letters sent between the Philips design office in Hastings (England) and Riedel Entformungstechnik in Germany. Figure 2.10 shows an article on the Philips Alessi kettle published in Design Week. Table 2.19 gives general background information on Riedel Entformungstechnik. The case study can be found in Appendix I.4.

figure 2.10 article on Philips Alessi kettle in Design Week

For most kettle connoisseurs, anything after the Russell Hobbs electric kettle is a bit like re-inventing the wheel – the best has already been designed, anything else is an afterthought. But Alessi's collaboration with electrical manufacturer Philips has provided a good-looking afterthought. A couple of years ago, the partnership launched its range of kitchen products designed to "rehumanise the kitchen with the very best in form and function". Called the Philips-Alessi Line, the range has been designed by Italian architect and designer Alessandro Mendini and consists of four electrical kitchen products: toaster, citrus press, coffee maker and the kettle shown here. The product shapes and colours go back to the Fifties. As the Italian design company's managing director Alberto Alessi says: "Anyway, why do all domestic appliances have to be white?" Or even chrome?
Bhavna Mistry

"We start with the idea of the user being blind, wearing ski gloves and wanting to wreck t thing," says James Dyson abc how he approaches the art of vacuum cleaner design. Dyso cleaners. He manufactured th Dyson Appliances now emplo not only look good, they're rur expensive, priced at £199 for
Beverley Cohen

Movers and shaker

Just as plastic-injection moulded furniture, nylon and Elvis are i of the Fifties, the Design Week team has selected favourites fron bikes to Lycra that sum up the mid-Eighties to the present day

I could say that I chose the Newton Apple MessagePad 130 because it is a handy, computerised filofax which can be attached to a computer, fax *table 2.19 summary of general information on Riedel Entformungstechnik*

background	company visited	Riedle Entformungstechnik GmbH
	address	Schalksmühle, Germany
	ownership	privately owned
size	turnover p.a.	15m Euro
	no of employees	60
	structure	1 technical director, 1 production manager
business	main activities	development of injection moulding tools, volume production of injection moulded plastic parts
	products	plastic components for vacuum cleaners, washing machines, kitchen appliances
	markets	domestic appliance divisions of large electrical engineering companies, mainly Siemens and Bosch
	strategy	The company specialises in tool making and production of plastic components which require complicated and difficult cores.

WILA light

WILA lighting company decided to develop a high quality light for offices and banks and asked the electronics supply company INSTA to develop an customised electronic ballast for their product. Contacts with INSTA were made through the author's friend who works as an electronic engineer in the company's marketing department. The head of product development invited the author and explained how the development project evolved. Figure 2.11 shows an advert for the new WILA light. Table 2.20 gives general background information on INSTA. The case study can be found in Appendix I.5.

figure 2.11 advert of E Connect

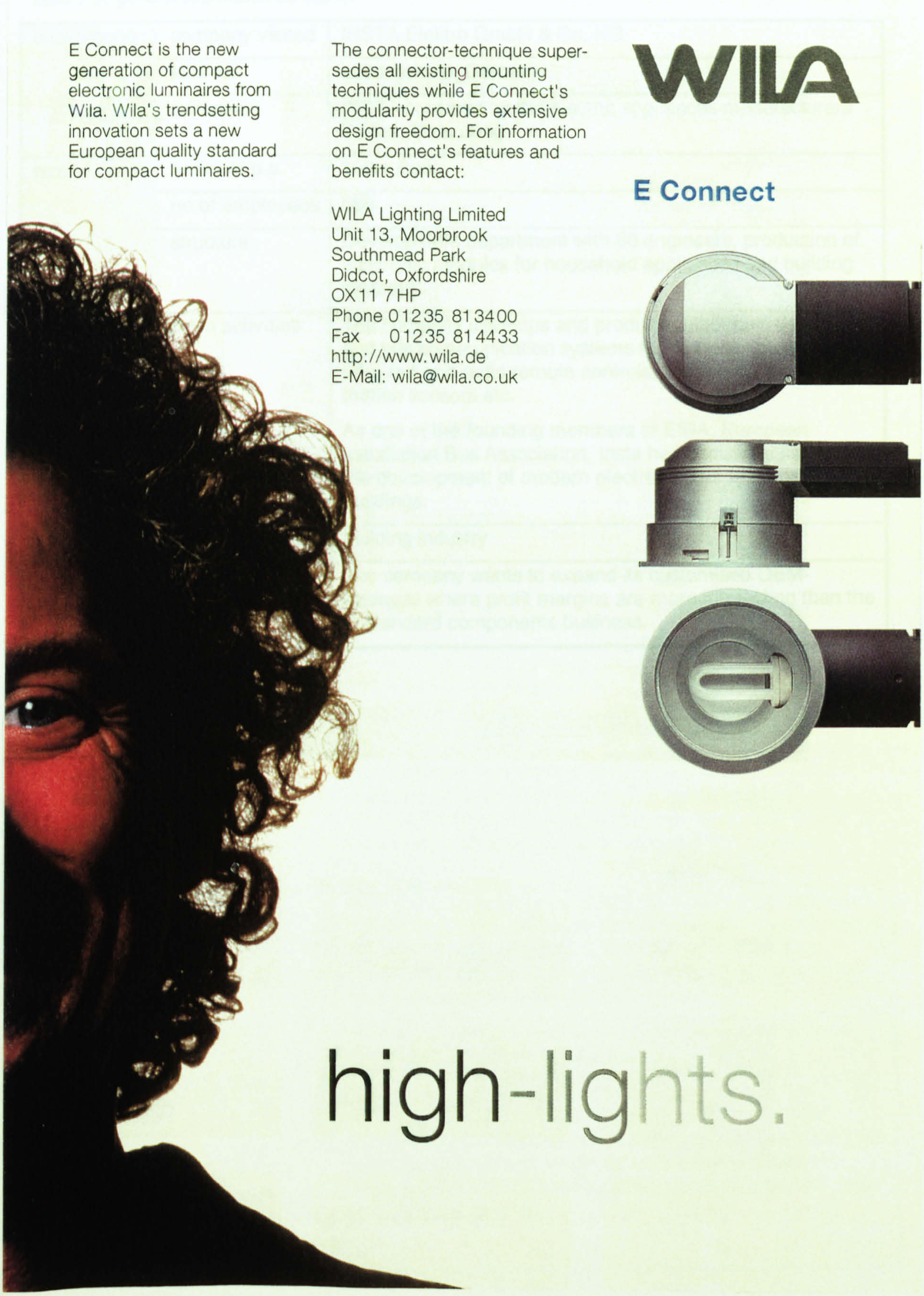


table 2.20 general information on INSTA

background	company visited	INSTA Elektro GmbH & Co. KG
	address	Lüdenscheid, Germany
	ownership	INSTA is owned by the electric appliances manufacturers Berker, Gira, Jung
size	turnover p.a.	100m Euro
	no of employees	560
	structure	Development department with 60 engineers, production of electronic modules for household appliances and building systems.
business	main activities	The company develops and produces electronic devices and bus communication systems for domestic products like infra-red and radio remote controls, lighting systems, motion sensors etc. As one of the founding members of EIBA, European Installation Bus Association, Insta has decisively influenced the development of modern electronic bus systems for buildings.
	markets	building industry
	strategy	The company wants to expand its customised OEM-business where profit margins are more interesting than the in standard components business.

Hydraulic unit for CASE Poclain excavator

The following case study describes the development of a hydraulic unit for Case Poclain excavators. The head of product development at HIBY-ELAFLEX has worked at Rötelmann GmbH for seven years. Rötelmann specialises in the design and manufacture of ball valves for heavy engineering applications. One of Rötelmann's design engineers gave the author a detailed account of a project in which they had developed a hydraulic unit for Case Poclain excavators. Problems with malfunctioning front shovels of medium-sized excavators had often caused damage to equipment on building sites. No appropriate technical solution was found until Rötelmann decided to solve the problem using ball valve technology. Table 2.21 gives general information on Rötelmann. The case study can be found in Appendix I.6.

table 2.21 summary of general information on Rötelmann

background	company visited	Rötelmann GmbH
	address	Werdohl, Germany
	ownership	family owned
size	turnover p.a.	7m Euro
	employees	60
	structure	Technical Manager, project acquisition through sales, 3 design engineers responsible for project management from design to production;
business	main activities	The company specialises in the design and manufacture of stainless steel ball valves for high-pressure hydraulic applications of up to 2000 bar. The ball valves are machined into solid blocks of stainless steel. The quality of the sealing surfaces is crucial for a safe and reliable function.
	products	Half of the company's turnover depends on standard ball valves which are manufactured in high volumes and sold at low prices. The other half of the business consists of customised ball valve assemblies with additional features on an engineer-to-order basis.
	markets	Its main customers are large companies in the chemical and heavy engineering industry.
	strategy	The market for standard catalogue components has become crowded and new competitors from southern Europe are aggressively undercutting prices. Profit margins for more customised, engineered-to-order products are more interesting and management decided to expand this part of the business.

Con-rod for Daewoo engine

The case study describes the development of a connecting rod at Brockhaus & Söhne for a Daewoo 6 cylinder combustion engine. The head of product development at Brockhaus is a personal friend of the author. He is responsible for managing development projects for the large automotive customers in Germany (VW, Audi, Mercedes-Benz, BMW) and Sweden (Volvo, Saab, Scania).

Brockhaus had recently completed the design of a connecting-rod for a new 6-cylinder engine for the Korean company Daewoo: This project seemed particularly interesting for two reasons. Firstly, Brockhaus had developed a new and innovative production process for reducing the cost of forged con-rods. This process was introduced with the Daewoo project and was meant to stop the advance of sintering technology in con-rod production. Secondly, the Korean industrial conglomerate Daewoo had no previous experience in the design of internal combustion engines and was completely dependent on Brockhaus' support for the con-rod project.

Figure 2.12 shows a picture of con-rod and piston. Table 2.22 gives general information on Brockhaus. The case study can be found in Appendix I.7.

figure 2.12 picture of con-rod and piston

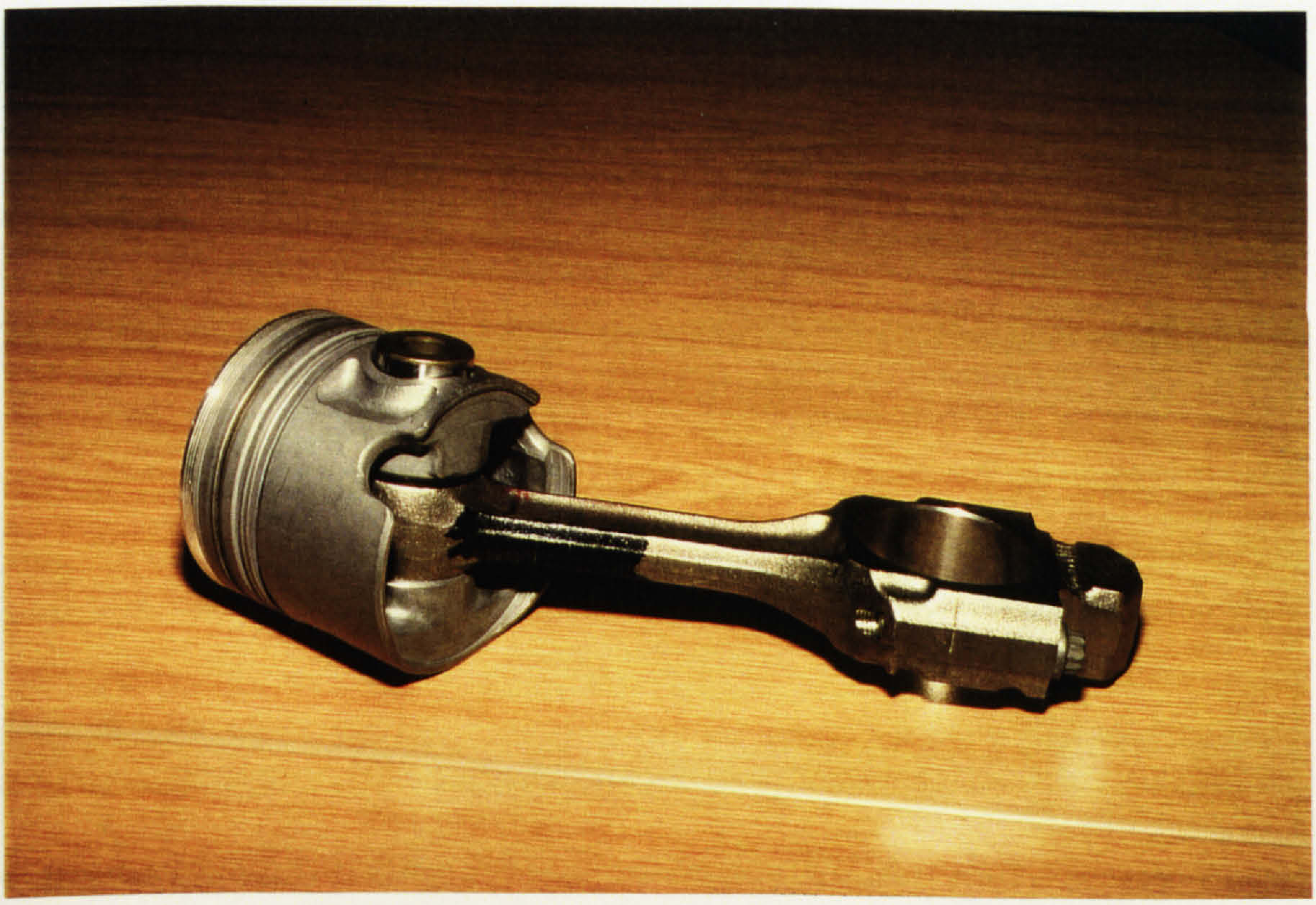


table 2.22 summary of general information on Brockhaus

background	company visited	Brockhaus & Söhne GmbH
	address	Plettenberg, Germany
	ownership	family owned
size	turnover	50m Euro p.a.
	no of employees	480
	structure	project managers responsible for development of component and contact with lead manufacturers
business	main activities	development and production of forged steel and aluminium products and components like connecting rods, steerage components and stub axles, steel vices
	markets	European, Asian and American motor industry
	strategy	technology leadership in forging technology

Phase II: Define phenomenon, identify variations, categorise shared characteristics and differences

Information on product development in supply relationships was acquired from seven companies during phase I. The task in phase II was to structure this information systematically. The steps were:

1. Review the supply model developed in section 2.4.
2. List the model features of the categories.
3. develop what-, why- how- questions using the model features.
4. Design an analysis template based on the questions.
5. Structure the case study information acquired in phase I using the analysis template.

The features of the model are shown in figure 2.13:

1. Involvement
2. Customisation
3. Knowledge
4. Importance

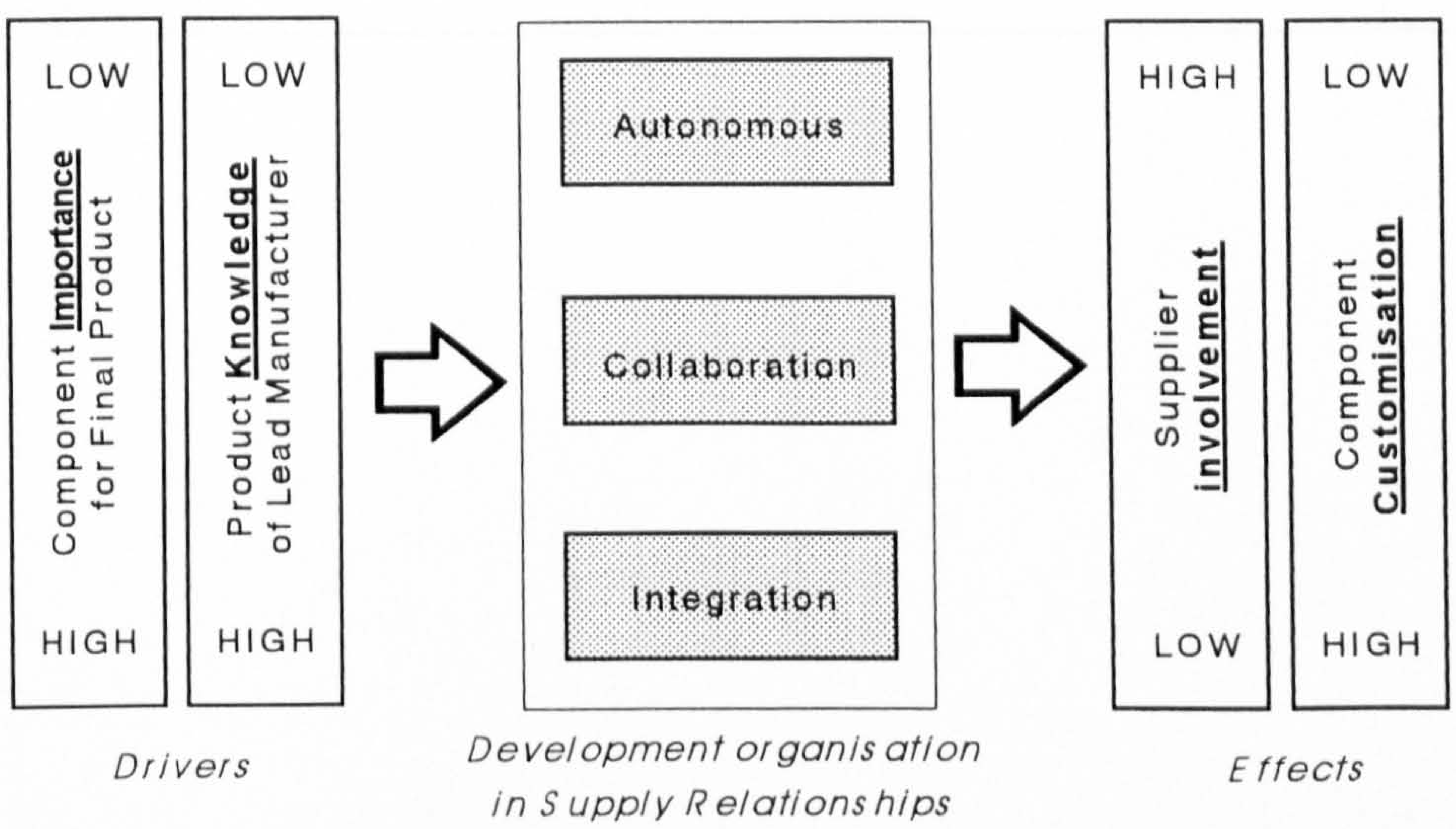


figure 2.13 model of product development showing features

Using on these four features a number of qualitative what-, why- and how- questions were derived. To establish whether component visibility affected any of the four features, components were classified into components with visible elements μ and components without visible elements λ.

table 2.23 questions developed from model features

feature	questions derived from the feature	visible (μ) non-visible (λ)
Control	What did the lead manufacturer control? Why was the lead manufacturer in control? How did the lead manufacturer control it? What did the supplier control? Why was the supplier in control? How did the supplier control it?	
Customisation	What was customised and what was not customised for the lead manufacturer ? Why was it customised or not customised for the lead manufacturer? How was it done?	
Knowledge	What did the lead manufacturer know and what did the lead manufacturer not know? Why did the lead manufacturer know or didn't know?	
Importance	What was important and what was not important to the lead manufacturer ? Why was it important and why wasn't it important to the lead manufacturer ?	

To structure the case study data, a systematic analysis tool was required. King, 1988 [65] suggested *template analysis* for a structured analysis of case study information. In *template analysis*, the researcher produces a list of codes (a 'template') representing themes identified in the textual data. The template was developed from the questions in table 2.23. A further section on supply company success was added. The template format is shown in table 2.24. The structured case studies are published in Appendix I.

table 2.24 template for structuring industrial case studies

	visible/ non-visible	What	Why	How
lead manufacturer involvement				
supplier involvement				
customisation for lead manufacturer				
knowledge of lead manufacturer				
importance for the final product				
supplier success				

Phase III create list of case features, review deviant cases, explain variations
Information on product development in supply relationships was acquired from seven companies during phase I. The information was structured in templates in phase II.

The task in the following phase was to develop a series of hypotheses which predict the impact of product visuals on supplier control over the development and on supply company success. The steps were:

1. Review the structured information.
2. Compile a component list out of 'what' information.
3. Decide whether component contained visible elements or not.
4. Extract 'why and how' information for each component and determine the form of development organisation (integration, collaboration, autonomous).
5. Discuss the findings and define component categories.
6. Examine to what degree suppliers have controlled visual development and whether visuals have affected product success in the supply industry.
7. Develop hypotheses which predict the impact of product visuals on development control and on product success in the supply industry.

2.6.3 Results
Table 2.25 shows a list of components extracted from the case study templates in Appendix I. By extracting why and how information the features supplier involvement, customisation, importance, lead manufacturer knowledge as well as the visible/non-visible flag were set yes (1) or no (0).

table 2.25 list of case study components, model features were set yes (1) or no (0)

case	components	supplier involvement	customisation	importance	lead manufact. knowledge	contains visible elements
Exxon	architecture	0	1	1	1	1
	graphic design	0	1	1	1	1
	technical interfaces	0	0	0	1	0
	arrangement of compon.	0	1	1	1	1
	technical functions	1	0	0	0	0
	non-visual elements	1	0	0	0	0
	shape of tech compon.	0	1	1	1	1
	fuel and lubrication	0	1	1	1	0
BP	colours, surface texture	0	1	1	1	1
	materials	0	1	1	1	1
	architecture	0	1	1	1	1
	compon. arrangement	0	1	1	1	1
	shape of compon.	0	1	1	1	1
	technical functions	1	0	0	0	0
	interfaces	0	0	0	1	0
	visual elements	0	1	1	1	1
ERCO	housing	0	1	1	1	1
	connectors	0	1	1	1	1
	power tracks	0	1	1	1	1
	reflectors	0	1	1	1	0
	luminaries	1	0	0	0	0
	bus systems	1	0	0	0	0
	ballasts	1	0	0	0	0
	sockets	1	0	0	0	0
	special shape ballasts	1	1	1	0	1
Riedel	kettle shell	0	1	1	1	1
	base	0	1	1	1	1
	lid	0	1	1	1	1
	back plate	0	1	1	1	1
	shape	0	1	1	1	1
	aesthetic weight	0	1	1	1	1
WILA	modular concept	0	1	1	1	1
	shape	0	1	1	1	1
	reflector	0	1	1	1	0
	electronic ballast	1	1	1	0	1
	case	0	1	1	1	1
	connector	0	1	1	1	1
Rötlemann	attachment	0	0	0	1	0
	seals	1	0	0	1	0
	unit size	0	1	1	1	0
	ball valve unit	1	0	0	0	0
Brockhaus	con-rod	1	1	1	0	0
	sum	**12**	**30**	**30**	**31**	**25**

In total 25 components containing visible elements and 17 components containing no visible elements were extracted from the case studies. Table 2.26 summarises the findings. The first column lists the three types of development organisation plus a further type which has not been identified by supply literature. The second and third column show effects and drivers behind the different types of organisation. The fourth column lists the absolute numbers of components with and without visible elements which correspond to a particular type of development organisation. The last column converts the absolute numbers of components with and without visible elements into percentage points. The percentage points are represented graphically in figure 2.14.

table 2.26 results of case studies, development of components with and without visible elements

	effects		*drivers*		absolute		percent	
development organisation	supplier control	customisation	importance	knowledge	with visible elements	without visible elements	with visible elements	without visible elements
autonomous	1	0	0	0	0	8	0	47
collaboration	1	1	1	0	2	1	8	6
integration	0	1	1	1	23	3	92	18
other	0	0	1	1	0	5	0	29
sum					***25***	***17***	***100***	***100***

The majority of components with visible elements (90%) was integrated by the lead manufacturers. The remaining 10% of components containing visible elements were developed in collaboration between lead manufacturers and suppliers. 50% of components without visible elements were autonomously developed by suppliers, 5 % in collaboration and 25% were integrated by lead manufacturers. A small percentage of components without visible elements (20%) were not customised, but integrated by lead manufacturers together with other lead manufacturers. Competitors like Esso, BP and Shell for example cooperated in the development of an industry standard electronic interface between pump dispensers and check-out systems. Pump manufacturers had tried to develop their own systems and oil companies were concerned about becoming dependent on supplier-specific solutions. This type of development organisation had not been identified in supply literature.

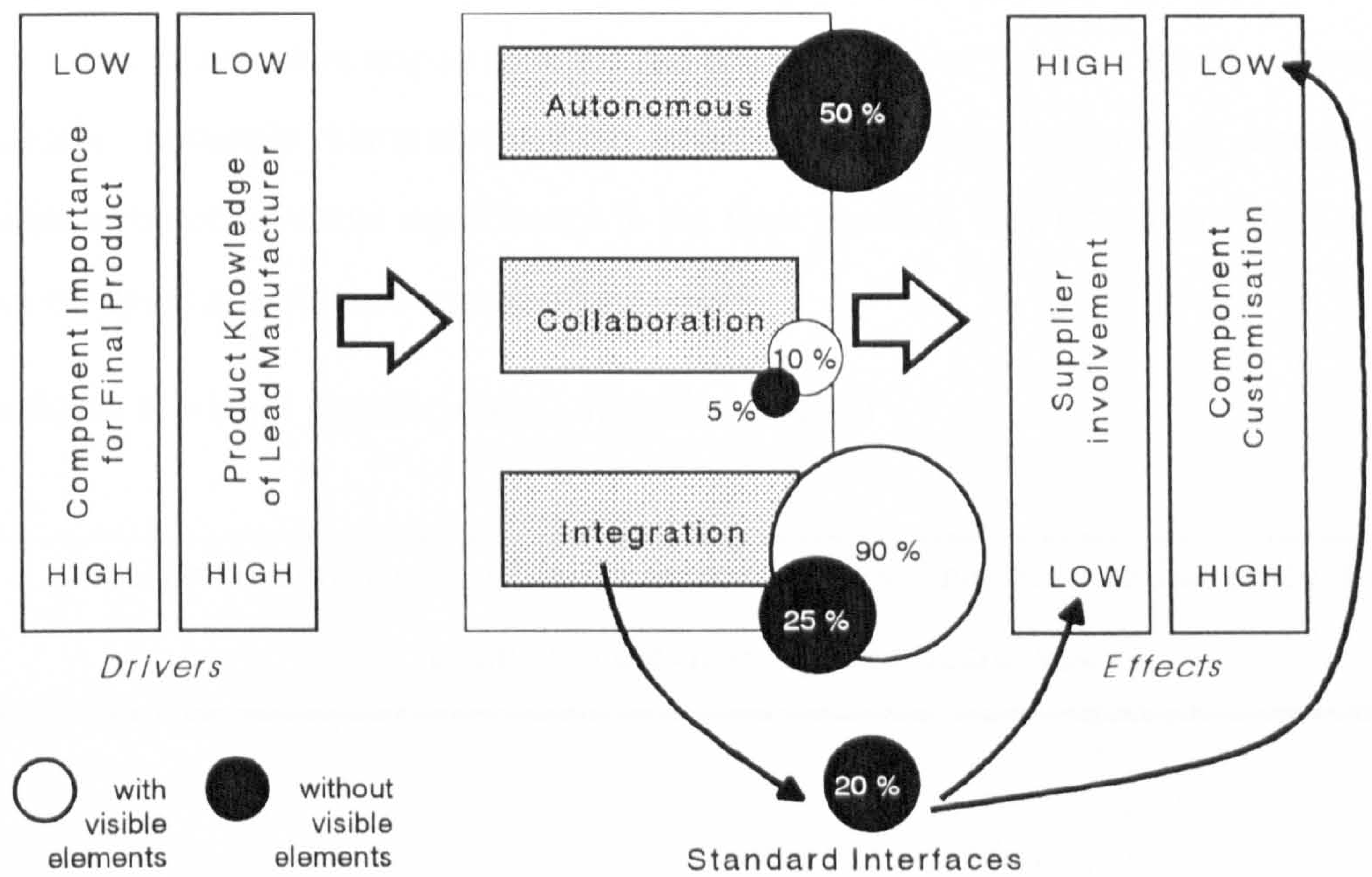


figure 2.14 model of product development and percentages of components with and without visible elements

2.6.4 Discussion

Impact of product visuals on supplier control

The case studies confirm the findings of past literature summarised in section 2.1. Lead manufacturers concentrate on the development of technologies and components which they consider important for their business (fuel and lubrication products for Esso and BP, light reflectors for ERCO). Development collaborations with suppliers are set up if the lead manufacturer knowledge of the component technology is still insufficient (see Brockhaus-Daewoo project). Suppliers tend to develop all those components autonomously whose technologies are not core to the lead manufacturer's business.

When examining the impact of product visuals on supplier control in product development, figure 2.14 shows that the development of components with visible elements was largely integrated by lead manufacturers. A small number of components with visible elements was developed in collaboration and none were developed autonomously by suppliers. Section 2.4 identified component importance for the final product as a driver for development organisation in supply relationships. One aspect of component importance seems to be its visual importance or visual significance in the final product. The first hypothesis predicts the impact of visual significance on supplier control:

Hypothesis 1: visual significance - supplier control

> If the visual significance of the component in the final product increases, supplier control in the development decreases.

Impact of product visuals and supplier control on success

Table 2.27 summarises how the suppliers in the case studies evaluated the success of their projects.

table 2.27 visible components, non-visible components and supplier success

μ components with visible elements	λ components without visible elements
Philips - Alessi kettle shell Riedle received premium margins for the kettle shell. Philips was willing to pay a high price in order to have the convex body shell produced in filled PP. After two years into production, Riedle reports that orders and prices are very stable.	Hydraulic unit for Case Poclain excavator Rötelmann could only benefit for six months until their competitors had copied the unit. In order to stay in business Rötelmann had to cut prices.
Electronic ballast for WILA Light Through this project INSTA could establish itself as a supplier of customised electronic ballasts for the lighting industry. INSTA's profit margins for customised electronic ballasts are 30-50% higher than for standard components. Orders and prices for the new component are very stable.	Connecting-Rod for Daewoo Since completing the Daewoo project, Brockhaus has introduced the crack technology to all major auto manufacturers. The company is now dominating the market for con-rods in Europe. Brockhaus can not charge higher prices for their innovation. Profit margins per con-rod remained flat.

Section 2.5 summarised literature on success strategies for component suppliers. It was recommended that suppliers should control the development process and develop components which are identifiable to the end-user and important for the quality or quality image of the final product. The industrial case studies have shown that Rötlemann and Brockhaus produced non-visible components, had no control over visible development and faced tough pricing pressures. Riedle and INSTA produced visible components, INSTA also had a substantial amount of control over visual development. Both companies got relatively high profit margins and stable orders. Based on these observations and the review of literature on supplier success strategies, hypotheses 2 and 3 express the relationship between supplier control, visual significance and success:

Hypothesis 2: supplier control - success

> If supplier control in the development of component visuals increases, component success for the supply company increases.

Hypothesis 3: visual significance - success

> If the visual significance of the component in the final product increases, component success for the supply company increases.

2.6.5 Conclusions

The objective of section 2.6 was to develop a series of hypotheses which predict the impact of product visuals on supplier control in development and on product success in the supply industry.

Seven case studies were analysed using the model of product development in supply industry which had been derived form past literature. Based on the findings, three hypotheses were developed:

H1: visual significance - supplier control

If the visual significance of the component in the final product increases, supplier control in development decreases.

H2: supplier control - success

If supplier control in the development of component visuals increases, component success for the supply company increases.

H3: visual significance - success

If the visual significance of the component in the final product increases, component success for the supply company increases.

2.7 Summary of chapter 2

The objectives of chapter 2 were to:

1. explore issues of development control and strategies for business success in the component supply industry,
2. derive hypotheses which predict how product visuals affect development control and product success in the supply industry.

Section 2.4 picked up the general questions on development control, effects and drivers and reviewed past literature. A model of product development in supply industry was set up describing different forms of development organisation development in supply relationships, their drivers and their effects. The different forms of development organisation were called integration, collaboration and autonomous. They determine the level of supplier control in development.

Section 2.5 picked up the general questions on success strategies of component suppliers and reviewed past literature. Based upon Porter's competitive theory, researchers recommended that suppliers should control the development of their components which allows them to:

- differentiate their components from the competition,
- tailor specifications towards their components thereby locking lead manufacturers into the relationship,
- develop components which are identifiable to the end-user or important for the quality or perceived quality of the final product.

Section 2.6 used the model of product development and the success strategies to analyse a number of supply relationships in industry. Based on the findings, three hypotheses were developed which predict the impact of product visuals on supplier control in development and on supplier product success. To find answers to the specific questions, the hypotheses could later be tested on a larger scale.

3 Research Method

3.1 Introduction

In chapter 1 the reader was introduced to current issues in the component supply industry. Many industrial companies have reduced their in-house technology depth and have given more development responsibility to component suppliers. The product development function has become an important competitive asset for many suppliers. In order to establish how supply companies control the development process and whether supplier control in component development affects business success, four research questions were derived.

It was also demonstrated that visual and aesthetic properties are important for manufactured products. Companies can systematically control and plan their products' visual qualities. Another four research questions were put forward to establish the effect product visual aspects have on supplier development control and supplier success.

Chapter 2 explored the issues of development control and success strategies of supply companies in more detail. Because the specific questions on how product visual aspects affect development control and product success in the supply industry could not be answered with past literature, the model of product development was used to examine seven industrial case studies. The findings led to three hypotheses which can be tested on a larger scale.

The following chapter develops a research method for testing the hypotheses.

3.2 Objectives

The objective of chapter 3 was to develop a research method for testing the three hypotheses in a larger sample of supply companies.

3.3 Method

3.3.1 Summary of methods for design research

Researchers have investigated design related issues by using a wide variety of methodologies. Examples of some of the main approaches are detailed below:

Hales (1986)[[67]] investigated the use of product design specifications within the engineering design process using evidence from just one project through 'participant research'. Hales actually worked as a participant in the engineering team observing and recording 'key design influences'.

Svengren (1993) [[68]] examined the integration of industrial design into the activities of a Swedish multinational using 'action research'. In this example Svengren acted as a consultant to the company, giving advice on design issues and then observing and recording changes within the company.

Moody (1980) [[69]] examined the role of industrial design in technological innovation in nine companies through 'qualitative' interviews from which he produced nine 'case studies'.

Slappendel (1996) [[70]] investigated the role of industrial designers in product development projects through a quantitative survey involving 66 respondents.

Faced with such an array of approaches it is at first sight difficult to select an appropriate methodology for this study. Potter (1992) [[71]], however, provides some useful advice based on review of design research methodologies suggesting:

> "Having used both case studies and surveys, I think that to get anything like the full picture of any design...subject requires both the detailed qualitative data possible by an in-depth case study, and the breadth provided by a sample survey."

3.3.2 Data collection

The three hypotheses were derived on the basis of a literature review and seven qualitative case studies. Following Potter's recommendation, it now appeared most effective to test the hypotheses with a quantitative survey based on a large sample of development projects in supply companies. This required a method for collecting data from many companies. Hussey, 1997 [72] described a typical data collection process in business research which includes 7 steps. Table 3.1 lists Hussey's generic process, table 3.2 shows how the framework was adapted for this study.

table 3.1 data collection in business research according to Hussey, 1997

step 1	*Identify variables or phenomena*
step 2	*Select sample*
step 3	*Select type of data required*
step 4	*Choose appropriate collection method*
step 5	*Conduct pilot study or exploratory research*
step 6	*Modify collection method*
step 7	*Collect data*

table 3.2 adaptation of Hussey's data collection process for this study

step 1	*Identify variables* Review the 3 hypotheses developed in chapter 2, extract variables.
step 2	*Select Sample* Identify the unit of analysis and delimitations of the study.
step 3	*Select type of data required* Review past literature on how researchers have measured variables similar to the ones extracted in step 1.
step 4	*Choose appropriate collection method* Review design methods with which variables could be measured and adapt them for the study.
step 5	*Conduct pilot study* Conduct a pilot study based on 10 components. 1. car seat for BMW 7-series, supplier: Bertrand Faure 2. pilot manifold for US Navy, supplier: L.Adams 3. pneumatic operating unit for Renault, supplier: Alfmeier 4. refrigeration unit for ICE, supplier: Behr 5. sunroof for Mercedes A-Class, supplier: Webasto 6. petrol dispenser for Aral, supplier: Salzkotten 7. industrial power sockets, supplier: Mennekes 8. control unit for Demag cranes, supplier: TER 9. price sign for Fina petrol stations: supplier PWM 10.push-on knobs for household appliances, supplier OKW
Step 6	*Modify collection method* Evaluate whether the method is suitable for generating data, identify weaknesses using the following criteria: • Was it easy to generate data using the method ? • Does the method deliver ordinal or quantifiable data ? • Is the method applicable across the survey ? • Is the method clearly defined ? Modify the method to compensate weaknesses.
Step 7	*Collect data*

3.4 Step 1: Identify variables

The objective of this chapter was to develop a research method for testing the three hypotheses.

The first step was to review the hypotheses and extract their variables. Figure 3.1 shows how the three hypotheses are based on three variables:

1. visual significance of the component in the final product
2. supplier control in the development/ of component visuals
1. component success for supply company

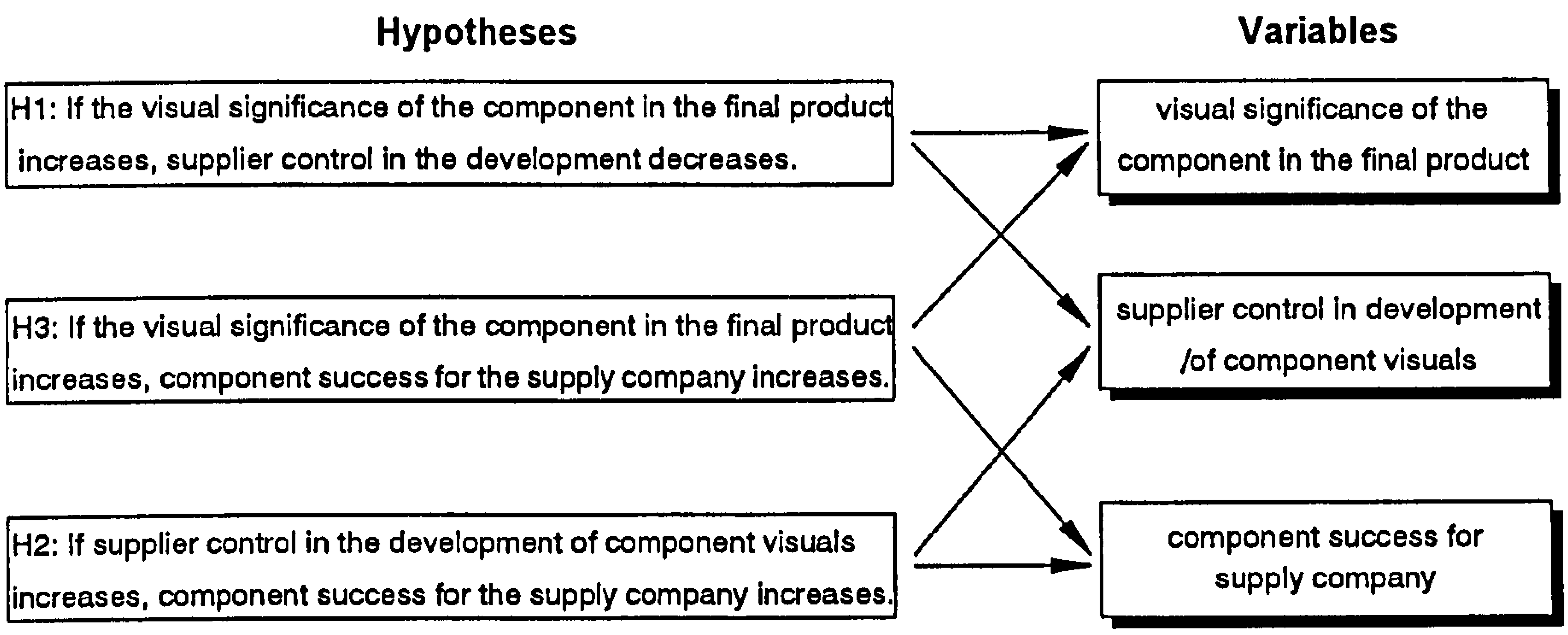


figure 3.1 diagram showing hypotheses and variables

3.5 Step 2: Select Sample

Attention in step 2 turned to the selection of the sample. This included firstly, a definition of the unit of analysis and secondly, an identification of the study's delimitations.

The unit of analysis is the case to which the variables and the research problem refer to and about which the data is collected. Kervin, 1992 [73] defined different types of analysis units which are commonly used in business research. He structured the units into different levels suggesting that researchers should always try and select the lowest level possible (see table 3.3).

table 3.3 list of units of analysis according to Kervin, 1992

level	unit of analysis	description
lowest	an individual	A person or individual is the most basic unit of analysis in business research; for example, a manager, a union member or a customer
	an event	This is a particular incident, for example, a strike, a decision to relocate or a purchase
	an object	In business research this is likely to be a commodity, a machine, a product or a service
	a body of individuals	This includes groups of people and organisations; for example, a work group, a committee or a department
	a relationship	This is a connection between two or more individuals or bodies; for example, a work group, a buyer/ seller relationship, a management/ union relationship.
highest	an aggregate	This is a collection of undifferentiated individuals or bodies with no internal structure; for example, supporters of a football club, parents of children at a certain school,

Following Kervin's suggestion, time was spent in identifying the lowest level of analysis appropriate for this study. It was decided to base the survey on product components, a unit of analysis which would fit under Kervin's classification 'object'. Each sample in the study would consist of a component manufactured by a supply company and sold to a lead manufacturer who builds or assembles it into a larger product.

After having chosen the unit of analysis, the next step was to define the delimitations or constraints of the study. Three criteria were set up to focus the sample on certain technologies and industry sectors:

1. Product components had to be physically accessible to the author. The research was mainly conducted in Germany and the sample was restricted to components the author could find in the country and which were fairly typical or representative of German industry.

2. Product components had to be intellectually accessible to the author, i.e. components needed to be based on technologies the author and sponsoring company HIBY-ELAFLEX were familiar with.

3. Product components had to come from component-based products, i.e. components needed to be part of complex products containing different items from different suppliers.

A number of industry sectors were rejected (see table 3.4).

table 3.4 list of reasons for rejecting industry sectors to focus the sample

Industry sector	**reasons for rejection**
Aerospace	Compared to countries like the United States, Britain and France, aerospace manufacturing is relatively under-represented in Germany.
Automotive	
Chemical/ Pharmaceutical	Chemical or pharmaceutical products are less component-based.
Domestic equipment/ appliances	
Food Industry	Food products are less component-based
Industrial equipment	
Information Technology	The author is less familiar with IT technolgy. Compared to countries like the United States, Japan and France, IT product development is relatively under-represented in Germany.
Retail equipment	
Telecommunication	The author is not familiar with telecommunication technology.

After having chosen the unit of analysis and rejected a number of industry sectors, the research sample was defined as:

> Components manufactured by supply companies and sold to a lead manufacturers who build or assemble them into a larger products; The products could be automotive, retail equipment, industrial equipment or a domestic appliances.

Step 3 & 4: select type of data, choose collection method

In step 1, three variables were extracted from the hypotheses. The variables were:

1. visual significance of the component in the final product
2. supplier control in the development/ of component visuals
3. component success for supply company

In step 2, the sample of the study was defined as:

Components manufactured by supply companies and sold to a lead manufacturers who build or assemble them into a larger products; The products could be automotive, retail equipment, industrial equipment or a domestic appliances.

The task in step 3 and 4 was to select the type of data and choose an appropriate collection method for measuring the three variables.

3.5.1 Variable visual significance of the component in the final product

Objective

The objective of the following section was to identify how variable *visual significance of the component in the final product* could be measured. Figure 3.2 shows the two hypotheses associated with the variable.

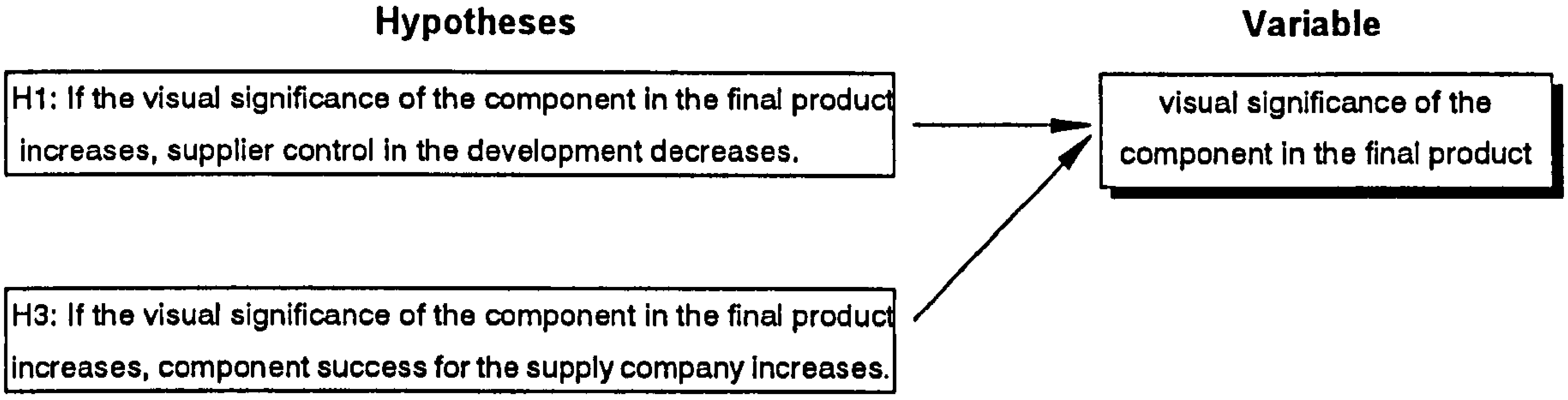


figure 3.2 diagram showing hypotheses containing variable visual significance of the component in the final product

Method

Developing a process for measuring *visual significance of the component in the final product* involved the following stages of activity:

1. Review supply literature and establish how the general significance of a component for the final product can be defined.
2. Explore method designers use to measure component significance in the final product.
3. Adapt the methods to measure *visual significance* instead of general significance of the component in the final product.

Results

Supply literature defined general significance of a component in the final product using the terms customisation effort, cost, component importance for differentiation, function and competitiveness. The process of selecting and adapting methods for measuring *visual significance* is described in tables 3.5, 3.6 and 3.7.

The first row of table 3.5 lists a supply literature definition of component significance in the final product. The second row introduces a method for measuring customisation effort. The third row suggests how this method could be adapted for measuring *visual significance of the component in the final product.*

table 3.5 measuring visual significance with customisation

supply literature definition of significance of a component in the final product

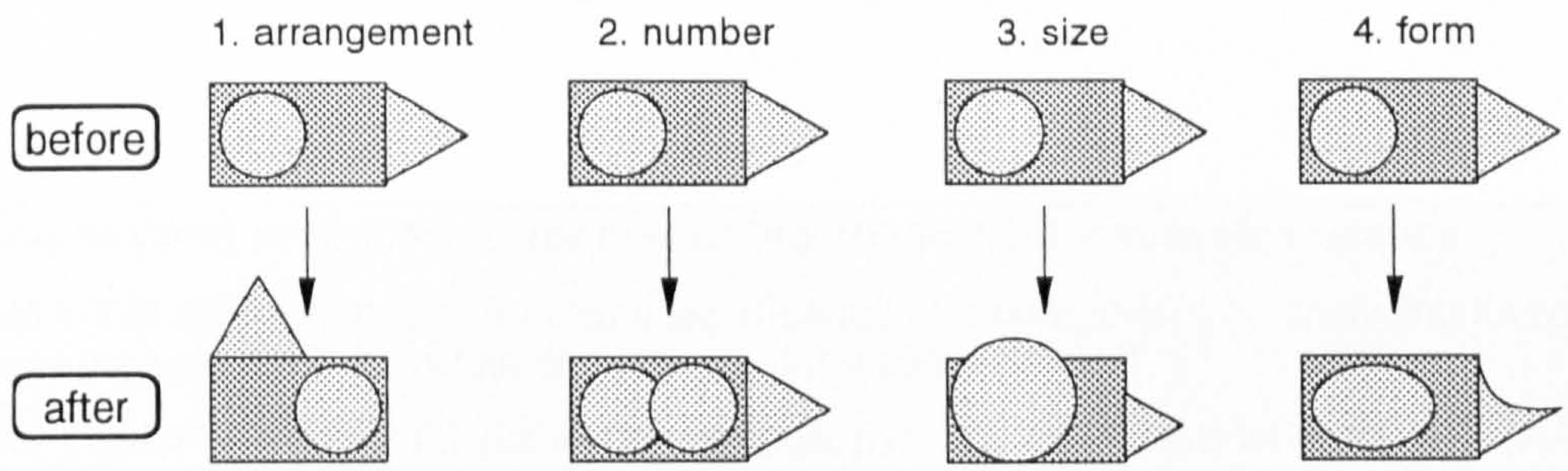
- *customisation effort*

SM&P Unternehmensberatung, 1993 [59] defined the significance of a component for a product in terms of the customisation effort, i.e. the effort necessary to adapt a component design to the requirements of a different manufacturer and product. SM&P distinguished between high and low customisation effort. See also section 2.5.

Design method for measuring component customisation effort

Tjalve parameters

Tjalve, 1962 [74] suggested four geometric parameters for the variation of product design:



Adapting *Tjalve parameters* for measuring visual significance

On the basis of Tjalve's parameters, the researcher could measure visual significance by examining how many parameters the supplier had to change in order to customise the component to the visual requirements of the lead manufacturer.

<u>Question:</u> Which of the following parameters were changed for customising the components to the visual requirements of the lead manufacturer.

1. arrangement of elements in the component
2. number of elements in the component
3. size of elements in the component
4. form of elements in the component

If more parameters were used for customisation, the effort and therefore the visual significance of the component was higher.

The first row of table 3.6 lists a supply literature definition of component significance in the final product. The second row introduces a method for measuring component significance for the cost of the final product. The third row suggests how this method can be adapted for measuring *visual significance of the component in the final product.*

table 3.6 measuring visual significance with cost

supply literature definition of significance of a component in the final product

Wynstra [49] defined component significance in the final product in terms of

- importance for the cost of the final product

see also section 2.4

Design method for measuring component significance for cost of final product

Product cost analysis

Traditional Product Cost Analysis or the more modern approach called Activity Based Costing (ABC) examines material, manufacturing and assembly costs of product components. The relative importance of a component is equal to its share in the overall product cost. For an introduction to Traditional and Activity Based Costing see Burch, 1994 [75] or Ehrlenspiel, 1996 [76].

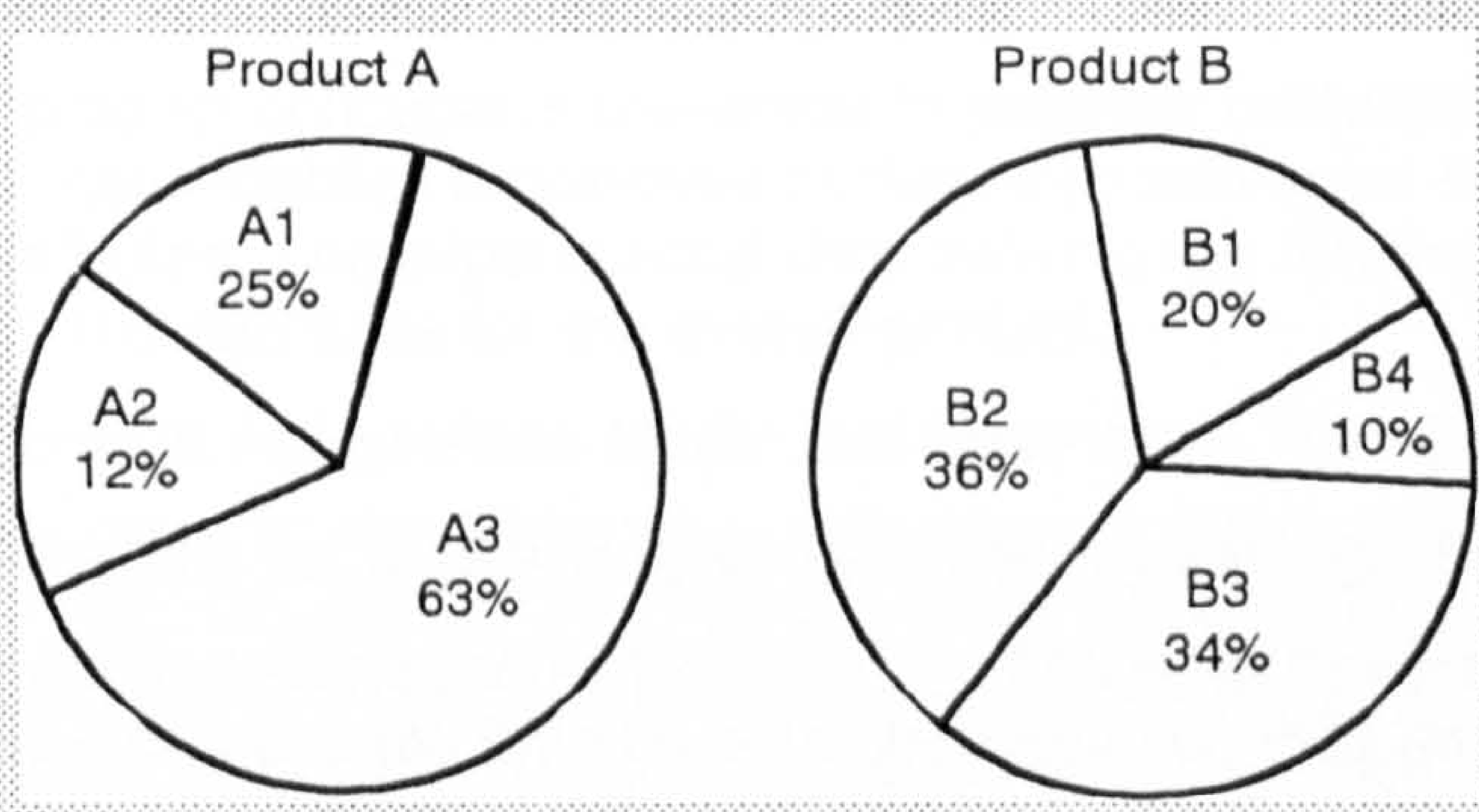
Adapting *product cost analysis* for measuring component visual significance

The researcher could measure the visual significance of a component by analysing its cost relative to the cost of other visible component in the same product.

example: Product A contains 3 visible components (A1, A2, A3). The cost of A1 + A2 + A2= 50 Euro. A1 = 17.5 Euro (25%), A2 = 6 Euro (12%), A3 = 31.5 Euro (63%).

Product B contains 4 visible components (B1, B2, B3, B4). The cost of B1+ B2 + B3 + B4= 100 Euro. B1 = 20 Euro (20%), B2 = 36 Euro (36%), B3 = 34 Euro (34%), B4 = 10 Euro (10%).

In this example, A3 is the most significant with 63% cost share followed by B2 with 36% cost share and B3 with 34% cost share.



<u>Question:</u> If the component is visible, what is its cost relative to the cost of all other visible components in the final product?

The first row of table 3.7 lists a supply literature definition of component significance in the final product. The second row introduces a method for measuring component importance for function, competitiveness and differentiation of final product. The third row suggests how this method could be adapted for measuring *visual significance of the component in the final product.*

table 3.7 measuring visual significance with importance for function, competitiveness, differentiation

supply literature definition of significance of a component in the final product
General significance of a component for the final product was defined as: • significance for differentiation, SM&P Unternehmensberatung, 1993 [[59]] • importance for competitiveness, Hermes [[47]] • importance for differentiation of final product, Bongardt [[48]] • importance for function, performance, Wynstra [[49]]
Design method for measuring component importance for function, competitiveness, differentiation of final product
Conjoint Analysis Consumer preference for product concepts, attributes and components is often examined with *Conjoint Analysis*. *Conjoint Analysis*, sometimes called *Trade-Off Analysis,* breaks products down into either measurable attributes (e.g. speed, power, price) or identifiable components (e.g. sunroof, CD-player, airbag). Designers can then systematically vary these features and develop an array of product concepts. Example: concept A motorcar with 100 hp engine, sunroof, air-bag for 20.000 Euro concept B motorcar with 80 hp engine, sunroof, no air-bag for 16.000 Euro. The array of different product concepts is presented to potential customers. Through pairwise comparison, designers can establish a customer preference ranking for certain combinations of components and attributes. The experimental data delivers the relative importance of individual components and attributes for the overall product. For a description of Conjoint Analysis see Moore and Pessemier, 1993 [[77]].
Adapting *Conjoint Analysis* for measuring component visual significance
Components belonging to the same product type (e.g. office light, motorcar) could be grouped. The components in each group could then be compared against each other by asking: • which component is seen more often by the end-user? • which component is touched more often by the end-user? • which component has a greater share in visible surface? This pairwise comparison could then deliver a rank table for component visual significance in the final product.

Figure 3.3. summarises the process of generating a method for measuring variable *visual significance of the component in the final product.*

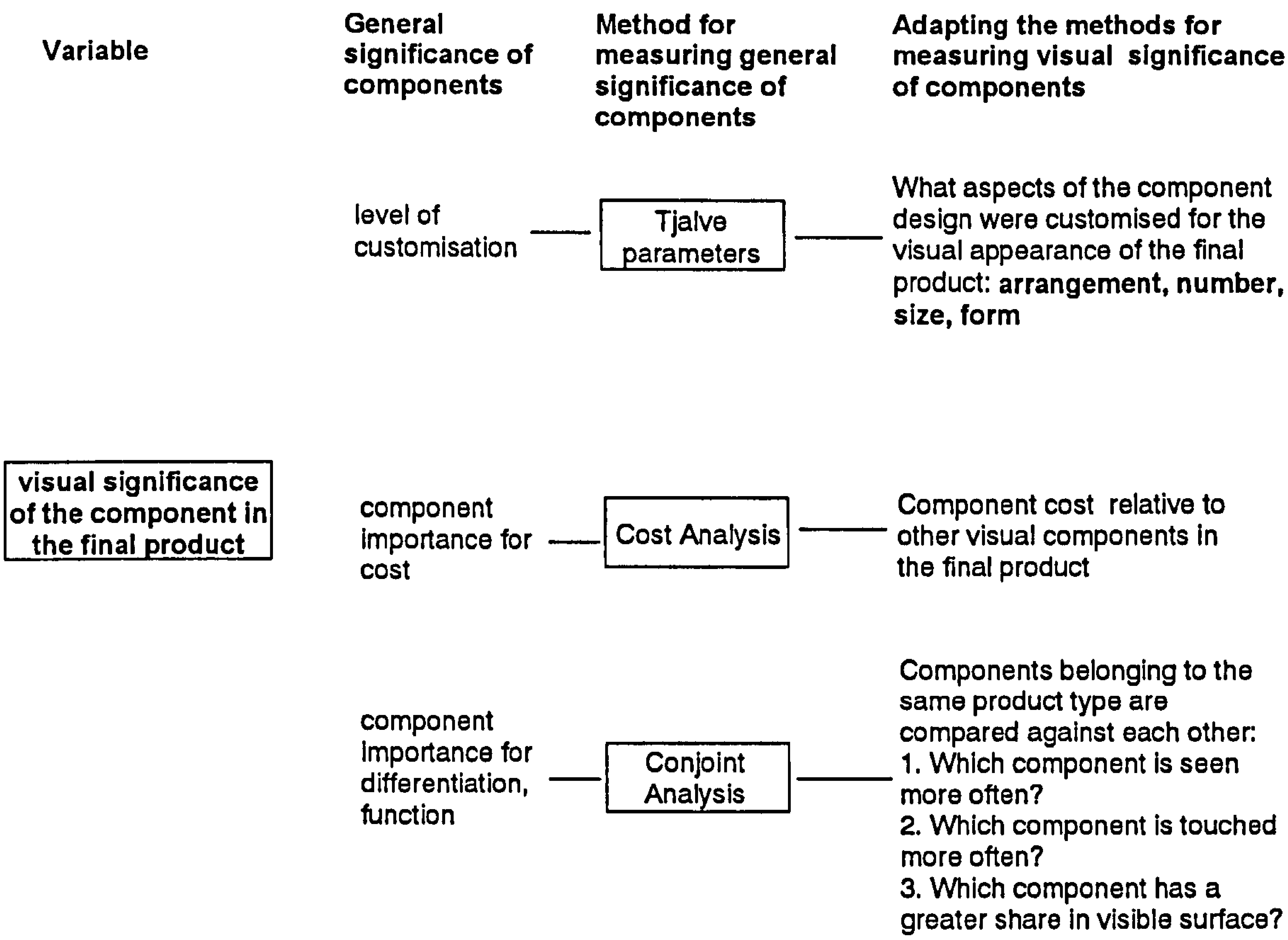


figure 3.3 methods for measuring visual significance of the component in the final product

3.5.2 Variable supplier control in development/ of component visuals

Objective

The objective of the following section was to identify how variable *supplier control in the development/ of component visuals* could be measured. Figure 3.4 shows the two hypotheses associated with the variable.

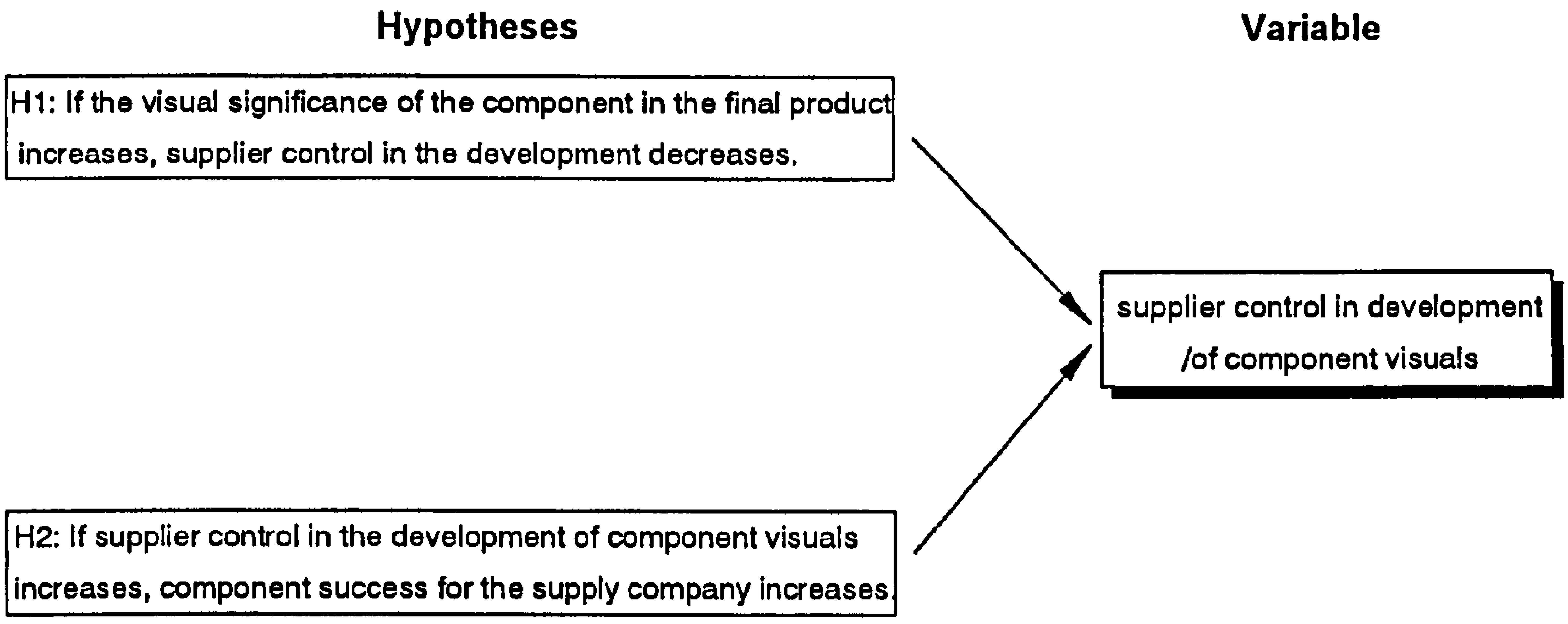


figure 3.4 diagram showing hypotheses with variable supplier control in the development/ of component visuals

Method

Developing a method for measuring *supplier control in the development/ of component visuals* involved the following stages of activity:

1. Review supply literature and establish how supplier control in the development is defined.
2. Explore methods designers use to measure the definition of supplier control in the development.
3. Adapt the method to measure *supplier control in the development and in the development of component visuals.*

Results

The results of this exercise are displayed in table 3.8.

The first row of table 3.8 lists a supply literature definition of supplier control in the development. The second row introduces a method for measuring timing and responsibility in the design process. The third row suggests how this method can be adapted for measuring *supplier control in the development/ of component visuals.*

table 3.8 measuring supplier control with timing and responsibility

supplier control in the development

Bonnaccorsi, Lipparni, 1994 [19] and Muffatto, Pannizolo, 1996 [52] expressed supplier control in the development in terms of:

- the timing of supplier involvement in the design process, at early or later stages
- the responsibility during their involvement, amount of design entrusted to suppliers

Timing of involvement is the stage of the development process at which lead manufacturers begin to search for suitable suppliers and make them aware of the projects. (See also section 2.4.)

method for measuring timing and responsibility in the design process

Timing

The development process can be divided into different stages. Inns, 1998 [78] conducted an extensive literature survey on design process theory and identified 6 development stages:

1. Opportunity
2. Feasibility
3. Concept
4. Embodiment
5. Detail
6. Validation

Responsibility

Responsibility of supplier during their involvement could be described using the different forms of development organisation established in section 2.4.:

- integration = no supplier responsibility
- collaboration = some supplier responsibility
- autonomous = full supplier responsibility

adapting the process approach for measuring supplier control in the development/ of component visuals

In order to measure supplier control in the development and in the development of component visuals, the researcher could

1. Divide the component into visible and non-visible elements,
2. Determine at what process stage and at what organisational level (integration, collaboration, autonomous) the supplier became involved in the development of visible elements.
3. Determine at what process stage and at what organisational level the supplier became involved in the development of non-visible elements.

3.5.3 Variable component success for supply company

Objective

The objective of the following section was to identify how variable *component success for supply company* could be measured. Figure 3.5 shows the two hypotheses associated with the variable.

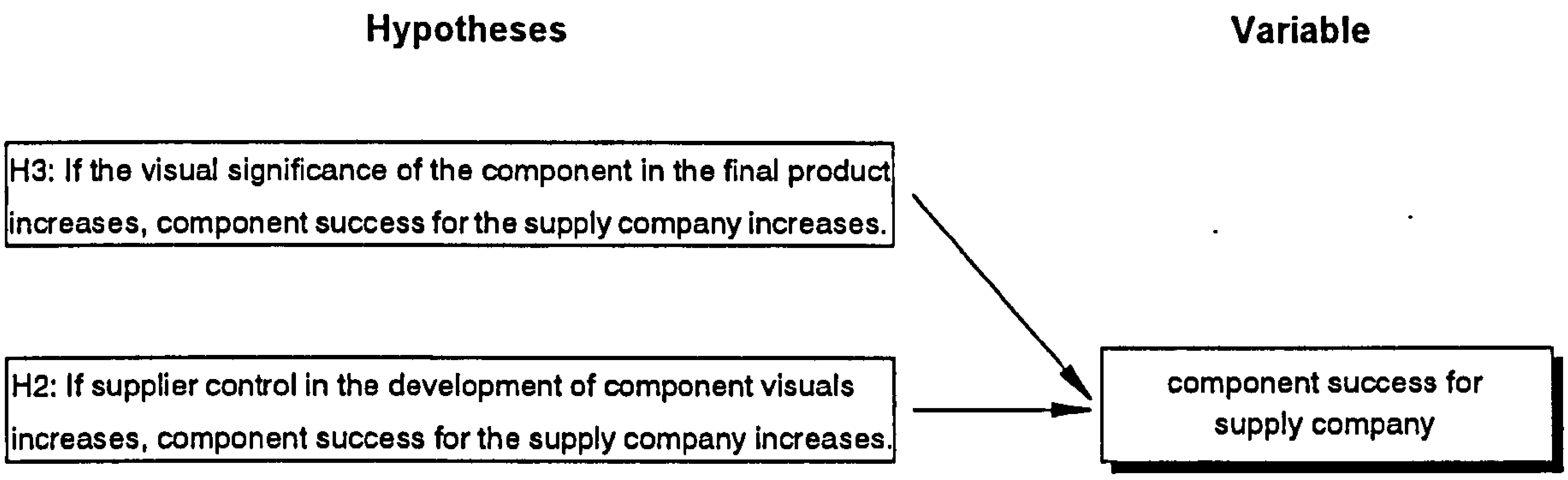


figure 3.5 diagram showing the hypotheses with variable component success for supply company

Method

In order to achieve this objectives, two studies were reviewed in which researchers have compiled success measures for product development.

Results

Table 3.9 contains a list of success measures. The left column shows measures found in design literature which had been compiled by Hart, 1996 [79]. The right column is a list of success measures used by designers. The list was compiled by Hertenstein and Platt, 1997 [80] in a survey amongst design professionals in the United States.

table 3.9 measures of success for product development

measures of success in design literature, Hart, 1996 [79]	measures of success used by designers, Hertenstein and Platt, 1997 [80]
financial measures of success	financial performance measures
profit-based	*profit based*
profitability, degree to which product's profitability fell short or exceeded firm's acceptable profitability level for this type of investment	gross profit - total
profits relative to other new products introduced in the last 5 years	gross profit - new products
meeting profits objectives	net income/ profit
profits for the new product minus the cost of the new product programme	
profit margin	
profit growth	
financial success or failure, i.e. exceeded or fell sort of acceptable profitability level	
profitability of product over its life cycle	
payback period (time to break even)	
achievement of break even	
average return on sales	
net direct money gains, accruing from the sale and/ or licensing of the innovation and from the sale of technical know-how generated through the innovation	
Importance of programme in generating profits for the company	
asset-based	
asset growth	economic value added (EVA)
	stock price

measures of success in design literature, Hart, 1996 [79]	**measures of success used by designers, Hertenstein and Platt, 1997 [80]**
sales-based	*sales-based*
turnover growth	market share - product
export sales	percent sales - new products
percentage sales growth	percent sales - new customers
meeting sales objectives	percent sales - repeat customers
sales relative to other new products introduced in the last 5 years	percent sales - proprietary customers
	sales to break even
ratio of cumulative sales in the first 3 years on the market to the investment in R&D for the project	revenue/ sales
	cash flow
domestic market share, percentage share of domestic market 3 years after launch	
foreign market share, percentage share of foreign markets 3 years after launch	
diffusion coefficient, fitting installation data to classify diffusion equation	
market share in terms of the number of units sold and the average sales per price per unit	
Importance of programme in generating sales for the company	
percentage of company sales made up by new products introduced in the last 5 years	
capital-based	
return on capital	
average return on capital	
equity-based	
component equity growth	
	cost-based
	product cost

measures of success in design literature, Hart, 1996 [79]	**measures of success used by designers, Hertenstein and Platt, 1997 [80]**
	development process cost - total development process cost - by phase
non-financial measures of success *design-based* number of design awards number of citations by Design Council competitors' measures of their design reputation winning Queen's Award	non-financial performance measures *Innovation measures* number of patents number of new products developed number of new products introduced number of design awards peer evaluation of design work percent new features
activity-based regularity of updated and new products in relations to competitive nature of market number of launches resulting from new product development projects in last 5 years percentage of successful launches from total number success to which the new product met its performance objectives over the last 5 years successfulness of programme - global rating success, failure and 'kill' rates (percent) of products developed in the last 5 years products developed in the las*t 5 years*	*volume measures* number of products in pipeline number of products started number of products completed
market-based opportunity window on the new markets, extent to which a new market for the firm was opened up by the new product market potential, uniqueness or	*timing measures* time to market cycle time - by phase time to revision time to break even

measures of success in design literature, Hart, 1996 [79]	measures of success used by designers, Hertenstein and Platt, 1997 [80]
interchangeability of product from buyers point of view (greater uniqueness equals greater potential)	
technologically-based degree of novelty/ uniqueness of technological solutions degree of patent protection time for development company's 20-year record for innovation opportunity on new categories, extent to which a new category of product was introduced *to the firm by the new product*	
	employee related measures employee morale team assessment of individual contribution
	design efficiency measures number of design modifications frequency of specification changes
	design effectiveness measures percent projects that reach production percent first design meets needs assessment of CAD use team assessment of design effectiveness
commercially-based commercial success, successful if having been marketed it had sold beyond the initial installation for at least 1 year and not been	*customer satisfaction measures* satisfaction - product satisfaction - style/ appearance satisfaction - ease of use

measures of success in design literature, Hart, 1996 [79]	**measures of success used by designers, Hertenstein and Platt, 1997 [80]**
withdrawn commercial success, i.e. the consensus as to whether the product met or did not meet original expectations on all important respects success if survival for more than 4 years	

Figure 3.6 summarises financial and non-financial measures with which *component success for supply companies* could be established.

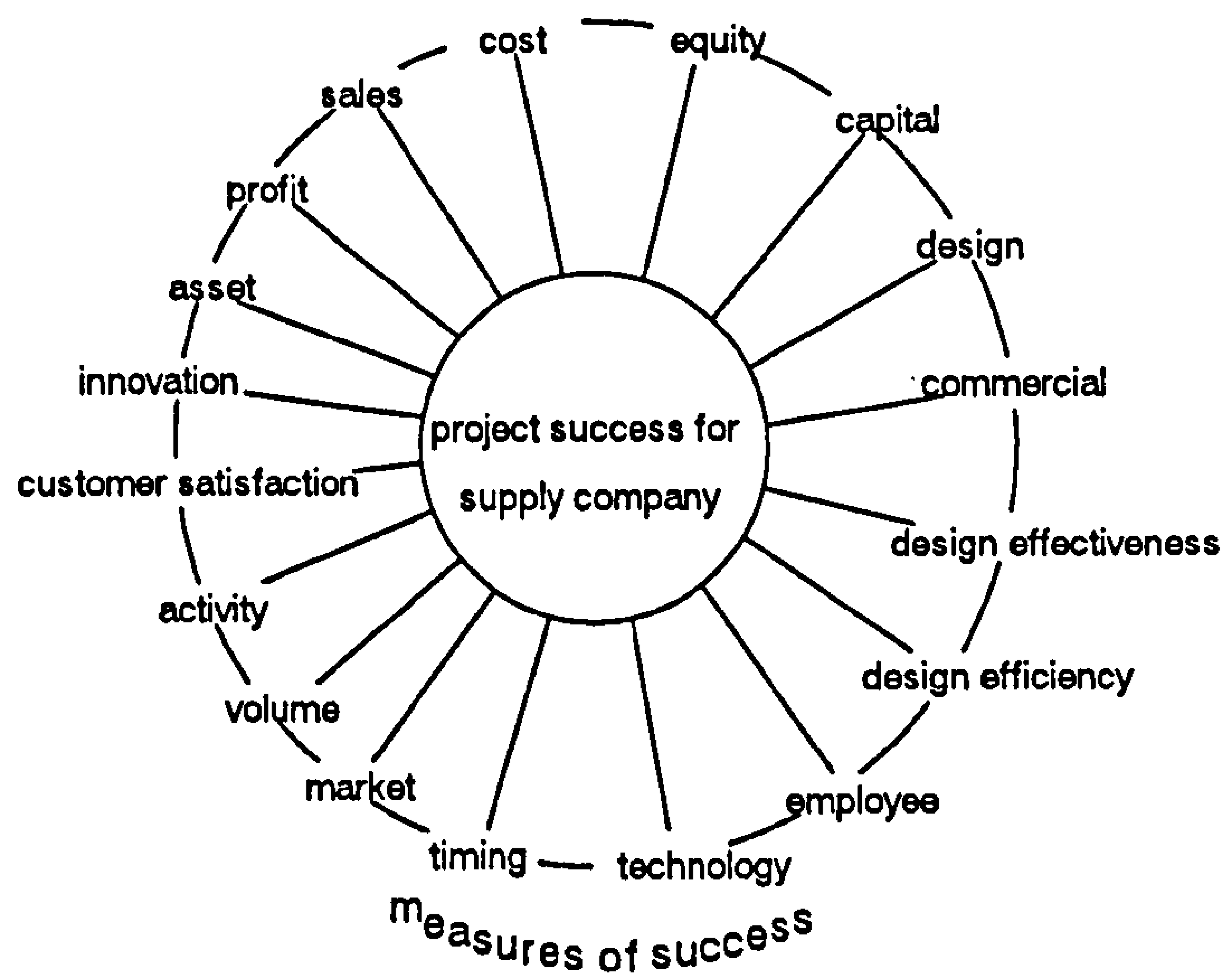


figure 3.6 model of financial and non-financial measures of component success

3.6 Step 5: Conduct pilot study

The objective of this chapter was to develop a research method for testing the three hypotheses in a larger sample of supply companies.

The first step was to review the hypotheses and extract their variables.

1. visual significance of the component in the final product
2. supplier control in the development/ of component visuals
3. component success for supply company

The second step was to define the sample of the study:

Components manufactured by supply companies and sold to a lead manufacturers who build or assemble them into a larger products; The products could be automotive, retail equipment, industrial equipment or a domestic appliances.

The 3rd and 4th step was to select the type of data and collection method for measuring the three variables.

Variable *visual significance of the component in the final product* could be measured by adapting Tjalve parameters, cost analysis and conjoint analysis.

Variable *supplier control in the development/ of component visuals* could be measured by dividing each component into visible and non-visible elements and then examining at what stage and at what organisational level the suppliers became involved in the development of each element.

Variable *component success for supply company* could be measured using a range of financial and non-financial success measures.

table 3.10 summary of how variables were measured in pilot study

variable	method
visual significance	Which of the following parameters were changed for customising the components to the visual requirements of the lead manufacturer. 5. arrangement of elements in the component 6. number of elements in the component 7. size of elements in the component 8. form of elements in the component If more parameters were used for customisation, the effort and therefore the visual significance of the component was higher.
	If the component is visible, what is its cost relative to the cost of all other visible components in the final product?
	Components belonging to the same product type (e.g. office light, motorcar) could be grouped. The components in each group could then be compared against each other by asking: • which component is seen more often by the end-user? • which component is touched more often by the end-user? • which component has a greater share in visible surface? This pairwise comparison could then deliver a rank table for component visual significance in the final product.
supplier control in development	In order to measure supplier control in the development and in the development of component visuals, the researcher could 4. Divide the component into visible and non-visible elements, 5. Determine at what process stage and at what organisational level (integration, collaboration, autonomous) the supplier became involved in the development of visible elements. Determine at what process stage and at what organisational level the supplier became involved in the development of non-visible elements.
component success	The list of success measures was shown to suppliers in order to find whether they used any of them: sales, cost, equity, design, commercial, design effectiveness, design efficiency, employee, timing, technology, market, volume, activity, customer satisfaction, innovation, asset, profit

The objective of step 5 was to use these methods in a pilot study of 10 components.

The 10 components were:

1. car seat for BMW 7-series, supplier: Bertrand Faure
2. pilot manifold for US Navy, supplier: L.Adams

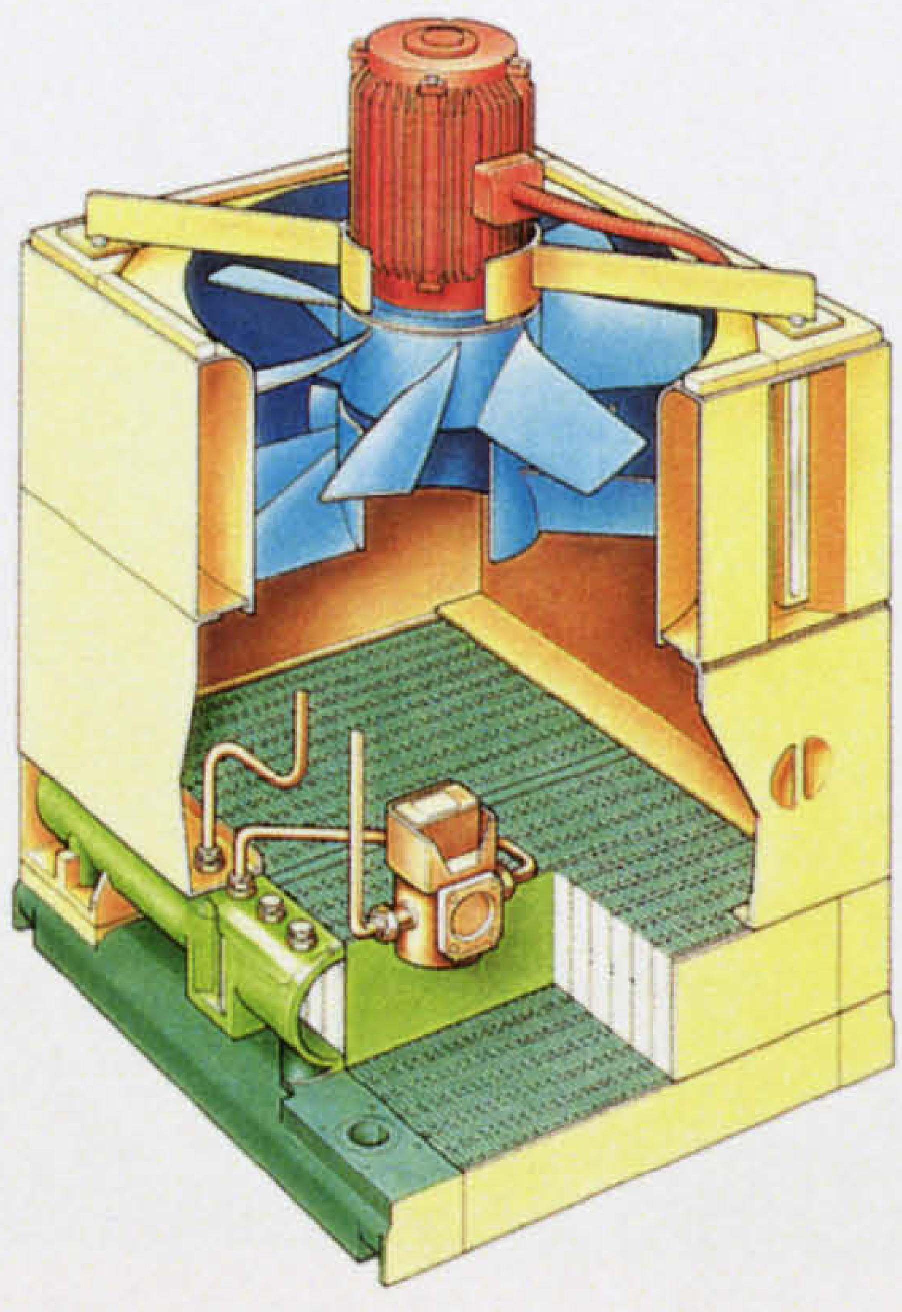
3. pneumatic operating unit for Renault, supplier: Alfmeier
4. refrigeration unit for ICE, supplier: Behr
5. sunroof for Mercedes A-Class, supplier: Webasto
6. petrol dispenser for Aral, supplier: Salzkotten
7. industrial power sockets, supplier: Mennekes
8. control unit for Demag cranes, supplier: TER
9. price sign for Fina petrol stations: supplier PWM
10. push-on knobs for household appliances, supplier OKW

figure 3.7 picture of seat for BMW 7-series

figure 3.8 picture of pilot oxygen manifold for US navy

figure 3.9 picture of pneumatic operating unit for Renault

figure 3.10 picture of refrigeration unit for ICE



Jeder ICE-Triebkopf ist mit zwei dieser Kühlanlagen bestückt. Sie sind aus Leichtmetall und kühlen Transformator und Stromrichter.

figure 3.11 picture of lamellar sunroof for Mercedes A-class

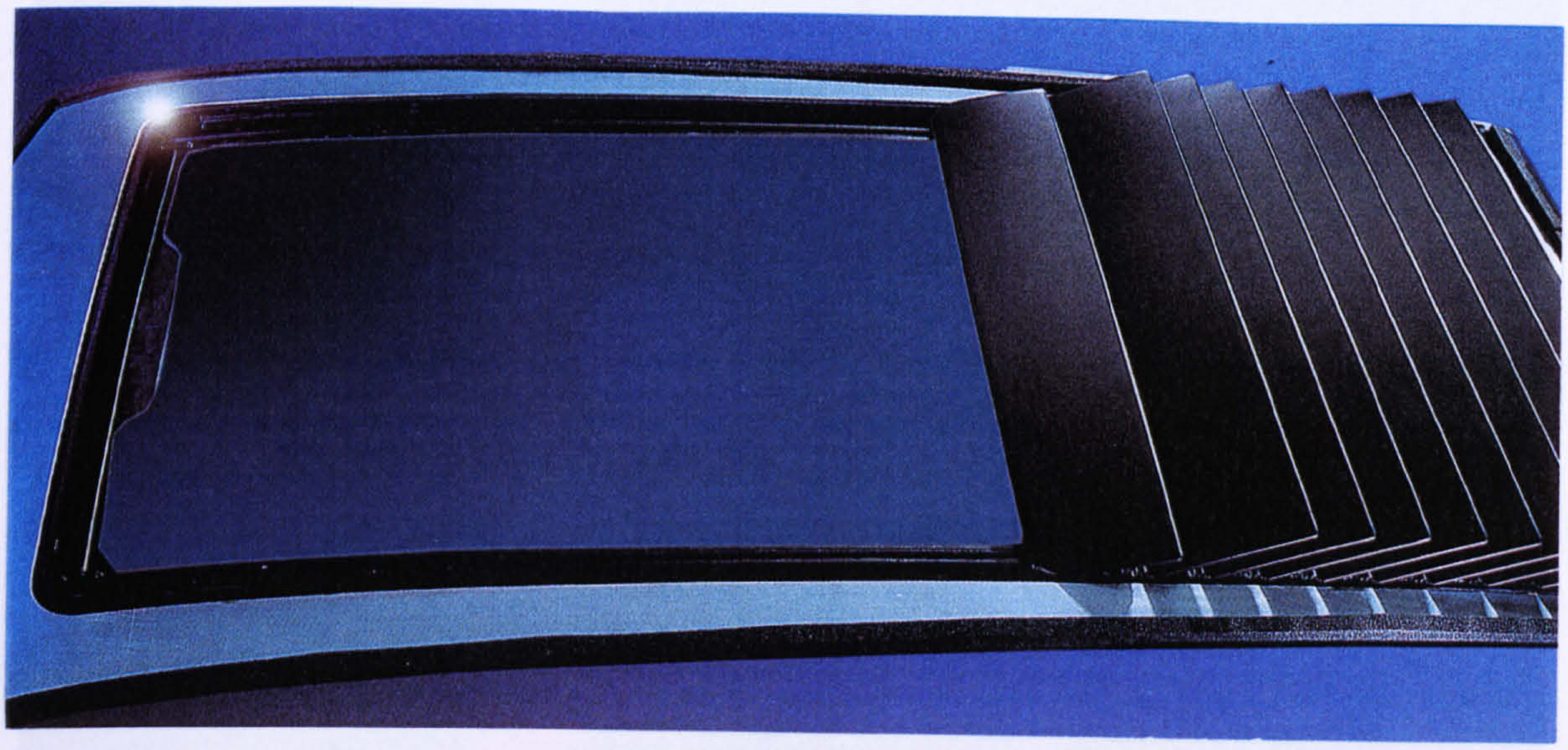


figure 3.12 picture of industrial power sockets

figure 3.13 picture of control unit for cranes

arianten Sonderbearbeitungen, wie z.B. der Einbau von entsprechend der Verwendungen g(
isplays oder elektronischen Karten, die Steuer- und Kontaktelemente ersetzten können, sind möglich. Die Hängetaster
önnen auf Anfrage personalisiert werden.

/artung und Reparatur Die Wartung und Verdrahtung des Hängetasters Serie*** ist einfach und wurde so l
aschinenstillstandszeiten und Kosten verringert werden können.

Allgemeine Eigenschaften

Gemeinschaftsrichtlinie	73/23/CEE 93/68/CEE
Harmonisierte Normen	EN 60204-1 EN 60947-1 EN EN 60529 EN 418 EN 50013
Umgebungstemperatur	Lagerung -40°C / +70°C Betrieb -25°C / +70°C
Schutzart	IP 65
Isolierklasse	Klasse II
Mechanische Lebensdauer	1 x 10^6 Schaltungen
Zulassungen	CE (in Erwartung UL / cUL)

Daten der Kontaktelementen

Nennstrom	3 A
Nennspannung	250 V
Nennthermstrom	10 A
Nennisolierspannung	500 V
Betriebsklasse	AC 15
Klemmenkennzeichnung	gemäß EN 50013
Anschluß	Schraubklemmen
Zulassungen	CE (in Erwartung UL / cUL)

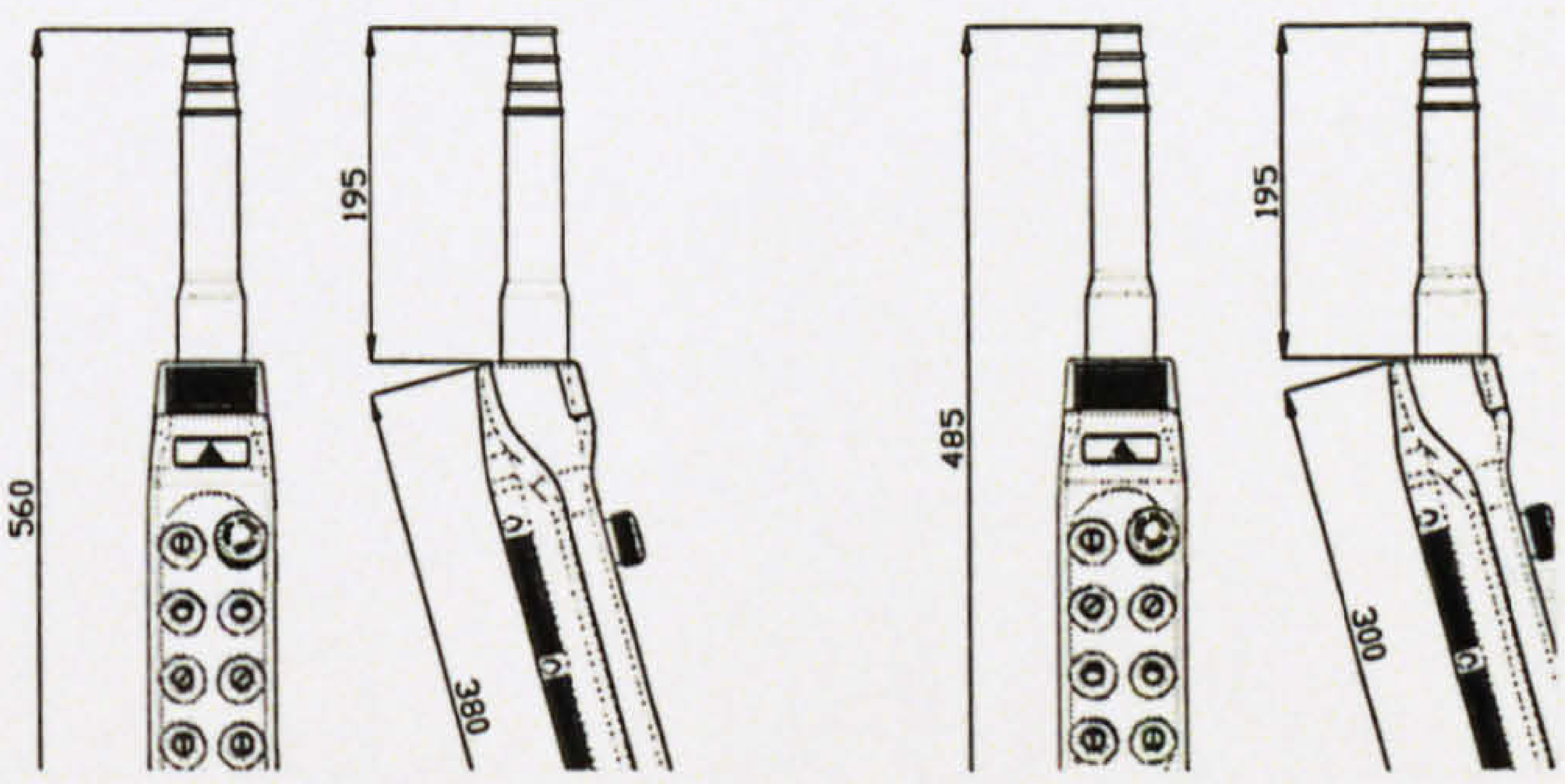
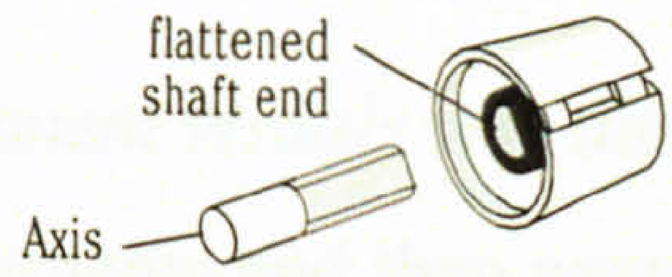


figure 3.14 picture of push-on knobs for household appliances

Now also to push on

TOP-KNOBS



- suitable for axes with flattened shaft ends ø 6/4.6 mm
- alternatively with lateral screw fixing for boreholes of 4 mm, 6 mm and 1/4 inches (ordering data in knob catalogue)
- standard colour volcano, NCS 5502-G and nero, NCS 9000-N in PA 6 reinforced (UL 94 HB)

- Functional marking elements are supplied in up to five different standard colours – must be separately ordered, see OKW knob catalogue

NEW

	TOP-KNOBS		
Part-No. colour volcano	Part-No. colour nero	Knob ø	borehole
A 10 16 648	A 10 16 649	16 mm	6/4.6 mm
A 10 20 648	A 10 20 649	20 mm	6/4.6 mm
A 10 24 648	A 10 24 649	24 mm	6/4.6 mm
A 10 31 648	A 10 31 649	31 mm	6/4.6 mm
A 10 40 648	A 10 40 649	40 mm	6/4.6 mm

3.7 Step 6: Modify Collection Method

The type of data and collection method for measuring the three variables were selected in step 3 and 4.

Variable *visual significance of the component in the final product* was measured by adapting Tjalve parameters, Cost Analysis and Conjoint Analysis.

Variable *supplier control in the development/ of component visuals* was measured by dividing each component into visible and non-visible elements and then examining at what stage and at what organisation level the suppliers became involved in the development of each element.

Variable *component success for supply company* was established using a range of financial and non-financial success measures.

In step 5 the adapted methods were used in a pilot study of 10 components.

3.7.1 Objectives

The objectives of step 6 were to evaluate whether the methods are suitable for generating data and modify them for a larger survey where necessary.

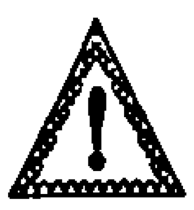
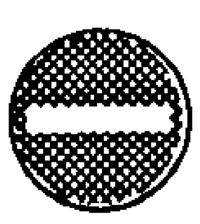
3.7.2 Method

The methods were evaluated against four criteria:

1. Was it easy to generate data using the method ?
2. Does the method deliver ordinal or quantifiable data ?
3. Is the method applicable across the survey ?
4. Is the method clearly defined ?

The methods were assessed against each of the four criteria using the classification shown in table 3.10. The left column shows the classification symbols, the right hand column describes their meaning.

table 3.10 assessing data collection method

Symbol	Meaning
	Method works well for this criterion.
	Method shows deficits for this criterion and needs further modification.
	Method does not work at all for this criterion and should be abandoned altogether.

3.7.3 Visual significance

Variable *visual significance of the component for the final product* was measured by adapting:

1. Tjalve parameters
2. Cost Analysis
3. Conjoint Analysis

Figure 3.15 summarises how the methods were developed.

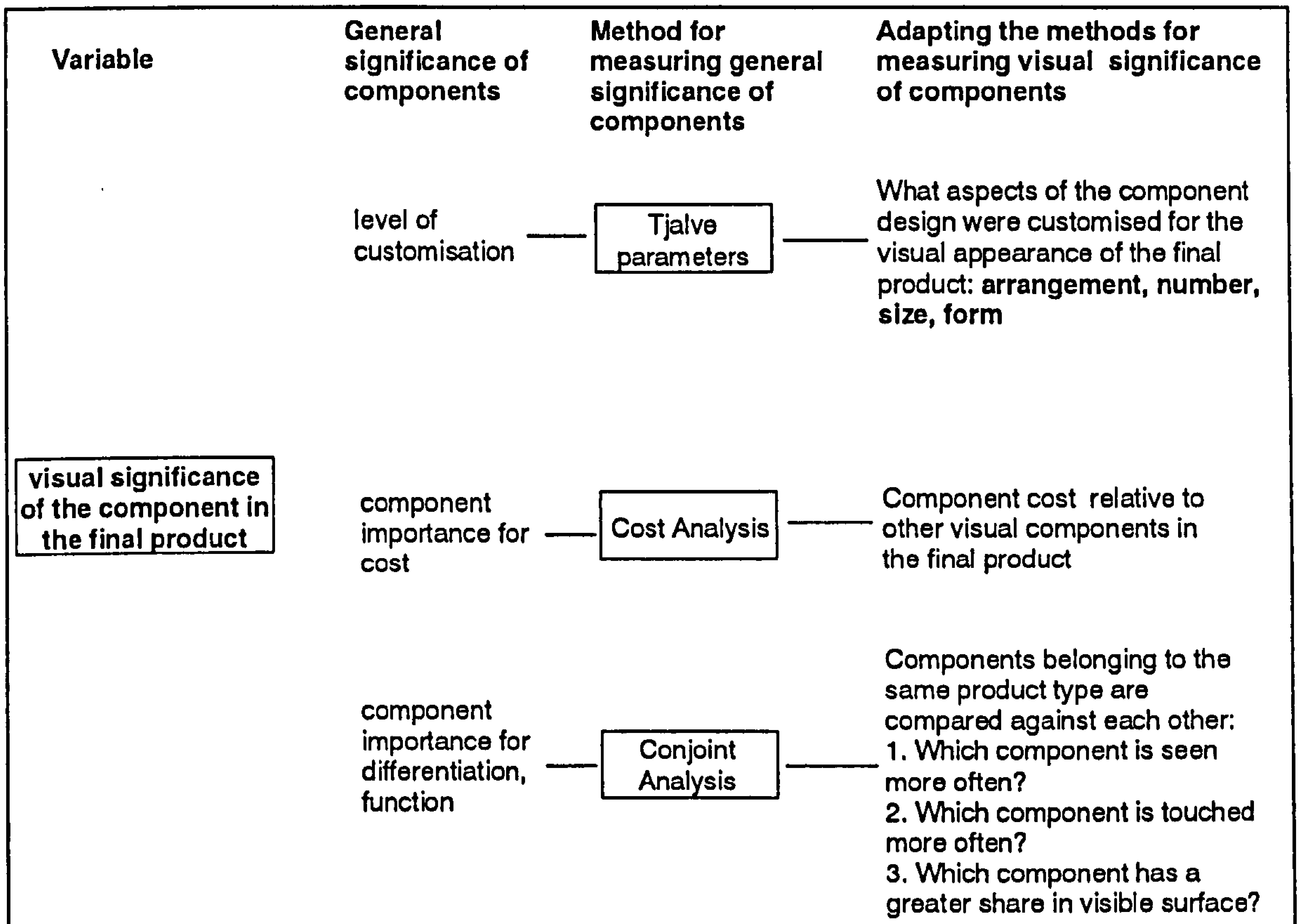


figure 3.15 summary of how the methods for measuring visual significance were developed.

The adapted methods had been tried in the pilot study on 10 components. The details of the evaluation process are shown in tables 3.11, 3.12 and 3.13.

Evaluating Tjalve Parameters

Variable *visual significance of the component in the final product* was expressed in terms of customisation. This was measured using an adaptation of Tjalve parameters on 10 components. The method was assessed against the four criteria listed in section 3.8.2. Table 3.11 shows the results of the assessment process.

table 3.11 assessment of Tjalve parameters for measuring visual significance

Tjalve parameters		
Criteria	**Result**	
Was it easy to generate data using the method?	⚠	The parameters were not strictly independent of the component technology. Electronic products used 'arrangement' of resistors, capacitors, IC's, power tracks etc. to achieve different overall product 'form'. Mechanical elements often varied in 'size' due to different requirements for strength and stiffness. Comparing the customisation effort of mechanical and electronic components proved difficult using Tjalve parameters.
	⚠	Component complexity (number of elements) had an impact on the type of variation parameters used. The more complex a component, the more parameters were used for customisation.
Does the method deliver ordinal or quantifiable data?	⚠	Tjalve parameters do not specify a level or rank: Does customisation of 'form' require higher effort than customisation of 'size', or 'arrangement'. A further observation was that the parameter 'number' was hardly used.
Is the method applicable across the survey?	⚠	Many suppliers offer design variations or components with different performance or interfacing specifications that are not lead manufacturer-specific, but part of their standard catalogue range. For example, suppliers of submersible pumps offered standard pumps with 3 bar, 7 bar and 15 bar operating pressure. Each pump was available with a connection for 2", 1" or 3/4" piping. Many pump variations exist, but none of them are customised to the needs of any particular lead manufacturer.
	⚠	Tjalve's parameters do not include design variation through colour and graphics which may be an important element of brand identity and brand recognition.
Is the method clearly defined?	⚠	Tjalve's parameters are not independent of each other. A change in 'size' or 'arrangement' of some elements inside a component had a direct impact on 'form' or 'arrangement of other elements in the same component.
		Similarly problems occurred when distinguishing between visible and non-visible elements of components. The form of some visible elements like housings had to change because a number of non-visible elements were arranged differently.

Modifying Tjalve parameters

Based on the assessment in table 3.11, Tjalve parameters were found to be inappropriate for measuring component customisation.

1. The parameters do not include customisation based on colour and graphics.
2. The parameters are not independent of component technology.
3. The extent to which parameters are used depends on component complexity.
4. The parameters do not indicate an order or rank.
5. The parameters are not independent.

To overcome these problems, a number of simplifications to Tjalve can be suggested.

In order to measure degree of component customisation, Tjalve's parameter *number* was dropped and *arrangement, size, form* were combined into a general variable *form or shape*. Another option for *graphic* customisation was added. Figure 3.16 shows how the question was laid out in the survey questionnaire.

	Is the component customised for certain lead manufacturers ?		
	not customised	only graphics	form or shape
component elements visible to end-user	O	O	O
component elements not visible to end-user	O	O	O

figure 3.16 excerpt from questionnaire: establishing customisation of visible and non-visible elements

When using Tjalve parameters in the pilot study it was found that the use of some parameters triggered the use of other parameters. In some cases visible *form* had to be adapted after some non-visible elements were arranged or sized differently. In this case, component development must have been driven by non-aesthetic requirements. In other cases, the visible *form* of a component was developed first and the non-visible elements of the components were *arranged, formed* or *sized* to fit. Here component development must have been driven by aesthetic requirements. In order to establish *visual significance of the component in the final product,* it could be interesting to examine whether component development was driven by aesthetic requirements of the final product. Figure 3.17 shows how this issue was addressed in the survey questionnaire.

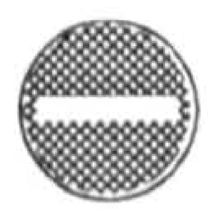
	Was component development driven by specifc aesthetic requirements of the final product ?	
	No, component development was not driven by aesthetic requirements of the final product	Yes, component development was driven by aesthetic requirements of the final product
component elements visible to end-user	O	O
component elements not visible to end-user	O	O

figure 3.17 excerpt from questionnaire: establishing whether component development was driven by aesthetic requirements of the final product

Evaluating Cost Analysis

Variable *visual significance of the component in the final product* was measured using an adaptation of Cost Analysis on 10 components. The method was assessed against the four criteria listed in section 3.8.2. Table 3.12 shows the results of the assessment process.

table 3.12 assessment of Cost Analysis for measuring visual significance

Cost Analysis		
Criteria	**Result**	
Was it easy to generate data using the method?		Lead manufacturers were able to give fairly precise figures for the price of each component inside their final product. Component suppliers could give price data for their own components. They knew almost nothing about the price, the technology or even the companies who supplied the other components in the final product.
Does the method deliver ordinal or quantifiable data?		
Is the method applicable across the survey?		
Is the method clearly defined?		

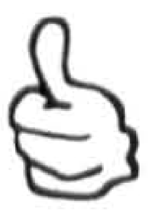
Abandoning Cost Analysis

Based on the assessment in table 3.12, cost analysis was found to be an inappropriate method. The interviewed component suppliers could not determine the relative cost of their components in the final product as they had no price data on all other components in the final product that were supplied by other companies. Product cost analysis was therefore abandoned altogether.

Evaluating Conjoint Analysis

Variable *visual significance of the component in the final product* was measured using an adaptation of Conjoint Analysis on 10 components. The method was assessed against the four criteria listed in section 3.8.2. Table 3.13 shows the results of the assessment process.

table 3.13 assessment of Conjoint Analysis for measuring visual significance

Conjoint Analysis		
Criteria	**Result**	
Was it easy to generate data using the variable ?		This tedious and detailed process of pairwise comparison was not appropriate for conducting a large number of interviews each of which could not last longer than 20 minutes.
Does the variable deliver ordinal or quantifiable data?		Functions are ranked through pairwise comparison.
Is the variable applicable across the survey?		The process of pairwise comparison worked well for ranking components of one product type. Problems arose when components were compared across product groups: Is the component ranked third in the product group 'lighting systems' equal to the third rank component in the group 'motorcar'? Non-visible components might also be important for the aesthetic qualities of the final product. The WILA case study demonstrated that the lighting company needed a special electronic ballast which would to fit into the shape of the housing.
Is the variable clearly defined?		

Modifying Conjoint Analysis

Based on the assessment in table 3.13 using 10 components, Conjoint Analysis was found to be inappropriate for measuring *visual significance.*

1. The process was too complicated for a 20 minute interview.
2. The method could only rank components which were part of the same product group.
3. The method did not cater for non-visible components which were important for the aesthetic qualities of the final product.

To overcome these problems, several modifications to Conjoint Analysis were made. The complicated and tedious process was simplified by expressing visual significance of the component only in terms of the *component share in the visible surface.* The other criteria *seen more often* and *touched more often* were abandoned.

To rank components which were part of different types of products, components were classified into four groups: components with no, low, medium or high share in the visible surface of the final product (see figure 3.18).

	What is the component's share in visible surface compared to other components in the final product or system?			
	none	low	medium	high
component elements visible to end-user	does not apply	O	O	O
component elements not visible to end-user	O	same as above	same as above	same as above

figure 3.18 excerpt from questionnaire: establishing share in visible surface of component

An additional question was to establish whether a non-visible component had any effect on the size, shape or configuration and therefore visual appearance of the final product. Figure 3.19 shows how this question was laid out in the questionnaire.

	If the component is not visible to the end-user, does it have an impact on the size, shape or configuration of the final product ?	
	NO	YES
component elements not visible to end-user	O	O

figure 3.19 excerpt from questionnaire: establishing whether non-visible components have an impact on the visual qualities of the final product

3.7.4 Supplier control

Variable *supplier control in the development/ of component visuals* was measured by:

1. Dividing the components into visible and non-visible elements,
2. establishing at what process stage and at what organisational level the supplier became involved in the development of visible elements.
3. establishing at what process stage and at what organisational level the supplier became involved in the development of non-visible elements

This method had been tried on 10 components in the pilot study. The details of the evaluation process are shown in table 3.14.

Evaluating process stage and form of organisation

Variable *supplier control in the development/ of component visuals* was measured using process stages and forms of supply organisation. The method was assessed against the four criteria listed in section 3.8.2. Table 3.14 shows the results of the assessment process.

table 3.14 assessment of Process Stage and Organisation to measure supplier control

Process stages & organisation		
Criteria	**Result**	
Was it easy to generate data using the method?		Designers do not describe their work in terms of process stages. Designers tend to describe their work in terms of design output. This observation confirms the findings of Ulrich and Eppinger, 1995 [[23]]: " *Note that most of the phases of development are defined in terms of the state of the product, although the production process and marketing plans, among other tangible outputs, are also evolving as development progresses.*"
Does the method deliver ordinal or quantifiable data?		The variable delivers ordinal data.
Is the method applicable across the survey?		
Is the method clearly defined?		Bonnaccorsi and Lipparni measured supplier involvement by examining at what process stage lead manufacturers made suppliers aware of their projects. The pilot study and the case studies of chapter 2 have shown that it is not always the lead manufacturers who drive the initiative and make suppliers aware of development projects: Rötelmann, the ball valve specialist, developed a hydraulic unit without the involvement or knowledge of the lead manufacturer Case Poclain. It is therefore not sufficient to examine when lead manufacturers make suppliers aware of projects. Suppliers sometimes specify their own business opportunities before developing components. The pilot study also suggested that the level of supplier responsibility may vary from one stage to another.

Modifying the process stage and organisation approach

Based on the assessment described in table 3.14 using 10 components, the process stage and organisation approach was found to be inappropriate for measuring supplier control:

1. Designers described their work in terms of design output rather than process stages.
2. The form of organisation, the scope of supplier activities and responsibilities may change at different stages during the process.
3. It is not always lead manufacturers who make suppliers aware of opportunities.

Several modifications to the process stage approach were made to overcome these problems. Each process stage was translated into a number of outputs which designers could recognise. Table 3.15 shows a list of design outputs that correspond to the generic process stages compiled by Inns, 1998 [78].

table 3.15 list of design process stages and corresponding design outputs compiled by Inns, 1998

Process stages	Design output
Opportunity	opportunity specification, product brief
Feasibility	design specification, requirement list
Concept	concept sketches, mock-up models
Embodiment	prototypes, drawing, product test report
Detail	component drawing, tooling
Validation	pre-production prototype

Rather than using the form of development organisation (integration, collaboration, autonomous) a description of the exact supplier functions at each development stage seemed more appropriate. Inns divided design activities into three basic functions:

1. seeking of information
2. synthesis
3. approving the result

Table 3.16 lists the design functions and their graphic symbols.

table 3.16 list of design functions represented by graphic symbols

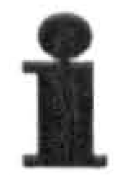
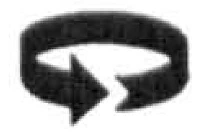
Information	
synthesis	
approval	

Figure 3.20 shows how *supplier control in the development/ of component visuals* was tested in the survey. Designers could work through a list of design outputs on the left and specify for each output whether they were responsible for information seeking, synthesis and for approval.

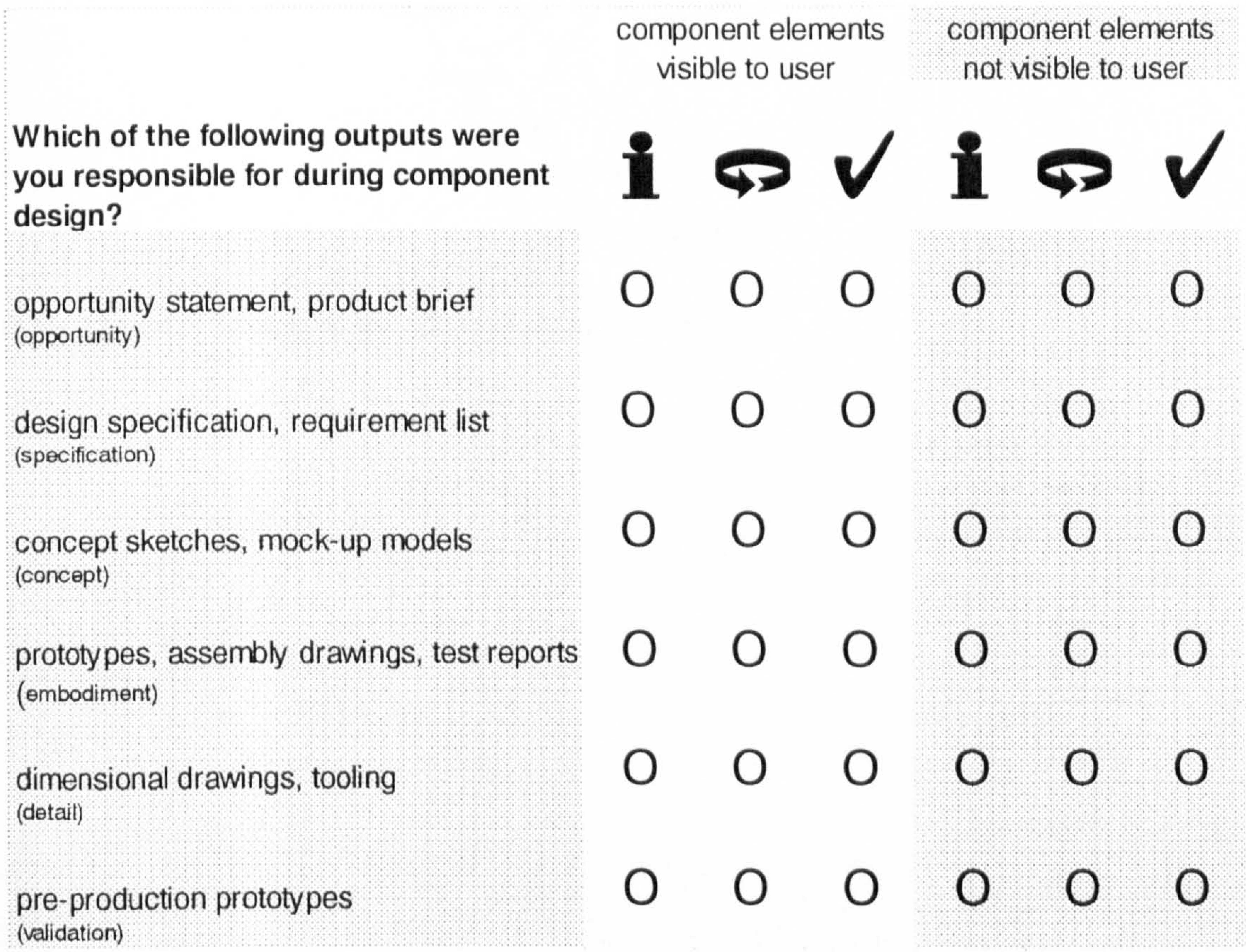


figure 3.20 excerpt from questionnaire: establishing supplier control in the development

3.7.5 Component success

Variable *component success for supply company* can be determined using financial and non-financial success measures (see model in figure 3.21). The list of measures had been presented to the companies in the pilot study. The details of the evaluation process are shown in table 3.17.

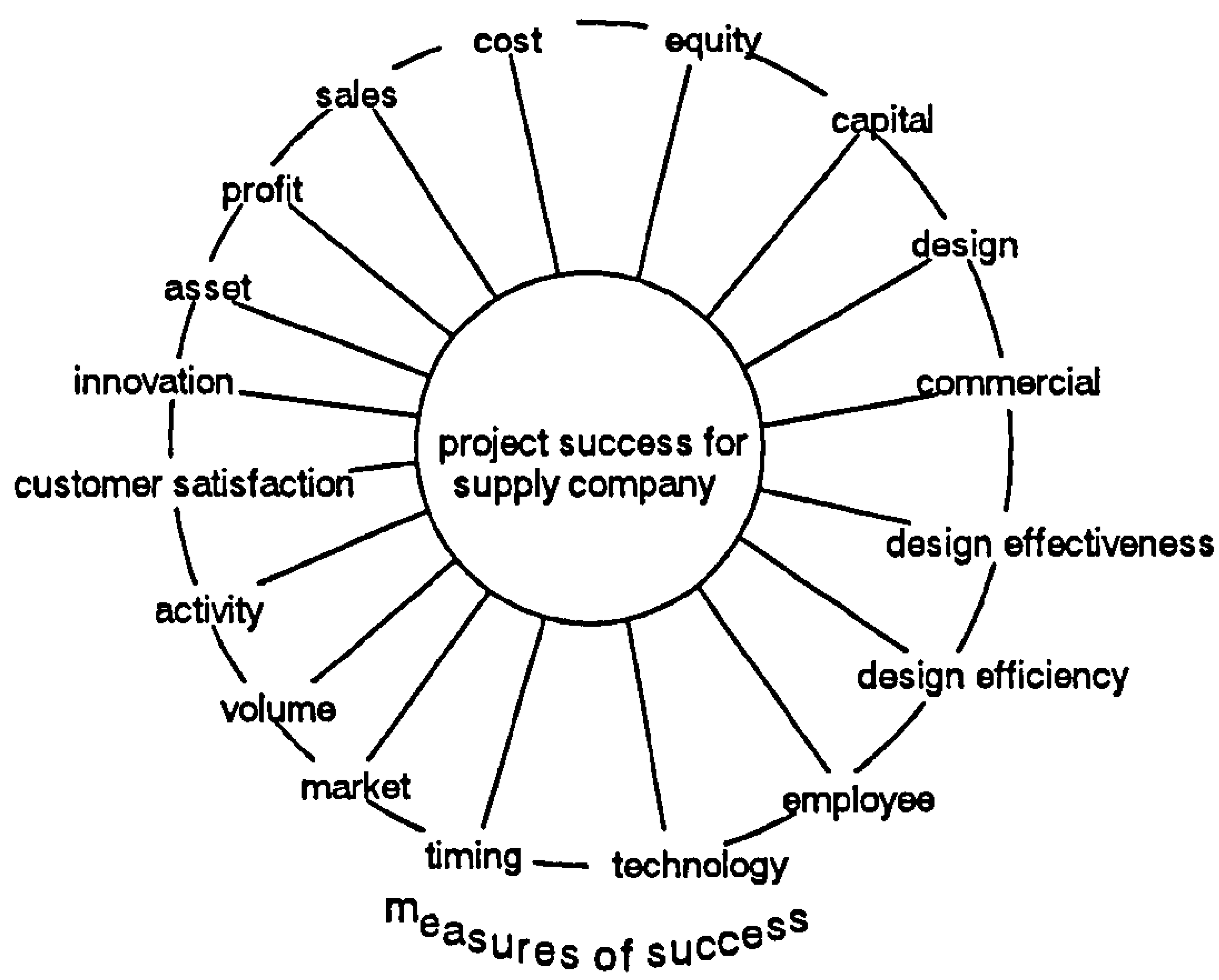


figure 3.21 model of financial and non-financial success measures

Evaluating success measures

Variable *component success for supply company* can be expressed using financial and non-financial measures. The measures were assessed against the four criteria listed in section 3.8.2. Table 3.17 shows the results of the evaluation.

table 3.17 assessment of success measures to establish component success

success measures **Criteria**	**Result**	
Was it easy to generate data using the variable?		Obtaining detailed data on the financial performance of individual products was unrealistic. In many cases the accountancy systems of many privately owned businesses failed to render profit data for individual products or components. If data on product profitability, sales and cost was available, the information was considered highly sensitive and part of the company's trade secrets which could not be disclosed to outsiders. This was also found with public limited companies like BP and Exxon who issue financial reports to investors. Data which would allow competitors to acquire information on sales, cost and profitability performance of individual products is hidden in divisional balance sheets.
Does the variable deliver ordinal or quantifiable data?		
Is the variable applicable across the survey?		The use of non-financial measures was not satisfactory for comparing component success. Companies were very different in terms of scale, business, competitive situation, market structure. In recent years, business researchers have increasingly used performance measures to compare or 'benchmark' the success of companies and operations. Oliver, Gardiner and Mills (1997) [81] examined the use of benchmarking techniques in product development processes. They found that scales of development projects and market structures differ considerably between companies making the assessment of product development success through comparison of performance measures extremely difficult.
Is the variable clearly defined?		

Modifying success measures

Based on the review described in table 3.17, most of the success measures were found to be inappropriate for the following reasons:

1. Obtaining financial data on components from a large number of companies is not realistic.
2. Companies vary in terms of structure, scale, competitive situation and market. A comparison of financial or non-financial measures is often difficult.

Several simplifications were made to overcome these problems.

Many of the interviewed designers explained that they had no access to financial product data. However, nearly all designers seemed to have a very good awareness of how profits for individual products had developed in relation to other products in their company:

- Financial management informed Designers which products were under severe price pressure asking them to analyse competing products from a cost perspective.
- Designers were often involved in the bidding process during which design was constantly assessed for cost.
- Marketing and sales staff complained to Designers about price pressures or informed them which product features contributed most to sales success.
- Designers experienced price pressures by being involved in cost-cutting exercises as well as a target costing processes.

Cooper and Kleinschmidt, [82] expressed success by describing product profits relative to other new products introduced in the last 5 years. Based on this approach component success could be described relative to the typical component in the company. Figure 3.22 shows how the survey question was laid out in the questionnaire.

How would you describe the profits for this component compared to the typical component in your company ?		
below average	about average	higher than average
O	O	O

figure 3.22 excerpt from questionnaire: establishing relative component profitability

Potter (1992) [71], see section 3.3.1, suggested to use qualitative as well as quantitative research. An open question was also set allowing designers to comment on the reasons for their components' financial performance (see figure 3.23).

Why do you think are component profits below/ about/ above average ?

figure 3.23 excerpt from questionnaire: establishing reasons for component profit performance

Figure 3.24 shows how the suggested success measures were adapted for the study.

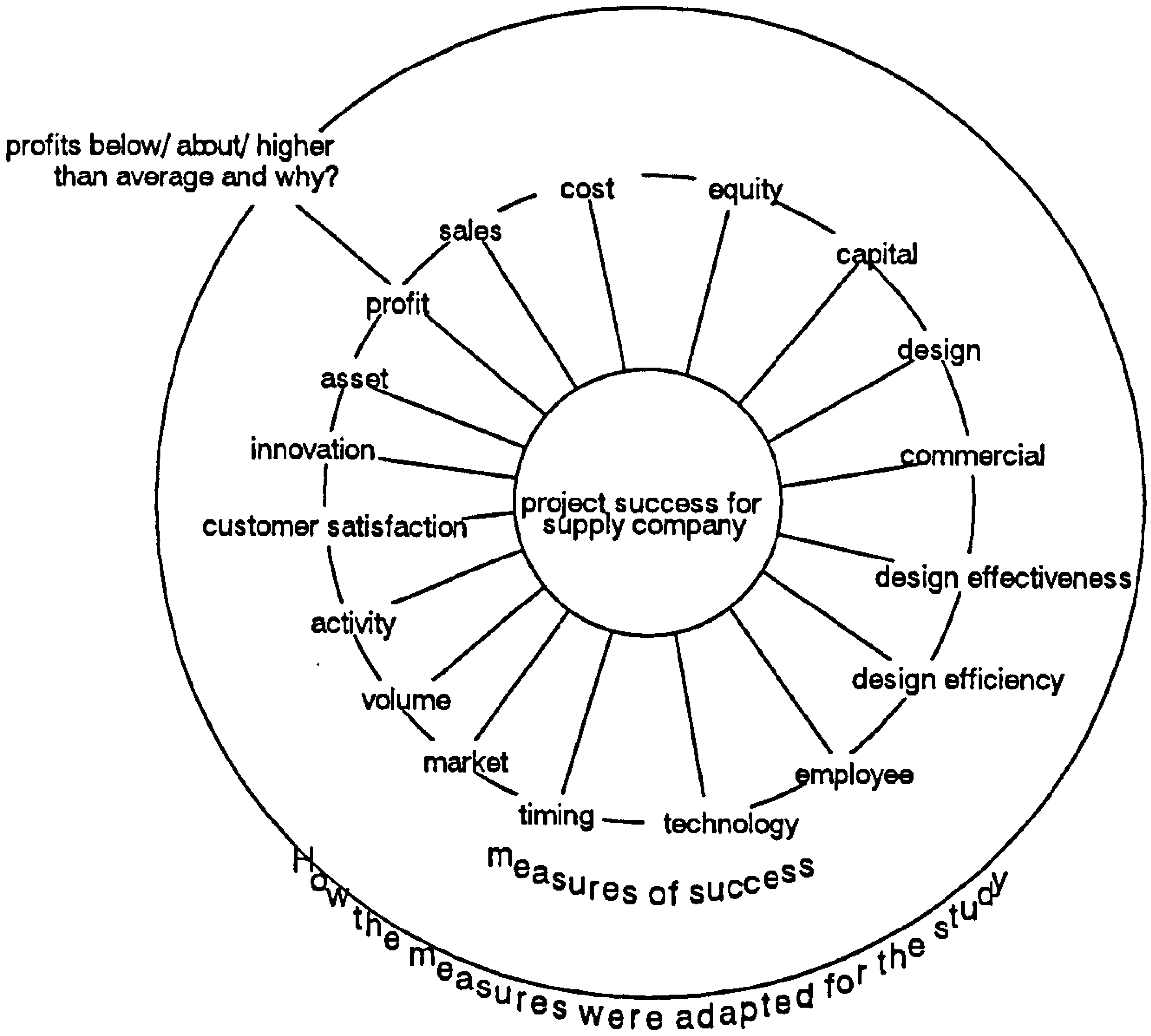


figure 3.24 adaptation of success measures for survey

3.7.6 Conclusion

The objectives of step 6 were firstly, to evaluate whether the methods are suitable for measuring the variables and secondly, to modify them for a larger survey if necessary.

The variables extracted from the hypotheses were now measured using the following methods:

Variable *visual significance of the component in the final product* was measured by establishing:

1. the component's degree of visible customisation,
2. whether the component's development was driven by aesthetic requirements,
3. the component's share in visible surface,
4. the component's impact on size, shape or configuration of final product.

Variable *supplier control in the development/ of component visuals* was measured by identifying:

1. process stage indicated by the type of design output
2. precise function at each stage, i.e. information, synthesis and approval
3. differences between supplier involvement in the development of visible and non-visible elements.

Variable *component success for supply company* was measured by:

1. Describing the component's profit performance relative to the typical component in the company.
2. An open question allowing designers to explain the reasons behind the profit performance.

An overview of hypotheses, variables, and methods for data collection is shown in figure 3.25 and table 3.18.

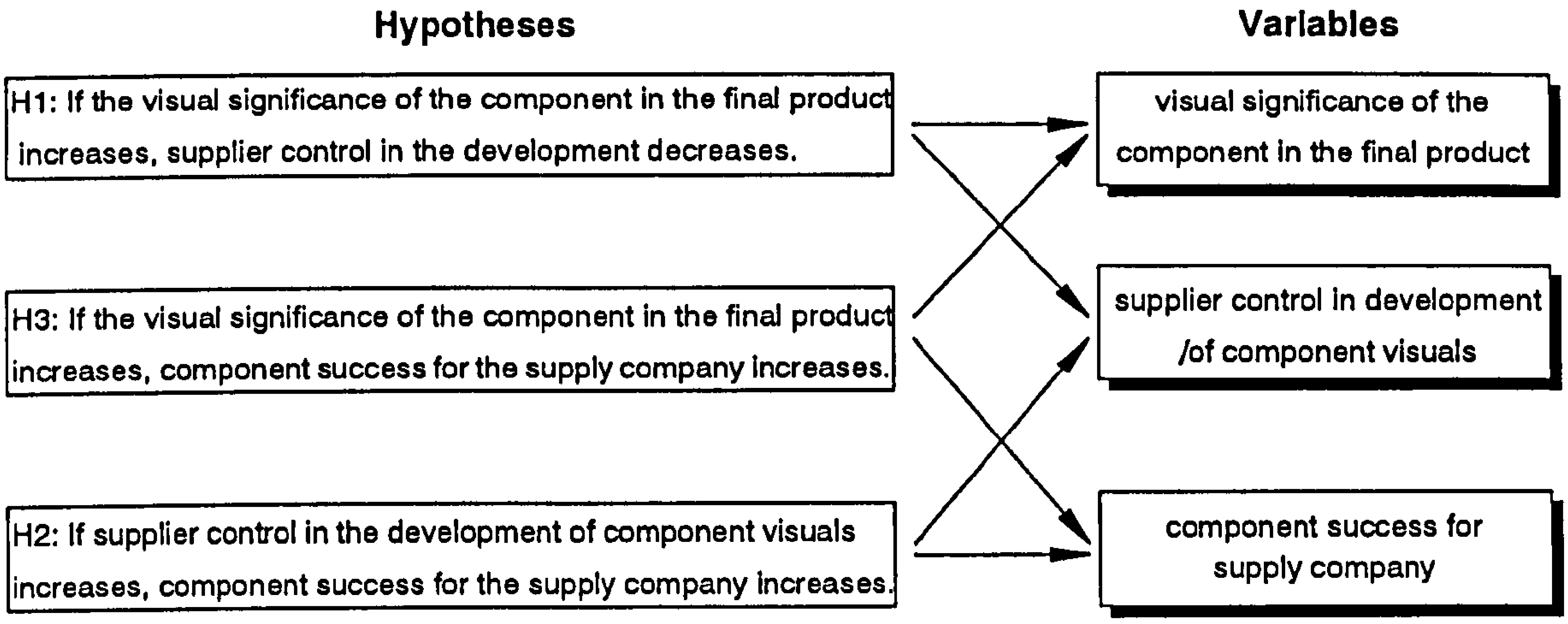


figure 3.25 diagram of hypotheses and variables

table 3.18 list of measures, questions and answers for variables

Variables	Measures	Questions	poss. Answers
visual significance of the component in the final product	customisation	Is the component customised for certain lead manufacturers?	not customised/ only graphics/ form or shape
	aesthetics-driven	Was component development driven by specifc aesthetic requirements of the final product?	aesthetic requirements of the final product/ no aesthetic requirements
	share in visible surface	What is the component's share in visible surface compared to other components in the final product or system?	none/ low/ medium/ high
	impact on size, shape or configuration	If the component is not visible to the end-user, does it have an impact on size, shape or configuration of the final	No/ Yes
supplier control in the development/ of component visuals	process stage	list of design outputs representing process stages	No/ Yes
	function	each stage is divided into information, synthesis, approval	No/ Yes
	visual/ non-visual elements	functions at process stages for elements visible and elements invisible to end-user	No/ Yes
component success for supply company	relative profit performance	How would you classify the profits for this component compared to the typical component in your company?	below average/ about average/ higher than average
	comment on profit performance	Why do you think are component profits below/ about/ above average?	open question

3.8 Step 7: Collect data

In step 1 three variables were derived.

In step 2 the unit of analysis and the sample were defined.

In step 3 and 4 the type of data and a collection method for measuring the three variables were chosen.

In step 5 the adapted methods were used in a pilot study of 10 components.

In step 6 the adapted methods were assessed and modified for a larger survey.

Attention in step 7 turned to collecting the data.

When conducting larger surveys, researchers can choose between in-person interviews, telephone interviews or mail questionnaires. SPSS, 1996 [[83]] compared the advantages and disadvantages of these methods (see table 3.19).

table 3.19 comparison of in-person, telephone and mail surveys

characteristic	in-person	telephone	mail
data collection costs	high	moderate/low	low
time for data collection	long	short	long
control over respondent selection	high	high	low/moderate
accessing non-enumerated population	high	moderate	low/moderate
response rates	high	high	moderate
length of questionnaire	long	short	moderate/long
complexity of questions	moderate/high	low	moderate/high
completion of boring, tedious questions	high	moderate	moderate
interviewer bias or error	moderate/high	moderate/high	none
acquiring open-ended responses	high	low	moderate
avoiding interviewer contamination	high	moderate	low
perceived respondent anonymity	low	moderate/high	moderate/ high

For this study, the *in-person* interview method was chosen for a number of reasons:

- Mail surveys have an unsatisfactory response rate, see Lancaster and Massingham, 1993 [84].
- The unit of analysis was 'product component'. Experience analysing the 10 components in the pilot study showed that the only way to extract information on product visual aspects was to have the component in front during the interview.
- It appeared that designers were better at recalling details of the development process when they see the product.
- The researcher could identify the most appropriate respondent who was competent to answer questions on the development of the component.
- The researcher was keen to meet designers in person and use the survey as an opportunity for making contacts which could be useful for future work.
- Designers could give the researcher additional information on component technology, company strategy and market structures. The information was not required for the quantitative survey, but was very useful for qualitative, contextual information.

Because financial resources and time available for data collection were limited, it was difficult to obtain large sample size by relying merely on the 'company-visit approach'. In order to increase the number of interviews within the given financial and time constraints it was decided to collect additional data at large international industry fairs at which supply companies exhibit their work and component designers explain past projects to potential clients.

The industry fairs targeted were the *Internationale Automobilausstellung* (IAA) 1997 and the *Automechanika* 1998 in Frankfurt and the *Hanover Industry Fair* 1998.

3.9 Summary of chapter 3

The objective of chapter 3 was to develop a research method for testing the three hypotheses in a larger sample of supply companies.

The first step was to review the hypotheses and extract their variables.

1. visual significance of the component in the final product
2. supplier control in the development/ of component visual aspects
3. component success for supply company

The second step was to define the unit of analysis and the constraints of the study:

Components manufactured by a supply company and sold to a lead manufacturer who builds or assembles it into a larger product; The product could be automotive, retail equipment, industrial equipment or a domestic appliance.

The 3rd and 4th step were to select the type of data and collection method for measuring the three variables.

Variable *visual significance of the component in the final product* could be measured by adapting Tjalve parameters, Cost analysis and Conjoint analysis.

Variable *supplier control in the development/ of component visual* could be measured by dividing the components into visible and non-visible elements and establishing at what stage and at what organisation level the suppliers became involved in the development of which elements.

Variable *project success for supply company* could be measured using a range of financial and non-financial success measures.

The 5th step was to use the adapted methods in a pilot study on 10 components.

In step 6 the methods were evaluated and modified for a larger survey. Variable *visual significance of the component in the final product* was now measured by establishing:

1. the component's degree of visible customisation,
2. whether the component's development was driven by aesthetic requirements,
3. the component's share in visible surface,
4. the component's impact on size, shape or configuration of final product.

Variable *supplier control in the development/ of component* visuals was now measured by identifying:

1. process stages indicated by the type of design output
2. precise functions at each stage, i.e. information, synthesis and approval
3. differences between supplier control in the development of visible and non-visible elements.

Variable *component success for supply company* was now measured by:

1. Describing the component's profit performance relative to the typical components in the same company.
2. An open question which allowed designers to explain the reasons behind the financial performance.

In step 7 it was decided to collect the data through in-person interviews by visiting supply companies as well as industry trade shows.

4 Results

4.1 Introduction

In chapter 1 the reader was introduced to current issues in the component supply industry. Many industrial companies have reduced their production depth and have given more development responsibility to component suppliers. The product development function has become an important competitive asset for many supply companies. In order to establish how supply companies control the development process and whether supplier control in component development affects business success, four research questions were derived.

It was also shown that visual and aesthetic properties are important for manufactured products. Companies can systematically control and plan their products' visual qualities. Another four research questions were put forward to establish the effect product visuals have on supplier development control and supplier success.

Chapter 2 explored these issues in more detail. Because the specific questions on how product visuals affect development control and product success in the supply industry could not be answered with past literature, the model of product development was used to examine seven industrial case studies. Three hypotheses were set up which predict how product visuals affect development control and product success in the supply industry.

Chapter 3 developed a research method for testing the three hypotheses in a larger sample of supply companies. Using this method, the author collected data on components visiting supply companies at their production sites and at industry trade shows.

The following chapter plots the collected data for analysing the hypotheses.

4.2 Objectives

The objective of the following chapter was to plot the collected survey data for analysing the three hypotheses.

4.3 Summary of Results

Data was collected for 58 components manufactured by a supply companies and sold to lead manufacturers who build or assemble them into larger products. The components were for retail equipment, industrial equipment domestic appliances and automotive products. Table 4.1 lists the industry sectors of the 58 components. The left column shows the different sectors, the right column lists the number of components which belonged to each sector.

table 4.1 list of components from industry sector

industry sector	number of components
automotive	19
retail equipment	8
industrial equipment	11
domestic appliances	20

Table 4.2 shows the country of origin of the components in the survey.

table 4.2 list of components from country

country	number of components
Germany	40
Great Britain	7
Italy	4
France	2
Sweden	2
United States	2
Israel	1

Table 4.3 shows how many components generated below average, about average and higher than average profits.

table 4.3 list of component profit levels

profits	number of components
below average	16
about average	19
higher than average	23

Table 4.4 and 4.5 list the components in the study.

table 4.4 list of components, suppliers and lead manufacturers (a)

component	supplier	lead manufacturer
fridge for snacks	Electrolux	food retail
fuel dispenser	Tokheim	Shell
fuel dispenser	Gilbarco-Salzkotten	Aral
ZVA 200 GR	HIBY-ELAFLEX	oil companies
submersible pump	Red Jacket	oil companies
shearvalve	OPW	oil companies
scuba	L. Adams	MOD
manifold system	L. Adams	US navy
hydraulic unit for lift trucks	Rexroth	Demag
axle stub	HB Seissenschmidt	Volkswagen/ Audi
cool unit	Behr	SNCF
fuelcircuit	Alfmeier	Volvo
conrod	Brockhaus	Mercedes-Benz
seatvalve	Alfmeier	Renault
flask	Cannie	Sainsbury's
UPsensor	Gira	building installation
motionsensor	Jung	building installation
vacuum cleaner tube	Riedel	Siemens
pricesign	PWM	Fina
cockpit for lorry	Sachsenring	Mercedes-Benz
trolleywheel	Gaililee	food retail
programmable dimmer	VLM	lighting industry
dimmerswitch (1)	VLM	lighting industry
dimmerswitch (2)	VLM	lighting industry
car door seal	Conti Tec	Peugeot
Instrument board	VDO	Audi
control unit for cranes	TER	equipment handling
box for measuring device	OKW	electronics industry
control buttons	OKW	domestic appliances
machine control seat	Gessmann	heavy machines
control seat for cranes	Gessmann	Siemens
joystick	Gessmann	heavy machines
safetylocks	Fortress	power stations
shade control switch	Bosch	domestic appliances
shade drive	Somfy	Bosch
Panic button	ASG	airport luggage system
power connector box	Mennekes	factory equipment
sunroof	Webasto	Ford
lock	Kiekert	Volkswagen

table 4.5 list of components, suppliers and lead manufacturers (b)

component	supplier	lead manufacturer
seat	Bertrand Faure	Volkswagen
seat	Johnson Controls	Opel
window drive	Brose	Audi
visco drive	GKN	Ford
cardan shaft	GKN	Ford
ignition system	Valeo	Renault
engine themostat module	Behr	Mercedes-Benz
thermostat	Behr	combustion engines
seatbelt system	Autoliv	BMW
HFC	INSTA	Hoffmeister
Adapter	Vossloh	ERCO
carrier	Schuster	ERCO
VG CuFe	INSTA	ERCO
Fassung	Vossloh	Zumtobel
installation plate	Schürholz	AEG
reflector	Hella	ERCO
plastic frame	Schuster	Waldmann
plastic lid	Westmark	Kärcher
Aluminium housing	Mössner	Kärcher

4.4 Plotting the two variables of Hypothesis 1

4.4.1 Objectives

The objective of section 4.4 was to plot the two variables associated with Hypothesis 1. Evidence proving or disproving H1: *visual significance - supplier control* could later be identified on the basis of these graphic plots.

4.4.2 Method

The diagram in figure 4.1 shows Hypothesis 1 and its two variables.

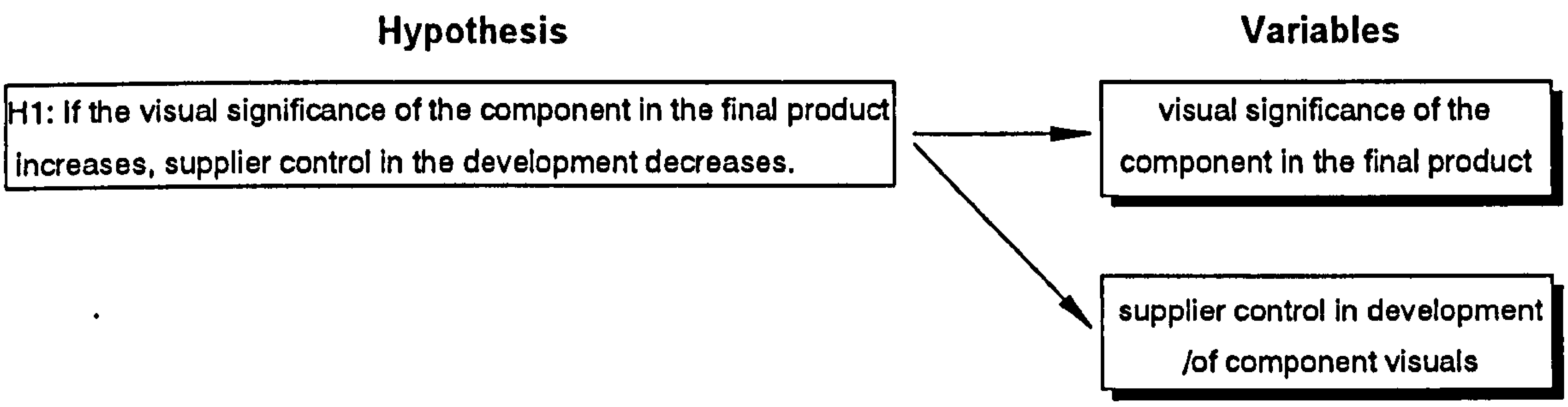


figure 4.1 diagram showing H1 and its two variables

Plotting supplier control

Variable *supplier control in the development/ of component visuals* was measured by examining:

1. the process stage indicated by type of design output
2. supplier functions at each process stage, i.e. information, synthesis and approval
3. differences between supplier functions in the development of visible and non-visible elements.

See also table 4.6.

table 4.6 list of measures, questions, possible answers to establish supplier control

Variable	Measures	Questions	poss. Answers
Supplier control in the development/ of component visuals	process stage	list of design outputs representing process stages	No/ Yes
	function	each stage is divided into information, synthesis, approval	No/ Yes
	visual/ non-visual elements	functions at process stages for elements visible and elements invisible to end-user	No/ Yes

Each process stage was divided into an information, a synthesis and an approval function. The 3 functions gave $2^3 = 8$ possible combinations at each stage see figure 4.2.

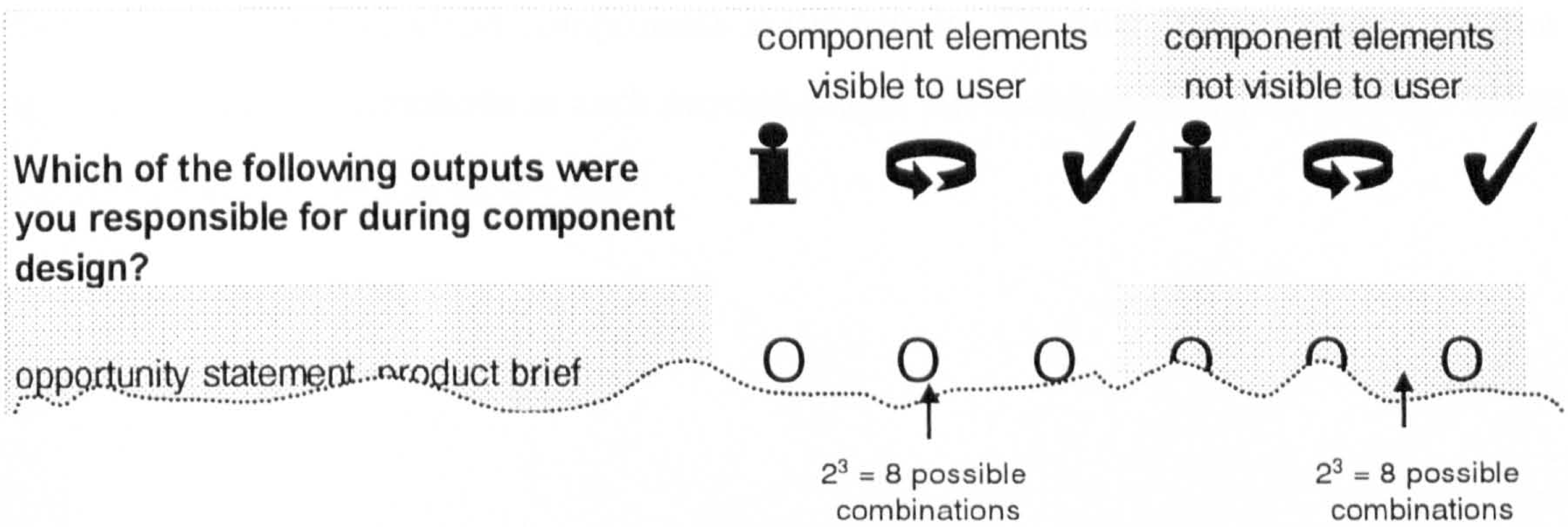
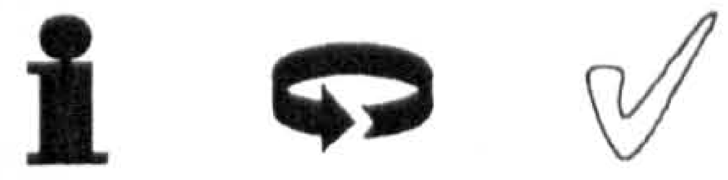
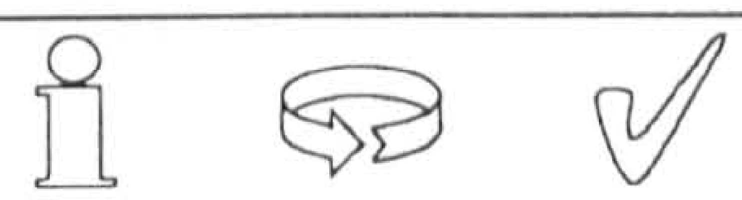


figure 4.2 excerpt from questionnaire: supplier functions offered 8 possible combinations

Although 8 different combinations of supplier functions were possible, only 4 different combinations had emerged in the survey. This was very useful for simplifying the analysis. Table 4.7 shows the four different combinations of supplier functions that had emerged in the survey.

table 4.7 list of different supplier functions identified in the survey

	Supplier fully autonomous, responsible for information, synthesis and also approval.
	Supplier working like a consultant, responsible for information seeking and synthesis. The lead manufacturer approves the design.
	Supplier only responsible for synthesis, needs to get information and approval from lead manufacturer.
	Supplier outside the development process, not responsible for anything

Based on the four levels of supplier functions and the six process stages, development charts were plotted for all 58 components in the survey. The development charts showed the level of supplier functions at each process stage. An example of such a supplier function/ process chart is shown in figure 4.3.

The horizontal axis was divided into the six process stages: opportunity, specification, concept, embodiment, detail and validation. The vertical axis was divided into the four levels of supplier functions defined in table 4.7. Black circles were used to indicate the development of a component's non-visible elements and white circles for the development of a component's visible elements. Figure 4.3 shows supplier functions at process stage for visible and non-visible elements of an automotive widget. For example: At the specification stage, the supplier was responsible for information, preparation and approval of the widget's non-visible elements. At the same stage, the supplier was only responsible for synthesis when developing of the widget's visible elements. Each component in the survey was plotted on such a supplier function/ process chart.

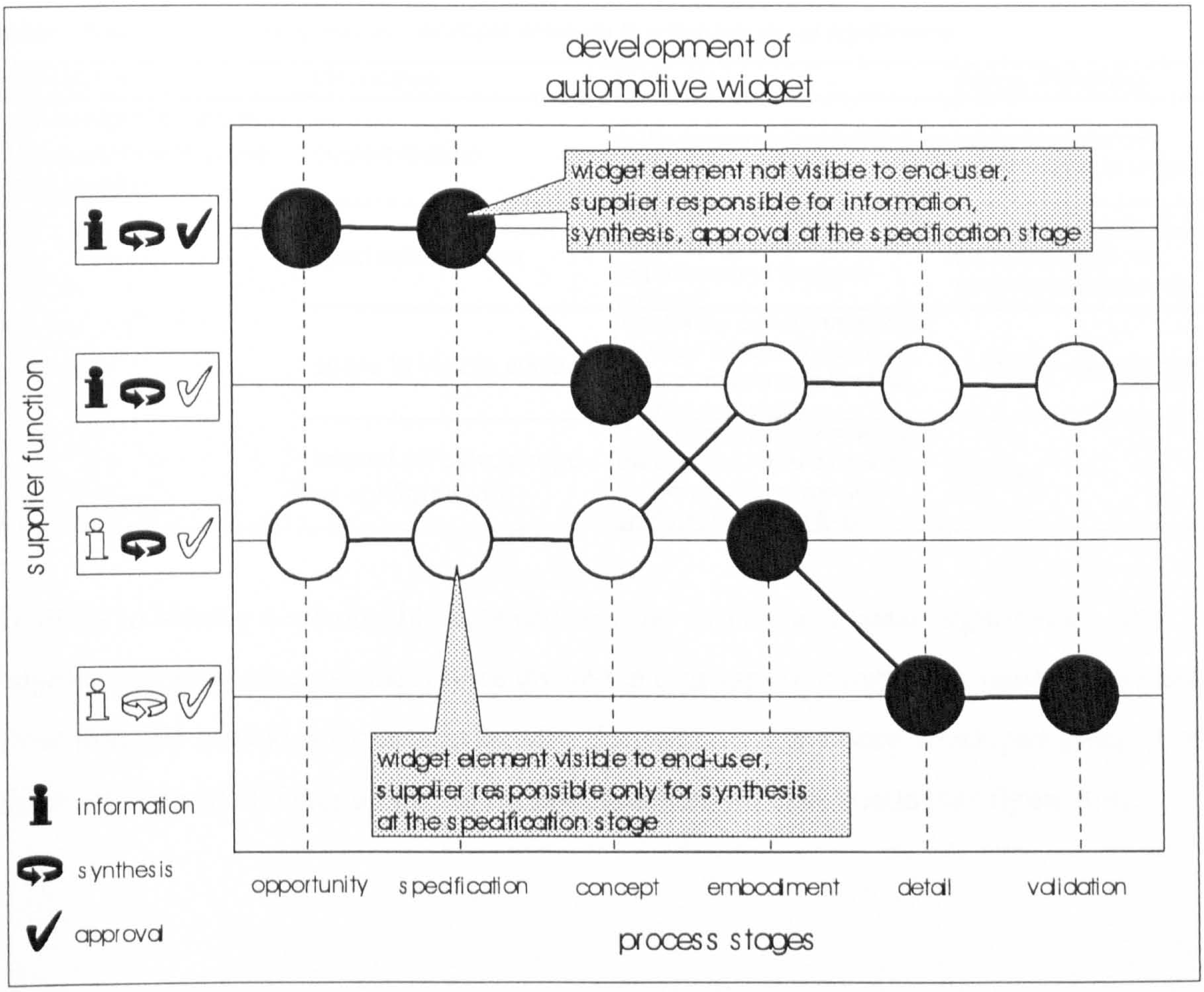


figure 4.3 example of supplier function/ process chart

Relating supplier function/ process charts to levels of visual significance

Supplier control in the development/ of component visuals was plotted using supplier function/ process charts. As shown in table 4.8 variable *visual significance of the component in the final product* was measured by establishing:

1. the component's degree of visible customisation,
2. whether the component's development was driven by aesthetic requirements,
3. the component's share in visible surface,
4. the component's impact on size, shape or configuration of final product.

table 4.8 list of measures, questions, possible answers to establish visual significance

Variables	Measures	Questions	poss. Answers
visual significance of the component in the final product	customisation	Is the component customised for certain lead manufacturers?	not customised/ only graphics/ form or shape
	aesthetics-driven	Was component development driven by specifc aesthetic requirements of the final product?	aesthetic requirements of the final product/ no aesthetic requirements
	share in visible surface	What is the component's share in visible surface compared to other components in the final product or system?	none/ low/ medium/ high
	impact on size, shape or configuration	If the component is not visible to the end-user, does it have an impact on size, shape or configuration of the final	No/ Yes

In order to identify a relationship between *supplier control* and *visual significance*, the supplier function/ process charts were divided into groups of component visual significance. Four different questions for measuring *visual significance* had been developed giving four different ways of dividing up the 58 supplier function/ process charts (see figure 4.4).

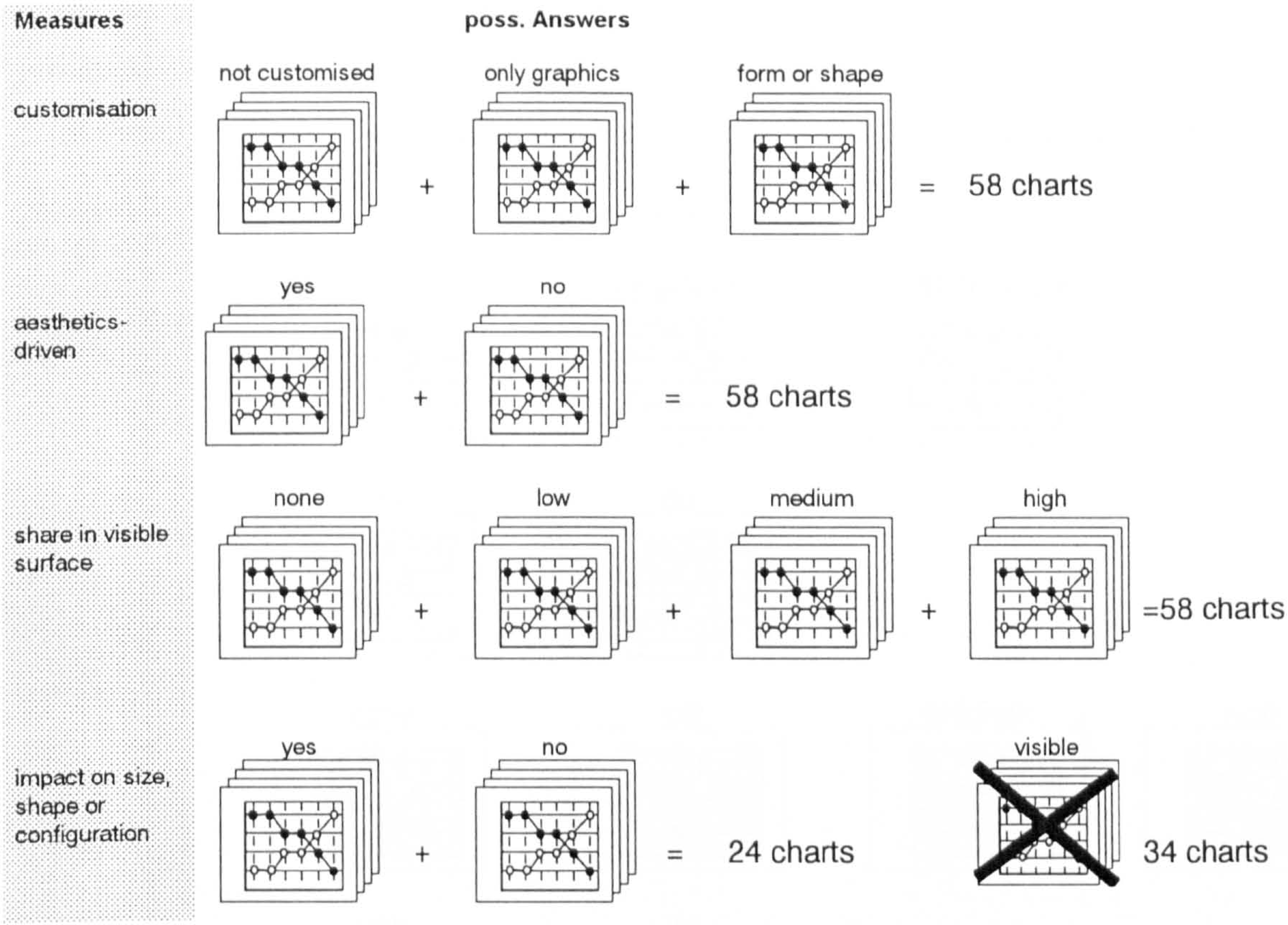


figure 4.4 diagram showing four ways of dividing 58 supplier function/ process charts into levels of visual significance

The next step was to represent each group of supplier function/ process charts in a single diagram. Because the number of charts in each group was not constant, the absolute frequencies were amalgamated into percentages (see figure 4.5). This made a direct

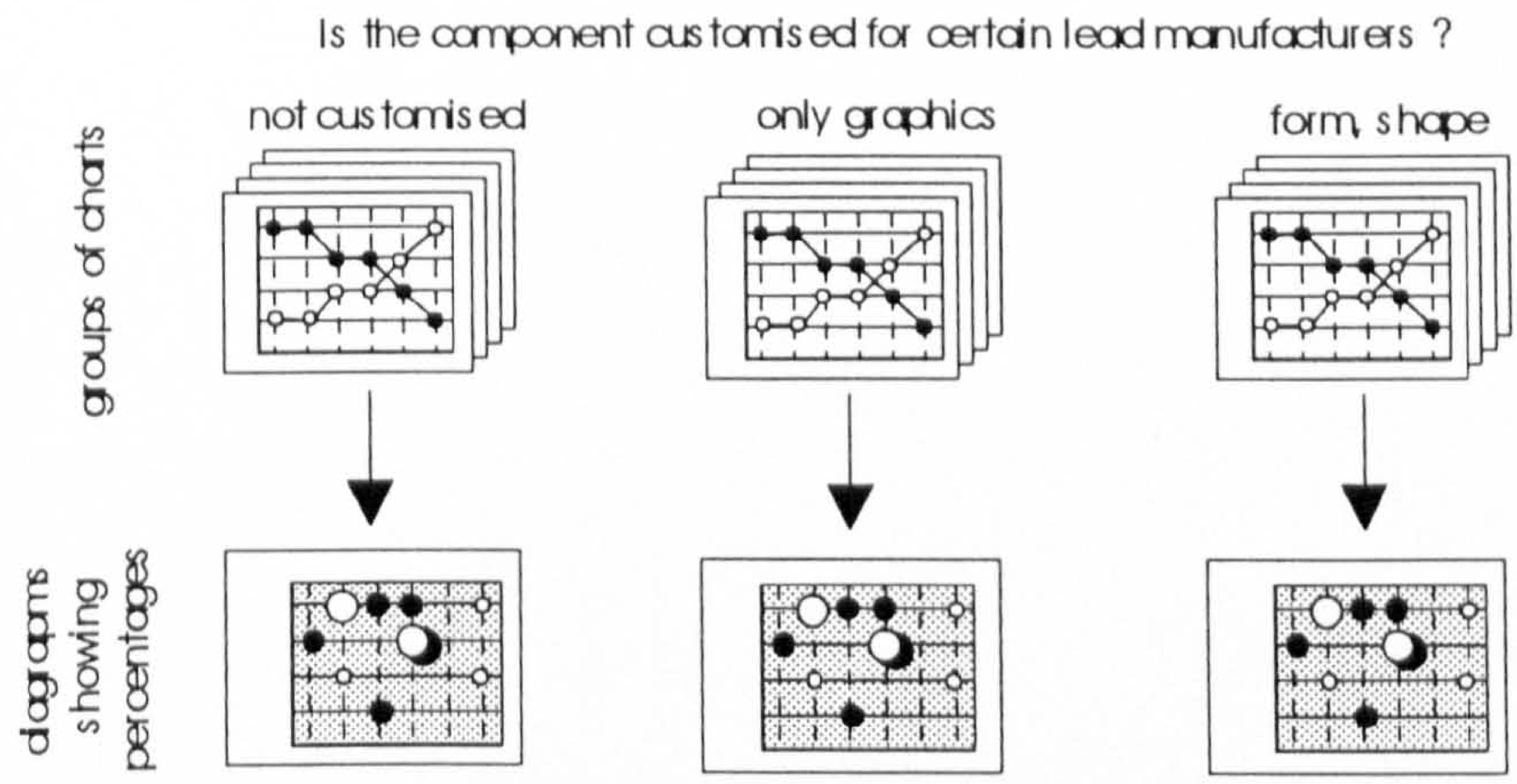


figure 4.5 example showing groups of charts represented in single diagrams

comparison between the groups easier.

The 58 supplier function/ process charts had been divided into levels of visual significance of the components. This gave 3 groups for customisation, 2 groups for aesthetics-driven, 4 groups for share in visible surface, 2 groups for impact on size, shape or configuration. Each group of charts could now be represented in single diagrams (see figure 4.6).

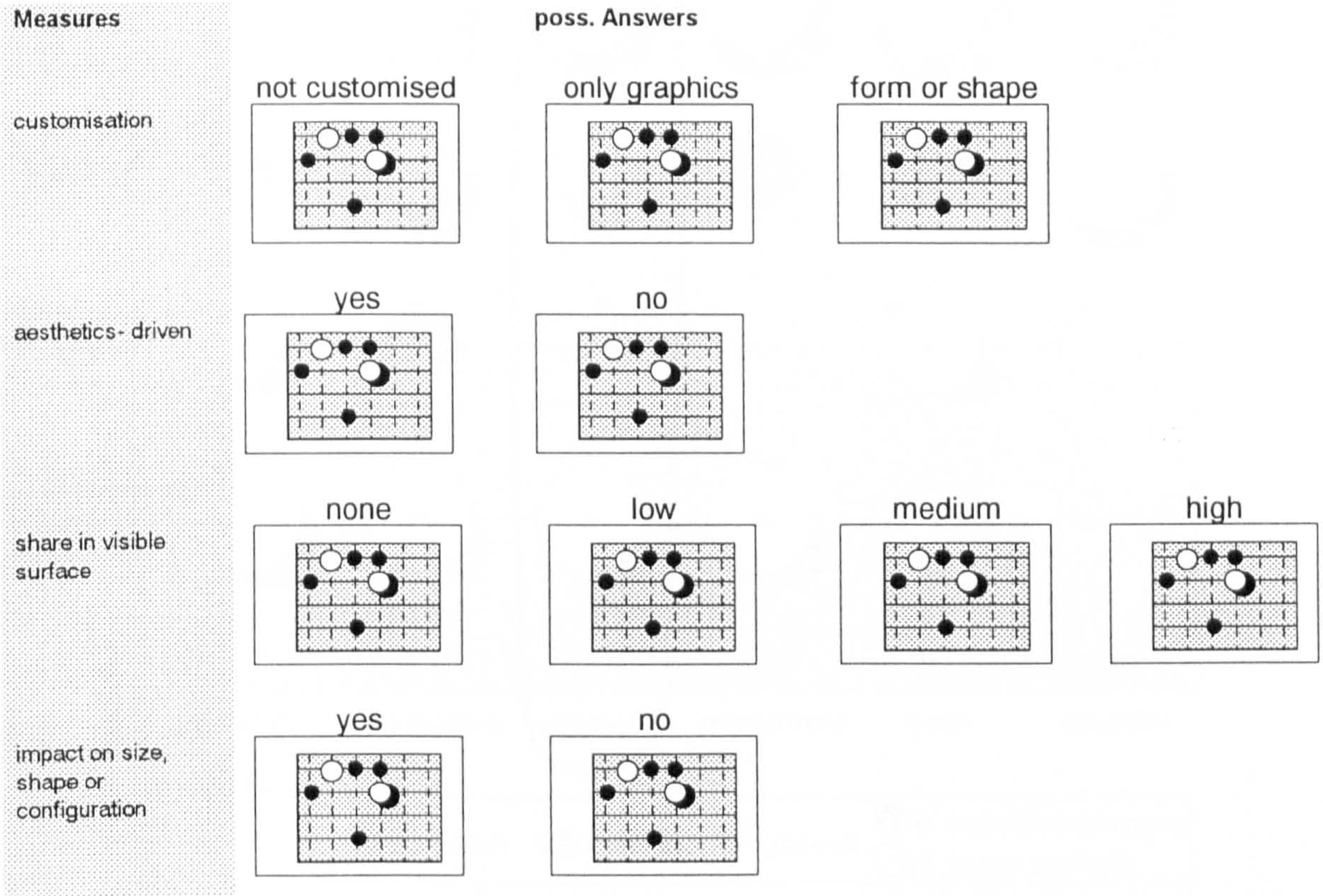


figure 4.6 diagram showing how groups of charts were represented in single diagrams

An example of such a chart is shown in figure 4.7.

Figure 4.7 is an amalgamation of all 58 supplier function/ process charts.

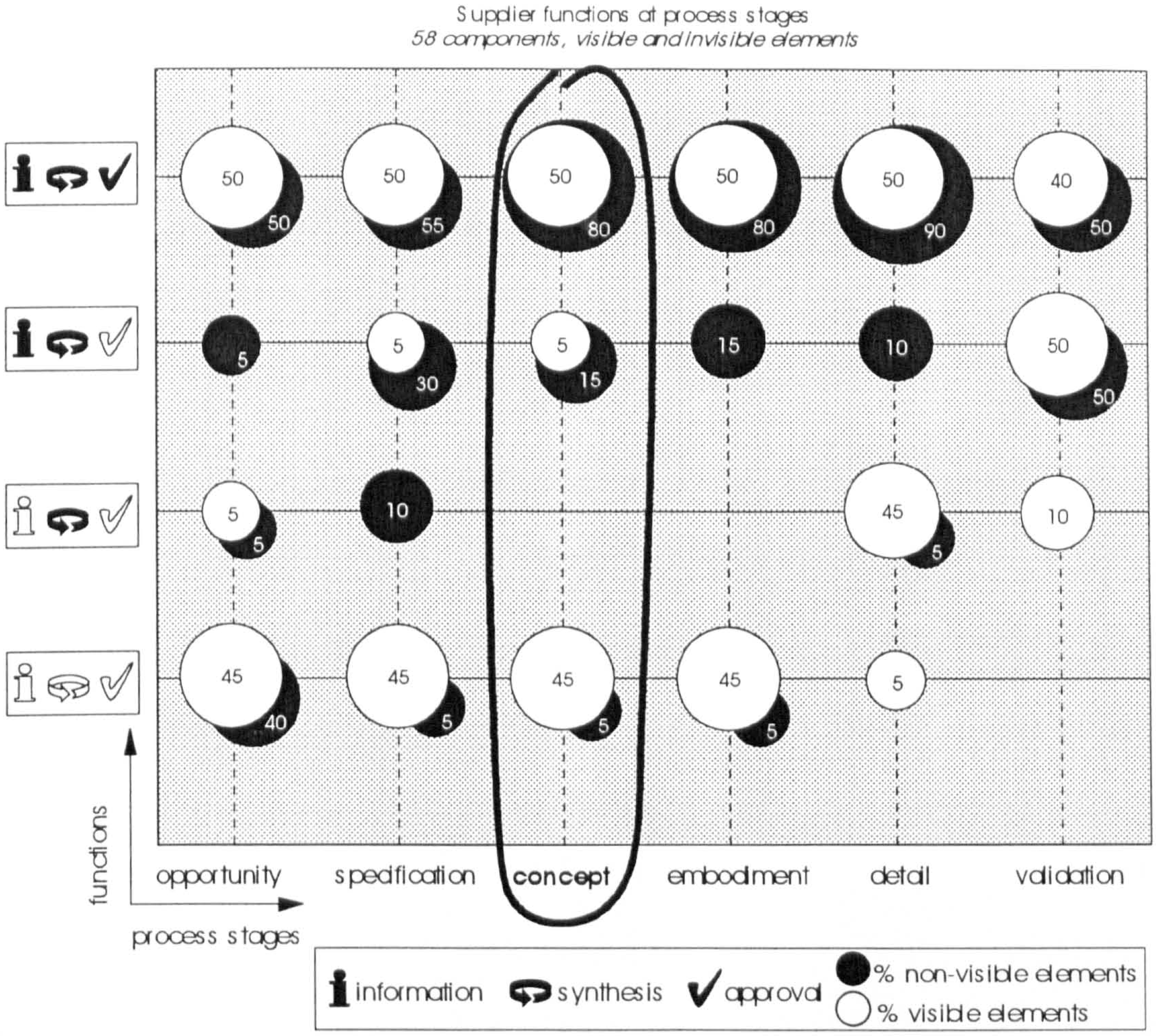


figure 4.7 supplier function/ process chart: development of visible and non-visible elements for 58 components

Visible elements (μ) at concept stage

At the concept stage, 50 % of visible elements within components were developed with the supplier responsible for information, synthesis and approval. 5% of visible elements within components were developed with the supplier responsible for information and synthesis, but not responsible for approval. 45% of visible elements within components were developed without the supplier, i.e. responsible for neither information, nor synthesis, nor approval ().

Non-visible elements (λ) at concept stage

At the concept stage, 80 % of non-visible elements within components were developed with the supplier responsible for information, preparation and synthesis. 15% of non-visible elements within components were developed with the supplier responsible for information and synthesis, but not responsible for approval. 5% of non-visible elements within components were developed without the supplier, i.e. responsible for neither information, nor synthesis, nor approval ().

4.4.3 Results

Figure 4.8 shows supplier functions at process stages for components that had their form or shape customised for lead manufacturers. The six process stages are written along the horizontal axis. The levels of supplier function are written along the vertical axis. The full collection of diagrams plotted for H1: *visual significance - supplier control* can be found in Appendix IV.

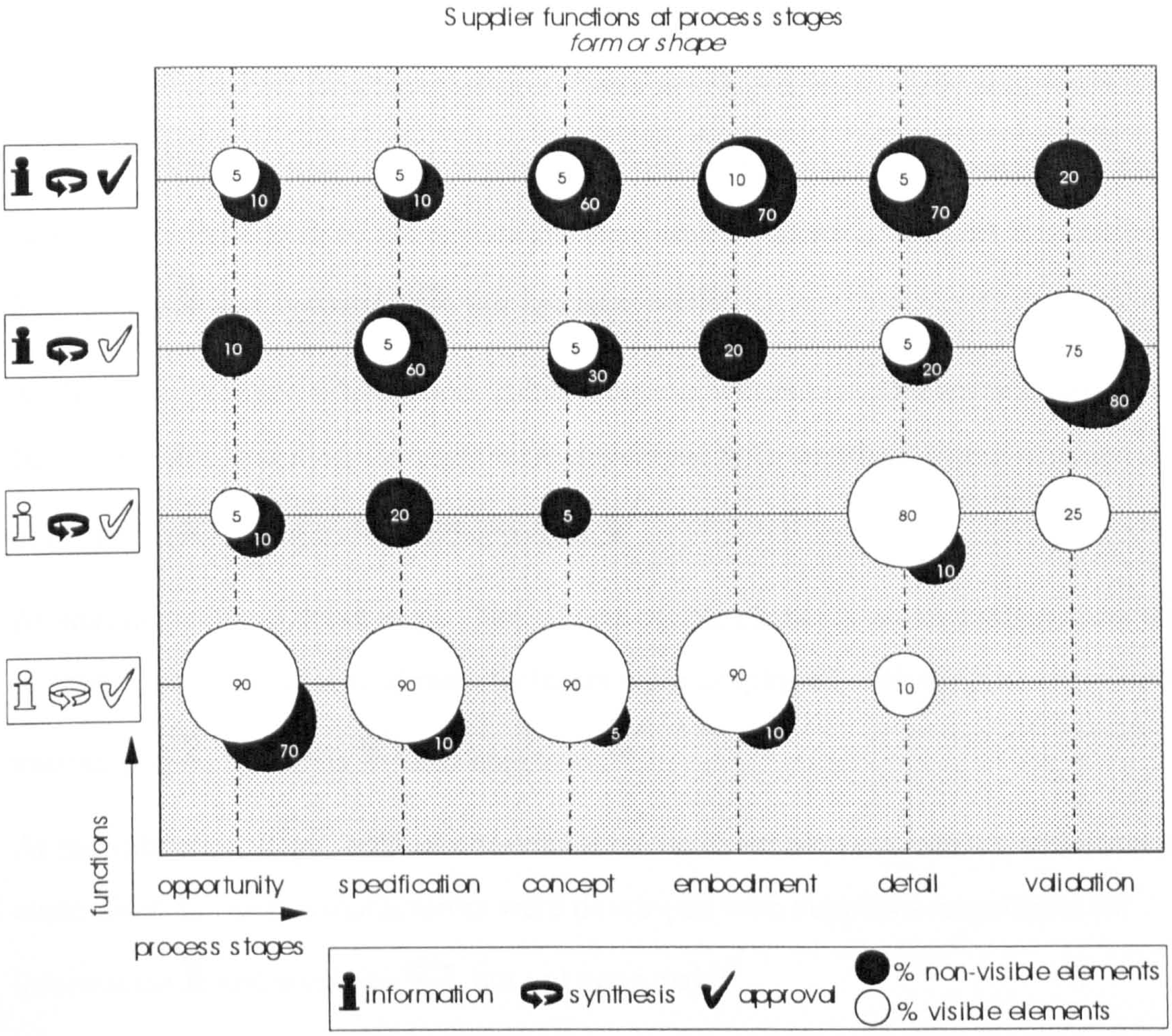


figure 4.8 supplier function/ process chart: components with form or shape customised for lead manufacturers

Visible elements

From opportunity to embodiment stage, 90% of visible elements within components with form or shape customised for lead manufacturers were developed without the suppliers ( ).

At the detail stage, 80% of visible elements within components with form or shape customised for lead manufacturers were developed with the suppliers only responsible for synthesis .

At the validation stage, 25% of visible elements within components with form or shape customised for lead manufacturers were developed with the suppliers only responsible for synthesis and 75% of visible elements within components with form or shape customised for lead manufacturers were developed with the suppliers responsible for information and synthesis, but not approval.

Non-visible elements

At the opportunity stage, 70% of non-visible elements within components with form or shape customised for lead manufacturers were developed without the suppliers ( ).

At the specification stage, 60% of non-visible elements within components with form or shape customised for lead manufacturers were developed with suppliers responsible for information and synthesis, but not approval.

At the concept stage, 60% of non-visible elements within components with form or shape customised for lead manufacturers were developed with suppliers responsible for information, synthesis and approval.

At embodiment and detail stage, 70% of non-visible elements within components with form or shape customised for lead manufacturers were developed with suppliers responsible for information, synthesis and approval.

At the validation stage, 80% of non-visible elements within components with form or shape customised for lead manufacturers were developed with suppliers responsible for information and synthesis, but not approval.

4.5 Plotting the two variables of Hypothesis 2

4.5.1 Objectives

The objective of section 4.5 was to plot the two variables associated with Hypothesis 2. Evidence proving or disproving H2: *supplier control - success* could later be identified on the basis of these graphic plots.

4.5.2 Method

The diagram in figure 4.9 shows Hypothesis 2 and its two variables.

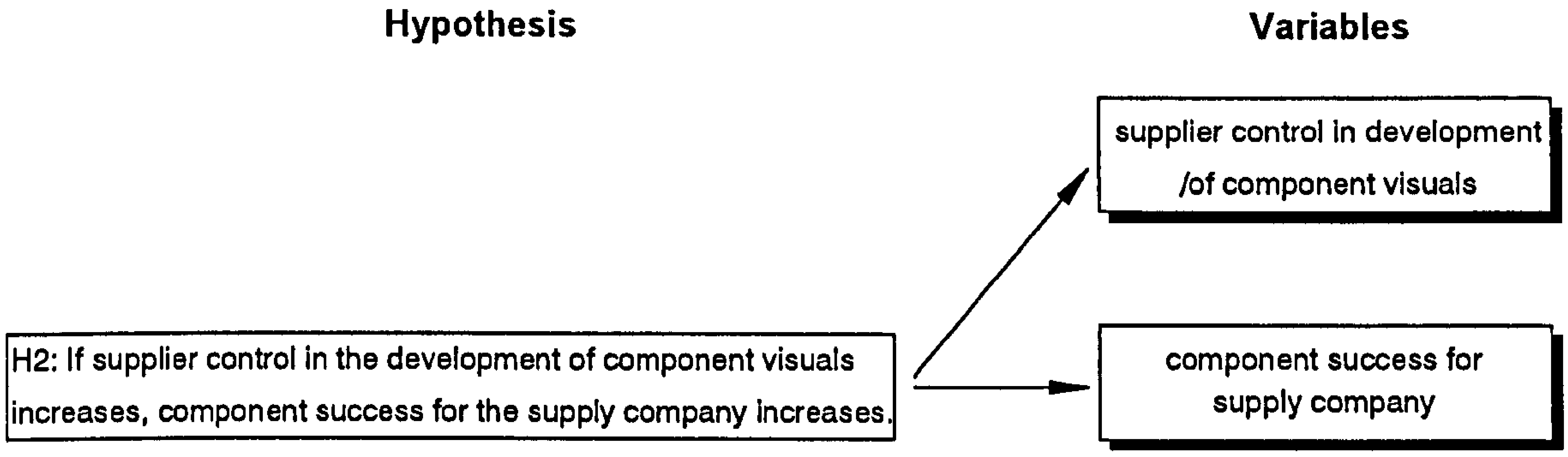


figure 4.9 diagram showing H2 and its two variables

Supplier control

Supplier control in development/ of component visuals was plotted in section 4.4.2 using supplier function/ process charts.

Success

Variable *component success for supply company* was measured by establishing component profit performance relative to the typical component in the company. An open question allowed designers to comment on the reasons for their component's financial performance (see table 4.9).

table 4.9 list of measures, questions and possible answers to establish component success

Variable	Measures	Questions	Answers
component success for supply company	relative profit performance	How would you classify the profits for this component compared to the typical component in your company?	below average/ about average/ higher than average
	comment on profit performance	Why do you think are component profits below/ about/ above average?	open question

Relating supplier control to success

In order to identify a relationship between *variable supplier control in development/ of component visuals* and variable *component success for the supply company*, the 58 supplier function/ process charts were divided into levels of profit performance. The number of charts in each group was not constant and the absolute frequencies were again amalgamated into percentages (see figure 4.10).

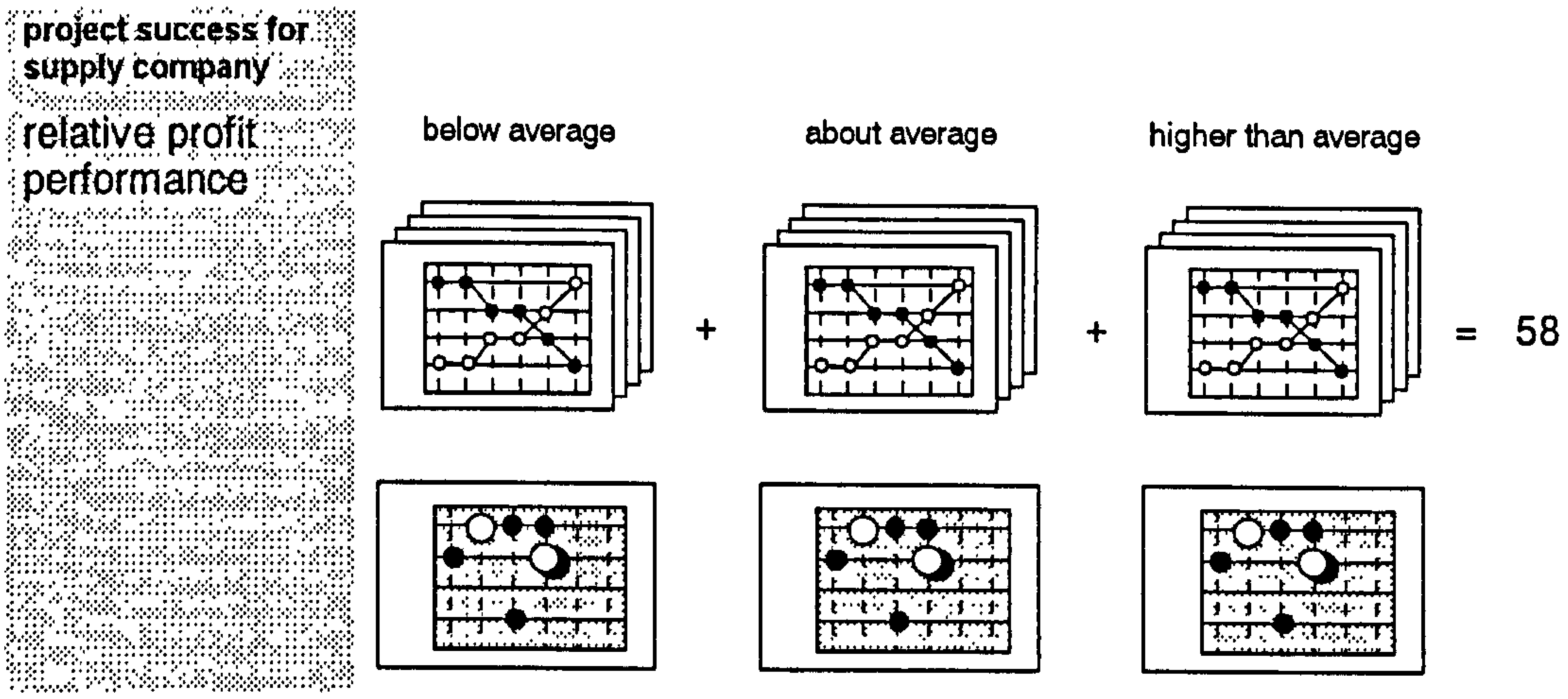


figure 4.10 diagram showing supplier functions/ process charts divided into levels of profit performance and represented in single diagrams

Open question

The comments obtained from designers for the open questions were listed and classified into themes.

4.5.3 Results

supplier function/ process charts

Figure 4.11 shows supplier functions at process stages for components that generated higher than average profits. The process stages are written along the horizontal axis. The levels of supplier function are written along the vertical axis. The full collection of diagrams plotted for the supplier control - success hypothesis can be found in Appendix V.

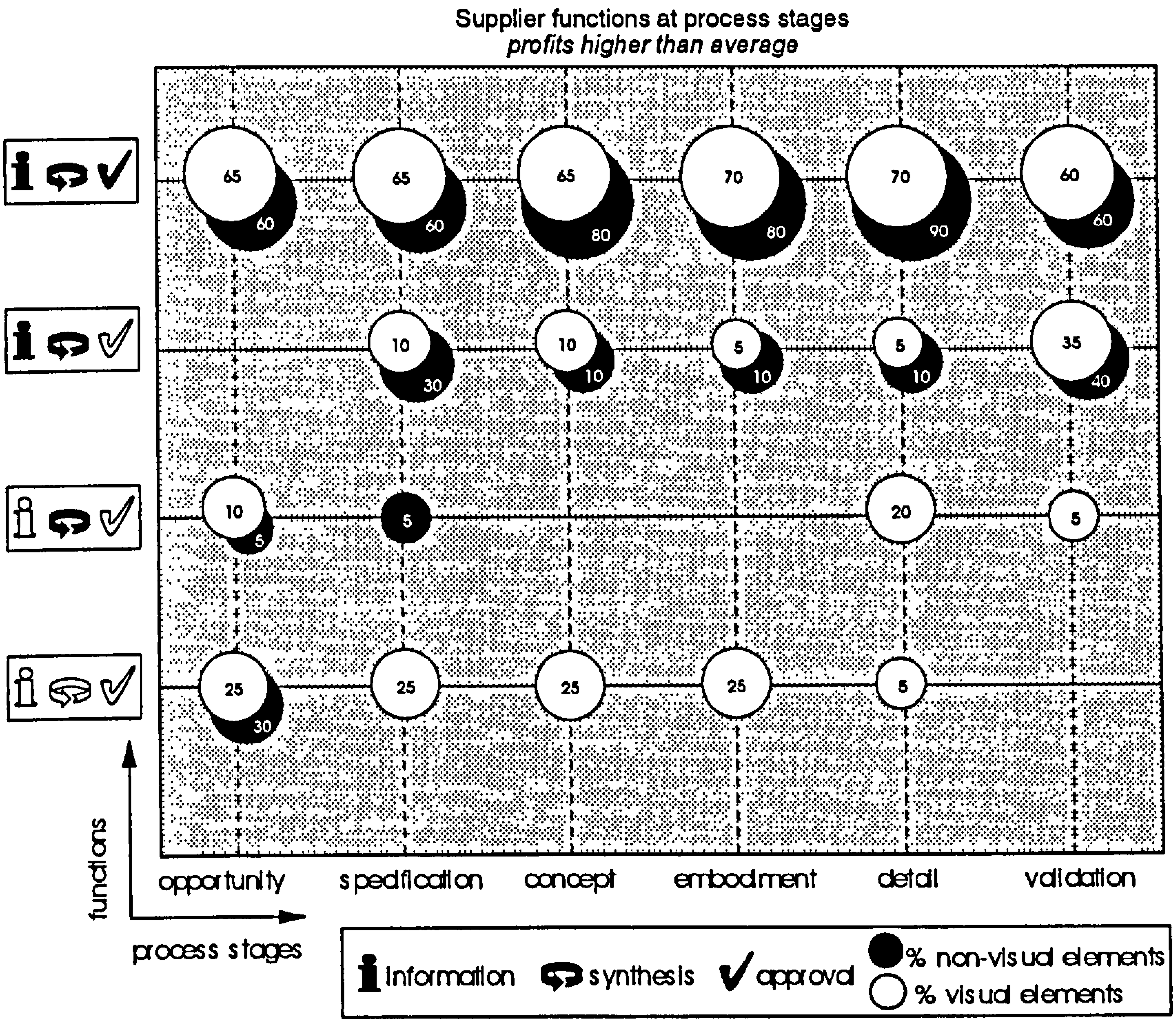


figure 4.11 supplier functions/ process chart for components that generated higher than average profits

Figure 4.11 states clearly that from opportunity to validation, 60%-70% of visible elements within components that generated higher than average profits were developed with suppliers responsible for information, synthesis and approval.

Open question

The full list of comments obtained from designers for the open question and their classification into themes can be found in Appendix III. Table 4.10 shows a summary of the most frequently found themes. Competitive prices was the most common theme identified 19 times. Visual differentiation was the second most common theme identified 14 times.

table 4.10 list of most frequently found themes for the open question

Rank	themes
1	competitive prices (19)
2	visual differentiation (14)
3	technical differentiation (13)
4	no differentiation (12)
	purchasing power (12)
5	easy to make (11)

Table 4.11 shows the most frequently identified themes designers used for explaining below average, about average and higher than average profit performance. The most frequently identified theme for components generating below average profits was competitive prices (11 times). The most frequently found theme for components generating higher than average profits was visual differentiation (14 times).

table 4.11 ranking of themes with which designers explained profit performance of their components

Rank	reasons given by designers for profits being below average	reasons given by designers for profits being about average	reasons given by designers for profits being higher than average
1	competitive prices (11)	competitive prices (8)	visual differentiation (14)
2	no differentiation (8)	purchasing power (6)	technical differentiation (10)
3	easy to make (7)	good prices (4)	good prices (7)
		easy to make (4)	
		no differentiation (4)	
4	purchasing power (6)	technical differentiation (3)	difficult to make (3)

4.6 Plotting the two variables of Hypothesis 3

4.6.1 Objectives

The objective of section 4.6 was to plot the two variables associated with Hypothesis 3. Evidence proving or disproving H3: *visual significance - success* could later be identified on the basis of these graphic plots.

4.6.2 Method

The diagram in figure 4.12 shows Hypothesis 3 and its two variables.

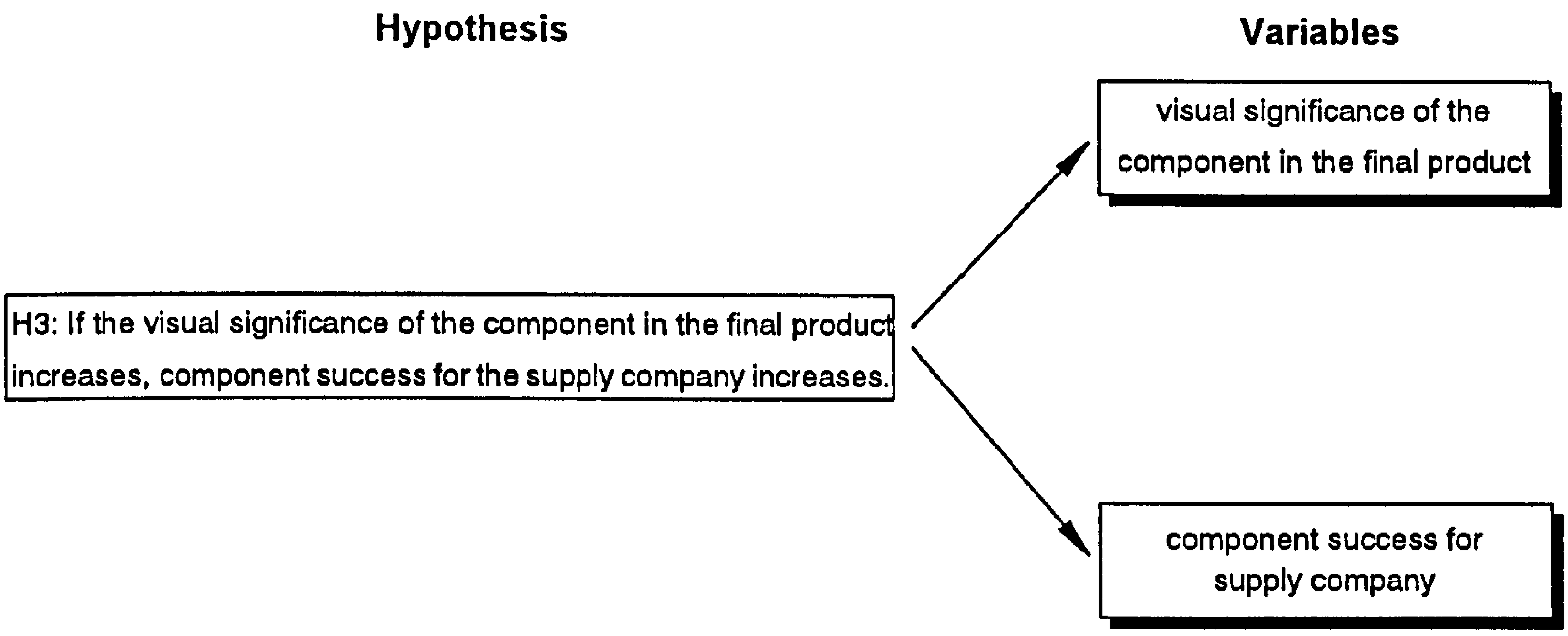


figure 4.12 diagram showing H3 and its two variables

Visual significance

Variable *visual significance of the component in the final product* was measured

1. the component's degree of visible customisation,
2. whether the component's development was driven by aesthetic requirements,
3. the component's share in visible surface,
4. the component's impact on size, shape or configuration of final product.

Success

Component success for supply company was measured by establishing component profit performance relative to the typical component in the company. An open question allowed designers to comment on the reasons for their component's financial performance (see table 4.12).

table 4.12 list of measures, questions and answers to establish component success

Variable	Measures	Questions	Answers
component success for supply company	relative profit performance	How would you classify the profits for this component compared to the typical component in your company?	below average/ about average/ higher than average
	comment on profit performance	Why do you think are component profits below/ about/ above average?	open question

Relating visual significance to success

In order to identify a relationship between *visual significance* and *component success*, the information was displayed in a bar chart diagram. An example is shown in figure 4.13. The three levels of profit performance (below, about, higher than average) were placed on the horizontal axis. The different shaded bars represent the levels of *visual significance*, in figure 4.13 expressed in terms of *share in visible surface*. The black shade stands for *no share*, the grey for *low and medium share* and the light grey for *high share* in the visible surface of the final product. The length of bars indicates the percentage of components in each profit category for the share in the visible surface of the final product. The diagram indicates that components with a *high share* in the visible surface are more likely to generate higher than average profits than components with *no share* in the visible surface. These are more likely to generate below average profits.

Figure 4.13 shows that the percentage of components with a high share in the visible surface increased with profits:

29% of components in the below average category

37% of components in the about average category

48% of components in the higher than average category

Figure 4.13 shows that the percentage of components with no share in the visible surface decreased with profits:

43% of components in the below average category

37% of components in the about average category

17% of components in the higher than average category

Figure 4.13 shows that the percentage of components with low and medium share in the visible surface remained flat in the below and about average profit category, but increased in the higher than average category.

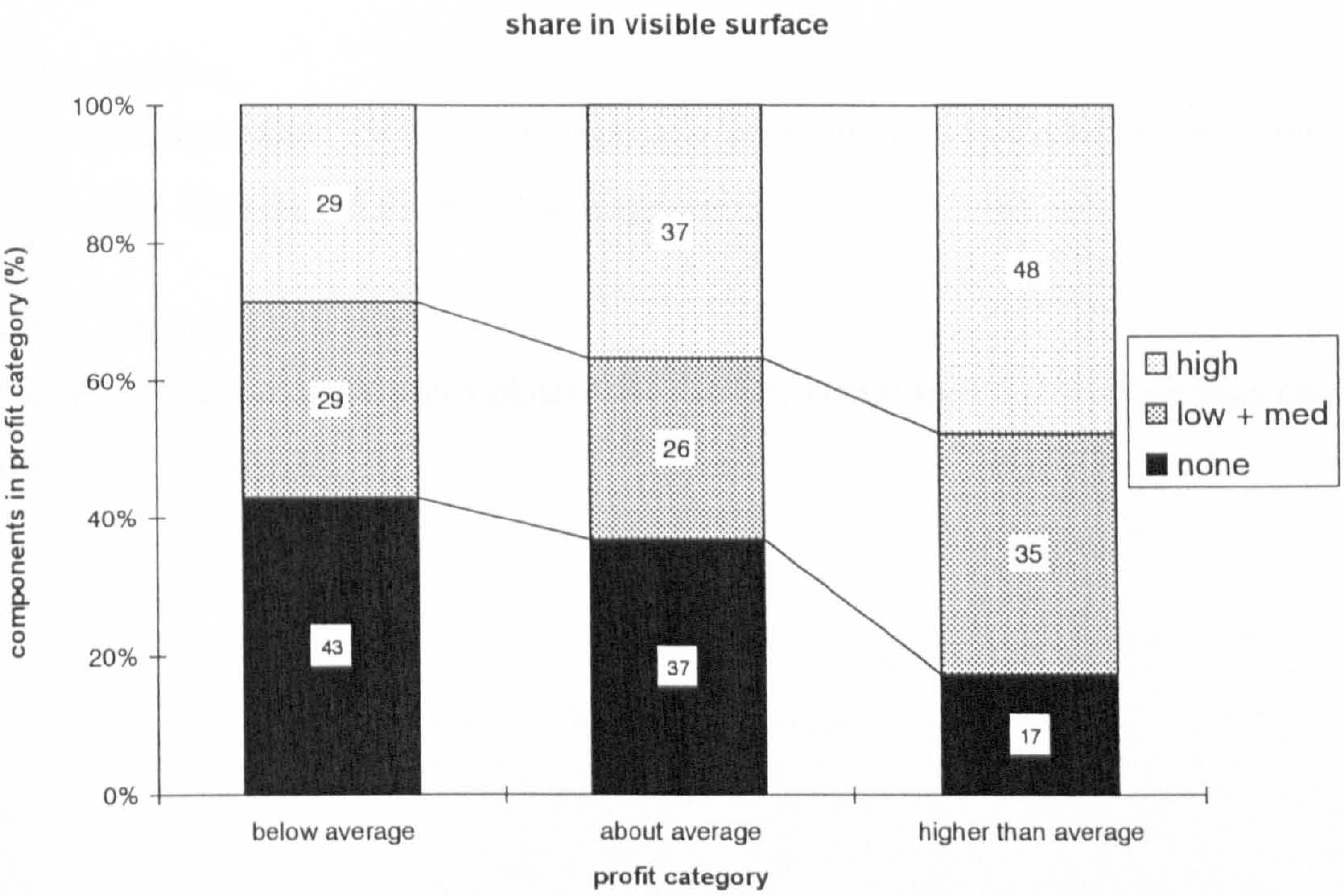


figure 4.13 diagram of component profits and share in the visible surface of the final product

As shown in figure 4.14, the four measures of visual significance produced four bar diagrams.

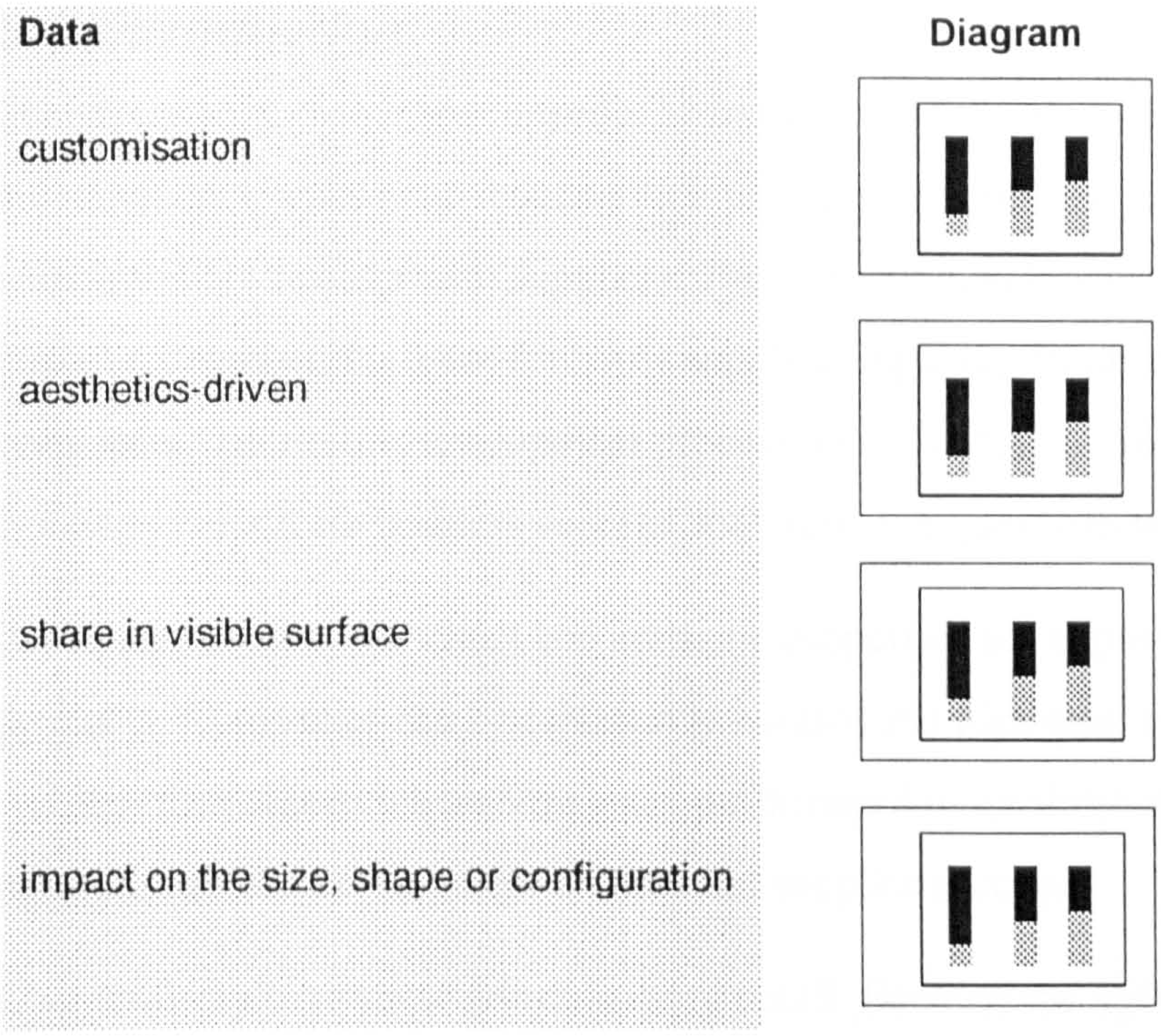


figure 4.14 diagram showing that the four measures of visual significance produced four diagrams

Open question

The answers obtained for the open questions were reviewed to explain some of the phenomena identified in the four bar diagrams.

4.6.3 Results

The full collection of diagrams plotted for the H3: *visual significance - success* can be found in Appendix VI.

5 Discussion of Results

5.1 Introduction

In chapter 1 the reader was introduced to trends in the component supply industry. Many industrial companies have reduced their production depth and have given more development responsibility to component suppliers. The product development function has become an important competitive asset for many supply companies. In order to establish how supply companies control the development process and whether supplier control in component development affects business success, four research questions were derived.

It was also shown that visual and aesthetic properties are important for manufactured products. Companies can systematically control and plan their products' visual qualities. Another four research questions were put forward to establish the effect product visuals have on supplier development control and supplier success.

Chapter 2 explored these issues in more detail. Because the specific questions on how product visuals affect development control and product success in the supply industry could not be answered with past literature, the model of product development was used to examine seven industrial case studies. Three hypotheses were set up which predict how product visuals affect development control and product success in the supply industry.

Chapter 3 developed a research method for testing the three hypotheses in a larger sample of supply companies. Using this method, the author collected data on components visiting supply companies at their production sites and at industry trade shows.

Chapter 4 plotted the collected survey data for an analysis of the hypotheses.

The following chapter discusses these plots and examines evidence in favour or against the hypotheses.

5.2 Objectives

The objective of the following chapter was to discuss the results of chapter 4 and identify evidence which proves or disproves the hypotheses.

5.3 Method

In order to achieve these objectives, the results were analysed in two steps.

1. examine the plots for graphic indicators which support or do not support the hypotheses,
2. test whether the indicators are statistically significant on the basis of the sample size.

The graphic plots were examined using the process shown in table 5.1. The first column lists the hypotheses. The second column refers to the relevant series of plots in the appendix. The third column describes what aspects had to be examined in each series of graphic plots.

table 5.1 table showing how the graphic plots were examined

Hypothesis	App.	Examine
visual significance - supplier control	IV	Whether supplier control changed at different levels of visual significance.
supplier control - success	V	Whether component success changed at different levels of supplier control.
visual significance - success	VI	Whether component success changed at different levels of visual significance.

The next step was to establish statistical significance, i.e. the probability that the relationship or finding based on the sample was not the result of sampling error, but reflects the characteristics of the population from which the sample was drawn.

For testing the statistical significance of categorical data and of the difference in proportions, Robson, 1996 [85] and Spiegel, 1990 [86] suggested chi-square analysis. The chi-square test uses two contingency tables. The first table displays the actual frequencies observed in the survey. The second table lists the expected frequencies which are usually derived from a hypothesis. The observed and expected frequencies are then compared by calculating χ^2 (chi-square). If χ^2 is smaller than the critical value of χ^2 at probability error of 0.05, the observed frequencies are significantly similar to the expected frequencies. The hypothesis (from which the expected frequencies were derived) can be accepted on a 95% probability basis. If χ^2 is bigger than the critical value of χ^2 at probability error of 0.05, the observed frequencies are significantly different to the expected frequencies. The hypothesis can be rejected on a 95% probability basis. For a comprehensive introduction to chi-square analysis see Spiegel, 1990 [86] and Sirkim, 1995 [87]. In order to test whether the indications found through the graphic analysis were statistically significant on the basis of the sample, the survey data was examined using the following process:

1. Pick data measured for the 1st variable and define a HIGH and a LOW level.
2. Pick data measured for the 2nd variable and define a HIGH and a LOW level.
3. Write observed frequencies (O) into O-table.
4. Based on the findings from graphic analysis, write expected frequencies (E) into E-Table.
5. Calculate difference between observed and expected frequencies: x^2 (chi-square) using the formula: $\chi^2 = \sum_i \frac{(O_i - E_i)^2}{E_i}$
6. Compare the computed value of ^{2} against the critical value for test of association for 5 per cent and 1 per cent level of significance.
7. There is a relationship if the computed value for ^{2} > than the critical value, There is no relationship if the computed value for ^{2} < than the critical value.

Figure 5.1 shows how this process was used.

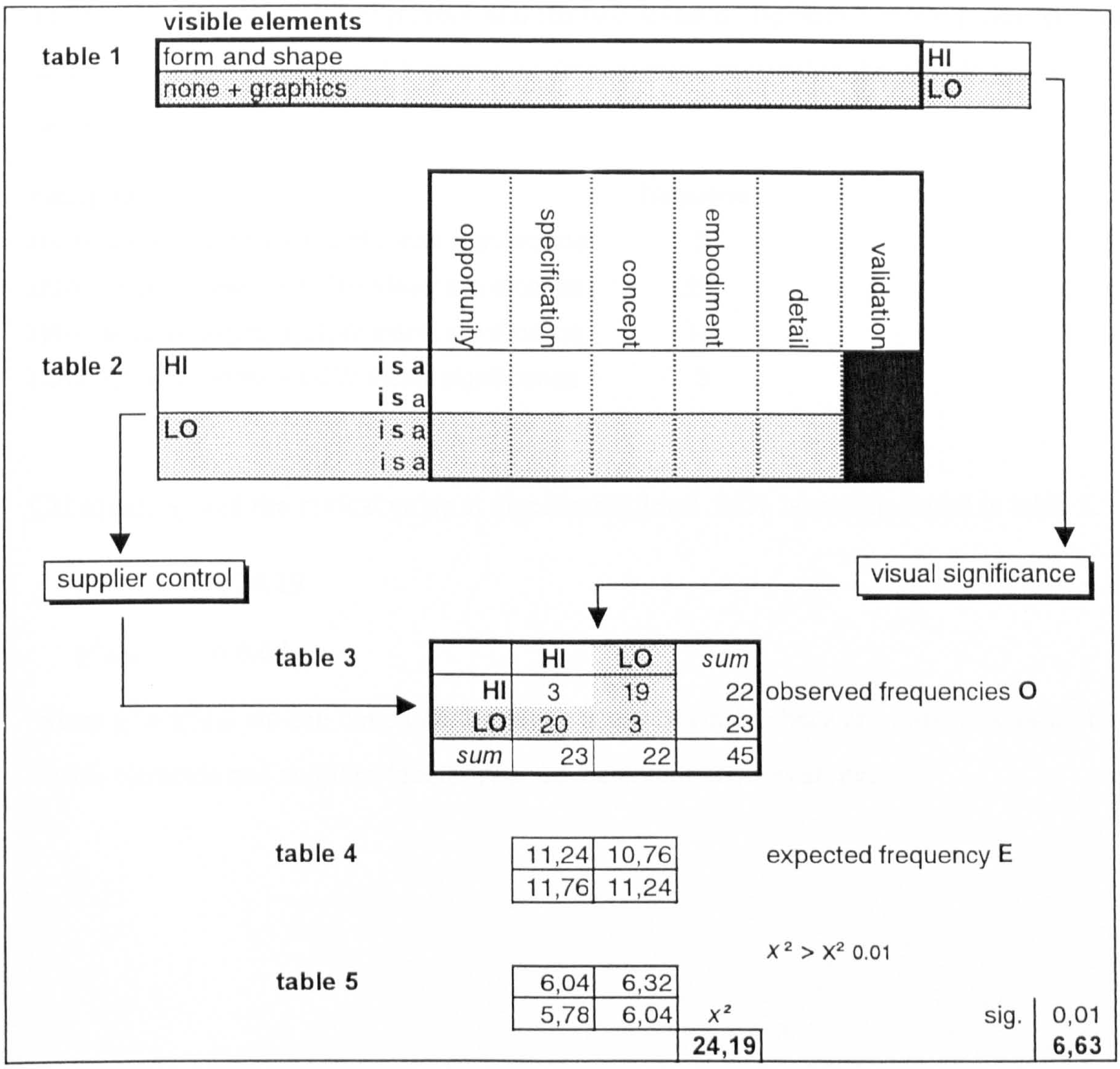


figure 5.1 example of significance test

Table 1 in figure 5.1 shows the high and low levels of variable *visual significance*:

HIGH visual significance = visible elements with customised form and shape

LOW visual significance = visible elements not customised or only graphics

Table 2 in figure 5.1 shows the high and low levels of variable supplier control:

HIGH supplier control = information, synthesis, approval (**isa**) or information, synthesis and no approval (**is**a), from opportunity to detail stage

LOW supplier control = nothing (isa) or only synthesis (i**s**a) from opportunity to detail stage

The two levels of *visual significance* and the two levels of *supplier control* produced four categories. Table 3 in figure 5.1 shows the frequencies observed in the sample for the four categories:

category	frequency
HIGH supplier control + HIGH visual significance	3
LOW supplier control + HIGH visual significance	20
HIGH supplier control + LOW visual significance	19
LOW supplier control + LOW visual significance	3

Chi square χ^2 and the critical value at significance level 0.01 were calculated in table 5:

$$\chi^2 = 24.19$$

$$\chi^2_{0.01} = 6.63$$

Since $\chi^2 > \chi^2_{0.01}$ we can conclude that there is a relationship between customisation of visible elements and supplier functions at development process stages.

5.4 *Examining data for Hypothesis 1*

5.4.1 Objectives

The objective of the following section was to examine the survey data and look for evidence which proves or disproves H1: *visual significance - supplier control.*

5.4.2 Method

The diagram in figure 5.2 shows H1 and its two variables. Table 5.2 lists how the two variables were measured.

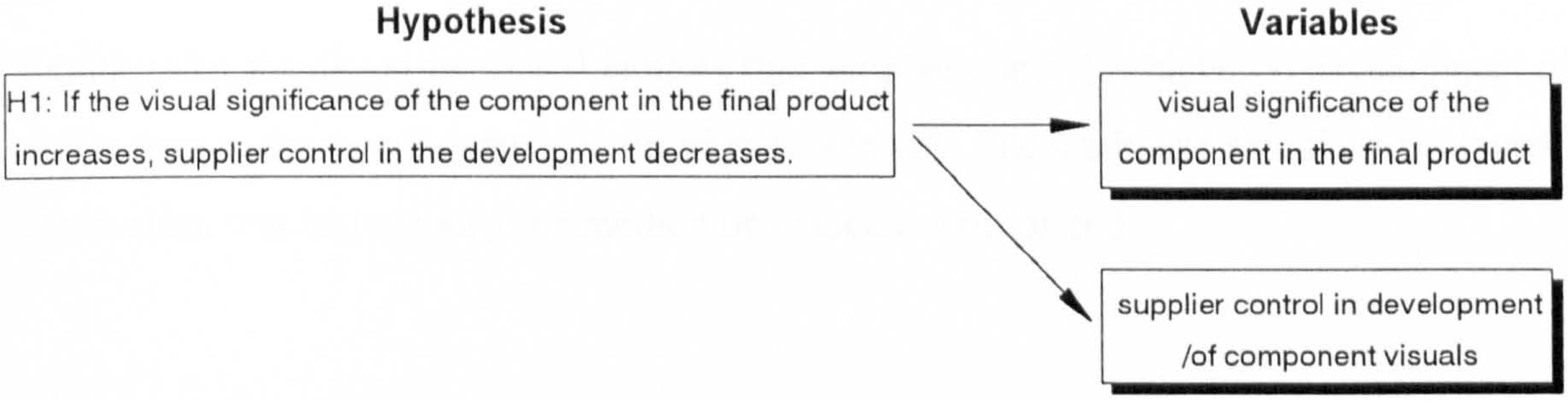


figure 5.2 diagram showing H1 and its two variables

table 5.2 list of measures, questions and answers to establish visual significance and supplier control

Variables	Measures	Questions	poss. Answers
visual significance of the component in the final product	customisation	Is the component customised for certain lead manufacturers?	not customised/ only graphics/ form or shape
	aesthetics-driven	Was component development driven by specifc aesthetic requirements of the final product?	aesthetic requirements of the final product/ no aesthetic requirements
	share in visible surface	What is the component's share in visible surface compared to other components in the final product or system?	none/ low/ medium/ high
	impact on size, shape or configuration	If the component is not visible to the end-user, does it have an impact on size, shape or configuration of the final	No/ Yes
supplier control in the development/ of component visuals	process stage	list of design outputs representing process stages	No/ Yes
	function	each stage is divided into information, synthesis, approval	No/ Yes
	visual/ non-visual elements	functions at process stages for elements visible and elements invisible to end-user	No/ Yes

To support H1: *visual significance - supplier control*, the plots should indicate that supplier control in the development decreases if:

1. component visible customisation increases,
2. component share in visible surface increases,
3. component development is driven by aesthetic requirements rather than technical requirements,
4. non-visible components have an impact on size, shape or configuration of final product.

Additionally, the diagrams should indicate that supplier control is higher in development of visible than in the development of non-visible elements. The statistical significance of each observation was tested using the method described in section 5.3.

5.4.3 Step 1: graphic analysis

Component customisation

To support H1, the diagrams should indicate that supplier control in the development decreases if component visible customisation increases.

1st observation

When comparing the development of visible elements in diagrams of Appendix IV.1, it is possible to observe that higher component customisation coincides with lower supplier control. Figure 5.3 shows supplier functions at process stages for components that were not customised. Figure 5.4 shows supplier functions at process stages for components that had customised graphics only. Figure 5.5 shows supplier functions at process stages for components that had customised form or shape.

Table 5.3 summarises the findings.

table 5.3 summary of findings: customisation and supplier control

figure	customisation	Supplier function at process stage (visible elements)
5.3	Components were not customised.	100% of cases: suppliers were responsible for information, synthesis and approval at every stage.
5.4	Components had only customised graphics.	80% of cases: suppliers were responsible for information, synthesis and approval at every stage.
5.5	Components had customised form or shape	5% -10% of cases: suppliers were responsible for information, synthesis and approval from opportunity to detail stage.

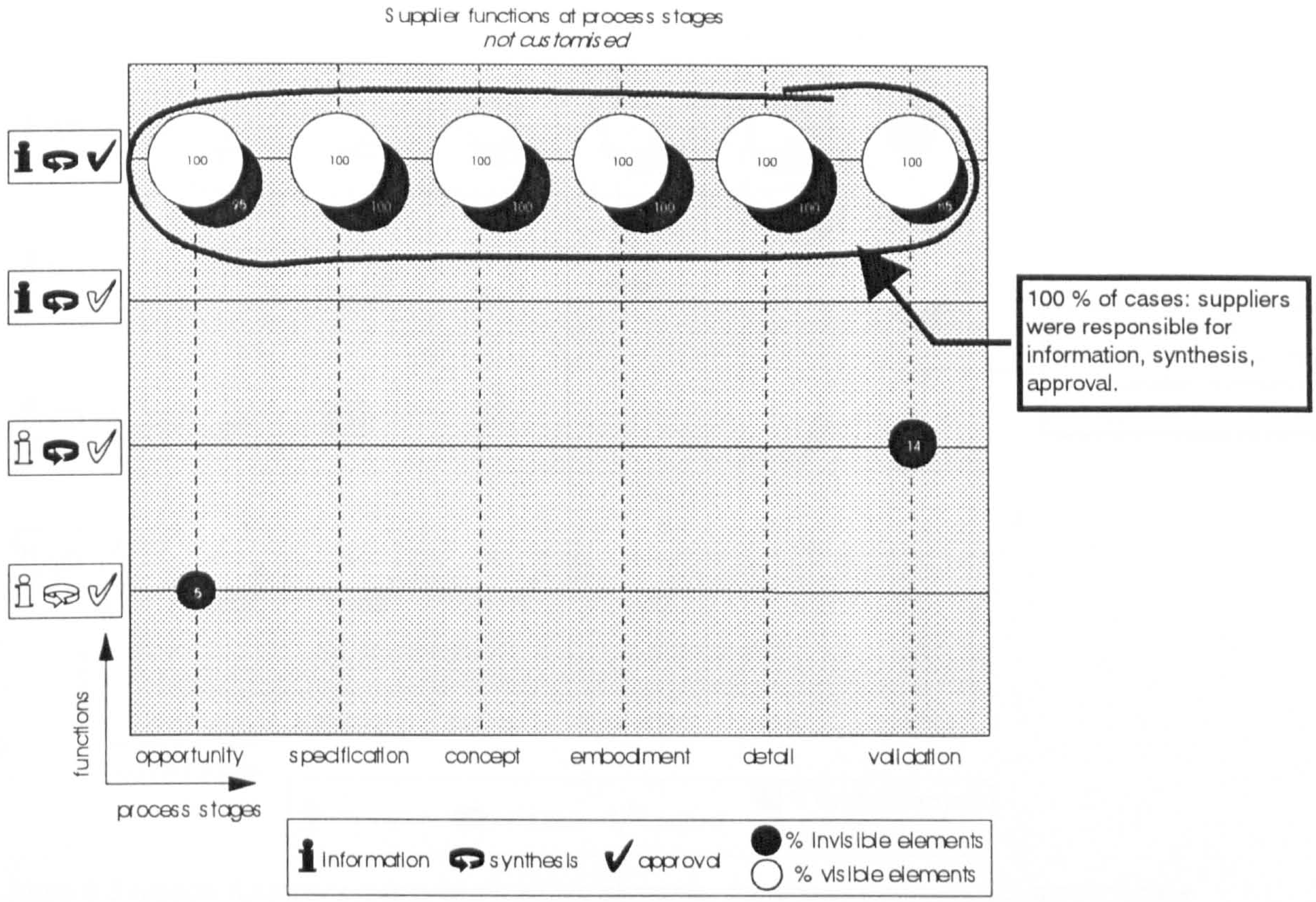


figure 5.3 supplier function/ process chart: visible elements, components not customised

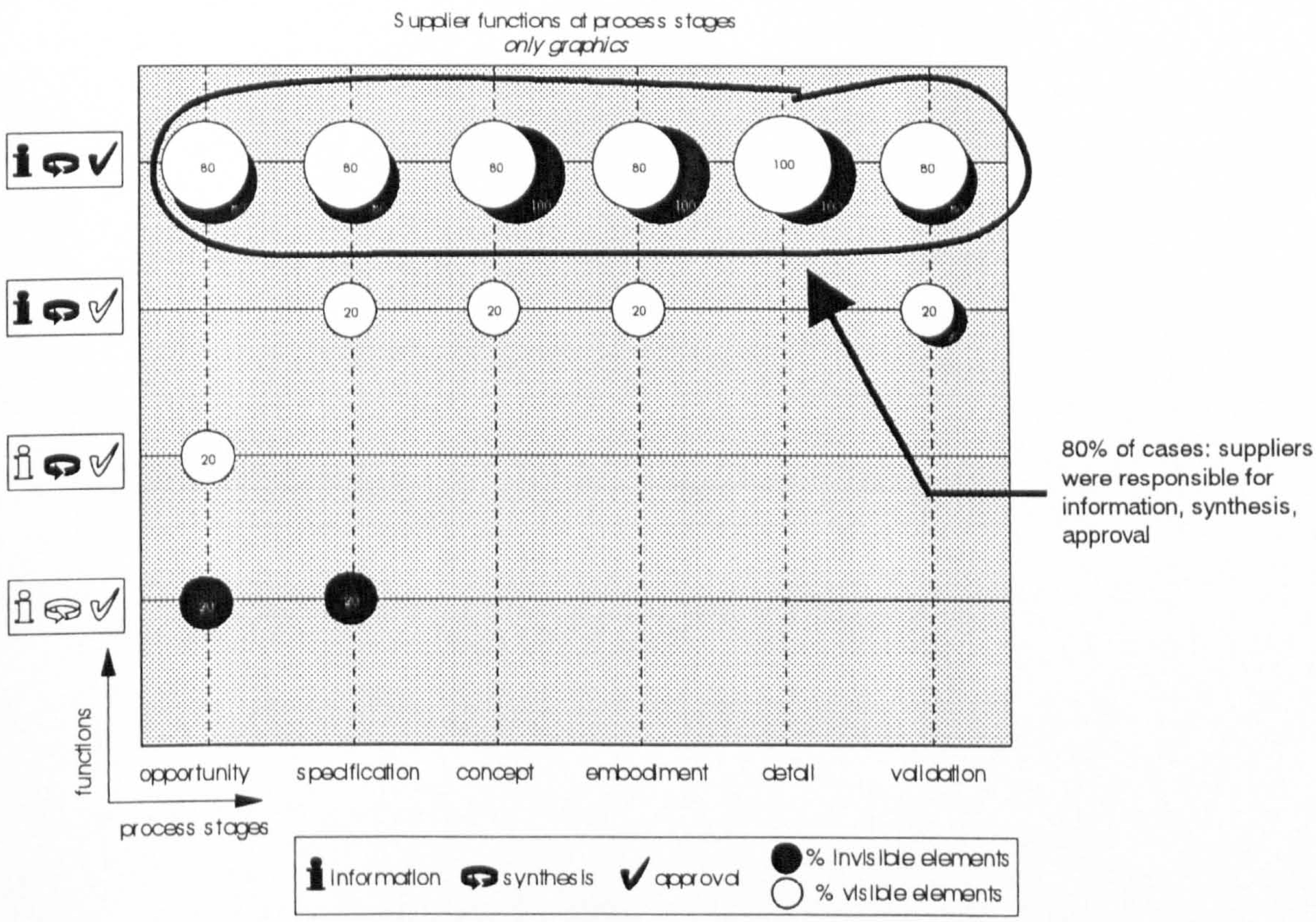


figure 5.4 supplier function/ process chart: visible elements within components customised graphics

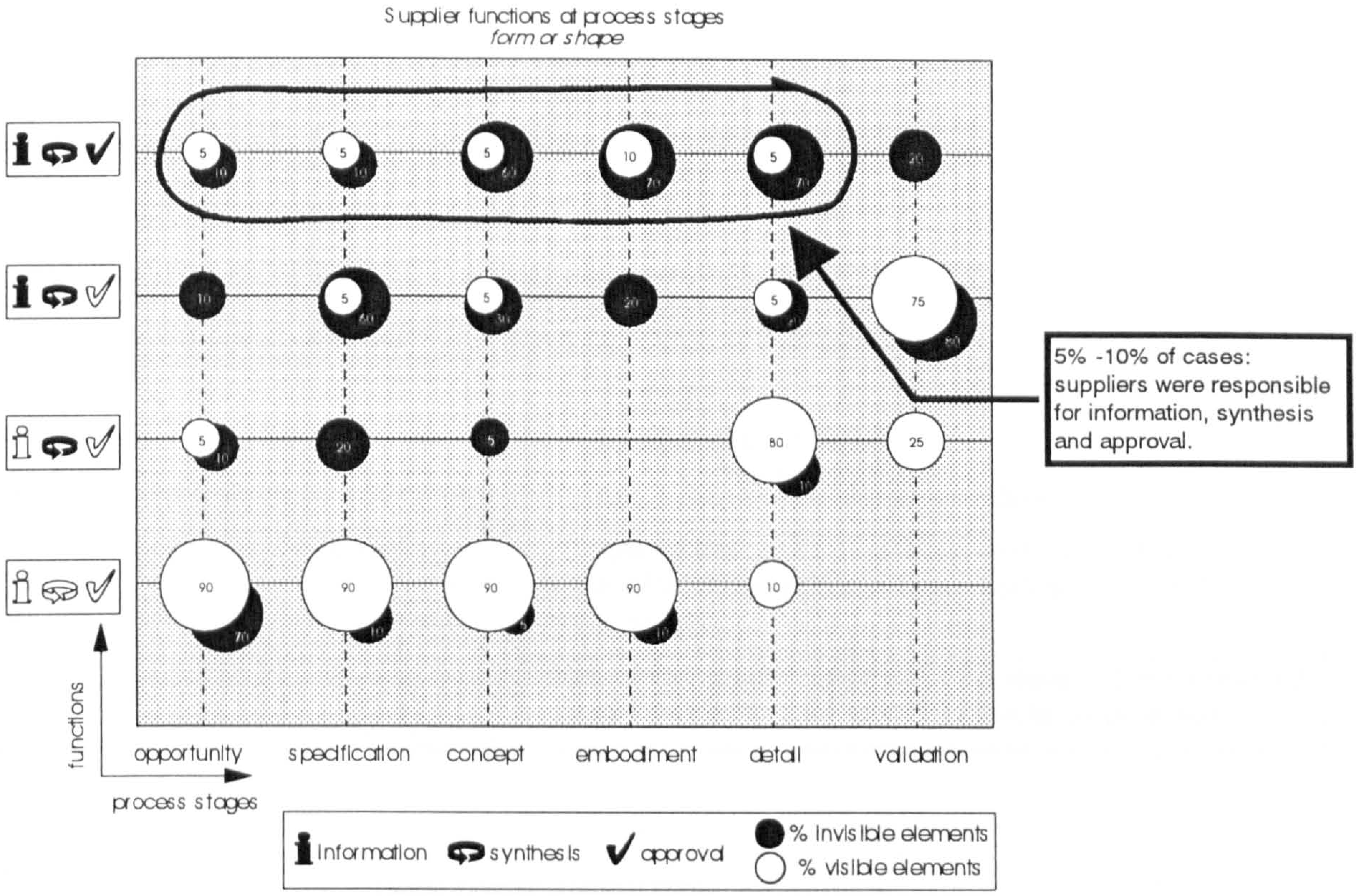


figure 5.5 supplier function/ process chart: visible elements, components customised form or shape

2nd observation

To support the H1, the diagrams should indicate that *supplier control during the development* is higher for non-visible elements than for visible elements.

When comparing the development of visible with the development of non-visible elements in the diagram on components with customised form or shape, it is possible to observe that visible elements coincide with lower supplier control. Figure 5.6 shows supplier functions at process stages for components that have customised form or shape.

table 5.4 summary of findings: visible, non-visible elements and supplier control

figure	customised form or shape	Supplier function at process stage
5.6	non-visible elements	70-90% of the cases: suppliers were responsible for at least information and synthesis from specification to detail stage.
	visible elements	90% of the cases: suppliers were responsible for nothing or only synthesis from specification to detail stage.

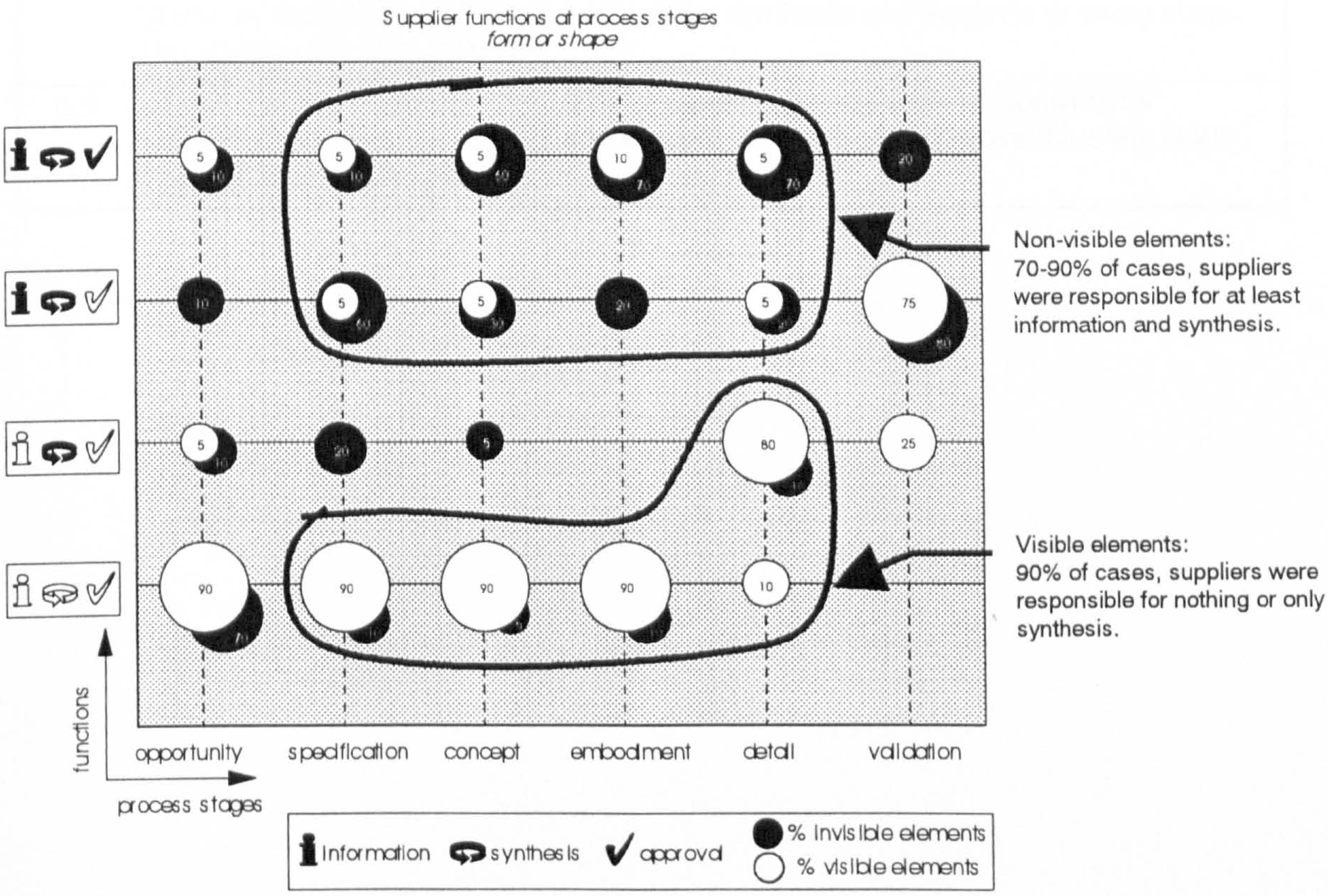


figure 5.6 supplier function/ process chart: visible, non-visible elements

aesthetics-driven

To support the H1, the diagrams should indicate that supplier control in the development of visible elements is lower if components are driven by aesthetic requirements.

By comparing the development of visible elements in diagrams of Appendix IV.2, it is possible to observe that aesthetics-driven development coincides with lower supplier control.

Figure 5.7 shows supplier functions at process stages for components whose development was driven by specific aesthetic requirements of the final product. Figure 5.8 shows supplier functions at process stages for components whose development was not driven by any specific aesthetic requirements of the final product.

table 5.5 summary of findings: aesthetics driven development and supplier control

figure	aesthetics-driven	Supplier function at process stage (visible elements)
5.7	component development not driven by aesthetic requirements of final product	80% of cases: suppliers were responsible for information, synthesis and approval at every stage.
5.8	component development driven by aesthetic requirements of final product	30% of cases: suppliers were responsible for information, synthesis and approval at every stage.

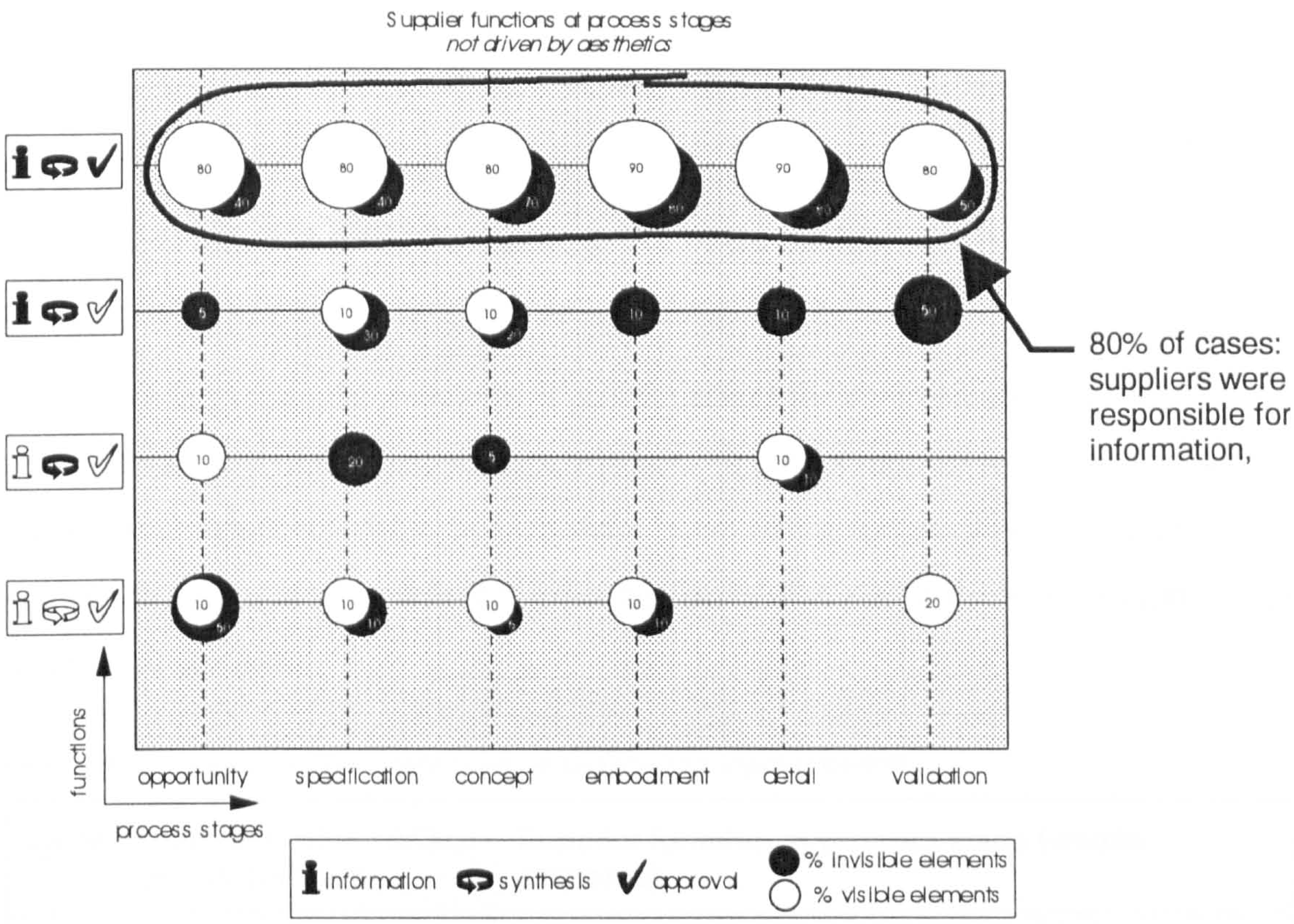


figure 5.7 supplier functions/ process chart: visible elements, components not aesthetics-driven

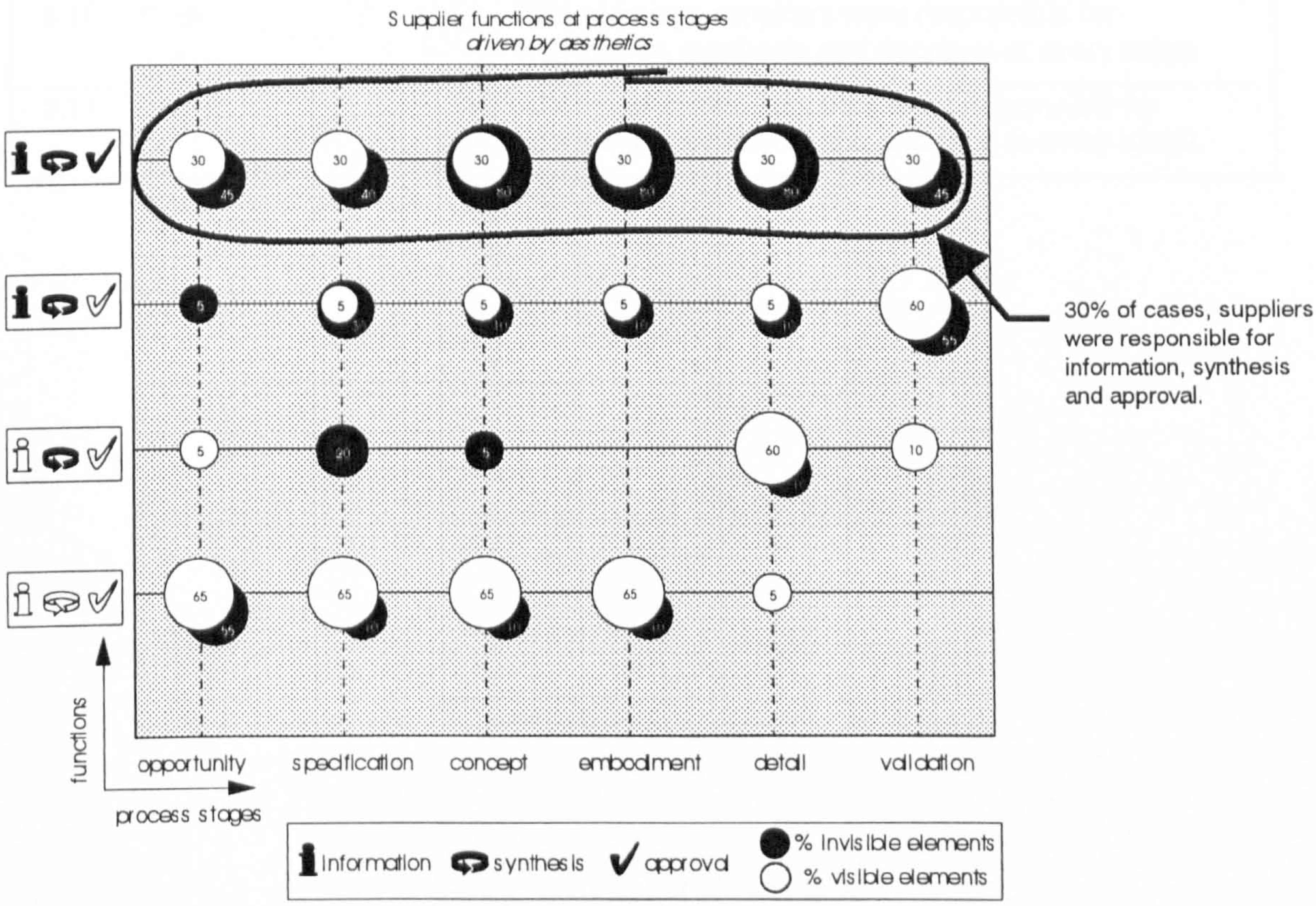


figure 5.8 supplier functions/ process chart: visible elements, components aesthetic-driven

share in visible surface

To support H1, the diagrams should indicate that supplier control in the development of visible elements is lower if components have a higher share in visible surface.

When comparing the visible elements in the diagrams of Appendix IV.3, it is possible to observe that higher share in the visible surface of the final product coincides with lower supplier control during the development.

Figure 5.9 shows supplier functions at process stages for components with a low share in the visible surface of the final product. Figure 5.10 shows supplier functions at process stages for components with a medium share in the visible surface. Figure 5.11 shows supplier functions at process stages for components with a high share in the visible surface of the final product.

table 5.6 summary of results: share in visible surface and supplier control

figure	share in visible surface of final product	Supplier function at process stage (visible elements)
5.9	low	70% of cases: suppliers were responsible for information, synthesis and approval at every stage.
5.10	medium	70% of cases: suppliers were responsible for information, synthesis and approval at every stage.
5.11	high	30-40% of cases: suppliers were responsible for information, synthesis and approval at every stage.

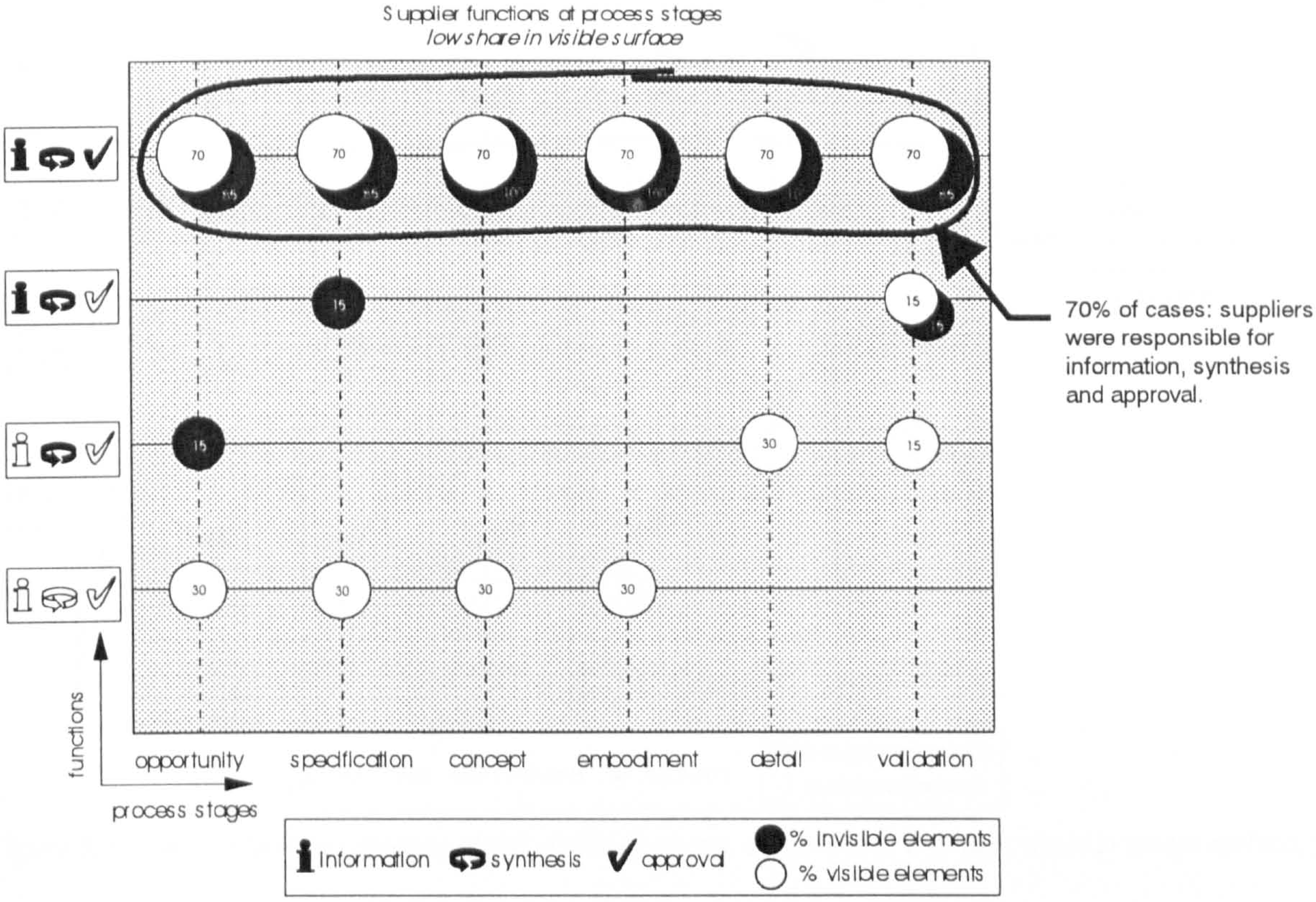


figure 5.9 supplier function/ process chart: visible elements, components with low share in visible surface

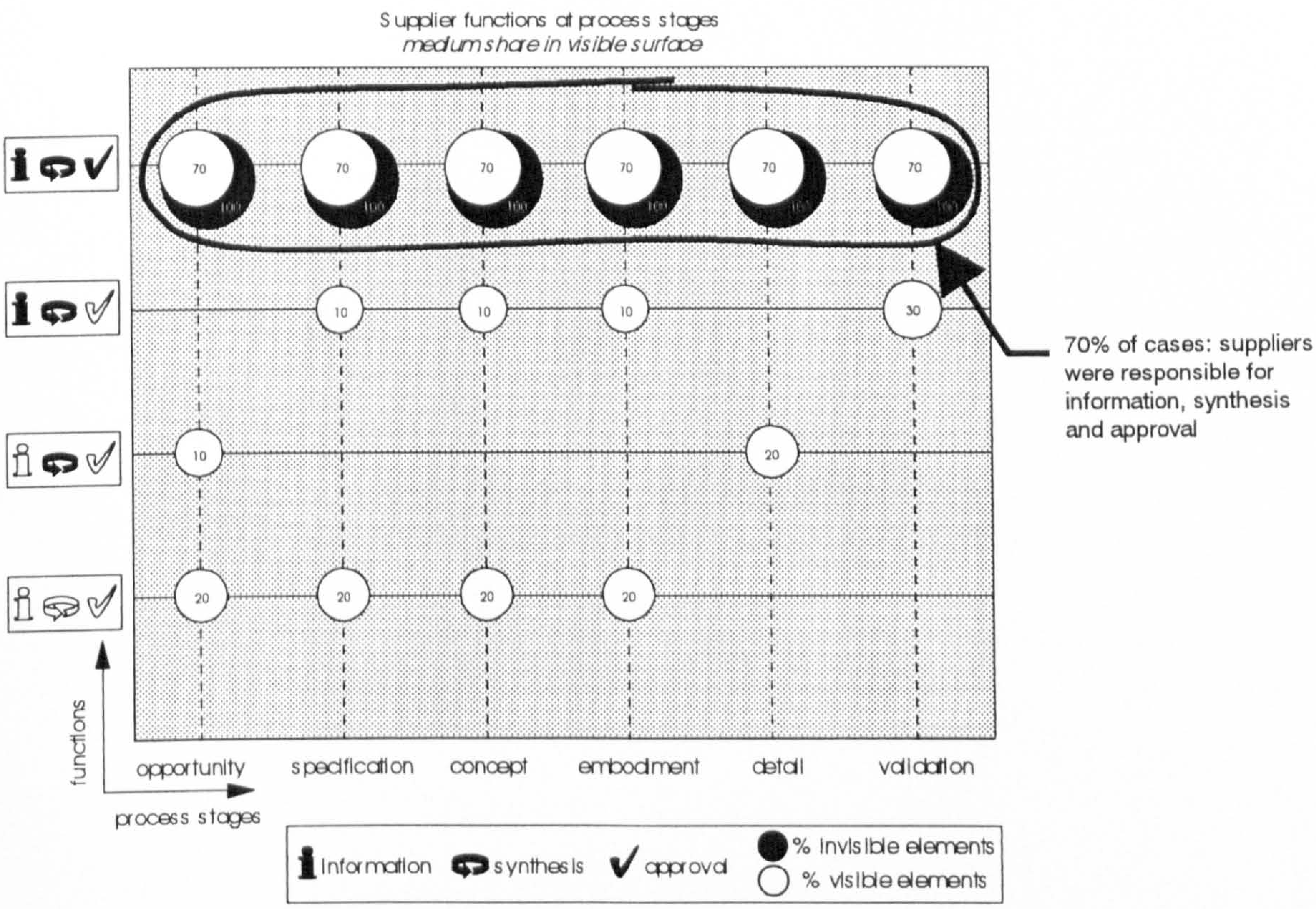


figure 5.10 supplier function/ process chart: visible elements, components with medium share in visible surface

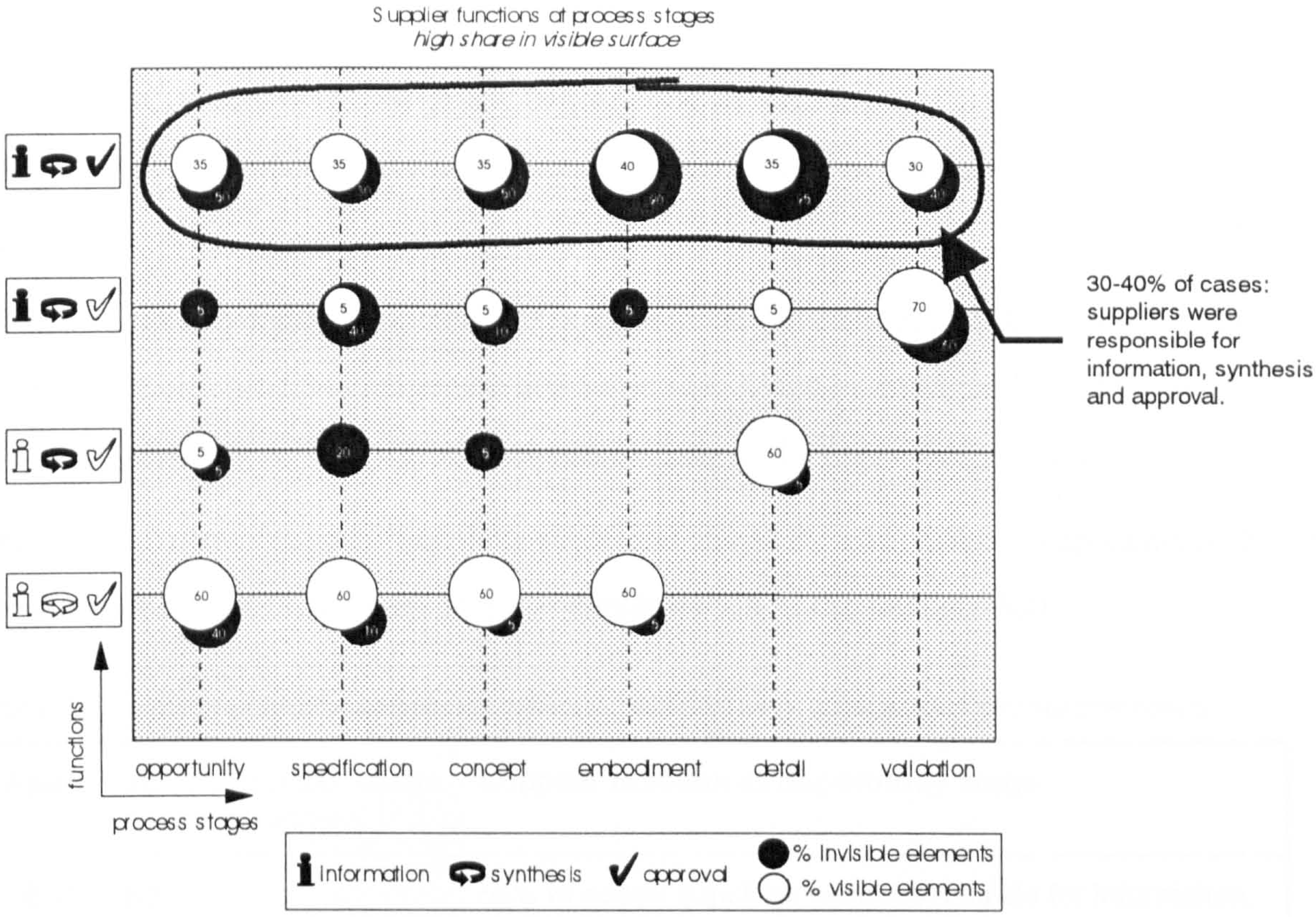


figure 5.11 supplier function/ process chart: visible elements, components with high share in visible surface

impact on size, shape or configuration

To support H1, the diagrams should indicate that supplier control in the development decreases if components have an impact on the size, shape or configuration of the final product.

When comparing the development of components in the diagrams of Appendix IV.4, it is possible to observe that component impact on size, shape or configuration of the final product coincides with lower supplier control only at the opportunity stage.

Figure 5.12 shows supplier functions at process stages for non-visible components with and without an impact on the size, shape or configuration of the final product.

table 5.7 summary of results: component impact on size, shape or configuration and supplier control

figure	impact on size, shape or configuration	Supplier function at opportunity stage
5.12	no	55% of cases: suppliers were responsible for information, synthesis and approval.
	yes	20% of cases: suppliers were responsible for information, synthesis and approval.

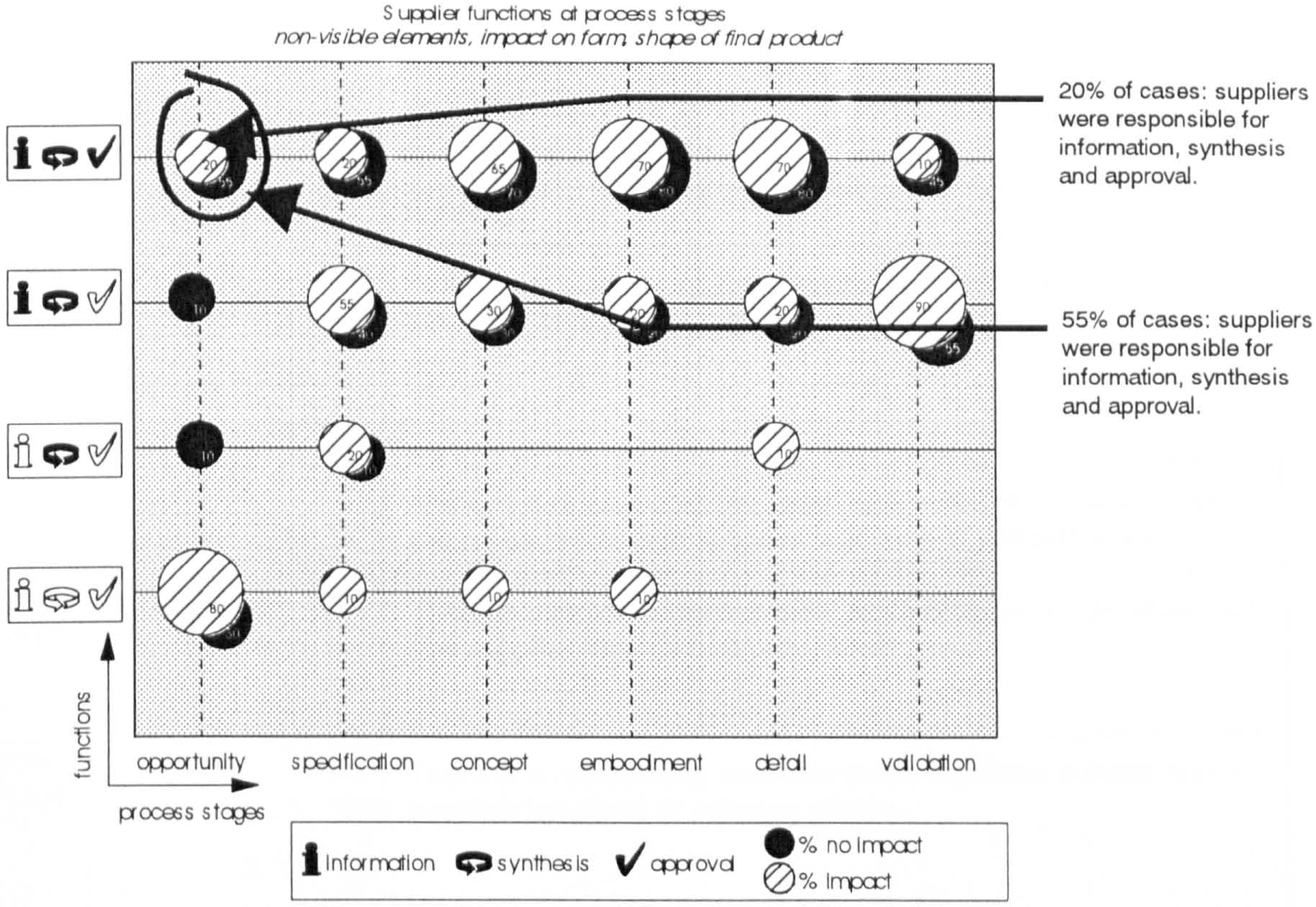


figure 5.12 supplier function/ process chart: non-visible components with and without impact...

5.4.4 Step 2: significance test

The second step was to test whether the observations of section 5.4.5 were statistically significant on the basis of the sample size. The complete collection of significance tests for H1: *visual significance - supplier control* are in Appendix IV. Table 5.8 summarises the statements derived from the chi-square analysis.

table 5.8 statements with statistical significance supporting H1

Measure	Diagram		Finding
custom-isation	figure 5.3, 5.4, 5.5	App. IV.1	There is a relationship between customisation and supplier functions at process stages.
	figure 5.6	App. IV.1	There is a relationship between customisation of visible/ non-visible elements and supplier functions at process stages.
aesthetics-driven	figure 5.7, 5.8	App. IV.2	There is a relationship between aesthetics-driven development and supplier functions at process stages.
visible surface	figure 5.9, 5.10, 5.11	App. IV.3	There is a relationship between share in visible surface and supplier functions at process stages.
impact on size, shape...	figure 5.12	App. IV.4	The sample size was too small and statistical significance of the findings could not be established.

5.5 *Examining data for Hypothesis 2*

5.5.1 Objectives

The objective of the following section was to examine the survey data and look for evidence which proves or disproves H2: *supplier control - success.*

5.5.2 Method

The diagram in figure 5.13 shows H2 and its two variables. Table 5.9 lists how the two variables were measured.

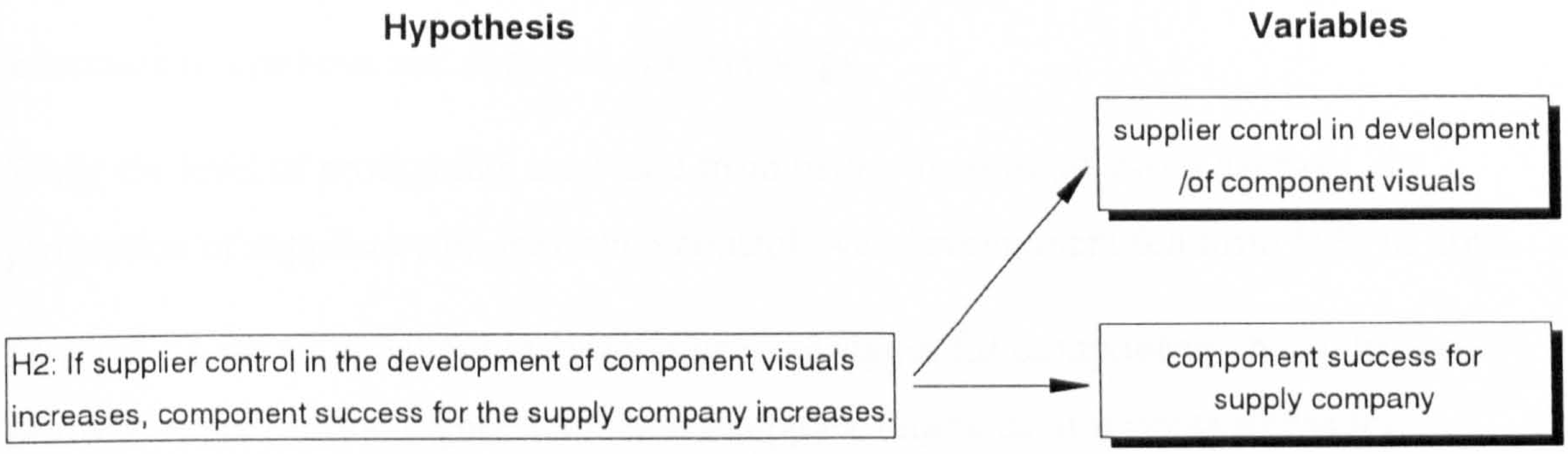


figure 5.13 diagram showing H2 and its two variables

table 5.9 list of measures, questions and answers to establish supplier control and component success

Variable	Measures	Questions	poss. Answers
Supplier control in the development/ of component visuals	process stage	list of design outputs representing process stages	No/ Yes
	function	each stage is divided into information, synthesis, approval	No/ Yes
	visual/ non-visual elements	functions at process stages for elements visible and elements invisible to end-user	No/ Yes
component success for supply company	relative profit performance	How would you classify the profits for this component compared to the typical component in your company?	below average/ about average/ higher than average
	comment on profit performance	Why do you think are component profits below/ about/ above average?	open question

To support H2, the graphic plots should indicate that the number of successful components increases if suppliers have more control in the development of component visuals. The statistical significance of each observation was tested using the method described in section 5.3.

5.5.3 Step 1: graphic analysis

To support H2: *supplier control - success*, the diagrams should indicate that the number of successful components increases with supplier control in visual development.

When comparing supplier functions at process stages for the development of visible elements in diagrams of Appendix V, it is possible to observe that higher supplier control in development does not coincide with a rise in profits: Out of all components that generated *below average profits*, 50% were cases in which suppliers had been responsible for information, synthesis and approval at every stage. Out of all components that generated *about average profits*, only 20% were cases in which suppliers had been responsible for information, synthesis and approval at every stage.

While the level of profitability increased from *below average* to *about average*, the proportion of suppliers with maximum control over development fell from 50% to 20%.

Figure 5.14 shows supplier functions at process stages for components that generated below average profits. Figure 5.15 shows supplier functions at process stages for components that generated about average profits. Figure 5.16 shows supplier functions at process stages for components that generated higher than average profits.

table 5.10 higher profitability does not coincides with higher supplier control

figure	profits	Supplier function at process stage (visible elements)
5.14	below average	50% of cases: suppliers were responsible for information, synthesis and approval at every stage.
5.15	about average	20% of cases: suppliers were responsible for information, synthesis and approval at every stage.
5.16	higher than average	60-70% of cases: suppliers were responsible for information, synthesis and approval at every stage.

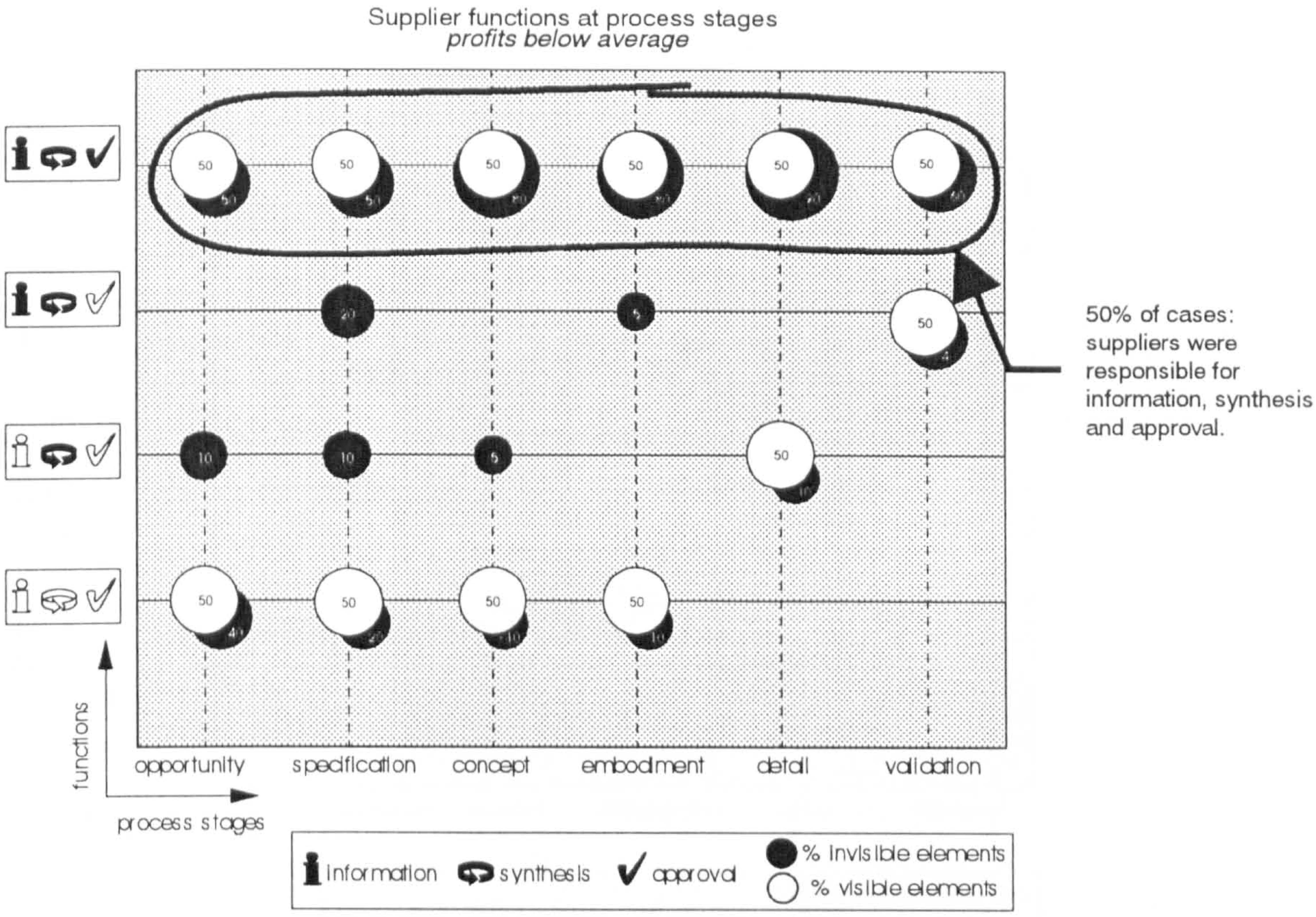


figure 5.14 supplier function/ process chart: visible elements, components with below average profits

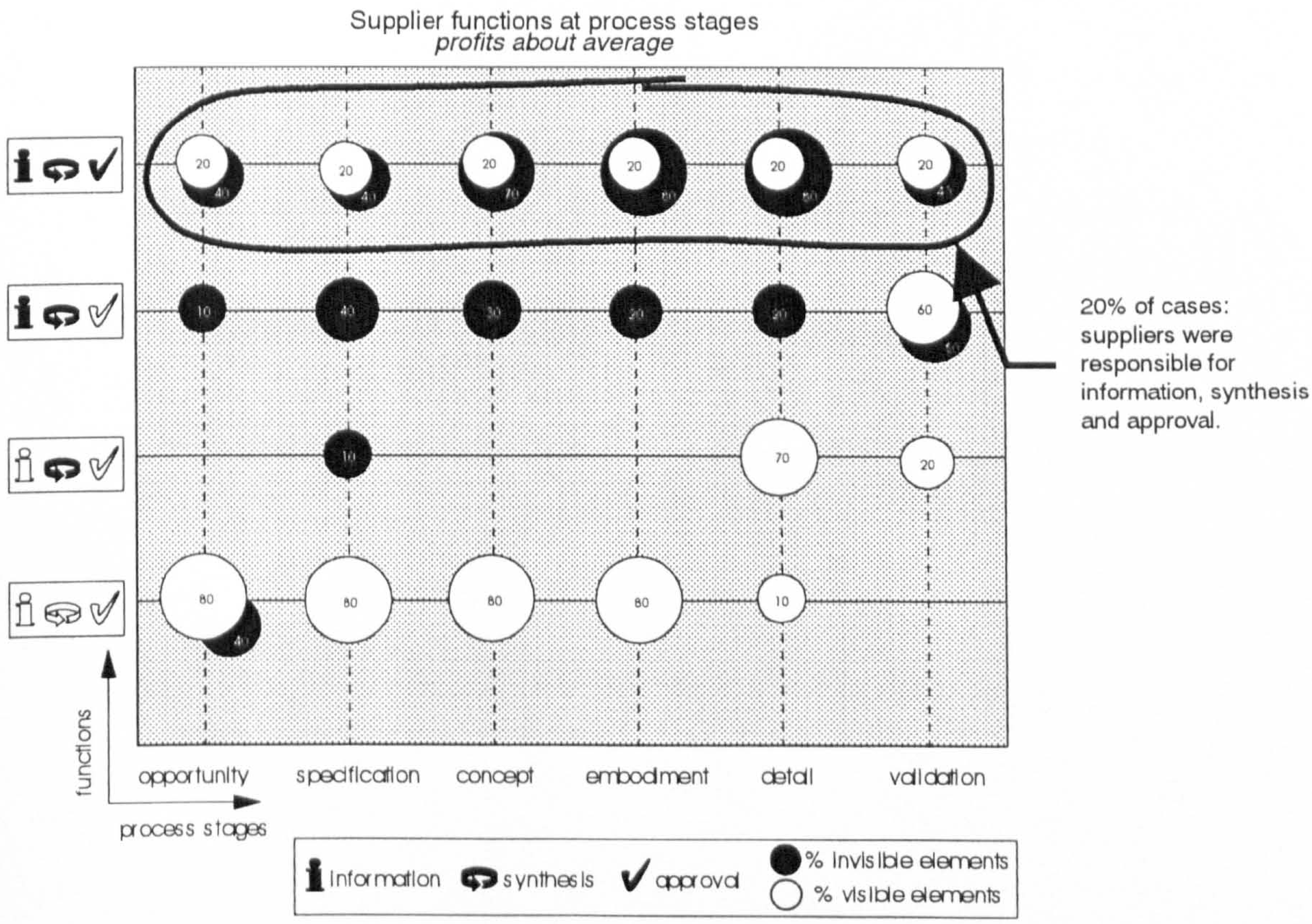


figure 5.15 supplier function/ process chart: visible elements, components with about average profits

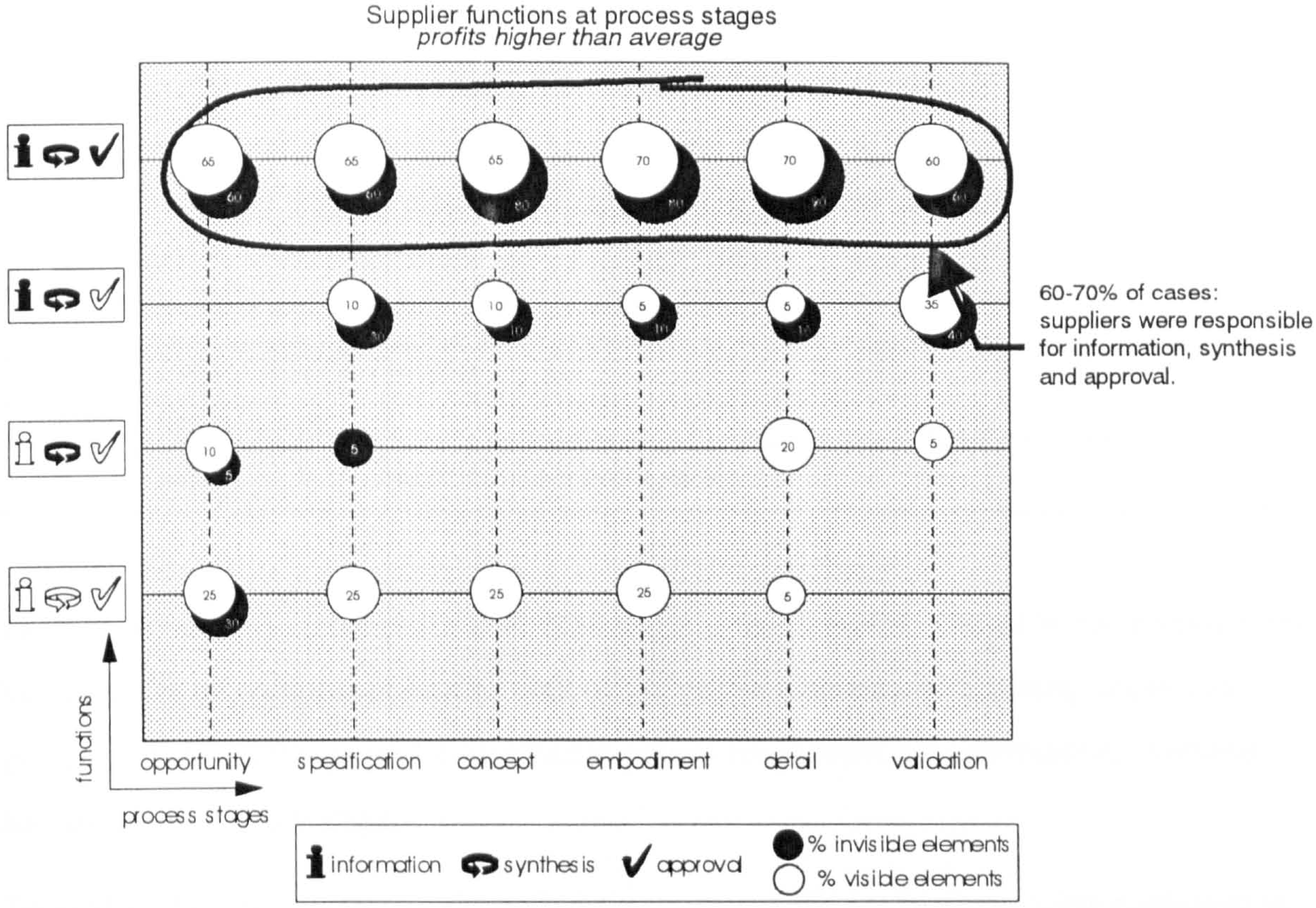


figure 5.16 supplier function/ process chart: visible elements, components with higher than average profits

5.5.4 Step 2: significance test

The second step was to test whether the observations of section 5.5.3 were statistically significant on the basis of the sample. The significance tests conducted for H2: *supplier control - success* are in Appendix V. The statement in table 5.11 does not support H2. The comments on profit performance were reviewed to explain the findings.

table 5.11 statements with statistical significance not supporting H2

Data	Diagram		Finding
profits	figure 5.14	App. V	There is no relationship between supplier function at process stages and component profit levels.

Figure 5.14 and the statement in table 5.10 suggest that supplier control in the development has no effect on component profits: Half of the visible elements within components that generated below average profits also had suppliers responsible for information, synthesis and approval at every stage.

To explain this observation, designers' comments on profit performance were compared in table 5.12. The left column lists themes identified for components that generated higher than average profits for which suppliers were responsible for information, synthesis and approval at every stage of the development process. The right column lists themes for components that generated below average profits for which suppliers were also responsible for information, synthesis and approval at every stage of the development process.

table 5.12 list of designers comments, full development responsibility comparing higher than average and below average profits

Rank	suppliers fully responsible, profits 'higher than average'	suppliers fully responsible, profits 'below average'
1	visual differentiation (8)	no differentiation (3)
		purchasing power (3)
		competitive prices (3)
2	technical differentiation (6)	easy to make (1)
3	good prices (4)	

Table 5.12 suggest that high supplier control in the development of visuals is not sufficient to generate high profits. Suppliers can be fully responsible for visual development, but still generate below average profits if their components lack differentiation, if lead manufacturers have buying-power and if the price situation in the supply market is difficult. Rather than being a guarantee for higher profits, control in development appears to be an opportunity for suppliers to create differentiated components. Suppliers can only earn higher than average profits if they use their control in development to differentiate their components from the competition. Furthermore, lead manufacturer have to be willing to pay for the differentiation.

5.6 Examining data for Hypothesis 3

5.6.1 Objectives

The objective of the following section is to examine the survey data and look for evidence which proves or disproves H3: *visual significance - success.*

5.6.2 Method

The diagram in figure 5.17 shows H3 and its two variables. Table 5.13 shows how the two variables were measured.

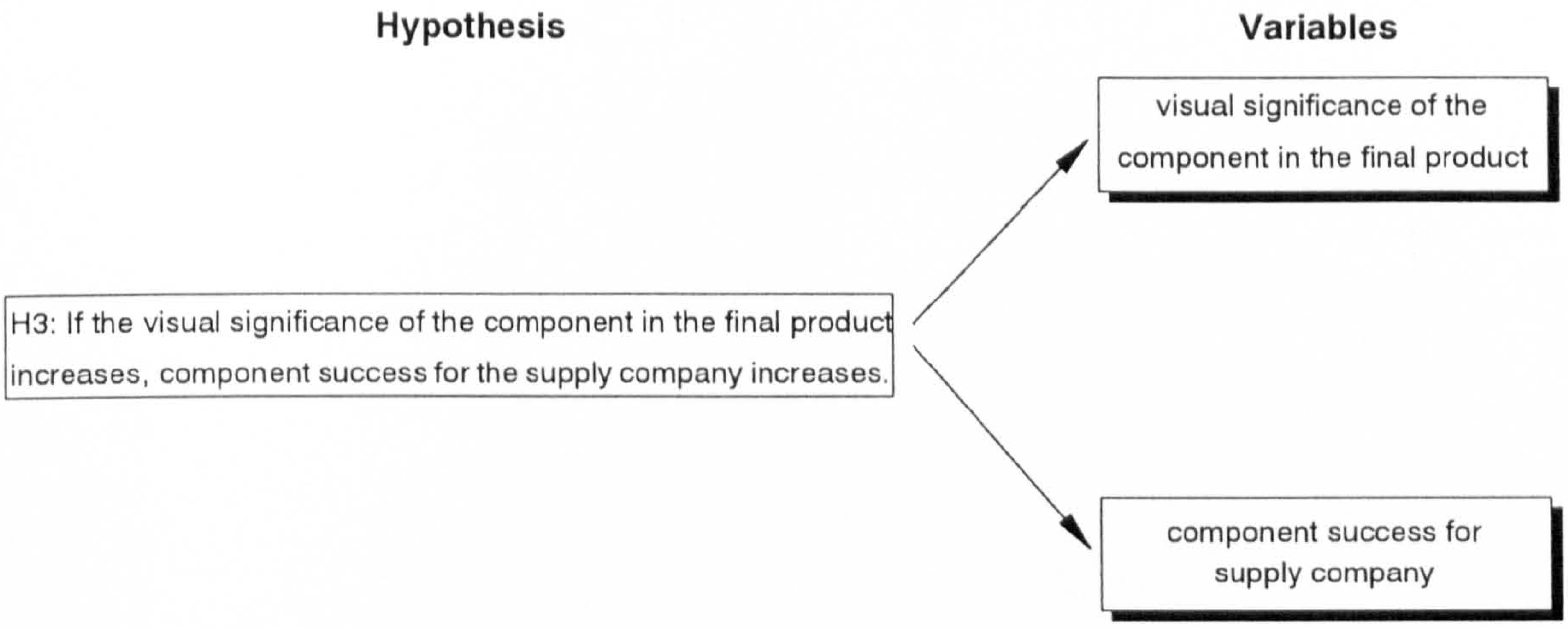


figure 5.17 diagram showing H3 and its two variables

table 5.13 list of measures, questions and answers to establish supplier control and component success

Variable	Measures	Questions	Answers
Component significance for product visuals	customisation	Is the component customised for certain lead manufacturers?	not customised/ only graphics/ form or shape
	aesthetics-driven	Was component development driven by specifc aesthetic requirements of the final product?	aesthetic requirements of the final product/ no aesthetic requirements
	share in visible surface	What is the component's share in visible surface compared to other components in the final product or system?	none/ low/ medium/ high
	impact on size, shape or configuration	If the component is not visible to the end-user, does it have an impact on size, shape or configuration of the final	No/ Yes
component success for supply company	relative profit performance	How would you classify the profits for this component compared to the typical component in your company?	below average/ about average/ higher than average
	comment on profit performance	Why do you think are component profits below/ about/ above average?	open question

To support H3, the graphic plots should indicate that the number of successful components increases together with visual significance of the component. The statistical significance of each observation was tested using the method described in section 5.3.

5.6.3 Step 1: graphic analysis

component customisation

To support H3, the diagrams should indicate that component profits increase with customisation. Figure 5.18 shows that the percentage of components with customised form or shape is highest in the *about average* profit category and considerably lower in the *higher than average* category and *below average* category:

30% of components in the *below average* category have customised form or shape

87% of components in the *about average* category have customised form or shape

41% of components in the *higher than average* category have customised form or shape

This indicates that profits do not increase with customisation.

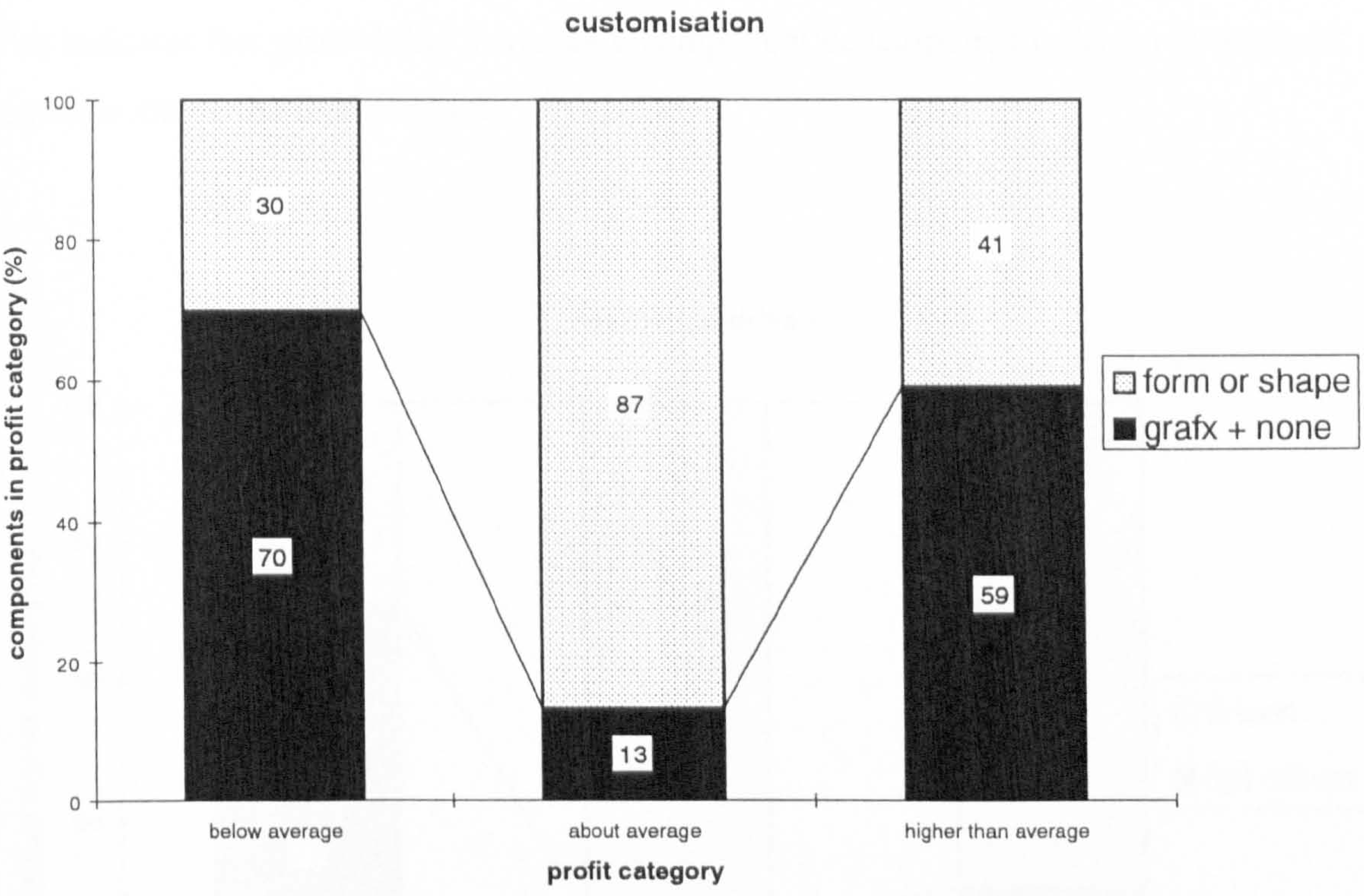


figure 5.18 bar chart showing component profit category and degree of customisation

aesthetics-driven

To support the H3, the diagrams should indicate that component profits increase if component development is driven by specific aesthetic requirements of the final product.

Figure 5.19 shows that the large majority of components that generated *below average* profits are components whose development was not driven by aesthetic requirements. A large majority of components that generated *about average* and *higher than average* profits were components whose development was driven by aesthetic requirements of the final product:

70-74% of components in the about and higher than average profit category are *aesthetics-driven* components

71% of components in the below average profit category are *not aesthetics-driven* components

This indicates that profitability increases if component development is driven by aesthetic requirements of the final product.

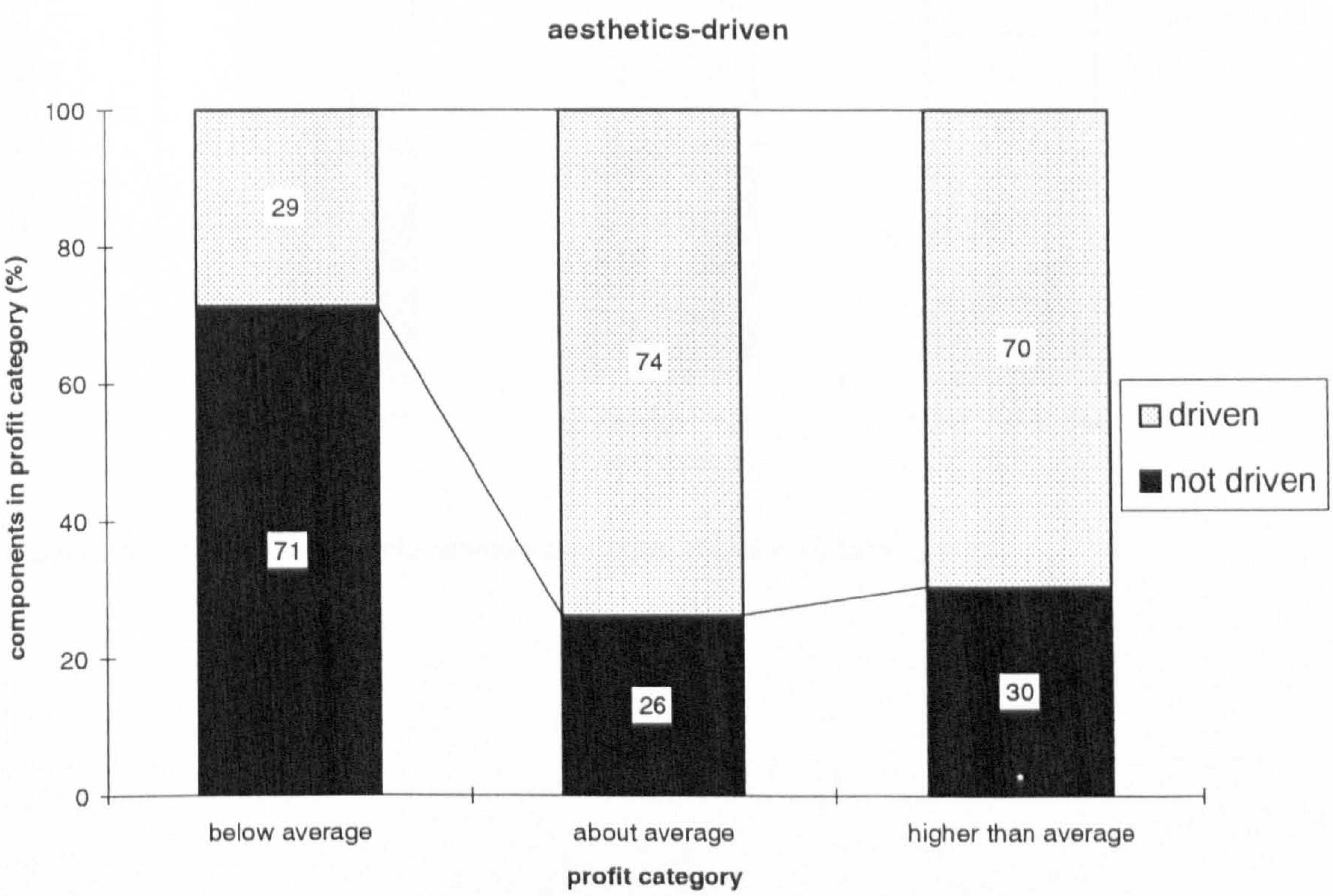


figure 5.19 bar chart showing profit category and aesthetics-driven component

share in visible surface

To support H3, the diagrams should indicate that profits increase if components have a higher share in the visible surface of the final product. Figure 5.20 shows that the percentage of components with a high share in the visible surface increases with profits:

29 % of components in the *below average* category have a high visible surface.

37 % of components in the *about average* category have a high visible surface.

48 % of components in the *higher than average* category have a high visible surface.

This indicates that component profits increase with share in visible surface of the final product.

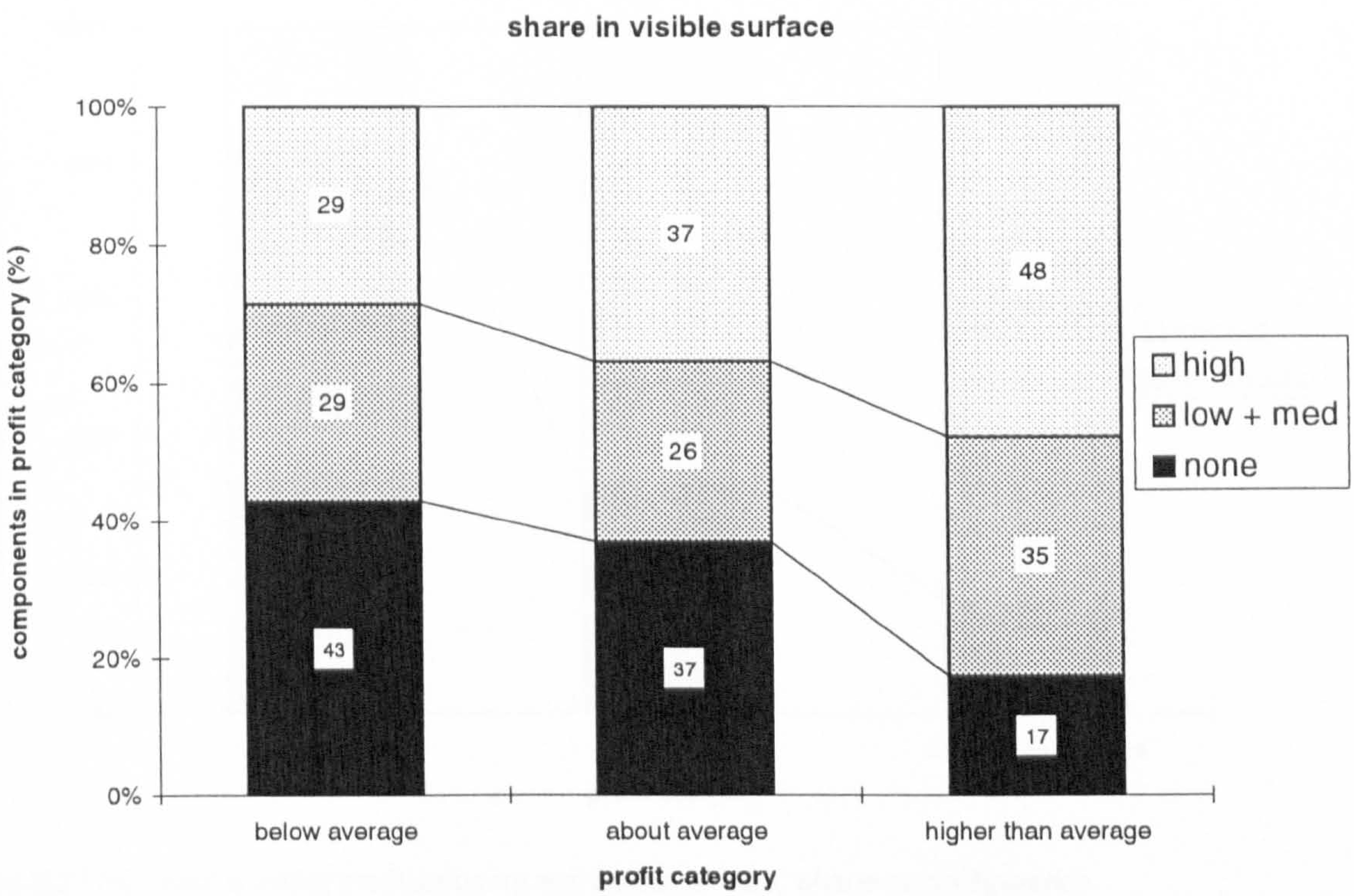


figure 5.20 bar chart showing profit category and share in visible surface

impact on size, shape or configuration

To support H3, the diagrams should indicate that profits increase if components have an impact on the size, shape or configuration of the final product. Figure 5.21 shows that the percentage of components which have an impact on size, shape or configuration of the final product increases with profits:

17 % of components in the *below average* category have an impact.

67 % of components in the *about average* category have an impact.

83 % of components in the *higher than average* category have an impact.

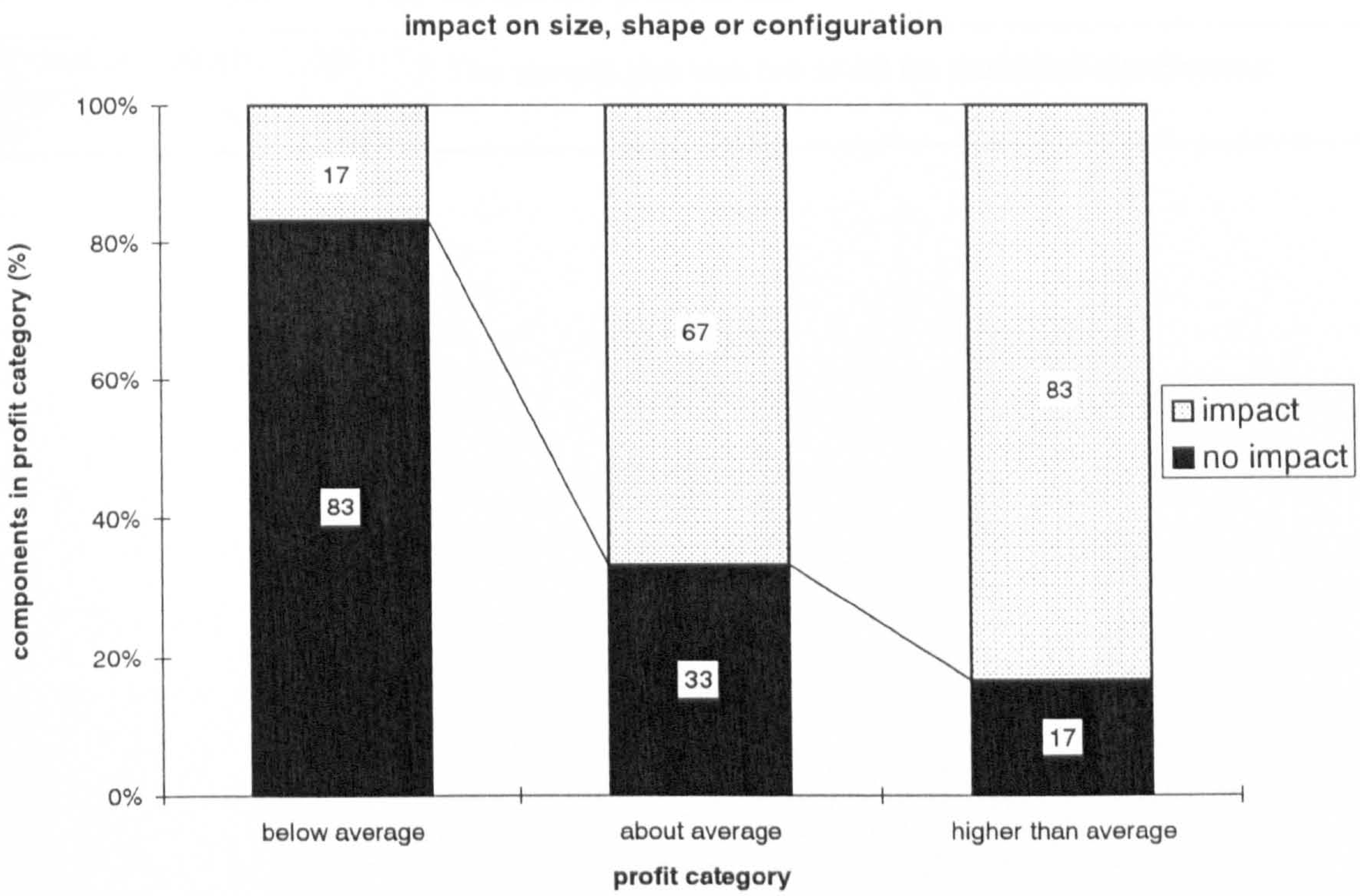


figure 5.21 bar chart showing profit category and impact on size, shape or configuration

5.6.4 Step 2: significance test

The second step was to test whether the observations were statistically significant on the basis of the sample. The significance tests are in Appendix VI. The summary of statements in table 5.14 support the H3: *visual significance - success.*

table 5.14 list of statements with statistical significance supporting H3

Data	Diagram		Finding
customisation	figure 5.18	App. VI.1	There is no relationship between level of component customisation and component profit levels.
aesthetics-driven	figure 5.19	App. VI.2	There is a relationship between aesthetic-driven development and component profit levels.
visible surface	figure 5.20	App. VI.3	There is a relationship between share in visible surface and component profit levels.
impact on shape	figure 5.21	App. VI.4	The sample size was too small for statistical significance.

5.6.5 Comments on profits

Table 5.15 lists designers' comments on higher than average and about average profits. The left column shows themes for components whose development was driven by aesthetic requirements of the final product, the right column shows themes for components whose development was not driven by aesthetic requirements of the final product. One interesting result is that the price situation seems to be quite relaxed for aesthetics-driven components.

table 5.15 list of designers' comments on profit performance, comparing aesthetics-driven and not aesthetics-driven components

Rank	profits higher than & about average, driven by aesthetic requirements	profits higher than & about average, not driven by aesthetic requirements
1	visual differentiation (15)	technical differentiation (6)
2	*good prices (11)*	*competitive prices (5)*
3	technical differentiation (7)	
4	difficult to make (4)	
	purchasing power (4)	

Table 5.16 lists themes of designers' comments on components that generated higher than average profits. The left column shows themes for components with no share in the visible surface. The centre column shows themes for components with a low or medium share in the visible surface of the final product. The right column shows themes for components with a high share in the visible surface of the final product. One interesting point is that components with no share in the visible surface generated higher profits because they supported the visual differentiation of the final product.

table 5.16 list of designers' comments on higher than average profits, comparing components with no, medium or low and high share in the visible surface of the final product

		profits higher than average	
Rank	no share in visible surface	medium or low share in visible surface	high share in visible surface
1	visual differentiation (4)	technical differentiation (5)	visual differentiation (7)
2	technical differentiation (1)	visual differentiation (4)	good prices (5)
3		good prices (3)	technical differentiation (4)

Table 5.17 lists themes of designers' comments on components with and without impact on the size, shape or configuration of the final product. The first column lists themes for components that had an impact on size, shape or configuration of the final product and

generated higher than average profits. The second column lists themes for components that had no impact on size, shape or configuration of the final product and generated below average profits. The table shows that invisible components can generate superior profits if they support the visual differentiation of the final product.

table 5.17 list of designers' comments on profit performance, components with and without impact on size, shape or configuration of final product

Rank	impact on size, shape or configuration	no impact on size, shape or configuration
	higher than average profits	**below average profits**
1	visual differentiation (5)	competitive prices (5)
2	technical differentiation (1)	easy to make (4)
3		purchasing power (2)
		no differentiation (2)

6 Conclusions

The following chapter draws conclusions and suggests opportunities for further research.

Section 6.1 gives answers to the research questions set up in chapter 1.

Section 6.2 interprets the findings of this study and explains the success behind HIBY-ELAFLEX existing product line.

Section 6.3 summarises recommendations for future projects.

Section 6.4 suggests opportunities for further study listing knowledge deficiencies identified during the literature review.

Section 6.5 suggests opportunities for further research based on the work and findings of this thesis.

6.1 Research questions

In chapter 1 the reader was introduced to trends in the component supply industry. Many industrial companies have reduced their technology depth and have given more development responsibility to component suppliers. The product development function has become an important competitive asset for many supply companies. In order to establish how supply companies control the development process and whether supplier control in component development affects business success, four research questions were derived.

- How is product development controlled in supply relationships ?
- What are the effects and drivers behind the different levels of control?
- What success strategies can suppliers follow?
- Are success strategies driven by control

The general questions were answered through research into past literature (see figure 6.1). The findings were summarised in a model of product development in the supply industry.

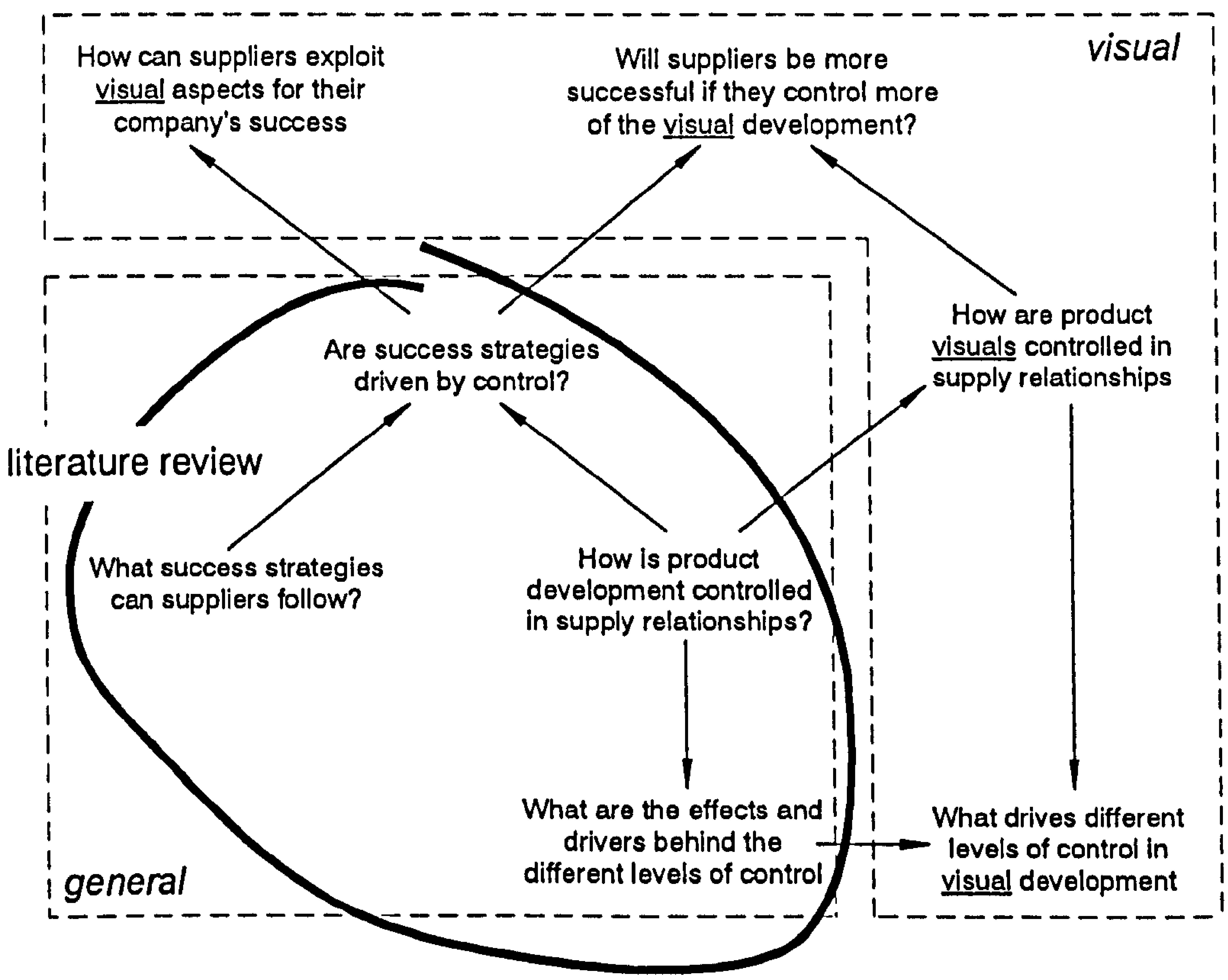


figure 6.1 model showing how general research questions were dealt with in the study

1. How is product development controlled in supply relationships?

Different forms of development organisation determine how product development is controlled in supply relationships. Literature on supply industry described three basic forms of development organisation:

integration: component development is controlled by lead manufacturers, suppliers have no control and are only responsible for production;

collaboration: lead manufacturers and suppliers jointly develop components;

autonomous: suppliers are in complete control of component development;

2. What are the effects and drivers behind the different levels of control?

Most researchers suggested that the different levels of control are driven by:

- component importance for the final product
- lead manufacturer knowledge of the component.

The different forms of organisation affect:

- supplier involvement in the development process
- the degree of component customisation

3. What success strategies can suppliers follow?

A number of success strategies for component suppliers were extracted from past literature. All strategies recommended that suppliers should control the development of their components. Control of the development process allows suppliers to:

- differentiate their components from competitors,
- tailor specifications towards their components thereby locking lead manufacturers into the supply relationship,
- develop components which are identifiable to the end-user or important for the quality or perceived quality of the final product.

4. Are success strategies driven by control

Supplier control in the development process is critical for all success strategies put forward. Suppliers should therefore work on the autonomous or the collaboration level. If supplier involvement in product development is low, they can only offer unique production quality or price advantages.

Figure 6.2 shows the model of product development in supply industry which had been set up in section 2.4.

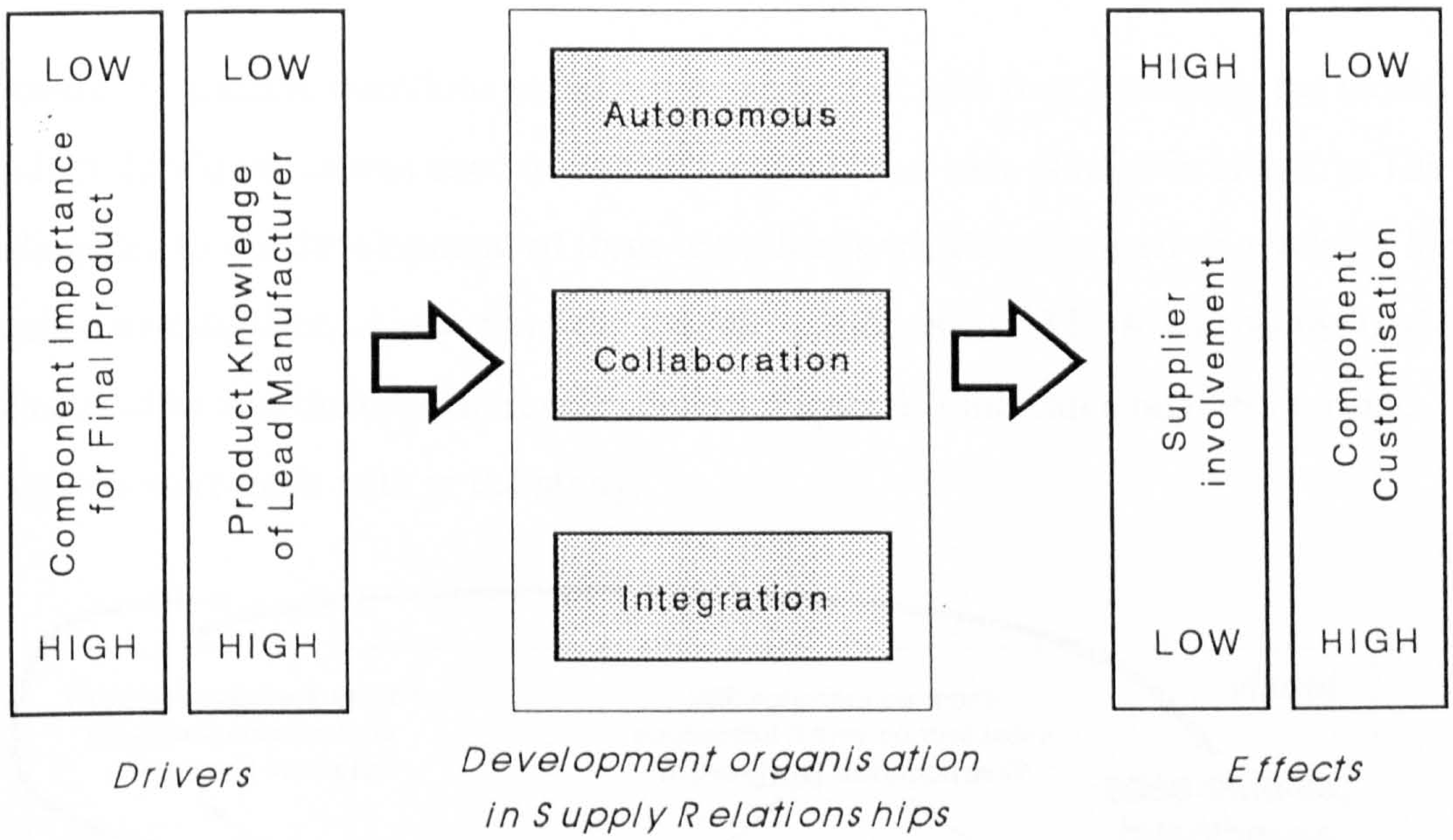


figure 6.2 model of product development set up in section 2.4 showing forms of development organisation, drivers and effects

Chapter 1 also established that visual and aesthetic properties are important for manufactured products. Companies can systematically control and plan their products' visual qualities. Another four research questions were put forward to establish the effect of product visual aspects on supplier development control and supplier success:

- How are product visual aspects controlled in supply relationships?
- What drives different levels of control in visual development?
- How can suppliers exploit visual aspects for their company success?
- Will suppliers be more successful if they control more of the visual development?

Because the specific questions could not be answered with past literature, the model of product development was used to conduct a number of case studies in industry. The findings led to the development of three hypotheses which were used as a vehicle for a detailed investigation. Answers to the specific questions could be found on the basis of the collected data and the hypotheses discussion. Figure 1.3 indicates how the specific questions were dealt with in the study.

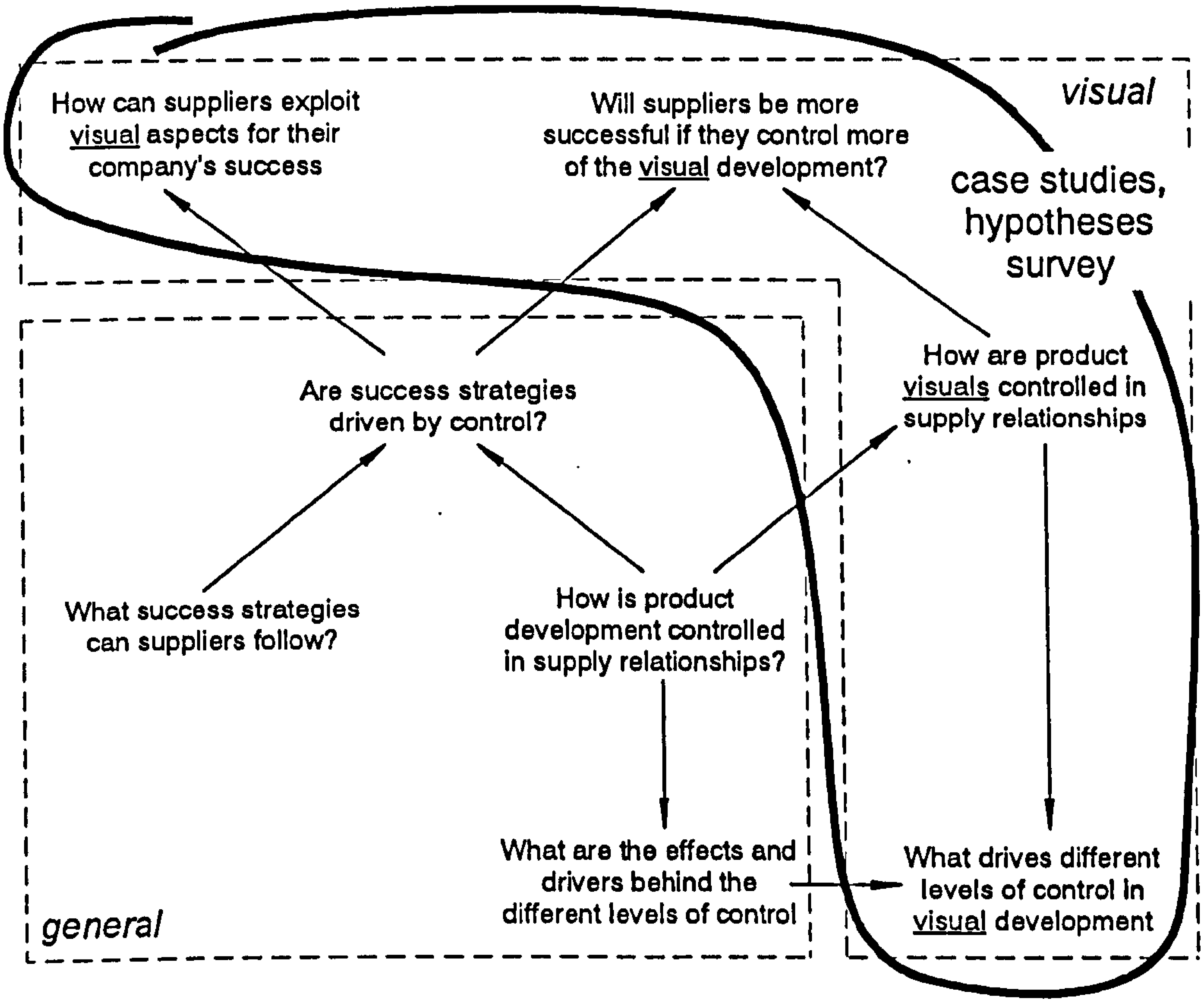


figure 6.3 model indicating how specific research questions were dealt with in the study

1. How are product visual aspects controlled in supply relationships?

Figure 6.4 represents supplier functions at process stages for all 58 component development projects in the survey.

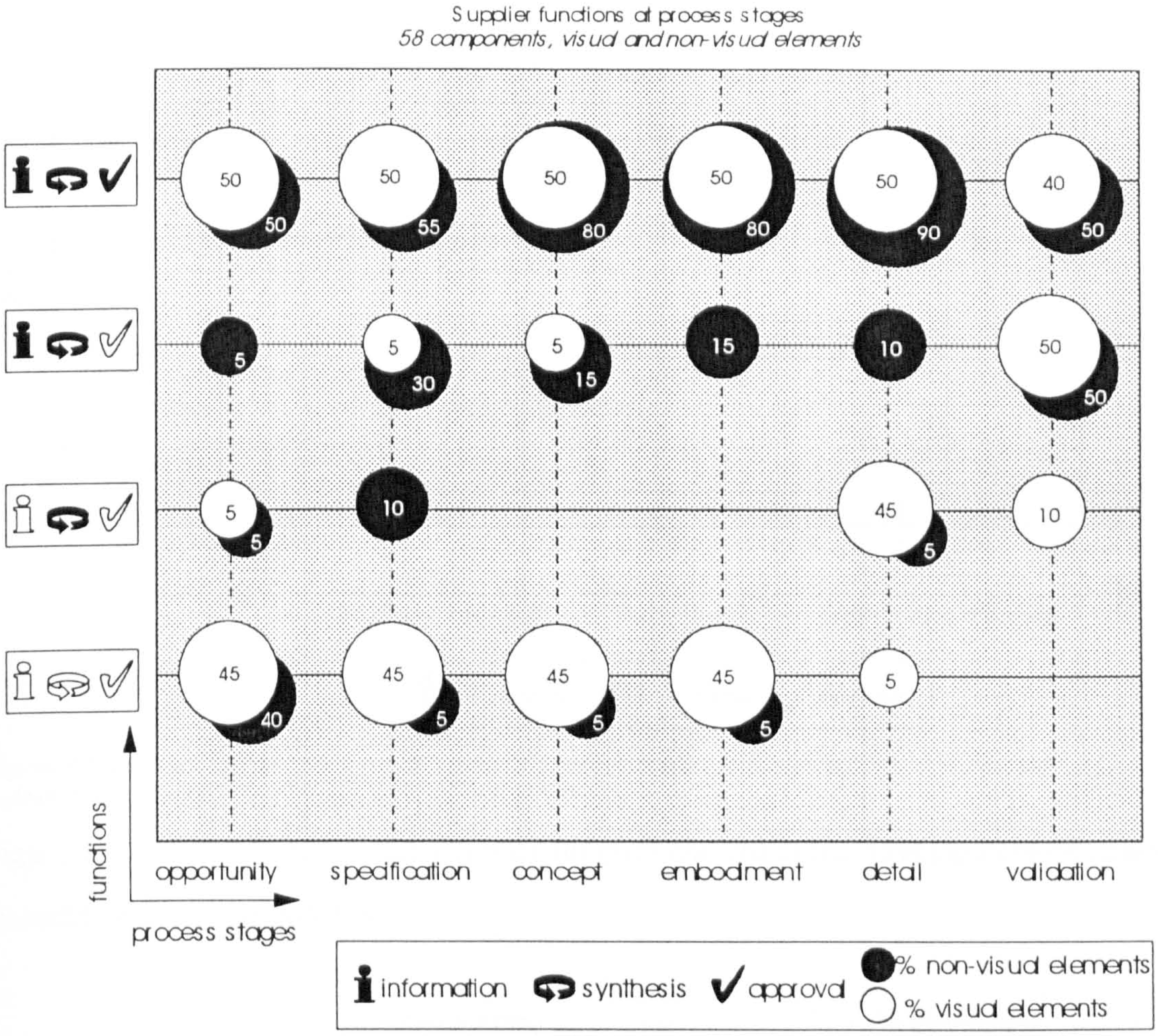


figure 6.4 supplier function/ process chart: all 58 components in the survey

This plot of supplier functions at six process stages reveals two major types of supplier control in the development of visible elements within components and two major types of supplier control in the development of non-visible elements within components. Figure 6.5 shows the two most common forms of supplier control in the development of visible elements.

1. In Visible $_{\text{hi cntrl}}$ suppliers are responsible for information, synthesis and approval at every stage. This form is mainly found if the visual significance of the component in the final product is low.

2. In Visible $_{lo\ cntrl}$ suppliers are outside the development project from opportunity to embodiment stage. They are responsible for synthesis at the detail stage and for information and synthesis at the validation stage. This type is very common if the visual significance of the component for the final product is high.

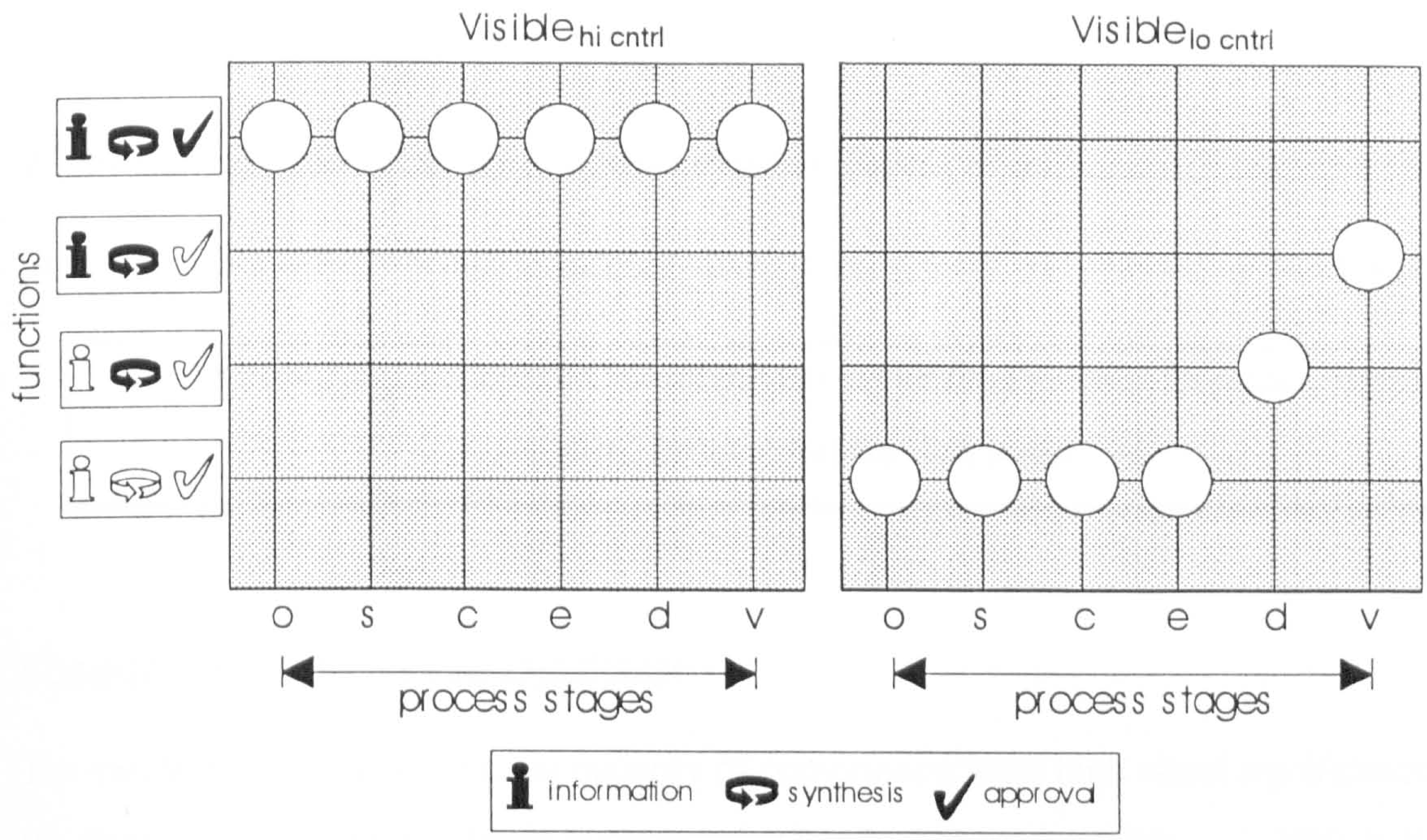


figure 6.5 diagram showing two major types of supplier control in development of visible elements within components

Figure 6.6 shows the two major types of supplier control in the development of non-visible elements within components.

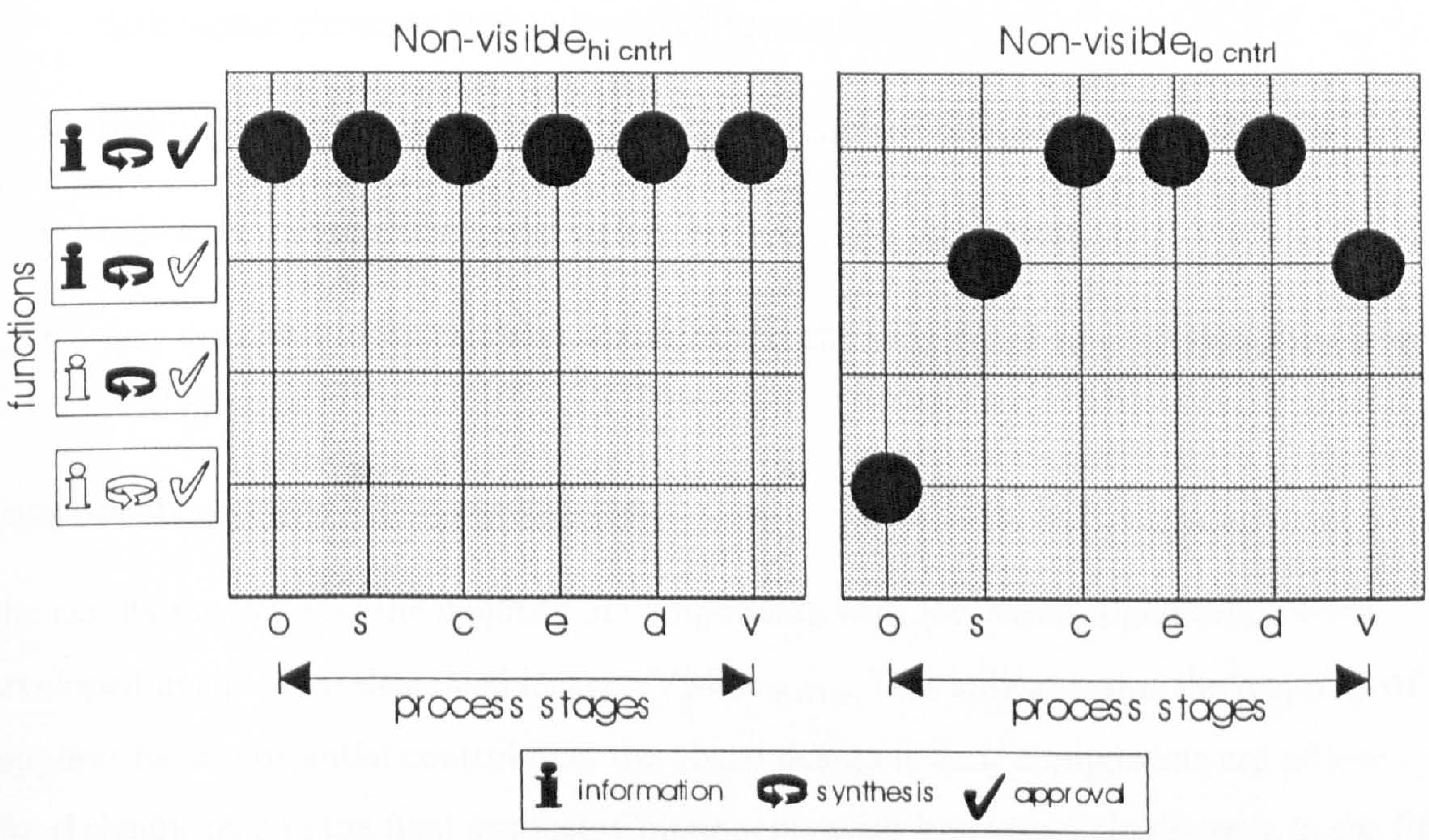


figure 6.6 diagram showing two major types of supplier control in development of non-visible elements within components

Non-visible $_{hi\ cntrl}$ is identical to Visible $_{hi\ cntrl}$. There is, however, a strong difference between Non-visible $_{lo\ cntrl}$ and Visible $_{lo\ cntrl}$: When developing *non-visible* elements, lead manufacturers withdraw from the development process after the specification stage and will not interfere in the design process until validation. When developing *visible* elements, lead manufacturers take the design up to the embodiment stage before involving suppliers.

2. What drives different levels of control in visual development?

To examine the drivers behind control in visual development, H1 was set up and tested:

If the visual significance of the component in the final product increases, supplier control in development decreases.

Components with high visual significance

The results showed that the great majority of components with high visual significance in the final product were developed in a process described by type Visible $_{lo\ cntrl}$. This indicates that the majority of suppliers have only limited control over the visual design if their components are of high visual significance in the final product. Components with a high visual significance were identified using at least one of the following criteria:

- their visible elements have customised form or shape
- their development was driven by aesthetic requirements of the final product
- they have a high share in the visible surface of the final product
- they are non-visible, but have an impact on the size, shape or configuration of the final product.

Components with low visual significance

The results showed that the majority of components with low visual significance were developed in a process described by type Visible $_{hi\ cntrl}$. This indicates that the majority of suppliers have substantial control over the visual design if their components are of low visual significance in the final product. Components with low visual significance in the final product were identified using the following criteria:

- their visible elements are not customised or have only customised graphics
- their development is not driven by aesthetic requirements of the final product
- they have a low or medium share in the visible surface of the final product
- they are non-visible and have no impact on the size, shape or configuration of the final product.

The analysis showed that there is a relationship between the level of visual significance and the level of supplier control. It was not shown that visual significance causes a certain level of supplier control. This assumption stems from past literature which claims that component importance for the final product drives product development organisation in supply relationships.

3. How can suppliers exploit visual aspects for their company success?

To identify how suppliers can exploit visual aspects for their success, H3 was set up:

If the visual significance of the component in the final product increases, component success for the supply company increases.

The graphic analysis of the survey data indicated that components generated higher profits if:

1. their development was driven by aesthetic requirements of the final product.
2. they had a higher share in the visible surface of the final product
3. they were non-visible, but had an impact on the size, shape or configuration of the final product.

There was significant evidence for a relationship between component success and aesthetic-driven development (1.) as well as share in the visible surface (2.). It was possible to identify a trend suggesting a relationship between impact on size, shape or configuration and component success, but the sample size was too small to establish statistical significance. Interestingly, no relationship was found between customisation and component profits. The review of designers' comments on component profitability showed:

1. Components whose development was driven by aesthetic requirements of the final product seemed to achieve better prices than components whose development was not driven by aesthetic requirements of the final product.

2. A number of non-visible components generated higher profits because their shape, size or configuration enabled lead manufacturers to create visually differentiated products.

To exploit product visuals for company success, suppliers need to control the visual development of their components. Components should also be of high visual significance in the final product. However, if components are too significant, lead manufacturers will integrate visual development and deny supplier input.

Suppliers who are not in control of component visuals should develop versatile component platforms which lead manufacturers can use and adapt to their visual requirements.

Suppliers who develop non-visible components should create special sizes, shapes or configurations which allow lead manufacturers to differentiate the visual aspects of their final products.

4. Will suppliers be more successful if they control more of the visual development?

To identify whether suppliers will be more successful if they control more of visual development, H2 was set up:

If supplier control in the development of component visuals increases, component success for the supply company increases.

The results of the survey did not indicate a relationship between component success and supplier control in the development of component visuals. Designers' comments on profit performance revealed that development control is not enough to generate higher profits. Instead, lack of technical or visual differentiation, buying power of lead manufacturers and competitive pricing put pressure on supplier margins. Supplier control in development is not a guarantee for higher margins, it is merely an opportunity of creating differentiated components.

6.2 What has made HIBY-ELAFLEX components successful?

HIBY-ELAFLEX have complete control over the development of visual and technical aspects of their component. The nozzle component is visually significant, but its share of visible surface in the final product is not too high. Lead manufacturers have quite willingly refrained from developing their own component. A small and inexpensive concession to visual customisation was made by giving lead manufacturers the option to order nozzle covers in the colours of their choice. Additionally, a 30 mm diameter circular surface on the top of the nozzle is reserved for a plastic tag which may carry the name, symbol of the oil company, the fuel product or any other form of advertising. Overall product form, shape and configuration remain the same for every ZVA nozzle. Each nozzle carries the ZVA-brand name at the sides.

HIBY-ELAFLEX have used their control to develop a differentiated component with a strong brand identity. Component design was driven by ergonomic and aesthetic considerations.

6.3 Recommendations for future projects

The list below summarises recommendations for future component development projects. The first part lists criteria which should be considered when identifying new component opportunities. The second part lists key recommendations for managing component development development projects.

Choose components...

- with a high-medium share in the visible surface of the final product.
- in products with special visual/ aesthetic requirements.
- which have an impact on the size, shape or configuration of the final product.
- and create an identifiable, visually distinguishable brand.
- and design technical platforms which lead manufacturers can adapt to their own visual requirements.
- and design technical platforms which suppliers can adapt to the visual requirments of individual lead manufacturers

Manage the development...

- by keeping control of the development process, particularly the early stages.
- by getting feedback from lead manufacturers before making major design decisions.
- by knowing the needs of lead maufacturers better than they do.

6.4 Knowledge deficiencies identified

The literature review in chapter 1 showed that research is still insufficient in many interesting areas. Table 6.1 lists some of the knowledge deficiencies identified.

Table 6.1 knowledge deficiencies identified in the literature review

Issue	Observation
capital products and visuals	The importance of visuals and aesthetics for consumer products has been described by many researchers. Very little information was found on how visuals appearance, style and aesthetics are used in the design of capital products.
Corporate identity and product visuals	According to Ollins' model of corporate identity (see section 1.3.2) product is an important element in a company's identity mix. It was acknowledged that for some companies, product can be the most significant element of their identity. The literature review has shown that the majority of work on corporate identify deals with company communications. There is very little information on how companies plan, develop and control their identity through product design.
Systematic methods for product visuals	Researchers from the discipline of Engineering Design have published a large amount of work on systematic methods, tools and techniques for designing technical functions. For an overview of engineering design see Pahl and Beitz, 1988 [[88]]. Research on systematic methods, tools and techniques for the development of product visuals is relatively under-represented considering how critical product visuals are for many businesses.
Market success and product visuals	Many companies claim that the visual properties of their products are critical in the success of their products. There is, however no scientific study analysing the relationship between product visuals and market success.
Design research from business perspective	Although product design and development is a key activity in many businesses, very little design research is done from a business perspective.

6.5 Further study

The work of the thesis can be used as a basis for further research. Table 6.2 lists some of the aspects dealt with in the thesis and suggests points of interest for further study.

Table 6.2 what has been done, what could be done

What has been done	What could be done
The study established a relationship between component visual significance and supplier control in the development. The study did not prove that higher component visual significance causes lower supplier control.	One could examine whether lead manufacturers assess component visual significance first and then decide at what level they want to involve suppliers in the development process.
The study examined development control and component success in supply companies from different industrial sectors.	One could examine whether the sector has any effect on supply company's development control and the project success.
The study analysed aspects of supply company success.	One could analyse aspects of lead manufacturer success.
The study demonstrated a method for measuring visual significance of components.	One could examine how this method can be developed into a tool.
The study developed a research method for establishing: • supplier involvement in the development • visual significance of components • component success	One could examine how this research method can be developed into a company audit. The company audit could then point out opportunities of optimising supply company business strategies and component development strategies. The research method could be used for conducting a number of qualitative case studies on companies who are pursuing particular component supply strategies. The qualitative case studies would include "why" and "how" questions.
The study established that development control and component visual significance are very important for supplier success.	Based on qualitative case studies, one could examine how the strategies were implemented.

Appendix

Appendix I Case studies

Appendix I.1 Esso Retail

table Appendix I.1 Esso Retail: control Esso

○ visible ● non-visible	What	Why	How
	Exxon developed global petrol station design which included	The company wanted to create a cost effective, but attractive retail site on which it could efficiently market its automotive fuels and lubrication products.	Exxon Company International investigated global technology trends in petrol station design by interviewing in-house prime experts from its national offices. This knowledge was then compiled. Together with US-design consultancy Bass-Jaeger a detailed value analysis was conducted. The result of this exercise was a highly value engineered Exxon/ Esso station for a global fuel market. The design is specified a document called *Site Layout Facility Standard.*
○	**architecture** of station roof, pump, car wash system, shop building		
○	**graphic design** of surfaces		
●	**technical interfaces** between components		
○	**arrangement** of components		

table Appendix I.2 Esso Retail: control suppliers

○ visible ● non-visible	What	Why	How
●	Design, development of **technical functions** inside dispenser pumps, hydraulic equipment, cash registers, car wash systems etc.		Suppliers are fully responsible for developing, testing and manufacturing their components. Exxon does not become involved in any technical design. Exxon has no development facilities workshops or laboratories for retail engineering. Formal design verification or validation is carried out by independent bodies. Suppliers must cover the cost for design certification of their components.
●	The design, arrangement and choice of all **non-visible elements** inside technical components like dispenser pumps, hydraulic equipment, cash registers, car wash systems etc. is left to suppliers. Supply companies are free to sell these designs to other oil companies.		Suppliers must be able to reduce their prices . Until 1997, Exxon bought its forecourt pumps from Schlumberger and Gilbarco. Contracts with Gilbarco were renewed, but Schlumberger lost its supply status to Wayne Dresser who was able to undercut Schlumberger's prices. When assessing price offers, Exxon procurement engineers add the component's estimated cost of ownership to the component's original purchasing price. The cost of ownership which includes cost of maintenance, repair, replacement etc. is calculated for a period of ten years. Suppliers should therefore aim to find a design which optimises combined costs. combined cost = purchasing cost + cost of ownership
	Suppliers design and develop technical functions inside dispenser pumps, hydraulic equipment, cash registers, car wash systems etc. They offer these to Exxon procurement as soon as these components are certified by independent bodies and ready for production.	Exxon does not want to get involved or take responsibility for these functions. The award of business should be an incentive for suppliers to innovate.	Exxon never introduces innovative components first in the market. If experience at other oil companies is positive, Exxon will enter the market (me-too) and use its global purchasing power to get a competitive price advantage. Exxon sources components on an optimum cost basis. Procurement engineers at RES select suppliers and prepare world-wide supply contracts. A component catalogue is compiled from which national offices can order their equipment for building projects.

○ visible ● non-visible	What	Why	How
			Components with an annual purchasing value above 100.000 Euro are always sourced from two suppliers. The dual-sourcing principle should ensure supplier discipline and keep prices low. A third supplier may be allowed to enter the tender if the price offer is particularly attractive.
	Exxon develops the embodiment design for architecture of station roof, pump, car wash system, shop building graphic design of surfaces technical interfaces between components arrangement of components Suppliers are given the embodiment designs and have to turn them designs into manufacturable products	Exxon designers have no technical knowledge or facilities necessary to mass-produce these components.	Exxon specifies the embodiment of a dispenser pump using a full-scale block model. Dispenser manufacturers develop the design into mass-produced items using sheet metal or sheet plastics processes.
●	Architecture of shop building, roof, car wash system, graphic design, arrangement of components, **shape of technical components**	Exxon wishes to create its global corporate identity and differentiate its retail sites from the competition. Exxon customers are supposed to find the same layout, arrangement of functions and visual clues anywhere around the world.	In order to implement the *Site Layout Facility Standard* around the world, Exxon Company International set up its Retail Engineering Services (RES) centre in 1996. The central office is located in Brussels and regional offices in Miami and Singapore support operations in Asia and South America. National offices are forced to apply for funding before building or refurbishing a petrol station. They submit project proposals to RES which contain component lists, assembly drawings and cost forecasts. Engineers at RES checks these application documents for consistency with the *Site Layout Facility Standard.* If the project proposal is not in keeping with Site Layout Facility Standard,

○ visible ● non-visible	What	Why	How
			project funding is rejected.
			Dispenser pumps, for example may be sourced from two different suppliers (Wayne Dresser or Gilbarco). From the outside they will both look identical because both suppliers manufacture the body to Exxon's visual standard.
	The *Site Layout Facility Standard* also specifies technical performance requirements and technical interfaces of all components. These requirements are industry standards and not specific to Exxon.	Standard interfaces should ensure complete compatibility and interchangeability between components of different manufacturers. By making components interchangeable, Exxon wants to push prices down and become independent of individual suppliers. Pump dispenser manufacturers like Wayne Dresser Industries or Tokheim Corp. had developed specific cash register systems and software for the data exchange between pump meters and cash registers. By introducing different interfacing standards, the suppliers tried to protect their markets.	In a joint effort, a number of multinational oil companies introduced a world standard for electronic interface design. This standard has become part of the *Site Layout Facility* document.

table Appendix I.3 Esso Retail: customisation for Esso

❍ visible ●non-visible	What	Why	How
●	The *Site Layout Facility Standard* also specifies technical performance requirements and technical interfaces of all components. These requirements are industry standards and not specific to Exxon.	Standard interfaces should ensure complete compatibility and interchangeability between components of different manufacturers. By making components interchangeable, Exxon wants to push prices down and become independent of individual suppliers. Pump dispenser manufacturers like Wayne Dresser Industries or Tokheim Corp. had developed specific cash register systems and software for the data exchange between pump meters and cash registers. By introducing different interfacing standards, the suppliers tried to protect their markets.	In a joint effort, a number of multinational oil companies introduced a world standard for electronic interface design. This standard has become part of the *Site Layout Facility* document.

○ visible ● non-visible	What	Why	How
●	Exxon develops automotive **fuel and lubrication products**		Exxon has its own fuels and lubricants research division in New Jersey, USA
	Exxon knows about changes in customer requirements.		Exxon regularly conducts market surveys.
	Exxon knows about the performance characteristics, interfaces and prices of technical components for fuel retail which are available on the international supply market.		RES procurement engineers collect detailed data on technical performance, interfaces and prices of components available on the international supply market. They have no interest in detailed component technology. The field performance of new and innovative components is closely observed for one or two years at other oil companies.
	Petrol station architecture of station roofs, pumps, car wash systems, shop	Petrol station architecture, graphic design, arrangement, technical interfaces specified in the *Site Layout Facility Standard* is important for two reasons:	
	graphic design of surfaces technical interfaces between components	First it defines Exxon's global corporate identity. Market research has proved that consumer brand loyalty, recognition and trust is particularly strong in fuel retailing.	
	arrangement of components	Second, the *Site Layout Facility Standard* is part of Exxon's price leadership strategy. The Standard gives guidelines for the cost-effective construction of petrol stations. The company assumes that many older stations had been over-	

○ visible ● non-visible	What	Why	How
		engineered by local technical staff. By implementing a global standard, Exxon hopes to reduce the cost of its retail units and thereby increase its return on investment.	
	The function, design and manufacture of technical components is not important to Exxon.	Technical components are non-strategic products which Exxon does not consider critical for its competitiveness in the fuels and lubricants business.	

table Appendix I.4 Esso Retail: importance for Esso

○ visible ● non-visible	What	Why	How
	The function, design and manufacture of technical components is not important to Exxon.	Technical components are non-strategic products which Exxon does not consider critical for its competitiveness in the fuels and lubricants business.	

Appendix I.2 BP OIL Retail

table Appendix I.5 BP Oil Retail: control BP

○ visible ● non-visible	What	Why	How
	Development of global petrol station design. Including	BP wanted to create a high-tech company image and differentiate itself against main competitors such as Exxon or Shell.	BP developed its station together with the UK styling agency. Basic rules and visual specification is defined in its station manual.
○	**colours, surface texture, materials**		All visible elements of pumps, buildings and shop furniture are specified in engineering drawings.
○	**architecture**		
○	**component arrangement**		
○	**shape of components**		
	planning of new retail sites		The building of a new station starts with a project brief from BP's site development. Engineers visit the construction site and write down a rough estimation of the volume of petrol and diesel fuel that the station is expected to sell. A typical inner-city station with 10 pumps distributes about 6000m3 of petrol fuel and 1400m3 of diesel fuel per year. The volume determines the number of pump islands. Site development then chooses between a small, medium or large convenience shop. Because the oil company expects to increase turnover from its station shop business during the coming years, site development almost always selects the large shop size. The third item is the number of car wash systems.This project brief is handed over to the construction office.

table Appendix I.6 BP Oil Retail: control suppliers

○ visible ● non-visible	What	Why	How
●	Development of **technical**		

○visible ● non-visible	What functions	Why	How

table Appendix I.7 BP Oil Retail: customisation for BP

○ visible ● non-visible	What	Why	How
○	All **visible elements** of pumps, buildings and shop furniture The arrangement of components and buildings are specific to BP.	The consumer should be able to quickly comprehend the three services on offer: fuel, wash and shop.	The basic rules for component arrangement laid out in BP's service station design manual. Petrol pump islands are placed in parallel to the incoming customer and thereby guiding his view towards the large shop window. Car wash systems are positioned at the right giving a visual boundary. Architects position scale models of the shop module, pump islands and car wash systems on the cadastral plan of the site. Petrol pump islands are placed in parallel to the incoming customer and thereby guiding his view towards the large shop window. Car wash systems are positioned at the right giving a visual boundary. To specify colours, surface texture and materials, the oil company gives sheets of green and yellow plastic and silver aluminium to their suppliers
●	Technical performance of components and **technical interfaces** between components are industry standards. National offices are able to extend these requirements.	BP wants to buy industry standards to become independent of individual suppliers. BP acknowledges that requirements may vary across different regions. The requirements of station roofs in Finland may be different to the requirements of station roofs in southern Spain. Environmental standards that are sufficient in Portugal may be unacceptable in the Netherlands. Unlike Exxon, BP is not pursuing a strict policy of total compatibility and interchangeability between technical components.	BP's central office in Brussels defines minimum technical requirements. National offices do not have to submit technical details on construction projects. Central office checks the spending plan and releases the budget if the plan seems appropriate.

table Appendix I.8 BP Oil Retail: knowledge BP

○ visible ● non-visible	What	Why	How
●	The company collects performance and price data on components available on the international supply market		Through market research, observation of customers or competition, BP's marketing department establishes the need for a new function. Marketing division approaches technical staff and explains the identified need. Technical staff has to searches for a product on the international supply market which is able to provide the required function.

table Appendix I.9 BP Oil Retail: importance for BP

○ visible ● non-visible	What	Why	How
	Visual aspects must be identical at every BP station throughout the world.		The station roof, for example, has a green frame with bullnose edges and yellow writing greeting the customer in the country's official language. (Welcome, Willkommen, bienvenue, bienvenidos...)
	Component arrangement should comply with the BP's specification, although the company accepts variation due to site constraints.		
	Ownership and operation of the site network is not important to BP.	Ownership and operation of a site network is not critical for marketing of automotive fuels and lubrication products.	BP has decided to transfer management and operation of retail to the British construction company BOVIS. Since 1st of January 1997, BOVIS staff is working in BP's European offices. The contract between BP and BOVIS terminates in 2003 and the oil company will hold another competition for a service provider contract. BP is also considering to give ownership of their site network to independent construction companies. The construction companies will then be fully responsible for building, refurbishing and maintaining BP-type service stations. The oil company would sign leasing contracts with the construction company, allowing them to sell BP fuels and lubricants on

○ visible ● non-visible	What	Why	How
			the site.
●	Cost of ownership is not critical.	This is partly due to the fact that equipment may have to be replaced very quickly because of changes in consumer needs.	BP's technical departments have in the past examined the cost of ownership for a component over a period of 10 years. Corporate management has recently decided that component cost of ownership should

Appendix I.3 ERCO

table Appendix I.10 ERCO: control ERCO

○ visible ● non-visible	What	Why	How
	Development of visible components	product housing / cases, connectors and power tracks are visible to end-user and determine the company's product image	ERCO is in close discussion with manufacturers of luminaire like Philips and OSRAM. These companies suggest new developments in luminaire technology before new products are introduced to the market. ERCO also observes competition and the emergence of new interior design trends.
○	**product housing/ cases** made from injection moulded plastics or aluminium die castings.		Marketing establishes an opportunity for a new product. In-house stylist work with external consultancies to develop a new shape. The shape is then converted into a manufactured product. First a visual prototype is built. The visual prototype is then filled with technical functions. Each project is accompanied by two in-house designers who control the visual details of every product. They ensure that product proportions, radii, colour scheme, graphics etc. conform to ERCO's corporate identity.
○	**connectors** made from plastics & sheet metal components		
○	**power tracks** made from aluminium extrusions		Development department has full control over all manufacturing drawings. .
●	Development of **reflectors** light reflectors made from sheet metal	The quality and characteristics of emitted light depends on reflector geometry.	Calculation of reflector geometry with the help of formulae and computer simulation methods developed by ERCO. Extensive lab tests to optimise light radiation, heat dissipation and noise levels.

○ visible ● non-visible	What	Why	How

table Appendix I.11 ERCO: control suppliers

○ visible ● non-visible	**What**	**Why**	**How**
	Suppliers are responsible for developing electrical or electronic components like	ERCO has limited technological resources and expertise to compete in the development of such highly advanced components like electronic ballasts, bus systems and luminaires.	
●	**luminaires**		
●	**bus systems**		
●	**ballasts**		
●	**sockets**		
	which are not directly visible to the user.		
	If product shape requires special sizes of electronic components, ERCO pays for the development of a customised component. These are about 50 % more expensive than catalogue items.		
	The shape of visible components and reflectors is developed by ERCO. Suppliers get involved at the production stage.	Products are designed for ERCO's visual identity	
	Suppliers develop electrical or electronic components which are not directly visible to the user independent of ERCO.		These components are developed by suppliers, certified by independent test houses and then sold to ERCO through catalogues and electronic wholesalers.
	Special sizes of electronic components. Suppliers are involved early during the design process.	If product aesthetics require special size electronic components that can not be bought on the regular market, ERCO looks for supplier that is able to develop a customised version.	ERCO produces a block model of the case in which the component has to fit. Together with the component supplier, product requirements are defined. The component is developed by the supplier and certified by an independent test house.

table Appendix I.12 ERCO: customisation for ERCO

❍ visible ● non-visible	What	Why	How
	All visible components are fully customised.	All visible components have to reflect ERCO's identity.	Two in-house designers control the development of every visible component The ensure that radii, colour scheme, letters etc. are in keeping with ERCO's corporate identity.
	Non-visible, electrical and electronic components like luminaires, bus systems, ballasts, sockets are either unspecific or specific.	Electrical components are customised if the shape or configuration of the product requires special sizes which are not available from the catalogue.	If special sized electrical components are needed, ERCO gives technical requirements and size constraints to suppliers and pays them to develop a customised version. If no special sized electrical components are needed, ERCO buys the cheapest available on the market. The company has no direct control over the component's design or manufactured quality.

table Appendix I.13 ERCO: knowledge of ERCO

❍ visible ● non-visible	What	Why	How
	ERCO knows how to calculate optimise reflector geometry. The company has vast experience in designing aluminium and plastic cases for impact strength and heat resistance.		

table Appendix I.14 ERCO: importance for ERCO

❍ visible ● non-visible	What	Why	How

Appendix I.4 Philips-Alessi jugless kettle

table Appendix I.15 Philips-Alessi kettles: control Philips-Alessi

○ visible ● non-visible	What	Why	How
○	The Italian firm Alessi designed the **kettle shape**.		Alessi produced sketches and block models of the new kettle.
	Philips Hastings was in charge of turning the shape into a product.	Philips consumer electronics is competing in a market dominated by Japanese and Korean multinationals. Profit margins for electronic consumer products are very thin and new products are becoming commodities very quickly. Instead of developing innovative products which has driven up costs and generated disappointing income over the past decade, Philips now hopes to increase the profitability of its domestic appliance division by investing more money into product branding and using established technologies.	Model makers at Philips built a kettle prototype out of plastic sheet to simulate injection moulding parts. Manufacturing engineers at Philips soon discovered that the kettle body had a convex form which was not feasible for injection moulding tools. Philips researched other plastic moulding processes. Blow moulding produced an insufficient surface quality and the lost core process was too costly.

table Appendix I.16 Philips-Alessi kettle: control suppliers

❍ visible ● non-visible	What	Why	How
	Development of tools for kettle shell,	Riedel had patented a collapsible core which is capable of moulding hollow bodies with a diametric ratio of 1:1.3 The collapsible core allowed Philips to produce the convex shell using injection moulding process. Philips asked Riedel to develop the tool and produce the kettle shell.	<u>Tool development</u> Philips defines the surfaces and volumes of kettle shell, back cover, lid and base on a 3D-CAD system. With this data, the mass of each plastic component can be calculated. Riedle used the respective masses to calculate ex-factory prices for each component in batches of 5000 units. Riedle and Philips signed a contract which stated that tool and collapsible core belonged to Philips, but that the collapsible core could not be moved away from Riedle's production premises. A project plan for the development of the tool is agreed upon. Philips issues an official order for the shell tool including collapsible core at 239,000 DM and paid 10% of the total cost (21,000 DM) in advance for Riedle to start designing the tool. The spout of the kettle is a highly polished chromium-steel stamping. Philips manufacturing was particularly concerned about whether the spout could be moulded directly into the plastic and asked Riedle to carry out experiments. Riedle confirmed positive test results without having done any experimentation. The electrodes for spark erosion are finished and Riedle invites Philips designers to approve them before the mould is eroded. Philips approves the electrodes. .
❍	Development of tools for **kettle base**, **lid** and **back plate**	The tools for the kettle base, lid and back plate were fairly simple. Philips Hastings intended to mould those parts in England. Riedle threatened that they would not supply the collapsible core tool for the kettle shell	

❍ visible ● non-visible	What	Why	How
		unless they would also get the tender for the kettle base, lid and back plate. Philips agreed to give Riedle all plastic parts of the kettle.	
	Injection moulding of kettle shell, base, lid and back plate		Riedle starts the first production run. Due to the 50% filler content, scrap levels are very high. Philips accepts the scrap levels and increases the price per item to cover for the waste in production
	Riedle was involved after the kettle embodiment was finished. Philips' design office in Hastings and Riedel Germany collaborated in the development of manufacturing drawings for the kettle shell.	Alessi refused to modify the kettle shape. Philips was unable to find an appropriate production process. The project came to a standstill until a plastics engineer visited Riedle's Stand on an industry trade fair.	<u>Enquiry</u> PH sends a sketch of the body and enquiring for a quote on a collapsible core tool for 1 million shots. The material is mineral filled Polypropylene at 4DM per kilo. R quotes a price between 210,000 and 230,000 DM for the kettle body tool including a collapsible core. The tool for the kettle base would cost between 40,000 and 45,000 DM. <u>Factory inspection</u> Philips designers and procurement staff visited Riedle in Germany. They inspect the factory premises and examine samples of other components which had been manufactured using the same process. Project managers can be convinced of the collapsible core technology and sign a supply contract with Riedle.

table Appendix I.17 Philips-Alessi kettle: customisation for Philips-Alessi

○ visible ● non-visible	What	Why	How
	The kettle shape was specific to Alessi- Philips.	The kettle shape determined the product's unique identity	

table Appendix I.18 Philips-Alessi kettle: knowledge of Philips-Alessi

○ visible ● non-visible	What	Why	How

table Appendix I.19 Philips-Alessi kettle: importance for Philips-Alessi

○ visible ● non-visible	What	Why	How
	The convex body shape was considered highly important.	Designers at Philips asked their Italian partners to redesign the body shape for conventional injection moulding processes. Alessi refused to compromise stating that the convex shape was essential to the product's identity.	
●	The **weight** of the kettle was considered highly important.	Alessi demanded that the kettle should be moulded out of PP filled with 50% minerals to increase the weight of the kettle. During production it was discovered that the moulding properties of the material deteriorated due to this high mineral content. Manufacturing engineers asked Alessi whether they could reduce the mineral content. Alessi refused to compromise on the filler content. The aesthetic weight of the kettle would give the consumer the impression of a solid, quality product.	50% mineral content made the Polypropylene very difficult to mould producing wide production variances. Kettle body sizes and back cover sizes had to be classified to fit in assembly. Scrap levels for the kettle body were at 20%. Ultrasonic welding of shell and kettle base proved extremely difficult. The retail price was simply increased to cover the high waste in manufacturing. Alessi buyers believe that high retail price is the result of good design rather than inefficient production process.

table Appendix I.20 Philips-Alessi kettle: success for supplier

○ visible ● non-visible	What	Why	How

❍ visible ● non-visible	What	Why	How
	Riedle received premium margins for the collapsible core.		

Appendix I.5 WILA Light

table Appendix I.21 WILA light: control WILA

○ visible ● non-visible	What	Why	How
○	Wila lighting company decided to developed a high-value commercial light. The product was based on a **modular concept**. A flat rectangular box at the side of the reflector was to house the electronics as well as a new quick-connector. The new light had to operate at 18, 36 and 42 Watt.	WILA develops lights for administrative buildings, department stores and banks with average to high quality interior design. The company's strategy is to offer products with a long working-life, trouble free installation, easy maintenance that promote a good working atmosphere and strong corporate image.	Designers at WILA built a block model to show the shape and configuration of the entire product as well as the black box which was supposed to house the electronic ballast and quick connector.
○ ●	WILA developed the **product shape** and the **reflector.**	Large offices usually need long rows of ceiling lights. The new connector type and the modular design would enable electricians to quickly install long rows of lights behind office ceilings	

table Appendix I.22 WILA light: control suppliers

○ visible ● non-visible	What	Why	How
●	Traditional fluorescent lamps operate at frequencies of 50Hz. Simple copper-iron ballasts limit the current flow after lamp ignition. Light emitting characteristics of fluorescent lamps improve at high frequencies which are not available from the mains supply and cannot be produced using conventional copper-iron coils. Electronic ballasts generate frequencies at around 40kHz which considerably improves performance characteristics of fluorescent lights. Power losses and heat dissipation is also considerably lower with electronic ballasts than with conventional		Development Insta developed a functional prototype on breadboard which met the requirements of the PDS. WILA tested the prototype in their own laboratory. WILA decided that the electronic ballast needed an additional cut-off device to protect it against voltages above 400V. This function was not part of the first PDS. Insta designers investigated different technical options and found that additional electronic parts were needed which increased the cost of the ballast component. Wila agreed to pay for the additional function and the PDS was modified. Insta finished the PCB design and started developing the plastic housing from the sketches and block models they had received from WILA. WILA received and tested the first prototypes including PCB and plastic case. They discovered that the heat dissipated by the luminaire was damaging the electronic parts. Manual assembly of PCB and plastic housing was also slightly difficult. Insta analysed the problem and suggested to mould a plastic shield into the case which would protect the electronic parts from the heat dissipated by the luminaire. Manual assembly of PCB and case halves could be simplified by including a hinge mechanism on the two case shells. The heat shield required a change in circuitboard layout. The development contract did not cover the extra development work. WILA reviewed the contract and paid INSTA for the extra development time necessary to rearrange the electronic components to create space for the heat shield.

○ visible ● non-visible	What	Why	How
	copper-iron coils. A block model of the plastic case was developed by WILA.		Competing product analysis Insta analysed competing ballasts and drew up a parts list and cost estimations. Based on these estimations INSTA and WILA signed a development contract. WILA agreed to pay for the work that was necessary for INSTA to develop an electronic ballast to WILA's specifications. Specification WILA now disclosed a list of product requirements and more detailed information on the product shape, the connector and socket. Engineers at Insta received a sketch and a block model showing the size and shape of the box in which the electronic functions had to be fitted. WILA also quoted an annual production volume. From this data, Insta developed a detailed Product Design Specification containing a list of functions as well as the component's sales price at an annual production volume of 100,000 units. This specification was included in the development contract.
●	The **electronic ballast** was developed by INSTA	WILA had no expertise in electronic ballasts, but needed a special size for its new light. Shortly before the start of the project, INSTA had announced their attention to move into the development and production of customised electronic ballasts. WILA had worked with INSTA	

○ visible ● non-visible	What	Why	How
		on other projects before and expressed their interest in working with INSTA on the development of the electronic ballast. The new ballast had to be ready for production by April 1996 because WILA intended to launch the new product at the Hanover Industry Fair. INSTA had never developed electronic ballasts before, but reviewed the time scales of projects of similar complexity. INSTA and decided that they would be capable of finishing the project before April	

table Appendix I.23 WILA light: customisation for WILA

○ visible ● non-visible	What	Why	How
○ ○	The **shape** of ballast and the **connector** type were specific to WILA.	WILA was unable to find an electronic ballast that worked at three different wattage and that would fit the dimensions of the rectangular box which designers had created. WILA corporate management decided to invest into the development of a customised electronic ballast and identified Siemens' affiliate OSRAM or INSTA as two potential suppliers	.

table Appendix I.24 WILA light: knowledge of WILA

○ visible ● non-visible	What	Why	How
	WILA knows about reflector design and heat dissipation through plastic cases. INSTA knows about the design of electronic ballasts.		Electronic engineers at Insta started by conducting a feasibility study. Because they had never developed electronic ballasts before, they bought and analysed competitor's product's and estimated development times using experience of other projects of similar complexity.

table Appendix I.25 WILA light: importance for WILA

○ visible ● non-visible	What	Why	How
	Shape, size and configuration of ballast	The product's identity and installation qualities depended on the shape, size and configuration of the ballast.	

table Appendix I.26 WILA light: success for WILA

○ visible ● non-visible	What	Why	How
			The two companies finalised the design and presented the new product at the Hanover Industry Fair in April 1996. Through this project, Insta could establish itself as a supplier of customised electronic ballasts for the lighting industry. INSTA's profit margins from customised HFC's are 30-50% higher than for standard components.

Appendix I.6 CASE-Poclain hydraulic unit

table Appendix I.27 Case Poclain hydraulic unit: control suppliers

○ visible ● non-visible	What	Why	How

table Appendix I.28 Case Poclain hydraulic unit: control suppliers

○ visible ● non-visible	What	Why	How
●	Rotelmann was responsible for the development, testing and marketing of the hydraulic **ball valve unit.**		<u>1st Design</u> After three months of design work, Rötelmann presented a working prototype to EDC. The excavator assembler was pleased and also surprised that the problem could be solved using ball valve technology. The first prototypes proved technical feasible, but the hydraulic block did not fit into the existing excavators. Seals and attachment did not meet EDC's requirements. 2nd Design Rotelmann decided to redesign the product for EDC's requirements. They reduced the overall size by rearranging functional elements and changing the machining process. First tests of the second prototype were successful, but EDC's sales department suggested that the price of the new unit was still unacceptably high. 3rd Design Rötelmann reduced the product's manufacturing costs by using more standard

○ visible ● non-visible	What	Why	How
			elements and buying seals from suppliers who offered better price conditions. EDC and Rotelmann agreed on a retail price and signed a supply contract.
	Rötelmann was involved from the definition of product requirements. First prototypes were developed without the customer's knowledge	Rötelmann was approached by one of their customers, a hydraulics company from Munich which specialised in the development of excavator hydraulics. The hydraulics specialist asked whether it was possible for Rötelmann to develop a solution based on ball valve technology for the building machinery conglomerate EDC. Rötelmann agreed to develop a solution.	Rough specifications were obtained form the hydraulics company in Munich. EDC, the excavator manufacturer was informed about the project, but its management showed no interest and did not get involved. Rötlemann developed first concepts for the new product, but decided not to present them to EDC. For manufacturers of building machinery it is quite common to disclose detailed information on one supplier's development work to other suppliers in order to get high price discounts very early. Technical information about the new product had to be withheld from the potential customer until first working prototypes were available.

table Appendix I.29 Case Poclain hydraulic unit: customisation for Case Poclain

○ visible ● non-visible	What	Why	How
● ●	The **seals** and **attachments** and interfaces are SAE industry standards. The hydraulic unit can be used in excavators of other manufacturers.		

table Appendix I.30 Case Poclain hydraulic unit: knowledge of Case Poclain

○ visible ● non-visible	What	Why	How
	EDC knew nothing about ball valve technology.		

table Appendix I.31 Case Poclain hydraulic unit: importance for Case Poclain

○ visible ● non-visible	What	Why	How
	Rötelmann knew how to use ball valves for controlling hydraulic machines. They knew nothing about the excavator market and technical requirements of excavators.		The hydraulics company in Munich gave engineers at Rotelmann information on applied loads, maximum forces, time intervals and flow rates. Information on target prices and interfacing standards was not available.

table Appendix I.32 Case Poclain hydraulic unit: success for supplier

○ visible ● non-visible	What	Why	How
	EDC considered critical:	interface	
	interfacing standards	the hydraulic block had to fit into existing excavators and comply with safety standards.	
●	**unit size**		
	seals, attachment	Customers were only prepared to pay a limited sum of money for the extra security	

○ visible ● non-visible	What	Why	How
	retail price	function.	

Appendix I.7 Daewoo con-rod

table Appendix I.33 Daewoo con-rod: control Daewoo

❍ visible ● non-visible	What	Why	How
●	Daewoo was responsible for the integration of the **con-rod** into the new 6-cylinder engine.	The Korean industrial conglomerate Daewoo decided to diversify into the car business and develop their own product range.	Daewoo worked with leading component suppliers and an Austrian consultancy AVL specialising in the development of internal combustion engines.

table Appendix I.34 Daewoo con-rod: control suppliers

❍ visible ● non-visible	What	Why	How
	Brockhaus developed the crack process for forged con-rods	For many years Brockhaus and Söhne has been a supplier of forged components to the German car industry. Forged con-rods Connecting-rods are heavy duty components and traditionally forged in one part. A complicated and expensive machining process was necessary to attach the rod to the camshaft. First the lower ring had to be cut in half. Then a series of interlocking teeth had to be machined into the two halves of the ring. The two halves were then refitted together and fixed using two screws at either side. The refitted con-rod could then be machined to the diameter of the camshaft. For the piston, con-rod and cam shaft to run smoothly, the machined diameter needs a cylindrical accuracy of 6 micrometers.	In order to make the forging of con-rods more competitive, Brockhaus & Sohne developed a steel alloy which allows them to crack con-rods along notches and thereby eliminate the complicated cutting, machining and repositioning process. Two notches are applied to the con-rod bearing with a fine laser beam. Two conical tools enter the camshaft bearing and crack it apart. The crack propagates along the laser notches. The crack's structure allows a precise re-positioning and re-joining of the two bearing halves. The crack structure also increases the area of joining surfaces reducing mechanical stress inside the rod geometry. The process and equipment for cracking the camshaft bearing was developed in close collaboration with a machine tool specialist from Stuttgart.

○ visible ● non-visible	What	Why	How
		Competition through powder metallurgy About 10 years ago, American motor industry introduced sintered con-rods. Although powder metal forming is more expensive, the process saves the complicated machining of the positioning surfaces necessary with forged components. Powder metal can also be weighed before pressing it into shape. All con-rods inside a single engine must be of equal mass to ensure balanced running. While mass accuracy of forged con-rods lies at +- 7 g, the mass of sintered con-rods can be controlled to +-2g. Due to the disadvantages of the forging process, Brockhaus & Sohne was loosing much of its con-rod business to suppliers specialising sintered con-rods.	
		Advancement of forging process Engineers at Brockhaus developed a crack-process which reduced machining cost as well as the investment for machining centres for forged con-rods by about 25%. The capital investment required for high volume machining of one con-rod type is typically at about 20m Euro. Through the crack process, forged con-rods have become cheaper than sintered con-rods.	
	Brockhaus developed the con-rod of Daewoo's 6-cylinder engine. The company was responsible for: Design of con-rod	When Daewoo announced their plan to develop a 6-cylinder engine together with German component suppliers, Brockhaus managed to convinced the Korean car company of the advantages of the crack process for forged con-rods. Brockhaus saw the	<u>1st Design</u> Brockhaus and Daewoo signed a design contract after which Brockhaus had to deliver the design, a FEA, FMEA, forging tools, prototypes and first-off. Daewoo accepted the contract, but insisted that the FEA

○ visible ● non-visible	What	Why	How
	Finite Element Analysis in specified boundary conditions	Daewoo project as an opportunity to make the crack process known in Asia and prevent the spreading of sintered con-rods in the region.	should be verified by AVL, an independent consultancy specialising in engine design.
	Failure Mode and Effect Analysis		
	Construction of forging tools		Brockhaus received a rough sketch of the con-rod dimensions from Daewoo. In order to determine the exact design, Brockhaus required more detailed data on the engine. Engineers sent Daewoo a questionnaire which was used for a comprehensive finite element analysis.
	Delivery of prototypes		
	Submission of development report		
	delivery of first-off		The results of the Finite Element Analysis were rejected by AVL. The engineering consultancy estimated that the boundary conditions were incorrect. Brockhaus rejected AVL's claim and stressed the fact that the boundary conditions had been agreed with and had been signed by Daewoo as part of the design contract.
			Brockhaus finished the design of the new con-rod. The crack process was used for the first time and prototypes were delivered to Daewoo. Tests at Daewoo were successful, but the car company decided that they would now like to use the same con-rod design their new 4-cylinder engines as well. This required a change in con-rod geometry which had not been catered for under the terms of the first design contract.
			2nd Design
			Brockhaus and Daewoo signed a second contract

❍ visible ● non-visible	What	Why	How
			under which Brockhaus offered the same services as in the first contract. The boundary conditions for the FEA were now adapted to the ideas of AVL, the independent consultancy. Daewoo argued that the Finite Element Analysis was too expensive and asked for Brockhaus to reduce the price. Brockhaus insisted on the quoted price, but encouraged Daewoo to make enquiries and ask for cheaper suppliers. The car company accepted Brockhaus' conditions and the second prototypes are delivered.
	Brockhaus was involved from the definition of product requirements.	Daewoo had no knowledge of con-rods and relied on Brockhaus' support.	In 1996 engineers from the Korean car manufacturer asked Brockhaus to develop a con-rod for Daewoo's new 6-cylinder engine. Daewoo stressed the fact that the design result would be taken back to South-Korea. If Brockhaus wanted to produce these con-rods it would have to open a factory in either South-Korea or India. Management at Brockhaus decided to agree to these conditions. The company had just developed the new process for forged con-rods. The involvement with Daewoo was seen as an opportunity to make forged con-rods known in Asia and stop the advancement of sintered con-rods from North-America.

table Appendix I.35 Daewoo con-rod: customisation for Daewoo

○ visible ● non-visible	What	Why	How
	The con-rod was specific to Daewoo's 6-cylinder engine	For the motor industry engine parts such as pistons, connecting rods, camshafts and crankshafts are "heart elements" critical for engine performance and also for the technological competitiveness of the car manufacturer.	

table Appendix I.36 Daewoo con-rod: knowledge Daewoo

○ visible ● non-visible	What	Why	How
	Little knowledge of motor car design and technology existed within the Daewoo corporation.		The company set up a styling office in the UK and opened a centre for automotive engineering in Munich, Germany. The aim was to work together with leading European suppliers for the design of new cars and bring this knowledge back to Korea.

table Appendix I.37 Daewoo con-rod: importance for Daewoo

○ visible ● non-visible	What	Why	How
	Technical considerations behind the design of con-rods.	Daewoo had no knowledge of internal combustion engines. To become an independent car producer, the Korean company had to learn about internal combustion engines. The supplier had to submit a detailed development report to Daewoo.	

table Appendix I.38 Daewoo con-rod: success for supplier

○ visible ● non-visible	What	Why	How
			Since completing the project for Daewoo, Brockhaus has publicised the crack technology amongst all major auto manufacturers. The company is now dominating the market for con-rods in Europe. It has not been able yet to convince American motor industry of the new technology. American manufacturers seem to be more attached to a process which they have introduced themselves ten years ago. Brockhaus is competing in a market which has experienced strong price pressures since the early 1990's. Due to severe competition in the automotive supply industry, Brockhaus can not charge higher prices for their innovation.

Appendix II Questionnaire

component date

description

supplier lead manufacturer

contact

For which of the following were you responsible during the development ?	elements visible to user			elements not visible to user		
	i	⟲	✓	i	⟲	✓
opportunity statement, product brief	O	O	O	O	O	O
design specification, requirement list	O	O	O	O	O	O
concept sketches, mock-up models	O	O	O	O	O	O
prototypes, assembly drawings, test reports	O	O	O	O	O	O
dimensional drawings, tooling	O	O	O	O	O	O
pre-production prototypes	O	O	O	O	O	O

figure Appendix II.1 sheet 1 of questionnaire

component

	Is the component customised for certain lead manufacturers ?		
	not customised	only graphics	form or shape
component elements visible to end-user	O	O	O
component elements invisible to end-user	O	O	O

	Was component development driven by specifc aesthetic requirements or considerations ?	
	No, component development was not driven by aesthetic requirements of the final product	Yes, component development was driven by aesthetic requirements of the final product
component elements visible to end-user	O	O
component elements invisible to end-user	O	O

	If the component is not visible to the end-user, does it have an impact on the size, shape or configuration of the final product ?	
	NO	YES
component elements invisible to end-user	O	O

	What is the component's share in visible surface compared to other components in the final product or system?			
	none	low	medium	high
component elements visible to end-user	does not apply	O	O	O
component elements invisible to end-user	O	same as above	same as above	same as above

How would you describe the profits for this component compared to the typical component your company produces?		
below average	about average	higher than average
O	O	O

Why do you think are component profits below/ about/ above average ?

figure Appendix II.2 sheet 2 of questionnaire

Appendix III Comments on profits

A1 easy to make	A2 competitive prices	A3 purchasing power	A4 no differentiation	B1 difficult to make	B2 good prices	B3 visual differentiation	B4 technical differentiation	comments
	1	1	1					difficult to differentiate visually and technically, price war, customer powerful
		1	1					standard product for cutomer, same as any other supplier, power of oil company
								no need for such a product
	1							defend market position by cutting cost
1		1						commodity component, anyone can do it, market power of retaillers
	1		1					no different from competition, cheap item
1	1	1						tough competition, buying power of customer, many suppliers can do it
1	1	1						simple product, big customer, difficult price situation
	1	1						difficult price situation, large customer, price-driven procurement
	1							price-led competition
			1					other suppliers do the same thing
1	1							commodity component, difficult price situation
	1		1					very competitive, not important for product character
	1							competitive production, highly value engineered
1								not particularly difficult to produce
			1					many suppliers build the same thing, catalogue component
1	1		1					simple high-volume component, nothing special, price pressures
1								not particularly difficult
7	**11**	**6**	**7**					

figure Appendix III.1 list of comments for component profits below average

easy to make	competitive prices	purchasing power	no differentiation	difficult to make	good prices	visual differentiation	technical differentiation	reason
						1		special configuration and design
						1	1	looks and manual operation very different from competing products
						1		customer needed special shape to achieve visual effect
						1		help to achieve visual requirements
					1			cost lowered without customer knowing
							1	flexible design can be offered to many customers, but still variety
						1		flexible design for different visual requirements
				1	1			very difficult to make, upmarket
						1		special component more expensive, helps FINA to make their site look different, but still standard technology
				1				difficult to produce structure out of Al
						1	1	highly innovative, technology and shape
					1	1		high quality specific visual design, upmarket component
						1		important component for quality feel of entire product, aesthetics and manual operation unique to supplier
					1		1	high quality product, low purchasing power of customer, important for product feel and looks
						1		novel idea, unique aesthetics, desireable
							1	high quality, better than any competitor
							1	lots of design input from supplier, exceptional knowledge
						1	1	strong market presence, very good design, recongniseable
					1			hardly any competition
						1		upmarket product, strong brand identity
				1			1	unique product, safety requirements and licensing cost deters competition
					1	1		novel product concept, exclusive contract 2 years, top market segment
					1		1	high-end product, supplier knowledge
							1	special design more expensive, but saves cost for customer elsewhere
						1		special design for product shape
				3	**7**	**14**	**10**	

figure Appendix III.2 list of comments for component profits higher than average

A1 easy to make	A2 competitive prices	A3 purchasing power	A4 no differentiation	B1 difficult to make	B2 good prices	B3 visual differentiation	B4 technical differentiation	reason
	1	1	1					same product as competition, price pressure of powerful buyers
	1		1					innovative but tough price pressures, competition copies design
	1			1				price pressures, but difficult to manufacture
		1					1	extensive knowledge of technology, integration difficult, price power
	1		1					competitive pricing, many competitors difficult to differentiate
	1	1						purchasingh power, tough competition
			1					nothing special
1	1				1			competitive situation, only details are distinguishable
	1	1						high volume, difficult price situation, purchasing power of customer
						1	1	lighter, smaller than competition, allows designers to create slimmer doors,
	1	1						buying power, strong competition
1					1			easy component, but customer pays good prices
		1					1	customer can chose where to produce
1					1			not difficult, but customer pays well
1					1			not difficult, many suppliers can do it, price pressure not too great
4	**8**	**6**	**4**	**1**	**4**	**1**	**3**	

figure Appendix III.3 list of comments for component profits about average

Appendix IV plotting variables of H1: visual significance - supplier control

Appendix IV.1 customisation

Figure IV.1 shows supplier control in the development of components that were not customised for any lead manufacturers.

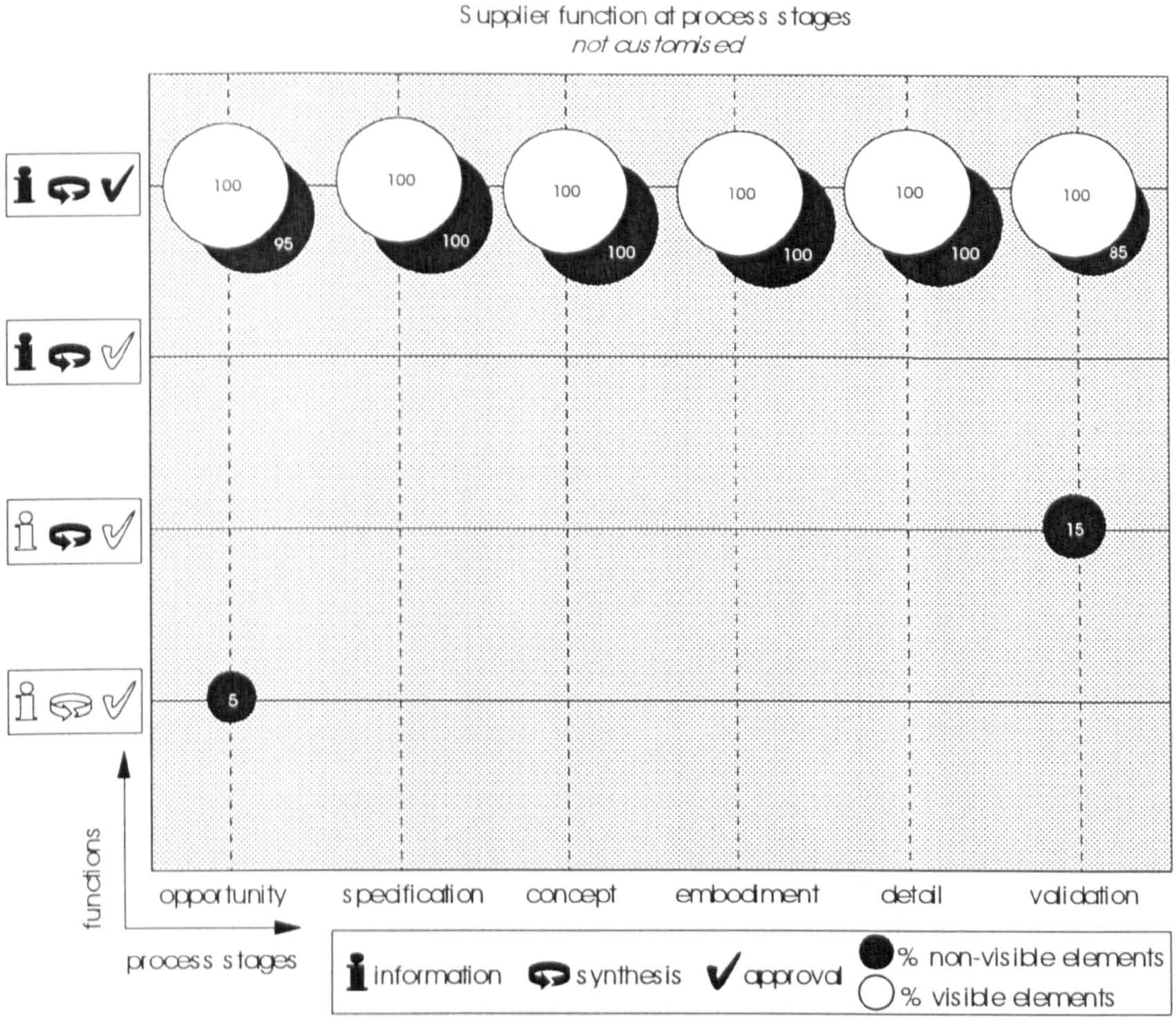


figure Appendix IV.1 supplier function/ process chart: components not customised for lead manufacturer

visible elements within components

From opportunity to validation stage, 100% of visible elements within components were developed with the suppliers responsible for information, synthesis and approval.

non-visible elements within components

At the opportunity stage, 95% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

From specification to detail stage, 100% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the validation stage, 85% of non-visible elements were developed with suppliers responsible for information ℹ, synthesis ⟲ and approval ✓.

Figure IV.2 shows supplier control in the development of components that have only graphics customised for lead manufacturers.

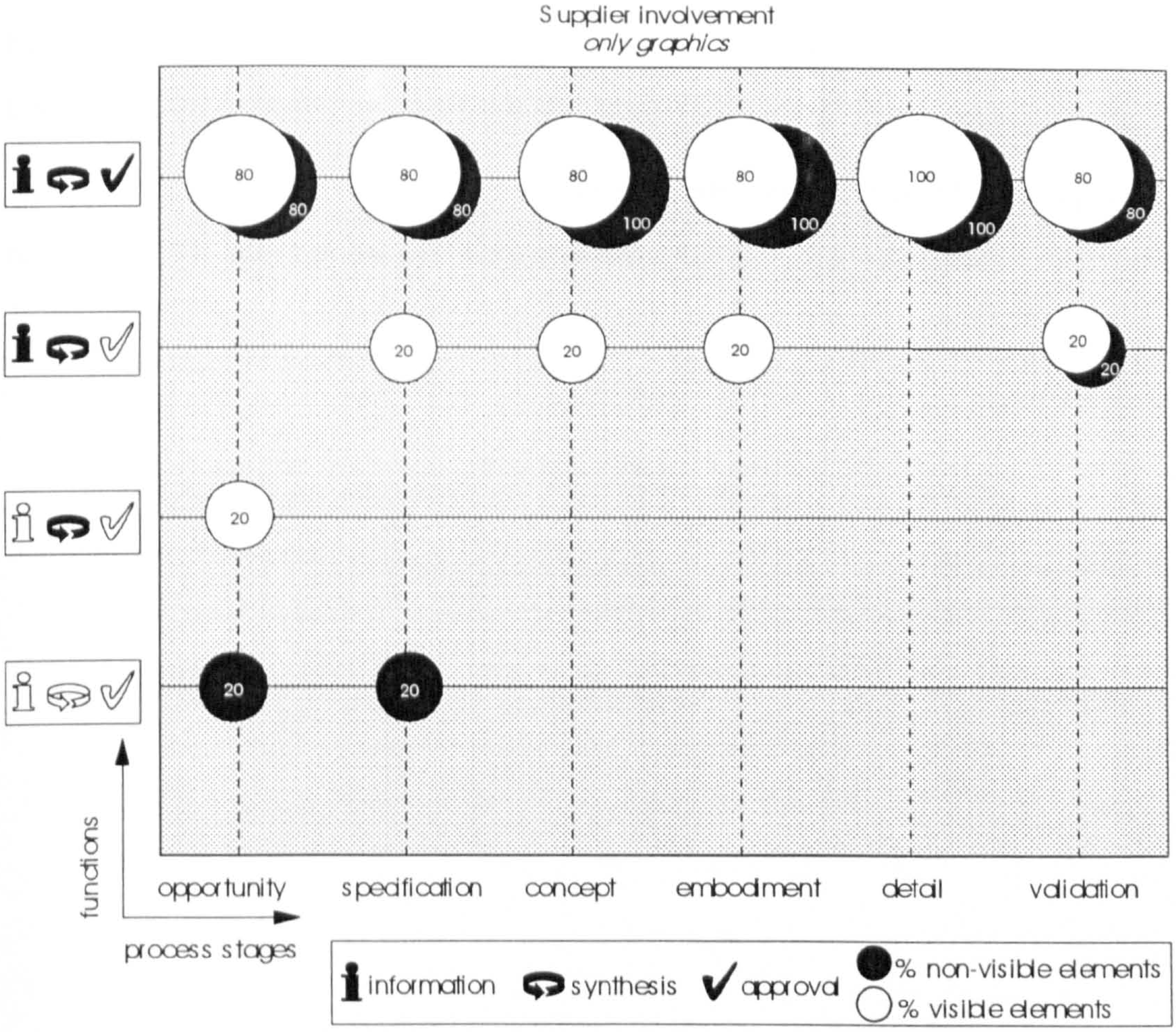


figure Appendix IV.2 supplier function/ process chart: components only graphics customised for lead manufacturer

visible elements within components

At the concept stage, 80% of visible elements were developed with suppliers responsible for information, synthesis and approval.

From specification to embodiment stage, 80% of visible elements were developed with suppliers responsible for information, synthesis and approval.

At the detail stage, 100% of visible elements were developed with suppliers responsible for information, synthesis and approval.

At the validation stage, 80% of visible elements were developed with suppliers responsible for information, synthesis and approval.

non-visible elements within components

At the opportunity and at the specification stage, 80% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

From concept to detail stage, 100% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the validation stage, 80% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

Figure IV.3 shows supplier control in the development of components with form or shape customised for lead manufacturers.

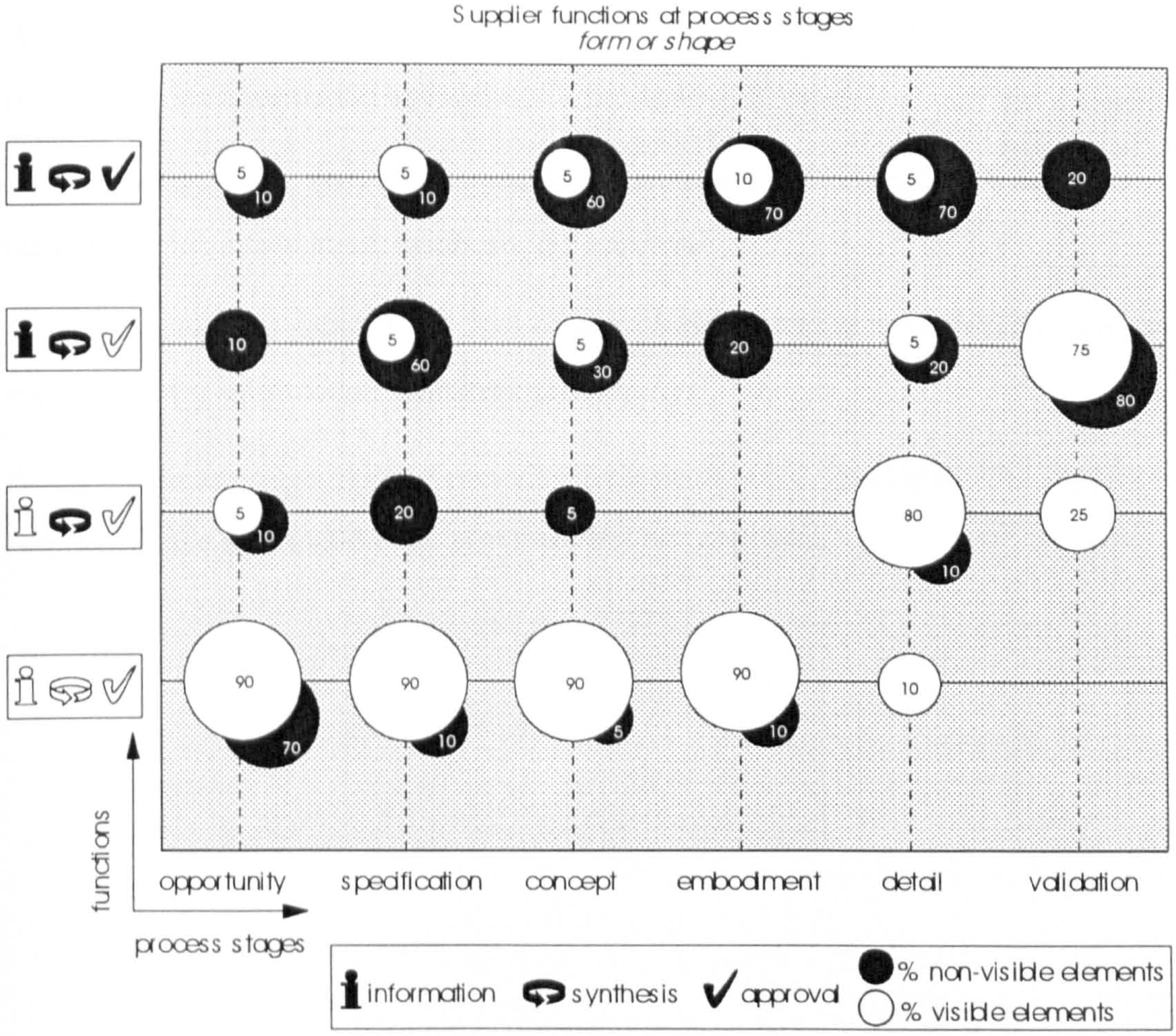


figure Appendix IV.3 supplier function/ process chart: components with form or shape customised for lead manufacturer

visible elements within components

From opportunity to embodiment stage, 90% of visible elements were developed without the suppliers.

At the detail stage, 80% of visible elements were developed with suppliers only responsible for synthesis.

At the validation stage, 25% of visible elements were developed with suppliers only responsible for synthesis and 75% of visible elements were developed with suppliers responsible for information and synthesis, but not approval.

non-visible elements within components

At the opportunity stage, 70% of non-visible elements were developed without the suppliers.

At the specification stage, 60% of non-visible elements were developed with suppliers responsible for information and synthesis, but not approval.

At the concept stage, 60% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At embodiment and detail stage, 70% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the validation stage, 80% of non-visible elements were developed with suppliers responsible for information and synthesis, but not approval.

There is very significant evidence for a relationship between the level of customisation of visible elements and supplier control in development (see figure IV.4):

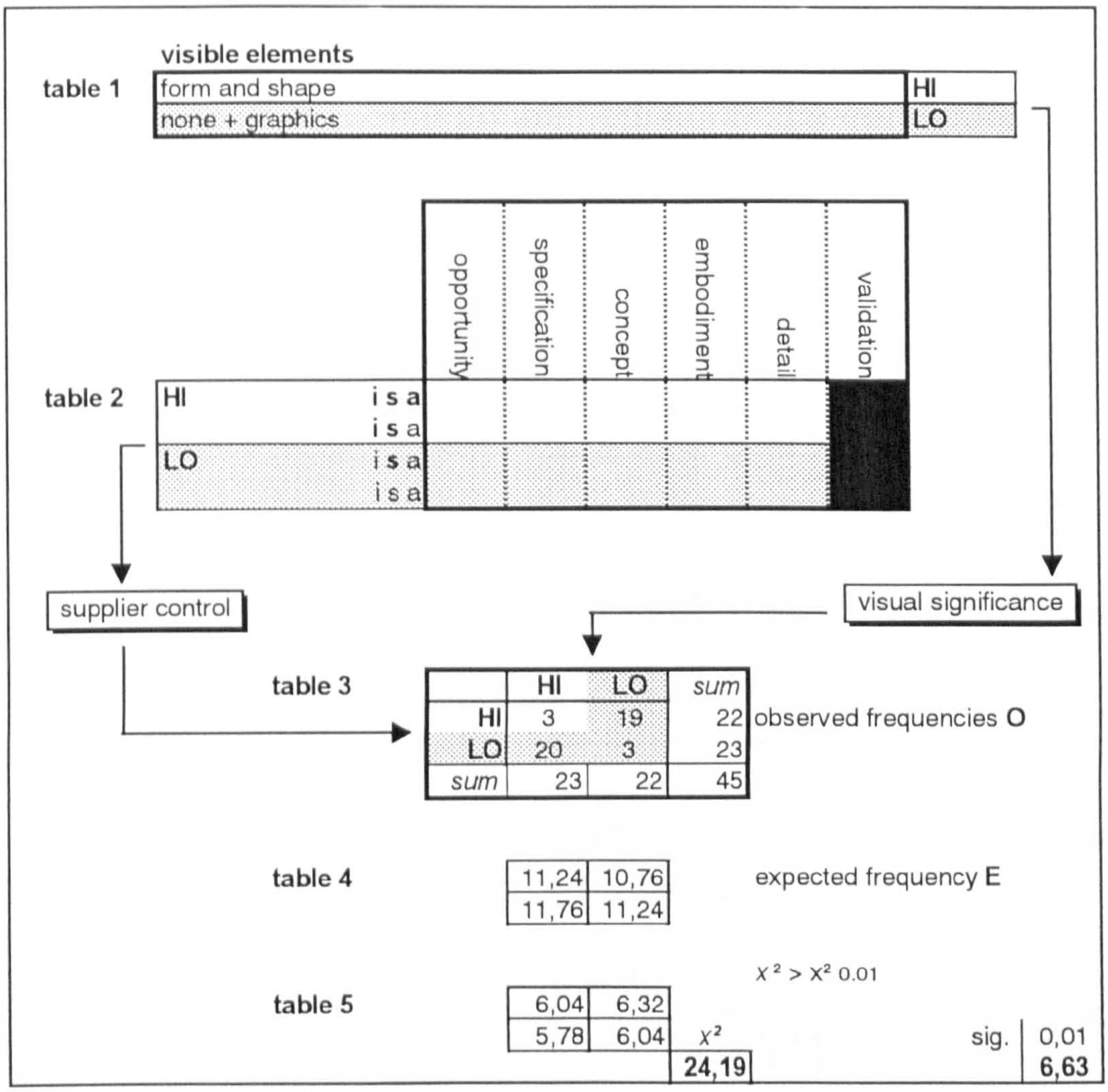


figure Appendix IV.4 significance test: supplier control - form or shape (not customised vs. only graphics

There is very significant evidence for a relationship between the visibility of elements and supplier control in development (see figure IV.5).

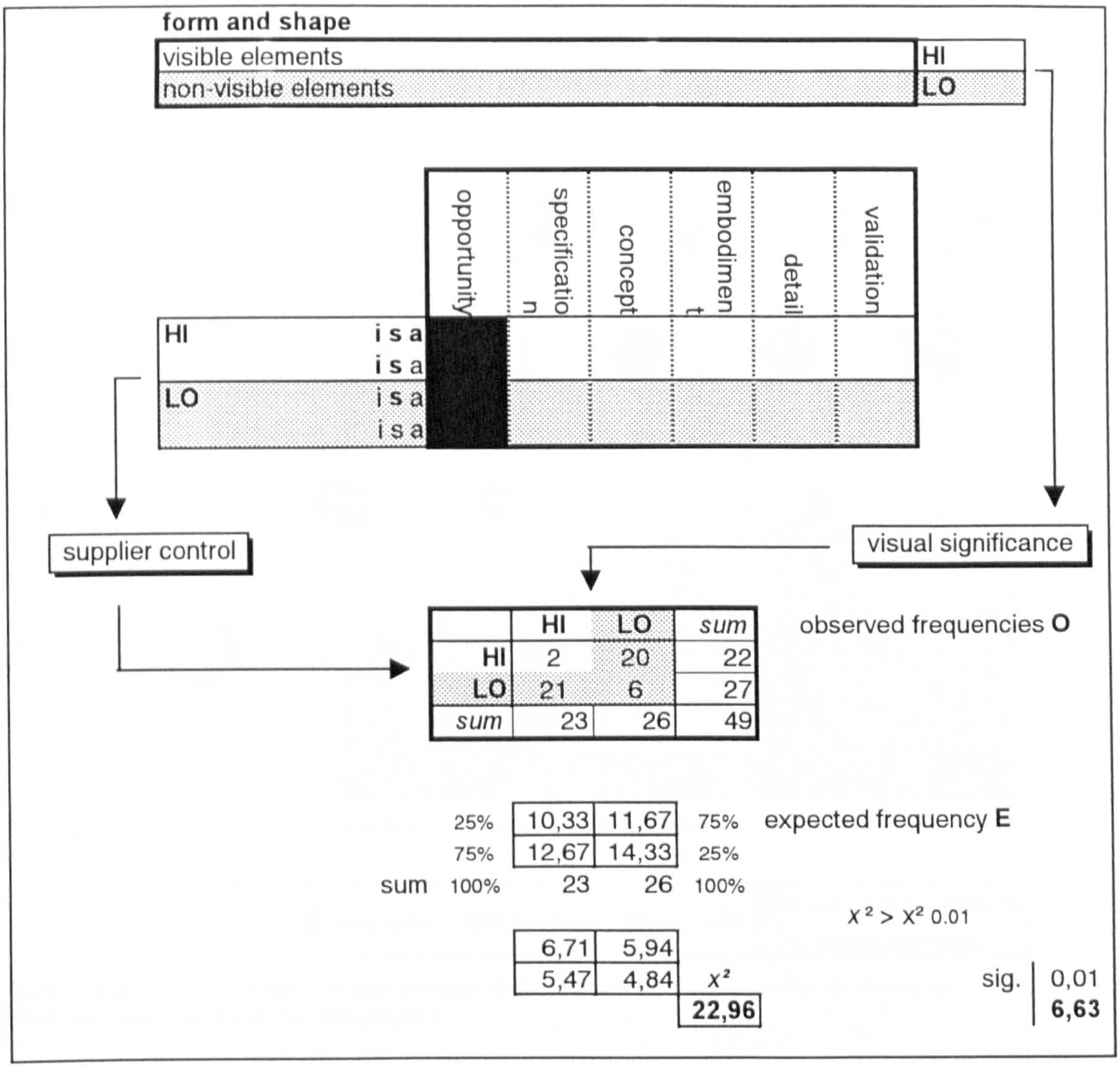


figure Appendix IV.5 significance test: supplier control - customised form or shape (visible vs. non-visible elements)

Appendix IV.2 aesthetics-driven

Figure IV.6 shows supplier control for components whose development was not driven by aesthetic requirements of the final product.

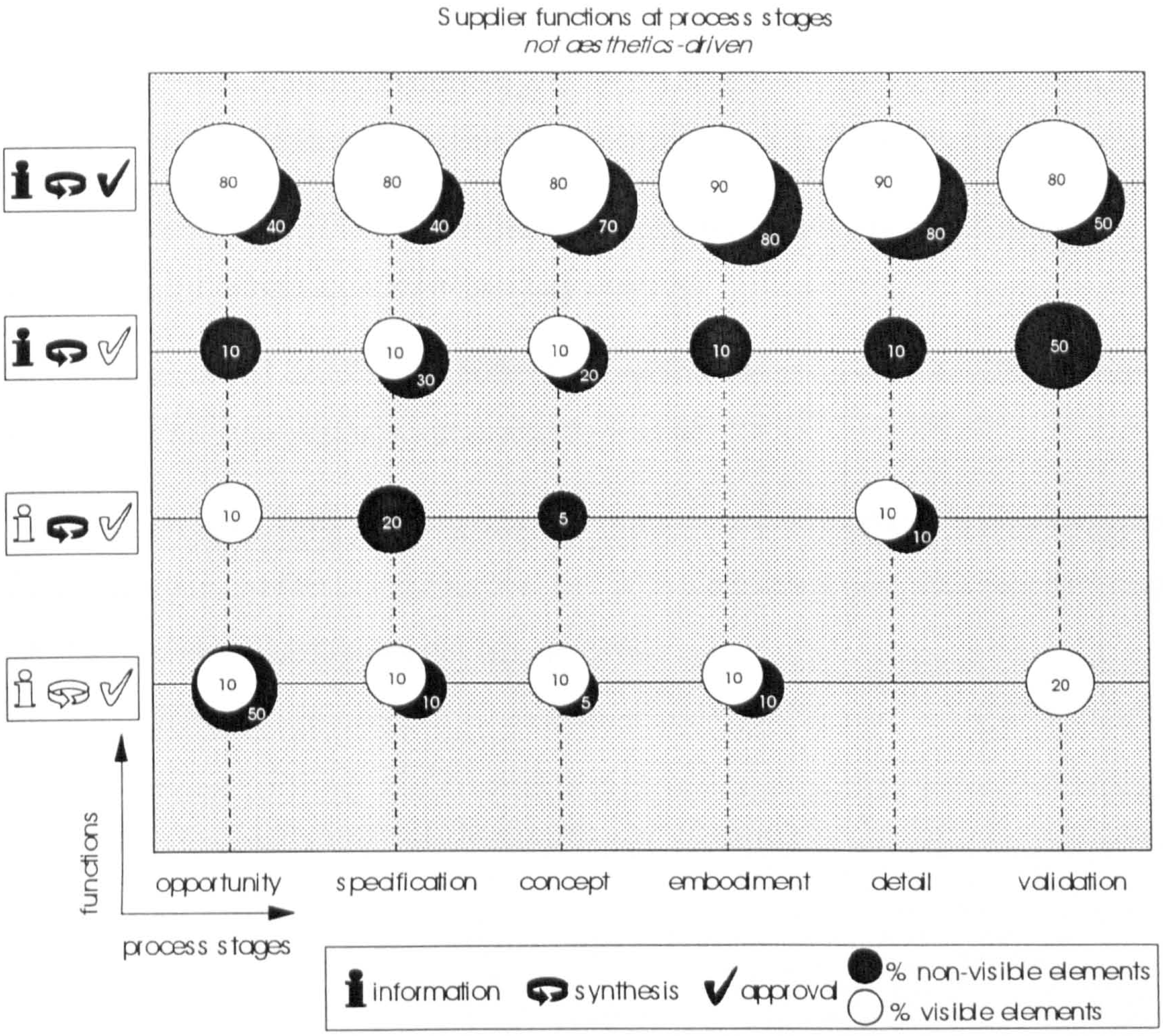


figure Appendix IV.6 supplier function/ process chart: component development not driven by aesthetic requirements of the final product

visible elements within components

From opportunity to concept stage, 80% of visible elements were developed with suppliers responsible for information, synthesis and approval.

From embodiment to detail, 90% of visible elements were developed with suppliers responsible for information, synthesis and approval.

At validation stage, 80% of visible elements were developed with suppliers responsible for information, synthesis and approval.

non-visible elements within components

At the opportunity stage, 50% of non-visible elements were developed with suppliers outside the development and 40% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the specification stage, 40% of non-visible elements were developed with suppliers responsible for information, synthesis and approval and 30% of non-visible elements were developed with suppliers responsible for information and synthesis, but not approval.

At the concept stage, 70% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At embodiment and detail stage, 80% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At validation stage, 50% of non-visible elements were developed with suppliers responsible for information, synthesis and approval and 50% were developed with suppliers responsible for information and synthesis, but not approval.

Figure IV.7 shows supplier control for components whose development was not driven by aesthetic requirements of the final product.

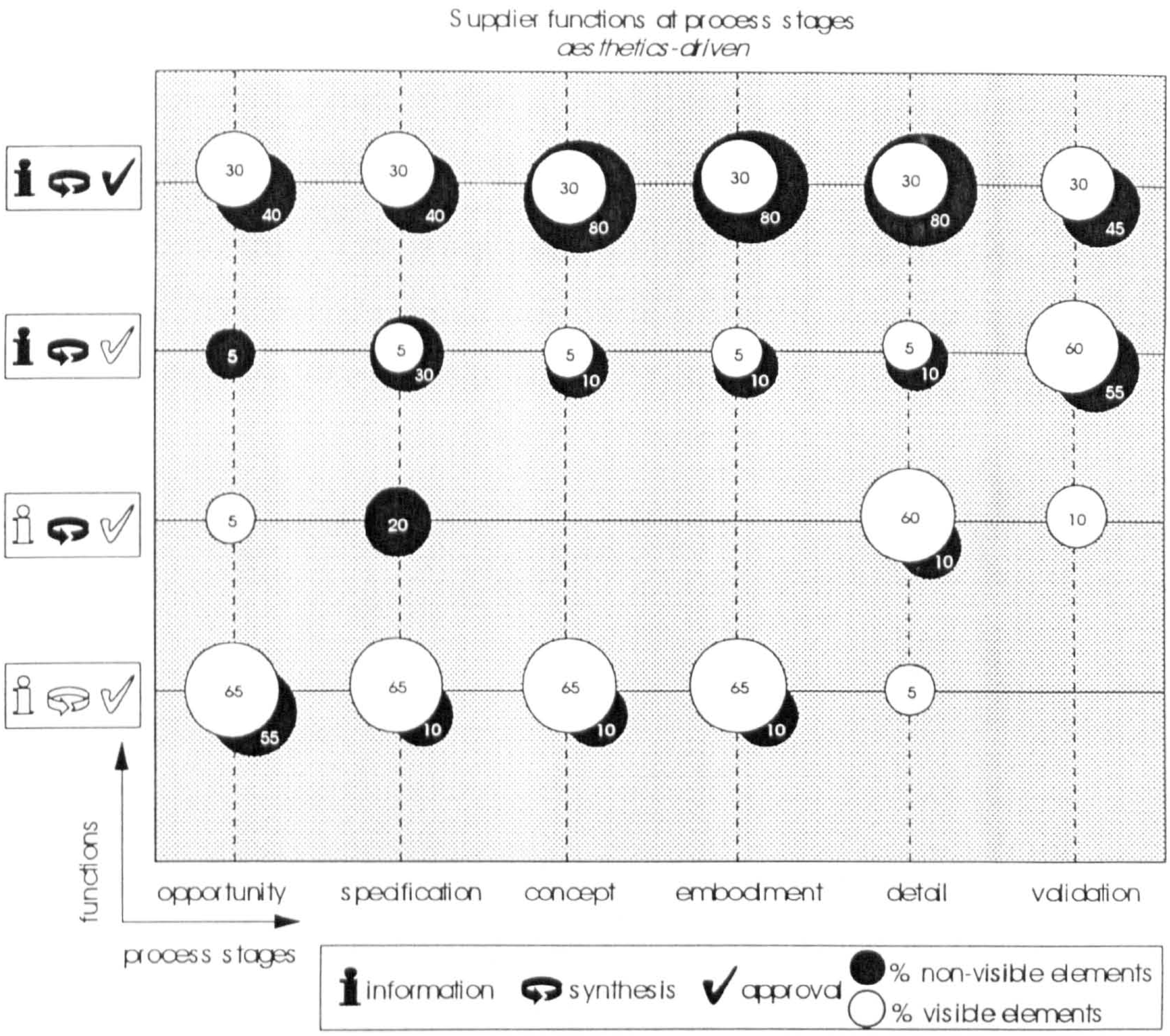


figure Appendix IV.7 supplier function/ process chart: component development driven by aesthetic requirements

visible elements within components

From opportunity to embodiment stage, 65% of visible elements were developed without the suppliers and 30% of the visible elements were developed with suppliers responsible for information and synthesis, but not approval.

At the detail stage, 60% visible elements were developed with suppliers responsible for synthesis, but not information nor approval. 30% of visible elements were developed with suppliers responsible for information, synthesis and approval.

non-visible elements within components

At the opportunity stage, 55% of non-visible elements were developed without the suppliers and 45% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the specification stage, 40% of non-visible elements were developed with suppliers responsible for information, synthesis and approval and 30% of non-visible elements were developed with suppliers responsible for information and synthesis, but not approval.

From concept to detail stage, 80% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the validation stage, 45% of non-visible were developed with suppliers responsible for information, synthesis and approval and 55% of non-visible elements were developed with suppliers responsible for information and synthesis, but not approval.

There is significant evidence for a relationship between aesthetic-driven elements and supplier control of development (see figure IV.8).

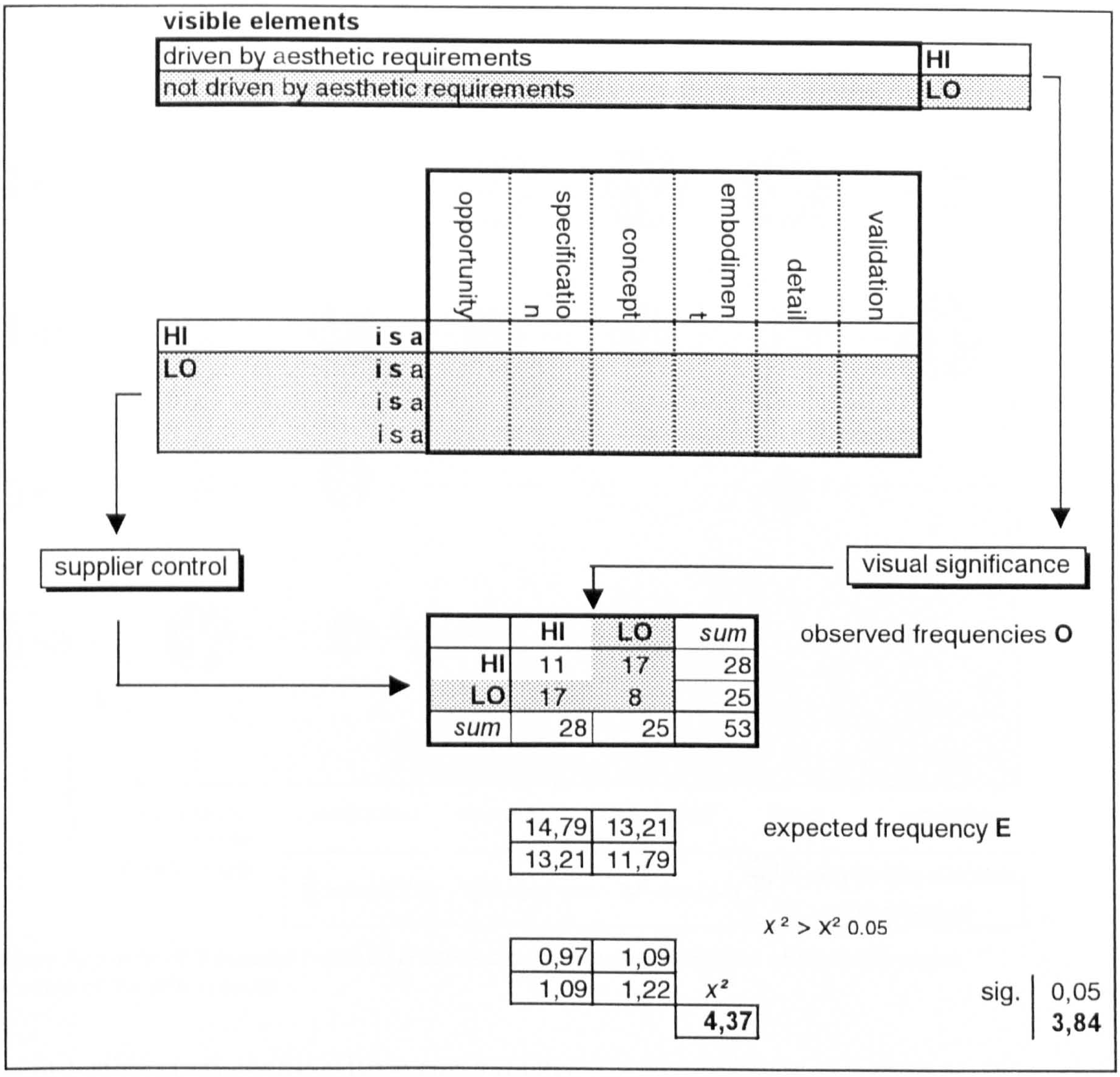


figure Appendix IV.8 significance test: supplier control - visible elements (driven by aesthetic requirements vs. not driven by aesthetic requirements)

Appendix IV.3 visible surface

Figure IV.9 shows supplier control for components with no share in the visible surface of the final product.

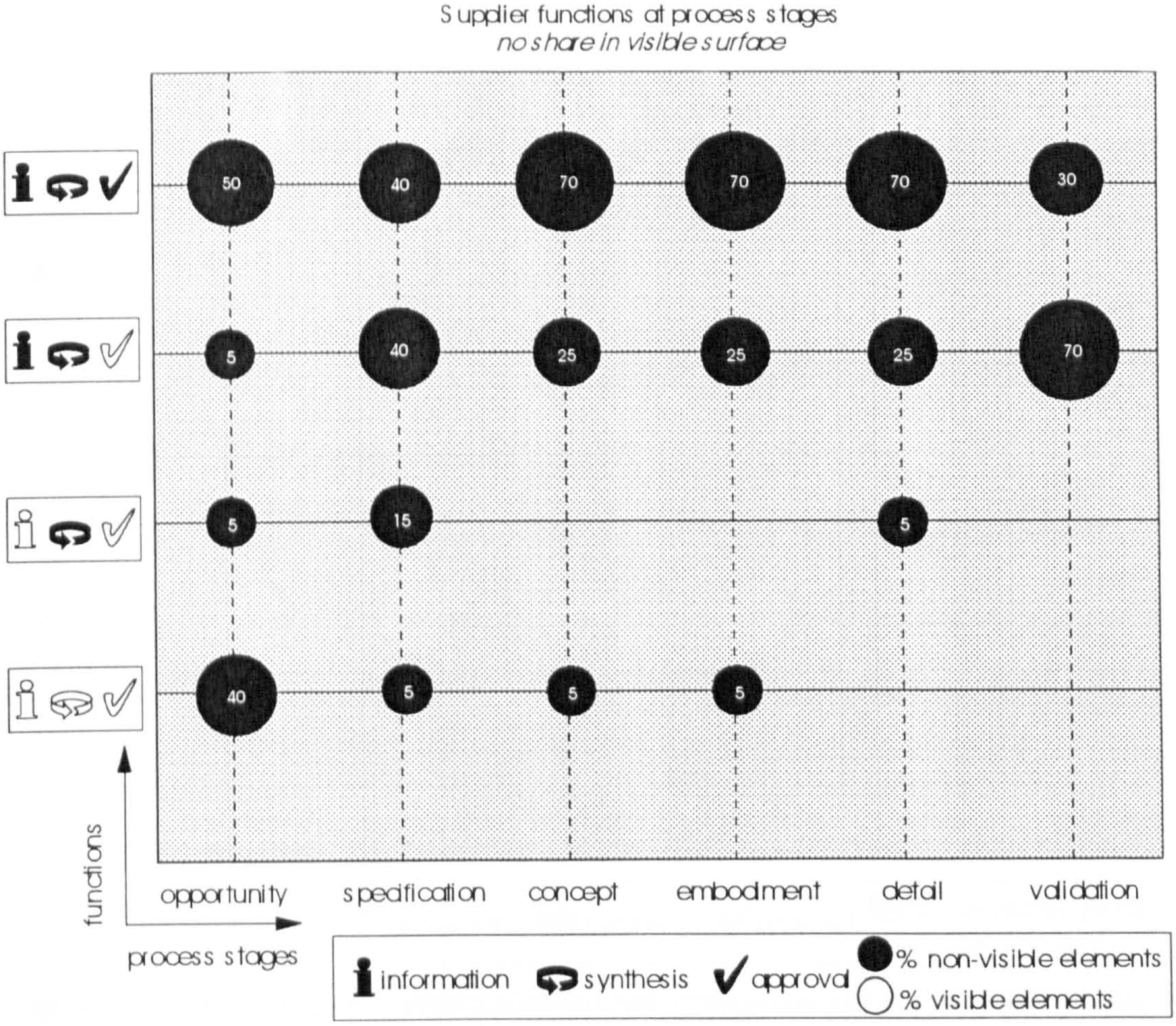


figure Appendix IV.9 supplier function/ process chart: components with no share in the visible surface of the final product

non-visible components within components

At the opportunity stage, 50% of non-visible elements were developed with suppliers responsible for information, synthesis and approval and 45% of invisible elements were developed without the suppliers.

At the specification stage, 40% of non-visible elements were developed with suppliers responsible for information, synthesis and approval and 40% of non-visible elements were developed with suppliers responsible for information and synthesis, but not approval.

From concept to detail stage, 70% of non-visible elements were developed with suppliers responsible for information, synthesis and approval. At the validation stage, 70% of non-visible elements were developed with suppliers responsible for information and synthesis, but not approval.

Figure IV.10 shows supplier control for components with low share in the visible surface of the final product.

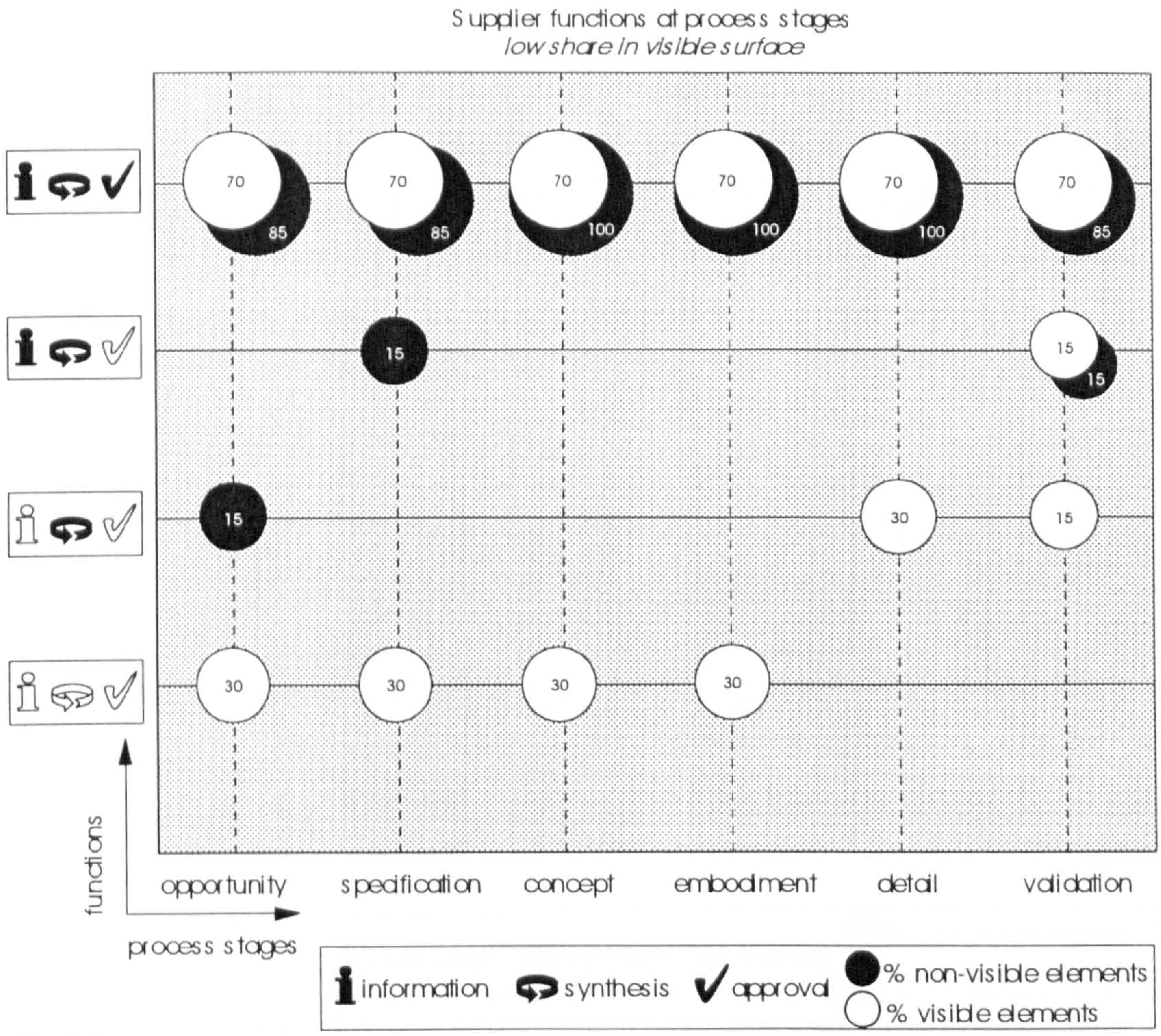


figure Appendix IV.10 supplier function/ process chart: components with low share in the visible surface of the final product

visible elements within components

From opportunity to validation stage, 70% of visible elements were developed with suppliers responsible for information, synthesis and approval.

non-visible elements within components

At opportunity and specification stage, 85% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

From concept to detail stage, 100% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the validation stage, 85% of non-visible elements were developed with suppliers responsible for information and synthesis, but not approval.

Figure IV.11 shows supplier control for components with medium share in the visible surface of the final product.

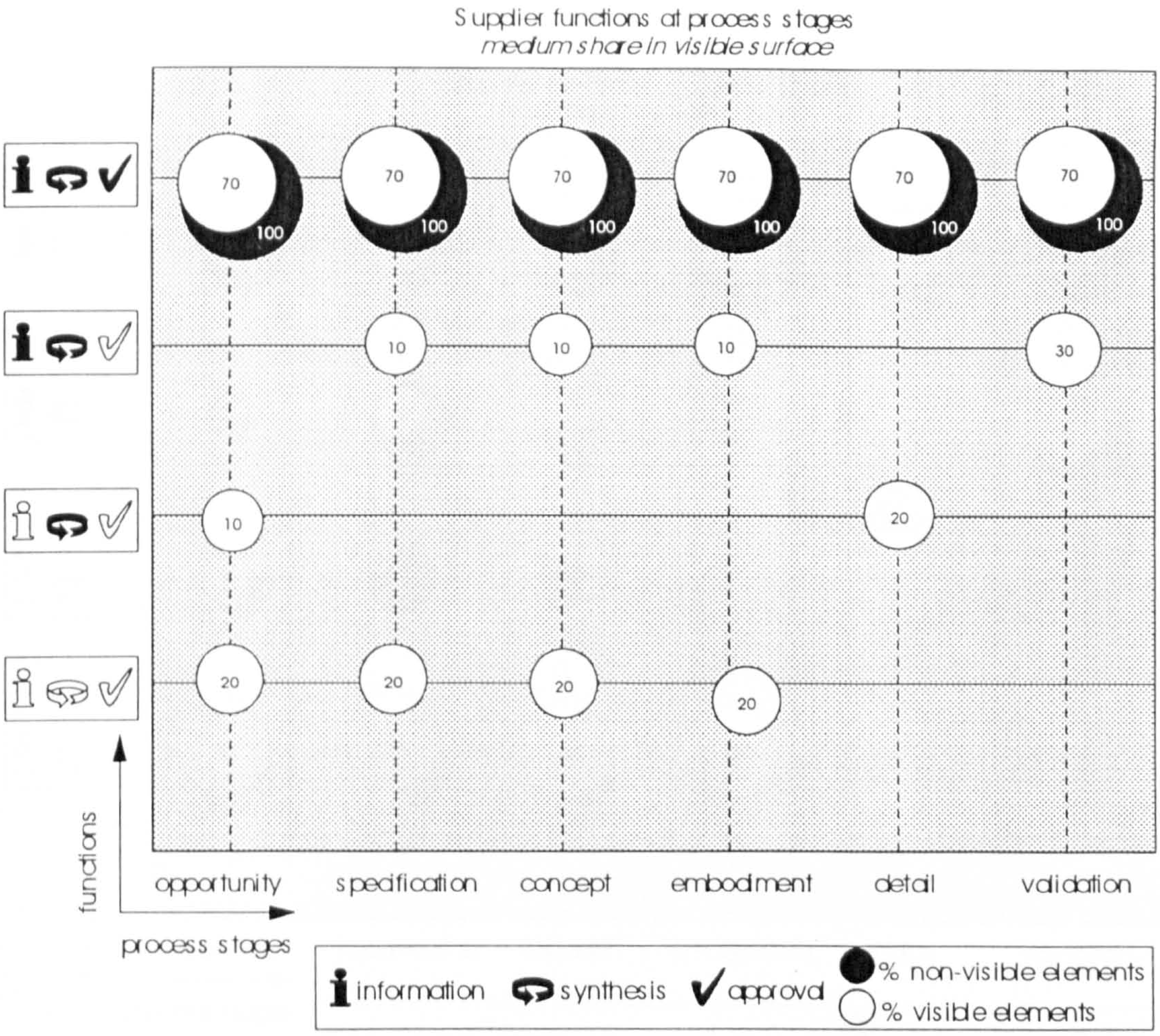


figure Appendix IV.11 supplier function/ process chart: components with medium share in the visible surface of the final product

visible elements within components

From opportunity to validation stage, 70% of visible elements were developed with suppliers responsible for information, synthesis and approval.

non-visible elements within components

From opportunity to validation stage, 100% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

Figure IV.12 shows supplier control for components with high share in the visible surface of the final product.

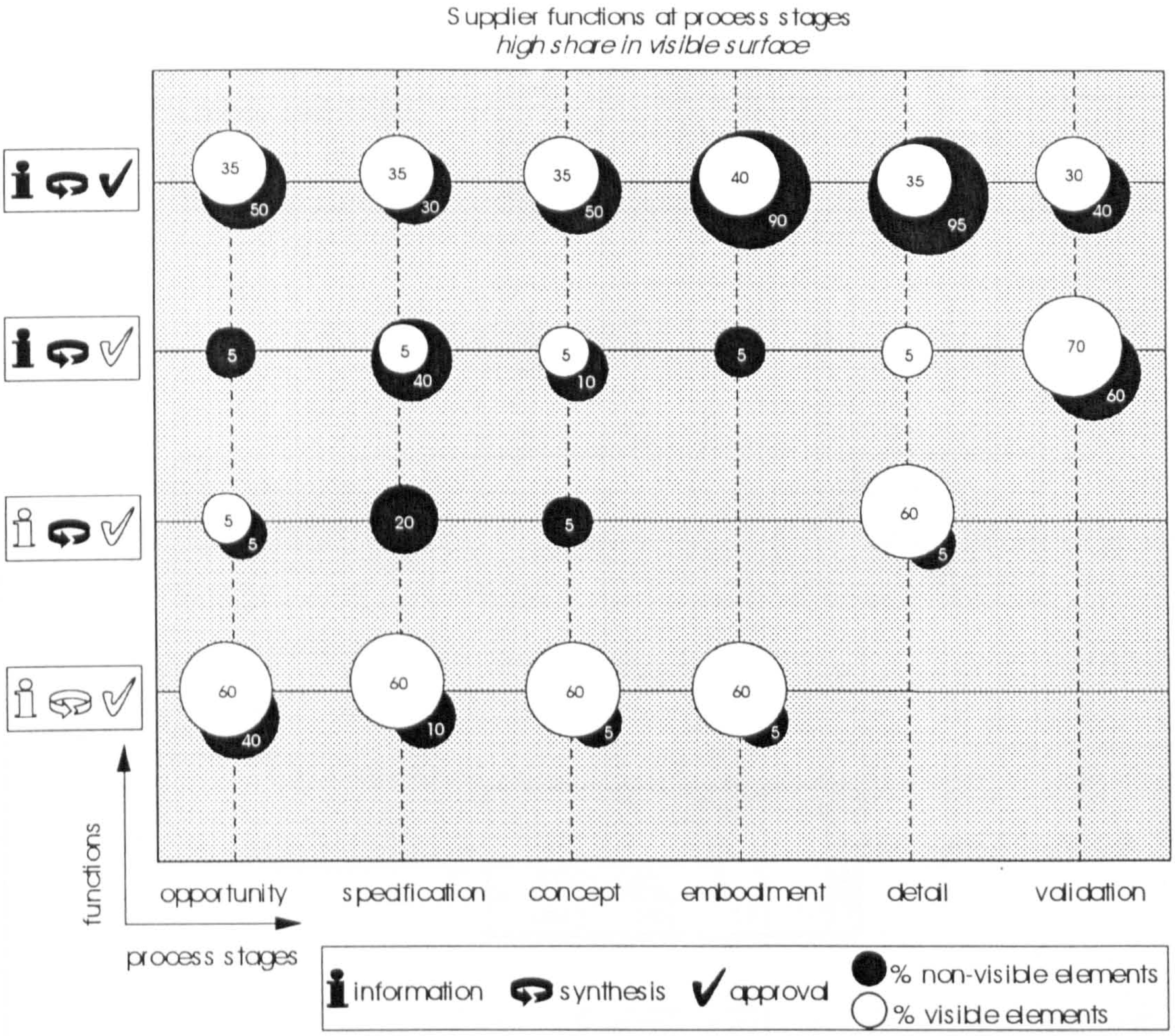


figure Appendix IV.12 supplier function/ process chart: components with a high share in the visible surface of the final product

visible elements within components

From opportunity to concept stage, 60% of visible elements were developed with suppliers outside the development and 35% of visible elements were developed with suppliers responsible for information, synthesis and approval.

At the embodiment stage, 60% of visible elements were developed without suppliers and 40% of visible elements were developed with suppliers responsible for information, synthesis and approval.

At the detail stage, 60% of visible elements were developed with suppliers responsible for preparation, but not information nor approval and 35% of visible elements were developed with suppliers responsible for synthesis, information and approval.

There is significant evidence for a relationship between component share in visible surface of the final product and supplier control of development (see figure IV.13).

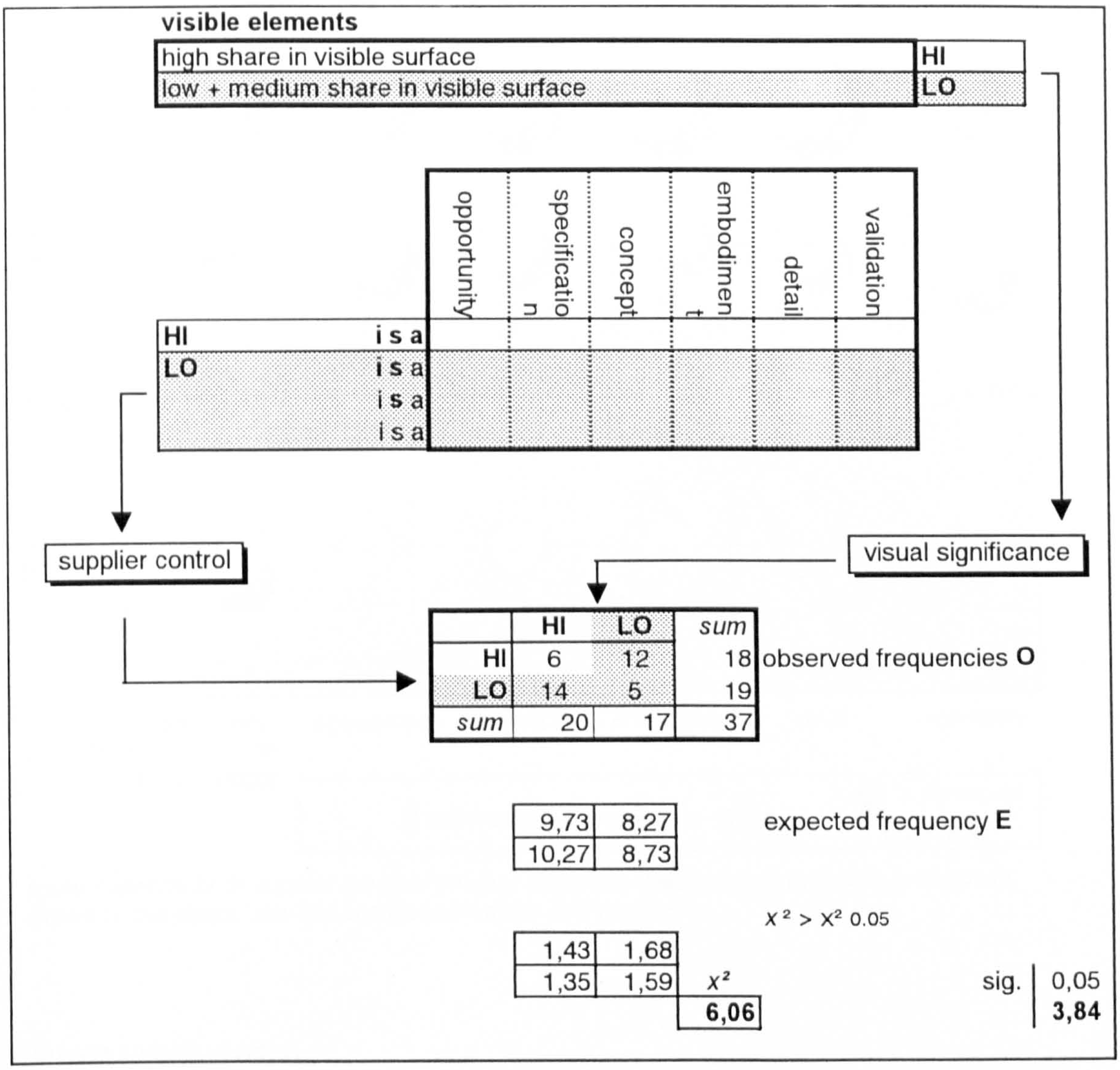


figure Appendix IV.13 significance test: supplier control - visible elements (high share in the visible surface vs. low and medium share in the visible surface)

Appendix IV.4 Impact on size...

Figure IV.14 shows supplier control for non-visible components with and without impact on the shape, size and configuration of the final product.

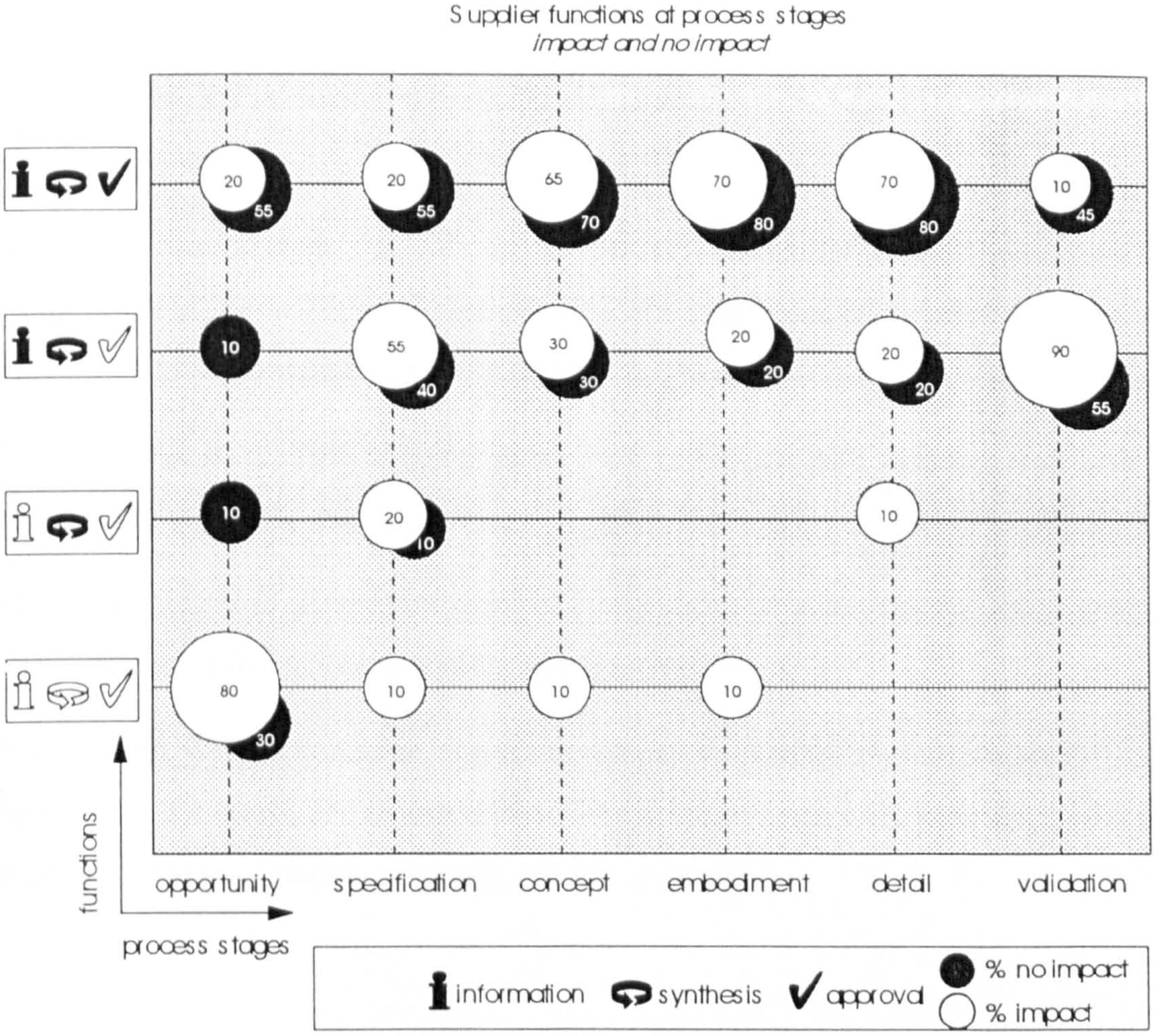


figure Appendix IV.14 supplier function/ process chart: non-visible components with and without impact on the shape, size and configuration of the final product

impact (white circles)

At the opportunity stage, 80% of components were developed without the suppliers. At the specification stage, 55% of components were developed with suppliers responsible for information, synthesis, but not approval.

At the concept stage, 65% of the components were developed with suppliers responsible for information, synthesis and approval.

At the embodiment and detail stage, 70% of the components were developed with suppliers responsible for information, synthesis and approval.

At validation, 90% of suppliers were responsible for information and synthesis, but not approval.

no impact (black circles)

At the opportunity stage, 55% of components were developed with suppliers responsible for responsible for information, synthesis and approval. 30% of components were developed without suppliers.

At the specification stage, 55% of components were developed with suppliers responsible for information, synthesis, and approval. 40% of components were developed with suppliers responsible for information, synthesis, but not approval.

At the concept stage, 70% of components were developed with suppliers responsible for information, synthesis, and approval.

From embodiment to detail stage, 80% of components were developed with suppliers responsible for information, synthesis, and approval.

At validation, 45% of components were developed with suppliers responsible for information, synthesis, and approval and 55% of components were developed with suppliers responsible for information, synthesis, but not approval.

The trend shows that more suppliers are autonomous or consultant at the opportunity stage if components have no impact on size shape or configuration than if components have impact on size, shape or configuration of the final product. The sample size does not allow for a statement on whether or not this observation is significant (see figure IV.15).

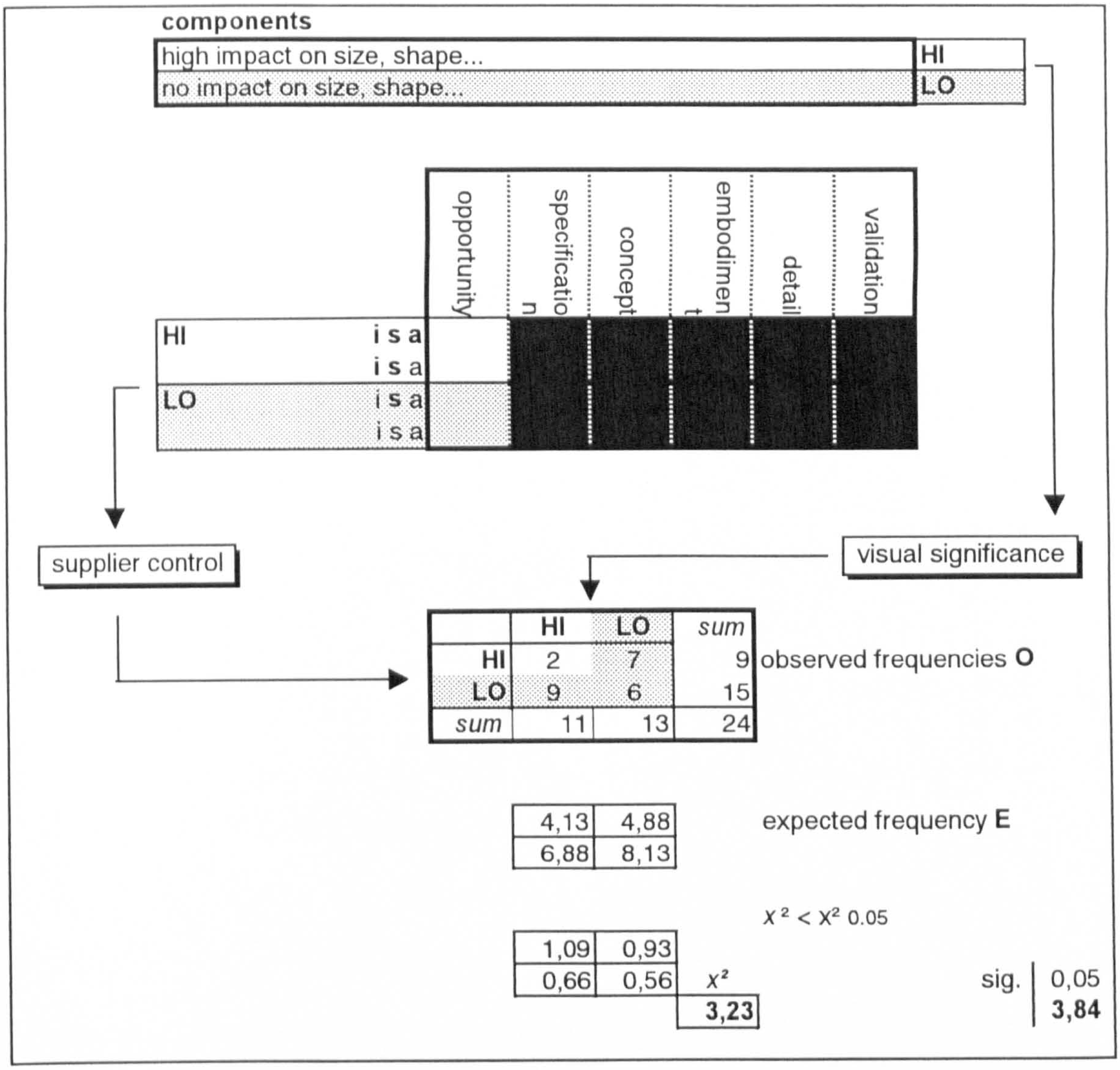


figure Appendix IV.15 significance test: supplier control - non-visible components (with impact vs. without impact on the size, shape or configuration of the final product)

Appendix V plotting variables of H2: supplier control - success

Figure V.1 shows supplier control for components that generate below average profits.

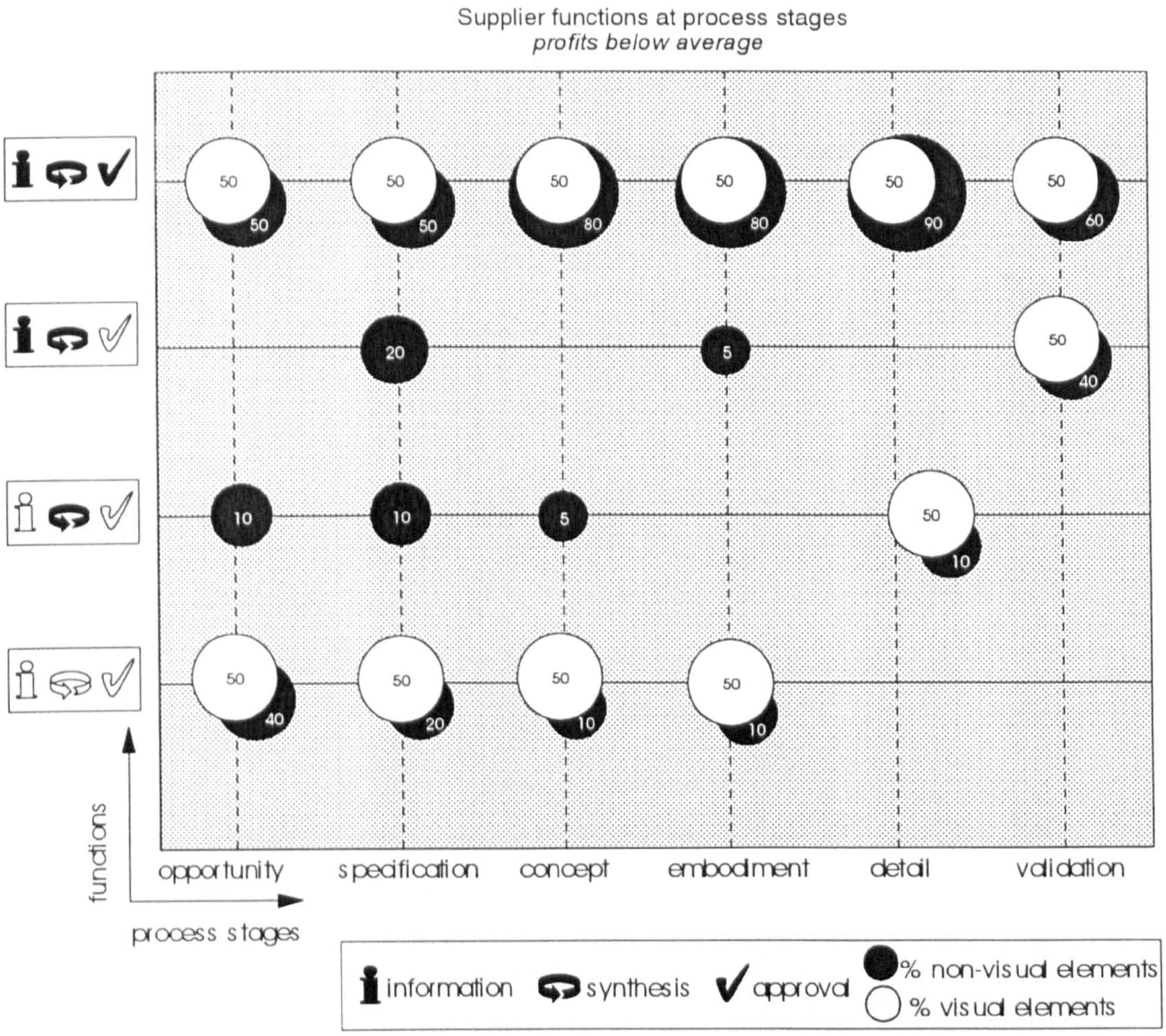


figure Appendix V.1 supplier function/ process chart: components generating below average profits

visible elements within components

From opportunity to validation stage, 50% of visible elements were developed with the supplier responsible for information, synthesis and approval.

From opportunity to embodiment stage 50% of visible elements were developed without suppliers. At the detail stage, 50% of visible elements were developed with the supplier only responsible for synthesis. At the validation stage, 50% of visible elements were developed with the supplier responsible for information and synthesis.

non-visible elements within components

At the opportunity and specification stage, 50% of non-visible elements were developed with suppliers responsible for information, synthesis and approval. From concept to detail stage, 80-90% of non-visible elements were developed with suppliers responsible for information, synthesis and approval. At the validation stage, 60% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the opportunity stage, 40% of non-visible elements were developed without suppliers.

At the validation stage, 40% of non-visible elements were developed with suppliers responsible for information, synthesis, but not approval.

Figure V.2 shows supplier control for components that generate about average profits.

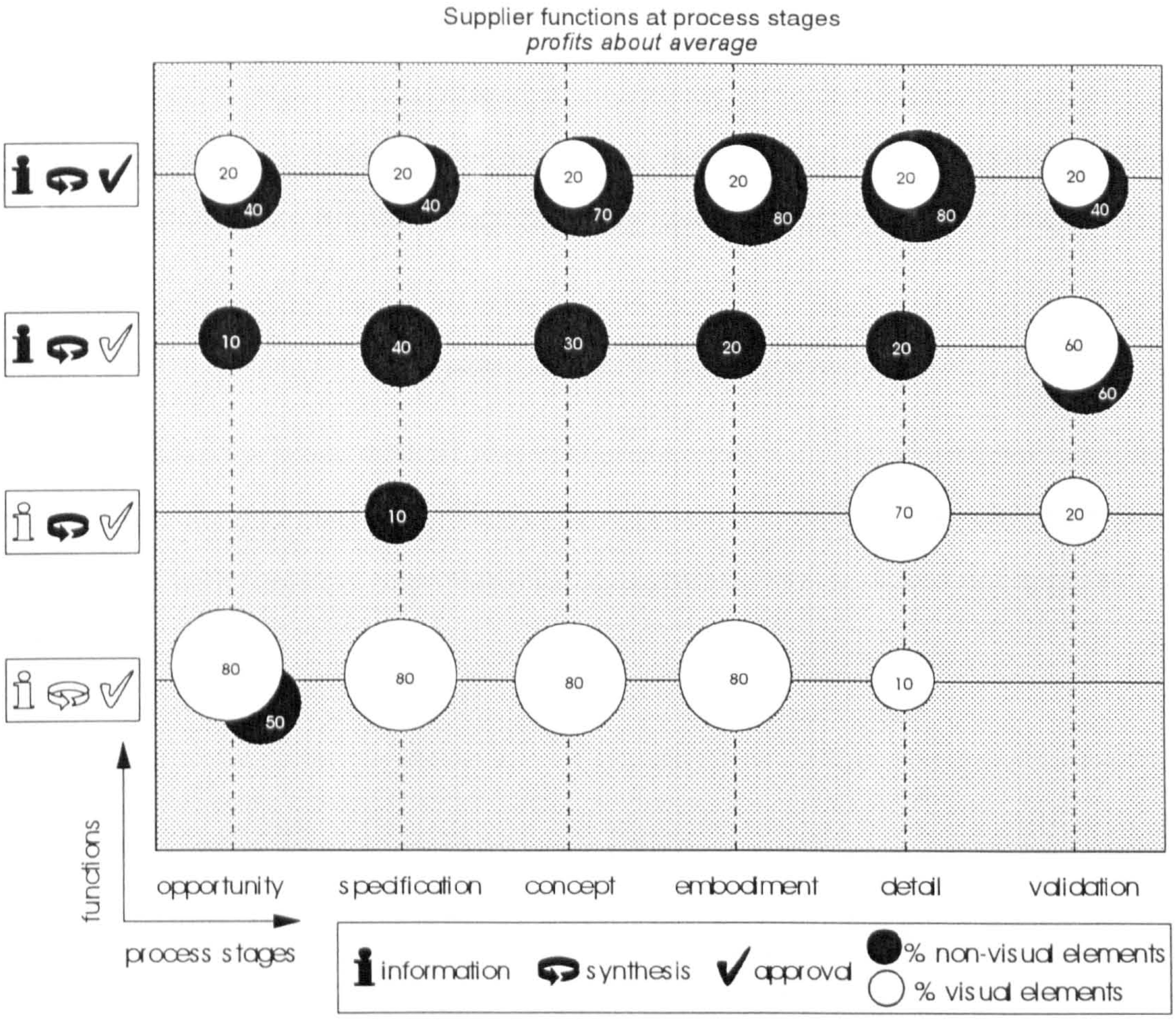


figure Appendix V.2 supplier function/ process chart: components generating about average profits

visible elements within components

From opportunity to embodiment stage, 80% of visible elements were developed without suppliers. At the detail stage, 70% of visible elements were developed with suppliers responsible for synthesis, but not for information and approval. At the validation stage, 60% of visible elements were developed with suppliers responsible for information, synthesis and not approval.

From opportunity to validation, 20% of visible elements were developed with suppliers responsible for information, synthesis and approval.

non-visible elements within components

At the opportunity stage, 45% of non-visible elements were developed with suppliers responsible for information, synthesis and approval and 45% of non-visible elements were developed without suppliers.

At specification stage, 45% of non-visible elements were developed with suppliers responsible for information, synthesis and not approval and 45% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

From concept to detail stage, 70-80% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

At the validations stage, 40% of non-visible elements were developed with suppliers responsible for information, synthesis and approval and 60% of non-visible elements were developed with suppliers responsible for information, synthesis and not approval.

Figure V.3 shows supplier control for components that generate higher than average profits.

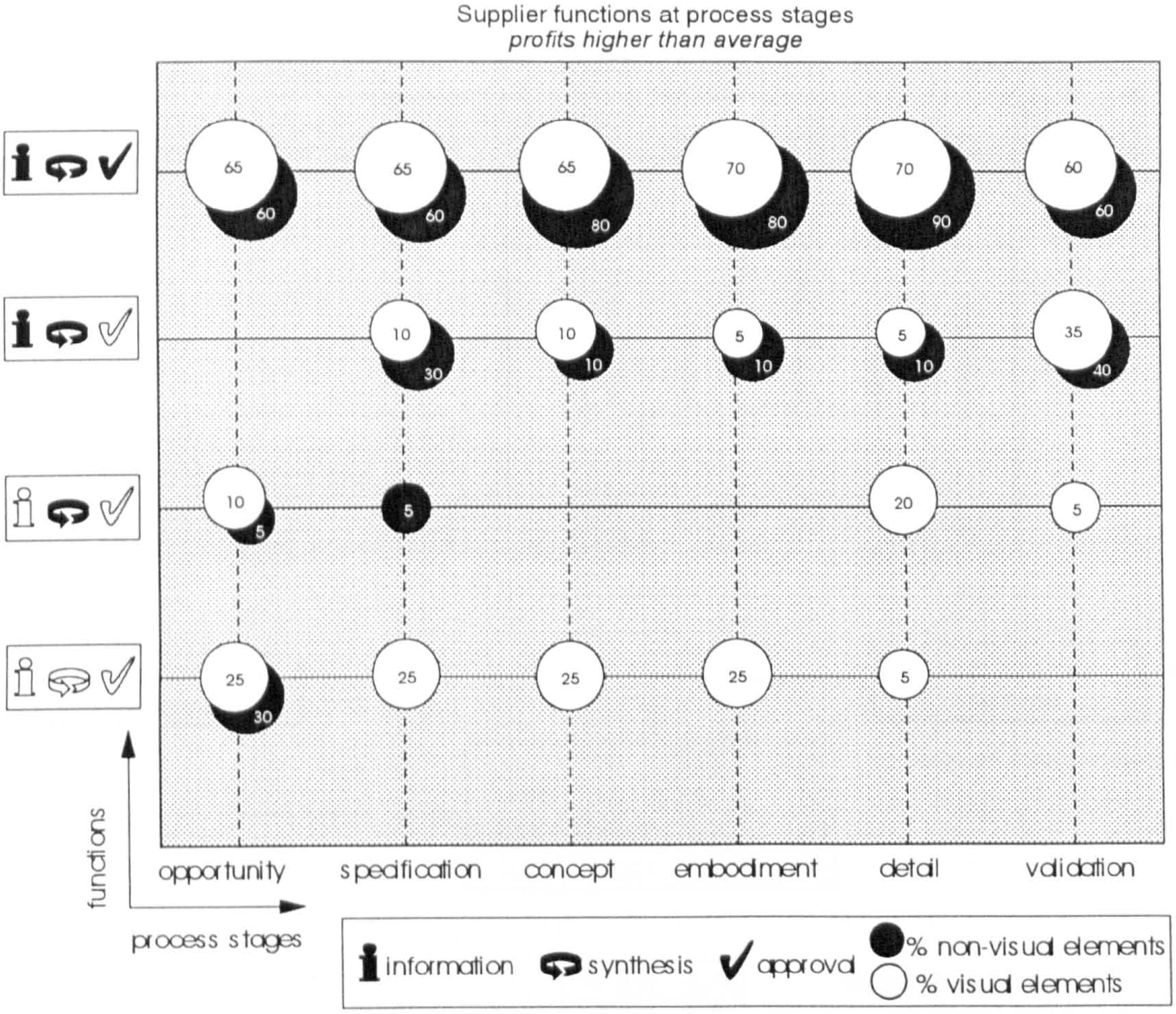


figure Appendix V.3 supplier function/ process chart: components generating higher than average profits

visible elements within components

From opportunity to detail stage, 65-70% of visible elements were developed with suppliers responsible for information, synthesis and approval.

non-visible elements within components

From opportunity to detail stage, 60-90% of non-visible elements were developed with suppliers responsible for information, synthesis and approval.

There is no evidence for a relationship between component profits and supplier control in development (see figure V.4).

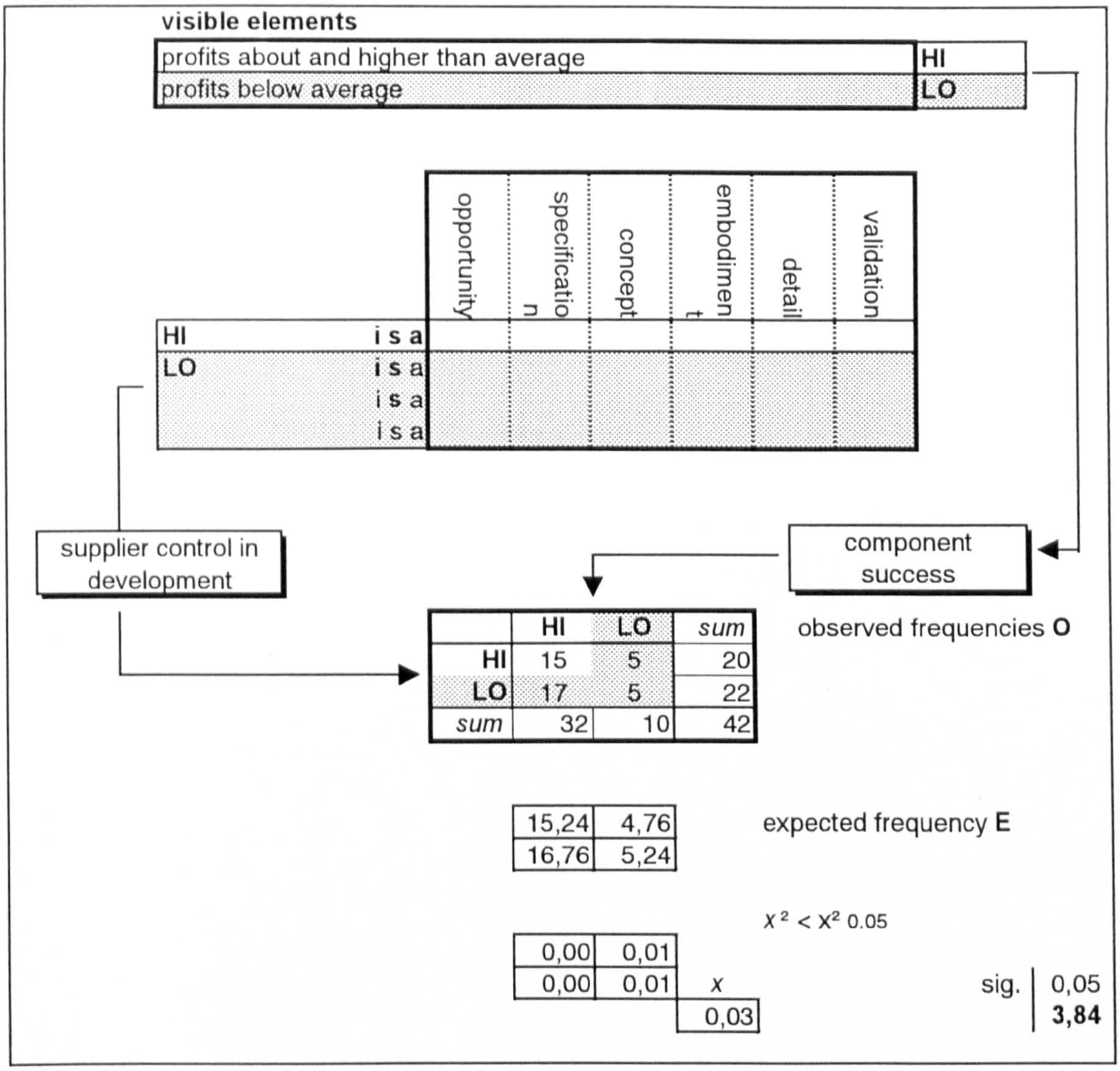


figure Appendix V.4 significance test: supplier involvement - components generating profits (about and higher than average vs. below average)

Appendix VI plotting variables of H3: visual significance - success

Appendix VI.1 customisation

Figure VI.1 shows that the percentage of components with customised form or shape is highest in the average profit category and considerably lower in the higher than average category and below average category:

components with customised form or shape:

30% in the below average category

87% in the about average category

41% in the higher than average category

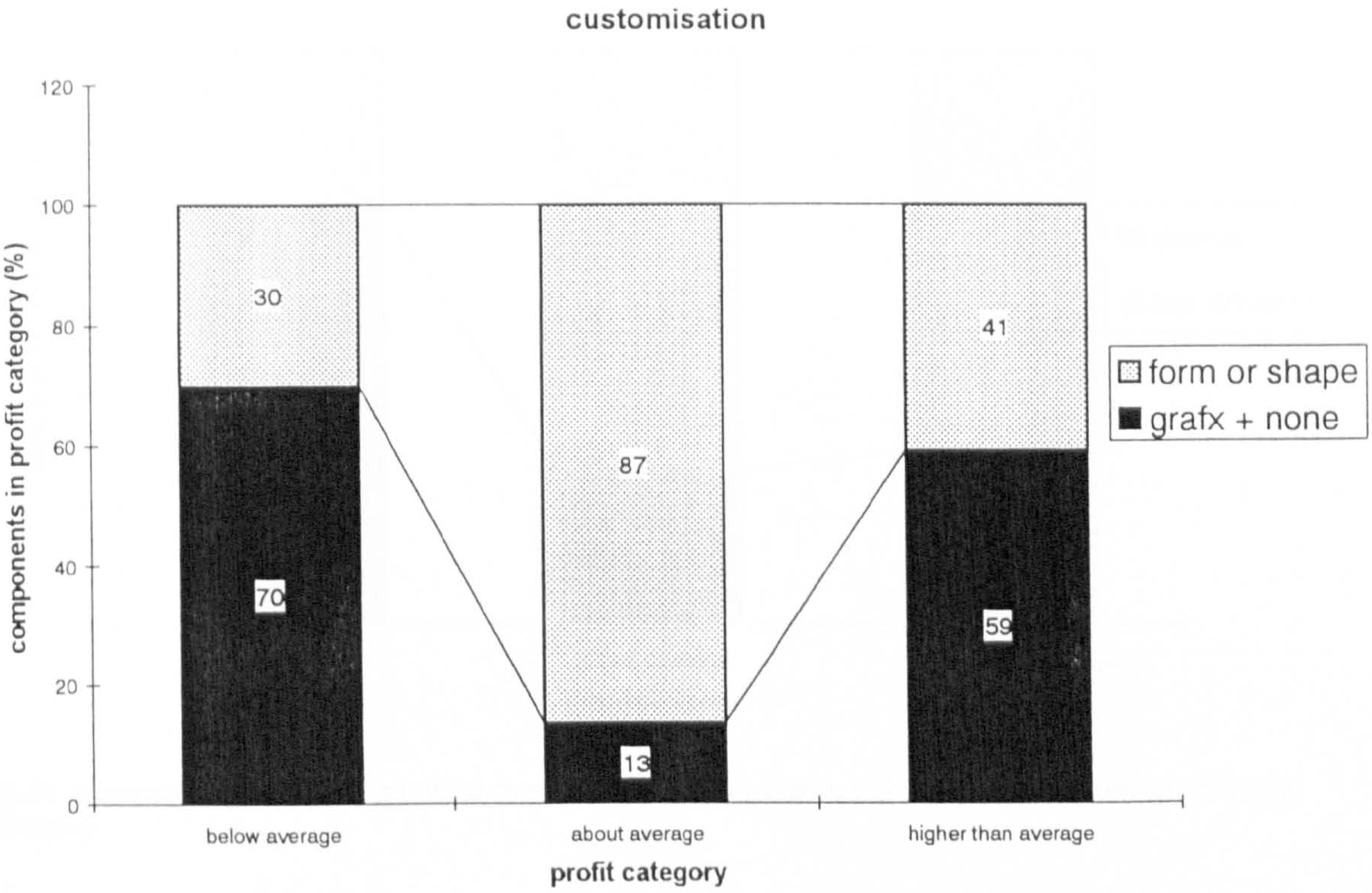


figure Appendix VI.1 bar chart showing component customisation vs. profit category

Appendix VI.2 aesthetics-driven

Figure VI.2 shows:

The majority of components that generate below average profits are components whose development is not driven by aesthetic requirements (71%).

The majority of components that generate about average and higher than average profits are components whose development is driven by aesthetic requirements (74% and 70%).

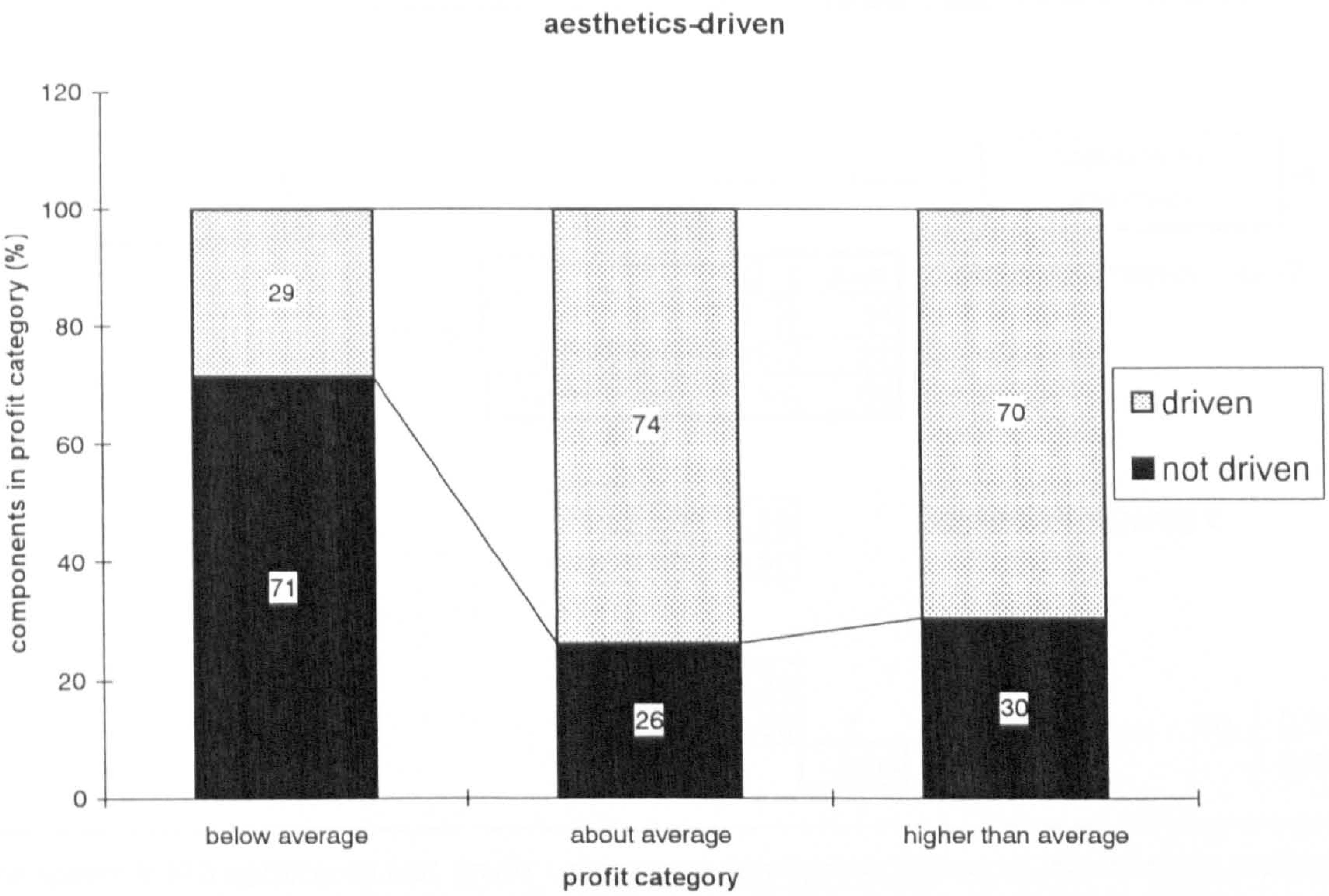


figure Appendix VI.2 bar chart showing component aesthetics-driven or not aesthetics-driven vs. profit category

There is very significant evidence for a relationship between aesthetic-driven components and component profits (see figure VI.3).

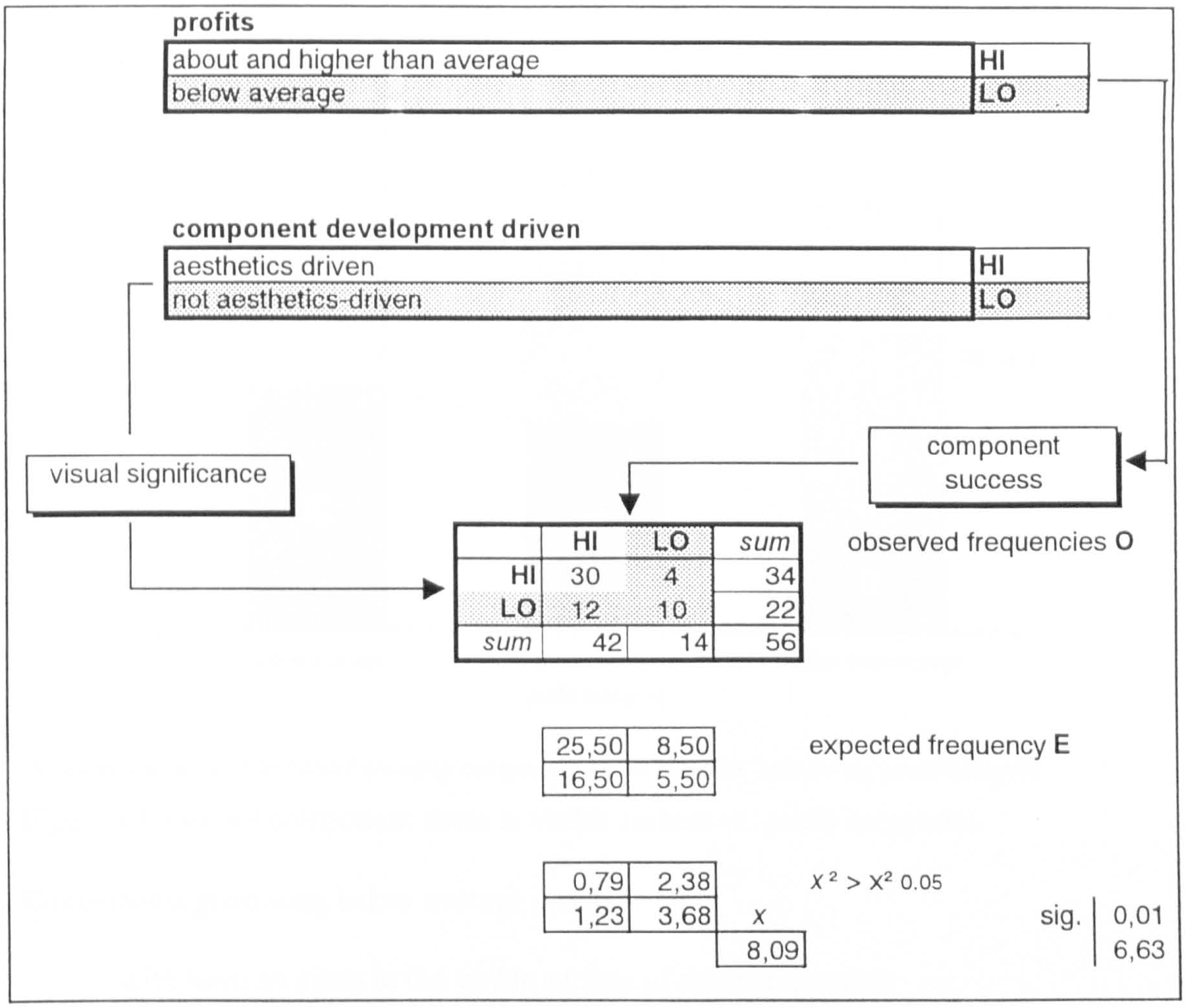


figure Appendix VI.3 significance test: profits - component development (driven vs. not driven by aesthetic requirements of the final product

Appendix VI.3 share in visible surface

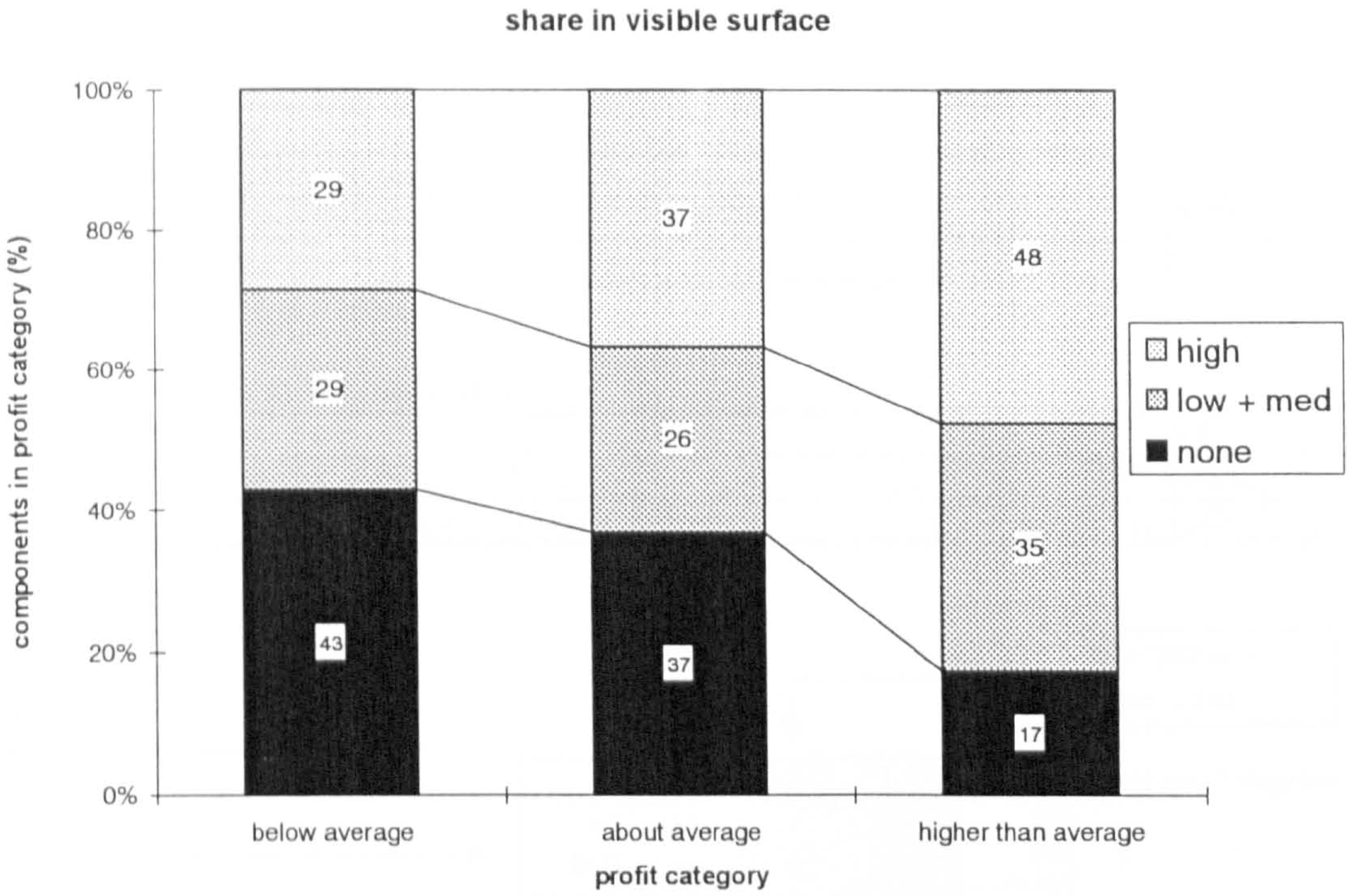


figure Appendix VI.4 bar chart showing component share in visible surface vs. profit category

Figure VI.4 shows component share in visible surface vs. profit categories.

Components generating below average profits:

43% have no share in the visible surface of the final product

29% have low or medium share in the visible surface of the final product

29% have high share in the visible surface of the final product

Components generating about average profits:

37% have no share in the visible surface of the final product

26% have low or medium share in the visible surface of the final product

37% have high share in the visible surface of the final product

Components generating higher than average profits:

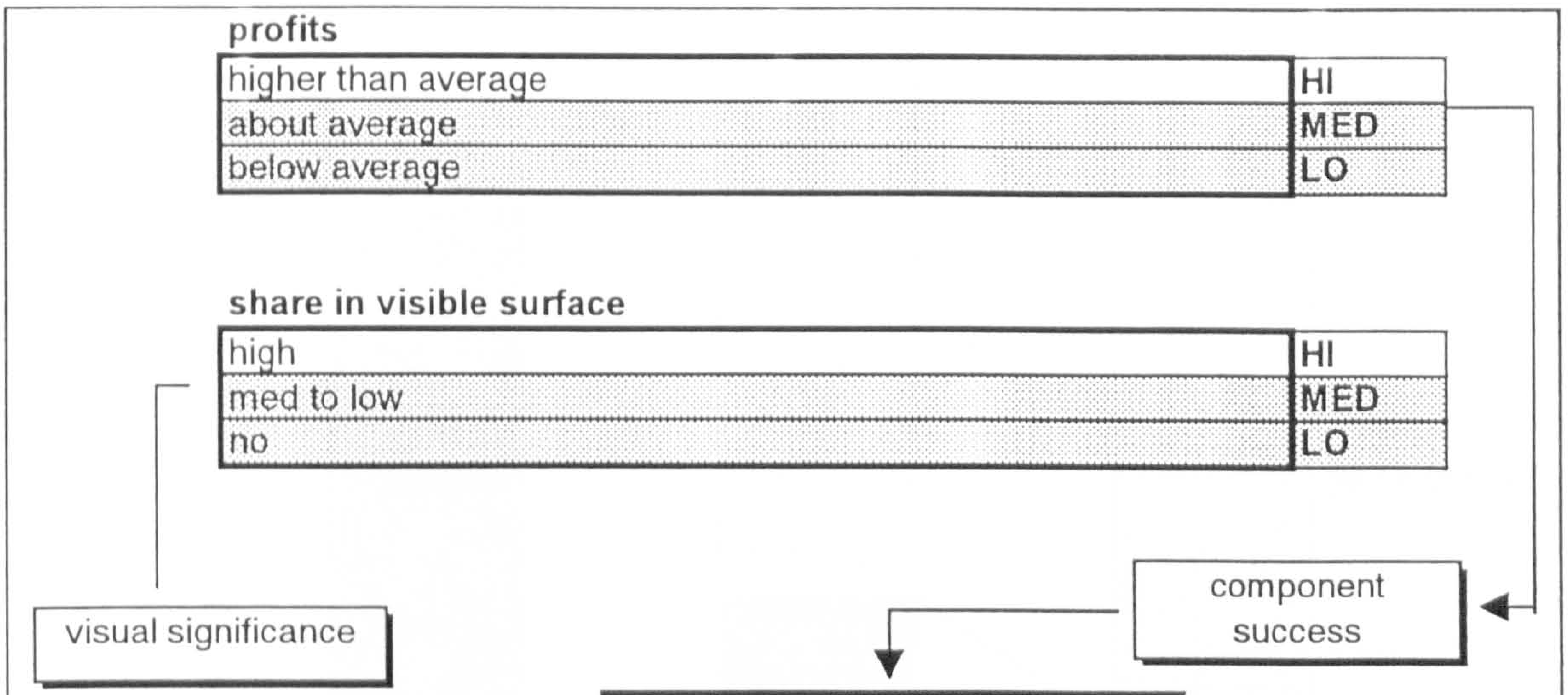
17% have no share in the visible surface of the final product

35% have low or medium share in the visible surface of the final product

48% have high share in the visible surface of the final product

Figure VI.5 shows the significant test component profits vs. share in visible surface.

There is very significant evidence for a relationship between component share in the visible surface and component profits.



observed frequencies O

	HI	MED	LO	*sum*
HI	11	7	4	22
MD	8	5	4	17
LO	4	7	7	18
sum	23	19	15	57

expected frequency **E**

8,88	7,33	5,79
6,86	5,67	4,47
7,26	6,00	2,21

$X^2 > X^2_{0.01}$

0,51	0,02	0,55				
0,19	0,08	0,05				
1,47	0,17	10,38	*X*		sig.	0,01
			13,40	0,00		11,34

figure Appendix VI.5 significance test: profits - components (high vs. medium to low vs. no share in the visible surface of the final product

Appendix VI.4 Impact on size...

Figure VI.6 shows non-visible components with and without impact on the size, shape or configuration of the final product vs. profit categories.

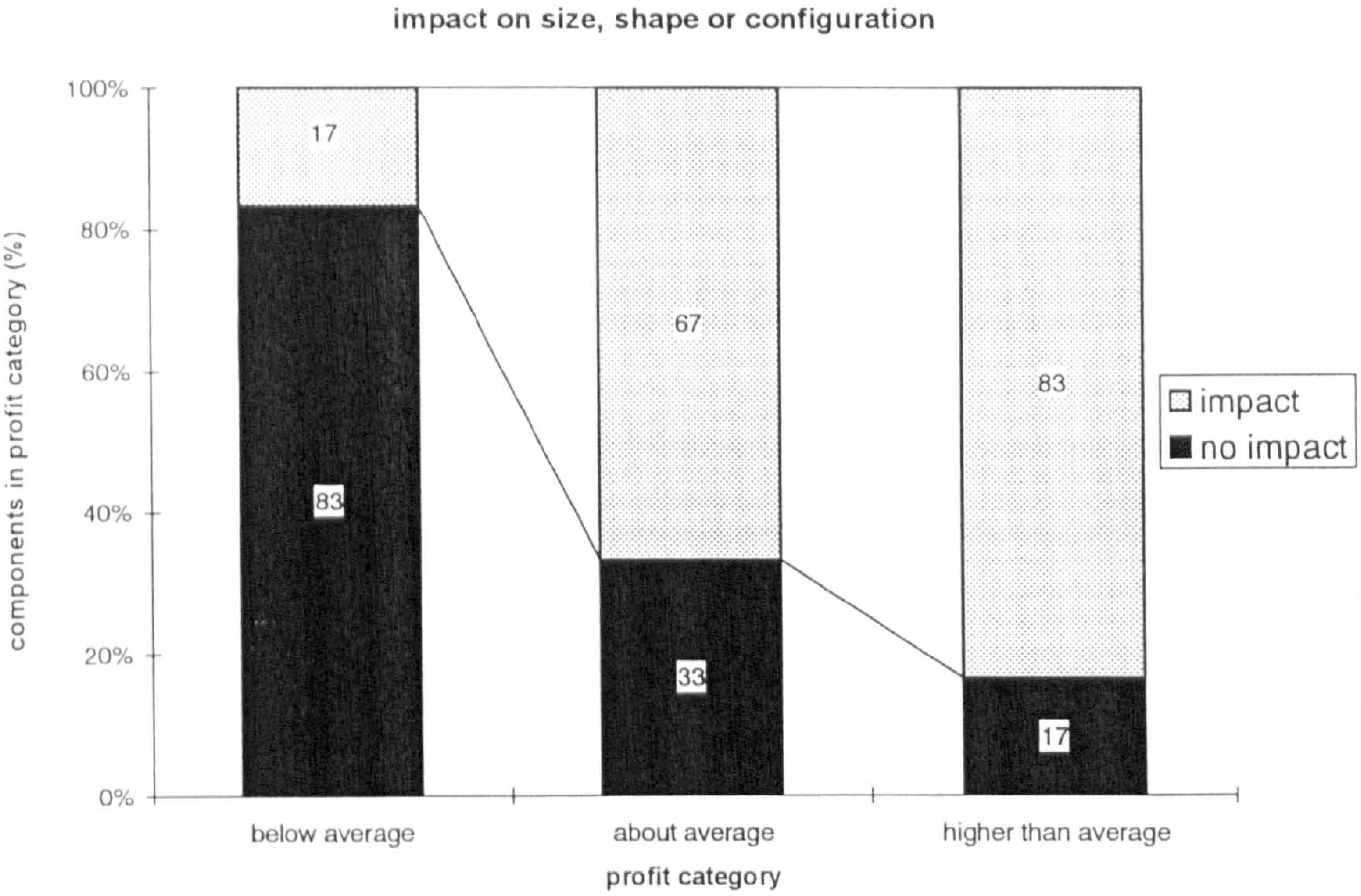


figure Appendix VI.6 bar chart showing non-visible components with and without impact on the size , shape or configuration of the final product vs. profit category

Components generating below average profits:

83% have no impact on the size, shape or configuration of the final product

17% have an impact on the size, shape or configuration of the final product

Components generating about average profits:

33% have no impact on the size, shape or configuration of the final product

67% have an impact on the size, shape or configuration of the final product

Components higher than average profits:

17% have no impact on the size, shape or configuration of the final product

83% have an impact on the size, shape or configuration of the final product

Figure VI.7 shows the significant test component profits vs. impact on size, shape....

The trend suggests that impact on size, shape or configuration of the final product affects profitability, but five of the expected frequencies are below 5. The sample size was therefore too small for statistical significance.

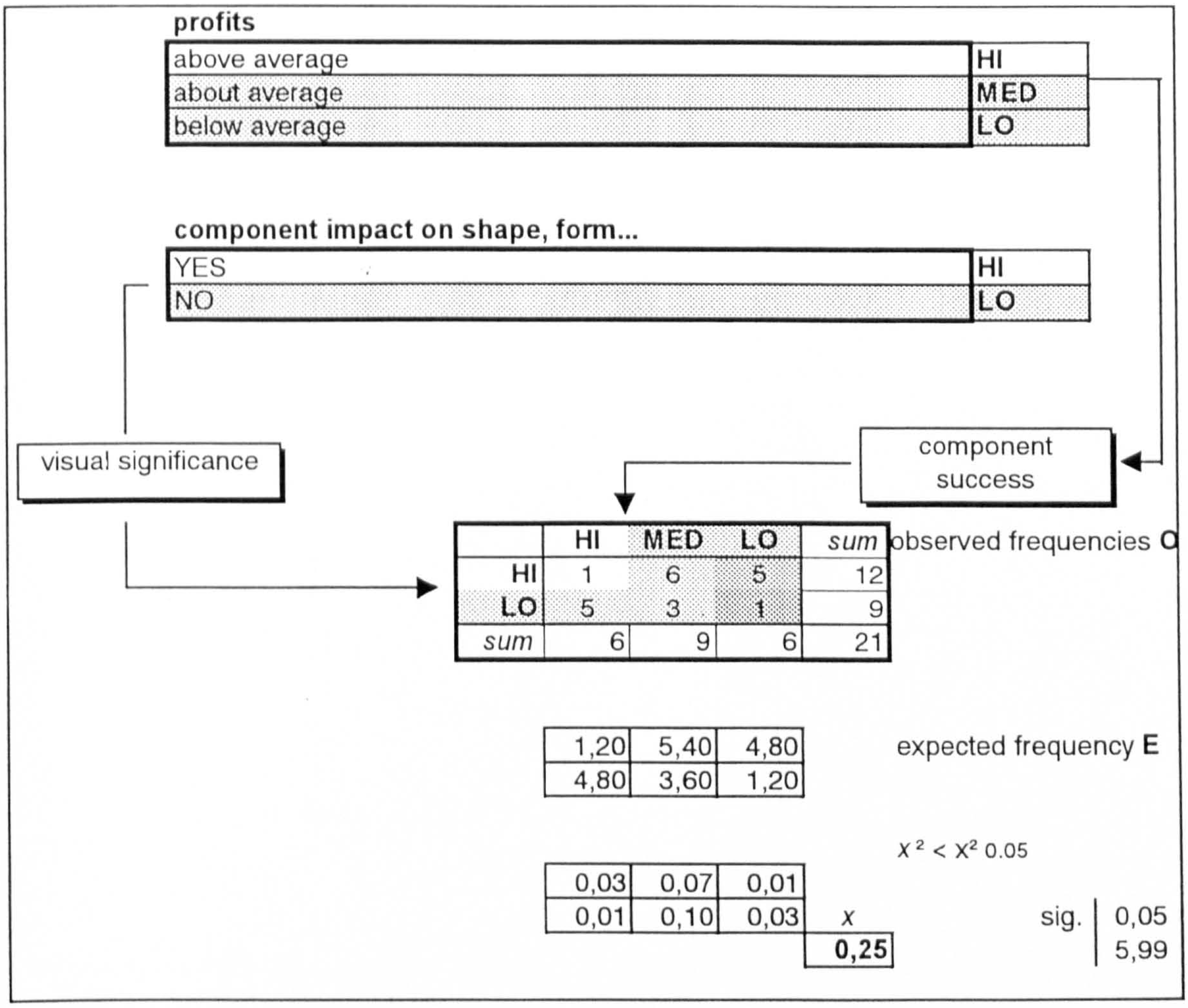


figure Appendix VI.7 significance test: profits - components (with vs. without impact on the size, shape or configuration of the final product

Appendix VII survey data

	visible elements						invisible elements								
component	oppvis	specvis	convis	provis	dimvis	validvis	opp	spec	conc	proto	dim	valid	development		
fridge	3	3	3	3	3	3	3	3	3	3	3	3	0	no supplier involvement	
dispenser shell	3	3	3	3	3	3	0	2	3	3	3	2	1	information	
Aral dispenser	0	0	0	0	1	2	0	2	3	3	3	2	2	information, synthesis	
ZVA 200 GR	3	3	3	3	3	3	3	3	3	3	3	3	3	information, synthesis	
subpump							3	3	3	3	3	3		and approval	
shearvalve							3	3	3	3	3	3			
scuba	3	3	3	3	3	3	3	3	3	3	3	3			
manifold	3	3	3	3	3	3	1	2	3	3	3	2			
hydraulic unit							3	3	3	3	3	2			
axle stub							0	2	2	2	2	2			
cool unit							0	2	2	2	2	2			
fuelcircuit							0	2	2	2	2	2			
conrod							2	2	2	2	2	2			
seatvalve	0	0	0	0	1	1	3	3	3	3	3	3			
flask	1	2	2	2	3	2									
upsensor	0	0	0	0	0	1	0	2	3	3	3	2			
motionsensor	0	0	0	0	0	1	0	2	3	3	3	2			
kettleshell	0	0	0	0	1	2									
pricesign	0	0	0	0	1	2	2	2	3	3	3	3			
führerhaus	0	0	0	0	1	2	0	0	1	2	3	3			
trolleywheel	3	3	3	3	3	3	3	3	3	3	3	3			
dimmerprog	3	3	3	3	3	3	3	3	3	3	3	3			
dimmerswitch2	3	3	3	3	3	3	3	3	3	3	3	3			
dimmerswitch1	3	3	3	3	3	3	3	3	3	3	3	3			
türgummilasch							1	2	3	3	3	2			
Instrutafel	0	0	0	0	1	2	0	2	2	3	3	2			
hängetast	3	3	3	3	3	3	3	3	3	3	3	3			
boxelectronics	3	3	3	3	3	3	3	3	3	3	3	3			
buttons	3	3	3	3	3	3	3	3	3	3	3	3			

figure Appendix VII.8 survey data on development of visible and non-visible components.

	visible elements						invisible elements								
component	oppvis	specvis	convis	provis	dimvis	validvis	opp	spec	conc	proto	dim	valid			
cntrl seat2	3	3	3	3	3	3	3	3	3	3	3	3	**development**		
cntrl seatSiem	1	2	2	3	3	2	1	2	2	3	3	2	0	no supplier involvement	
joystick	3	3	3	3	3	3	3	3	3	3	3	3	1	information	
safetylocks	3	3	3	3	3	3	3	3	3	3	3	3	2	information, synthesis	
rolladenschalt	3	3	3	3	3	3	3	3	3	3	3	3	3	information, synthesis	
rolladenantrieb							3	3	3	3	3	3		and approval	
schutzschalter	3	3	3	3	3	3	3	3	3	3	3	3			
industrstecker	3	3	3	3	3	3	3	3	3	3	3	3			
lamellendach	3	3	3	3	2	2	3	2	3	3	3	2			
VWschloß	0	0	0	0	1	2	3	3	3	3	3	3			
BMWSitz	0	0	0	0	1	2	0	1	3	3	3	2			
VWSitz	0	0	0	0	1	2	0	1	3	3	3	2			
Fenstermotor							3	3	3	3	3	2			
viscodrive							0	2	3	3	3	2			
gelenkwelle							0	1	3	3	3	2			
wegfahrsperre	0	0	0	0	1	2	0	1	3	3	3	2			
thermostatmod							0	2	2	2	2	2			
thermostat							3	3	3	3	3	3			
gurtautomat	0	0	0	0	1	2	3	3	3	3	3	3			
ERCOEVG	0	0	0	0	1	2	0	2	3	3	3	2			
Adapter	0	0	0	0	1	2	0	0	0	0	1	2			
träger	0	0	0	0	1	2									
VG CuFe							3	3	3	3	3	3			
Fassung							3	3	3	3	3	3			
Installträger							0	1	2	3	3	2			
reflektor							0	0	0	0	1	2			
blendrahmen	0	0	0	0	1	2									
K-Deckel	0	0	0	0	1	2									
AL Gehäuse	0	0	0	0	1	2									

figure Appendix VII.9 survey data on development of visible and non-visible components.

		visual significance						
component	profit	customisatn	driven by vis	share	impact			
fridge	1	1	2	2		**profits**		
dispenser shell	1	1	1	2		1	below average	
Aral dispenser	3	2	2	2		2	about average	
ZVA 200 GR	3	1	2	1		3	higher than average	
subpump	2	1	1	0	1			
shearvalve	3	2	2	0	2	**visual significance**		
scuba	3	1	1	1		0	none	
manifold	1	1	1	1		1	low	
hydraulic unit	3	1	1	0	1	2	high	
axle stub	2	2	2	0	2			
cool unit	3	2	2	0	2			
fuelcircuit	2	2	1	0	1			
conrod	2	2	1	0	1			
seatvalve	2	2	2	1				
flask	3	1	2	1				
upsensor	3	2	2	0	2			
motionsensor	2	2	2	0	2			
kettleshell	3	2	2	2				
pricesign	3	2	2	2				
führerhaus	2	2	2	2				
trolleywheel	1	1	1	1				
dimmerprog	3	1	2	1				
dimmerswitch2	2	1	2	1				
dimmerswitch1	1	1	1	1				
türgummilasch	1	2	1	0	1			
Instrutafel	2	2	2	2				
hängetast	3	1	2	2				
boxelectronics	3	1	2	2				

figure Appendix VII.10 survey data on visual significance and component success.

		visual significance						
component	profit	customisatn	driven by vis	share	impact			
buttons	3	1	2	1		profits		
cntrl seat2	3	1	1	2		1	below average	
cntrl seatSiem	3	1	1	2		2	about average	
joystick	3	1	1	1		3	higher than average	
safetylocks	3	1	1	1				
rolladenschalt	3	1	2	2		visual significance		
rolladenantrieb	1	1	1	0	1	0	none	
schutzschalter	3	1	1	1		1	low	
industrstecker	2	1	1	1		2	high	
lamellendach	3	2	2	2				
VWschloß	2	2	2	1				
BMWSitz	3	2	2	2				
VWSitz	1	2	2	2				
Fenstermotor	1	2	2	0	2			
viscodrive	2	2	2	2				
gelenkwelle	2	2	1	0	1			
wegfahrsperre	1	1	1	0	1			
thermostatmod	1	1	1	1				
thermostat	3	2	2	2				
gurtautomat	1	2	2	2				
ERCOEVG	2	2	2	2				
Adapter	1	1	1	0	1			
träger	1	1	1	0				
VG CuFe	2	2	2	2				
Fassung	2	2	2	0	2			
Installträger	2	2	2	1				
reflektor	2	2	2	2				
blendrahmen	2	2	2	2				
K-Deckel								
AL Gehäuse								

figure Appendix VII.11 survey data on visual significance and component success.

Appendix VIII bibliography

Title:Product Design: A practical guide to systematic methods of new product design and development

Author: M.R. Baxter

Date: 1996

Publisher: Chapman& Hall

ISBN 0-412-63230-6

Abstract: This text should be useful for anyone involved in the design of new products for manufacture. It offers both a systematic and practical approach to the development of new products. It offers a way of tracking the often haphazard and unstructured task of developing new products for manufacture, Special features of this edition include: practical step-by-step introductions on systematic design mehtods; structured approach to product styling; Comprehensive coveragecoverage from business planning to detail design; usage of familiar products as examples.

This book should be of interest to technical/ product development managers of manufacturing companies, business/ technology/ design advisors and consultants; professional designers and members of the Chartered Society of Designers/ Institute of Engineering Design.

Title: Survival of the fittest: New product development

Author: Philip A Himmelfarb

Date: 1992

Publisher: Prentice Hall

ISBN: 0-13-879313-1

Abstract: By shortening the time it takes to develop a product, companies can increase profits. This book outlines strategies such as parallel marketing, R&D, manufacturing and finance projects, continuous development and targeting small advances, designed to achieve this end.

Title: World-class new product development: Benchmarking best practices of agile manufacturers

Author: D. Dimanescu, K. Dwenger

Date: 1995

Publisher: Amacon

ISBN: 0-8144-0311-5

Abstract: This volume explores 12 management practices that are revolutionising the way products are now being developed in discrete manufacturing companies in Japan, North America and Europe. Each is documented, provable and repeatable.

The book documents seven years of benchmarking best practices, drawn from 60 of the leanest, most flexible and most robust companies in the world, it identifies an effective new style of management that merges total quality, concurrent engineering and process-reengineering practices, and provides a complete plan for improving product development, including how to: execute the concept of `holistic management´ of complete systems, replicate best practices in product development applied in world-class companies, manage product development as a strategic process and implement ideas that can lead to improvements consistently.

Title: New product development: Design and analysis

Author: Ronald E Kmetovicz

Date: 1992

Publisher: John Wiley & Sons

ISBN: 0-471-55536-3

Abstract: Designed to help project managers and design engineers deliver new products within budget, this study demonstrates how to integrate the best available tools with appropriate techniques in order to satisfy design objectives, market considerations and cost constraints.

Title: New product development: Managing and forecasting for strategic success

Author: R.J. Thomas

Date: 1992

Publisher: John Wiley & Sons

ISBN: 0-471-57226-8

Abstract: For increasing numbers of organisation, new product development is a priority concern, intense global competition, rapid technological change and mutating patterns of world market opportunities compel firms to continually revitalise products and services for existing and new markets – if not for profit, for survival. However, the risks of new product development are legendary. New products that fail to make the enable manufacturer to gain control of the process and develop reliable forecasts. Providing an original conceptual approach and logical programme of action for new product development and forecasting, this book links the art (development) and science (measurement) of new production. The author details a reliable and useful control framework for decision makers, which includes spreadsheet models, planning steps and examples.

Title: New product development: A multi-functional process

Author: Tim Jones

Date: 1996

Publisher: Butterworth Heinemann

ISBN: 0-7505-2427-2

Abstract: This text provides a unique cross-discipline approach to new product development. It looks at product development from all angles – research, design, engineering, marketing – and then, in turn, by management, purchasing, finance and quality personnel. It looks at the key stages and functions involved and discusses the contribution of each discipline, and points towards a means to encourage effective co-operation.

Title: The PDMA handbook of new product development

Edited: Miltion D. Rosenau Jnr

Date: 1995

Publisher: John Wiley & Sons

ISBN: 0-471-14189-5

Abstract: As traditional production is exported more and more to Pacific rim countries, successful product development is an essential ingredient of business success for the west.

Written by academic experts and industry professional from Fortune 1,000 companies, this text examines every area of product development and formulates the best practices in the 1990's

Title: Product design and manufacture

Author: J.R. Lindbeck

Date: 1994

Publisher: Prentice Hall

ISBN: 0-13-034257-2

Abstract: This text covers design history, aesthetics ergonomics and applications of technology, presenting real-world examples.

Title: Product design: fundamentals and methods: Product design and planning, development and engineering.

Author: N.F.M. Roozenburg, J. Eekels

Date: 1995

Publisher: John Wiley & Sons

ISBN: 0-471-95465-9

Abstract: This is a self contained treatment of product development, which covers not only strategy and planning but also engineering aspects and problem-solving techniques. The rules, methods and models are not presented as a tailor-made manual, but are accompanied by methodological deliberations, in which background information and the designer's original concepts are explained.

Title: Product development environment: A Design Council Title

Author: Paul Burall

Date: 1995

Publisher: Gower Publishing Group in Association with Design Council

ISBN:0-566-07659-4

Abstract: Environmental concerns are creating new threats and opportunities for business. This is a practical guide for managers and designers seeking to exploit expanding markets for the efficient and clean products demanded by a world seeking a sustainable future. Legal issues are also covered.

Title: Successful productdesign: What to do and when

Author: Bill Hollins, Stuart Pugh

Date: 1990

ISBN: 0-408-03861-6

Abstract: Describe how to organise the management of the design process, putting forward a highly structured approach that directs this process to ensure optimisation of the best product. The book is aimed at industrial designers and managers, technical directors and operations managers.

Title: Total design: Integrated methods for successful product engineering

Author: Stuart Pugh

Date: 1991

Publisher: Addison-Wesley

ISBN: 0-201-41639-5

Title: Winning by design: Technology, product design and international competitiveness

Author: Vivien Walsh, Robin Roy, Stephen Potter

Date: 1992

Publisher: Blackwell

ISBN: 0-631-18511-9

Abstract: The crucial role of product design in international competition is only now becoming fully appreciated. Based on a wide range of research in over 100 leading companies, this book describes and analyses from a new perspective how good product design contributes to competitiveness and profitability.

Title: Innovation management and new product development

Author: Paul Trott

Date: 1998

Publisher: Financial Times Pittmann Publishing

ISBN: 0-273-63111-X

Abstract: This work is an introduction to the process and issues of managing technical innovation and the development of new products. I uses international mini-cases including: the development of Guiness „in-can" system, Gilette Sensor and 3M.

Title: Managing new product and process development: Text and cases

Author: K.B. Clarke, H.G. Figgle, S.C. Wheelright

Date: 1992

Publisher: Free Press

ISBN: 0-02-905517-2

Abstract: Argues that a company's capability to conceive and design quality prototypes and bring a variety of products to market more quickly than its competitors is increasingly the focal point of competition. The authors present principles for developing speed and efficiency.

Title: Managing the new produc development process

Author: R.J. Dolan

Date: 1993

ISBN: 0-201-52627-1

Title: New food product development: From concept to marketplace.

Author: G.W. Fuller

Date: 1994

Publisher: CRC Press

ISBN: 0-8493-80002

Abstract: Providing an overview of the often chaotic, and frequently unpredictable new food development process, this text describes the stages of development from the vantage points of the technologist, marketer and senior management. It covers the various stages of product development , including generating and shifting ideas against the company's objectives, the consumer's perceived needs and expectations, the competitiveness of the marketplace, the technologist's ability to create and manufacture a safe product within budget and test marketing. Problems facing both small and large companies are confronted and solutions are proposed.

Title: Design & corporate success

Author: Clive Rassam

Date: 1995

Publisher: Gower Publishing Group

ISBN: 0-566-07534-2

Abstract: This volume aims to show how influential good design can be from the viewpoint of leading British product designers, corporate identity specialists and senior company executives. It includes interviews with designers and corporate identity experts and contributions from senior managers at Rover, Black&Decker, Electrolux, International furniture maker Steelcase Strafor, plus four export-led SMEs. Drawing on their experience, the book shows how successful companies use good design to their own advantage and why designing the right product of corporate identity requires changes in approaches and attitudes.

Title: Design methods in engineering and product design

Author: Ian Wright

Date: 1997

Publisher: McGraw-Hill

ISBN: 0-07-709376-3

Abstract: Using both industrially-based and specially prepared case studies and assignments, this book aims to help students understand the methods that designers use to collect, evaluate and process information. This text aims at a broad coverage of design methods in order to explain the transfer of information between methodologies and it provides assignments and solutions so that students can practice applying the methods.

Title: Engineering Design methods: Strategies and tactics for product design

Author: N. Cross

Date: 1993

Publisher: John Wiley & Sons

ISBN: 0-471-942286

Abstract: Including new topics and more recent examples of applications, this is the second ambition of a book concerned with the fundamental approaches to design, such as problem formulation and design embodiment. Divided into three parts, it discusses the nature of design for engineering, covers with various methods and deals with strategic design.

Title: Fashion design and product development

Author: Harold Carr, John Pomeroy

Date: Blackwell Science (UK)

ISBN: 0-632-02893-9

Abstract: Sets out to explain fashion design and product development as an integrated process, the function of which is to market a continuous stream of garments at a profit. It explores materials, manufacture, costs, quality and the organisation of the design and development.

Title: Human factors in consumer product design and evaluation

Edited: Neville Stanton

Date: 1998

Publisher: Taylor & Francis

ISBN: 0-7484-0602-6

Abstract: The text aims to provide a comprehensive and informative view of how human factors are applied successfully to the design and evaluation of consumer products. It illustrates by way of case studies how consumer products are designed and evaluated, emphasising the use of methods and techniques with supportive evidence of their efficiency.

Title: Integrated product and process development: Methods, tools and techniques

Author: Hamid Parsael, John M Usher, Uptal Roy

Date: 1998

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