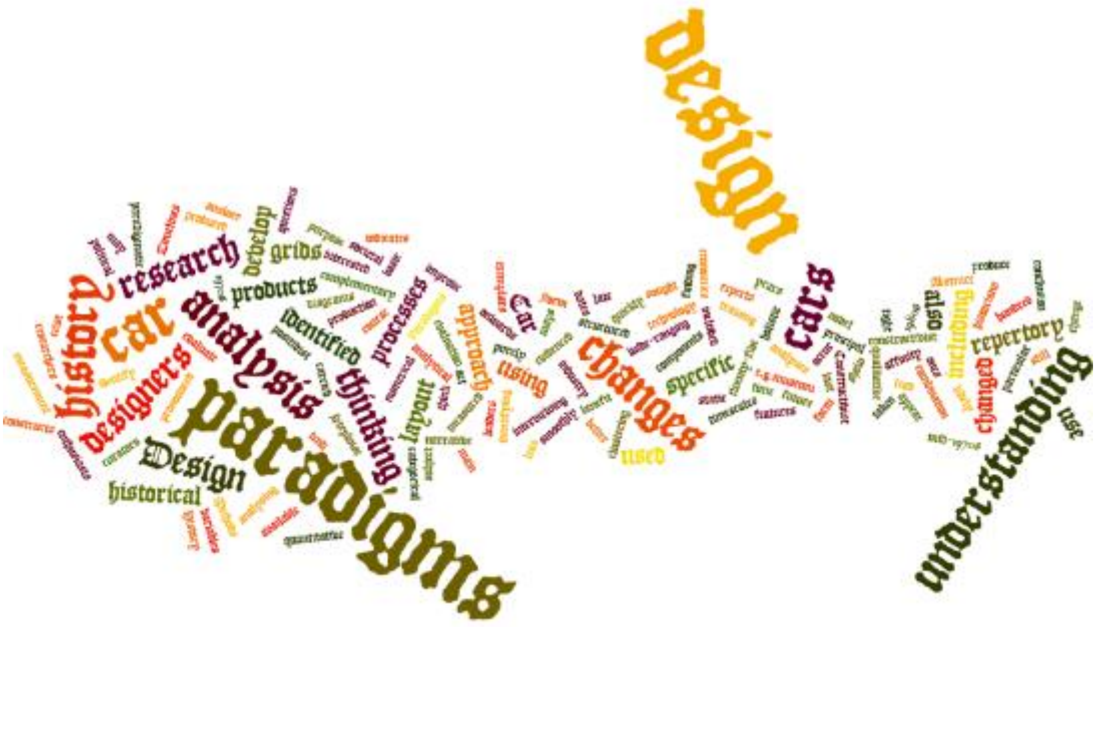
Design Paradigms in Car History

Chris Dowlen

Abstract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Abstract

The purpose of this research into Design Paradigms in Car History is to evaluate how production car design has changed over the last hundred and twenty-five years or so, using numerical analyses of specific cars, which act as exemplars. This evaluation should lead to a better understanding of car design history and how car designers think. Design thinking can be evidenced from how products have changed over the course of time. Design paradigms have been used to produce a structured analysis of these products (cars) to develop a more holistic understanding of design history than may be available from a purely narrative approach.

The research sought to answer some basic questions, including what are design paradigms, when did specific ones appear, and when, why and how quickly did they change?

A positivist, quantitative analysis was carried out, analysing over 500 cars from 1878 to 2013 for layout and form design, using a categorical principal components analysis. Timelines and maps were produced identifying paradigms, changes and timescales. A complementary qualitative approach was taken, interviewing car experts – historians, designers, industry leaders and enthusiasts – to identify their constructs on car history and design. Methods used included affinity diagrams and a novel use of repertory grids.

Car design paradigms were identified from static layout variables, from about 1904 to 1934, from the mid-1970s onwards, and less pronounced from the late 1930s to the 1980s. These show tight clustering of features. Stepwise changes tend to occur between paradigms. Form changes more smoothly, but still indicates likely dates and paradigmatic thinking. Constructivist analysis identified further wide-ranging paradigms, including societal changes, technology, political and economics.

The main conclusion of this research was that design paradigms not only exist, but they can also be measured and this measurement can improve historical understanding.

This finding will benefit not only those interested in cars and their history, e.g.museum curators and those training future designers, but also other researchers, who could use a combination of both analytical and constructivist processes, in particular repertory grids, to develop their subject thinking and understanding of historical processes.

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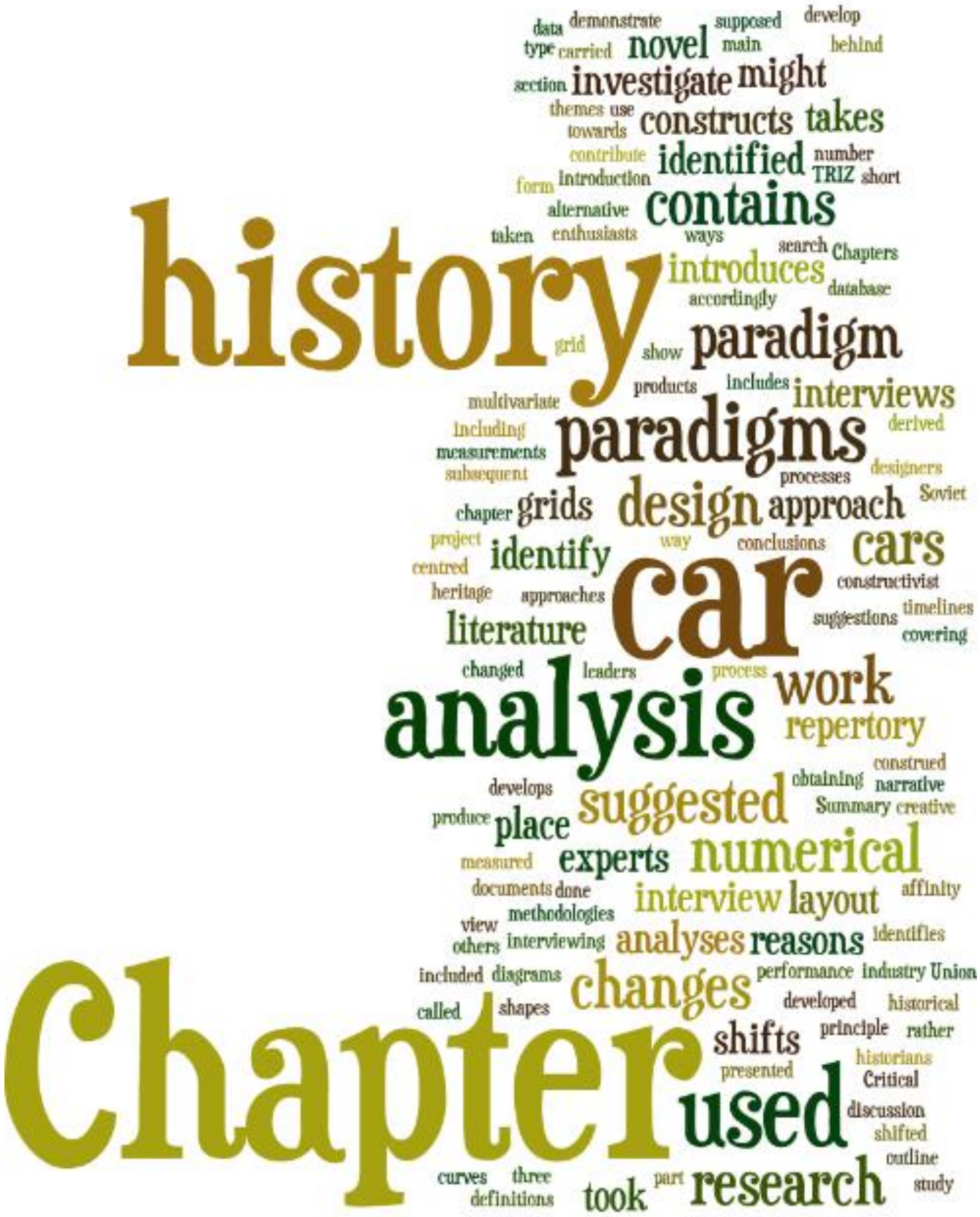
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Summary

This research project is about car history. After a short introduction in Chapter 1, Chapter 2 develops definitions for paradigm, design, car and history. Chapter 3 introduces the research methodologies that are used in the main part of the work. Chapter 4 introduces some themes before the analysis is presented. Chapter 5 contains a literature search covering an outline of car history, car history literature and documents that identify numerical approaches to the study of history.

The novel work is centred on Chapters 6, 7 and 8. Chapter 6 contains the numerical analyses, Chapter 7 an analysis of interviews, including a novel use of repertory grids, and Chapter 8 identifies paradigms, paradigm shifts and the reasons behind these shifts.

The approach taken in Chapter 6 has been to identify how measurements of cars contribute to a history rather than obtaining the history from narrative. A database of 571 cars from 1878 to 2013 was used. They were measured and multivariate analyses used to produce timelines for car layout and form. The shapes of the curves identified design paradigms, when these paradigms changed (or shifted) and how those changes took place.

The creative process called TRIZ that was developed in the Soviet Union includes a section on the way in which products are supposed to develop. It had been suggested that historical performance analysis of cars might not demonstrate this, and accordingly, such an analysis was carried out.

The interview analysis in Chapter 7 takes a constructivist view of car history derived from the constructs of a number of experts in car history and design and takes an alternative approach towards how car history and heritage are construed. This is done through interviewing experts – car historians,

designers, industry leaders and enthusiasts – to investigate their constructs. The interviews included affinity diagrams and repertory grids, and these grid processes were used in the subsequent interview analysis.

In Chapter 8 three principle layout paradigms are identified from the numerical data and others are suggested. The type of paradigm changes show where to investigate reasons why changes took place and these are suggested.

Critical discussion is in Chapter 9, and chapter 10 contains conclusions and suggestions for further work and ways in which the research might be used.

1 Introduction

1 Introduction

1.1 Background

Cars have always been a personal interest. From pre-school years most car models could be identified clearly. This interest grew into a degree in Automotive Engineering, supported by the then British Leyland group, and to several years in the motor industry, largely with Triumph Cars and BL Technology Ltd.

A significant amount of general tacit understanding of car history had been developed during this process, and when moving from the automotive industry into higher education it seemed appropriate that this understanding should, in some way, be passed on to students.

This particular project developed from a desire to produce a coherent car history for Engineering and Design students. The initial approach was to develop a set of colour slides of cars, illustrating their development by selecting significant models and trends. These were used to identify the way that design and engineering changes had taken place over the whole of car history from the late 19th century to the then current point, which was the late 1980s. The colour slides were either taken from car history books or from examples photographed in museums or in the street. However, this approach lacked coherent themes and analysis and was felt to be somewhat unsatisfactory, although publications had been written on how car history might be used to develop designers and engineers (Dowlen, 1997a, Dowlen, 1997b).

In those early days a car history theme started to be developed, which was that of the design paradigm. This topic, applied firstly to structural design, formed the basis of a short paper (Dowlen, 1995) and then was defined more coherently in a later paper which was illustrated by early cars (Dowlen, 1999).

In terms of form, integration seemed to form a coherent theme that brought together reasons for the visual developments that were seen.

Although many histories of cars have been produced, it would seem that the approach that they tend to take is to use significant events and individuals to tell that story (Sparke, 2002). Alternatively, books may focus on a single period (Burgess-Wise, 2006), may tell the story of one particular manufacturer such as Jaguar (Buckley, 1998), or may consist of a useful set of catalogue facts (Culshaw and Horrobin, 1997). All these approaches have their uses, but they were not the approach that was wanted in this case.

This project conjectures that by studying the end efforts of car creators, both designers and engineers, their thinking patterns can, to some extent, be made evident. Thus the first approach to car history is to study the creations, the cars, through the years, using a process that results in a set of numerical timelines from which those thinking patterns might be established. The main process for doing this is to use a multivariate analysis of categorical data, Categorical Principal Components Analysis (CATPCA). Previous research (Dowlen, 2002b) suggested that it may be possible through identifying the design paradigms evident in the cars to identify the thinking patterns of the designers and engineers. A second, more direct, approach towards establishing thinking patterns amongst car designers, historians and enthusiasts was also taken, using interviews to identify their constructs directly. One of the major processes used in this interview process has been the Repertory Grid process used in such a way as to identify experts' constructs using a hypothetical museum containing a small number of significant exhibits.

1.2 The study of car history

Cars found their way into human history at the end of the nineteenth century. By the early twentieth century a coherent form and layout for the car had been established. This was now clearly a car: previously the motor vehicles might have been horseless carriages. The democratisation of the car commenced with the start of Ford Model T production in 1908, allowing cars to be available for more people from then through to the inter-war period. Following the Second World War cars became almost ubiquitous, commoditised products. The motor industry has now grown to become one of the world's giants. Cars have changed from descendants of horse-drawn vehicles and bicycles to tools for travel. They have become cultural icons, harbingers of war, state conveyances, playthings, sports items and emotional family members with characters. They still have transport value but also have emotional value.

Historical cars are part of worldwide cultural heritage. Car history intertwines with general history and is not separate. The general history of the twentieth century includes the cataclysmic events of the two World Wars, the rise and fall of Communism, the development of capitalism and the consumer culture in the West. These significant changes in society affect all groups but are particularly seen in the reduction in landed gentry and rise of the middle-classes. All these changes are connected and connect with car development which was taking place alongside them and not divorced from them.

1.3 Car design

Automotive design developed alongside the more general Industrial Design discipline. An industrial design (as a noun and signifier) is defined as the form of a product that is produced in quantity. The industrial design process is that process of designing a product to be manufactured in quantity. This process is thus linked inseparably to quantity production and production methods. It is technically concerned with form-giving and determining a product's form. This may involve defining aesthetics, interface design, ergonomics and the development of manufacture and form. Describing industrial design as solely concentrating on aesthetics is to diminish its effect. De Noblet and Wooding suggest that industrial design came into its own with the democratisation of production and transport in the 19th century, and developed in the early 20th century, significantly from the late 1920s onwards (de Noblet and Wooding, 1993). This is paralleled by the growth of automotive design as a separate discipline, having its gestation in the Art and Colour section of General Motors from the late 1920s (Sparke, 2002). Several specific disciplines and processes evolved in the industry, although they could transfer to other design disciplines, such as marker rendering and form-making through clay models. From the late 1950s packaging design became of significant importance – this term being used for the process of finding space to accommodate the components as compactly as possible (Sparke, 2002). Designers have always juggled complex three-dimensionality.

Form design is not the only kind of automotive design. It is necessary to design the interplay between engineering aspects, form, and user needs. Engineering design disciplines such as engine design, transmission design, ride and handling, noise, vibration and harshness and layout design need to be considered – and although these may have three-dimensional aspects, the systems (including human systems) and engineering aspects need to achieve effective function, appearance and getting all the parts working together in one product that becomes the car.

The emphasis of this research is on the form-giving and the layout aspects of car design, with limited coverage of other, more technical aspects like performance design and noise, vibration and harshness. Performance design is covered as a historical overview rather than as a technical process. The argument for this concentration on layout and form design is that these two aspects of design are those that are developed significantly during the embodiment design phase rather than the conceptual or detail design phases and as such their resolution in physical terms includes the resolution of performance aspects of ride and handling which are demonstrated through suspension developments and changes in layout design. Noise, vibration and harshness are designed to some extent during the layout design process with such things as the choice of structural concept. But these are also included as part of the detail design process.

1.4 The process

Following the initial speculation that design paradigms existed (Dowlen, 1999) a convenience sample of cars from 1878 to 1998 was analysed numerically for layout and form and this indicated that design paradigms were worthy of study (Dowlen, 2002b). Given that early conclusion, this research identifies what constituted these paradigms, when they started and when they changed. It attributes causality and identifies why the changes and shifts – paradigm shifts – took place. A shift may be likened to a step change, which takes place quickly with no significant intermediate conditions.

The intention of this research was not only to carry out deductive quantitative analysis but also to augment this with an inductive qualitative process, gathering experts' opinions through a process of interviews, starting from the other direction, analysing experts' constructs on car history, heritage and design and identifying cars that the experts deemed to be worthy of the term 'heritage' rather than regarded as old and outdated. Methods used in this more constructivist approach are transferable to the ways in which car heritage might be construed by the public as well as the experts, by using them within car collections and museums. They can also be used alongside techniques such as Delphi (Baxter, 1995, page 189) to elucidate the understanding of a group of subject experts on a specific topic.

1.5 Why carry out this research?

This research was carried out initially to develop a deeper understanding of car design history, particularly to produce a more coherent body of material for undergraduate teaching. The aim was also to develop a more academic critical evaluation of relevant ideas and concepts. Future implications of this research were not considered at this early stage, but developed as the research progressed.

Quantitative research can demonstrate that numerical methods can effectively analyse product histories and that these methods can be relatively easily transferable to the study of other products. These numerical methods can, in a similar way, explain when changes to products occurred and identify what these changes consisted of. This then could direct how narrative processes can be used to establish the reasoning behind the changes and developments and point to exactly what sort of literature and documents need to be located to establish why the changes took place. The use of both timelines and maps might be used within museum contexts to identify key exhibits for the museum, what aspects of the exhibits need to be highlighted, and to shape the direction of future collecting policy.

Processes used during the constructivist analysis may also be used within the heritage industry, particularly in museums, where, for instance, repertory grid techniques might be used to develop future strategies for the museum collection and how the importance of that collection might best be communicated to the public. They might also find uses for developing overall understanding of subject areas through interviewing subject specialists: the repertory grid was originally invented to seek to understand constructs that were hitherto perceived as being tacit ones, and it is frequently these constructs that need to be passed on to future researchers in the subject areas and those seeking to work with them.

2 Definitions

2 Definitions

English is determined not by diktat from on high, but by convention and custom. It evolves and changes; somewhat different in concept from French, which is fixed and determined – *Le Dictionnaire de l'Academie Française* (l'Academie Française, 1694) intended this to happen – but which nevertheless changes despite formal *Academie* committee structures.

English terminology is flexible. How terms are used depends on the user, context and listener, reader, evaluator – receiver of that language. It depends upon thinking structures used by the message sender and receiver, and their perceptions: upon their previous experiences and their feelings. Lewis Carroll alluded to this in *Through the looking glass and what Alice found there* (Carroll, 1927). Alice meets an egg that turns into Humpty Dumpty and they have a deliberately confusing conversation with misunderstanding on both sides.

> "I don't know what you mean by 'glory,' " Alice said.
>
> Humpty Dumpty smiled contemptuously. "Of course you don't—till I tell you. I meant 'there's a nice knock-down argument for you!' "
>
> "But 'glory' doesn't mean 'a nice knock-down argument'," Alice objected.
>
> "When I use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean—neither more nor less."
>
> "The question is," said Alice, "whether you can make words mean so many different things."
>
> "The question is," said Humpty Dumpty, "which is to be master—that's all."
>
> Alice was too much puzzled to say anything, so after a minute Humpty Dumpty began again. "They've a temper, some of them—

> particularly verbs, they're the proudest—adjectives you can do anything with, but not verbs—however, I can manage the whole lot! Impenetrability! That's what I say!" (pages 129 – 131)

Sir Ernest Gowers (Gowers, 1948) said similarly:

> Writing is an instrument for conveying ideas from one mind to another; the writer's job is to make his reader apprehend his meaning readily and precisely. Do these letters always say what they mean? Nay, does the writer himself always know just what he means? Even when he knows what he means, and says it in a way that is clear to him, is it always clear to his reader? If not, he has not been getting on with the job. “The difficulty”, said Robert Louis Stephenson “is not to write, but to write what you mean, not to affect your reader, but to affect him precisely as you wish”. (page 1)

Melvyn Bragg (Bragg, 2004) explained this, describing the dictionary created by Samuel Johnson in 1755. He explained that Jonathan Swift had attempted to ascertain the English language (Swift, 1712). He used the term to describe the fixing of language. Johnson's initial plan was similar: the fixation of the English language. However, he had a change of mind. Bragg quotes his preface:

> Those who have been persuaded to think well of my design, will require that it should fix our language, and put a stop to those alterations which time and chance have hitherto been suffered to make in it without opposition. With this consequence I will confess I flattered myself for a while: but now begin to fear that I have indulged expectation which neither reason nor experience can justify. (page 211)

Bragg then says:

> With that calm sentence English bade farewell to any serious idea of an academy: just as in its eleventh century vernacular written form it

> had been leagues ahead of its 'European' rivals, so now through its non-elected word keeper, Dr Johnson, it declared that it would be for ever leagues behind any elected word-fixers. In both cases there is something to celebrate. English would never be lashed down and the power of its freedom gave it, I think, an extra cylinder when it came up against the obstacle or opposition of other languages. (page 211)

As English is a changing, living, breathing language it is worthwhile not heading straight for dictionary definitions. It can be more instructive to identify usage and how this determines and defines terms using a collective agreement of usage perception.

2.1 Definitions in this research

This conclusion concerning the changeability of English indicates that whatever a word might mean to certain individuals, it needs careful definition within this particular context to avoid confusion that might be perceived elsewhere.

The topic of the thesis is Design Paradigms in Car History. All five of these words, including the conjunction *in*, are subject to English usage conventions and cannot be defined using a dictionary. Parsing the phrase identifies a principal plural noun – *paradigms* – as the major topic of the work. These are located *in history* – not elsewhere: a description of a subject area. The kind of paradigms to be studied are *design* paradigms. *Design* is an adjective describing the paradigms. And *car* is an adjective describing the kind of history where paradigms will be investigated and identified.

The title phrase could be described using a Venn diagram, Figure 2.01.

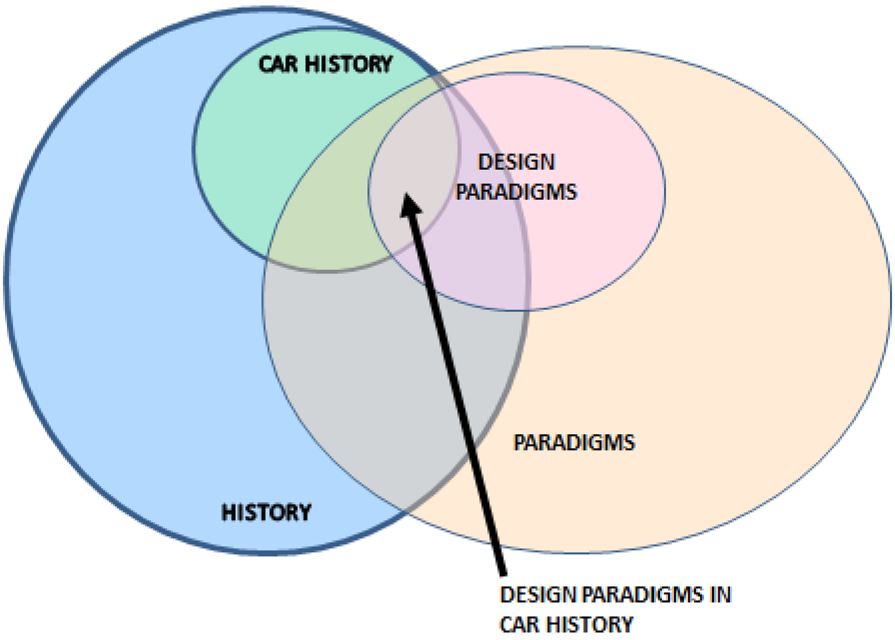


Figure 2.01 Venn diagram showing Design Paradigms in Car History

The main topic will be investigated first – *paradigm*. Then *design*, *car* and *history*.

2.2 Paradigm

Paradigm is somewhat confusing. At worst it can mean nothing at all, such as in the cartoon shown in Figure 2.02:

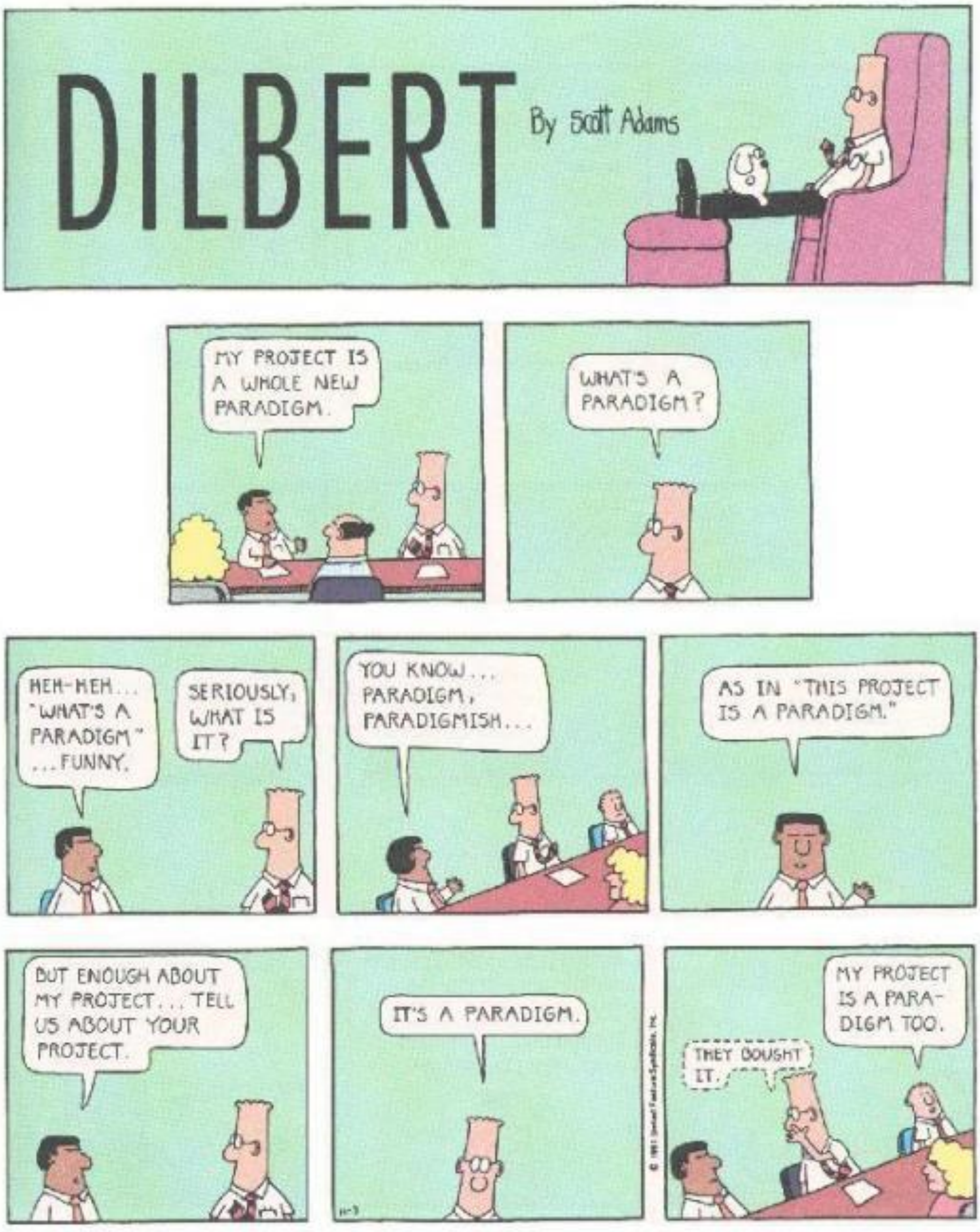


Figure 2.02 Dilbert cartoon on Paradigm (Fair use: © Adams) (Dilbert - Paradigms [Online] http://i39.photobucket.com/albums/e194/jnorfleet/dilbert-paradigm.jpg)

A paradigm might be a typical example or pattern of something: a pattern or model: it might also be a world view underlying a particular scientific subject. (Soanes and Stevenson, 2005).

A paradigm might be an exemplar, or a representative example. The term may be used for the underlying view or method or way of thinking about the world that seems to be time-dependent.

Paradigm is used as an adjective in two principal ways.

Paradigm shift was coined in the 1960s by Kuhn (Kuhn, 1962) who used it to describe fundamental changes in underlying world view in a time-related domain. Paradigm shifts do not have to be sudden processes: they may be gradual. The change in view may be the result of a particular event, such as the development of component interchangeability in the 19th century that enabled mass production to take place, changing from an artisan-developed world to one inhabited by mass-produced products with consumers: or the change in scientific world view following the realisation that the world rotated around the sun.

Paradigm case, the other use of paradigm as an adjective, is used in philosophy to denote a typical or stereotypical example used to construct meanings and definitions. The argument here is that of usage: dictionary definitions are unrealistic or inadequate to determine usage, and illustrations and instances are required to understand the nuances. Words develop into something other than the dictionary definition through usage. (Facione, 2015)

Paradigm cases are fundamental to the understanding of English usage. Utilising this approach it is appropriate to select specific examples, exemplars or paradigms of products to obtain a rounded view of the general usage attached to that description, in the process developing more comprehensive understanding of the usage and bypassing the dictionary definition – which becomes inferred from paradigm case usage.

2.2.1 Paradigm in this research

Paradigm is used here primarily as an exemplar to describe a car typical of a certain period. It is not a vague definition, but a concrete example of a specific car, with definable but perhaps idealistic characteristics. Although the word can be used to describe the underlying design assumptions that take place that developed that vehicle and to determine paradigm cases that develop historical descriptors and themes, these are largely not what is meant when the term is used.

2.3 Design

The 2005 Cox Review of Creativity in Business identifies design as “what links creativity and innovation. It shapes ideas to become practical and attractive propositions for users or customers. Design may be described as creativity for a specific end” (Cox, 2005). Design includes different disciplines – fashion, furniture, product, industrial, instructional, interaction, services, automotive, engineering and so on. Some relate to artistic and visual attributes: some to functional, some to systematic, process or business attributes. Design is many different things. A chameleon of disciplines, able to change colour and be multi-hued in character. So what is it really? And what is it in the context of this work?

Design can be a noun, of several different sorts, or a verb (Pearsal and Hanks, 2003). *Design* can be a plan or drawing that shows the look, function or workings of a building, garment or object before it is made. The next dictionary definition is that *design* can be the art or action of conceiving the plan or purpose before that thing exists. And *design* means the arrangement of an artefact’s features, such as describing the *design* of a particular car as being attractive, or something as having art deco *design*. The dictionary then suggests that a decorative pattern might be a *design*, and that the noun *design* may be the purpose or planning that exists behind an action.

Design as a verb – *to design* – is defined as deciding the look and function of a building, garment or object by making a detailed drawing of it, and suggests that *designed* is a more appropriate adjective than *design*. Perhaps in some circumstances.

By design indicates how something came into being (contrasting with its arriving by chance, default or perhaps by evolution) and *have designs on* is to aim to obtain something in an underhand manner.

Design can be used as an adjective – in many ways. A *design accent* identifies a feature that has been *designed*; a *design adjustment* identifies a change in the intention, *design ideas* can be incorporated, *design methods* are used in the *design process* – and so on. *Design* can easily be an adjective; paradigm cases quickly establish the usage.

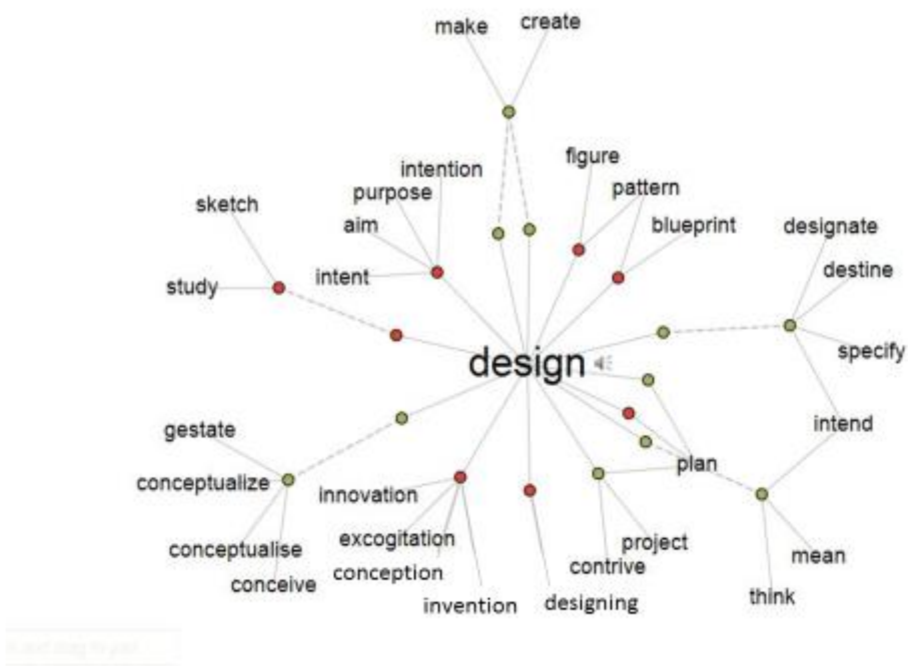


Figure 2.03 Design visual thesaurus (Thinkmap Inc: Visual Thesaurus http://www.visualthesaurus.com/app/view)

Design is a noun, a verb or an adjective. Design is the output of the process and the process – and is the discipline that crosses the arts and sciences divide (Snow, 1965). It is also a profession – the design profession. Here the term is an adjective describing profession. Designers have responsibilities. They have clients. They are educated in a particular manner; they have codes of conduct, and so on. The artistic and technological definitions and determinations of design, although similar, can also be very different, one concentrating on form, colour, decoration and human interaction whilst the other concentrates on function and performance.

2.3.1 Design in this research

Although *design* is used as an adjective in the title, design as investigated here implies a purposeful creation of something (a car) which combines three-dimensional form, aesthetics and (in some cases) beauty[1]: used by people not simply as transport, but to fuel desires, act out company marketing requirements and to be a functional product that (largely) transfers fuel's heat energy into motion and movement: that goes around corners, that carries occupants and their goods. Engineering layout, appearance, form and aesthetics are combined. Design transforms ideas from the designer's mind into the product's reality through material transformation. Design history and car history run alongside each other, merging. It is hard to produce a design history timeline that doesn't include aspects of car history.

Here design is both the form-giving design of industrial and product designers and the functional design used by engineers. The main functional design approach is three-dimensional layout design where components and assemblies are placed in three-dimensional space and fitted together. It covers visual aspects, including aesthetics and the three-dimensional output

[1] This does not imply that beauty is actually created by the designer, although the designer is responsible for creating things which may or may not be described as being beautiful.

resulting from engineering considerations such as performance, ride, handling, stiffness and manufacturability. Focus is on two major components: layout design and form design. Performance is covered, but not to the same extent as the other two aspects. The reason for this is that layout and form design are both aspects of the embodiment design stage where the specificity of the car takes shape and they are both fundamental to this process. Performance variables, although designed in from the start of the car design process, are what results from the performance of the embodied product. Although the required performance variables are normally identified at the product specification stage (somewhat earlier than the embodiment stage) it is only once that embodiment has become a reality that they are realised. This is not the case for layout and form, where the specifically required values are simply created.

2.4 Design Paradigm

Design paradigm means an exemplar of a designed object typical of how objects of that class are designed, or alternatively, the underlying view that the designer may hold.

A *design paradigm* is more limited in scope than a *paradigm*. It is an exemplar, a product (in this case a car), which indicates how that product is construed, designed, manufactured and embodied. Changes in how that product is perceived and embodied constitute paradigm changes. It is debatable whether designers, having passed through a design threshold by designing a product, construe the product differently from their previous understanding. Evidence is only available second-hand by analysing the designed products.

The research is not able to monitor designers' thinking processes and their design paradigms directly. It concentrates on an analysis of the products –

designs – that are produced and understanding how designers think as evidenced through the products.

Design paradigm can be used in literature in several ways.

Petroski's *Design Paradigms; case histories of error and judgement in engineering* (Petroski, 1994) consists of case studies where engineers designing within what they thought were established practices designed beyond the limit of their assumptions, resulting in engineering failure. This is similar to his approach in *To Engineer is human* (Petroski, 1985). Punning on the proverb *to err is human,* the book describes engineering failures. The failures took place because of the inability to think effectively outside established engineering design practices. Here the terminology and thinking of term *design paradigm* is similar to the above definition. Petroski sees failure as the subconscious adherence to inappropriate design thinking practice.

Wake explains in the preface to the book *Design paradigms: a sourcebook for creative visualization* (Wake, 2000):

> "'*Design paradigms*' is a term that we use to talk about a thousand different great little ideas that are at the heart of natural and manufactured devices. This book is a 'field guide' to the paradigms, introducing this powerful tool for design and creative visualization." (page xi)

He uses the dictionary definition of *paradigm* and describes how he thinks of these different great ideas as

> "a bag of tricks - knowledge gained over a lifetime of observing, drawing, and designing. We might divide these tricks, techniques and knowledge bits into several categories, such as basic forms, functional relationships (such as the way two parts relate to each other), and behaviors [sic.] (such as the ways in which an object can get bigger or smaller). Within each of these categories is a collection of distinct

> useful forms, mechanisms, techniques and relationships. Each of these embodies a fundamental design strategy. We will call these things *design paradigms*." (pages 1 & 2)

He then describes the concept further, asking how they might be recognised and used as metaphor. He relates paradigm as metaphor to the development of early cars.

> "Major changes arise periodically, as in the term 'horseless carriage'. The association with the previous technology is both verbal and visual. The early designs of such vehicles show visual evidence of the metaphor, as they retained much of the appearance of the horse-drawn carriages. The horse-drawn carriage was itself a technological innovation, as were the horseless carriage and later automobiles." (page 10)

Several chapters describe ways of performing common design tasks such as bending and flexing, joining, developing passages, and so on. At the end of the book he has a short section on misapplied paradigms. The quote beneath the section title (which should have been attributed to Seneca) returns us to Petroski's use of *paradigm*.

> "Errare humanum est, sed in errore perseverare diabolicum." -
>
> To err is human, but to continue to err is diabolical. (page 271)

He looks at instances where design paradigms have been compounded to achieve simply novelty.

This definition of *paradigm* (at the start of this chapter) was used in a brief paper written for an ICED conference in 1995 looking at three structural design paradigms (Dowlen, 1995). This described three ways of construing structural concepts. Essentially, each of these ways of construing structural concepts consisted of providing an exemplar that embodied that concept – a thing. The first concept was to use a separate chassis, the second an integrated external covering taking structural loadings and the third using load-carrying systems components. These were illustrated in vehicular form as a monocoque car, commercial vehicle with a separate chassis and a tractor. *Paradigm* here is an exemplar that describes a structural 'way of thinking' underlying later design decisions.

Mausbach (Mausbach, 2006, Mausbach, 2009) uses *paradigm* in the context of car design history and development of radical proposals to alter the approach (and hence the paradigm) to car design. He sees that approaching car design from the perspective of sustainability will develop appropriate paradigm shifts. In some senses he is correct; external influence significantly alters current design perspectives (aka paradigms) and it is necessary to effect the paradigm shifting process.

2.5 Car

Although the concept of a self-moving auto-motive vehicle is simple, its boundaries are unclear. *Car* is not a functional term like *screwdriver* which is something that drives screws. *Automobile* approaches a functional definition – it moves by itself. *Car* is narrower – and *automobile* usage is narrower than its functional perception.

In this research a car is a privately-owned powered means of personal transport that has more than two wheels. It does not cover a motorcycle and sidecar, or the sidecar itself, and does not cover pedal cars, velocars or other types of vehicles that may be privately owned and used as personal transport, such as small vans, minibuses, trucks or pick-ups. The grey area is whether it covers utility vehicles – the conclusion is that it sometimes does and the edges of the definition are somewhat flexible.

The research is primarily concerned with production cars. Concept cars and racing cars are only occasionally referred to, and occasional reference is made to amphibious and utility vehicles. However, it is acknowledged that concept cars are important, particularly to designers, and that these are intended to indicate future intentions and directions for the product. The reasons for omitting them from the study are covered in section 4.6. Racing cars have their own, related history. Utility vehicles started life as being significantly separate from the mainstream of car design, but have found their way into the mainstream over the latter years in the 20th century. However, they have not in general found their way into the best-selling lists of cars but are a significant minority. All these categories of cars were, however, important enough in the experts' thinking to find their way into their repertory grid 'museums' described in Section 7.3.

The dictionary suggests that a car is a road vehicle, typically with four wheels, powered by an internal combustion engine and able to carry a small number of people (Pearsal and Hanks, 2003). The origin of the word is from a Middle English meaning a wheeled vehicle and based on Latin and Old Northern French. It is similar in derivation but different from the word *carriage*.

It is difficult to know who invented the car. There is no coherent answer. Not because the story is unclear, but because it is difficult to define what a *car* is. The traditional answer of Daimler and Benz, independently, does not stand in the light of several successful self-powered road vehicles before their vehicles arrived in 1886. Some were in private ownership and carried small numbers of people on roads and could lay claim to be cars. One or two had internal combustion engines, such as Lenoir's carriage of 1863 (Figure 2.05). But an internal-combustion engine is not a requirement for being a car. Figures 2.04 to 2.09 show some of these early road vehicles.

Figure 2.04 Replica of Trevithick Carriage, 1801 (Classic and Sports Car, Tony Baker)

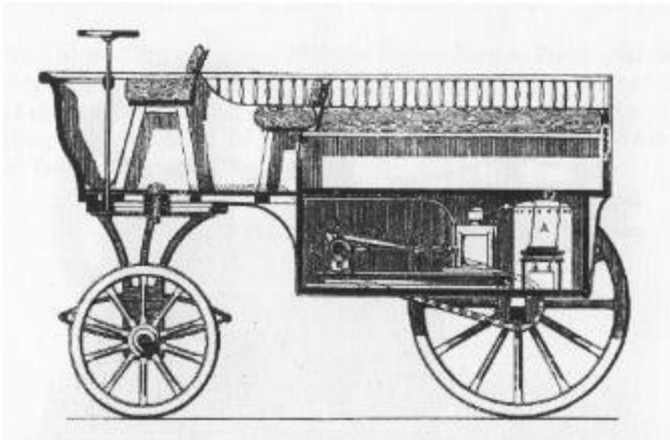


Figure 2.05 Lenoir's carriage, 1863 (Eckermann, 2001)

Figure 2.06 Amedée Bollée La Mancelle, 1878 (Kupélian, 1997, page 21. © Autoworld)

Figure 2.07 Markus, 1878 (date uncertain) (Chris Dowlen)[2]

Figure 2.08 De Dion et Trépardoux, 1884 (The Automobile)

Figure 2.09 Parker, 1884 (Eastern Daily Press)

[2] Subsequent figures that are the author's own are not credited.

Trevithick's, Bollée's and de Dion's vehicles (Figures 2.04, 2.06 and 2.08) were steam powered. Lenoir and Markus (Figures 2.05 and 2.07) used internal combustion power, while Parker (Figure 2.09) used electricity.

The maker of the first car is still in doubt. Cars arrived in the 19th century, before 1890. Karl Benz patented his petrol-powered machine in 1886, even if he was not the first person to have built one.

The supremacy of the petrol-powered internal combustion engine was not clear until after the start of the twentieth century: in 1900 40% of American automobiles were powered by steam, 38% by electricity, and 22% by petrol (Cromer, 2015).

The first design paradigm in car history is to identify a *car*, and that there is now a product that is effectively a *car* where previously there was none.

A car has three or more wheels but somehow is not a cycle, is powered by a power source that isn't human or animal and is used by an owner for private transport.

Figure 2.10 Morgan 3-wheeler, 1935

The Morgan in Figure 2.10 has three wheels and qualifies as *car* even with the wrong number of wheels and odd controls.

Figure 2.11 Stanley steam roadster, 1911

The Stanley is a steam-powered *car*. This is only a problem for those who define cars as having internal combustion engines.

Figure 2.12 Messerschmitt cabin scooter

Figure 2.13 Nissan Escargot

The Messerschmitt has three wheels. It doesn't have car controls – it is steered using handlebars. The driver and passenger sit in tandem and access is via a lifting canopy. It is still classed as a *car*. The Nissan is not a car but is a van. It may be designed for effect rather than transport, but transports goods, not people, and is used commercially.

Figure 2.14 Austin Seven chassis

Chassis are only partial cars. They do not qualify as cars. The form cannot be analysed. They don't provide transport but promise it in future.

There is a greyer area. The Land Rover was designed for multiple use, not simply for commercial use or carrying people. It can do either or both, and isn't limited to roads. This one might be categorised as a 'Truck ¼ ton 4x4 (Landrover)' (Research and Development Establishment, 1956). Not a car – according to the Army. It looks like a commercial vehicle as it has no side windows in the rear. In this guise it is not a car, although several other people think it is.

Figure 2.15 Land Rover Series 1

When a roof and side windows are added it becomes a station wagon for carrying people. It becomes a car, although underneath it is the same vehicle as the 'Truck ¼ ton 4x4'.

Figure 2.16 Land Rover Series 1 station wagon

2.5.1 Cars in this research

The emphasis in this research is on production cars. There are still some examples from before car production started (which was about 1903) and there are a few references to concept cars and racing cars, mostly in Chapter 7 which covers the interviews.

Vans, trucks and buses are not covered. Each has their own history which, while similar to car history, has a different trajectory, purposes and timings.

Racing cars similarly have a separate historical story relating to their purposes and formulae.

The grey area of the off-road 4x4 has also not been included in the analysis. This was not because they are not perceived to be cars, although some are not. They are also worthy of consideration on their own.

As the emphasis has largely been on cars that have been produced commercially, this removes some of the more marginal creations and effectively ignores them whilst not necessarily considering whether they are included within the definition of a car or not.

2.6 History

History is the study of past events, particularly in human affairs. It is the past as a whole, a series of past events connected with a particular person or thing, an eventful past, or one characterised by a particular thing, a continuous, typically chronological, record of important or public events or of a particular trend or institution (Pearsal and Hanks, 2003).

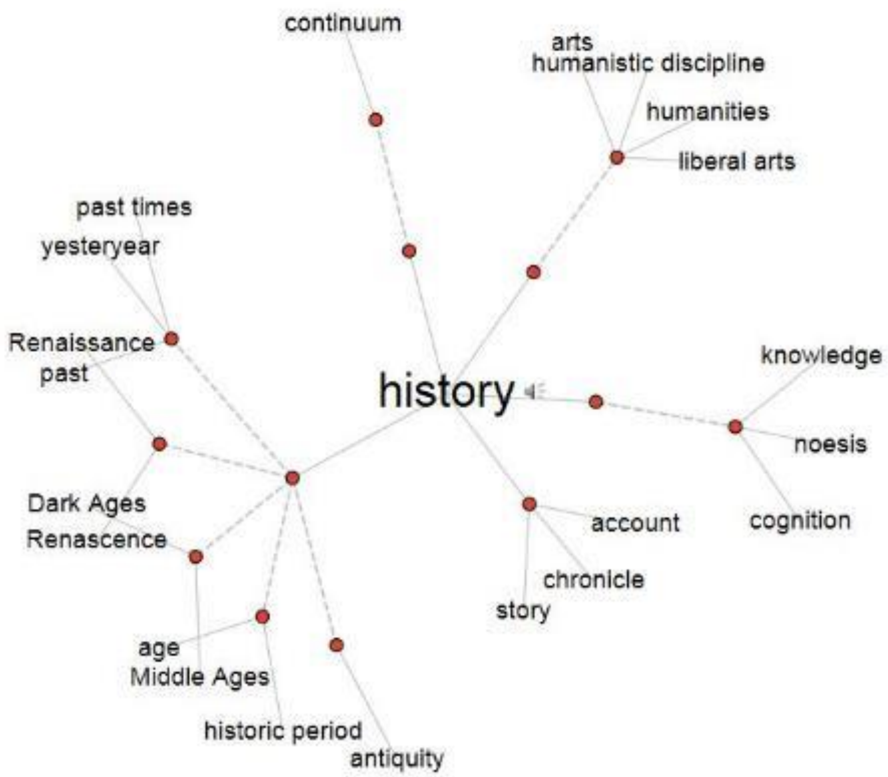


Figure 2.17 History visual thesaurus (Thinkmap Inc Visual Thesaurus: http://www.visualthesaurus.com/app/view)

Whilst the topic is huge, it does not merit the same kind of definition discussion. The definition above adequately identifies the sort of *history* required. This is not concerned with historical periods before the car appeared, and it is not overly concerned with other things taking place outside the world of cars, although there is significant overlap. Events outside car history interact with car history and it is not isolated from them.

Here *history* is the study of past events connected with a chronological record of the car. It might be what happened as fact, but much fact is not recoverable. Investigation of what happened is by identifying and uncovering the story through studying the main actor– the car: what happened to it, not the human affairs around it. It is concerned with how, say, French Motor Industry policy after World War II, affected car design (which it did) but not with how that policy worked or the machinations of the Fourth Republic.

2.7 Design Paradigms in Car History

The research analyses and seeks to understand car history and how designers think from the designed products. Current designers, investigating previous designs, simply say that they know better: they are unable to understand the thinking that created historical products.

More evident than some other paradigms is the numerical analysis paradigm: i.e., that all things are determined by numerical, scientific behaviour. In this instance non-scientific, irrational behaviour is ignored and determined as off the wall, nonsensical, illogical and an insufficient process to effect analysis. Hence, the only analysis processes that are deemed appropriate are those that use numerical or literal processes. Mauch et al express their use of this paradigm: “The history of popular music has long been debated by philosophers, sociologists, journalists and pop stars [1 - 6]. Their accounts, though rich in vivid musical lore and aesthetic judgements, lack what scientists want: rigorous tests of clear hypotheses based on quantitative data and statistics.” (p1) They own the scientific paradigm, and explain their analysis processes, comparing them to methods used by evolutionary biologists (Mauch et al., 2015).

An equally valid way to treat car history is to take an approach that concentrates on visual thinking, emotional behaviour, intuition and gut feeling, drawing out likes and dislikes, reasons for following up stories where the researcher has emotional attachment, selecting ‘interesting’ cars: that press the ‘favourite’ button, with no logical reason for the choice. They can be rich in automotive lore and aesthetic judgement.

This is not the process that has taken place here, although it could be argued that part of the interview process, in gathering experts’ constructs, was investigating this emotional attachment. Most of the work presented here has been couched in analytical terms. But the constructivist approach of the interviews sought to determine emotional responses, develop creativity, and ask questions rather than answer them. Although delving into perceptions and investigating paradigms it does not draw the same kind of conclusions as the numerical analysis.

2.8 Alternative Histories

Alongside the analysis of this kind of car history are several alternative histories – of single-seater racing cars, four-wheel drive vehicles, commercial vehicles, public service vehicles and of alternatively-fuelled vehicles. These are not analysed. Each needs separate treatment and comparison with this car history is through observation rather than coherent analysis.

2.9 Design paradigms for car designers

Having defined paradigms, design, cars and history, paradigms may simply be ‘things’ that are identified within car history; interesting and worthwhile themselves. Or these paradigms may be employed within design processes to identify ways for designing, taking a similar approach to post-modernist architects who deliberately utilise history to inform their ‘new’ architecture. Some architects have deliberately used historical styles, incorporating them into their own design work. Re-utilisation of classical styles in the seventeenth and eighteenth century and Gothic in the nineteenth century are examples of this (Bergdoll, 2000, Summerson, 1963, Thomas, 2000). Figures 2.18 and 2.19 show well-known examples of Neo-Classical and Gothic Revival architecture respectively.

Figure 2.18: Vilnius Cathedral – Neo-Classical Architecture (Wikimedia: Juliux)

Figure 2.19: Midland Grand Hotel, St Pancras – Gothic Revival architecture (Wikimedia: LepoRollo)

Designers might usefully employ them consciously in their car design work. There is evidence that this has been done, perhaps without clear identification of paradigms. Cars such as the Mazda MX5, the ‘new’ Volkswagen Beetle, Mini from 2001 onwards and the Fiat 500 from 2007 onwards identify this stance (Figures 2.20 – 2.22).

Figure 2.20 Lotus Elan and MGB – sports cars alluded to in the gestation of the Mazda MX5

Figure 2.21 Mazda MX5 (Wikimedia Commons: Francigf at en.wikipedia)

The Mazda MX5 (Figure 2.21) consciously employed ‘essence of Sports Car’. Sparke (Sparke, 2002) recognises the Lotus Elan in its character and Tumminelli (Tumminelli, 2004) places it in the ‘retro’ category. A US on-line magazine gives greater detail including quotes from Bob Hall, (Automobile Mag, 2005) who contributed to the concept and confirms the inspiration to be British Sports cars, but that design requirements were couched in layout terminology and not in exterior form. Figure 2.20 shows two cars that are frequently cited as being the inspiration for the character of the Mazda MX5, the Lotus Elan and the MGB.

Figure 2.22 Old and new: Volkswagen Beetles (top: Right: Wikimedia Commons: OSX): Minis (right: favcars.com): Fiat 500s (lower: Wikimedia Commons: dave_7)

The Volkswagen Beetles, Minis and Fiat 500s mimic the perceived external form of the earlier cars, the Beetle and Fiat deliberately going in a different direction from the earlier cars' layout concepts. Tumminelli places both the Volkswagen Beetles and the Minis firmly in both the retro and a remake category, which he explains in terms of reusing earlier branding as well as styling cues (Tumminelli, 2004). He devotes a whole chapter in a later book (Tumminelli, 2011) to the topic he calls retrophilia and mentions these three and others. He neglects to talk about the key aspect of what the motor industry calls packaging (the process of layout design – to ensure that all the components fit into the overall form) which is what industry experts cite as the key contribution of the original Mini to car design history.

Even if historical paradigms are deliberately used, the retrospective behaviour involved in utilising them will almost always include assessment of current paradigms alongside the earlier ones. Hence, perhaps, the utilisation of a more recent layout design for the retrophiliac Beetle and Fiat

3 Research Methodology

3 Research Methodology

3.1 Introduction

Design sits between the scientific, engineering disciplines on one hand and the humanistic, social science disciplines on the other side. On the one side there are hard requirements such as material behaviour and manufacturing where numerical theories of behaviour are utilised, backed up by years of empirical research and testing to become rules and the theories of engineering practice. On the other side there is the humanistic, psychological approach that develops interfaces with human behaviour: physical interfaces which feel and psychological interfaces where likes and dislikes and perceptions of beauty and aesthetics become the order of the day. Designs have to look good, work well, and relate to humans.

Dorst and Dijkhuis investigated these two paradigms (Dorst and Dijkhuis, 1995). They took the meaning of paradigm to be that of a world view, rather different to the meaning of paradigms as exemplars. This resulted in a dichotomy of design research approaches. The positivist approach is identified with the design methods movements in engineering, put forward by such as Vladimir Hubka and Ernst Eder (Hubka and Eder, 1996), Stuart Pugh (Pugh, 1991) and Gerhard Pahl and Wolfgang Beitz (Pahl and Beitz, 1984) but which originated earlier with authors such as Herbert Simon (Simon, 1969). In contrast, the constructivist approach is identified with the educational processes of reflecting on design, identifying the perceptions and thoughts of the designer and how these grew in a less rational but more natural and discursive manner, this might be exemplified by such as Donald Schön (Schön, 1991) and discussed at length during his tutorial approach within the architectural discipline.

Dorst and Dijkhuis used two coding processes as methods of evaluating the use of either world view. The positivist approach resulted in a set of somewhat awkward scenarios that were difficult to resolve and analyse and produced complex diagrams. The constructivist process resulted in a set of identifiable results that were considerably easier to comprehend and those results developed their own arrangements of patterns which made more sense than being fitted into a set of pre-existing patterns.

The research carried out for this paper utilised a combination of both approaches, the reasoning being that one approach is suitable for one type of investigation and the other for investigating different topics.

The rest of the chapter defines the research questions more formally and discusses the specific methodologies that were used in the research.

3.2 Area of the research

The main purpose of the research project was to investigate design paradigms in car history. This product area was selected in order to develop a broad exemplar of the ways in which historical design paradigms might be evidenced, how they can be identified, and what their characteristics are. This product area (cars) was chosen because of both long-standing personal interest and from experience using cars as exemplars when teaching design history to undergraduate students.

The purpose of the research is not to provide a philosophical debate about paradigms, but to *describe* and to *analyse* design paradigms in car history.

In the manner of Kipling's Six Honest Serving Men (Kipling, 1902), this includes the identification of what paradigms there are, when and where they started, how they grew and spread, when they seemed to cease to exist in that manner, why a paradigm shift towards them occurred, why they were superseded, and who was instrumental in creating the conditions for a paradigm shift to occur. In addition, the answer needs to be given to the ‘So what?’ question. What use is this piece of research and who might be able to benefit from it?

One of the desirable outcomes of the investigation is to produce an effective, measurable, timeline or sets of timelines that describe car history. These will each consist of an x-axis that in terms of the date that a car was made, and a y-axis referring to some measurable variable that identifies the changes that have occurred in car history.

The original intention was to analyse these paradigms from a qualitative angle as well. So car history and design have also been investigated from how they are construed by experts. During the course of the research it became apparent that these two approaches are complementary rather than confirmatory as significantly different paradigms emerged from this qualitative process.

3.3 Research Questions

The research questions take two major directions. These can be stated as being:

1. *What is the nature of the design paradigms that can be identified in car history?*
2. *How are car design, car history and car heritage viewed by car designers, historians and enthusiasts?*

A third question then needs to be answered:

3. *How do the answers to these two questions relate to each other?*

Connected with the definition of the research questions, but distinct from them, is the question of how such issues might best be researched. The next section introduces the processes and methodologies that were utilised.

3.4 The process

Following an initial constructivist speculation that design paradigms might exist (Dowlen, 1999), a more positivist approach was taken to carry out a numerical, statistical analysis on a convenience sample of cars from 1878 to 1998. This sample was analysed for layout and form, as these are the topics that are decided during the embodiment design stage, and this indicated that design paradigms existed and that expanding the analysis was worthwhile. Given that early conclusion, the research identifies what constituted these paradigms, when they started and changed. It attributes causality and identifies why the changes and shifts – paradigm shifts – took place. A shift may be likened to a step change. This takes place quickly and there are no intermediate conditions.

Two other approaches were taken. The first was to take a complementary approach to discover how experts in car history and design viewed car history and design, obtaining their constructs through a semi-structured process that included the development of their personal car history constructs obtained through use of repertory grid techniques (Kelly, 1955). What this approach does is that it seeks to identify current experts' constructs that relate to both car design and car history – the latter being significantly related to the topic of heritage rather than simply history, as heritage becomes a current interpretation of what is valued in history – usually in terms of artefacts, buildings, cultural objects and so on (Hannabuss, 1999). This is in contrast to what is regarded as being simply old or outdated.

A further approach took place following the quantitative work and involved literary investigation and search for reasons why changes took place, guided significantly by the results of that quantitative work that identified how to approach the literature and what information would be needed from it.

Thus, the research processes split into four sections.

1. An initial perception that design paradigms were important was gained through a constructivist approach of gentle discovery – somewhat unplanned, discursive, unstructured and informal until the research questions were framed.

2 A positivist, numerical, statistical approach was taken using measurements taken from over 500 cars from 1878 to 2014. These measured layout and form design variables and resulted in several dimensions for each. These were plotted against time and against each other to obtain visual maps of paradigms against time (history). They identified paradigms, their timing, the extent of their influence and the ways in which paradigm shifts took place.

3 A constructivist approach was taken using structured interviews of individuals who had been involved with car design and history. Repertory Grid techniques were used in the interviews to elucidate individuals' constructs as they related to cars and their history, and were also used to analyse the results of the interviews and compare individuals' constructs with each other. As this was a constructivist approach, the individual responses were not led towards identifying the same sets of paradigms, but for individuals' perceptions, which did not necessarily relate to the paradigms identified from the positivist approach previously taken. As stated above, this relates to their perceptions of the car history that is worth utilising and valuing – i.e. car heritage – rather than simply historical events.

4 Numerical methods were not appropriate for identifying and analysing why paradigm shifts took place and who was responsible for their

development, and a literature-based investigation had to be used. The numerical analysis indicated this had to be technical literature rather than historical due to the nature of the changes that were being sought. This does not mean that the technical literature has demoted the historical literature. It merely indicates that the kind of information that was sought from the literature referred to technical reasoning, and the technical literature used includes historical referencing and information, but history was not deemed to be the main purpose of the literature.

Each of these four processes will now be discussed in more detail.

3.5 The initial processes

These initial, somewhat unstructured processes were not deliberately chosen. They are deemed to be constructivist in retrospect as being directed somewhat haphazardly towards the identification of design paradigms in car history being appropriate as a topic for further study and therefore being exploratory in nature rather than towards the confirmation of a hypothesis.

What took place developed from a project to provide students with a set of colour slides on car history. These slides needed themes to show the development of the car. Through these themes a realisation developed that something termed a ‘design paradigm’ might be important and might indicate the ways in which designers perceived their development of cars. There was also the feeling that there were significant discontinuities in the history and that the changes that were perceived were not continuous ones, but consisted of series of jumps – that change was not constant, that things were not always changing faster and faster, and that periods of rapid change were followed by periods of considerable stasis, during which there was a ‘set way’ of designing a car. This ‘set way’ of designing developed into being the design paradigm at that stage of car history.

A short paper using the term paradigm was presented as a poster at the 1995 International Conference on Engineering Design (ICED) that took place in Prague (Dowlen, 1995). This paper used the term to identify three different ways that structural concepts might be construed. The term *paradigm* was used there to describe each of these concepts and to provide exemplars for them in terms of the use of a separate chassis, use of an integrated external form and structure and use of a system-based structure, where the system components also provided the structural stiffness required for the product. Current automotive illustrations were used as examples – commercial vehicles with separate chassis, cars with unitary external form-structures, and tractors with system-based structures.

The car history theme developed into two papers on using car history in teaching which were presented at conferences at the National Motor Museum in Beaulieu (Dowlen, 1997a) and at the ICED conference in Tampere in 1997 (Dowlen, 1997b).

Combining the use of the term paradigm with historical car illustrations took place in a short paper on the development of design paradigms presented to the 1999 ICED conference in Munich (Dowlen, 1999). This identified something termed a design paradigm, defined as an exemplar, and identified it as what developed to dictate how designers perceived their products. Whilst the paper was not written in terms of car history, historical car examples were used as illustrations of how design paradigms formed.

Other discussions around the same time suggested that car history might be an effective case history to identify that change is not constant or increasing, moving from periods of rapid change into periods of relative stasis that endured for several years, and that following perceived exemplars or paradigms might be a way of describing and determining the nature of the changes that took place.

This first approach was discursive and constructivist, not particularly searching for a research question but nevertheless developing them through the course of several years.

3.6 The numerical analyses

The theme of design paradigms in car history developed into a topic for study. The object is to *describe and analyse design paradigms in car histor*y. Having identified the desire to develop research questions around this topic a positivist approach was first used to describe and analyse car history, utilising numerical and statistical techniques that involved measuring car characteristics – many of which were of a categorical nature.

The reason for this initial choice might have seemed obvious at the time, but it was perhaps related to a personal engineering background that included the tacit personal construct (perhaps) that numerical approaches were worthwhile and the perception that a quantified timeline could be produced that would provide a clear graphical depiction that showed how cars developed and changed through their history. Engineers like numbers and graphs and tend to choose these approaches first.

The concept of a car history timeline was used by Artur Mausbach (Mausbach, 2006) in his analysis of car history, but did not use any y-axis measurement. Mausbach is not an engineer but is primarily an architect. Thus his approach was qualitative and illustrative in character. This resulted in the illustrative car history timeline shown in Figures 3.01 to 3.03. It should also be noted that the x-axis measurements are not in any way linear and seem to be have been more related to his perceptions of value in car history.

Figure 3.01 Mausbach's timeline, part one: 1886 – 1955 (Artur Mausbach)

Figure 3.02 Mausbach's timeline, part two: 1954 – 1993 (Artur Mausbach)

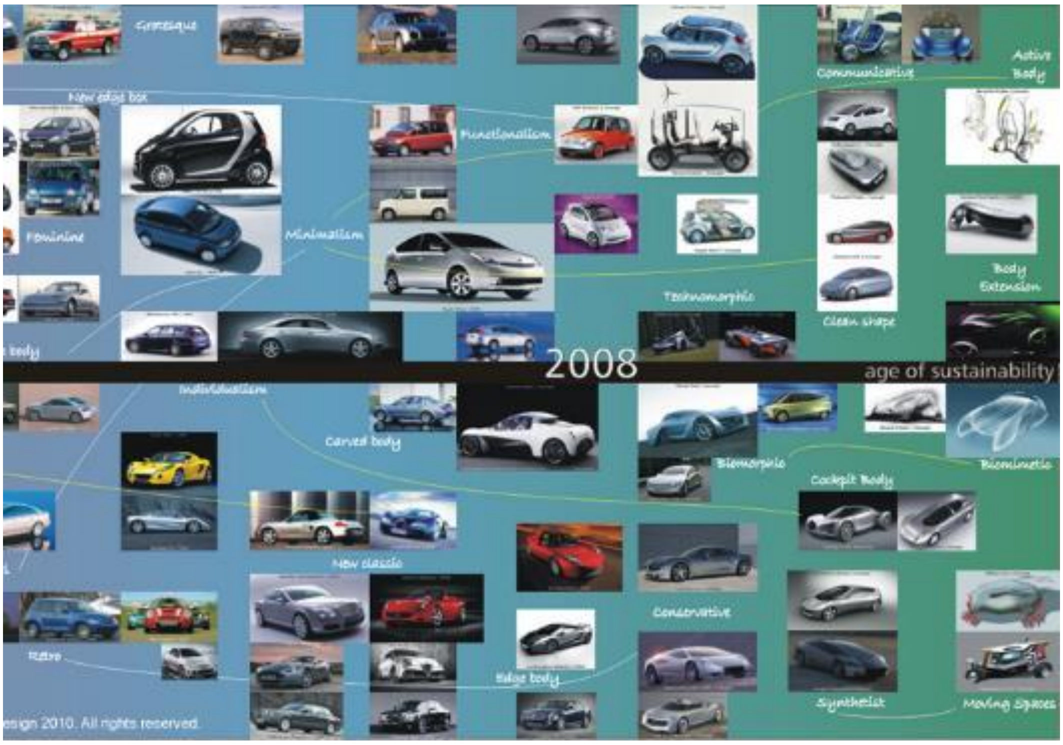


Figure 3.03 Mausbach's timeline, part three: 1990 – 2010 (Artur Mausbach)

This concept of a timeline was also used by Van Nierop et al, who use two timelines to illustrate developments in bicycle history. In the first, shown in Figure 3.04, the topic of each axis is clear but in this illustration the axes have no figures.

The second timeline expands into three dimensions, measuring time, diversity and fitness. Numerical data is included for both time and fitness but the measure of diversity is unclear. The fitness derives from the relative popularity of different bicycle forms. The authors say it is simplistic. Something is measured, but it is difficult to determine how the fitness is derived or how the diversity is measured.

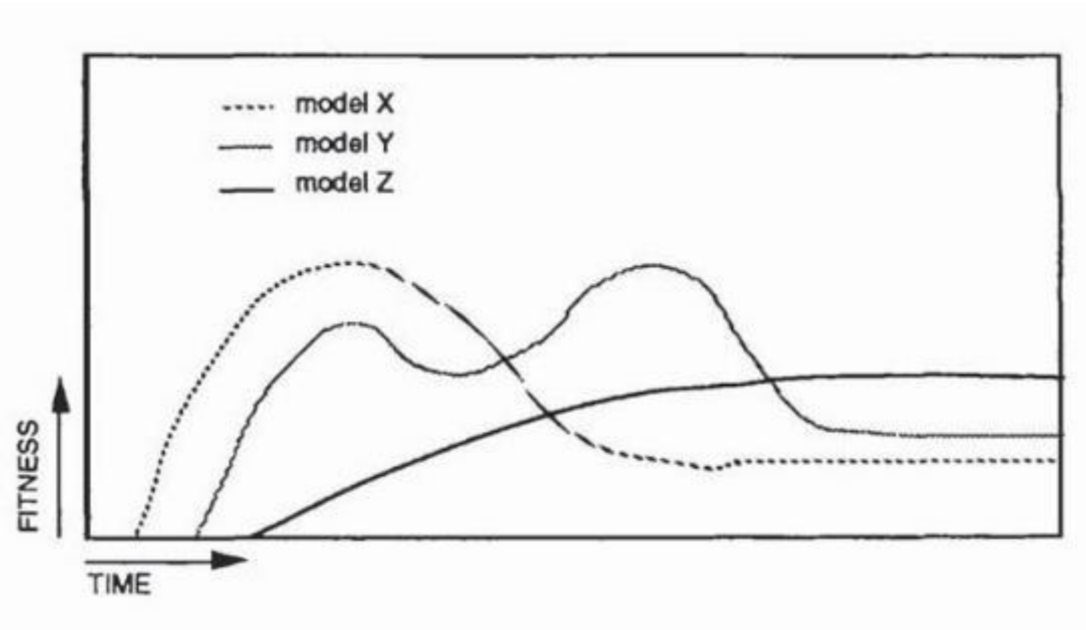


Figure 3.04 Fitness timeline (Van Nierop et al., 1997, page 255)

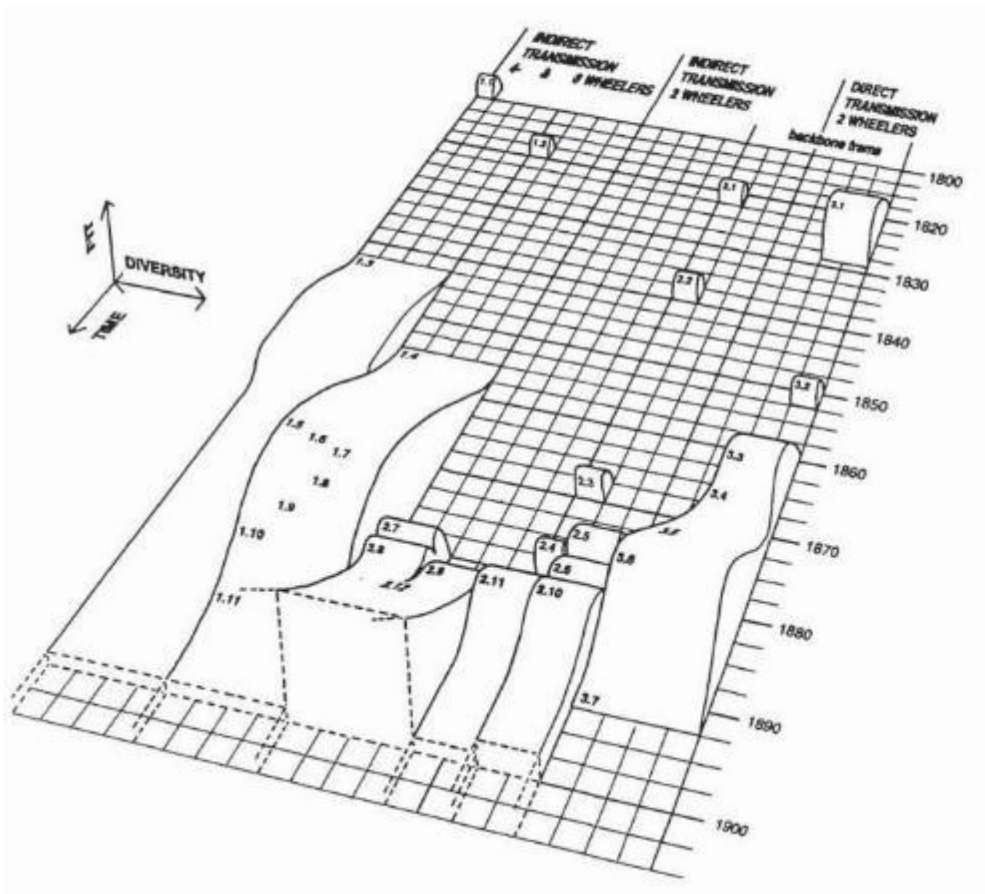


Figure 3.05 The second timeline (Van Nierop et al., 1997, page 257)

The approach taken here uses timelines that do have a numerical component in the y-direction.

In providing timeline-based numerical graphical output that related to design paradigms these processes identified what the paradigms consisted of, when they were current, how quickly they changed, the nature of the changes in terms of which variables changed and whether they were gradual or sudden, and the direction of the changes.

The process used a large number of variables to measure cars. The car is a physical product that is clearly developed by people through individual design processes where decisions are made of a spatial nature, and thus spatial design variables were selected as being appropriate measurement data items. The design methodology taken in order to identify what variables to measure is that developed largely by Pahl and Beitz. (Pahl and Beitz, 1984) as seen in Figure 3.06.

In this methodology one of the design stages in the text on the right is termed embodiment design. Although this was clear in Pahl and Beitz' original text it is not so clear in Figure 3.06 and is much clearer in a design process diagram produced by Michael French slightly later (French, 1985) as seen in Figure 3.07. It is clear that the term *embodiment* had been developed in response to a difficulty in translation of the original German term in Pahl and Beitz' text, as is explained in the Editor's foreword to Pahl and Beitz' original text (Wallace, 1983).

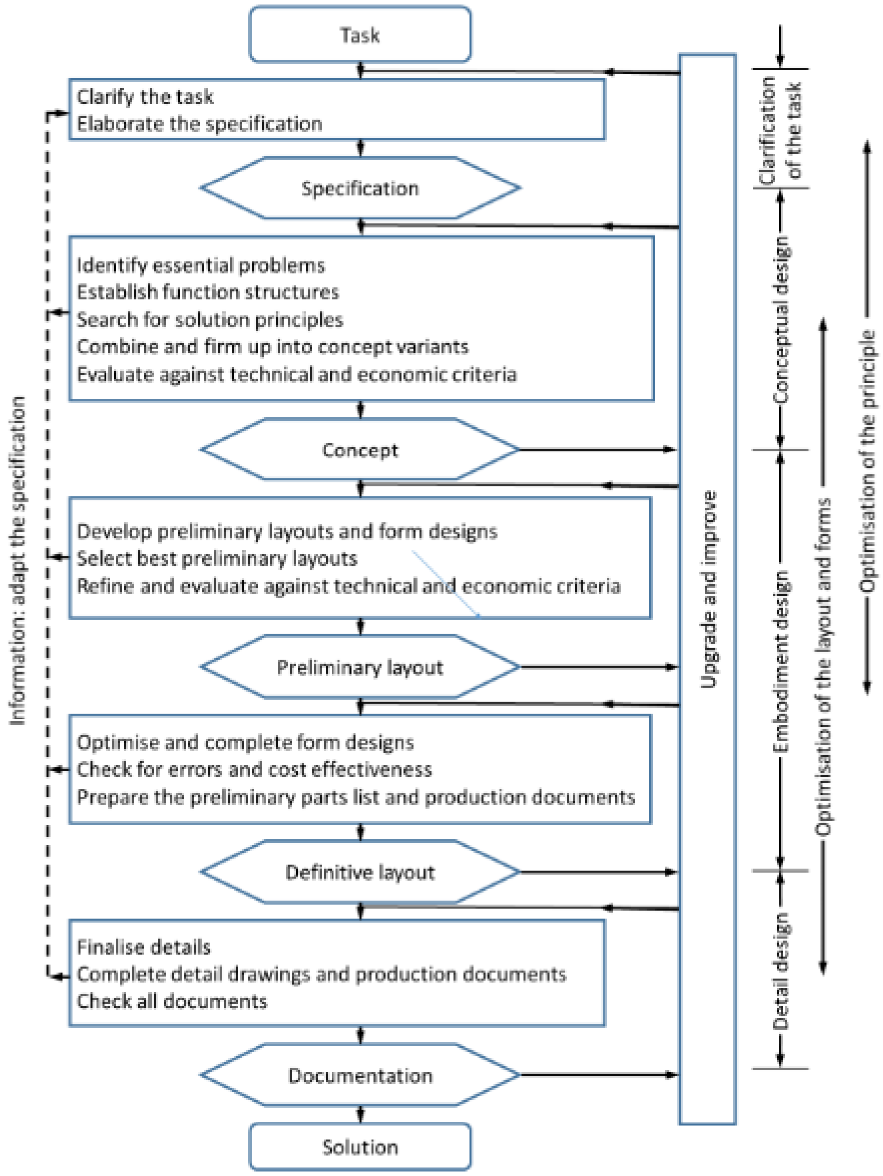


Figure 3.06 Design process as determined by Pahl and Beitz, (Pahl and Beitz, 1984, page 168)

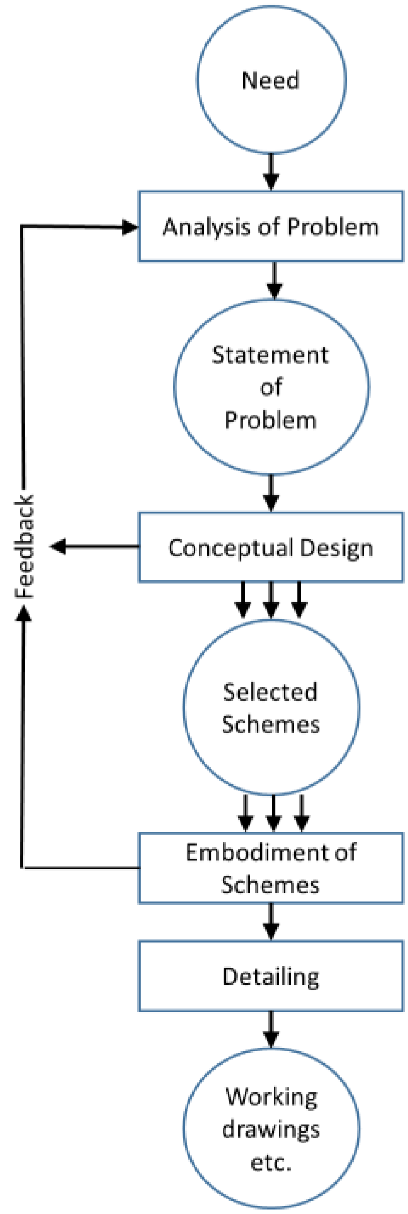


Figure 3.07 Design process model as developed by Michael French (French, 1985, page 2).

This embodiment stage is associated with the physical space-giving of the product, in this case the car. It is during this stage that the physical dimensions and positions of components are identified and two particular types of design need to take place – layout design and form design. These spatial design variables are associated with overall design processes that are largely taken during this embodiment design phase where the basic *layout* and *form* of the vehicle are determined (these lead to the terms *layout design* and *form design* being used from time to time to describe aspects of the design embodiment process), and it is these two sets of variables that have been chosen as suitable analyses to undertake. Investigating examples of cars over the period from the first cars to the present in a numerical manner demands the use of statistical processes, and as there are a large number of variables involved this appears to demand a multivariate analysis. This could be a factor analysis, but the variables involved, particularly in layout design, are categorical in nature, and hence a straightforward factor analysis, although possible, makes little sense. Instead, a categorical principal components analysis (CATPCA) was used which is able to analyse this type of variable using a probability-based approach rather than the more straightforward linear approach used by factor analysis. For both layout and form analyses pilot analyses were undertaken. The initial layout analysis used 19 variables, which was a manageable number and these nineteen were deemed to produce effective results without huge amounts of effort. For the initial form analysis 50 variables were used. During the process of the analysis a number of the variables were shown to have little effect on the analysis. There were two reasons for this. Firstly, some were removed because their vector multipliers were low and secondly some were removed because they were significantly secondary to the overall form of the cars. This left 28 variables for the later analyses. A comparison of the results of the initial analysis and the results of the later analyses indicates that there was little change in the results and demonstrates that such a reduction in variables was largely justified. Further analyses used this reduced number. The layout and form analyses behaved somewhat differently, suggesting that it had been appropriate to separate out the two different analyses. The layout analysis tended to produce periods of rapid change followed by periods of stasis, whilst form analysis changed in a more gradual fashion. This is probably to do with the nature of technical change and the categorical nature its changes relating to car layout, whilst form changes tended to be more related to positions in space, although some were also categorical in nature.

In theory the categorical principal components analysis used results in as many measured timeline curves describing car development over time as there are chosen variables. However, the concept of the data reduction process is such that the first few principal components produced (known by the program as either object scores or as dimensions) include the majority of the variance. In this case it was deemed appropriate to concentrate on the first two components of each analysis, enabling four timelines to be used in the subsequent discussions. The two layout and two form dimensions were able to be plotted against each other, producing two-dimensional mappings of layout and of form. Adding the timeline data to these mappings as colours showed clearly the ways in which designers in different eras and periods in car history had produced different car layouts and forms. These results are illustrated in detail in Chapter 6 of the research.

The layout behaviour clearly indicates that design paradigms are used for layouts and when these design paradigms were current. Titles for the layout clusters (paradigms) have been invented and these are described in detail in Chapter 8, using the subsequent literature investigation to identify why and how these took place.

Form behaviour does not demonstrate the same clear jumps from one paradigm to another. However, it does show that there is a time-related behaviour and that designers of one date do not generally consider developing forms that mimic designs of another date, even when they are seeking to find inspiration from cars of that date – unless there is a deliberate decision to produce a clear and specific replica (as opposed to a retro-themed car).

A later analysis was undertaken using the factor analysis approach when seeking to establish the way in which product performance develops over time. The reason for this analysis was in response to a suggestion that there might be sufficient data present to compare with the theoretical S-shaped logistic curve suggested by TRIZ practitioners (Mann, 1999, Slocum, 1999a). Performance variables tend to be linear in nature and this was appropriate at this point. The full paper written for the ICED conference in 2011 is contained within Appendix 8 (Dowlen, 2011).

In terms of car development, other technical requirements and developments (such as ride and handling, noise, vibration and harshness, engine control systems) are evident in the way that they a) alter a car's layout, b) alter a car's form and / or c) modify a car's performance in the broadest sense of that term, and hence a quantified analysis of layout, form and performance will identify and embody these developments.

A further analysis was undertaken using the outliers of the numerical data to identify innovative cars and seek to develop a numerical understanding of creativity. This used the timeline graphs to produce outliers of layout and form dimensions and classified them into a) always outsiders (i.e. for all time), b) outsiders looking backwards to previous thinking, or c) outsiders that started new design thinking – i.e. innovators. This analysis is not reported here in detail but the papers produced from it are also contained in Appendix 8 (Dowlen, 2012a, Dowlen, 2012b).

3.7 The interviews and their analysis

It was felt that a purely numerical approach was not necessarily the best process to use to analyse design thinking paradigms, and that an alternative approach of obtaining answers from experts might yield a set of complementary answers to those obtained from the numerical analysis. Thus a series of structured interviews were planned, utilising a constructivist approach to identify the constructs these experts might have that were related to car history. As this was deemed to be a constructivist approach, these experts could not be led by the outcomes of the previous analysis, although some had been present when some of this had been presented previously. Several categories of individual who might be questioned were identified – car historians, design academics, individuals with motor industry experience, individuals with PhDs in Automotive Design, and classic car enthusiasts. Thirteen interviews were carried out: twelve by direct personal interview and one through an email process.

The structured interview had a series of sections. Firstly, there was a section that asked for personal involvement in car design and history. Secondly, there was a section on car history and their perceptions, particularly of periods and what characterised these. The third section was concerning car design and the processes and influences that they might have when designing. Although some were not designers, all had at least some idea of what approach they would like to take.

A more structured section followed this and utilised an affinity diagram approach to history, where the interviewees were presented with pictures of cars through the years – approximately one from every five-year period from 1875 to 2014 – and asked to make a two-dimensional arrangement of them, as they chose. In many cases this was of a historical nature, but not always. If they were familiar with the cars it became a combination of personal choice, layout design and form design: if not, they tended to base their arrangement purely on the form of the cars presented.

Affinity diagrams were invented by Jiro Kawakita in the 1960s to improve product and process quality. They are one of Cohen's Seven Management and Planning Tools (Cohen, 1995) for understanding complex situations and relationships. They are found in the IDEO methods (IDEO, 2003) and the Innowiz collection of methods (Bonneux et al., 2007, Michiels et al., 2011). They consisted originally of topics each written onto single sheets (perhaps

Post-it-type sheets) and moved until the arrangement makes sense. Clusters of themes or ideas are identified and named.

This particular use of the affinity diagram differs significantly from the traditional use of the method, in that the written topics are not developed by the participants but these are replaced by the car pictures and the process is limited simply to the arrangement of those pictures to see how they are clustered and themed.

In the final section, each interviewee was asked to identify nine cars – any nine cars they wished to choose – to form their personal museum of car history and their constructs were elicited through a repertory grid process using triads. The intention of these interviews was to identify the individuals' constructs for car design and history. Repertory grid techniques were used to analyse each section of the interviews and to arrive at comparisons and constancies in their constructs.

When they were first envisaged as an analysis tool it was suggested that they might be used because they claimed to carry their own validation process within them, and that gave them a significant advantage over many other methods that might have been used. However, this aspect of their usage has not necessarily been supported through their use.

These techniques were developed in the 1950s by Kelly in order to identify individuals' constructs, initially for psychological comprehension (Fransella and Bannister, 1977, Kelly, 1955), and not for the type of purpose envisaged here. They have since been used to identify individuals' constructs for a multitude of different purposes. They have been used to identify individuals' responses to branding issues and to marketing and as a consumer analysis tool (Stewart and Stewart, 1981). Stanton and Young used them as one of their ergonomic evaluation methods when developing car radio designs (Stanton and Young, 1999).

Their conclusion of the method to develop design solutions is that it is potentially useful as a process, relatively easy to execute and can provide useful consumer information for designers, but that its analysis can be complex and its validity and reliability are to be treated with caution (page 69), which is somewhat different from the earlier suggestion. However, Stanton and Young were using grids with the same given topics for each participant. In the case used here, the topics (or, more technically, objects) are also identified by each participant, and this appears to be a key to their effectiveness at producing constructs.

However, repertory grids are a relevant process to utilise for any situation where the approach that is desired has an uncertain or undetermined outcome and where a key component is how individuals think about whatever is being discussed. They are a deliberately constructivist process, in that they set out to identify constructs – i.e. how an individual constructs and puts together their individual mental picture of the world (Marsden and Littler, 1998). In psychology the purpose is perhaps self-evident, in that it is to understand how an individual develops their world, but they also have an effective place as a novel technique alongside such techniques as Delphi (Baxter, 1995) for seeking to understand how experts think about their topic of expertise. It is in this manner that they are used in this research. They contrast with Delphi in that the questions to be asked (which equate in grid terminology to the objects) need to be identified by the participants rather than the investigator, and thus they seek to develop not only the answers to the questions but also the questions themselves. They are also not necessarily iterative in form, which means that they are less time-consuming to execute than Delphi.

For any grid analysis it is essential to identify individuals for whom the topic of discussion is not irrelevant – if it is deemed to be so, then the output will be irrelevant. Whilst the overall process of the repertory grid is normally to identify constructs by whatever means appropriate, there are a number of techniques that are frequently utilised in order to elucidate these constructs.

One of these is the identification of a certain number of specific items that are important to the individual and to utilise processes of triads to compare them with each other. If nine items are selected, then a process of 12 triads will cover every combination of the nine items. This combination coverage will only work with a number of objects that are a power of three, which in practice means that it has to be nine. Whilst this is not necessarily the only way that constructs can be identified, this process of selecting specifically nine items and using triads in the formal manner was the one that was used in this case, but it was particularly difficult to enforce the instruction that no previously used construct should be reused in the process. The nine items to be selected were cars that were to form the individuals' individual historical car museum, money no object. This process succeeded in finding many constructs – in excess of twelve for all of the experts interviewed. What was also found was that the process caused each of the interviewees some significant heart-searching and it did not appear to be a particularly easy process for any of them, although in general they found it pleasurable.

Repertory Grid processes were also used in a less formally constrained manner to identify constructs from the other sections of the interviews, resulting in construct maps for each of the experts. These were able to be compared, again using the grid process, to identify themes from each section of the interview that were common to several individuals and which might then be deemed to be general currency among similar groups of such experts.

The interviews complemented the numerical data, providing extra information. Although semi-structured and interesting in themselves, producing much data, they did not identify the paradigms so clearly although several interviewees talked about paradigms.

They identified issues that could not be discovered by measuring cars, such as outside issues, societal links, other manufacturing industries like aircraft, links with world events like wars and depressions. They showed that tax policy affects how products develop (e.g. after WWII in the UK). The interviewees suggested different car history eras, but most concluded the pioneer period was important even though several were not interested in it, claiming developments prior to WWII to be simply an early evolutionary period. They could identify eras that could not be identified with numerical analysis such as how Japanese companies grew in Europe and America: this did not result in physical change to car design practices, although it affected how cars were manufactured, marketed and their durability, which could not be measured numerically. This demonstrates that their perceived constructs are somewhat different from the numerically-derived perceptions of historical car periods and paradigms.

In the affinity diagram section all interviewees noted that car dates identify and categorise them. Most clustered the cars using date-related clusters, even when they said they used personal preference and when they were unable to identify the cars. This indicates time-based similarities are more significant than other categorisation possibilities, suggesting that unspoken car design paradigms are indeed used when categorising cars.

Interviewees tended to use decades as a shorthand for car history categories. They mentioned ‘the sixties’ with tacit suggestion that car design changed on 1^{st} January 1960 and on 31^{st} December 1969, although they all quite clearly knew that this was not the case. Decades are convenient ways to structure time, even before the individuals were born. World events like World Wars and the 1929 Depression also created memorable time punctuations. Car design changed with WWI in terms of the social behaviour of car purchasers, though the physical layout did not change. WWII did not change social structures, but cemented car design concepts, burying the beam front axle, even if the main transition occurred previously.

Designers had a narrower outlook than historians; those who were neither but were enthusiasts had the narrowest outlook. This narrowing of outlook was perhaps not unexpected. Designers, after all, are interested in designing the next car rather than analysing what has taken place beforehand. Whilst they are not uninterested in what has gone on beforehand, the interest is modulated by their more specific desire to initiate change in car history than to study it. J C Jones' definition of design was, after all, "to initiate change in man-made things" (Jones, 1981, page 4). Car enthusiasts, generally, are enthusiasts for whatever they like and they have no reason to be broad in their outlook. They tended to decide that they were unable to comment on things that were outside their specific interests. The breadth of knowledge of some people from the car industry was salutary; immersion within the industry and interest builds up significant tacit knowledge of car history as well as design.

3.8 Subsequent literary analyses

Whilst numerical statistical processes are effective at describing paradigms, they do not function very well when dealing with why the paradigms changed and the reasons behind the changes. For this purpose the numerical answers from the earlier process were used to identify where to start investigating existing literature. This provided pointers that led to reasons, particularly in the technical literature, for the changes and paradigm shifts that were identified through the numerical processes.

3.9 Use of the work

As discussed earlier, the original motivation for the research stemmed from the development of personal ideas of themes in car history leading to the concept of paradigms. Practical teaching aids led to a more theoretical approach that evolved over a number of years and was discussed in various papers (Dowlen, 1995, Dowlen, 1997a, Dowlen, 1997b, Dowlen, 2002a, Dowlen, 2002b, Dowlen and Shackleton, 2003). Experience as an automotive designer also provided knowledge of processes involved which enabled greater understanding of the subject area as well as a desire to explore it in greater depth.

This then leads to the questions of why the research might be useful, who might benefit from it, and how might it be used, apart from in the teaching context. It also expands into the question of how the methods used might be re-used in other contexts and in other studies

Section 10.1 outlines possible further work that might be developed from this research. This splits into two sections. The first is the continuation and development of the work itself, using both an enlarged sample and further expert interviews. The second section postulates developments from the work and suggests other possible uses for it.

In terms of the methods and processes used to analyse history, the use of numerical methods allied to the subsequent narrative investigations can be developed to the study of other artefacts. Furthermore, the relationship of found artefacts to others that already exist might be investigated by measurement and placing of these artefacts within a suitable numerically-derived map. It might then be possible to identify exactly where and in what sort of narrative fashion one might be investigating other information concerning them, their construction and the manner in which they were produced. Measurement might also be linked to the discipline of experimental archaeology, in which artefacts are reconstructed. Evidence from car history shows that these reproduction artefacts need to be very carefully constructed in order to preserve the measurements and incorporate the paradigms that were current when they were originally constructed, and that constructive process itself can be used as a significant educational research process.

Charts, maps and timelines might be used in connection with museums in order to develop their collection strategies and to identify key themes that might be sought in order to further the direction that they wish to take in their approach, and also to remove selected items that do not significantly add to the strategy that they wish to take. They can also facilitate the production of narratives with which they can engage visitors and further their understanding in a way that is both educational and entertaining. This need engage with visitors in an emotional way has resulted in both practical and philosophical discussion in tourism (Hannabuss, 1999, Visit Britain, 2010). Conservation bodies can also use them to alert and motivate the public to timely action in respect of species, habitats and environments.

The repertory grid approach might also be useful within the museum environment. This process could elicit the constructs of curators and identify directions for their museum collections, and help them to identify the key items and themes in the museum. This would allow them to build the museum strategy around these and of highlight them to the visitors and researchers.

This limiting approach has been taken by some museums (such as the *Ny Carlsberg Glyptotek* in Copenhagen) where the curators have thought to identify a few key exhibits in each gallery and explain these thoroughly to the visitors through giving them extra information about them and their circumstances. Another example, also Danish, is in the Roskilde Viking Ship museum, which builds its whole strategy around as few as key five exhibits – all of which are incomplete. The repertory grid approach used with the curators can identify the key constructs that they wish to explain to visitors, who might otherwise not "see the wood for the trees".

It has been suggested in Chapter 1 that repertory grids might be used alongside such methods as Delphi for quickly investigating a topic via a number of experts. The key here, as mentioned earlier, is that the experts be allowed to select their own 'objects' or 'topics' about which the constructs are developed (and which are selected to cover the range of that area of expertise). This allows them to freely compare the topics that are key to their expert understanding of their area of expertise. Use of a 'warm up' section of an interview might also be used to identify their constructs in a less formal manner.

Repertory grids used in the manner in this research have already been used with first year design students to seek to develop a reflective understanding of their relationships with products. In this case each student was asked to identify nine objects with personal associations, and to use triads to identify their own constructs relative to these objects and to develop a table of their personal importance to each object. If students were engaged with their subject, they found that this approach was helpful and allowed them to uncover some of their personal interests. Asking them to formally present their work also enabled a degree of personal understanding and friendship to develop within the class as likeminded students were able to develop friendships early in their courses.

A totally different use of the repertory grid process might be within popular culture, as a journalistic tool that might be used as preliminary research for an 'expert' or 'celebrity' article. These articles generally take the form of an interview, sometimes around key items that the expert or celebrity relates to (such as is done in the BBC programme Desert Island Discs). What is important to the reader, listener or viewer is not what those choices actually are, but what it was that made that person select them – i.e. their constructs. Use of nine pieces of music rather than the eight used currently in Desert Island Discs would, of course, change a long-running formula, and it would demand more work on the part of the researchers, which was one of Stanton and Young's perceived disadvantages of using the method (Stanton and Young, 1998).

3.10 Summary

The chapter identifies suitable research questions and then describes the research processes that took place.

After an exploratory period to seek to identify exactly what research might be usefully undertaken the topic of design paradigms became clarified. This early work had been aimed not at uncovering the importance of these, but at seeking to identify and develop trends in car history. The design paradigm concept was one that seemed to be appropriate and it seemed to require further investigation.

The first process was the numerical work. The use of categorical data, particularly for suspension form and medium, implied that a factor analysis was not appropriate, and thus a categorical principal components analysis was undertaken. The decision to use layout and form analysis was as a result of these being crucial activities in the formation of car embodiment.

The subsequent constructive analysis using interviews to identify the car design and history constructs of a number of experts in car design and history took a different approach, making significant use of the repertory grid technique both for the last part of the interviews and for much of the subsequent interview analysis. This technique was originally developed by Kelly (Kelly, 1955) specifically to identify individuals' constructs – initially as a therapeutic technique, but the process has been used outside of that sphere to elicit constructs more generally.

Numerical analysis is not able to answer questions of why the paradigms identified in (particularly) the layout analysis came to exhibit such pronounced shifts, and for this purpose a focused literature search had to be carried out.

Uses of the research are suggested.

The next chapter identifies several issues and themes that were important to clarify before the numerical analysis was undertaken – namely those of layout and form and the crucial issue of the sampling process. Chapter five carries out a literature search showing how car history is traditionally construed and of the way in which the literature tends to describe it and then chapter six describes the numerical analyses. Chapter seven is devoted to the constructivist analysis using the interviews with experts, and chapter eight looks in detail at the layout paradigms identified by the numerical analysis. Chapter nine contains a brief discussion and chapter ten concludes this particular research and suggests directions for further work.

4 Themes

4 Themes

This chapter concentrates on some specific themes that are developed and have significant bearing on the rest of the work. It covers the topics of exemplars, change, layout, form, measurable qualities and sample selection, which last topic also includes a discussion of representation.

Car history analysis needs to include descriptions of the changes. How the eras relate to each other and whether there are consistent characters that determine those eras, or whether they are determined solely by the dating agencies and clubs. This chapter introduces some important concepts that are taken up more fully in the analysis descriptions in Chapter 6.

4.1 Essence of...

Searching for 'essence of veteran', 'essence of vintage' and ‘essence of … (whatever)’ could answer the questions of the characteristics of cars of those eras, and whether veteran and vintage paradigms are construed differently. Chapter 5 introduces descriptions and identifies date limits that selected by various organisations. This approach does not concur with the way that descriptive linguistic definitions are developed. One could argue that a measure of typicality could achieve this, although the descriptor would still be determined by usage rather than formally. How is a veteran or vintage car recognised without resort to dating? Could a coherent set of values, characters or descriptors apply to cars of particular eras? If a fake or copy from those eras is made, how easy is it to detect? The UK clubs concerned with dating regard fakes as heretical and ignore copies, although magazines are less pedantic and carefully constructed copies are deemed acceptable. Journalists are writing for their readers and are not necessarily producing text that is a response to thorough analysis. They tend to be enthusiasts. If the essence of an original can be gleaned from a copy they will accept it. Poor examples of copying are omitted because the readership is more perceptive than to accept them.

The existence of Post-Vintage Thoroughbred as a category implies that 'vintage' can be extended and cars in this category are expected to share the characteristics of ‘vintageness’, without dating criteria being met.

The determination of the 'essence of’ other descriptors is harder to determine than for veteran or vintage. 'Essence of' may indicate a design paradigm.

4.2 Change

This is about how change happened and about what changed, and why. It is about the way in which changes related to technology, society and world events. Technology here does not mean simply the means of production such as the development of steels or of tyre behaviour theory, but it also includes communication, advertising channels and their relationship to societal development and change. Car development coincided with changes in classes, in the UK. It paralleled middle class development and removal of landed, moneyed gentry, emancipation of women, removal of cultural barriers. In other countries, particularly the United States, the availability of relatively cheap cars may have effected those changes and been the agent responsible for some of the equalisation of society. Other countries, such as the Soviet bloc, were larger starved of money and there the car maintained its symbol of status. The car may have effected changes: it followed others. Events like World Wars, stock market crashes, rise and failure of communism and removal of absolute monarchies have played their part in car history.

Measurement of change is crucial to analysis. The rate of change of factors defines paradigms: lack of change denotes paradigm-like behaviour whereas rapid change indicates a paradigm shift. The first task is to measure the change: the second describes it and the third identifies the causation and reasons. This could be expanded into determining the implications on present and future behaviour, and about how we might design now and in the future. Design, as an activity showing intention, is always a future activity.

4.3 Layout

The terms *Layout design* and *Form design* are used predominantly during the embodiment design phase of the design process. Thus, an analysis of these two significant elements is what has formed the bulk of the quantitative approach towards car history analysis.

Layout might be alternatively termed *arrangement*. A full list of the variables that were used for the work on layout analysis is shown in Chapter 6 and Appendix 1. What is described here are a set of examples of the different configurations.

Cars have some obvious requirements about where parts are placed and how they are connected, and this changes. Most cars have four wheels, one at each corner, alternatively three, fewer with wheels in diamond arrangement, and a few others. Cars have motive power. This is usually an engine, but is sometimes an electric motor. The engine is usually internal combustion and usually has at least one cylinder, driving a crankshaft. The engine is placed somewhere – at the front, rear, or in the middle. Mid-engined usually describes a car with the engine forward of the rear axle. The engine usually drives the wheels, with its drive shaft longitudinally or transversely or (very occasionally) vertically. It may drive the front wheels, the rear ones, all four, or occasionally just one.

The final drive is likely to be by shaft. Several cars have in the past used chains, and some have used belts.

The main structure of the car may take one of several forms. There can be a separate chassis, a monocoque structure or a combination of the two: the option of taking loads on the engine and gearbox is seldom used in production cars, as the vibrations are too great. Several racing cars have used stressed engine blocks to transfer suspension loads, and the arrangement is common with motorcycles (Ludvigsen, 2010) and tractors, neither of which are included in this analysis (Dowlen, 1995).

Separate chassis take several forms. The most basic are two longitudinal members. In many historical cars these are channel section pressings, but chassis vary from this to a full space-frame as used on the 1955 Mercedes-Benz 300SL (Lengert et al., 2006). Most chassis are made from steel, but cars have had wooden chassis, aluminium chassis or fibreglass composite structures (Adams, 2014, Ludvigsen, 2010). Body construction varies from no body at all, through non-structural coachbuilt bodies, to structural bodies using steel pressings or aluminium or glass-reinforced polymers.

Suspensions attach wheels onto the structure, providing a degree of comfort and allowing the wheels to remain in contact with the ground. Many arrangements have been used. Some use rigid axles or even a rigid frame. Others are independent with various geometries, perhaps upper and lower arms or a lower arm with a strut. There are many variations. Occasionally there is a semi-independent suspension, usually with a torsion beam, where a U-shaped assembly has wheels attached and pivoted on the body. Suspension geometries at front and rear are unlikely to be the same.

The suspension medium is usually a spring - perhaps a steel leaf spring, or a coil spring or something else. Hydropneumatic suspension use air as the medium and fluids transfer loads to the air vessel.

The first recorded use of pneumatic tyres was in 1895 where Michelin fitted them onto a Peugeot vis à vis (Figure 4.01): by the turn of the century virtually all cars had them. The 1920s Trojan (Figure 4.02) may be the last car to have solid tyres. They were still common on commercial vehicles in the 1930s.

Figure 4.01 Peugeot, 1895, with Michelin pneumatic tyres fitted

Figure 4.02 Trojan, 1924 with solid tyres

Designers had difficulty arranging direction control on early cars. This isn't needed with horse-drawn vehicles – the horse steers the vehicle. The steering wheel arrived relatively soon, but there were still some cars with tiller or lever steering until the 1950s and 1960s – the Messerschmitt (Figure 4.03) was one of the last cars with handlebars.

Figure 4.03 Messerschmitt, 1955 (Courtesy RM Sotheby's)

Car designers quickly placed the driver in a front seat. In the infrequent situation where cars were driven from the rear, the front passengers may face the rear so the driver can talk to them easily.

Figure 4.04 De Dion Bouton vis à vis, 1901

Most cars have two (or three) people abreast, with the driver on one side or the other, towards the centre of the road. Some cars place the driver in the centre, such as the Messerschmitt in Figure 4.03, or sometimes in the centre of three front seats.

The reasons for these descriptors are covered in Chapter 6 where the layout analysis is described in detail. The full lists of the categories are shown in Appendix A1.

4.4 Form

Similarly, *form design* is one of the significant components of design within the embodiment design phase. Form descriptors have been used to measure changes. Some are dimensional characteristics like overall length, width, height, wheelbase and distances between features or the rake of the screen.

Passengers sit in one or more rows. More than three rows and the vehicle is debatably a minibus. The number of car doors seems to have a distraction: some have no doors: some might have a single door and others have up to six doors. Counting passenger rows is more useful for seating capacity. Rows of seats have an effect on the car’s form.

Other form variables are harder to determine. Some are descriptive terms, such as the radiator grille shape, the form of the bonnet, the kind of windscreen and so on. Harder to determine are measures like the roundedness. The analysis of form is covered in detail in Chapter 6.

4.5 Measurable quantities

Several car data items are readily available, whether they are historically related or not.

These are engine capacity, bore, stroke; engine power and torque and the speeds at which peak power and torque are produced.

Also readily available are maximum speed and an acceleration times.

Length, width, height, wheelbase and unladen weight are also easily available. How these quantities change indicates technological development: car weight shows structural efficiency, strength, and may relate to legislation for crash resistance. Weight is related to the acceleration but has little to do with the top speed. Acceleration and top speed in relation to engine size demonstrate fuel efficiency. The car's form in relation to frontal area will affect wind resistance and hence top speed. Frontal area and weight are linked, as fatter, wider cars are heavier. How quantities change indicates whether design paradigms exist: gradual change indicates development, and high change rates indicate paradigm shifts.

4.6 Sample Selection

It is important to select an effective car sample. Tumminelli (Tumminelli, 2004) largely ignored pre Second World War cars (there are two examples in his book), and Mausbach (Mausbach, 2006, Mausbach, 2009) largely followed his example. Cars were certainly produced before the Second World War, many of them. These should be included in any analysis that is attempting to obtain an effective historical spread.

For engineers, the natural approach to analysis is numerical: for others it is less so. It is also used within social science and medicine, particularly in epidemiology where it is fundamental.

The sampling frame needs to be identified. The population to be measured is somewhat unclear. Whilst it is true that an analysis of any car is able to yield data, the question relates to exactly what is meant by statements as broad as 'cars of a certain date were like such and such'. This statement could be construed as meaning that every car made at that particular date had that characteristic. But it does not mean that. It means that there is a reasonable probability that a car of that date has that characteristic. The population is certainly of cars of each particular date, and some representation of cars from that date is required. The argument is that the sampling frame consists of each different model from that particular date. Sales figures might be used to determine the sampling frame – except that agglomerations of sales figures do not identify precise variants, and that sales figures are usually related to countries rather than globally and are notoriously difficult to obtain reliably.

The whole population of the sampling frame cannot be measured. Sampling is needed.

The approach is to identify a sample, find appropriate measures, see how they vary and seek to understand how those measures behave. In the case of this historical analysis, seek how these measures change over time.

The following need to be resolved.

What cars to analyse?

How are these selected?

How many are needed to obtain effective answers?

After the numerical analysis the more descriptive process will explore why things changed.

It is suggested that the following guidelines be followed:

The sample should cover from when cars first appeared to the present with no gaps. It should cover a range within each period and should provide normal distributions for each measure within each period.

In the early years of car production cars were largely built by hand and although a specific car might be identified as being a particular model, in those days each example was slightly different. It is helpful if these slight variations between individual examples of non-mass-produced cars are measured effectively. They may be treated separately or as a single example. Most mass-produced cars have been produced in several variations, in spite of Henry Ford's dictum that "Any customer can have a car painted any colour that he wants so long as it is black " (Ford and Crowther, 2003).

Figure 4.05 Black Ford Model Ts - 1914 and 1924

For some cars, such as the Ford Mustang, there may be more possible options than individual cars. The approach has been to select similar examples if appropriate (always allowing for the adequate coverage of the sampling frame) but similar cars must not skew the analysis.

Guidelines suggest that if the sampling frame consists of fewer than thirty examples, each member of the frame should be selected. If the sampling frame is larger, at least thirty members should be selected in such a way that a spread of data is likely to result from the sample (Saunders et al., 2009).

Figure 4.06 Ford Mustangs, 1966 (Right image, favcars.com)

4.6.1 The initial approach

The original premise was that any car provides data: thus a large sample over a long period is all that is required to demonstrate adequate behaviour. That may be correct but is a limited understanding. Guidelines are available about how to select samples, usually associated with identifying suitable samples from among human populations.

The first approach to be undertaken effectively ignored the need to identify a representative sample. Data were gathered from a convenience sample of cars provided simply because photographs of them were available. But the sample covered the whole range of dates. It comprised 453 examples ranging from 1878 to 1998 (when the sample was first selected). It is known in the following text as the ‘original sample'. The earliest car in the sample was Amedée Bollée’s La Mancelle.

Figure 4.07 Bollée La Mancelle, 1878 (Kupélian, 1997, page 21. © Autoworld)

Cars were identified by date of manufacture and not design date. A particular example of each model of car has been selected, not a range of possibilities. The intention was not to include more than one version of each model in the analysis. The sample concentrated deliberately on production cars. Racing cars and concept cars are largely excluded: racing cars because they have their separate history and concept cars because they are sometimes unrealistic and are not always functional, although they are influential, tend to demonstrate future suggested design directions, and are used significantly as role models by designers. They do not form the bulk of the car population of any particular time, which tends to be less innovative. It may also be that they overly represent a significant minority form of the car – in particular, there is a larger preponderance of sports cars among them than there is in the general population.

This simplistic and opportunist process produced answers that appeared effective, so then a larger representative sample was sought to confirm the analysis.

However, recommendations suggest that every specific period from 1878 to 2015 should have a sample of at least thirty cars (Saunders et al., 2009). In practice, the time period selected has been a period of five years, giving a suggested sample of about 850. With early periods this number is a little difficult to arrange, and it has also been difficult to provide an effective sample for the war years. The initial sample had 453 cars, which was of this order of magnitude but somewhat fewer than ideal. The initial approach clearly needed augmenting, particularly with non-historic cars.

4.6.2 UK Best-selling cars

The original sample was augmented by a set of cars that were the UK best-selling cars from 1964 onwards. These are not always at the forefront of design or influential, but they represent the UK market. A choice of model variation was made, usually which variation might be construed as most popular, with some variations being added to include particular features and to cover the range of variations available. This ignores how car companies massage the sales figures to improve them to their advantage. It is acknowledged that this selection could create bias in the sample and that it is not an ideal direction to have taken. It can also be argued that this sample majors on the median rather than the spread of values and is therefore not ideal.

It was initially thought that best-selling car lists would be available from the Society of Motor Manufacturers' and Traders (SMMT) (Society of Motor Manufacturers and Traders, 1926 - 2007) back to their first annual survey of the British Motor Industry, but this is not so. The data peter out before the mid-1960s, providing less and less useful information. Some of the cars that were best sellers in the early years (1965) of the list were first produced earlier, so cars on the lists include those from the 1950s, such as the Morris Minor 1000 (1956) and the Mini, Ford Anglia and Triumph Herald (1959). The UK lists are, by definition, peculiarly British and demonstrate British insularity and lack of international understanding[3]. As these are best-selling lists and the majority of people are not car enthusiasts, as might be expected, they show a preference for what car enthusiasts perceive as being boring and staid. It is clear that they tend to represent the median car rather than the range of car design that took place at a particular time, and car enthusiasts are usually more interested in what they perceive as being more innovative and thus in what might be observed as being the extreme of the range towards the direction that in which the range is perceived to be moving.

Figure 4.08 Ford Capri 1981

The only model in the UK lists with any sporting credentials is the Ford Capri – largely in the form (i.e. shape) of the car. The data cover up the 'hot hatch' phenomenon. 'Hot hatches' are listed within standard models, not

[3] This is shown via the way in which car models are amalgamated. In the 1960s all non-British cars are amalgamated into a single category as if they were simply regarded as being 'foreign' in some way. It also reflected, of course, that they were not sold in large numbers in the UK at the time.

separately. The people carrier trend has made little impact on UK sales. The Vauxhall Zafira and the Nissan Qashqai are the only examples in the lists. 4x4s are notably absent, although four-wheel drive versions exist of some cars in the lists.

Figure 4.09 Vauxhall Zafira and Nissan Qashqai (Left: Autocar: Right: favcars.com)

4.6.3 Sample Development

Some of the original sample were removed, because they were deemed to be racing cars or not cars at all. 434 of the original sample were augmented by the UK best-selling cars. The resulting analysis database contained 571 cars.

This succeeded in covering the whole period that cars have been produced. Benz and Daimler produced their pioneer cars in 1886. The pragmatic approach included a single example of a pre-1886 car: La Mancelle steam carriage built by Amedée Bollée père in 1878. The latest examples are from 2013.

This is somewhat less than if the guidelines of thirty cars per five-year period were adhered to, which would require 840 cars. The figure used is of that order, at 571, but is somewhat fewer. The number used in the sample creates a reasonable confidence level. It would be improved by additions to create at least thirty in each five-year period. If thirty are required for each year, then about 4200 cars might be required and would obtain better results.

4.6.4 Other possible approaches

Other approaches could be used to obtain a suitable sample. Examples for major marques could be analysed over time. Relatively few marques would need to be included. Many of the marques available today were first manufactured very early, and there would be continuity back to then. With several extra marques (such as splitting the Leyland names into constituents) it would be possible to develop a list to include a reasonable sample and covering all periods.

The cars that Tumminelli (Tumminelli, 2004) used could be analysed and the results compared. Although Tumminelli states his research contains 1,222 models from 1947 to 2004, the book only contains a selection - about three hundred. He says that they are not necessarily the best nor the most attractive and have been selected because they represent a style, an innovation or show a unique design feature. They were not intended to be representative. More are from Italian or American manufacturers than from others. His approach is supported by interview comments, where designers do not derive inspiration from representative cars but look to cars with particular styles, show cars, and sports cars for their inspiration, pushing the perception of boundaries of current form and being constrained by practicalities such as people, engines and luggage.

Several other collections of cars have been produced over the years, usually by journalists. An example of this is that of *Cars of the Year*. These have been selected each year since 1964 by an international jury of motoring journalists and may include cars manufactured in smaller quantities, although they limit themselves with sales of at least 5000 per year. It includes cars that were perceived at the time to be significant, but subsequently failed in the market place. The first jury was in 1964, similar to the UK sales data. This list was produced at the time, so there is no retrospective viewing window. The current process starts with a long list of cars – 30 or so – and reduces it to seven (or eight in 2007) nominees voted on by an international jury with 58 members. From 2002 onwards the shortlist can be found on the Car of the Year website (Car of the Year Organizing Committee, 2015): before that the website only lists the three highest scorers.

Other publications have produced their lists of top hundred most beautiful cars: this was done by the *Daily Telegraph* in 2008 (Daily Telegraph, 2008), and the *Autocar* in 2002 (Autocar, 2002). Whilst their readership voted on each of the cars, inclusion was based on personal aesthetic grounds. Such a list is timely. But it is retrospective and suffers from that bias, and also suffers because it omits cars that were not thought of as being beautiful.

The *Daily Telegraph* list includes no objective assessment of beauty. There was no attempt to make the list representative. It lists what met the readers' personal beauty criteria. Although subjective, there was still agreement that the Jaguar E type won, with the most votes (Figure 4.10). The list provides an overview of readership's car dreams. The cars are still representatives from the date they were manufactured.

The *Autocar* list of 100 beautiful cars (Autocar, 2002) suffers from the same issues.

An international group of motoring experts sought out the 20th Century's most important cars. They started with 700 cars selected by clubs and industry, which was reduced to a list of 200 in February 1997, and compressed to a list of 100 in September 1997. Voting reduced this to 26 by the Geneva Motor Show of 1999 and the Model T Ford was announced as the 'most important car of the 20th Century' in November 1999.[4]

[4] The only reference that could be found to support this was a Wikipedia one. This does refer to other sources, but these are web-based sources that are no longer available.

Figure 4.10 Jaguar E Type Roadster, 1963

This list was not intended to be representative. It selected preferred cars, and was chosen retrospectively, and may be affected by journalistic bias. There are more from some periods than others, making a period-based analysis difficult. The criteria are difficult to obtain. The selection was agreed by the jury, but the criteria used are not clear.

The deliberate selection of non-representative cars is an interesting approach. Its validity depends on what data are required from that study. If innovation takes place ‘at the edges’, then to study innovative car design it is important to study outsiders, as innovation happens from here. This approach was used, utilising the complete data set (Dowlen, 2012b) and developed into a journal paper (Dowlen, 2012a).

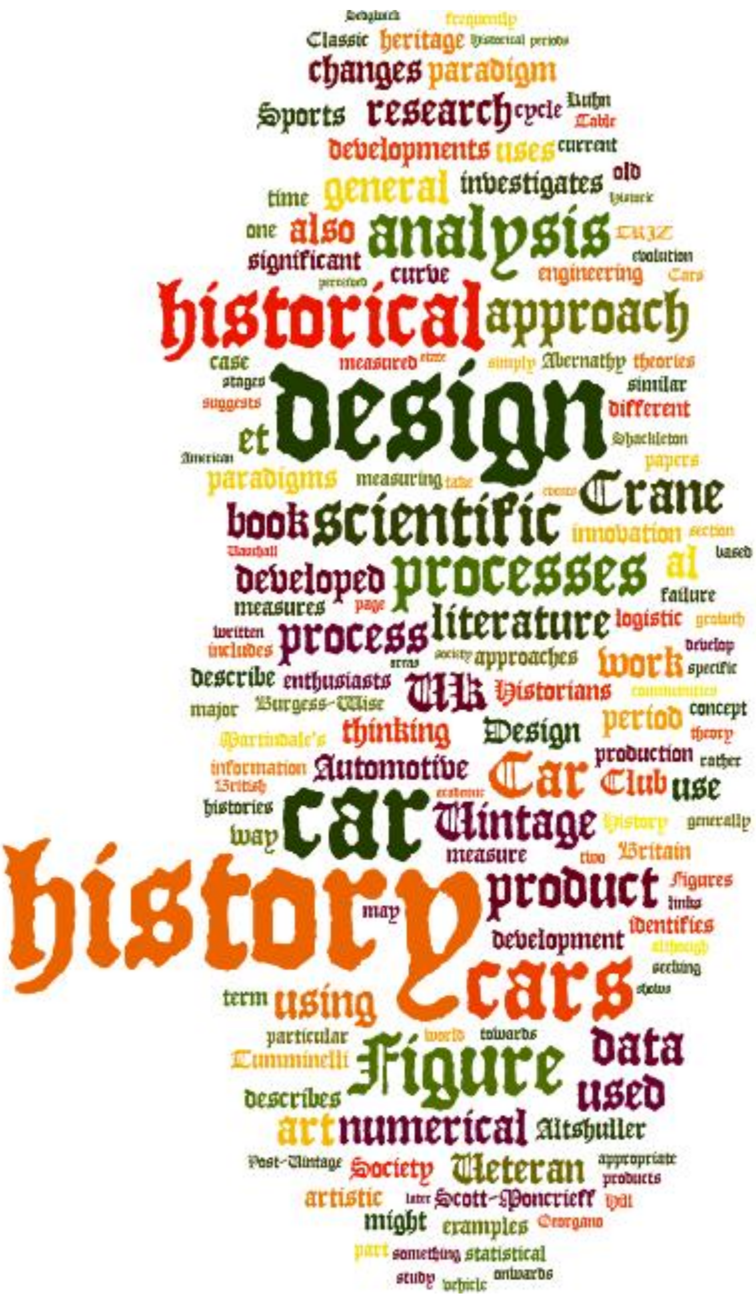
There is a danger of the omission of a significant minority group of cars. If best-selling cars are chosen, then minority groupings of sports cars and off-road vehicles would be ignored as these are unlikely to be best sellers. This is less likely with the Car of the Year list, although the significance of a potential entry may be missed. Inspection shows that several cars that have been subsequently perceived as influential were missed such as the Smart Car, Audi A2 and the original Range Rover of 1970.

Figure 4.11 Smart, Audi A2, Range Rover (left, Artur Mausbach)

4.6.5 Conclusion

The original approach, while suffering from being retrospective, has created an effective selection that adequately covers most periods and also includes enough cars from most periods to allow for effective variation. The addition of UK sales data allows a non-retrospective position to be taken and indicates that the range in this selection is significantly less, demonstrating a tendency towards the middle ground. This is deemed to be a reasonable compromise. The limitations are the retrospective nature of the initial selection and the lack of range of values from the sales data. Augmentation using any of the lists described would add data but may not develop additional novel themes.

5 Literature Search



5 Literature Search

In their PhD theses Mark Lange and Toni-Matti Karjalainen (Lange, 2001): (Karjalainen, 2006) develop their literature searches through the process of determining the research and how the thesis develops. Although this is a relatively short part of each thesis, relevant literature is utilised throughout both theses and not simply in the introductory chapter where the research questions are developed.

Lange is carrying out a scientific study from a department of machine design. This is firmly fixed within the engineering tradition in spite of the significant shift of emphasis evident in the title of the thesis. He admits that little direct literature exists on his most significant enquiry, which is that of product synthesis. He postulates that this is to do with it being conceived of as a black art and thus unknowable. But then he wishes to take a scientific line of enquiry about it, and starts to investigate scientific processes and thinking domains.

This is perhaps similar in scope to the current inquiry, which is centred around determining quantifiable product data and using these data to describe and determine patterns of information that lead to historical insights, using the car as a major case study.

Karjalainen, on the other hand, is making a business-based enquiry and seeking to fill a gap in the discussion of branding and product design. This is where the strategic goals and orientations of the company are transformed to be actualised through product branding. In this sense there are similarities between what he is doing and the process of Quality Function Deployment, which seeks to transform not company values, but customer wishes into design language for actualisation, embodiment, or whatever other term might be used to denote some form of transformation from wish into product reality.

This literature search covers two major areas – car history and the use of quantitative techniques and processes within historical evaluation. The chapter starts with a brief investigation of the conventional approach to car history.

5.1 An Overview of the conventional approach to car history

This first part of the literature search identifies the traditional categories and then shows how one particular reference describes car history. It then describes each of the categories.

Cars were first developed during the late 19th Century. Conventional car history states that says Karl Benz and Gottlieb Daimler were the – independent – inventors in 1886. (Feldenkirchen, 2003, Lengert et al., 2006, Mercedes-Benz Museum)

Figure 5.01 / 5.02 Replicas of Benz tricycle (L) and Daimler Phaeton (R) from 1886

Other early pioneers are frequently ignored in conventional histories such as Bollée (Barker and Harding, 1992), Jacquot, De Dion & Trépardoux, Markus (Hantschk and Schaukel, 1988), Johansen and Hammel.

Car history descriptors differ slightly between countries. This causes debates and confusion. Two events dominated the twentieth century – World Wars from 1914 to 1918 and 1939 to 1945. These caused significant changes in car history in all countries.

A Centenary Special publication from 1985 (Hutton, 1985) takes a typical UK perspective. The book identifies:

Era	**Title**	**Dates**
1	Early Days	1885 – 1904
2	The Edwardians	1904 – 1914
3	The car at war	1914 – 1918
4	Vintage era	1919 – 1930
5	Modern cars emerge	1930 – 1939
6	The car at war	1939 – 1945
7	The post-war car	1945 – 1955
8	Period of innovation	1955 – 1965
9	Boom time	1965 – 1975
10	Today and tomorrow	1975 – 1985

Table 5.01 Car history eras (Hutton, 1985)

The convenience of the last four decades after the Second World War might have coloured later divisions. The book identifies eight milestone cars which are seen in Figures 5.03 to 5.10.


Figure 5.03 Panhard, 1903 Figure 5.04 Ford Model T, 1912

Figure 5.05 Morris Bullnose, 1923 Figure 5.06 MG J2, 1932 (Right: MG Owners' Club)

Figure 5.07 Volkswagen, 1947 (Wikimedia Commons: Pfan70) Figure 5.08 Morris Mini-Minor, 1959

Figure 5.09 Ford Cortina, 1970 Figure 5.10 ECV3, 1983 (aronline.co.uk)

The book was written for the general public and is relatively free of jargon. Common titles for car history eras in the UK and US are summarised into

Table 5.02. These data have been distilled from various sources, but the major source has been the Society of Automotive Historians (Society of Automotive Historians, 1973 onwards-b, Wilson, 2011).

Era	**Dates**	**Country**
Steam	1700 - 1900	US only
Veteran	Before 1905	US and UK
Veteran	Before 1919	UK (sometimes)
Brass	Before 1918	US only
Horseless Carriage	Before 1916	US only
Nickel	1913 - 1929	US only
Edwardian	1905 – 1918	UK only
WWI	1914 – 1918	US and UK
Vintage	1919 - 1930	UK and US
Classic	1925 - 1948	US
Pre-WWII	1930 - 1948	US
Post-Vintage	1931 - 1939	UK
Post-Vintage Thoroughbred	1931 - 1939	UK, selected cars
Antique	Variable	US and UK (occasional)
WWII	1939 - 1945	US and UK
Post-War	1946 - present	US and UK
Historic	1941 - 1960	UK
Muscle	1964 - 1972	US, selected cars

Table 5.02 British and US car history eras

In Britain the terms *Veteran* and *Vintage* are used vaguely in general conversation – they simply mean ‘old and valued’ or ‘old’ - whilst the Veteran Car Club of Great Britain and Vintage Sports Car Club determine strict era definitions which are somewhat narrower (Veteran Car Club of Great Britain, 2012, Vintage Sports Car Club, 2007). There is little attempt to categorise post-World War II cars, although *Classic* is used loosely for anything before about 1990 that is still perceived as desirable.

5.1.1 Veteran

Veteran is used for someone with wartime service or with long specialist experience and significant expertise. The Veteran Car Club defines it as before 1905 (Veteran Car Club of Great Britain, 2012).

Figure 5.11 De Dion Bouton vis-à-vis, 1901

Figure 5.12 Peugeot 1902

The two cars in Figures 5.11 and 5.12 illustrate something of the variety. Further specific information on Veteran cars is found in Michael Ware's small Shire volume (Ware, 2003), in the well-illustrated book by David Burgess-Wise (Burgess-Wise, 2006) and in the excellent source book by Scott-Moncrieff (Scott-Moncrieff, 1963). The variety of Veteran cars can be found in programmes and outlines of the London to Brighton Run (Bennett, 2005, Heath, 2002a, Heath, 2002b, Lord Montagu of Beaulieu, 1990, Wearing and Burgess-Wise, 1994, Whitaker, 1985, Whitaker and McComb, 1988).

5.1.2 Edwardian

Edwardian generally refers to anything from the reign of King Edward VII, - 1901 to 1910. General usage is different from car use, where the dates start and finish later and are from 1905 to 1918. The era, for cars, is also covered excellently in Scott-Moncrieff's book cited in the previous section (Scott-Moncrieff, 1963)

Figure 5.13 Rover 1906 Figure 5.14 Vauxhall C Type 'Prince Henry' 1911

The two cars in Figures 5.13 and 5.14 give an idea of developments over the period. The term has little usage outside of Britain, which perhaps is not surprising.

5.1.3 Vintage

This is frequently used indiscriminately to refer to old cars, and has not kept the Vintage Sports Car Club's narrow meaning of dating. *Vintage* derives a wine's date. In general car parlance it is frequently used (car enthusiasts would say misused) to mean any valued old car or vehicle. The Vintage Sports Car Club defines *vintage* as between 1919 and the end of 1930 (Vintage Sports Car Club, 2007). Bill Boddy's small Shire volume outlines the characteristics of vintage cars well (Boddy, 1996) and Cyril Posthumus gives a reasonable account of their history (Posthumus, 1977). Other texts stretch the term somewhat (de la Rive Box, 2001).

Figure 5.15 Morris 1923 Figure 5.16 Mercedes-Benz 1927

Figures 5.15 and 5.16 show two examples of Vintage cars.

5.1.4 Beyond Vintage

The Vintage Sports Car club generally frowns on cars built after 1930, but allows some to be called Post-Vintage Thoroughbreds (Vintage Sports Car Club, 2007). Post-Vintage Thoroughbreds show vintage-like characteristics, whereas more general cars from that period showed significant innovation such as independent suspensions and monocoque construction. Figures 5.17 and 5.18 show Post-Vintage Thoroughbreds: Figure 5.19 shows a Vauxhall from 1937 (Ward, 2009).

Figure 5.17 Frazer-Nash 1932 Figure 5.18 Bentley 4¼ litre, 1936

Figure 5.19 Vauxhall 10, 1939 (Reproduced courtesy of Glasgow Museums Collection)

5.1.5 More generic terms

Other terms such as *Historic, Classic* and *Antique* are frequently used in a general sense and are not particularly specific – unless there are legal reasons for their determination (such as for *historic* vehicle legislation in the UK) (Austin and Harvey, 1986, Ball, 1987, Burgess-Wise, 1978, Frost et al., 2011, Frost et al., 2006, Robson, 1989). In most of these publications the term Classic is used simply to denote a broader dating interest than any of the more specific dating categories.

5.2 Car History Literature

This section covers the general spread of car history literature. It is not exhaustive, because car literature abounds. Cars have an enthusiastic following which generates literature almost to saturation point. The intention is to gain an overview of the types literature.

5.2.1 History or heritage

History and *heritage* are different. Car *history* studies what happened, when and how, with reasons. When historical interest is developed into enjoyment of old cars it becomes *heritage*. *Heritage* restores, reworks, displays, commercialises and enjoys car *history*. Worsley, (Millard, 2012) "is a natural adherent to the fact that once you take *history* outside academia it needs sexing up a bit" (page 20) and it becomes a *heritage* - saleable and part of tourism and leisure industries (Hannabuss, 1999).

Much car *history* work is by interested amateurs, enthusiasts and those who use and enjoy old cars – those interested in *heritage*. Most are knowledgeable about the cars they own and cars produced by those companies.

5.2.2 Historic vehicle associations

The primary car research society is the Society of Automotive Historians. This produces a bi-monthly newssheet, the SAH Journal (Society of Automotive Historians, 1973 onwards-b). It also publishes Automotive History Review (Society of Automotive Historians, 1973 onwards-a) containing peer-reviewed papers. The society has open membership. The British Chapter of the Society, the Society of Automotive Historians in Britain, produces SAHB Times (Society of Automotive Historians in Britain, 1995 onwards) containing general articles, and an annual publication, Aspects of Motoring History (Jeal, 2005 onwards) containing refereed papers.

Academic work is carried out by the University of Brighton on behalf of the Federation of British Historic Vehicle Clubs, a portfolio society subscribed to by enthusiasts' car clubs. Their remit encourages preservation and use of old vehicles as part of British National Heritage. They work in six main areas: legislation, research, trade and skills, links with FIVA (Fédération Internationale de Vehicules Anciens), heritage and cultural, technical and events. Their sponsored research has produced reports documenting the scope of the UK historic vehicle movement (Frost et al., 2006, Smith et al., 2011). The reports demonstrate the value of car *heritage*.

5.2.3 Magazines

Several magazines are devoted to Classic cars. The best-selling is *Classic and Sports Car* (Haymarket Publications, 1982 onwards), which provides journalist-produced articles for enthusiasts. Comparative tests provide first-hand accounts of car behaviour and specifications. A more historical approach is taken by *The Automobile* (Enthusiast Publishing, 1982 onwards); still enthusiast-led, it includes general news items and historical articles. Historical data aimed at what was then current design is provided by magazines that have been in continuous print for a long time, such as *The Autocar* (Autocar, 1896 onwards).

5.2.4 Books

Automotive history research tends to be book-based, usually aimed at enthusiasts. Many examples describe themes, movements and styles such as Sparke (Sparke, 2002), Georgano, Sedgwick and Ason Holm (Georgano et al., 2001) and Scott-Moncrieff (Scott-Moncrieff, 1963). Sparke, a design academic, treats historical design themes. Georgano, Sedgwick and Ason Holm (Georgano et al., 2001) produced a thorough analysis of design principles and processes, covering form and engineering. Scott-Moncrieff (Scott-Moncrieff, 1963) provides a historical discourse from the start of motoring to 1914. Eckermann (Eckermann, 2001) and Newcomb and Spurr (Newcomb and Spurr, 1989) take an engineering narrative-based approach.

The Daily Express souvenir guide for the car’s centenary contains useful historical information, giving a reasonable outline of car history.

Other books adopt a catalogue-type approach. Typical are Culshaw and Horrobin (Culshaw and Horrobin, 1997), The World of Automobiles (Northey and Ward, 1974), an encyclopaedia in 22 volumes, and Burgess-Wise (Burgess-Wise, 1987). Scheel (Scheel, 1963) combines general history with a catalogue ordered by country. The Observer's Books of Automobiles includes histories at the beginning (Manwaring, 1961, Manwaring, 1962, Manwaring, 1963).

5.2.5 Specific manufacturers

Other books investigate particular manufacturers (Buckley, 1998, Dymock, 1998, Filby, 1976, Ward, 2009) or particular models (Jamieson, 2001, Knowles, 2007). Dymock's history is of the Renault marque, Filby's of TVR, Buckley of Jaguar and Ward of Vauxhall. Jamieson's book covers simply the Lancia Lambda, and Knowles the Triumph TR7.

The Profile series of booklets (for instance (Ball, 1987, Barker, 1987, Berthon, 1987, Bird, 1987, Boddy, 1966, Buckley, 1987, Conway, 1966, Eaton, 1966, Eaton, 1967, Hull and Fusi, 1987, Jenkinson, 1987, McComb, 1987, Nicholson, 1966, Oliver, 1966, Pomeroy, 1987, Posthumus, 1987, Sedgwick, 1967, Sedgwick, 1987, Stone, 1987, Tubbs, 1987)) also cover just one car each, outlining developments and design.

Shire volumes cover many car and transport-related topics, including Electric Vehicles (Georgano, 1996), Three wheelers (Hill, 1995), Motoring Specials (Dussek, 1991), motoring history - Veteran Motor Cars (Ware, 2003), Vintage Motor Cars (Boddy, 1996), the Brighton Run (Lord Montagu of Beaulieu, 1990), Austerity Motoring 1939 - 1950 (Lane, 1987) - and some on specific manufacturers and cars: Morgan (Hill, 1996), Triumph Sports Cars (Robson, 1988), MG (McComb, 1994) and Citroën (Wood, 1993).

5.2.6 Historical analysis

Books occasionally contain historical analysis, such as Tumminelli (Tumminelli, 2004) and Womack, Jones and Roos (Womack et al., 2007), which is not concerned with design history, but production processes.

The categories and trends may result from a clustering arrangement such as that carried out by Mauch using k-means clustering (Mauch et al., 2015).

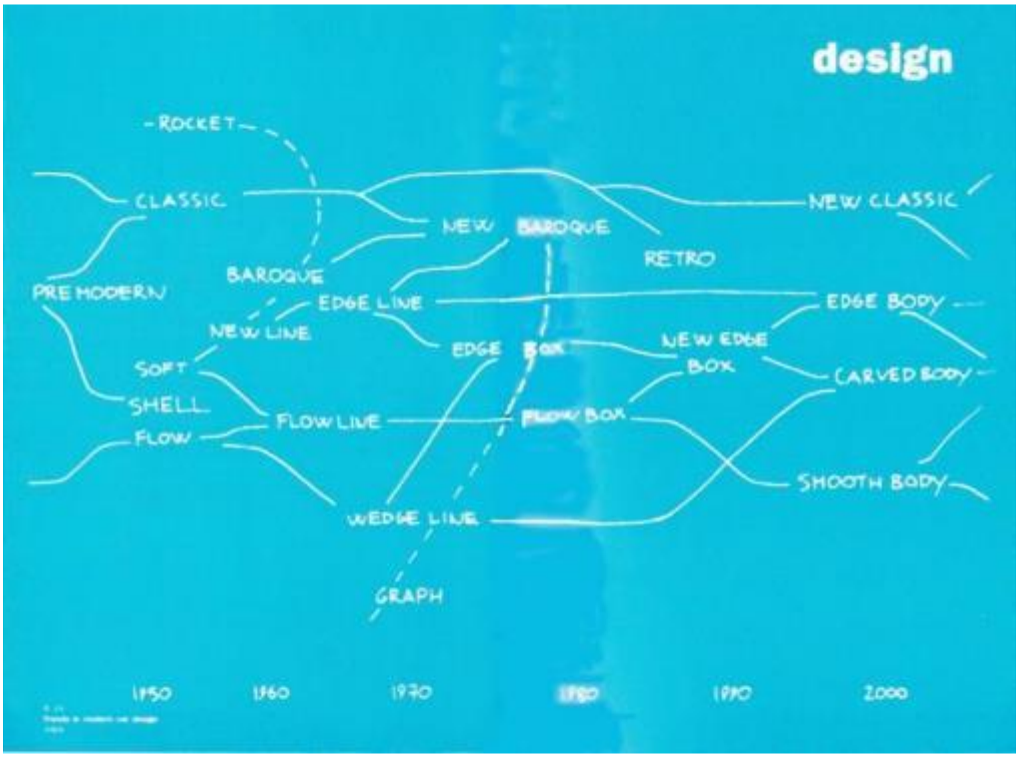


Figure 5.20: Car style development (Paolo Tumminelli, 2004)

Tumminelli has published a trilogy of books on European, American and Asian car design (Tumminelli, 2011, Tumminelli, 2012, Tumminelli, 2014). These major on cultural and social developments.

His 2004 analysis was the basis of Mausbach's (Mausbach, 2006) timeline showing developments using exemplars. (Figures 3.01 to 3.03).

Mausbach uses *paradigm* in his website and in his 2009 article (Mausbach, 2009). He agrees automobile design is stuck in paradigms. He claims a paradigm shift can be achieved through novel artistic approaches to sustainable design as outside influences interact with established processes.

The introduction to the 2007 edition of *The Machine that Changed the World*, (Womack et al., 2007) suggests that the book (1990) has become a classic alongside Peter Drucker's *Concept of the Corporation* (Drucker, 1946) and

Alfred Sloan's *My years with General Motors* (Sloan, 1965). Historical analysis is not the book's aim, but changing the management and organisation of production.

The automotive industry and its environment (Nieuwenhuis and Wells, 2003) is not a history book but contains automotive history, written to establish the history of the Buddist manufacturing paradigm – that is, use of mass-produced pressed steel construction using press tools, and to demonstrate that the paradigm is changing, as it doesn't supply vehicles in the manner the market expects.

Abernathy (Abernathy, 1978) charts changes and developments in the American automobile history. He indicates that early product innovation gave way to process innovation once the definitive design had been developed. The term *definitive design* may be similar to *design paradigm* or a representative car. He says this was determined in about 1922, and identifies the term with the Model T Ford. He investigates innovation versus productivity and shows how one subsumed the other. He analyses a vehicle plant as his unit, looking there rather than in the examples of cars. He identifies twenty automotive innovations: he tabulates these (page 51).

Abernathy is only concerned with the US and not worldwide motor industry and some of these innovations would be different on a world scale. Abernathy considers international technology transfer between the US and Europe, suggesting that earlier transfer tended to come from the US towards Europe, whilst later transfer has gone in the opposite direction.

He investigates incremental vs radical innovation and diffusion of process innovations, competition and the factors affecting and stimulating innovation and attempts to produce a general model of innovation and process change.

Abernathy includes numerical information related to production information, but little is related to design.

Decade	Automobile Design	Automobile Assembly	Engine Design	Engine Manufacturing
1920 - 1929	Closed steel body	Use of seam welding in body and chassis assembly	Aluminium alloy piston	Cemented carbide cutting tools
1930 - 1939	Independent suspension	Unit body construction	Automatic choke and downdraft carburettor	Cast crankshaft and camshaft
1946 - 1955	Improved automatic transmission	Electronic-assisted scheduling for assembly	High-compression V8 engine	Extensive automation of engine plants using transfer-line concepts
1956 - 1965	Disc brakes	Body corrosion protection	Aluminium engine	Thin-wall grey cast-iron engine
1966 - 1874	Energy-absorbing steering assemblies	Automatic chassis and body assembly	Electronic ignition	Programmable control

Table 5.03 Twenty Automotive Innovations (Abernathy)

5.2.7 A very different approach

The opposite approach is taken by *Driving Passion* (Marsh and Collett, 1986). Its topic is emotional attachment to cars. It is not an obvious car history book, but contains considerable history. It investigates how cars are related to psychology. It includes costume, fashion, jewellery, fantasy and weapons, ending with thrill.

The Pegaso in Figure 5.21 espouses this. The name says it is more than a car – an experience. This links with Mr Toad from The Wind in the Willows (Grahame, 1908), who falls in love with the thrill of the car.

Figure 5.21 Pegaso Thrill Berlinetta (Autoconcept-reviews.com-2008)

5.2.8 Conclusion

Car history literature majors on enthusiasts and not the academic. It centres on stories of cars written by marque authorities. Separating heritage from history, enthusiasm from rationality, is difficult. It is hard to remove personal elements, and difficult to find time-based analysis.

Analysis of car history is most comprehensive in management and industry-based texts, presenting historical reasoning as precursor to recommending changes in production systems. Authors are not enthusiasts and historical reasoning from data is foremost.

Investigation of car owners', users', drivers' psychology is a contrasting position and alternative direction.

5.3 Design Paradigms

The book that initiated the thinking on Design Paradigms was Thomas Kuhn’s Structure of Scientific Revolutions (Kuhn, 1962). This is not related to design paradigms but to scientific ones. It relates to ways in which he perceived that scientific thinking changed and in the process the whole way of thinking about how the world works is changed as well. It was posited that this type of approach takes place not just in scientific communities, but also in product design communities, and is evidenced in the way that the product changes from one date to another. This was suggested in a paper written for ICED in 1999 (Dowlen, 1999), but this was in no way backed up by data: it was a speculation backed up by some hunches which needed to be clarified.

Petroski’s *To engineer is human* (Petroski, 1985) suggests that failure is to be perceived as part and parcel of the process of engineering and developing products. Learning by product failure, sometimes in an expensive manner, is an essential part of both what it means to learn and what it means to engineer. The book is a set of case histories of this. He has also written on the process of product evolution, using sets of case histories of a number of products to do so (Petroski, 1993) and directly on design paradigms (Petroski, 1994) He views these as sets of examples and case studies illustrating the state of the art at any point in time. He suggests that over-reliance on these proven ways of doing things has a tendency to result in a climate of confidence that tends to precede design failure in some way. The book charts a number of these as ‘paradigms for error’ and shows why an over-reliance on the way things are done results in significant difficulties. These are exemplars of design failure where there was an over-reliance on a prior methodology. This caused failure to occur where it was unexpected and unanticipated. The designers were aware that there was a design issue with their design that needed resolving, so they concentrated on this to the detriment of the overall product behaviour, resulting in failure. The thinking is described as blinkered and the whole is not adequately seen.

For him *Design Paradigm* is understood as currency of state-of-the-art thinking. He covers engineering practice, but it could be extended to other design aspects. This is similar to this definition: *A typical example or pattern of a product: a view underlying the theories and methodology encapsulated within the design of a particular product area* (Dowlen, 1999).

5.4 Use of numerical analysis in design history

This section identifies approaches towards analysis of design history. It starts by describing typical approaches and then investigates the development of numerical analyses of design history.

5.4.1 Typical approaches to design history

Historical analysis employs narrative processes. It determines what took place, describes it and develops understanding from narratives. Deductions and causality are developed using logical processes rather than analytical. Design history is frequently based on movements, themes and descriptions of developments and styles. Typical examples are de Noblet and Wooding (1993), Woodham (1997) and Raizman (2010).

Most designers are communication designers (Design Council, 2010), so design histories have tended to major on communication issues such as graphics and typography. But architecture, interior design, furniture, industrial and automotive design are included. Design history also seeks to include the themes of analysis of production and consumption. But this approach still uses examples to develop the analytical study of designs.

The primary academic journal covering design history, *the Journal of Design History*, seldom includes numerical analysis. Historians are not generally statisticians and narrative processes are generally appropriate.

5.4.2 Engineering approaches to design history

Engineering design text books like *Engineering Design – a systematic approach* (Pahl and Beitz, 1996) may not include much history. This is an exception, including historical background (section 1.2.2) concentrating on history of systematic processes within engineering design. They state that systematic processes were impeded until the 1950s by the absence of means of representing abstract ideas and the view that design is artistic and not technical. Numerical analysis would not be appropriate. The section states that all developments have antecedents and these mature when needed, when technology and economic conditions are appropriate. Whilst the authors acknowledge their thinking is based on predecessors', they are moulded into the forward-thinking mode of modernity and technological determinism. Current processes are better than previous in this way of thinking.

5.4.3 Quantifying history

Van Nierop, Blankendaal and Overbeeke describe cycle history (Van Nierop et al., 1997). They use graphical information, but the graphs are more illustrative than numerical. The first half of the paper discusses theories of product evolution and the second concentrates on the cycle.

They suggest dynamic systems theory is suitable for analysing cycle development, and explain their thinking processes. This relates to perceived 'cycle needs' and how different 'cycle needs' might be satisfied by different cycles.

They suggest it is difficult to measure cycle ‘fitness for purpose’, leading to qualitative analysis. They develop the concept of a fitness landscape giving an overview – although the graphs initially appear quantitative. They suggest measuring cycle sales or variety might approximate, but seem confused about how to produce this.

This approach does not satisfactorily answer the fitness for purpose question and does not physically measure design changes. This contrasts with the numerical approach taken here.

Several have attempted to produce historical overviews based on quantifiable data obtained from products. One such is Martindale’s Clockwork Muse (Martindale, 1990). This work has been influential. It investigated histories of art and literature. Martindale wished to take a scientific approach. He hypothesised laws for art and literature and sought to confirm them. He needed numerical measures for this. He investigates artistic topics as diverse as French poetry, British poetry, American fiction, American music, Gothic architecture, musical evolution and Japanese prints. A list of the techniques he uses includes basic statistical concepts such as sampling, determining appropriate measures, production of graphs, probabilities and regression analysis, and techniques such as equation-fitting, variance analysis, autoregression and factor analysis. He claims he obtained his methods from Ezra Pound:

> The proper METHOD for studying poetry and good letters is the method of contemporary biologists, that is careful, first-hand examination of the matter, and continual COMPARISON of one ‘slide’ or specimen with another (Pound, 1934). (page 7 of Martindale’s text)

He chose not to study artists or writers, but their work. He measured each work and identified changes to confirm his hypothesis. Later artistic or literary work depends on the existence of previous work for its being. It has a genealogy: a history. He proposed investigating this history using a timeline

– an x axis – demonstrating change of whatever he is investigating. Martindale contrasts this with the approach of historians.

> Narrative historians present us with a congeries of facts and dates and speculations. Because such historians do not usually admit that they have a theory, they do not need to tell us why they are presenting these data. If one did not have at least an implicit theory to write history, one would be confronted with pure chaos (Lévi-Strauss, 1962), ignorant of what to report and what to leave out. (page 19)

(The reference is in Martindale's quote). He says art or literature researchers spend time and effort on their favourite artist or author, ignoring centuries to make amends for concentrating on their favourite – at the expense of ignoring an effective timeline. He claims the impact of art and literature is based upon arousal potential, quoting the Wundt curve (Baxter, 1995), and seeking to identify characteristics of each genre that might conceivably measure that. He identifies something called primordial content and measures artistic style, relating these to each other through history, whilst novelty is proposed as a significant characteristic of art over the years, driving changes and developments in the art world. He sought to find measures of novelty, primordial content and artistic style for different art forms and investigated these over lengthy time periods, identifying changes that took place and their timing.

He states that cars would not respond to his processes: they are not art objects and because they serve practical use they do not respond to his art-based criteria. Different criteria need to be measured. He also investigates scientific behaviour, discussing its similarities as it is developed primarily for scientists rather than the general public. He investigates shifts in scientific paradigms, quoting and using Kuhn and Crane (Crane, 1972). He also quotes Snow (Snow, 1965), saying how he seems to have confused communities and segregated them rather than helping them develop links and collaborative ventures. He is clear on the differences between science and technology and does not confuse the two, which he says lay people are wont to do.

This work utilises Martindale's concepts of measurement – cars and not artwork – using an x axis to represent time and many of his methods, although his theories include curve-fitting to seek to confirm his historical hypotheses, which is not the approach taken in the current work.

Early research was carried out with John Shackleton, who had researched car form in Japan (Shackleton and Sugiyama, 1996a, Shackleton and Sugiyama, 1996b, Shackleton et al., 1996, Shackleton et al., 1997). This investigated the form of then-current recreational vehicles. This applied statistical processes to cars, but not to history. He wanted to cluster these four-wheel-drive recreational vehicles, perceive their attributes and categorise them. He measured several characteristics and carried out a multivariate analysis, a Factor analysis, following it by clustering on the derived dimension variables (Child, 1990). A similar approach might determine historical dimension variables and identify the changes and when they occurred.

5.4.4 Numerical measurement of paradigms

Kuhn developed the concept of paradigms (Kuhn, 1962) to understand scientific developments. In this case he used it largely to determine a scientific world view, introducing the concept of a paradigm shift when such world views change relatively quickly. He also coined the term "normal science" to describe periods of relative stasis when paradigms do not shift significantly. Crane (Crane, 1972) quotes Price (Price, 1963) who had analysed scientific papers and described their growth as fitting a logistic curve. This gave four stages: 1 a preliminary growth period with small increments; 2 a period of high growth; 3 a period when the rate of growth declines and 4 a period when the rate of increase declines towards zero.

Price argued science was in state 2 when he wrote but that it would enter the later stages. Crane produces an illustrative figure, Figure 5.22.

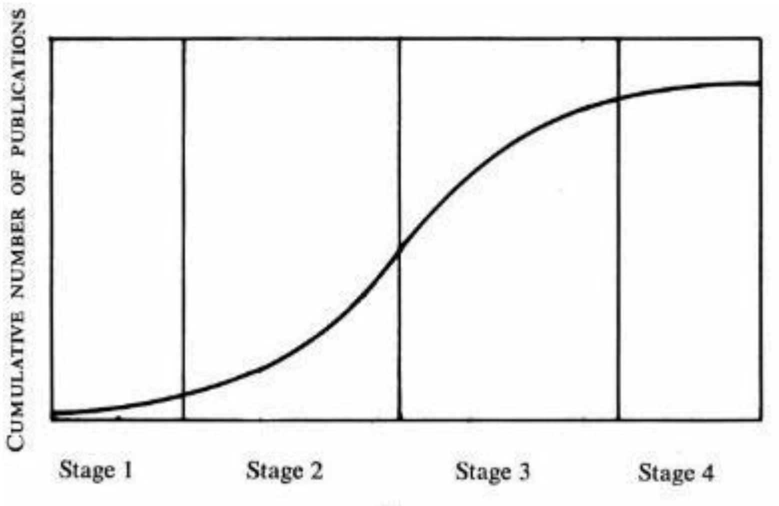


Figure 5.22 The logistic curve and its stages (Crane, 1972, p172)

A table summarises these stages:

	Stage 1	Stage 2	Stage 3	Stage 4
Characteristics of knowledge	Paradigm appears	Normal Science	Solution of major problems	Exhaustion
			Anomalies appear	Crisis
Characteristics of scientific communities	Little or no social organisation	Groups of collaborators and an invisible college	Increasing specialisation	Decline in membership
			Increasing controversy	Decline in membership

Table 5.04: Characteristics of stages of the logistic curve (Crane, 1972, p 172)

Crane uses *paradigm* to describe the characteristic of a specific area of scientific research. This is something less overarching than the genre of the scientific thinking process.

Crane is not measuring historical artefacts but is counting examples of scientific publications. She investigates diffusion theories for how scientific theories are distributed.

She looks at a combination of paradigm shifting processes and normal science, and how these change and develop over time.

She suggests other topic areas may behave similarly. She moves towards more generalised interaction theory where general knowledge grows and is owned by academic groups. She says Gombrich (Gombrich, 1996) developed a model for artistic growth similar to Kuhn’s and suggests art is progressing (page 134) but says that the concept is controversial.

Communication possibilities have developed since the book was published. Although Crane felt she was measuring the development of research subject areas, she may also have been measuring the development of communication systems.

Crane (Crane, 1972), investigating scientific writing, uses numerical analysis, measuring numbers of scientific papers and comparing results with the logistic curve.

These measures of quantity might compare with market saturation, so are logical. This logistic curve is used in the TRIZ design process – almost incidentally to the key process. This creative process is used for engineering but not art-based design. TRIZ uses this curve to explain development processes for generic products like aircraft (Altshuller, 1988, Altshuller, 1996), air conditioning systems (Mann, 1999) and hermetic sealing (Slocum, 1999b). These are not measuring market diffusion so the use is questionable.

Marchetti uses numerical analysis to ask whether human society follows repetitive cycles (Marchetti, 1996). This uses long-wave theory of Kondratiev. Critics of Kondratiev say he imagines statistical patterns of data. The data is presented as S-curves and repeated wave curves that describe historical events. This is mentioned by writers in Roy and Wield's compilation on Technological Product Evolution (Roy and Wield, 1986) – Hall (Hall, 1986) and Ray (Ray, 1986).

Part of the TRIZ process has been developed from the use of historical logistic curves to postulate the development of product performance.

Altshuller, the founder of the TRIZ process, (Altshuller, 1996) provides no graphs and no measures, but simply describes four historical periods of the system as, initially, a period of the selection of parts for the system, followed by the second period, which is identified as the period for the improvement of parts. The third and fourth historical periods identified by Altshuller are the dynamization of the system and, finally, the self-development of the system. Altshuller uses aircraft development as an example, but indicates that period 4 has yet to be reached. It seems to be difficult to align his descriptors with aircraft history.

Savransky (Savransky, 2000) describes the evolution of technique during which he describes paths of evolution and subsystem trends, concluding with a case study from Altshuller.

A few people have produced historical overviews based on quantifiable product data. Martindale's influence has been noted earlier (Martindale, 1990). He utilises a scientific approach to art, using statistics to support his data. For him cars are not art and not amenable to his techniques; the drivers may be other than artistic novelty. That would mean his art-based theories would not be relevant and not that numerical analysis fails to be useful. He investigates paradigm shifts, using Kuhn and Crane (Crane, 1972) and quoting Snow (Snow, 1965), saying how he has confused and segregated communities rather than encouraging links and collaboration.

Some non-historical disciplines utilise historical data. Medical approaches to epidemiology use numerical methods and take historical approaches towards the spread of infections and diseases, sometimes long-term. The BBC Four production *The Joy of Stats* (Hillman, 2010) is an example.

Sir Austin Bradford Hill is the person credited with demonstrating the strong statistical links between smoking and lung cancer. He also developed nine viewpoints for assessing whether numerical data indicates causation or otherwise (Bradford Hill, 1965). These would seem to be generally relevant for historical statistical research although caveats are necessary (Phillips and Goodman, 2004). The discipline has developed significantly since Bradford -Hill but still uses statistical processes to describe historical events.

5.4.5 Comparison with the current research

The current research utilises a similar concept of paradigm to that used by Kuhn and Crane, in that it describes a state of relative stasis. However, it is also used to describe the way that a product is construed at a particular moment, whether this is a static or a changing concept.

Martindale’s work indicated that there was significant benefit in attempting to use numerical processes to measure historical changes in products, although these are not the same as art. He used the processes, however, to seek to fit the measured data to his particular hypotheses and thus the data that he measured was not seeking to be a general time-line description for whatever he was analysing.

Crane used the processes to seek to emulate the logistic curve, which in her case was appropriate, as she was dealing with a topic where saturation might have occurred. This is the process that is suggested by Altshuller and others using the TRIZ models: but there is an assumption that technological saturation occurs when performance is measured, and this is not necessarily justified as the reason for the changes that they seek to measure.

Crane mentions paradigms and describes them, but her numerical work measures the quantity of scientific papers and does not attempt to measure any quantities relevant to each of the papers, such as their significance. Measuring the existence of something is not the same as seeking to measure quantities from that ‘something’, which is what the current research is seeking to do.

6 Numerical Analyses

6 Numerical Analyses

This chapter introduces the process whereby cars are measured. The intention is that by this process a reasonably objective sense of history might be achieved. There are three sections: section 6.1 Layout analysis, section 6.2 Form analysis and section 6.3 Using real number data. The first two of these cover similar analyses of the two specific areas of embodiment design that are deemed to be both important and generic. The third section deals with a combination of form measurements and performance data.

6.1 Layout analysis

A number of suitable variables from each car were selected, and then data reduction processes were used.

6.1.1 Variables

Most measurements were categorical.

Nineteen layout variables were chosen: see Table 6.01 and Figure 6.01

Variable
Engine position
Crankshaft Orientation
Driven Wheels
Cylinders
Cylinder Arrangement
Front Suspension Form
Rear Suspension Form
Front Suspension Medium
Rear Suspension Medium
Structure Type
Body Construction

Variable	Default category
Engine Type	Reciprocating (Petrol)
No of Wheels	4 wheels
Wheel Orientation	2F2R
Wheel Sizes	Same
Steering Control	Wheel
Final Drive	Shaft
Driver Position	Front, Side
Tyre Type	Pneumatic

Table 6.01 Layout variables

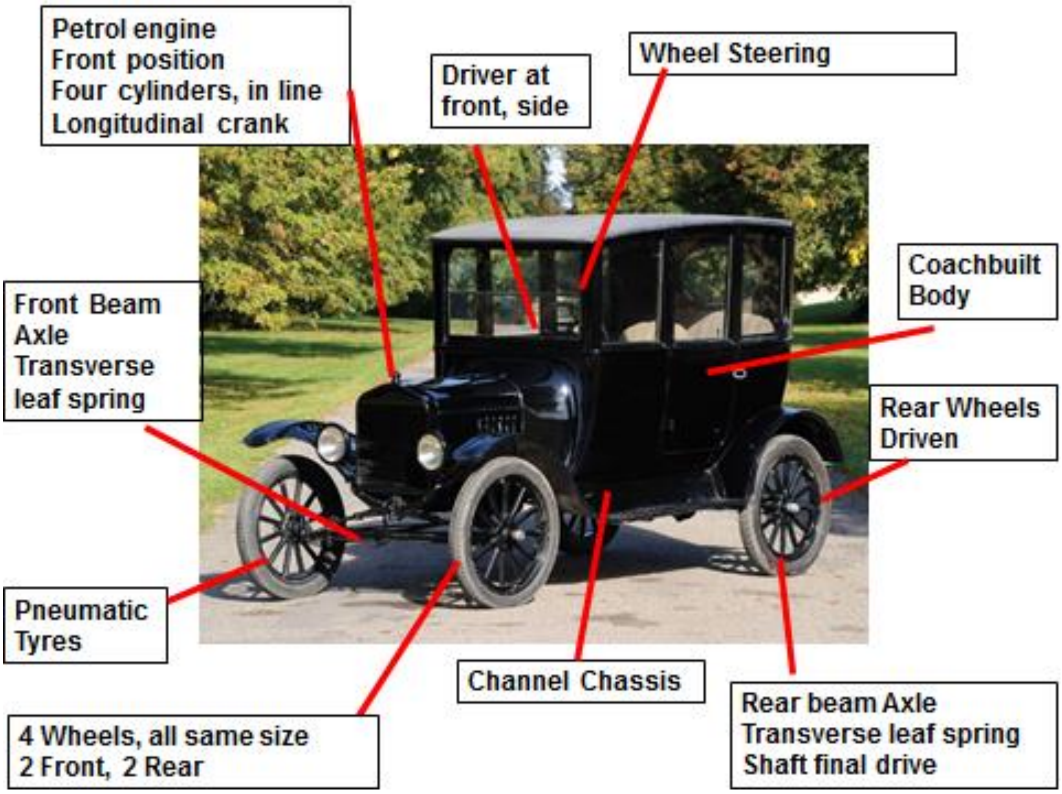


Figure 6.01 Layout variables (Ford Model T, 1923) (Courtesy RM Sotheby's)

6.1.2 Piloting variables

These variables describe features of car layout. More variables might have been included – engine design features, transmission type, brakes, steering etc. The analysis identifies a variable’s importance. It determines the loading vector’s magnitude and direction. The most important factor is front suspension form, then rear suspension medium, rear suspension form, structure type, and front suspension medium. Analysis of these five variables produces useful data and graphs; the others add to the form of the data. The variables with the lowest importance are number of wheels, tyre type, engine position, wheel size, driver position and engine type. The low apparent importance is because these were decided in early car history and have little variation. It is not their real importance. Engine position and type are important despite their low position.

6.1.3 Detail of the variables

The variables are all categorical variables. The categories need ordering. Some variables are ordered naturally, such as the number of wheels or cylinders, but for others it is less obvious. Ordering for these variables is by approximate date order.

The meaning of zero needs clarification. The analysis takes a zero as a blank and doesn’t analyse it. If a variable has a natural value of zero, it needs to be given a non-zero category, leaving zero for ‘unknown’ or ‘nonsense’ (such as arrangement of cylinders in a single-cylinder engine or cylinders in an electric motor).

Six variables are engine-related (including location), four to suspension, four to wheels and tyres, two to structure, two to control and one to transmission.

Some variables are dependent on the choice of others. Number of cylinders is only relevant for a reciprocating engine: cylinder arrangement for more than one cylinder.

The variables in the right column table 6.01 were determined early in car history and default values were useful. Most cars follow the default value. Only one of the default variables has significant variation – engine type, which saw a shift towards diesel engines from the late 1990s.

The earliest cars were steam powered. But there were relatively few of them, so the steam era does not figure largely in car history; although Olley mentions early car designers were familiar with steam technology (Milliken and Milliken, 2002), this is ignored after around 1905. In 1900 there were more electric and steam cars in the US than petrol cars (Burgess-Wise, 1987). From about 1905 on, cars were powered by petrol internal combustion engines, until Diesel cars arrived in 1935 or 1936 (Ricardo plc, 2015, Lengert et al., 2006) but 50% of the UK car market was only reached in 2010 (Wray, 2010). Piston engines were challenged by the rotary Wankel engine in the 1960s and although they are still in production by Mazda the technology is not challenging the piston engine. Hybrid and electric cars challenge petrol-powered piston-engined cars. Technically, the hybrid cars available are generally an electric transmission system coupled to an internal-combustion generator with electric cells to hold energy stores. The Toyota Prius hybrid cars have been in the Car of the Year lists in 2001 and 2005, but sales have not yet challenged cars powered by conventional internal-combustion engines.

Some cars have three wheels and a few of these are in the sample. From time to time cars have had different numbers of wheels – two, five, six or eight – but there are none in the sample and very few have been in series production. An example of the one-off Panther Six, with six wheels, is shown in Figure 6.02. This car is not part of the sample.

Figure 6.02 Panther Six, 1977 (Panther Car Club)

Most cars have wheel steering. For early cars the need for steering control was a novelty as it is unnecessary where a horse steers a carriage.

Early cars used various levers for direction control, which may have been forward pivoting, side-pivoting levers or levers pivoted at the rear. Some had what are generally termed ‘coffee grinders’, some handlebars and some even had reins, but none of these are in the sample. Since 1904 most cars have had steering wheels for direction control.

Early cars had solid tyres. At first this was with iron tyres but latterly with rubber ones. Bijker describes pneumatic tyre development (Bijker, 1997). The first car with pneumatic tyres was a 1985 Peugeot fitted with Michelin pneumatics.

Figure 6.03 1895 Peugeot fitted with pneumatic tyres by Michelin

From then adoption has been swift; after 1900 cars with solid tyres are rare, although were used by commercials well into the 1920s. Pneumatic tyres not only give improved ride but also allow faster travel. Solid tyres use more energy to traverse even slightly rough terrain and overheat beyond about 20mph.

Eleven other variables were chosen. Four relate to engine design, four to suspension design, two to structure, and the last to the driven wheels.

Figure 6.04 shows a timeline graph with the category values for the default variables.

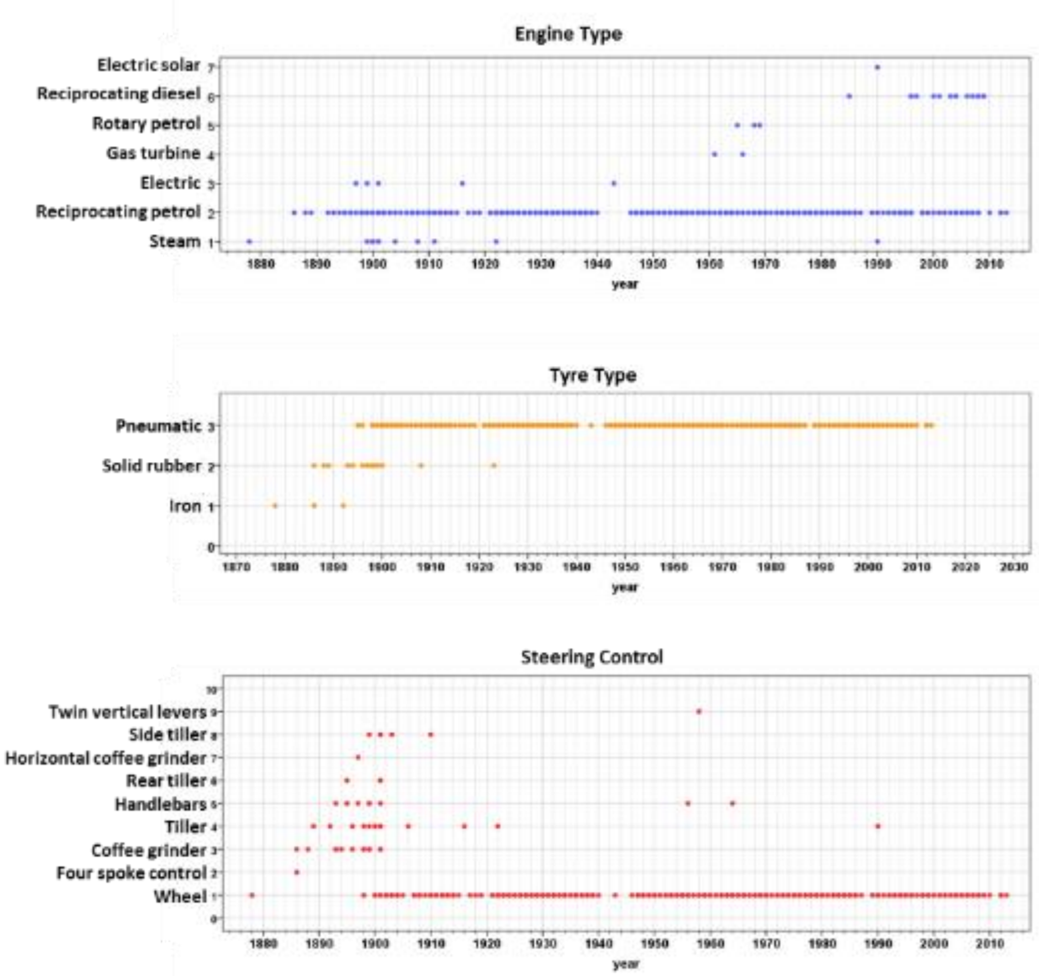


Figure 6.04 These graphs shows three of the default variables plotted against date. All three variables show that the large majority of cars in the sample have a predominant value for each variable. For engine type, this is for a reciprocating petrol engine; for tyre type this is for pneumatic tyres, and for steering control this is for wheel steering. Engine type, however, shows later changes, whilst the other two variables show that the default values were decided upon after about 1904.

6.1.4 Engine design variables

Four variables relate to engine design: engine position, crankshaft orientation, number of cylinders and arrangement of cylinders. Many others could have been added such as valvegear choice, lubrication, and so on. These four variables were chosen because they are fundamental to car arrangement and engine behaviour and were shown as being significant in the pilot analysis. Engine location and crankshaft orientation relate to the engine arrangement in the vehicle and the number and arrangement of the cylinders have significant overall car design consequences.

Figure 6.05 shows a timeline graph with the categorical variables for engine design in the y direction. The engine position graph shows that the most common position for the engine is the front, although that was not so before the start of the 20th century. Since then, there have been relatively small numbers of cars with engines in other positions, always a minority, but these do constitute some significant groups of cars. The engine orientation shows the orientation of the engine crankshaft. This has been longitudinal in most cars, but a shift tool place from the late 1970s onwards and currently the preferred orientation is to orient the crankshaft transversely. The third graph shows the number of engine cylinders. Early cars had engines with only one or two cylinders. Four cylinder engines have been the most popular since the early 1900s, but for a brief while in the 1930s the six-cylinder engine had a spell of popularity. The fourth graph, cylinder arrangement, shows that in-line arrangement to be the most popular, with vee engines coming second. These tend to be predominantly with six or more cylinders

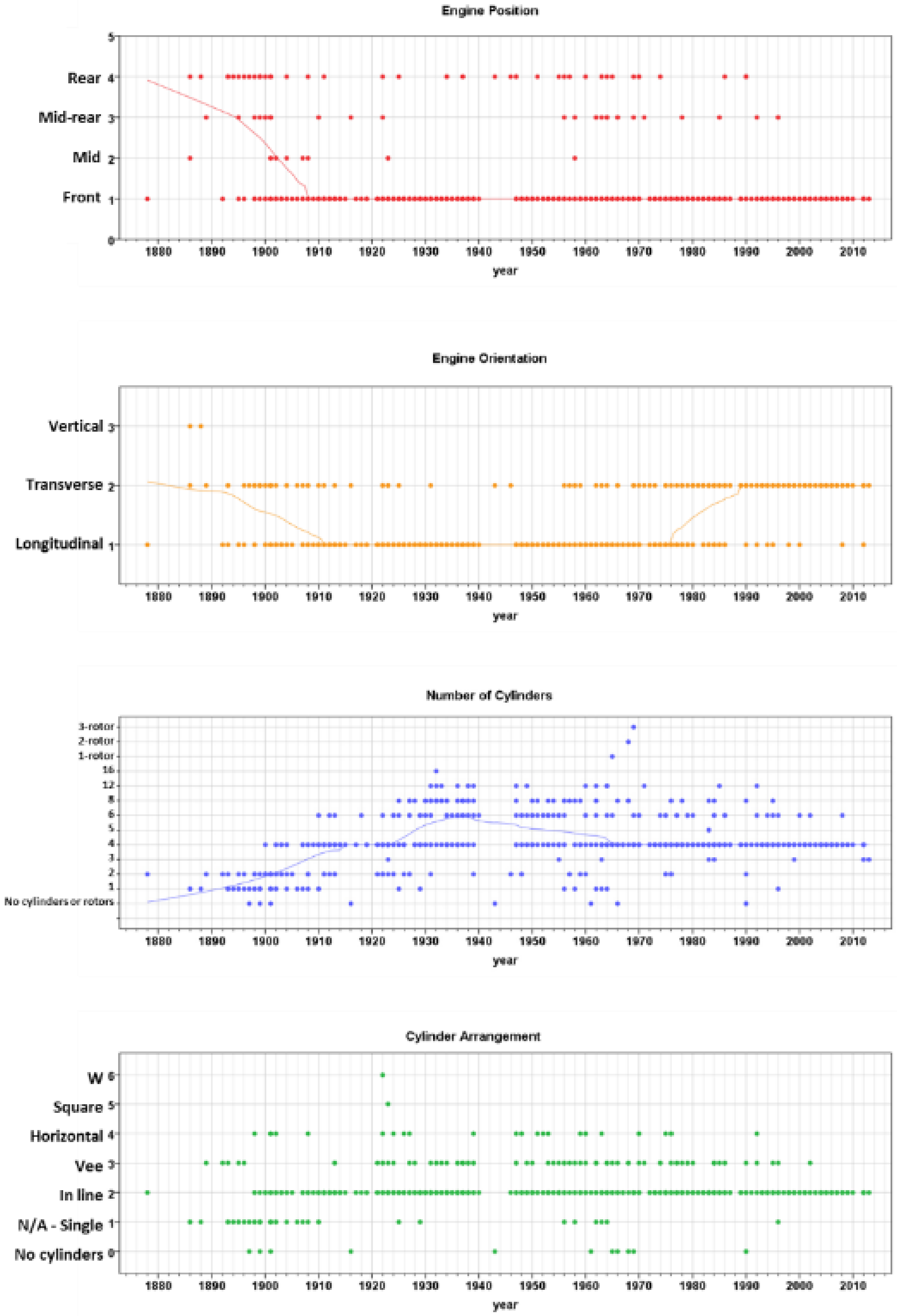


Figure 6.05 Engine design variables

6.1.5 Suspension variables

Four suspension variables are analysed – two variables for either end of the car – form and medium. Geometry has greater influence for front suspension, dictating how the car corners and rides more than the medium choice. For rear suspension the medium is more important because the form changes less than front suspension form. These variables are all categorical, the sequence determined by popular, not first, usage.

These co-vary significantly. It is clear that values stay static before changing and changes herald a change of accepted suspension type.

Figure 6.06 shows timeline graphs with the variations in suspension variables for the front and rear suspension.

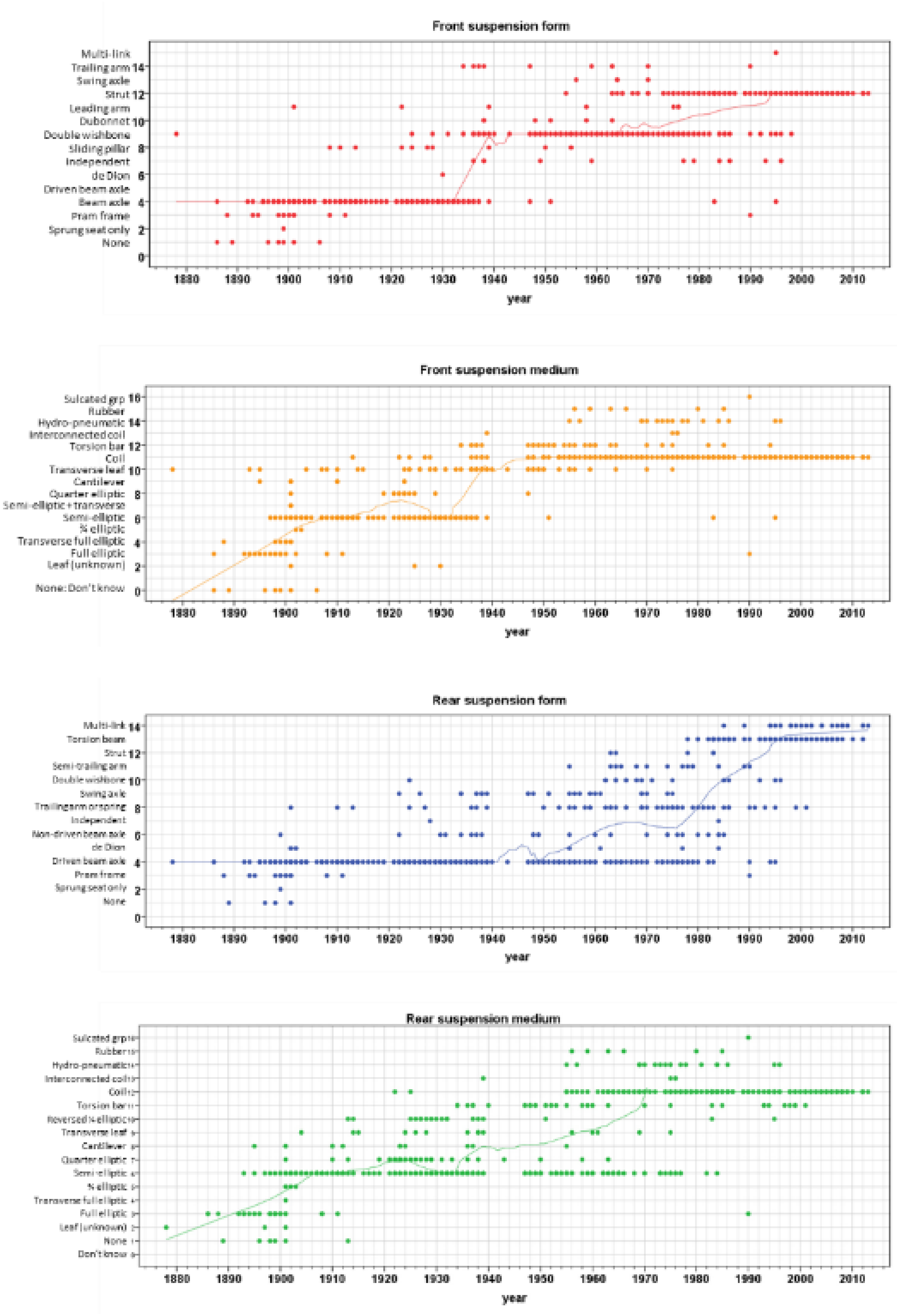


Figure 6.06 Suspension form and medium

6.1.6 Structure and body type

Here significant shifts occur from early tubular to channel section chassis, back to tubular chassis and to monocoque constructions. Changes of structure seem to take place when other changes happen. The change from early tubular channel section chassis were from 1900 to 1905 and the change from channel chassis was in the late 1930s. The change from channel chassis, largely in the late 1930s in Europe (but in the 1950s in the United States), is two-part: first to tubular chassis, and then to monocoque, integrated construction.

Early tubular chassis had a single pair of longitudinal parallel tubes. This was inadequate for long wheelbase cars due to inadequate bending stiffness and channel section chassis gave improved bending behaviour and became the norm. Channel section chassis were inadequate for the torsional loads of independent front suspensions and tubular designs were introduced which were either multi-tubular or formed from larger section tubes frequently constructed by welded box-sections to provide greater torsional rigidity. Monocoque bodies are lighter than separate chassis and bodies where both are welded steel, but are harder to design adequately and cannot be changed easily for fashion reasons or to allow different body styles

There is a similar picture for body construction but fewer variations. Construction moved from coachbuilt bodies with metal panels on wooden frames to steel welded construction. Many changes happened during the late 1930s. First, coachbuilt bodies were replaced with similar welded steel constructions, and then welded steel bodies were developed into monocoques without separate chassis. Glass reinforced plastic (fibreglass) arrived in the 1950s, but mostly for low-volume production, normally with a separate chassis.

6.1.7 Transmission variables

Almost all early cars had rear-wheel drive. The catalyst for widespread adoption of front-wheel drive was the BMC Mini in 1959. The first transverse engine / front wheel drive ‘copy’ was the Autobianchi Primula of 1965, but the arrangement didn’t become popular until the mid-1970s Volkswagen Golf, Fiat 128 and Ford Fiesta. By 1990 a majority of cars had the layout. Four-wheel drive is a minority arrangement – in spite of its current apparent popularity.

Figure 6.07 Graf, 1895. A very early example transverse-engined front-wheel drive car. This car is not part of the sample.

6.1.8 The analysis

Correlations in the movements of variables were identified using Categorical Principal Components Analysis (CATPCA). This is a statistical process for reducing the dimensionality of a large number of variables, and has similarities with factor analysis. The process reduces a large number of variables to a smaller number in such a way that the majority of the information contained within that large number of variables is preserved.

In the case of factor analysis, the data are assumed to have a linear relationship. However, in the case of a categorical analysis that relationship is non-linear and is related to the probabilities for each category.

A small number of variables are produced, called object score variables, which combine the original variables and allow the variance within the data to be included. The graphs picture these object score variables. These can be pictured as being a number of mutually orthogonal independent dimensions. There are as many object scores (or dimensions) as variables, but most variation is accounted for by the first few object score variables and it makes sense to obtain results for simply the first two object score variables, which can then be termed dimensions. As these dimensions simply result from the Principal Components Analysis it is not usually very simple to determine to what they refer, and their meaning is only able to be inferred from the apparent changes that are seen in the objects (in this case the cars).

A plot can be obtained that indicates the ways in which the original categorical variables align with the reduced object score results, and the meaning of the object score variables can be inferred from inspection of this plot. This plot for the layout analysis is shown in Figure 6.08.

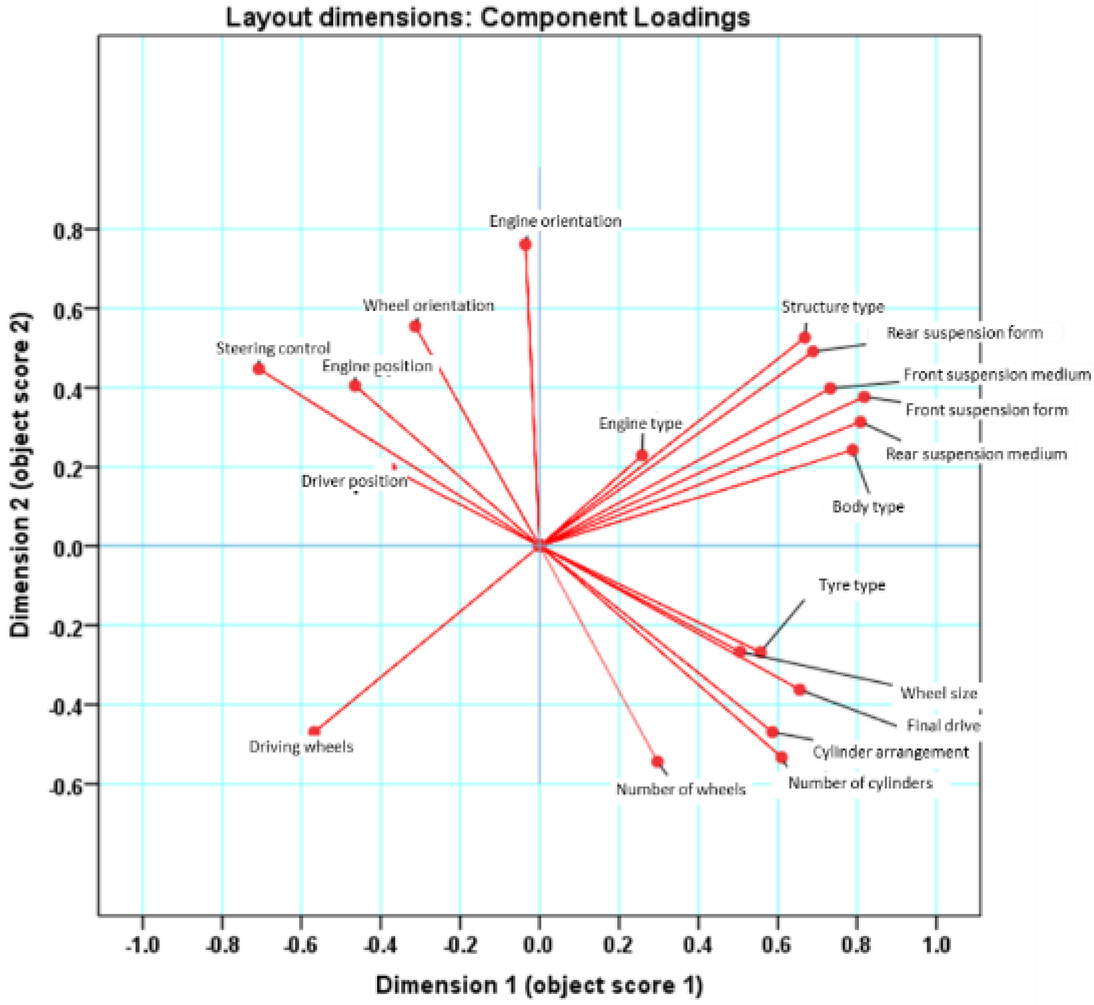


Figure 6.08 Categorical variables plotted onto the plane represented by the first two object scores.

If the first dimension of object scores is considered, then Figure 6.09 shows a histogram giving the frequencies of different values for that first dimension. It will be seen that a few values are predominant. The values of the object scores are related to the changes in the categorical values and it is difficult to assign any specific meaning as such to them.

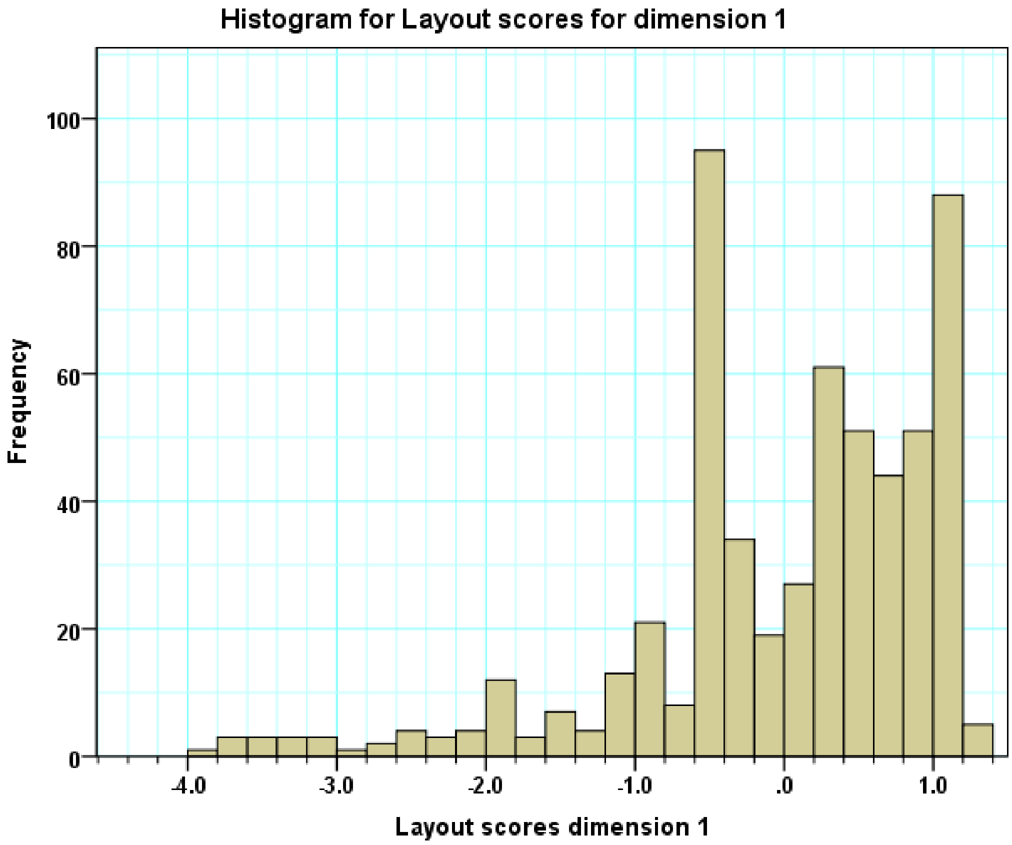


Figure 6.09 Histogram for layout dimension 1

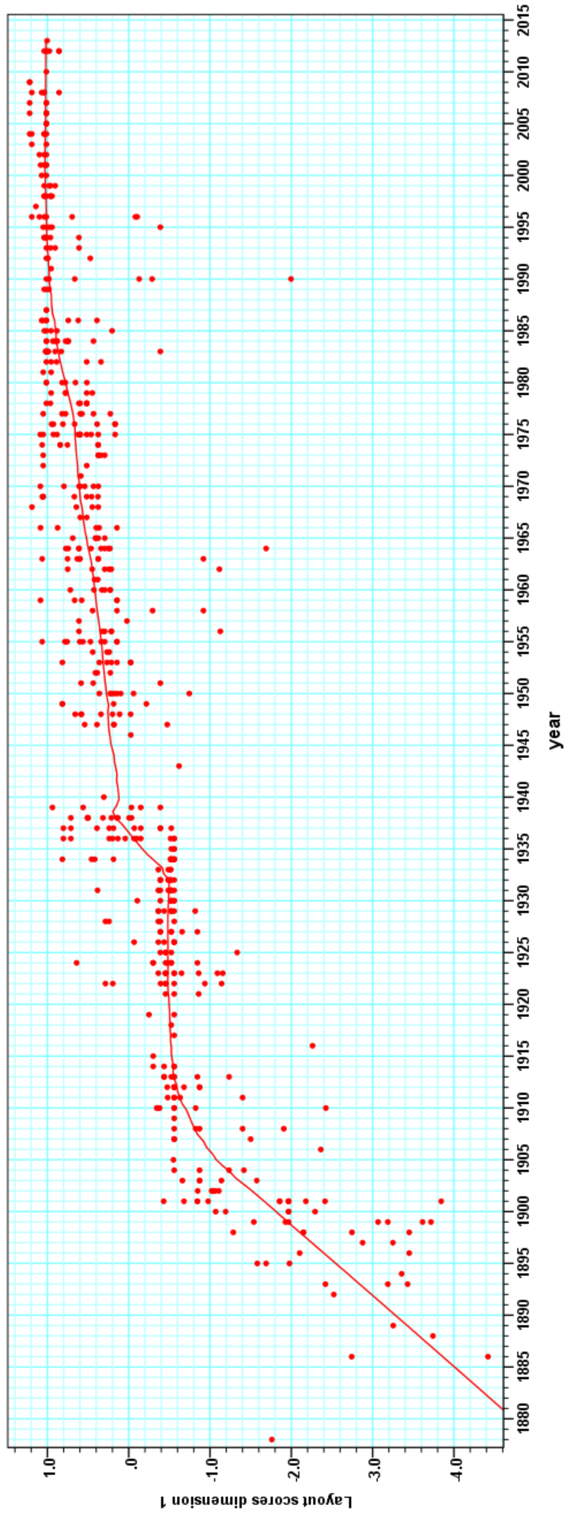


Figure 6.10 Object scores for Layout dimension 1. Each point represents one car in the sample. The line is a mean line produced by interpolation of the results (with a smoothing process).

Figure 6.10 shows a graph for this first dimension plotted as a timeline. Whilst some variation is inevitable, the tendency for the points to jump from one value to another, relatively suddenly, will be noticed. In particular, there is a static point that is reached around 1905 which remains the predominant value until about 1934, when there is a significant shift.

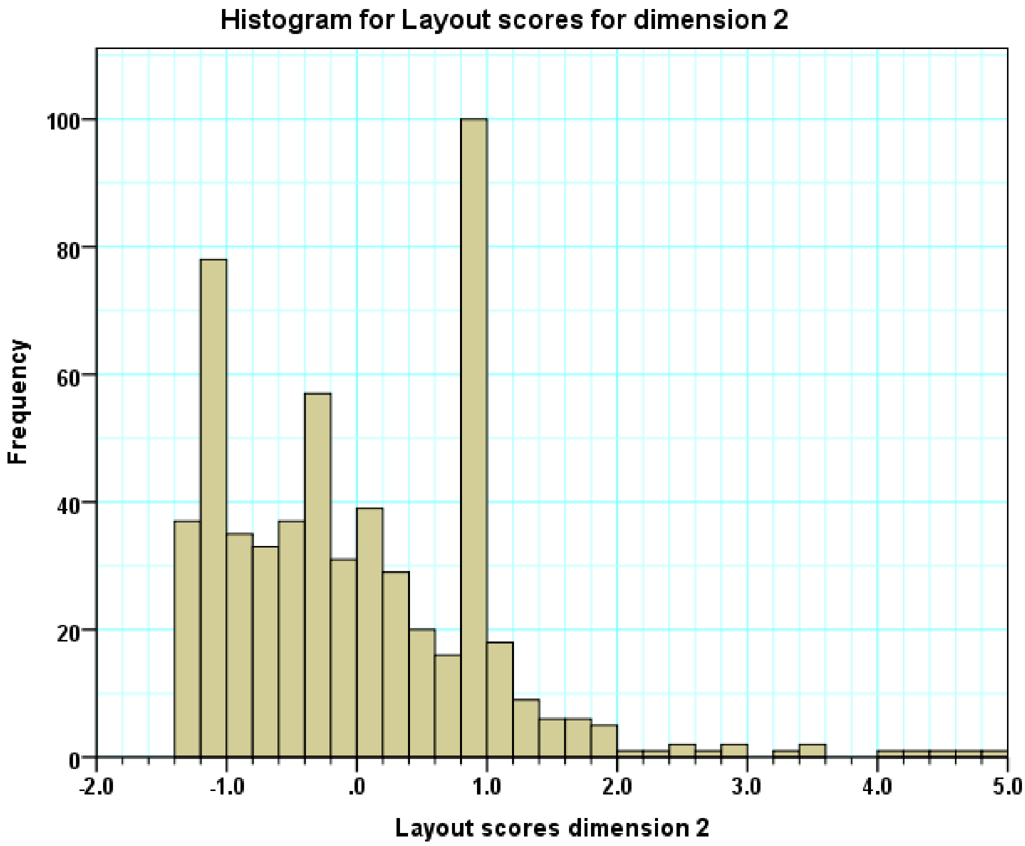


Figure 6.11 Histogram for Layout dimension 2

Figures 6.11 and 6.12 show the same set of results for the second dimension. Figure 6.11 shows the histogram of frequencies. Again, there are three sets of figures that are predominant. Figure 6.12 shows the timeline for this second dimension. In a similar way to the first dimension graph, this graph shows a series of relatively straight lines and sudden changes. This first straight line is reached, similarly to dimension 1, at around 1905, and then this value moves around 1935 or so – the same date as the first dimension movements.

Figures 6.13 and 6.14 are graphs that show not a timeline picture, but the two dimensions (object scores) plotted against each other, with five-year periods coloured in Figure 6.14 to indicate the dates of each data item. These two-dimensional pictures are an equivalent to a map of car design and particular cars in the sample can be identified by their position on the map. Figure 6.14 indicates that these positions are date-related.

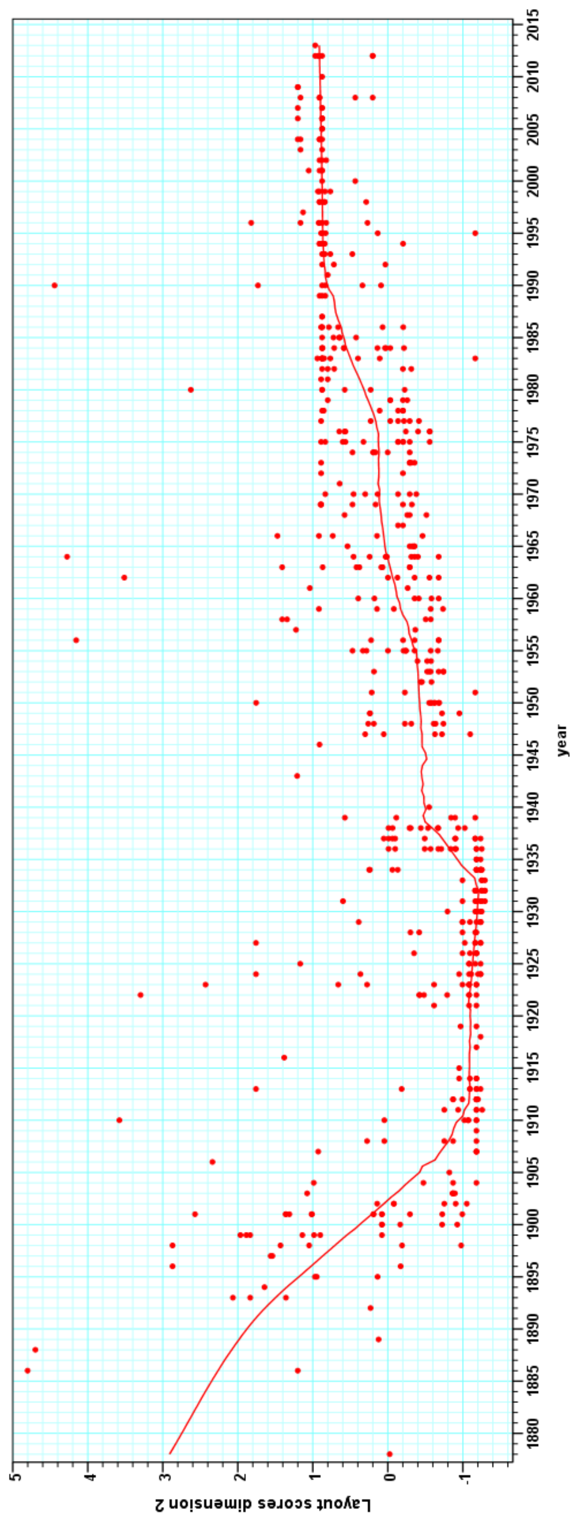


Figure 6.12 Object scores for Layout dimension 2

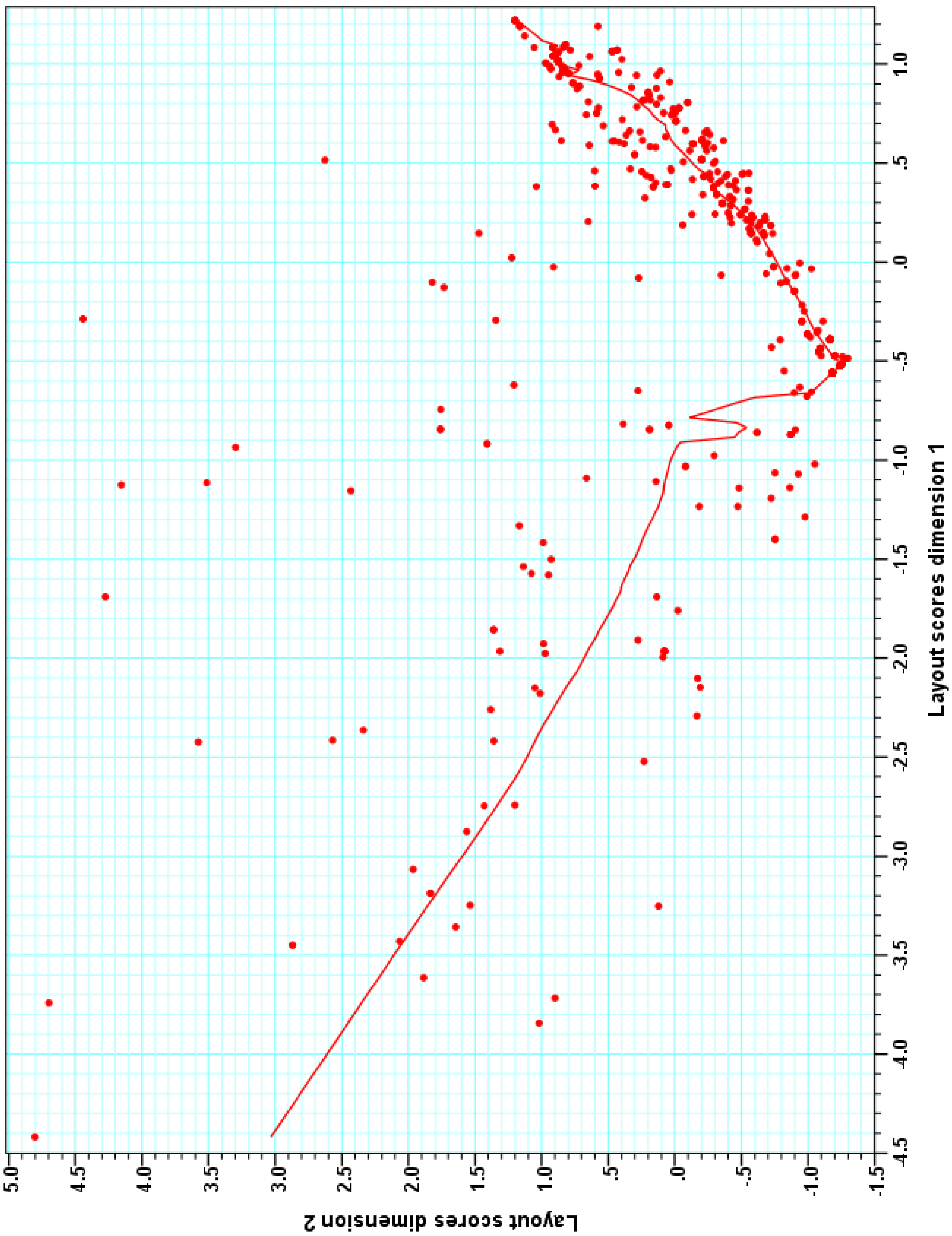


Figure 6.13 Object scores for Layout dimensions plotted against each other. This graph effectively provides a map for car layout design. However, it needs somewhat more explanation before it can be usefully used. Some of this is provided by colouring of the points that represent the cars as seen in Figure 6.14, but ideally this is provided by inspection to identify where individual cars are positioned.

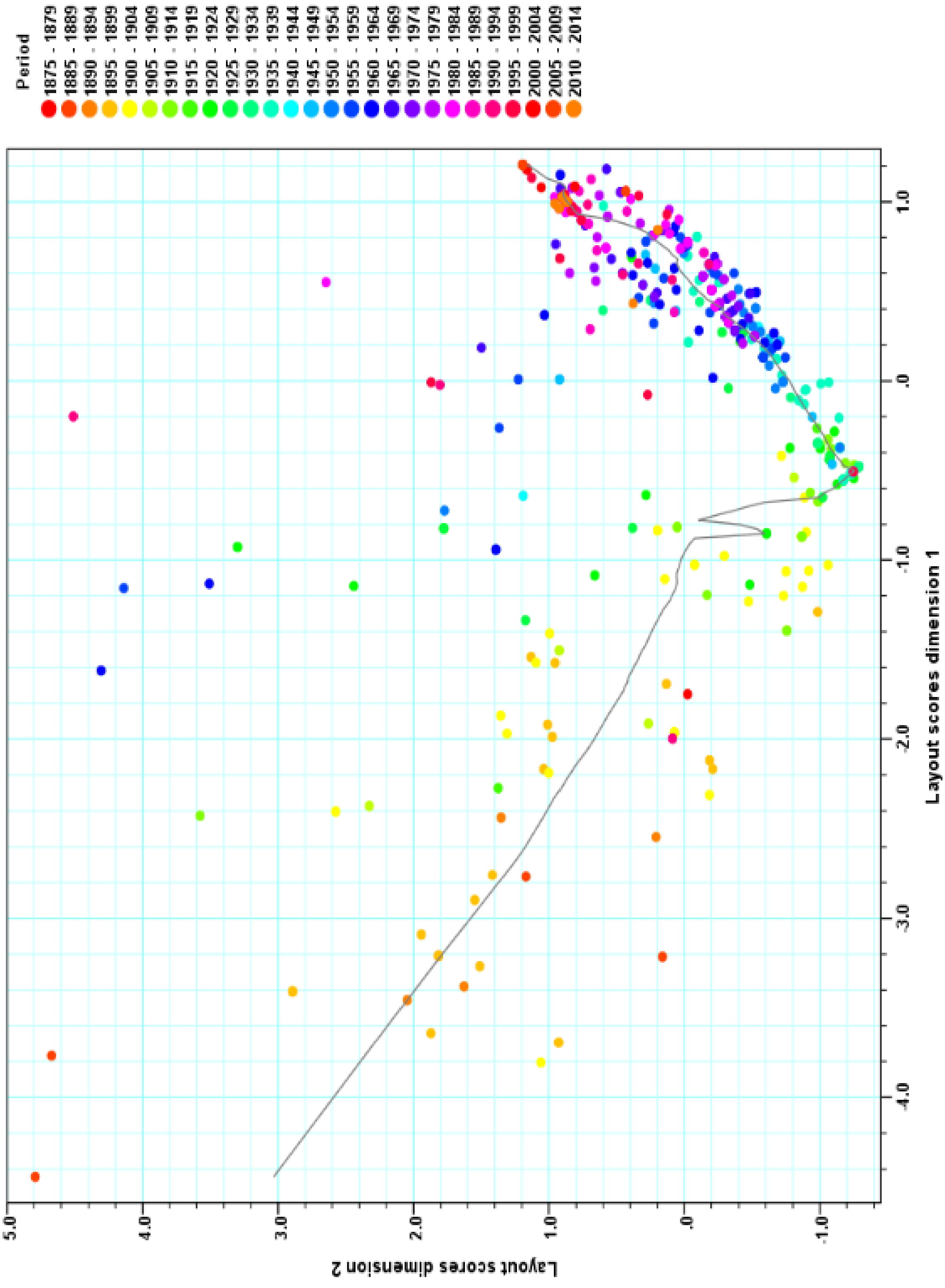


Figure 6.14 Layout score dimensions plotted against each other with periods coloured. This helps to provide the explanation of the ‘map’ for car layout scores.

The two histograms, Figures 6.09 and 6.11, show that some scores appear to be more frequent than others. There are three particularly high scores for dimension 1, and either three or four (depending on perception of peak significance) for dimension 2. These can be seen, from Figures 6.10 and 6.12, to pertain to particular periods. The peak in dimension 1 corresponding to values between -0.6 and -0.4 is between 1901 and 1936. The first layout paradigm has been formed by 1901. From 1901 to 1936 the layout dimensions both tend to remain within tight variables, moving after 1936 with the widespread introduction of independent front suspension and monocoque construction. Layout dimension 1 shows two lesser peaks, representing layouts popular after WWII. The first of these is between 0.2 and 0.4. These cars have independent front suspension; most have front engine and rear wheel drive and have monocoque bodies. Another peak occurs between 1 and 1.2. These cars have front wheel drive, transverse engines, monocoque structures and independent front suspension.

Chapter 8 describes and analyses these results in greater detail.

6.2 Form analysis

Two form analyses were carried out. After a pilot analysis using many variables the number was reduced for a subsequent analysis, several variables being irrelevant.

6.2.1 Pilot Analysis

The pilot used 50 form variables. These are shown in Table 6.02. The logic behind the selection of some of the variables was from variables John Shackleton had used to analyse Japanese recreational vehicles (Shackleton and Sugiyama, 1996a, Shackleton and Sugiyama, 1996b, Shackleton et al., 1996, Shackleton et al., 1997). The list was augmented because of their perceived potential utility value.

Variable	**Variable**	**Variable**	**Variable**
Length	Width	Height	Front Overhang length
Rear overhang length	Screen Position	Rear of Cockpit Position	Bonnet Length
Side Window Base Height	Screen Rake	Rear Window Rake	Boot Length
Boot Slope	Headlight Shape	Headlight Number	Headlight Position
Grille Shape	Front Wing Shape	Rear Wing Shape	Running Board
Front Bumper Type	Rear Bumper Type	Bonnet Plan	Bonnet Profile
Screen Type	Number of Seat Rows	Side Doors	Side Window Form
B Post Type	C Post	D Post	Roof Type
Body width form	Rear Form	Wheel Type	Wheel Width
Rear Window Type	Rear Light Position	Rear Light Shape	Rear Light Number
Rear Number Plate Position	Rear number plate shape	Front Roundedness	Rear Roundedness
Edge Roundedness	Panel Roundedness	Roof Roundedness	Rear Window Roundedness

Table 6.02 Form Variables

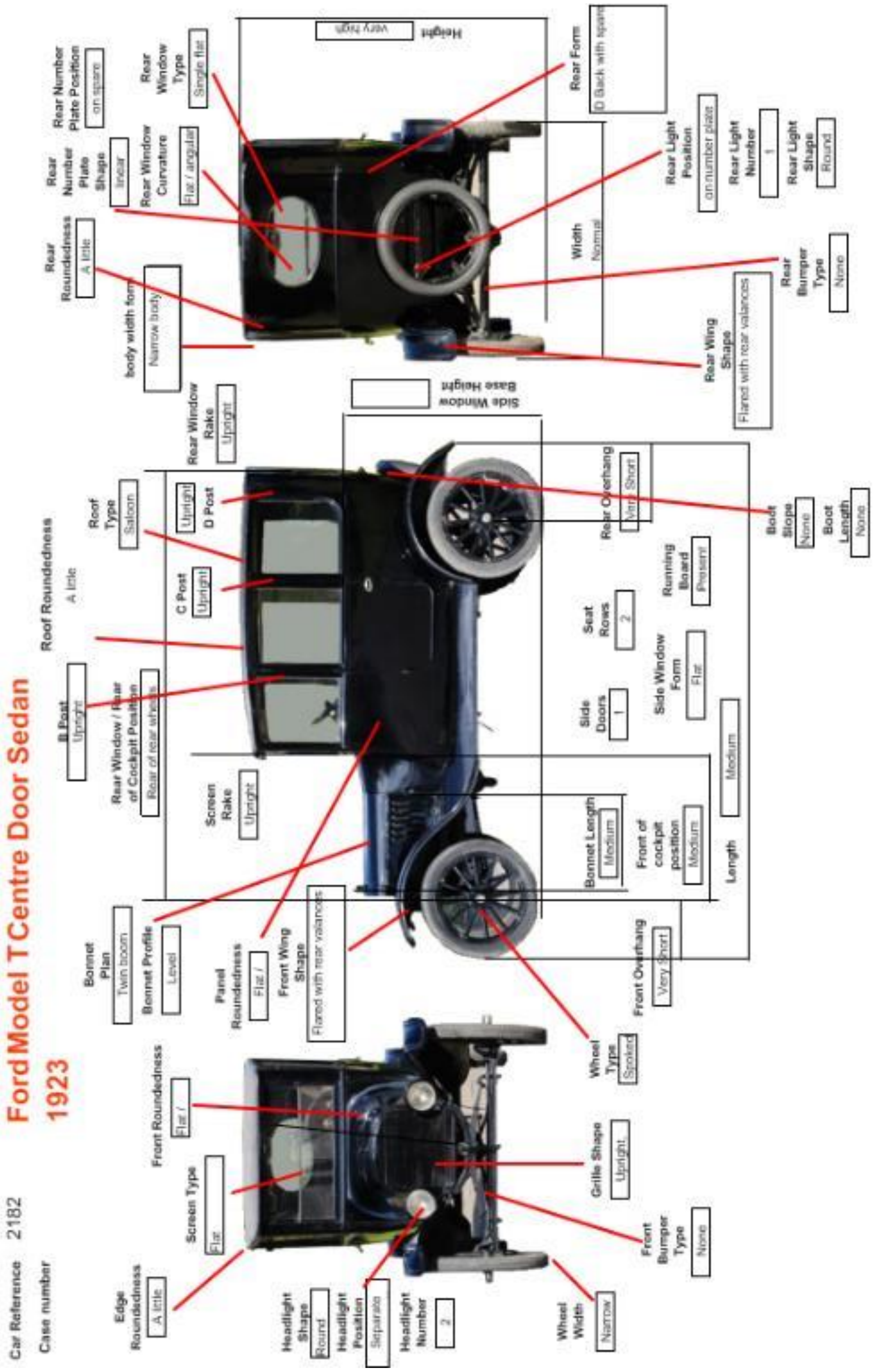


Figure 6.15 Input screen for the Form Variables showing all 50 variables. (Courtesy RM Sotheby's)

They were all taken as being categorical for the pilot: the first pilot assigned categories in a natural fashion or arbitrarily, and they were re-ordered following that analysis.

Figure 6.14 shows the form variables for the initial analysis on a three-view composite illustration of a 1923 Ford Model T Center Door Sedan.

6.2.2 Form Variables for the Later Analyses

Variable	**Variable**	**Variable**	**Variable**
Length	Width	Height	Front Overhang length
Rear overhang length	Screen Position	Rear of Cockpit Position	Bonnet Length
Side Window Base Height	Screen Rake	Headlight Shape	Headlight Position
Grille Shape	Front Wing Shape	Rear Wing Shape	Front Bumper Type
Rear Bumper Type	Bonnet Plan	Screen Type	Number of seat Rows
Roof Type	Body width form	Rear Form	Wheel Type
Wheel Width	Rear Roundedness	Edge Roundedness	Rear Window Roundedness

Table 6.03 Variables used in later analyses

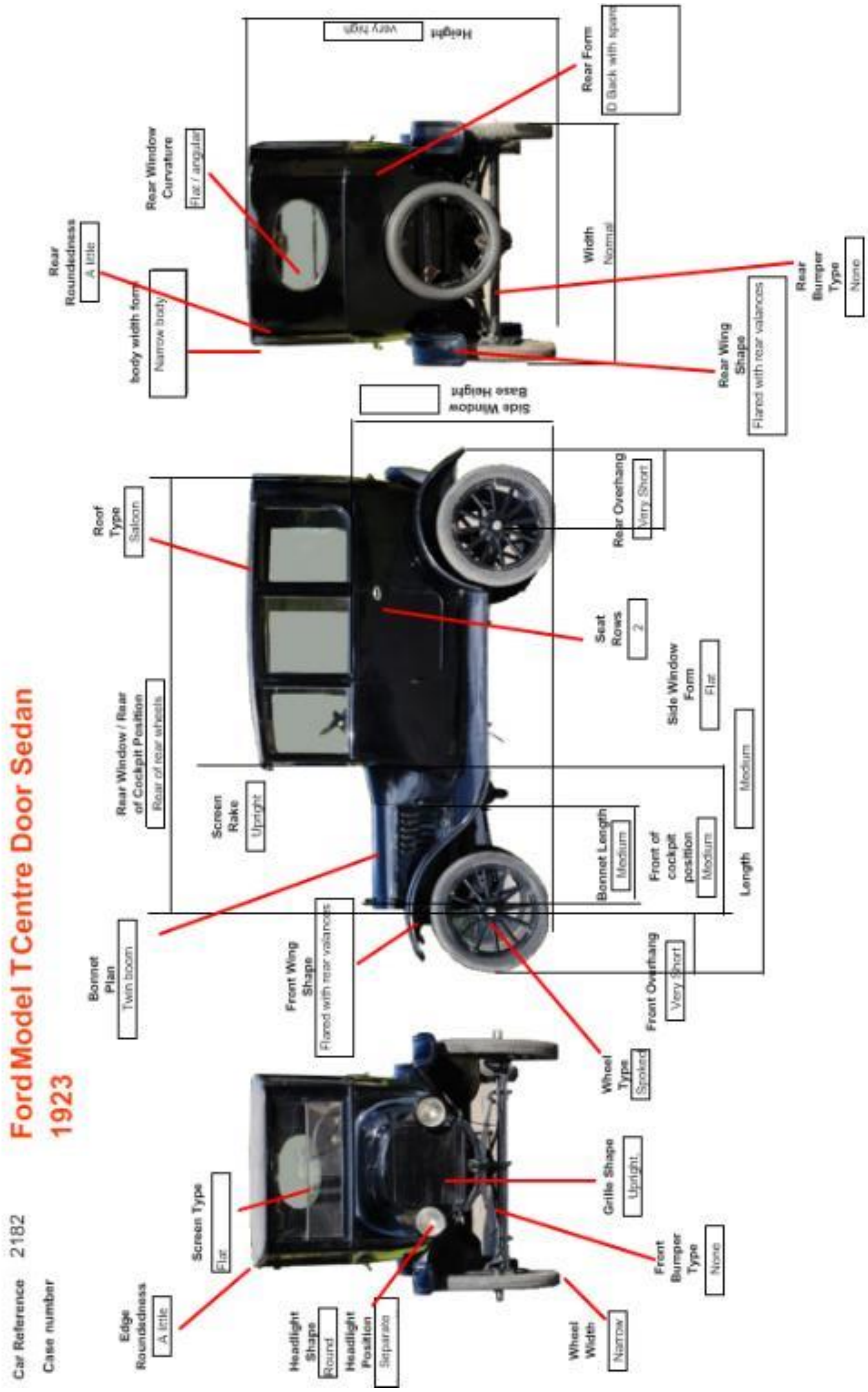


Figure 6.16 Input screen for the Form Variables showing the variables used in the later analysis (Courtesy RM Sotheby's)

The pilot indicated that some variables had little bearing on the analysis There were two reasons for this. Firstly, some were removed because their vector multipliers were low and secondly some were removed because they were significantly secondary to the overall form of the cars. This left 28 variables for the later analyses. A comparison of the results of the initial analysis and the results of the later analyses indicates that there was little change in the results and demonstrates that such a reduction in variables was largely justified These 28 variables are shown in Table 6.03 and on the side view of the 1923 Ford Model T Centre Door Sedan in Figure 6.16.

6.2.3 Discretised overall dimensions

These are the overall length, width and height of the car. Whilst the current market categorises cars as ‘mini’, ‘supermini’, ‘medium range’, ‘large’, executive etc., these do not relate effectively to a length range, although ‘mini’ car is shorter than ‘executive’ car. These were obtained from published numerical literature and discretised. For some cars a photograph of the side view was used to obtain dimensions.

6.2.4 Other discretised dimensions

Several other dimensions were obtained from side view information and discretised. These are front and rear overhangs, bonnet length, screen position and rake, rear of cockpit position, side window height and wheel width.

6.2.5 Wing forms

These are the most important. They show how the passenger compartment is integrated into the car. They change significantly over time. They are categorical variables with descriptions assigned numerical values. These values were ordered by date.

6.2.6 Roof type and rear form

These categorical variables were ordered by date. The rear form is more important than the roof type.

6.2.7 Bumper and headlight variables

They are categorical and relate to types and position of these features. They were originally treated as accessories, headlights becoming necessary as night driving increased and lighting technology changed. The headlight type variable is correlated with technological systems in cars. Electric lighting produced headlight changes: changes in material and lighting technologies produced changes in the lamp form – from round to rectangular and from geometric forms to amorphous integrated forms from the 1990s. This and the headlight position correlate with integration of overall car form, one of the distinguishing dimensions of the form analysis. Separate bumpers became added as accessories from about 1918 in the United States, becoming common as additions only in the 1930s. They were separately attached body items until the 1970s when they became integrated within the body form. Bumper types correlate with this integration and these four variables are identified as being important in car history.

6.2.8 Roundedness variables

The three roundedness variables are edge, rear and rear window roundedness (or curvature). They are discretised variables but are hard to measure. Real data were not measured, but placed into categories similar to a Likert scale, where a few easy-to-define categories form a discretised continuum, but which do not have a more formal accuracy. Figure 6.17 shows the three roundedness variables plotted against time.

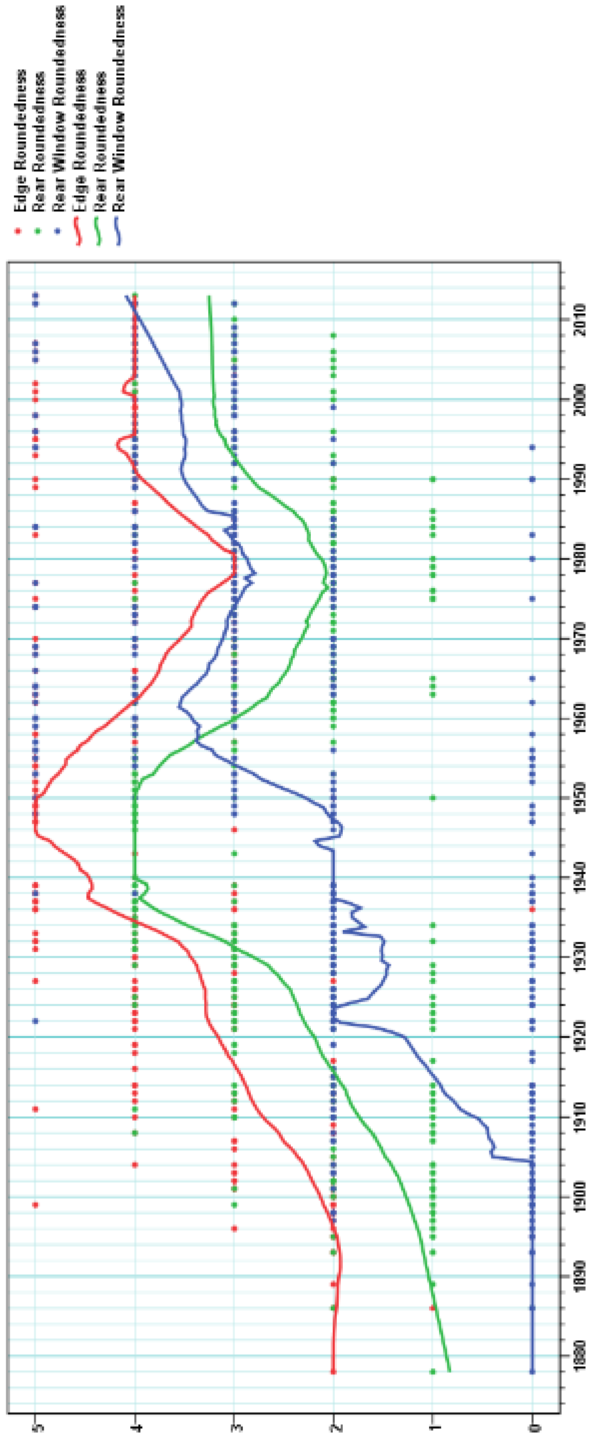


Figure 6.17 Graph for Roundedness variables against time

These variables show significant variation. The cyclical nature demonstrates that sometimes curves are ‘in’ and sometimes not, and what comes around returns. There is a tendency to move towards cars with moderate roundedness, which is not the tendency that Setright noted towards completely spherical cars, (Setright, 2002).

6.2.9 Wheel type and width

These two variables might not be form variables but layout ones. Wheel type is a categorical variable, and wheel width is a discretised variable with few values. Both variables are seen to be of relatively low importance.

6.2.10 Other variables

The number of seat rows (not seat or door numbers) tends to indicate whether the car is an economy car (single row), Sports car (also single row), family model (two rows) or people carrier or formal vehicle (more than two). Rear form indicates the luggage arrangements (usually) or the spare position; bonnet plan indicates whether the bonnet is parallel sided, tapered and whether the rear is narrow or wide. This correlates with front wing type, but is of lower importance.

6.2.11 Categorical Principal Components Analysis

The same Categorical Principal Components Analysis was carried out for form. As with the layout analysis, two object score variables (dimensions) were deemed sufficient to indicate the time-based variations. In a similar way to the layout analysis, the precise meaning of the dimensions is difficult to quantify. They relate to changes in the categories. However, the meaning of these first two form dimensions is somewhat easier to identify than the layout dimensions. The first form dimension indicates the degree of form integration with the higher figures representing greater form integration. The second dimension relates to the car’s proportions. Higher figures tend towards a longer form with a longer bonnet. Initially it was suggested that the trend might be towards shorter and shorter bonnets, but this seems to have changed and dimension two is now not changing as much as expected.

Figure 6.18 shows the first dimension plotted against time. This shows a consistent increase throughout time, with gradual changes generally taking place – although the changes seem to have been somewhat greater during the late 1930s period when the somewhat abrupt layout changes were noted.

Figure 6.19 is a similar graph of the second form dimension against time. This again shows gradual changes and not the abrupt changes that are seen for the layout variables. However, the direction of change in this variable is inconsistent. Towards the 1930s cars were getting longer and lower, with a notional peak around the late 1930s, and then after that they became less elongated and more compact in character.

Figure 6.20 has both dimensions plotted against time, showing the different characteristics of the two dimensions more clearly.

Plotting the two form dimensions against each other gives the plots seen in Figures 6.21 and 6.22. In Figure 6.22 the scatter markers are coloured to indicate which five-year period they relate to and the time-based changes can be seen on that graph in terms of a movement along the best-fit line. This shows how the two dimensions change with time, starting in the lower left quadrant and moving towards the upper left one: then moving across to upper right and lastly to lower right.

The recent changes in the way that bonnet length seems to be changing can be seen in these two graphs where the best-fit line moves suddenly upwards on the right-hand side, indicating changes seen in car form since around 2000.

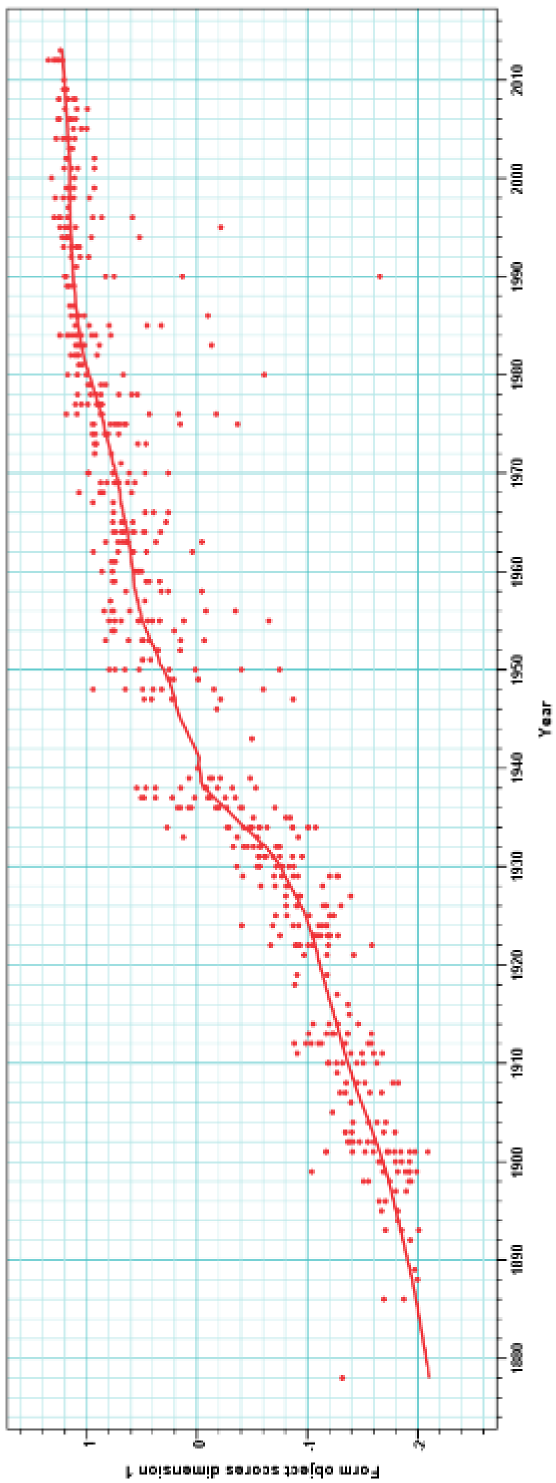


Figure 6.18 Object scores for Form dimension 1

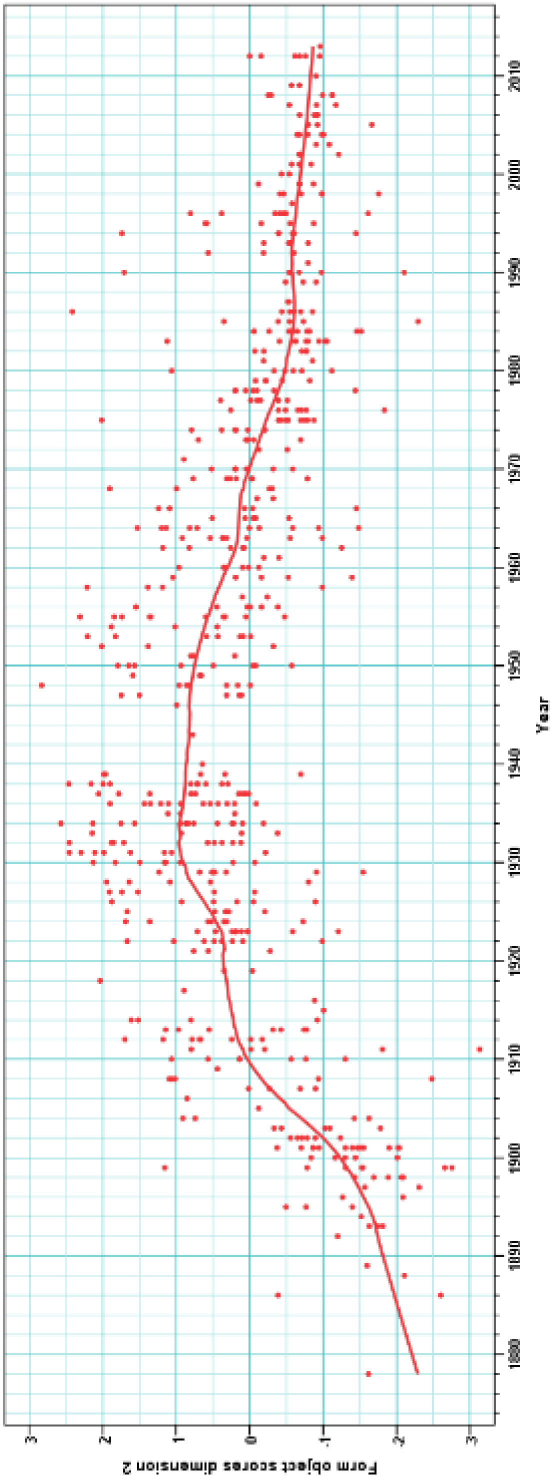


Figure 6.19 Object scores for Form dimension 2

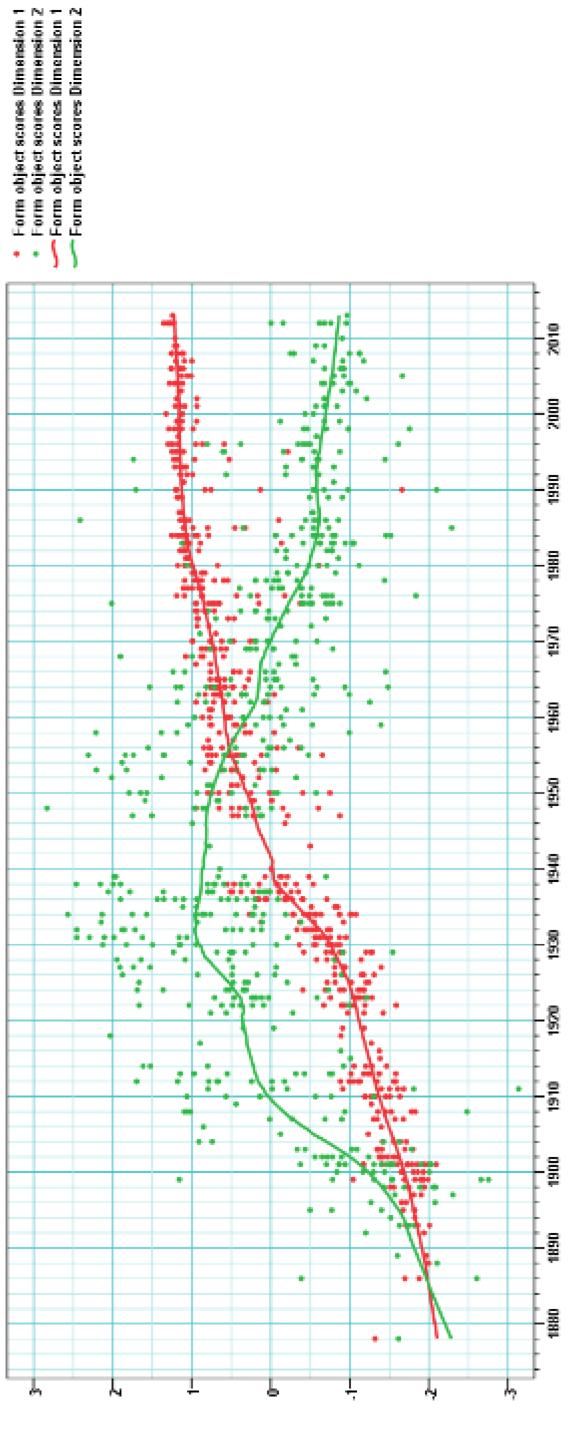


Figure 6.20 Both form dimensions plotted on the same graph

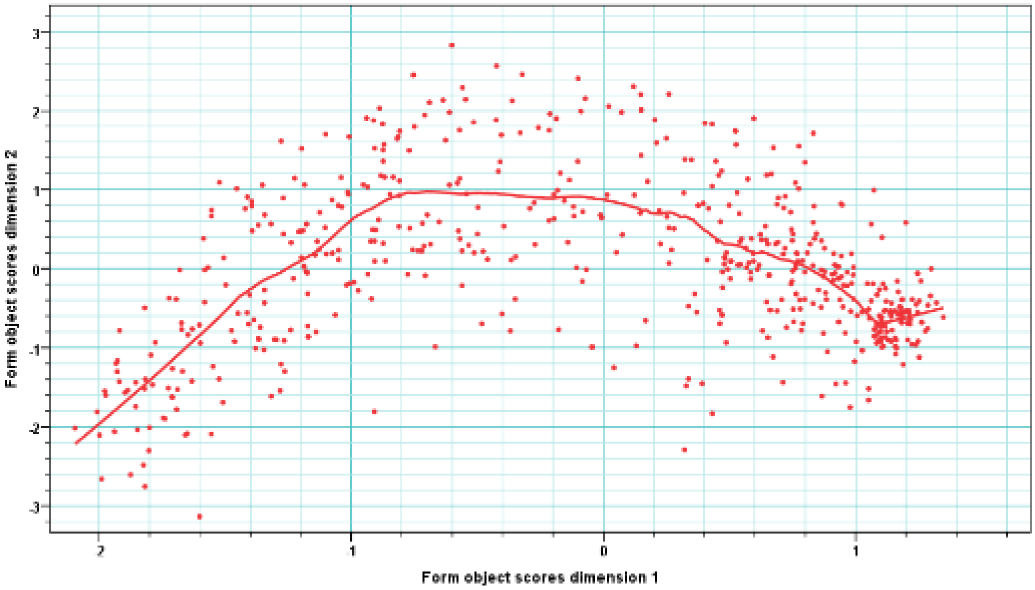


Figure 6.21 The form dimensions plotted against each other

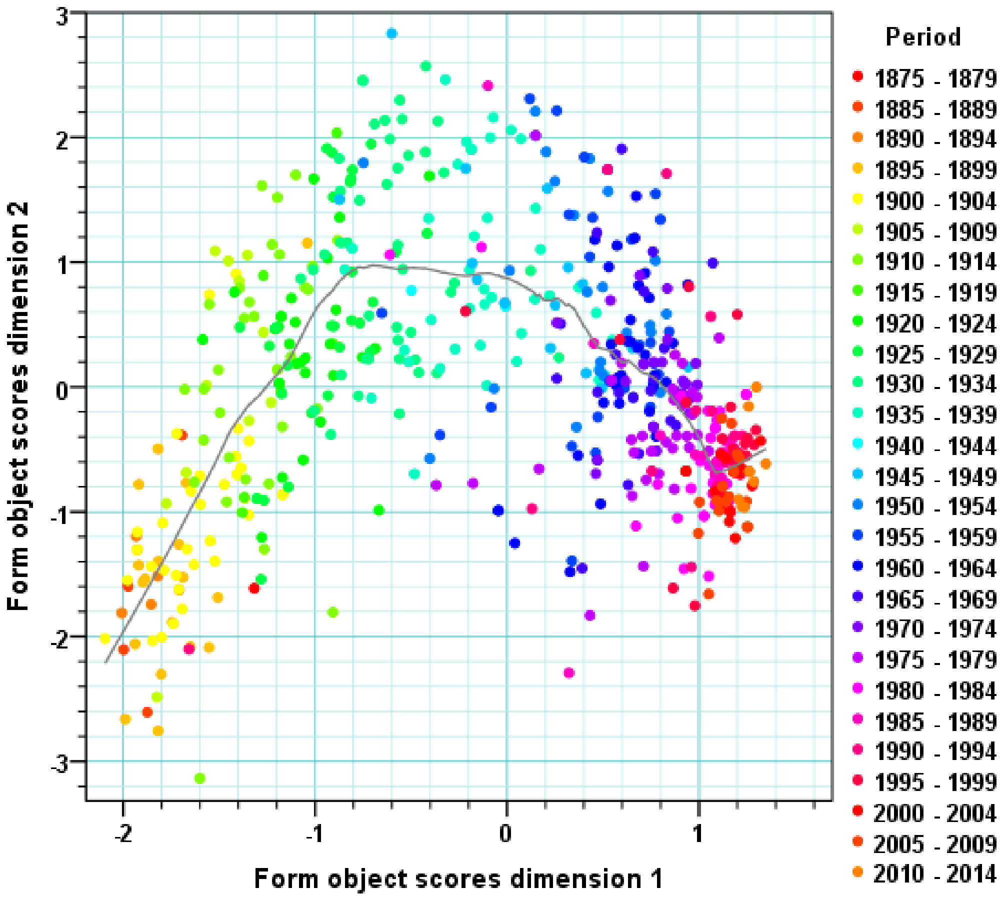


Figure 6.22 The form dimensions plotted against each other with periods coloured.

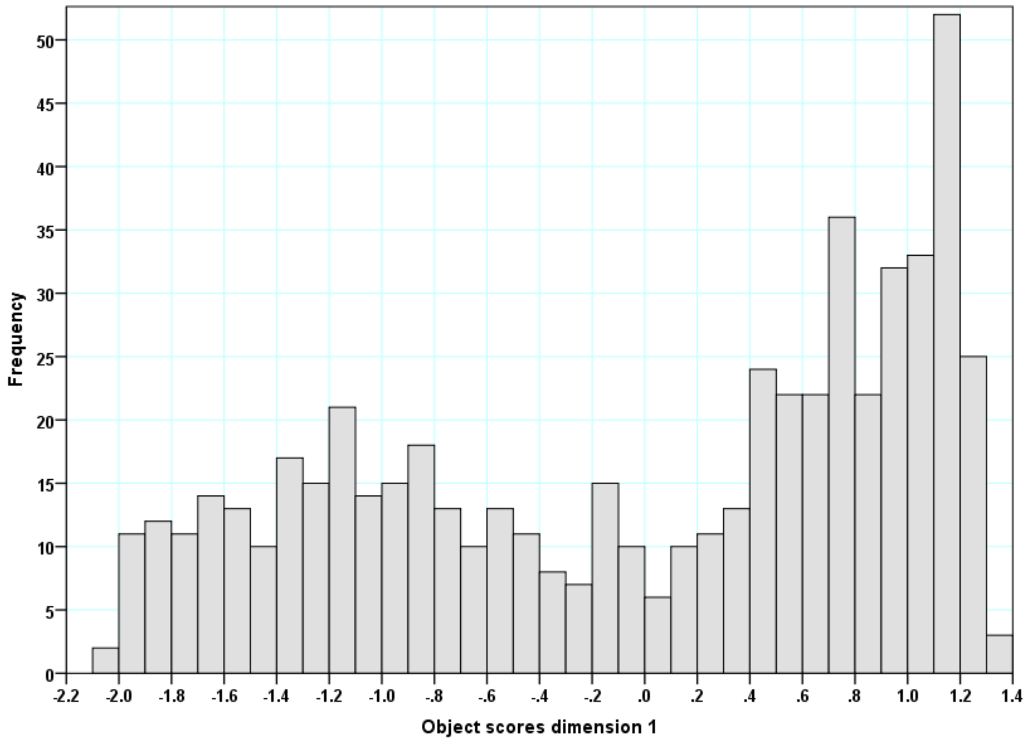


Figure 6.23 Histogram of scores for dimension 1

Figure 6.23 is a histogram showing the frequencies of the different values for the first form dimension. This indicates some scores that might that form paradigms exist, between 1.1 and 1.2 and between 0.7 and 0.8. The histogram also indicates a flattening of the curve at lower values between (say) -1.6 and -0.6, with a relatively steep section between about -0.4 and +0.4, a flat section from 0.4 upwards to the maximum between 1.3 and 1.4. If the binning interval is lower, the histogram does not display the elongated point between 1.1 and 1.2.

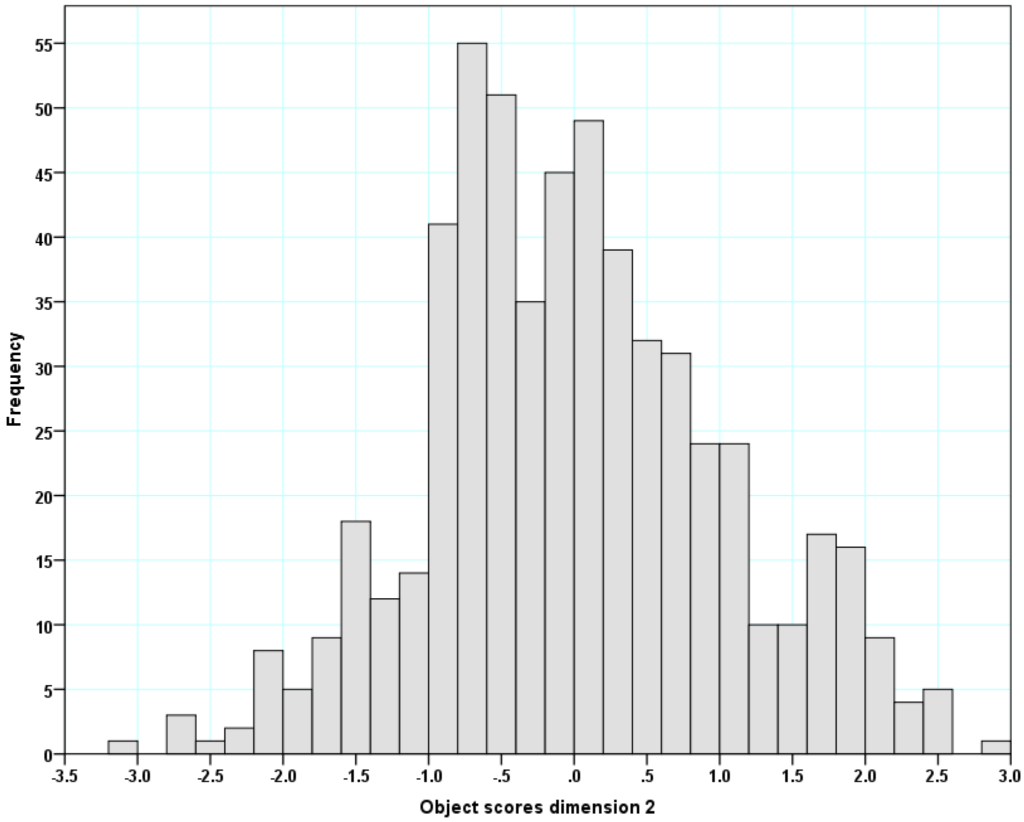


Figure 6.24 Histogram of scores for dimension 2

Figure 6.24 is the histogram for scores for form dimension 2. It indicates flattening off between -0.8 and -0.6 or even between -0.8 and -0.4. Car designers recognise current forms. The curve does not jump with time, but this does not necessarily indicate that designers use form paradigms consciously or subconsciously. The graphs indicate that time-related thinking affects form design.

Dimension 2 contains the Front of Cockpit variable (the position of the screen) with loadings from the bonnet length, overall length and two roundedness variables. Negatively, height, wing height, seat rows and rear of cockpit position load onto it. This dimension is related to proportion, and the proportion of the overall car length that is bonnet.

The other variables load onto the first dimension, mostly positively, whilst the overall height and wing height load negatively. This is related to how the car's form is integrated. Many categorical variables such as wing form, bumper type, screen rake and headlamp type tend to increase with integration.

Figure 6.25 is the same as Figure 6.22 with the superposition of illustrations of cars showing their approximate position on the graph. Early cars are in the lower left quadrant with a discrete collection of components assembled together and are short and tall, with short bonnets. Cars move into the next quadrant and become more integrated and a lot longer, with longer bonnets. In the third quadrant they become more integrated, keeping long bonnets, and lastly the passenger compartment moves forwards and they become taller.

Does form analysis demonstrate that paradigmatic thinking takes place for car form design? The graphs do not demonstrate the linear form of the layout graphs and they clearly do not jump suddenly from one value to another as the layout variables do. Designers are not necessarily copying each other: they do not have the same paradigmatic approach to form design that they have to layout design. But there is a significant time-based element to form graphs: a 1920s car designer would not consider a 1980 car form; even with one-hundred plus years of heritage designers from the 1990s do not emulate designs from the past. From time to time they create pastiche-like designs, but there are elements of form design that still locate these in the period they were designed, rather than the period they are trying to emulate – with the exception of cars deliberately designed as faithful replicas of older cars.

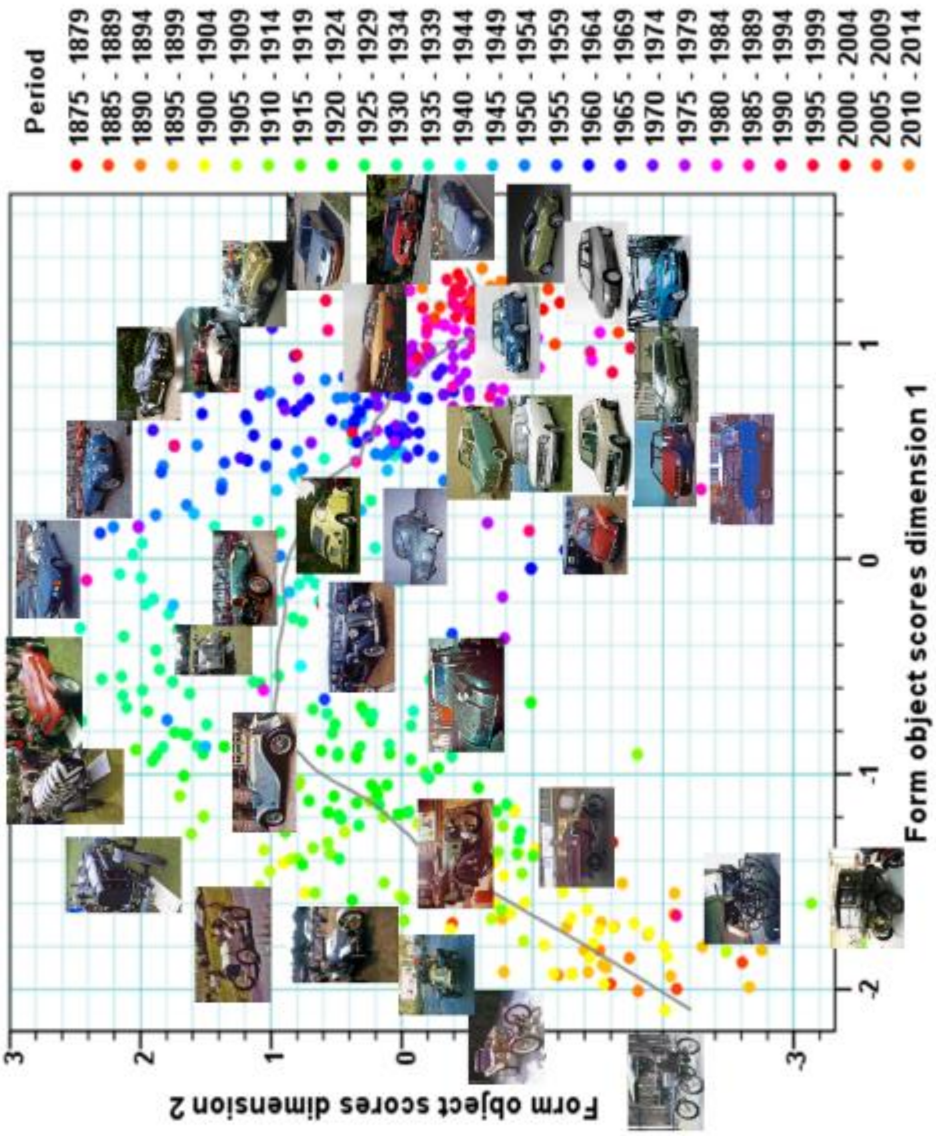


Figure 6.25 Object scores graph with added car pictures to illustrate how the changes in form variables relate to physical car appearance.

For example, the new Volkswagen Beetle was never designed as a faithful copy of the old Beetle – it was merely designed to mimic some of its form characteristics. The side view comparison in Figure 6.26 immediately identifies that the different screen rake and screen base position clearly shows the later car is more contemporary, even if the separate wings hark back to the 1940s of the original Beetle.

Figure 6.26 Comparison of profiles of the original and later Volkswagen Beetles (lower, favcars.com)

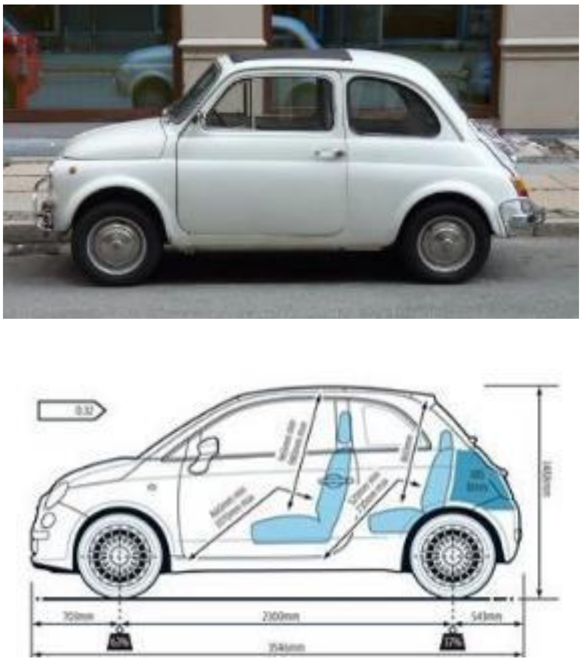


Figure 6.27 Comparison of Fiat 500 profiles old and new (lower, Autocar)

The side-view comparison of the Fiat 500 seen in Figure 6.27 is similar. The form-evident differences are also the screen rake and base of screen position.

6.2.12 Expansion

This section expands and describes Figure 6.25.

Lower left quadrant

Figure 6.28 expands this quadrant of Figure 6.25. This contains the earliest cars. Here cars tend to be relatively short and tall, with a discrete uncoordinated set of components with little attempt to integrate the vehicle. Here is the fledgling that becomes a car. It is a transport idea or something that functions, but only just does. To some extent this seems to be an experimental period

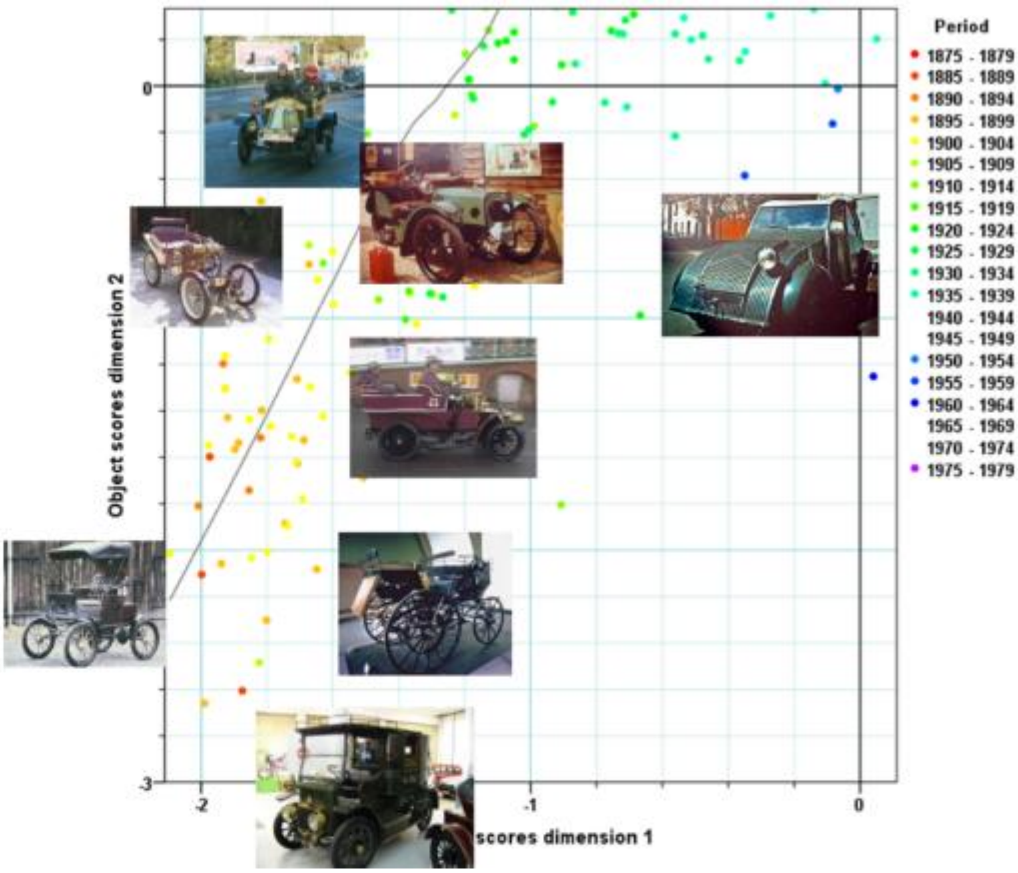


Figure 6.28 Expanded lower left quadrant of Figure 6.25

At the lower left is a Baker Electric from 1902.It demonstrates the form of a classic battery box on wheels. There is a seat on a box with spindly wheels and a tall fabric roof which probably only offered protection when going slowly. There is not much in front of the driver, just a leather dashboard. Lighting is by carriage lamps on the side. It is a set of disjointed boxes and the form could almost be a seat on an orange box on pram wheels.

At the bottom in the centre is an Austin Town car of 1911. It is tall and stately and very carriage-like. There is no bonnet: the engine is under the driver's seat to shorten it to become more manoeuvrable. The wheels are outside the body width, have mudguards, and are artillery type like a carriage.

The car above it is a replica of the first Daimler of 1886. This was a carriage with an added engine. It is short, with the horse shafts removed from the front and a four-spoked steering 'spider'. It is a collection of parts with no bonnet. It is further up dimension 2 because it has no roof and is not as tall as the Austin.

Above that is a James and Browne from 1902. It is still a collection of parts but it is lower and longer. The body shell is a more integrated rear-entrance tonneau. It has a coal-scuttle form of bonnet with no radiator grille. Headlamps are separate spirit-fired carriage lamps.

Further up and to the left is a De Dion-engined combination (1899). This has minimal body and is a chair on wheels with an outboard motor at the front. There appears to be no integration – or almost no integration. It is lower than some in this quadrant. Lighting is by carriage lamps. It has mudguards on spindly wheels.

At the top left is a 1901 Renault. This is a bit lower: it is more integrated and is more of a car. But it is still a collection of parts. The bonnet is coal-scuttle shaped, as on the James and Browne. The lights are now nearer the front, and are spirit-fired carriage lamps.

To the right and a little lower is a 1913 Morgan three-wheeler, looking more integrated and lower, but it still appears as a collection of boxes, with wheels under separate mudguards and lights mounted further back on the scuttle.

Creeping into this quadrant is the Citroën 2CV prototype on the far right, where the pattern is coming back down again. It is in this quadrant for its separate wings and headlamps. It is an upright collection of bits, with little roundedness.

Upper left quadrant

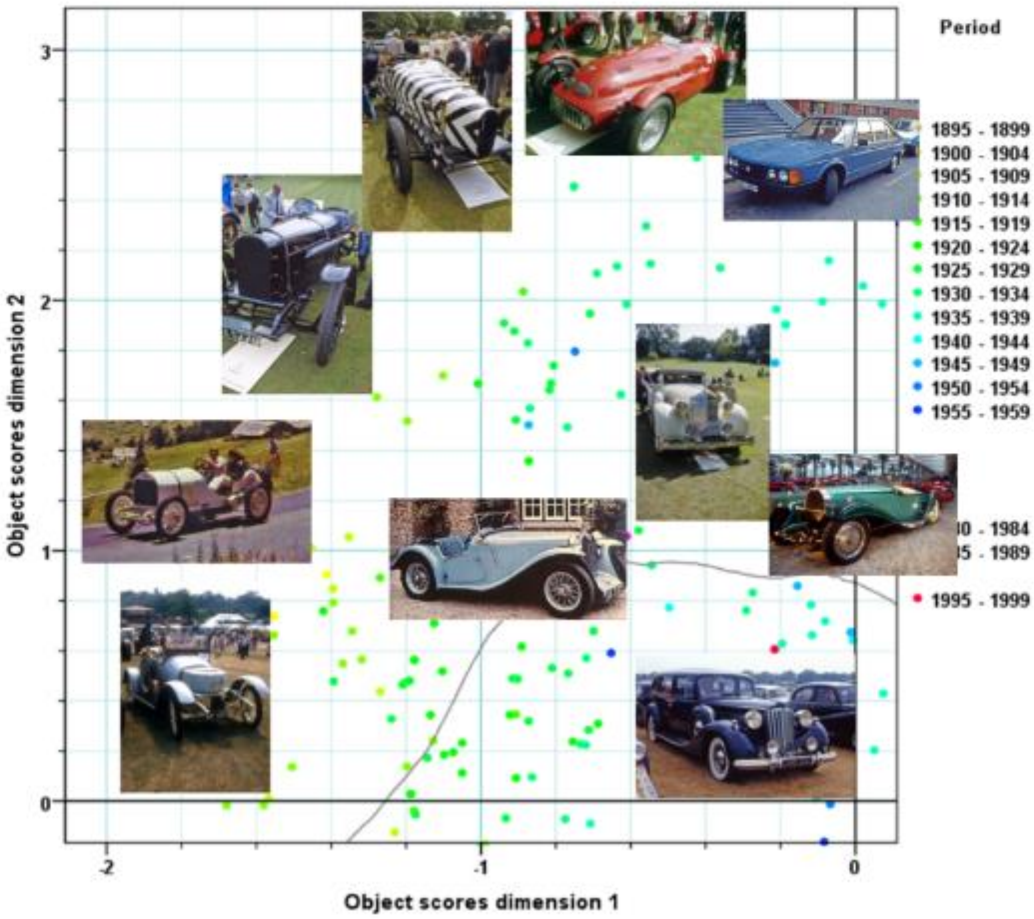


Figure 6.29 Upper left quadrant

Figure 6.29 shows the upper left quadrant. This contains the classic Vintage-style sports cars. These are longer and lower than the lower left quadrant, but are still square in character and appear like a collection of parts.

In the lower left is a Stanley (1911) and a Benz racing car (1908): the Benz is longer than the Stanley. The Stanley has a single carriage lamp in the centre and the Benz has no lamps.

Moving around the top, the Sunbeam, Straker-Squire and Nardi at the top are thinly-disguised racing cars. The Nardi is much later car (1947) and is more integrated.

To the top right is a Tatra saloon from 1990. This is a more integrated form and is a saloon car but it is still long and low in character, but from much later.

In the lower centre is an MG PB from 1934. This is a square sports car with separate flowing wings. To its right are two Packards from the 1930s, and a Bugatti. The Packards show different body styles on the same underpinnings.

The Bugatti is a more integrated, rounded form. It is one of the longest cars in the sample (and one of the longest cars ever) with a single row of seats.

Upper right quadrant

Figure 6.30 shows the upper right quadrant. This quadrant also contains sports cars which are longer and lower. These are more rounded and integrated, and are all later than those in the upper left quadrant. These are all post-war, the earliest being the Gordini at the top of the diagram, from1953.

Moving towards the x axis the cars gain roofs. Along the x axis they gain extra rows of seats – the Ford Capri at the bottom centre and the red BMW

(2012) to its right are still relatively low but have this extra passenger capacity.

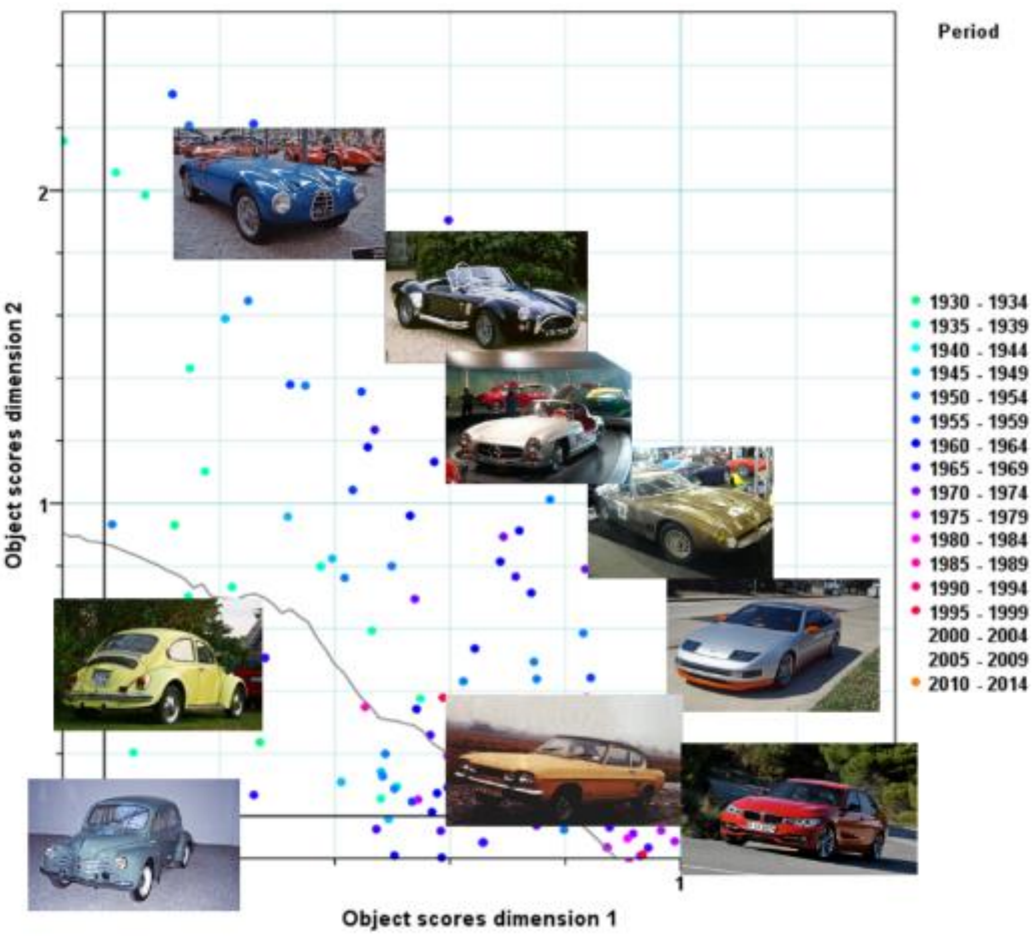


Figure 6.30 Upper right quadrant

In the left of this diagram but in centre of the overall picture (Figure 6.25) are two post-war cars – a 1950s Renault and a Volkswagen Beetle (1970). These are saloons with rounded form but with separate wings. They are not as integrated as cars to the right and are significantly more rounded than the Citroën 2CV prototype seen in the lower left quadrant.

Lower right quadrant

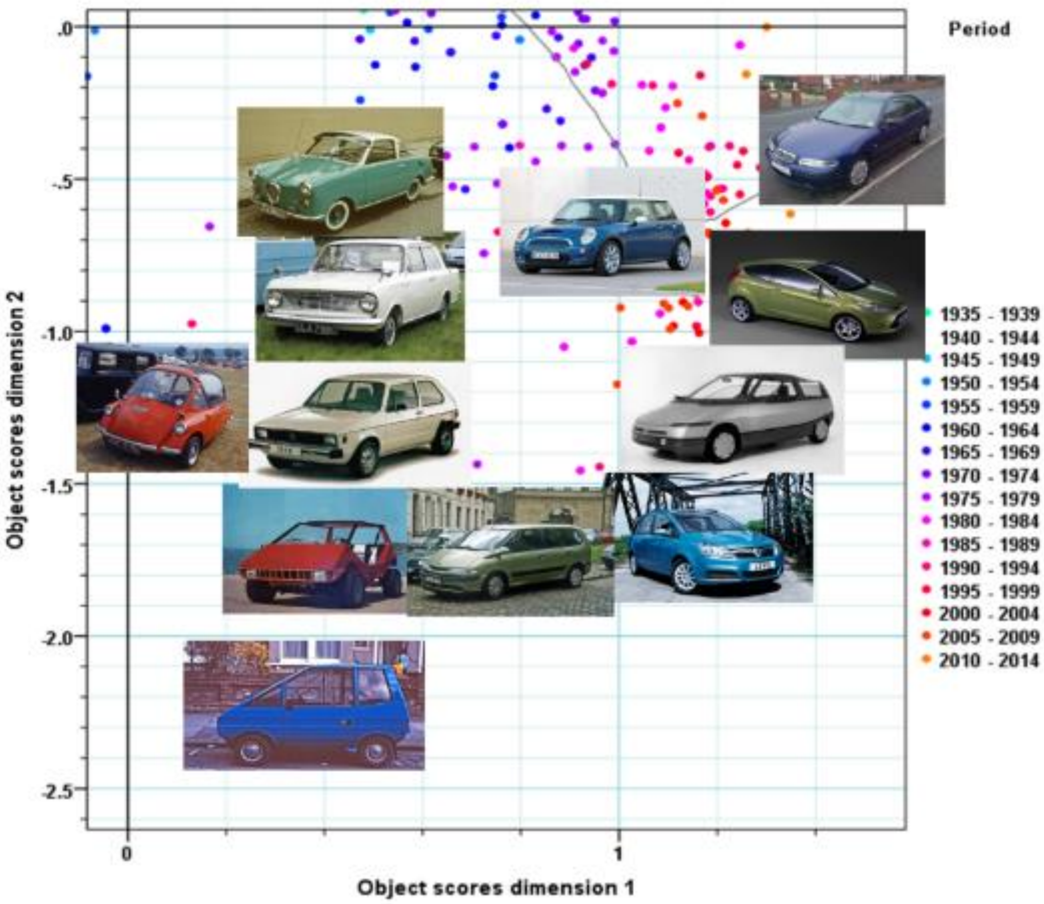


Figure 6.31 Lower right quadrant

Figure 6.31 illustrates the lower right quadrant. This still contains some two-seaters, but these are economy cars rather than sports cars and are shorter. Most cars in this quadrant are family-type cars, and most are rounded and integrated in form.

At the lower left they become more rectangular, but are still integrated, even trying to lose bonnets, and short – the lowest car is the Elswick Envoy (1985) (Willis, 2007). Also at the bottom of the diagram but slightly further to the right are the Renault Espace and Vauxhall Zafira people carriers.

Above these two are a Citroën Economy prototype, the Ford Fiesta (2009) and Rover 420Si (1999). These seem to indicate the direction where car form is heading – it is a more integrated form with a discernible bonnet. The headlamps are now fully integrated and amorphous. Round headlights have been displaced by integrated irregular ones because the form of the car is irregular, and the material of the headlight can now be manufactured in such a way that its form does not distort light.

Car form changes and moves around the diagram. The mean line seems to be strongly linked with when a car is made.

Evidence suggests that car designers consciously or subconsciously design cars with links to previous forms and that form develops continually from disparate components attached to a frame towards an overall integrated form. Perhaps this is because the car body shell has multiple functions of also being the car's structural component, carrying out the wind-cheating task and comforting and protecting occupants.

Form design developments and changes are different in character to those for layout design. Chapter 8 identifies in what ways this might demonstrate that car designers have an exemplar, a paradigm, consciously or subconsciously in their minds when they are designing and indicates evidence for this.

6.3 Using real number data

An analysis was carried out with real number data. The purpose of this analysis was primarily to investigate TRIZ assertions that the performance curve is the S-shaped logistic curve (Dowlen, 2011).

TRIZ is a creative design process developed in the Soviet Union by Altshuller, an engineer. He used process derived from physics and engineering to develop a radical creative thinking approach to the development of new product concepts, which tended to relate primarily to the embodiment of novel scientific and engineering principles (Altshuller, 1988, Altshuller, 1996, Nisanov, 2004, Savransky, 2000, SI:online, 2009)

TRIZ is a general design process and not primarily concerned with product histories. However, one section of TRIZ does consider product histories and this was investigated alongside numerical data from the car sample. The analysis showed the S-curve is simplistic and does not account for influences that affect performance such as legislation, politics, warfare and economic crises. It indicates that an S-curve may not be relevant for a product where performance is limited by legislation, economics and ethics rather than technology and physics. Cars are this sort of product. Car performance is associated with speed, power and acceleration. These are limited within society and there are very few places where such performance is used. Thus overall performance becomes an irrelevant design factor and target. Legal and traffic conditions limit car performance to around 120 Km/h in most countries. So although TRIZ asserts that a generic product's performance curve is S-shaped one, it is not so for cars.

The more open question is to determine the shape of the performance curves of cars. A subsidiary question is to define perceived performance. If not, how might performance be measured consistently over time?

Real number data is of two types. Firstly, are published performance data – physical measurements relating to car performance. Easily obtainable are engine capacity, bore, stroke and car weight. Output performance figures are dependent: engine power and torque, engine speeds these occur, maximum speed and acceleration. No figures of fuel economy were obtained. It is dependent on use as well as design factors and these are difficult to quantify. Attempts to do so have been made by different bodies and assessors, causing more controversy than conclusions. General consensus is that it is unreliable.

Length, width, height and wheelbase are generally available from specification data. Other dimensions obtained from side elevations: front and rear overhangs, bonnet length, screen rake, side window base height, the position of the front of the screen and the rear of the cockpit (the position of the rear of the glasshouse or upper part of the car). These last two are measured rearwards from the centreline of the front wheels (the zero point for car designers).

Side views of the cars are not always easily obtainable, particularly for older cars.

Figure 6.32 shows a graph of car length against time, and Figure 6.33 is a graph showing the changes in car weight over time.

Overall length increases until about 1940 and then stays reasonably constant. Wheelbase and length correlate, as expected. The mean car width is rising noticeably; the line crosses the boundary from ‘normal’ into ‘wide’ category (over 70”) in 2010. Cars are getting wider.

The weight scatterplot indicates that ‘getting fatter’ includes getting heavier from the 1970s. An increase in structural efficiency is offset by increases in safety legislation, particularly side impact, and equipment.

The form analysis in Section 6.2 suggested that the relative position of the screen is important historically. Figure 6.34 is a plot of the car’s screen position (rearwards from the front axle) as a proportion of the car’s wheelbase, plotted against time. The numerical data show an interesting change of direction in 2005, when screens stopped moving forwards relative to the wheelbase –away from the one-box car. This change in direction is also shown in Figure 6.21.

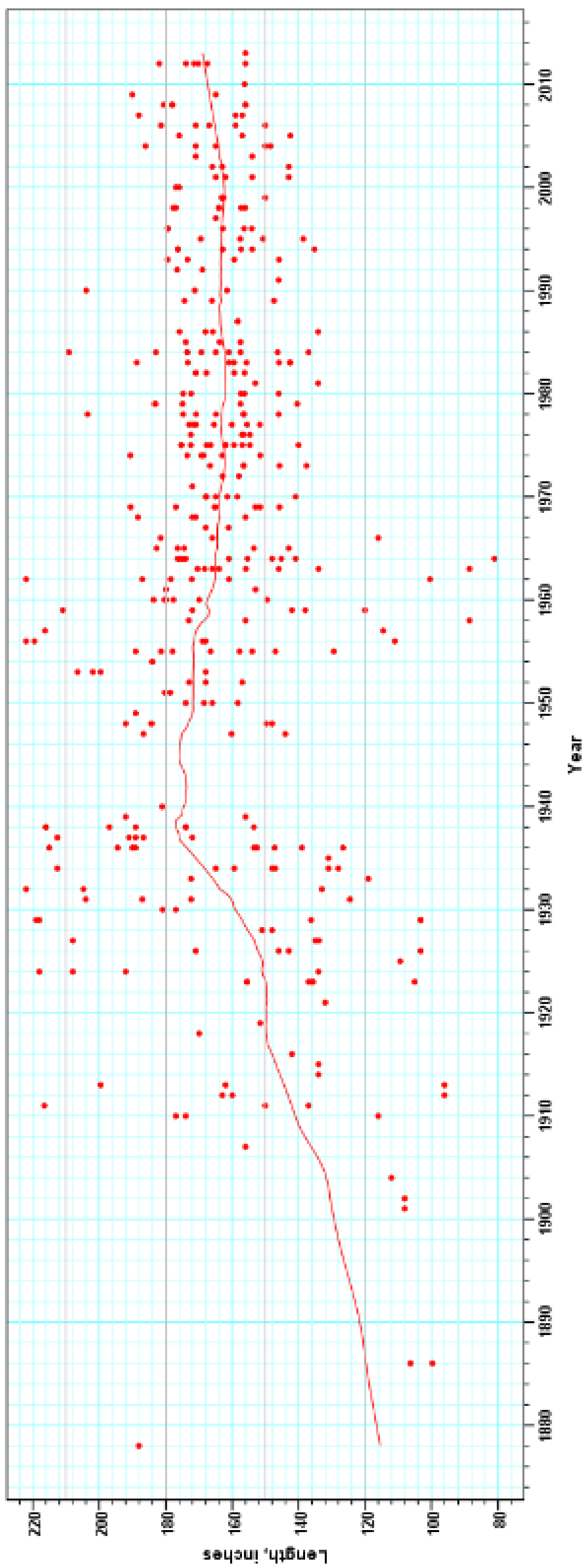


Figure 6.32 Length scatter plot

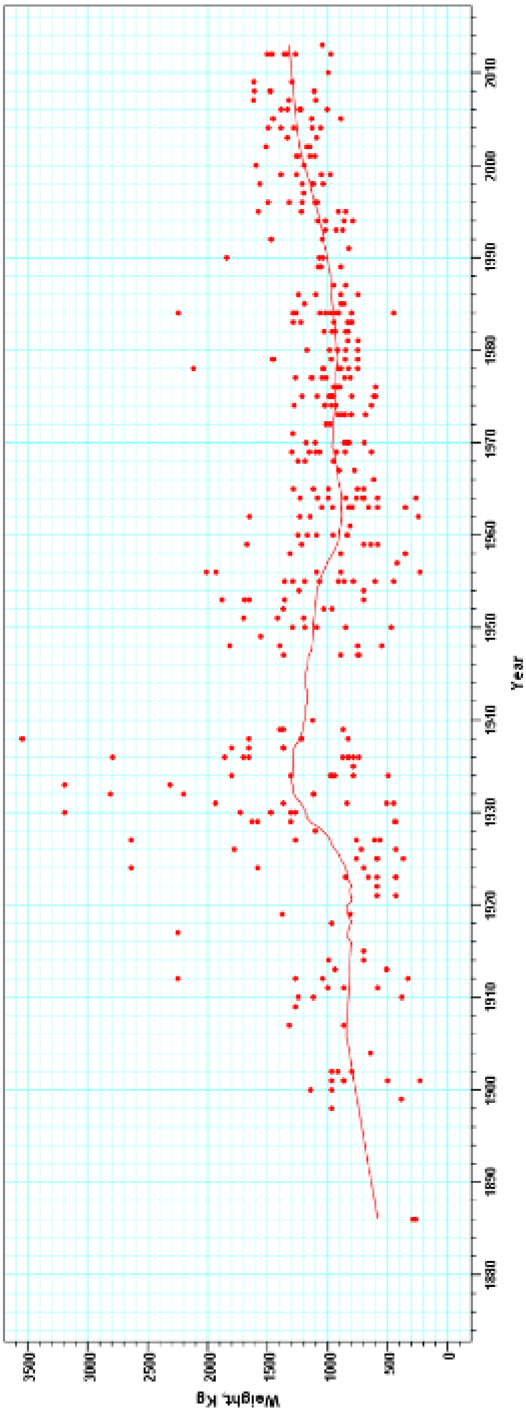


Figure 6.33 Scatterplot of weights

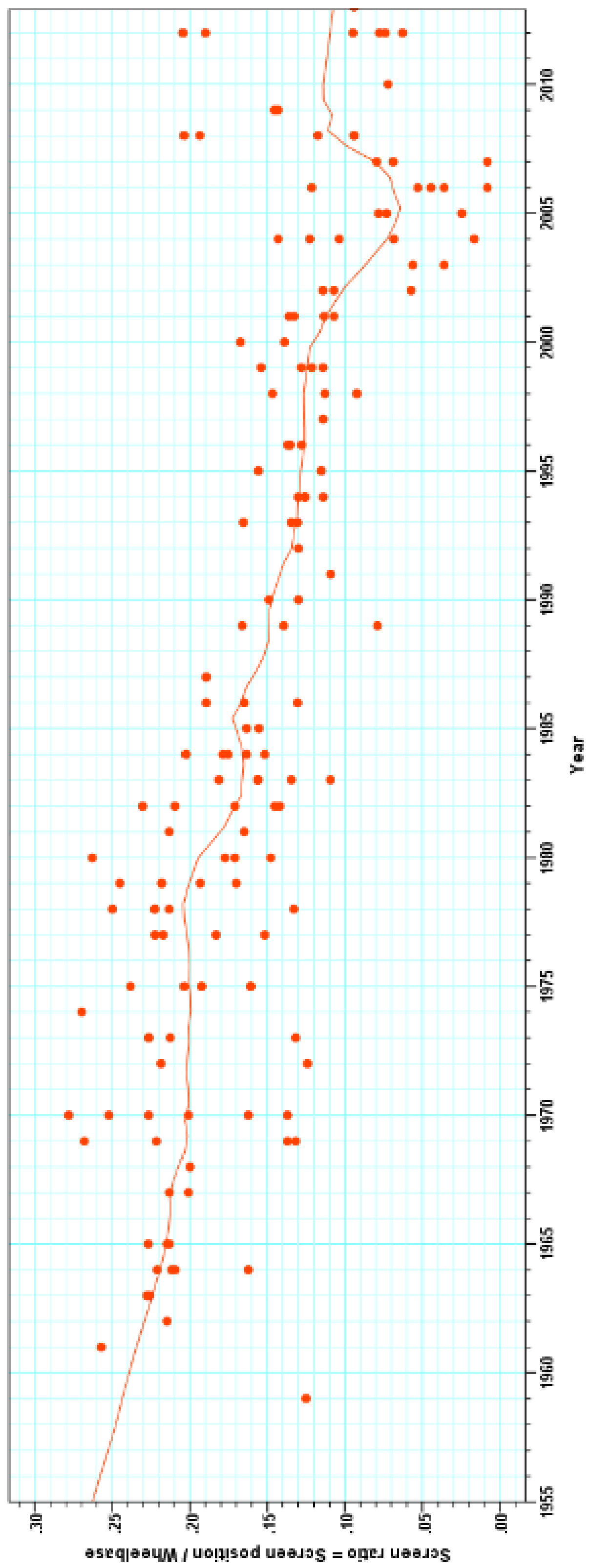


Figure 6.34 Screen position ratio w.r.t. wheelbase

The TRIZ comparison required performance data to be investigated over time. Traditional definitions of performance were investigated – maximum speed, engine power and acceleration.

What is seen is that power rises generally, but with a significant dip taking place for ten years or so from the Second World War onwards. It may be related to such non-motoring events as the period of austerity and rationing in the UK after the war, and the Suez Crisis of the late 1950s, both of which might have made more economical motoring more popular for a period. Maximum speed data is also available for a lot of cars and is reasonably consistent in its measurement. The following few paragraphs quote from the paper of 2011 that compared the data with the TRIZ assertion that product performance follows the logistic S curve over time.

A similar lack of levelling off is also seen in the quest for more speed – although from the Second World War years there is a slight flattening, suggesting that designers were starting to become interested in efficiency – the achievement of higher speed with less power.

Acceleration includes a certain amount of compromise. This data only goes back to 1930 or so: it could not be found for cars before this date. The available figure is a time for acceleration from zero to 50mph (80.45 kph), 60mph (96.45kph) or 100kph. A comparative figure for these three categories is needed. The average acceleration figure for the maximum acceleration run has been used for this, although it will not be the same for 0-50mph as 0-60mph figure, making for a compromise. The figure has been multiplied by 100 to enable it to fit with the scale of the graph.

None of these power graphs shows an S-shaped curve – there is little evidence for a flattening out of the curves as time progresses, even though the car might be reasonably perceived to be a mature product (Dowlen, 2011).

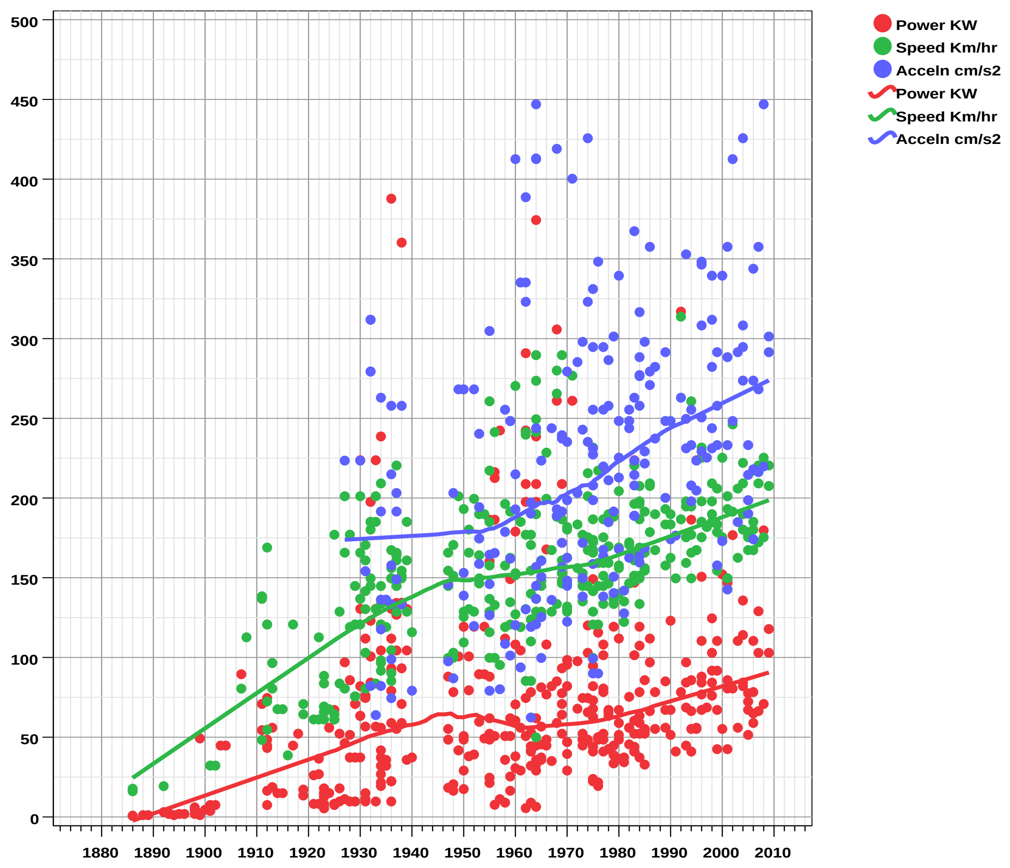


Figure 6.35 Measurements of car performance at different dates

These data are shown in the time-based plot in Figure 6.35. Other possible efficiency-based measures of performance are shown plotted against time in Figure 6.36.

Whilst specific power and power to weight ratios have increased, the speed to power ratio has decreased, possibly an aerodynamic factor. The specific power curve indicates a continuing rise with no sign of lessening. Whilst there is a slight decrease in slope of the power / weight curve, this hardly represents an S-shaped curve. Slight inflections in the specific power curve and the Kph / power curve in 1980 suggest something occurred then. It may have been the weight increase because of awareness of safety, and a drive towards efficiencies in engine design and aerodynamics after the fuel crisis of the mid-1970s (Dowlen, 2011).

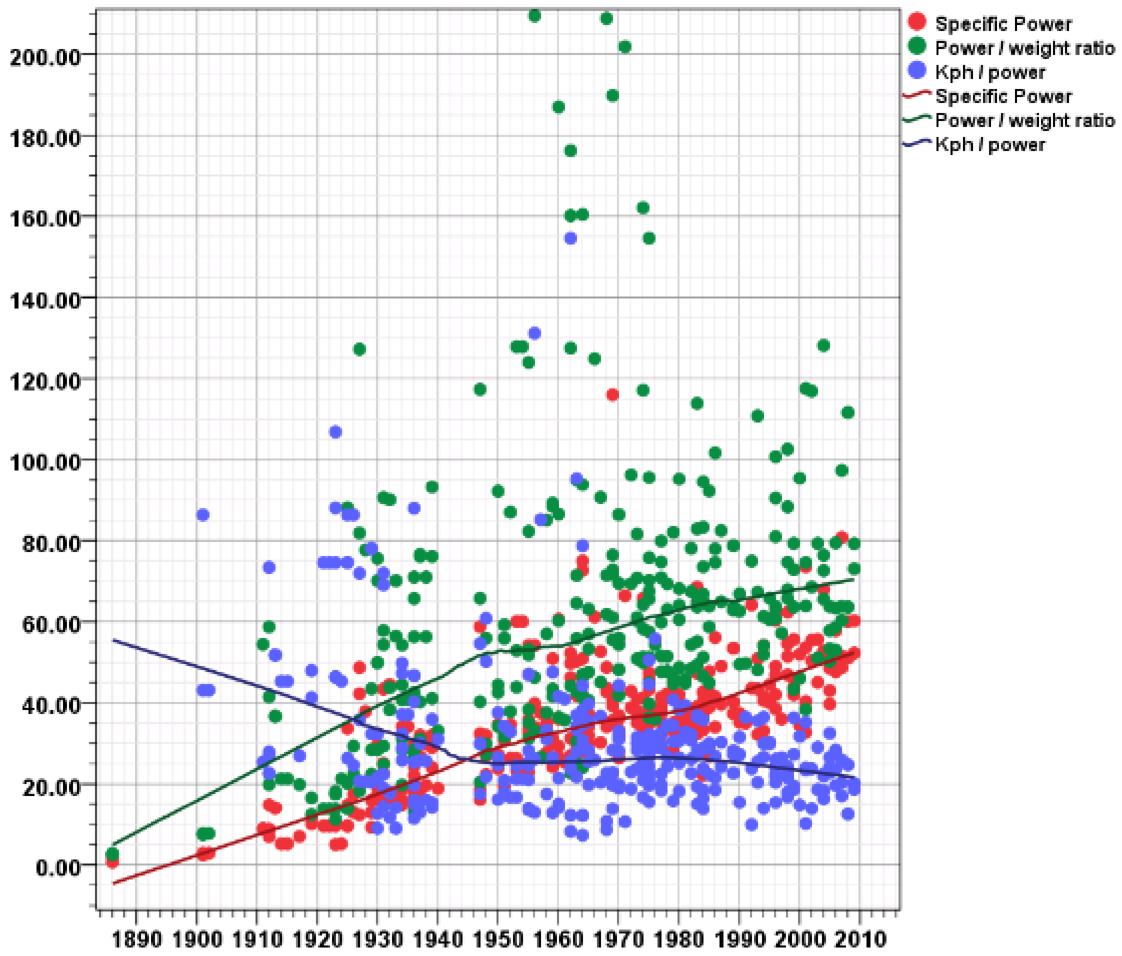


Figure 6.36 Possible efficiency measures for cars

A multi-variable approach was taken next. This used variables related to car performance – engine capacity, power, torque, frontal area, weight, maximum speed and acceleration – and a factor analysis was carried out (Child, 1990). The first two factors are plotted against time in Figure 6.37 and against each other in Figure 6.38. The factors cannot be defined easily and it is not particularly clear what they each represent.

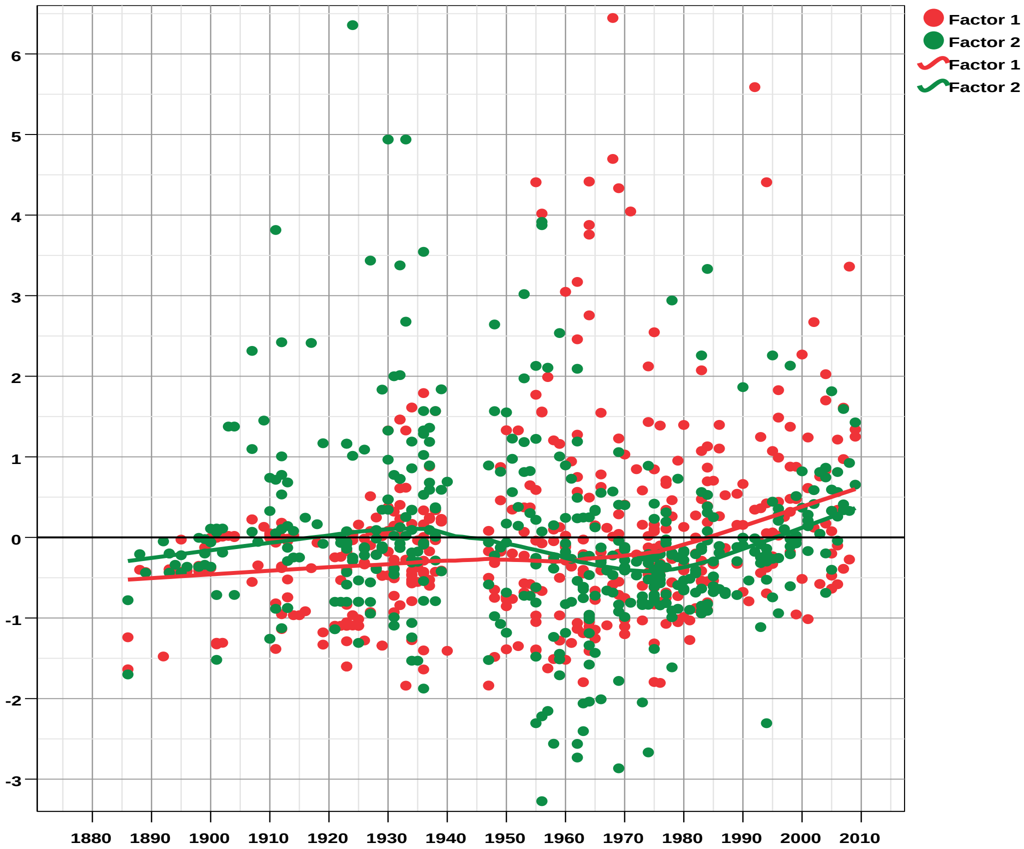


Figure 6.37 Factor analysis scores

However, Figure 6.37 shows no sudden shifts in performance data. Design shifts do not seem to produce significant shifts in car performance.

It is difficult to identify specific relationships from Figure 6.38, and the large jump in behaviour seen in the late 1930s in both layout and form analysis is not evident, most probably because of the paucity of available data from the earlier periods.

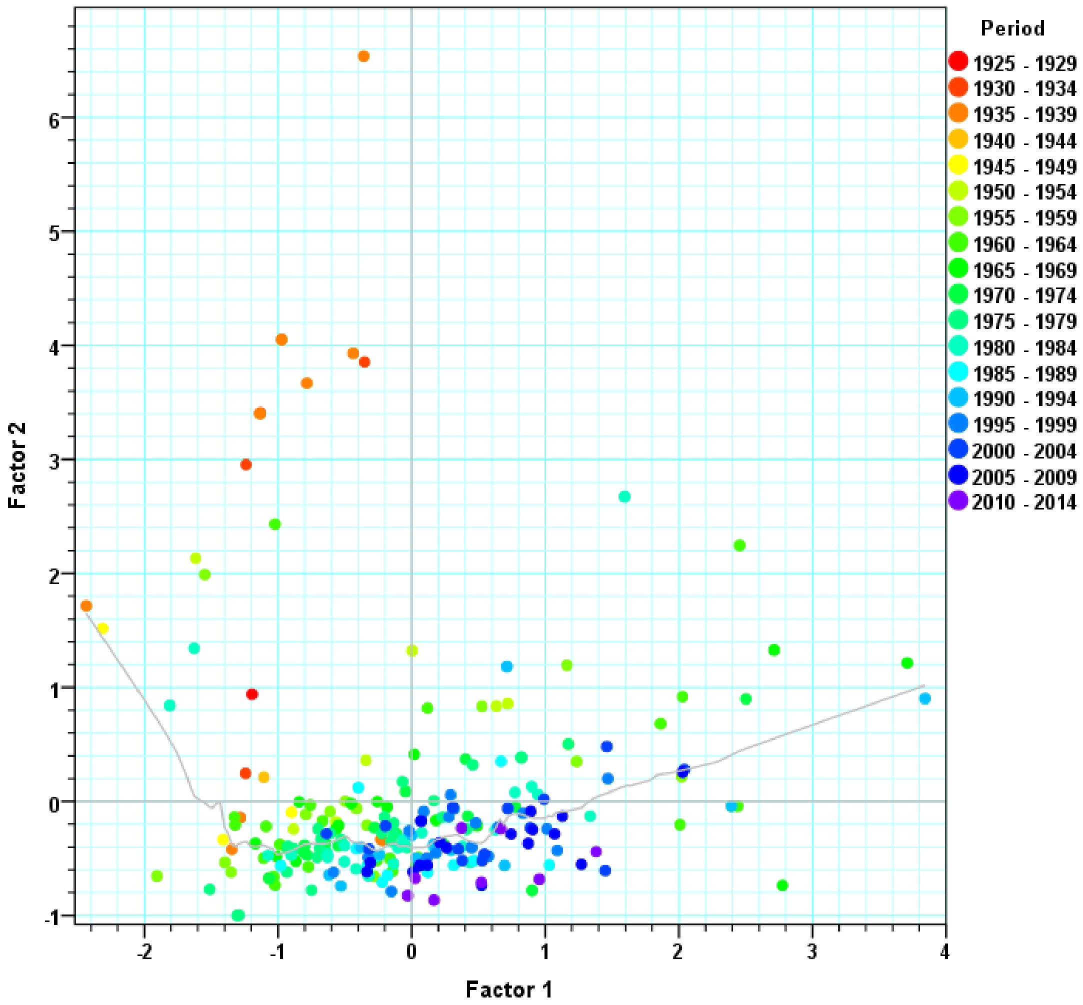


Figure 6.38 Factors plotted against each other

Cars have not reached maximum possible performance – at least, road cars have not. It would also seem unlikely that road cars will ever reach the maximum performance, as their speeds are limited by road conditions and by politics and not physics. Quoted maximum speeds and acceleration figures seem to be increasing, even if drivers never use their car's performance. So the TRIZ S-curve assertions are disproved.

The major question raised by the data and analysis was whether the measures of performance taken were real measures of performance.

Car magazines' rating systems and their basis were investigated, which include subjective data that seems to change over time, making effective timely analysis difficult.

Although the S-curve is not appropriate for the car's performance, it might be for some of the car's components. The change from solid rubber to pneumatic tyres was for technical performance limitations of solid rubber tyres. The change from solid beam front axles to independent suspension in the 1930s resulted from technical performance limitations of the rigid front axle, and the development of alternative front suspension systems allowed subsequent history to be freed from the performance limits of the S-shaped curve that might have been relevant and limiting for the beam axle. This is developed in Chapter 8 as a reason for the changes seen in the categorical layout analysis in Section 6.1.

6.4 Summary of numerical analyses

This chapter has outlined the numerical analysis processes that were carried out. These split into three significant sections. The first section covered the categorical analysis of car layout, the second the categorical analysis of car form and the third section covered a more general analysis using real number data.

The main findings of the layout analysis are that the layout variables show a behaviour that is characterised by a number of straight lines on time-line graphs for the first and second dimension (see Figures 6.10 and 6.12), indicating that at some point in car history (about 1904) a particular combination of layout variables was reached that became the norm for car design for a period of around thirty years. Following that, from about 1934 onwards, there is a relatively sudden shift in the layout values, with a new combination identified from perhaps 1937 onwards. This combination changes more gradually, but from the early 1960s another new combination of layout values is identified. These three particular combinations of layout values are indicative that paradigmatic behaviour is taking place in that there is some identifiable ‘car’ paradigm that is relatively tightly defined that is being used as an exemplar. Eckermann (Eckermann, 2001) even identifies an illustration of what he calls an ‘American Standard Automobile’ which is of no particular manufacture but which exemplifies the paradigm current in 1928 – as seen in Figure 6.39.

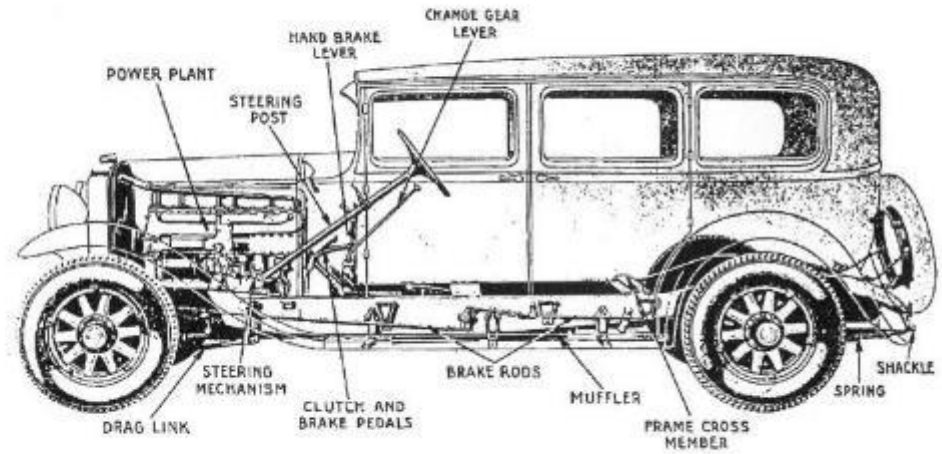


Figure 6.39: American Standard Automobile (Eckermann, 2001)

The items identified in Figure 6.39, however, are more detailed than the layout variables that are used for the current analysis, showing that the paradigm was more tightly constrained than those variables.

The form analysis showed that form does not behave in the same way as the car’s layout. The changes are significantly more gradual, but they are based on the current form of the car and are modified from that – they do not appear as a random scattering of form points but are related to the era in which they were designed. See Figures 6.18, 6.19 and 6.20. Form seems to have followed the themes of integration through time, with more parts of the car becoming embodied under a general form and losing aspects such as separate headlights, wings, bumpers, luggage compartments to become in some cases a one-box form. Recently there has been a slight change in this, with an emphasis now being placed upon having some identifiable form of bonnet. The second axis of the form dimensions seems to be related to the proportions of the overall form. Up to the mid-1930s this moved towards a longer, lower form with a longer bonnet portion. After the 1930s car bonnets became shorter and the vehicle became relatively taller again, with shorter bonnets.

The relationship between the form and layout variables and the specific results of the layout and form analyses and their implications for design paradigms in car history is expanded in Chapter eight.

The third section of the numerical analysis, of real number data, was initially carried out in order to investigate the TRIZ claims that product performance follows a historical logistic S-shaped curve. The analysis plotted several variables against each other, but was not able to establish the claims of the TRIZ theories. It suggested that the historical measurement of car performance may not be able to be carried out using relatively simple numerical data and that events such as the financial crash of 1929 and the First and Second World Wars had more impact upon car performance development than technical limitations.

The next chapter covers the constructivist analysis where several car designers and car historians were interviewed in order to obtain their constructs on car design and history.

7 Constructivist analyses

7 Constructivist analyses

It is apparent from the research in the previous chapter that the numerical data have identified what changed and when. A constructivist analysis process was then carried out using interviews.

A questionnaire approach might have been possible through the Society of Automotive Historians. This would have covered members' perceptions of car history and not their perceptions of design because too few had experience of design practices. This was attempted and whilst the few pilot questionnaires seemed to give results that indicated that the approach would provide effective answers, the first few responses from the Society suggested that another approach might be better. There were two reasons for this. Firstly, one respondent publicly circulated a response that indicated to the Society members that the questionnaire was not worth doing as he felt the conventional descriptors were sufficient. "This has been done before. The results are the conventional descriptors" was his public response. Others who took the questionnaire more seriously showed narrow interests – only their favourite manufacturer, period or type of car. "I am only interested in Formula 1 racing cars" or "Stanley Steam cars started manufacturing in 1899 and finished in 1924", were typical responses. Neither answered the questions. They pointed to the Society's members being specialists and not generalists (Society of Automotive Historians, 1973 onwards-a, Society of Automotive Historians, 1973 onwards-b, Society of Automotive Historians in Britain, 1995 onwards). These data suggested a questionnaire approach was not suitable.

Semi-structured interviews were used which guided discussions around historical and design-related questions. Where an individual seemed to have a narrow interest this could be probed to expand that interest and move away from it which would not have been possible with a questionnaire.

The interviews included affinity diagrams (Cohen, 1995, IDEO, 2003) for exploring historical perceptions and repertory grids (Fransella and Bannister, 1977, Kelly, 1955, Stanton and Young, 1998, Stanton and Young, 1999, Stewart and Stewart, 1981) for identifying car enthusiasms and interviewees' car-related constructs. Influences and why these happened could be explored – in contrast with a questionnaire approach. This same constructivist process was used to analyse the questionnaires, giving rich sets of constructs within the specific areas related to the questions.

7.1 Interviews

7.1.1 The interviewees

Thirteen interviews were carried out. Twelve were face-to-face and one was via email as the interviewee was not in Britain. Selecting suitable interviewees was not random because the general public do not have the required knowledge or interest. Consequently, the candidates were chosen for both qualifications and interests. The age spread was uneven and all were male. Two were not British and one British but not English. Four had engineering qualifications; one had abandoned engineering for the financial sector. Four were amateur automotive historians. Seven were designers – not all car designers. Five had Motor industry experience, two at senior level. Four had automotive qualifications. Eleven were car enthusiasts. The other two were nevertheless knowledgeable on car history. They took a more balanced perspective on history than an enthusiast, and still had a passion for cars, despite their non-enthusiast's position. Three had competed in rallies or racing. Three had taken part in historical events – classic car shows or the London to Brighton Run. Six were academics, including one visiting professor. Five had PhDs. Eight owned historic cars and five had restored cars. Table 7.01 shows a summary of these data. Each individual is represented by a letter and these are the column headings.

		A	S	N	B	L	R	D	J	P	T	E	C	M	
18	Competitors	0	2	0	1	0	1	0	6	5	2	7	1	1	Non-competitors
49	Historians	5	4	4	4	4	3	5	2	0	1	3	7	7	Uninterested in history
44	Motor Industry	2	7	3	7	5	3	5	7	0	2	0	0	3	No industry experience
52	Designers	7	7	7	5	7	5	7	2	0	0	0	1	4	No design experience
55	Engineers	4	5	5	7	4	6	7	2	0	5	4	1	5	No interest in engineering
53	Academia	4	6	7	6	7	3	7	4	7	0	0	0	2	No links with academia
58	PhDs	7	7	7	5	7	4	4	4	7	0	3	0	3	No qualifications
61	Older	2	3	6	6	2	4	5	6	6	4	4	7	6	Younger
75	English	0	1	7	7	7	7	6	5	7	7	7	7	7	Not European
48	Restorers	2	2	0	2	3	5	4	2	2	5	7	7	7	No experience of restoring
54	Owners	5	2	0	0	6	2	3	6	5	7	7	7	7	Non-owners
75	Enthusiasts	5	7	2	2	6	6	7	6	7	7	7	6	7	Not enthusiasts
		A	S	N	B	L	R	D	J	P	T	E	C	M	

Table 7.01 Repertory Grid of individual interviewees' background and experience

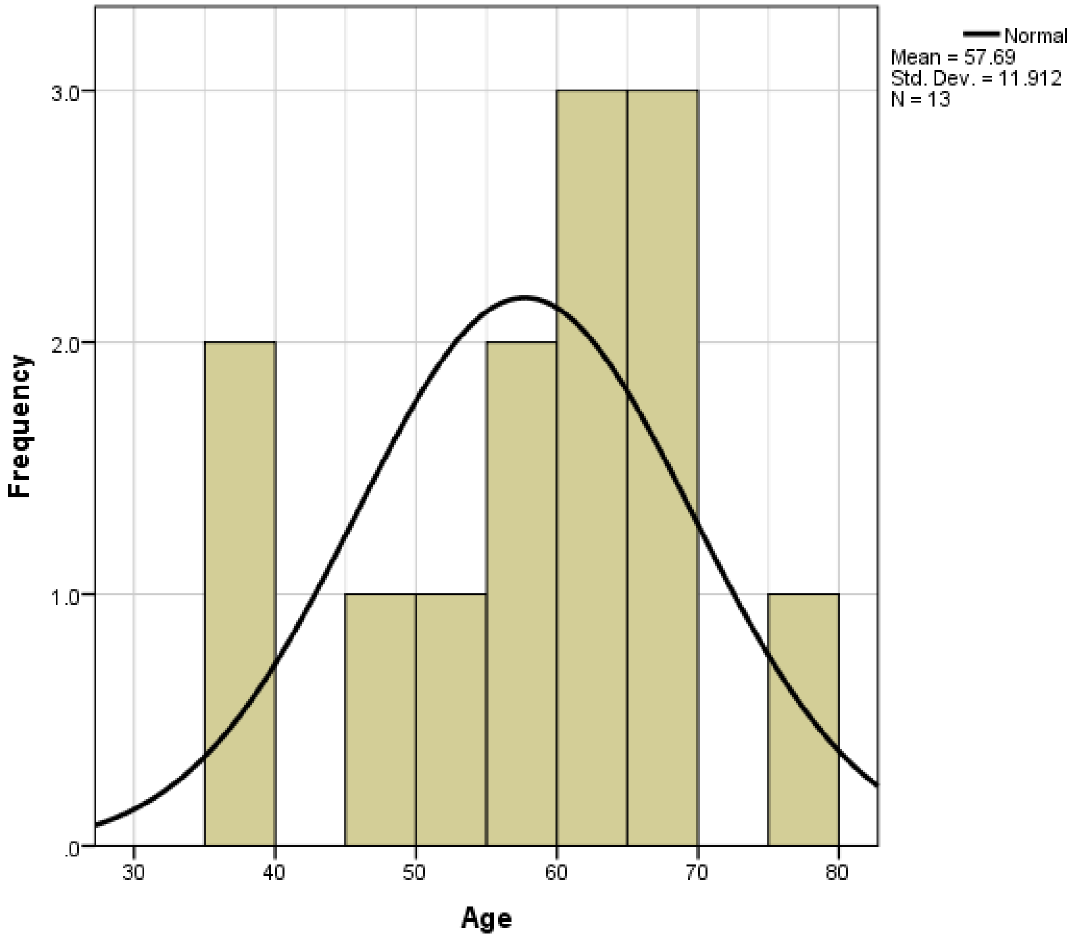


Figure 7.01 Histogram of ages

A repertory grid, Table 7.01, summarised the combinations and complexities of the individuals. Interviewees are identified by letters in order to maintain some degree of anonymity. The grid was clustered to group individuals and their backgrounds. This is shown in Figure 7.02. Five clusters were produced for individuals and their backgrounds. The primary division separated designers from non-designers. The non-designers' cluster divides between two racing enthusiasts and the others. These are all enthusiasts, none in academia and with no motor industry experience. Two (slightly) younger designers working outside Europe are separated from the others.

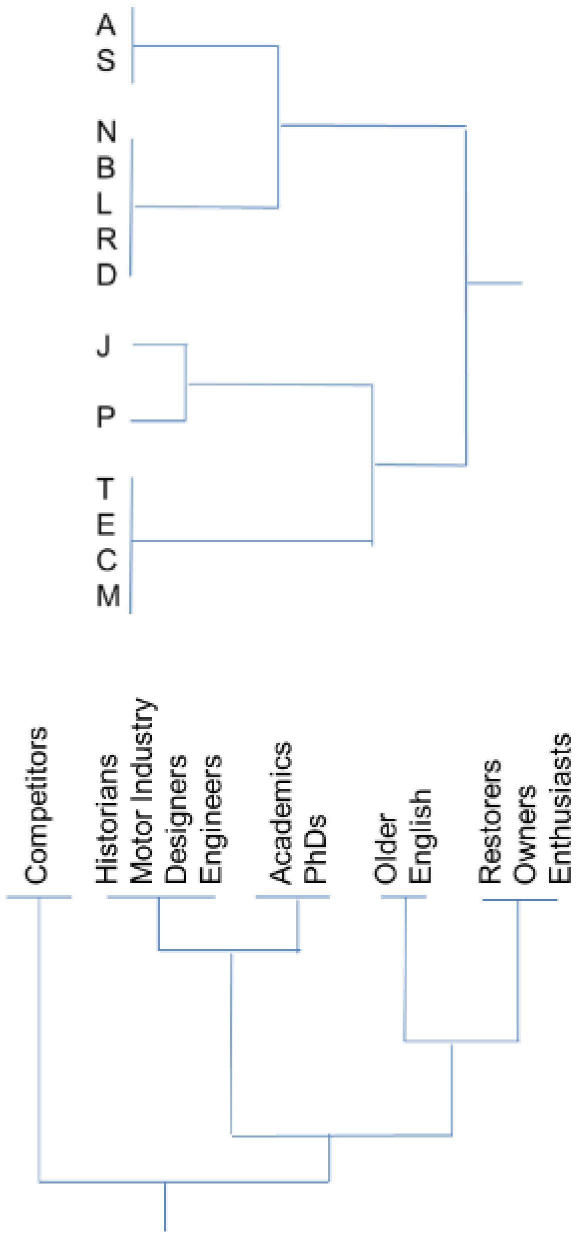


Figure 7.02 Clusters for individuals and their backgrounds

Descriptors cluster into competitors and the rest, and then the rest splits with things that are occupational in character on one side and other characteristics on the other. Two existential characteristics – age and nationality – split from car-related activities – owning, restoring and enthusing. Lastly, academics and PhDs show synergy and split from other occupational characteristics.

7.1.2 Interview Questions

The detailed information on the interview questions is found in Appendix 3. The interviews split into sections.

1 Overview questions to discover the interviewees interests in cars, how it grew and what form it took.

2 Perceptions and constructs of car history and how they perceive periods and themes.

3 How they might design cars and their design influences, and whether these might be paradigmatic in character. Were they largely car-related or were their influences from outside of the automotive world.

4 Affinity diagram. They were presented with car pictures from 1878 to 2014 and arranged these however they chose, clustering them and identifying the clusters – an affinity diagram using pictures, not themes.

5 Repertory grid. This was a modification of the repertory grid process. They each chose nine cars for their personal museum and their constructs were identified using triads and general discussion. This gave more than the twelve constructs that would result from simply triadic differentiation.

7.1.3 Interview analysis

The interviews were transcribed, and were between 1000 and 16000 words long. Much of the longer interviews was not directly answering questions. These were more fascinating – but fascination isn't measured. It develops data related to the individuals' constructs and understanding of car history generally but is otherwise not necessarily relevant to the thesis and tends to be of a personal nature. If it were outlined in much detail, then anonymity might be compromised. The longer interviews wandered off subject and included anecdotes and comments.

Car history includes makes and what manufacturers did. How many manufacturers did each mention? How much outside of car history did each mention?

There were two groups: one mentions a lot of manufacturers, over 30 each, and another a much smaller number. This latter divides into two: those mentioning fewer than ten manufacturers and those mentioning fourteen to twenty. The clear gap between these two and the other group seems to indicate broader understanding of motor industry and its history and less enthusiasm for particular manufacturers.

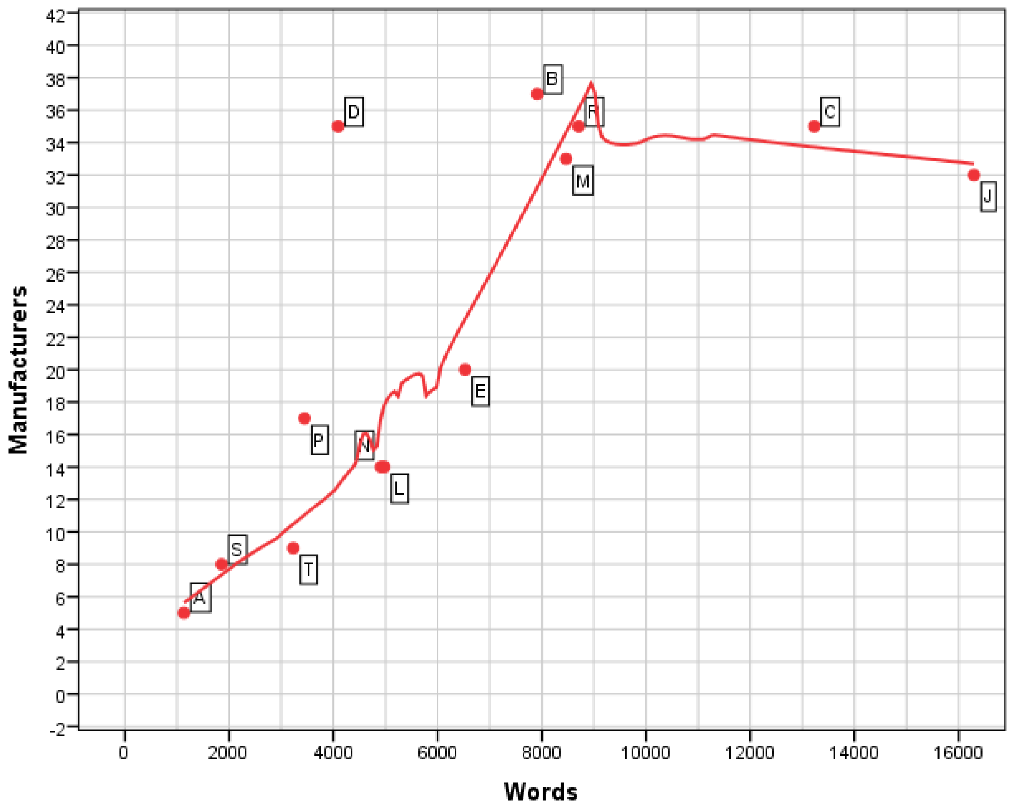


Figure 7.03 Number of words against manufacturers mentioned

7.1.4 Interests

At the start each interviewee was asked whether their interest related to periods, manufacturers, styles or design features. Some answered relatively quickly whilst others took longer, talking over ideas with examples and some digression. Figure 7.04 describes the interests, using a timeline. Several mentioned paradigm shifts, although the meaning wasn't always clear when they used this term. Designers tended to use the term, but they weren't the only ones. In some cases it signalled a major direction change, in others the incorporation of novel manufacturing systems and processes – certainly a change from established practice.

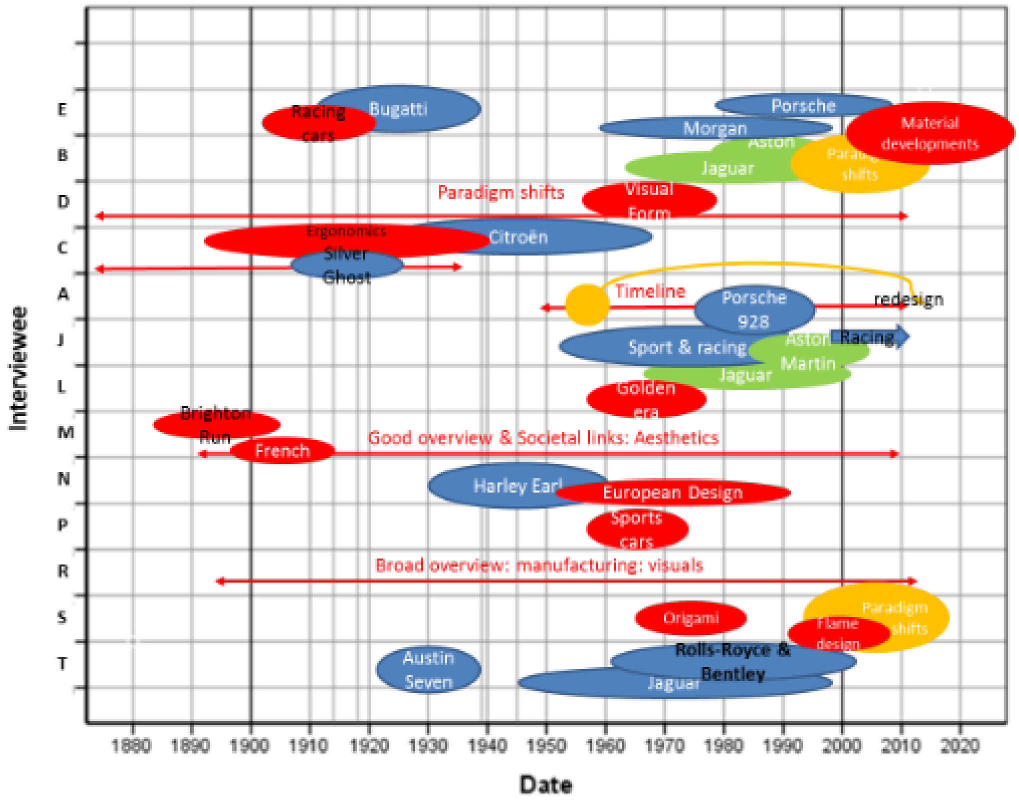


Figure 7.04 Timeline of interviewees' interests in cars. Interviewees are identified by letter on the left and their particular interests are marked on the timeline.

The youngest three were uninterested in pre-WWII cars, whilst the oldest limited himself to pre-1939, but contradicted this later. He had also owned one of the earliest cars – a 1900 Benz.

Table 7.02 shows features of car history in reducing importance.

1	Overview of all periods
2	World Wars make breaks
3	Pioneering age earlier and mentioned in detail
4	Interest in pre-Second World War
5	Growth of mass-produced product
6	Detail before WW1
7	Interested from an industry point of view rather than the product
8	Fabulous designs from the 1930s
9	Sustainability a big influence and a driver for history
10	Electronics developments from 1975 (or so)

At the bottom of the list in numbers 20 and 21 come:

20	Japanese development
21	Veteran, Edwardian, Vintage mentioned

Table 7.02 Features of car history rated by importance

Top interests were driving, visuals, beauty, originality and manufacturing – all general car-related interests, significantly. Next down are performance, a spread of history, technical interests, the 1950s, light cars, Jaguar and Great Races. Then more specialist interests start to become noticeable (1950s period, Jaguar, Great Races). These colour later answers and indicate their validity. Of these interests, items 7, 9 and 10 indicate links with non-automotive history, and although item 8 might have indicated a general interest in fabulous designs from general design history, this was not the case. They were car designs.

7.1.5 Car history periods

Next the questionnaire asked for identification of car history periods. In Figure 7.05 coloured lines indicate similarities. Some designers decided that the pioneer period lasted until WWII. Some had little to say here, including one who did not wish to answer it at all.

Specific makes as influences are not mentioned in this list, contrasting with other parts of the questionnaire analysis where they figure strongly.

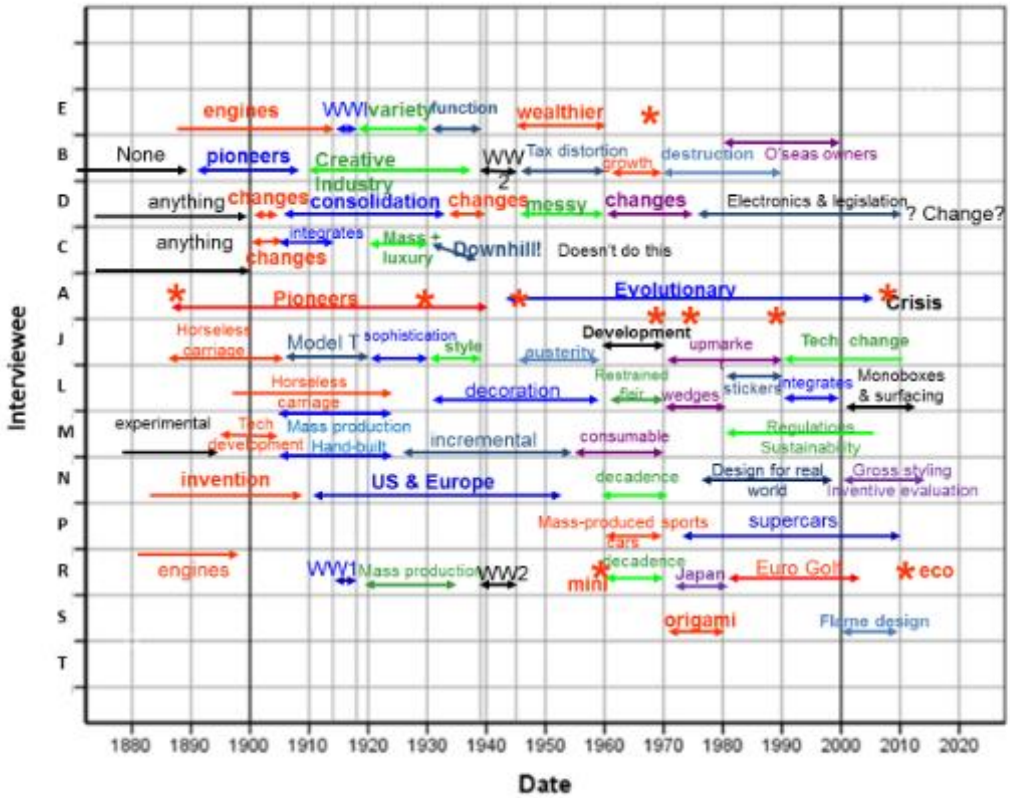


Figure 7.05 Car history periods. The interviewees are identified by their code letter on the left and their historical interests are identified across the timeline of the date. Significant one-off events they identify are labelled with asterisks.

A cluster analysis was carried out, clustering interviewees and the historical themes they identified. This showed that if two clusters of interviewees are envisaged, then the split is with five interviewees in one cluster and eight in the other. The people in cluster 1 ignore pre-WWII history: in cluster 2 the opposite applies. This second cluster splits equally into 2A and 2B. The people in cluster 2A talk happily about very old cars, in 2B they talk about car manufacturing processes and how and when they were incorporated. The 2A people talk about influences and periods and their enjoyment of car history and the 2Bs converse about legislation, the pioneers and also their enjoyment of beauty.

If the historical themes are clustered into five, Table 7.03 results.

Cluster	Constructs relating to the cluster
C1	Interest in pre-WWII: detail before WW1: luxury cars (20s and 30s) related to society: functional design (1920s and 30s): overview all periods: Pioneers earlier and detailed: growth of mass-production: industry viewpoint (not product): Wars make breaks.
C2	Early inventive period
C3	Aesthetics
C4	Fabulous designs (1930s): Veteran, Edwardian, Vintage mentioned: from aircraft industry links: UK industry — 1960s - 1980s: decline, overseas ownership: Japanese development
C5	Electronics from ~1975: luxury and sophistication from 1990s: exuberance of 1950s US: regulations, legislation (1980s): sustainability influence

Table 7.03 Clustered historical themes

Despite several ignoring the early period, the interviewees generally agreed that it is important to have a thorough overview of all of car history, and for the pioneering age (however determined) to be described in detail. Both World Wars create historical breaks. This is not just perception, as they cause industrial disruption and change the pace of industrial development. Following a war various processes help replace industry on its feet, but interfere and affect how industry develops. Sometimes technology (general and not automotive) develops hugely due to war, but the rebuilding of industries takes the resources of both winners and losers. The winners assist the losers to develop (as in Germany after WWII). This indicated that non-automotive history was important to most of the interviewees.

Category	Aspect of car history
A	Overview of all periods: Pioneering age earlier and detailed: World Wars make breaks
B	Growth of mass production: Early inventiveness: aesthetics: industry point of view vs product
C	Functional design (1920s and 30s): pre-Second World War interest: luxury cars (20s and 30s) related to society: detail before WW1

Table 7.04 Aspects of history in order of importance. This table was created from the numbers of times that each construct was discussed by the interviewees and the priorities that they identified.

Top priorities for historical interest are seen in Table 7.04:

The percentage of conversation relating to each decade was measured in terms of word numbers and can be seen in Figure 7.06. WWII (1939 - 1945) had little worldwide car production, so there was little to say specifically on car history. The favourite decade is the 1960s. Some are interested in the 1910s, some the 1920s and some the 1930s, which reflects particular interests. In contrast, the 1950s, 1970s and 1990s compare poorly with the 1960s and 1980s.

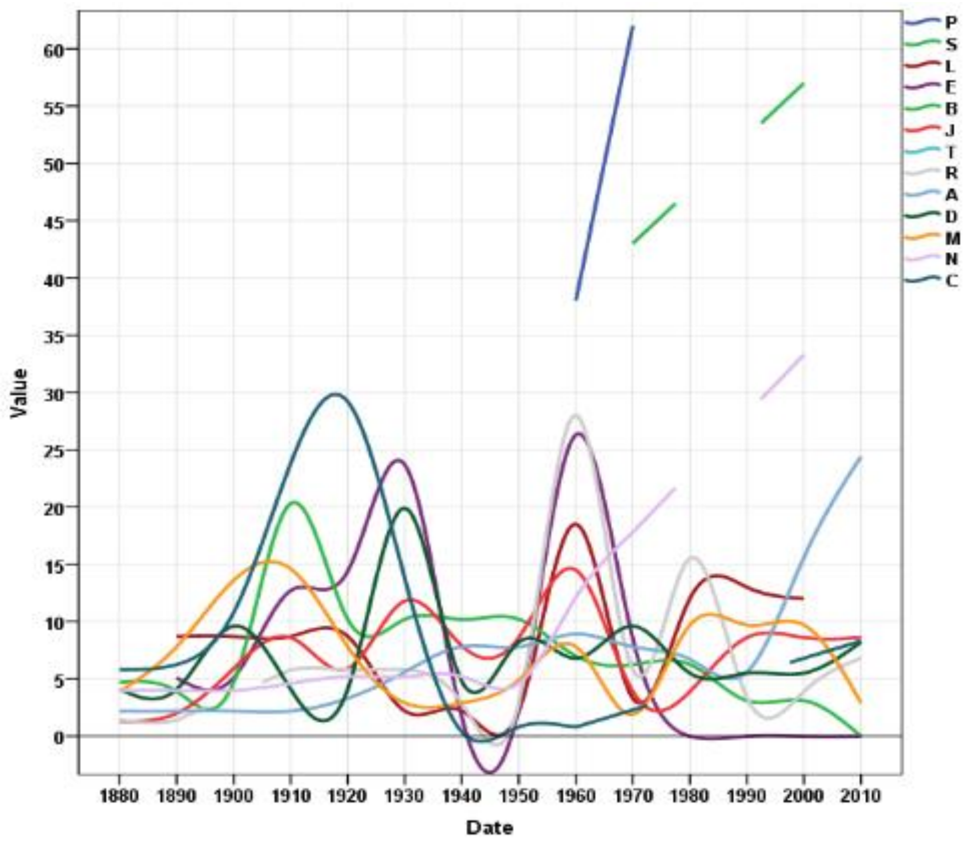


Figure 7.06 Emphasis on each decade from each individual

7.1.6 Car design thinking

The next question related to design thinking. What initiates a new car design and what should be incorporated? This was meant to cover practical design processes including current constraints and not blue-sky thinking. Points were gathered and rated. Interviewees identified their important constructs and what should be incorporated in a new, practical, car design.

All of the interviewees imagined that they were designing *something* and that this was a car. No interviewees started with a disembodied list of requirements and allowed the object to take an amorphous shape before the embodiment stage of design was reached. They were clearly designing a car. This is some sort of exemplar and thus a paradigm. They were always designing *cars* and not 'means of personal transport'.

The top construct on their list was to design non-boring cars – 85%. This description is their one and is formed from their constructs of what they consider to be boring. There a small gap before a list that shows little differentiation and which is thus difficult to categorise effectively. The top four grades are seen in Table 7.05.

Priority Rating	**Design requirement**
A	Non-boring
B	Stunning beauty, style, Performance, Trends and markets, Manufacturing processes, Visibility and light, Interested in designing, Branding, Thrill of driving, Novelty, imagination, inspiration
C	Evolutionary, Sustainability, Engines important, Regulations, Safety, Interior, Capacity, Hobby extension, Narrative, Lightness
D	Alternative fuels, Shared platforms, Luxury, Novel systems

Table 7.05 Perceived design importance

Bottom of the list comes ‘boring’ – the opposite of non-boring. This is, of course, their perception of what constitutes non-boring.

There is a significant difference between what designers like to design and what they might be required to design. Designers like to design interesting sports cars. In practice most car design replaces the current production offering. But car history suggests some cars perceived as being ‘interesting’ can be small, economical family cars. These were frequently mentioned in answer to the later part of the questionnaire where they identified nine cars for their personal museums.

7.1.7 Car design influences

The next design-based question probed what or who were their great design influences. It also probed whether these were people, design typographies or previous cars. For some this was a hypothetical question but for others it was a real one. Those interviewees who have not been car designers may have been car specifiers and have used their influences to support or encourage design preferences. These priorities are categorised and graded in Table 7.06.

Priority rating	Automotive Influences	General influences
A	Low-volume cars, Sports cars, Innovators	Honesty
B	Previous jobs, Driving experience,	Practicality, Aesthetics, Technology
C	Period cars, 1960s cars	Social change
D	Jaguar, Porsche, Unreliability, Coachbuilding, Stories and narratives	Getting correct sums, Design methods, Making money
E	Specific cars, Competition, Henry Ford	
F	Small cars, Bugatti, Historic racers, Harley Earl, Aston Martin, Pininfarina, Citroën	Ergonomics
G	Alfred Sloan	Getting a team, Meccano
H	Lancia, Trabant, Fiat	

Table 7.06 Car design influences in order of importance

Large volume producers are not influential. Most influences seem to be 'pin-up' cars – low-volume, sports cars and innovators. These are dreamlike or slightly wild characters, and not necessarily practical. Influence of low-volume cars suggests car designers look to the edges of current practice to find what they consider to be interesting directions for design work. However, the non-automotive influences are also significant although significantly less so than the automotive ones. Designers may be actively thinking about paradigm shifts in car design, if possible, and changing car history. Honesty is seen as being important: to tell the public exactly what you are designing without pretending. This implies high positive ethics from car designers, perhaps tempered with cynicism once the dream car becomes a concrete proposal. Within car design positive ethics does not necessarily embrace sustainability as a high priority: this may be considered as government interference and not appreciated.

Next come some strong influences from experience – previous employment and driving. The need for a strong emphasis on practicality, aesthetics and technology, which are all intangible, is very important. These, however, are conceptual influences that are not related specifically to car design and are not paradigmatic in character.

The next category of period cars, 1960s and social change indicates an appreciation of the historical design aspects of cars, and harks back to the 1960s era. Investigating non-design aspects of social change shows a broader outlook for designers than perhaps perceived and is certainly not paradigmatic in character.

Specific vehicles or designers are only mentioned next – Jaguar and Porsche. One designer suggested that deliberately including historical cues resulted in bastardised styles that fail honesty tests. He saw a significant design trend here and included one in his later repertory grid – Tumminelli calls it a ‘Remake’, not a ‘Retro’ (Tumminelli, 2004). At this point the influence of economics is seen, showing that car designs start by ignoring financial aspects and move towards them before finalisation. Considering unreliability here says that current cars’ unreliability influences desired changes.

In summary, most of these influences point to cars as exemplars – paradigms – but included in the influences are broader conceptual issues that are not specifically related to cars.

7.2 Affinity Diagrams

Affinity diagrams were invented by Jiro Kawakita in the 1960s to improve product and process quality. They are one of Cohen’s Seven Management and Planning Tools (Cohen, 1995) for understanding complex situations and relationships. They are found in the IDEO design methods (IDEO, 2003) and the Innowiz method collection (Bonneux et al., 2007, Michiels et al., 2011).

They consist of topics each written onto single sheets (perhaps Post-it-type sheets) and moved until the arrangement makes sense. Clusters of themes or ideas are identified and named.

7.2.1 The process

A modified process was used. Interviewees were given pictures of cars, and moved them into their 'sensible' arrangement, talking it through. These cars were not selected at random, but were deliberately chosen to be at approximate five-yearly intervals from 1887 onwards, and to be relatively close to the lines of 'average' form from the form analysis in Section 6.2. No guidance was given – they placed them where they wanted. The car pictures provided are shown in Table 7.06.

7.2.2 The pictures

		
1 Bollée La Mancelle 1878 (Kupélian, 1997. © Autoworld)	2 Daimler Phaeton 1886	3 Panhard 1892

		
4 Delahaye 1897	5 De Dion Bouton 1902	6 Argyll 14/16 1908

		
7 Renault AX 1912	8 Ford Model T 1916	9 Citroën Type A 1919

		
10 Morris Oxford 1926	11 Invicta 4½ litre 1930	12 Panhard Dynamique 1937
		
13 BMW 326 Cabriolet 1940	14 Tatra T87 1947	15 Austin A40 Devon 1952
		
16 Jaguar 3.4 litre Mark 1 1958	17 SEAT 1500L 1963	18 Vauxhall Viva HB 1966 (favcars.com)
		
19 Austin Maxi 1972 (Wikimedia Commons: Simon Tagish)	20 Saab 99 Turbo 1977 (favcars.com)	21 Morris Ital 1983 (Wikimedia Commons: Andrew Ward)

		
22 Oldsmobile Custom Cruiser 1985	23 Ford Orion 1992 (Wikimedia Commons: Rudolf Stricker)	24 Peugeot 306 1996 (Wikimedia Commons: Rudolf Stricker)
		
25 Volkswagen Golf R32 2002 (Autocar)	26 Ford Mondeo 2007 (Autocar)	27 Citroën DS3 2010 (Autocar)

Table 7.07 Car pictures used for the Affinity Diagram

7.2.3 Affinity diagram analysis

Figures 7.07 and 7.08 show two of the arrangements that were proposed by individuals. In these illustrations both of the affinity diagram arrangements have been clustered by eye. These clusters were then analysed to obtain an overall cluster diagram showing how the cars are arranged by all the interviewees.

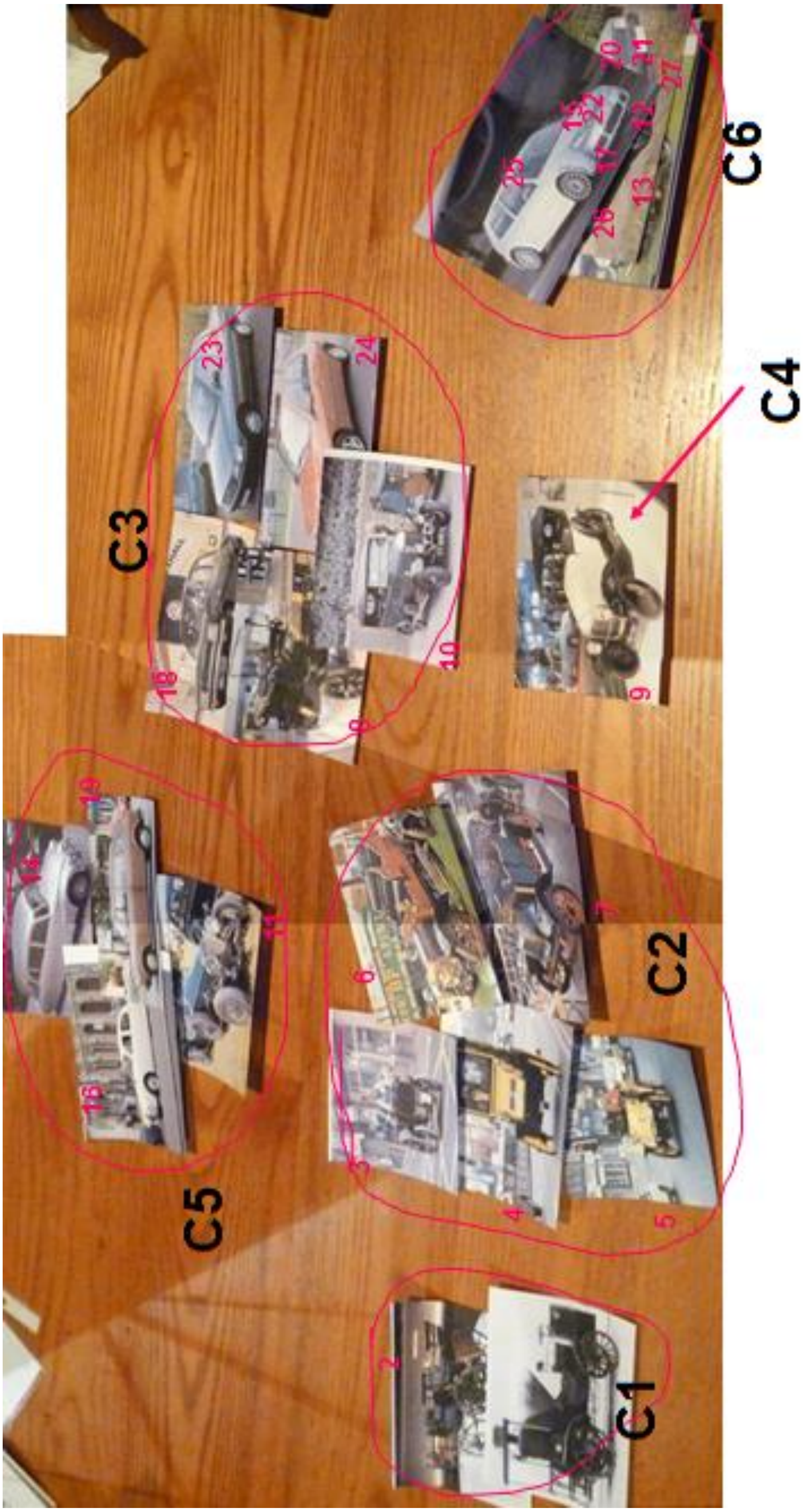


Figure 7.07 Clustered Affinity Diagram

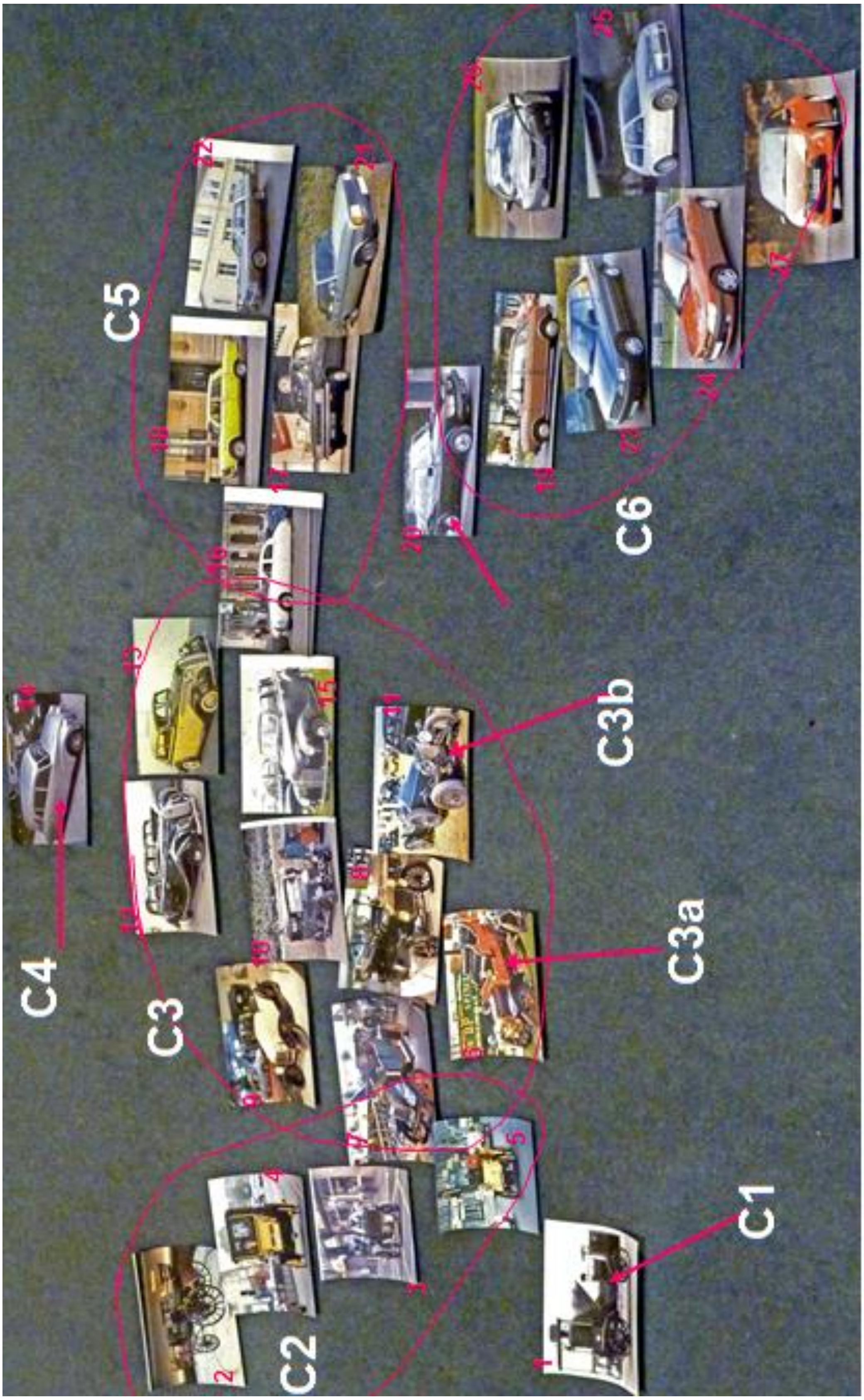


Figure 7.08 Clustered Affinity Diagram

This arrangement is shown in Figure 7.09 and the dendrogram that produced the clustering is shown in Figure 7.10.

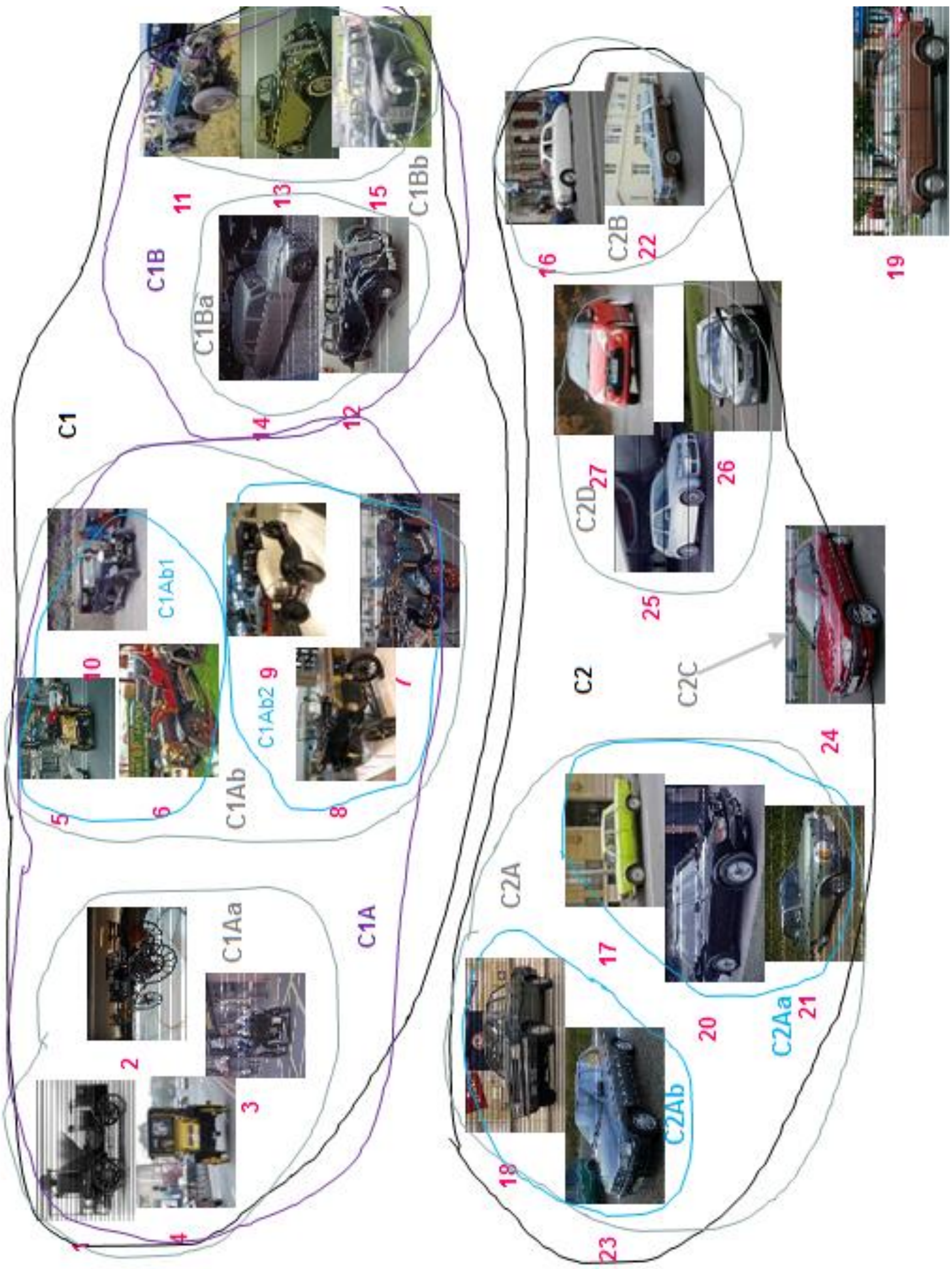


Figure 7.09 Overall Clustered Affinity Diagram

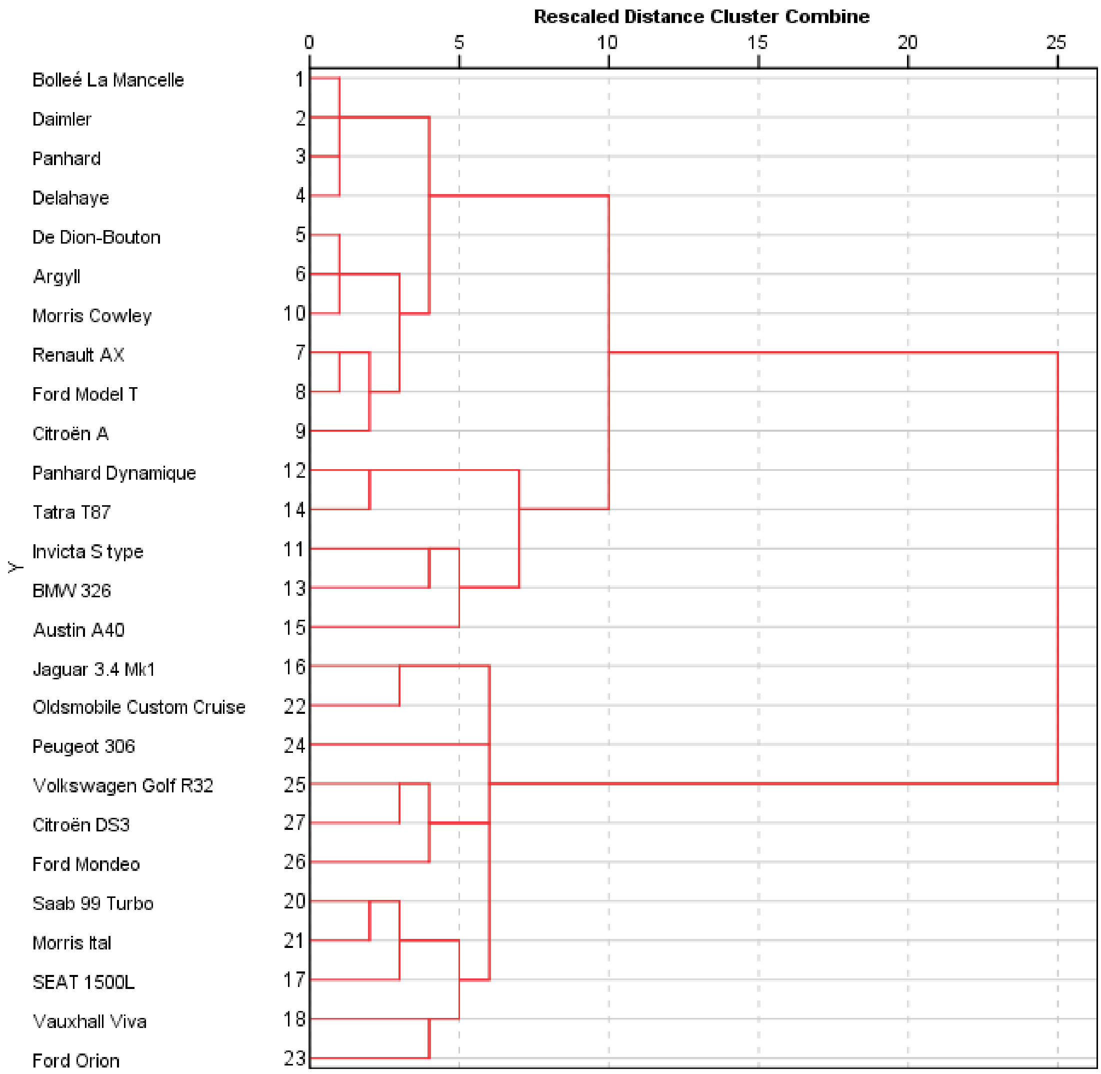


Figure 7.10 Cluster analysis

The major cluster split occurs in the 1950s, with the Austin A40 Devon (15) in the earlier cluster and Jaguar Mk 1 (16) in the later. The earlier cluster splits into pre-1930 with the Invicta (11) in the later (C1B). This splits with the Panhard (12) and Tatra (14) separated from the Invicta (11), BMW (13) and Austin (15). The Austin (15) is then separated from the others – possibly deemed less desirable. C1 splits into pre- the1904 de Dion Bouton (5) and after. C1Ab splits but not along date lines. The later main cluster (C2) splits four ways. One is date-based, with three late cars, the Volkswagen Golf R32 (25), Citroën DS3 (27) and 2007 Ford Mondeo (26). Criteria for the other splits are unclear. Whilst this clustering analysis is dependent upon the precise selection of the pictures and the cars, it gives a clear indication that the clustering that was produced was date-related. Using a significantly larger collection of cars would have provided a clearer indication of this, but would have proved cumbersome and difficult for the interviewees to manage.

The Austin Maxi (19) was not analysed as it was omitted by three interviewees.

The major split dates not from the mid-1930s, as perhaps predicted from the quantitative work, but later, in the mid-1950s. The quantitative work would have suggested that cluster C1B should be joined to C2 cluster.

The two major clusters do not split as predicted from quantitative analysis, although this might have predicted some of the first cluster's splits. Cluster C1A contains cars from before the mid-1930s changes identified in the quantitative analysis, and cluster C1B contains cars from the 1930s to mid-1950s which might be perceived as transitional. C1Aa contains cars from before the first paradigm was formed (c.f. quantitative analysis), whilst cluster C1Ab contains cars in the 'vintage' paradigm (Chapter 8). This difference in cluster behaviour may well be related to the specific cars selected. It may also be related to individuals' knowledge of cars or their interests – discussion showed that both specific knowledge and personal preferences affected how they carried arranged the pictures, although historical perceptions were the primary construct. The interviewees' factual errors were not corrected.

Thus the results of this affinity diagram process were somewhat inconclusive in nature; they indicate that further work on the perception of form might prove beneficial. Whilst this might be interpreted as pointing to the difficulty of quantitative form analysis, it might be related more to perceptions of form and brand image than to difficulties of form analysis. This would point to the desirability of further investigation of these areas.

7.3 Repertory Grids

The final interview task was developing a personal repertory grid. The process is inherently a constructivist one (Marsden and Littler, 1998). It seeks to identify the constructs of individuals, usually through a structured interview process and an analysis using a process of triads. The emphasis moves from understanding history towards heritage – perception of history through appreciative later eyes. Heritage describes how the past is appreciated and constructed, not the facts. It takes interviewees' constructs which identify their interests and unravels them – what they like and dislike. These are personal constructs and are construed in the individual's personal terms. In this case it deliberately includes significant cars and constructs their 'car appreciation space' and their thinking about historical cars. Heritage distils the historical things people affirm and appreciate – their likes and fond memories, and not facts.

Henry Ford is reported to have said "History is more or less bunk. It's tradition. We don't want tradition. We want to live in the present, and the only history that is worth a tinker's damn is the history that we make today" (Wheeler, 1916, page 10). Ford's attitude is relatively common and is that what is currently taking place is inherently better than what took place before. Templeton (Templeton, 1997) takes this view of progress as inevitable. The future is always better, and Templeton invested his fortune in it. In a more thoughtful and thorough study, Bury (Bury, 1955) investigated attitudes towards history, analysing and evaluating the concept of progress and what that meant. He concluded that progress happened only when the inevitable societal and technological changes that take place result in something that is perceived as an improvement. This contrasts with Henry Ford's myth of history and the inevitability of progress. This notion of inevitable progress might be termed Modernism. Positive value in history or historical objects might be termed heritage, post-modernism or cultural tourism. The ‘progress’ attitude is all-pervading. It is prevalent in design textbooks such as Dormer’s (Dormer, 1990) and Ferebee’s (Ferebee, 1970); Engineering texts (Bélanger, 1995, Faro and Giordana, 1999) and papers and conferences (Wessex Institute of Technology, 2009) and even car history (Georgano et al., 2001) and car design (Happian-Smith, 2002, Hutchinson, 2002).

Heritage values past items, styles and perceptions and may conveniently forget that improvement has taken place and that current cars don’t break down so frequently, are less crude, use less fuel and have better headlights. Past items are still valued and not ignored or destroyed. Past items are placed in collections and museums, giving them value.

7.3.1 The task

The repertory grid task is designed specifically to identify individuals’ personal constructs. However, the more common process of using the grid is to identify these in general terms and not in terms that are associated with a specific area – in this case that of car history.

In this case each interviewee was asked to select nine cars for their personal car history museum. These could be any car that they wished to include and no restrictions were placed upon them. They did not have to be production cars, and their choices could include racing cars or concept cars. None of the interviewees chose hypothetical cars, although no restriction was formally placed on them to ignore these. These nine cars formed their private car history collection. None has owned as many as nine cars, and this collection is wishful thinking and not reality. The process uncovers their ‘car’ *constructs* and car heritage thinking. It is thus a constructivist approach towards car history, with the individuals creating their own (limited) map of important events, paradigms and car exemplars that identify their particular car history values.

After initial selection, the cars are set up in a three by three grid, with arbitrary numbering. Each interviewee compared the cars in a structured manner, in triads to compare each with each, and the differences between each were elicited, and these differences formed their constructs.

Each triad compares three items. Twelve sets of three are compared to give twelve *constructs*. In practice, more constructs were identified from each interviewee through the process. Table 7.08 shows the three by three grid and Tables 7.09 to 7.12 show the process of triad comparison, lines A to L.

1	2	3
4	5	6
7	8	9

Table 7.08 Repertory Grid

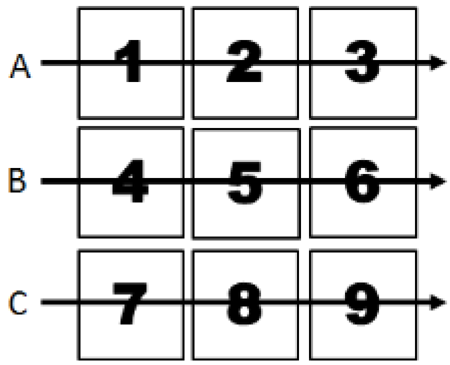


Table 7.09 Across: A, B, C

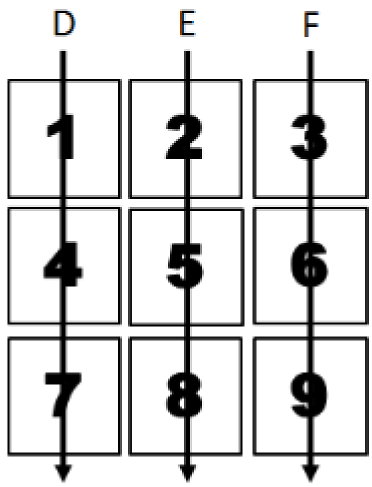


Table 7.10 Down: D, E, F

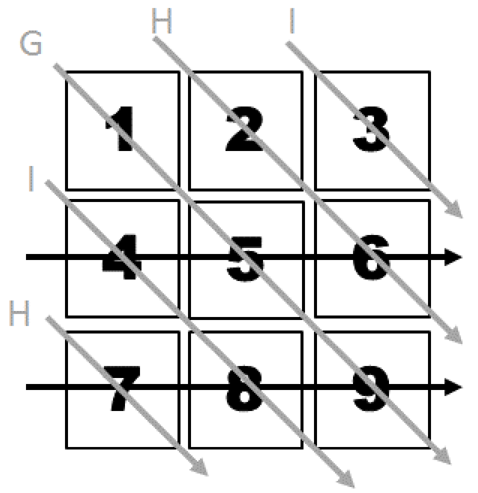


Table 7.11 Diagonal Top Left – Bottom Right: G, H, I

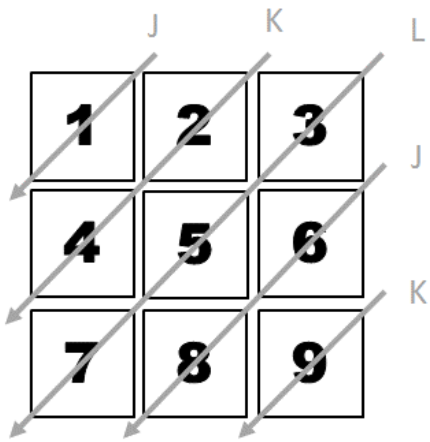


Table 7.12 Diagonal Top Right – Bottom Left: J, K, L

Each triad is compared to identify why the three differ for the individual; this becomes a *construct*. Other constructs were also recorded and this resulted in more than twelve constructs. Each car was marked for each elicited construct.

The most significant car from each triad was also identified, producing a hierarchical diagram, rating the constructs in importance. Clustering processes produced a grouped grid and a hierarchical list of significance where this was possible.

7.3.2 An individual example

One example indicates the process. Nine cars were chosen as shown in Table 7.13. Table 7.14 shows the list of triads that were identified from the interviewee. Table 7.15 shows the cars ranked in importance. Table 7.16 is the repertory grid containing the constructs.

1 Porsche 911(1960s) (favcars.com) 	2 Trabant 601s 	3 Porsche 356 
4 Mini Cooper (original) (Wikimedia Commons: Writegeist) 	5 Land Rover Series 1 	6 Bentley 1920s 
7 Porsche 911 (1990s) (Wikimedia Commons: Wistar Rinearson, Landmark Extra) 	8 Citroën DS19 	9 Citroën 2CV (Wikimedia Commons - Thomas Forsman) 

Table 7.13 The nine cars chosen for the museum

Differences

The triads are compared and differences noted (nomenclature from the individual):

Triad	Different	Construct
123	2	Ultimate vehicle you make when you have nothing. Everything is constrained – material, labour, technology
456	6	Grand engineering
789	8	More likely to break down
147	4	Not a Porsche. No clear lineage
258	8	A designed, luxurious thing: Not cobbled together: Inspired: Good design: Elegant
369	3	Sculpted – hewn out of something: Not bolted together: Not so much an engineered thing
159	1	More refined: Not bolted together like Meccano
267	2	Low engineering
348	4	It's much smaller
168	6	Visible engineering
249	4	Had a profound effect on cars
357	5	A functional object: Not a plaything

Table 7.14 The constructs from the triad analysis

Importance

The most important member of the triad is noted.

Triad	Most important	Comments
123	3	From a historical perspective
456	5	
789	9	
147	4	It beats the other two
258	5	
369	9	
159	5	
267	2	
348	4	
168	1	
249	4	
357	5	

Table 7.15 Importance table from the triads

A table was drawn up with the nine cars and the constructs. There are 24 constructs here.

Construct	1 Porsche 911 (1960s)	3 Porsche 356	7 Porsche 911 (1990s)	8 Citroën DS19	4 Mini	9 Citroën 2CV	5 Land Rover	6 Bentley 3-litre	2 Trabant	Anti-Construct
10 Luxurious	1	1	1	1	0	0	0	1	0	Austere
24 Plaything	1	1	1	1	0	0	0	1	0	Transport
15 Sculpted	1	1	1	1	0	0	0	0	0	Bitsa
18 Refined	1	1	1	1	0	0	0	0	0	Unrefined
9 Self-conscious design	1	1	1	1	0	0	0	0	0	Un-self-conscious design
14 Elegant	1	1	1	1	0	0	0	.5	0	Inelegant
7 Porsche	1	1	1	0	0	0	0	0	0	Not Porsche
8 Clear lineage	1	1	1	0	0	0	0	0	0	Unclear lineage
5 Grand engineering	.6	.6	.6	1	.5	.5	.6	1	0	Not grand engineering
13 Good design	1	1	1	1	.5	.5	.5	1	0	Not so designed
12 Inspired	1	1	1	1	1	1	1	1	0	Uninspired
1 Nothing vehicle	0	0	0	0	.5	1	.5	0	1	Something vehicle
2 Constrained material	0	0	0	0	.5	.8	.3	0	1	Unconstrained material
19 Low engineering	0	0	0	0	.5	.5	.5	0	1	High engineering
3 Constrained labour	0	0	0	0	.5	.5	0	0	1	Unconstrained labour
20 Small	0	0	0	0	1	1	0	0	1	Large
11 Cobbled together	0	0	0	0	0	1	1	0	1	Not cobbled together
6 Likely to break down	0	0	0	1	.4	.7	.5	0	1	Unlikely to break down
4 Constrained technology	0	0	0	0	0	0	.5	.5	1	Unconstrained technology
21 Visible engineering	0	0	0	0	.5	1	1	1	1	Invisible engineering
23 Functional	0	0	0	0	1	1	1	.5	1	Sophisticated
17 Engineered thing	0	0	0	0	1	1	1	1	0	Not so much engineering in evidence
22 Profound effect on car history	0	0	0	.5	1	.5	1	0	0	No effect on car history
16 Bolted together	0	0	1	1	0	0	0	0	1	Integrated

Table 7.16 The Repertory Grid

This is a focused grid – the cars and the constructs are positioned by similarity. SPSS was used to cluster the cars and the constructs as shown in Figures 7.11 and 7.12.

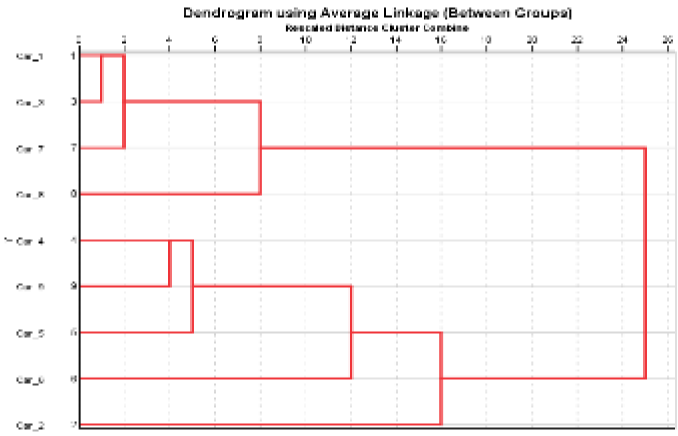


Figure 7.11 Clustering for cars

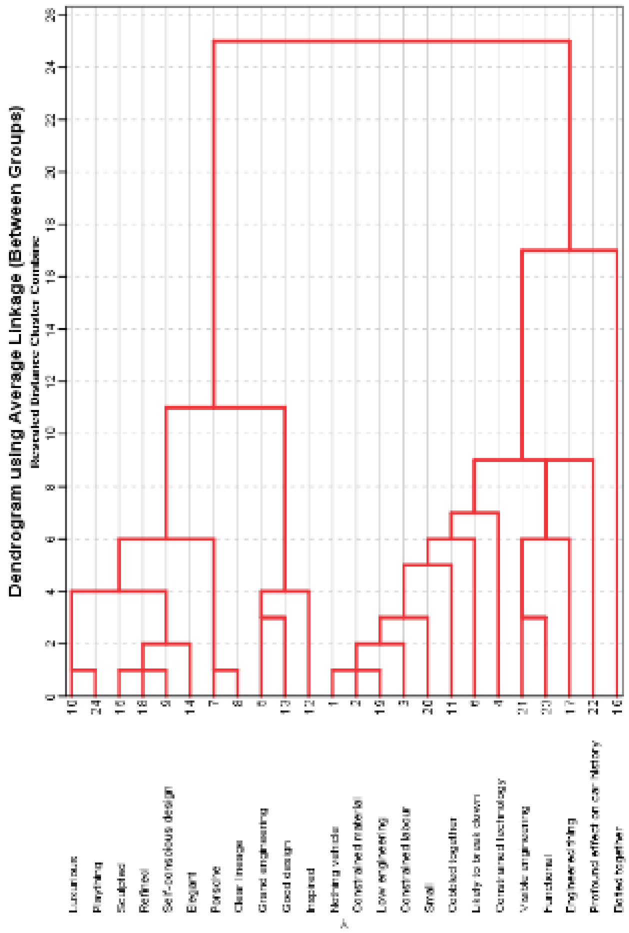


Figure 7.12 Clustering for constructs

Some cars and constructs correlate and the table can be reduced.

Construct	1, 3 Porsche 911 (1960s) Porsche 356	7 Porsche 911 (1990s)	8 Citroën DS19	4 Mini	9 Citroën 2CV	5 Land Rover	6 Bentley 3-litre	2 Trabant	Anti-Construct
10, 24 Luxurious, Plaything	1	1	1	0	0	0	1	0	Austere, Transport
15, 18, 9 Sculpted, Refined, Self-conscious design	1	1	1	0	0	0	0	0	Bitsa, unrefined, Un-self-conscious design
14 Elegant	1	1	1	0	0	0	.5	0	Inelegant
7, 8 Porsche, Clear lineage	1	1	0	0	0	0	0	0	Not Porsche, unclear lineage
5 Grand engineering	.6	.6	1	.5	.5	.6	1	0	Not grand engineering
13 Good design	1	1	1	.5	.5	.5	1	0	Not so designed
12 Inspired	1	1	1	1	1	1	1	0	Uninspired
1 Nothing vehicle	0	0	0	.5	1	.5	0	1	Something vehicle
2 Constrained material	0	0	0	.5	.8	.3	0	1	Unconstrained material
19 Low engineering	0	0	0	.5	.5	.5	0	1	High engineering
3 Constrained labour	0	0	0	.5	.5	0	0	1	Unconstrained labour
20 Small	0	0	0	1	1	0	0	1	Large
11 Cobbled together	0	0	0	0	1	1	0	1	Not cobbled together
6 Likely to break down	0	0	1	.4	.7	.5	0	1	Unlikely to break down
4 Constrained technology	0	0	0	0	0	.5	.5	1	Unconstrained technology
21 Visible engineering	0	0	0	.5	1	1	1	1	Invisible engineering
23 Functional	0	0	0	1	1	1	.5	1	Sophisticated
17 Engineered thing	0	0	0	1	1	1	1	0	Not so much engineering in evidence
22 Profound effect on car history	0	0	.5	1	.5	1	0	0	No effect on car history
16 Bolted together	0	1	1	0	0	0	0	1	Integrated

Table 7.17 Constructs

Importance

The cars are rated in terms of importance. Here the ratings are consistent, which is not always the case.

5 	Land Rover: Inspired, cobbled together, visible engineering, functional, profound effect on history
4  (Wikimedia Commons: Writegeist)	Mini Cooper: Inspired, small, functional, engineered thing, profound effect on history.
9  (Wikimedia Commons - Thomas Forsman)	Citroën 2CV: Inspired, nothing vehicle, small, cobbled together, visible engineering, functional, engineered thing
3 	Porsche 356: Luxurious, plaything, sculpted, refined, self-conscious design, elegant, Porsche, clear lineage, good design, inspired

1  (favcars.com)	2 
Porsche 911 (1960s): Luxurious, plaything, sculpted, refined, self-conscious design, elegant, Porsche, clear lineage, good design, inspired	Trabant: Nothing vehicle, constrained material, low engineering, constrained labour, small, likely to break down, constrained technology, bolted together

6 	7  (Wikimedia Commons: Wistar Rinearson, Landmark Extra)	8 
1920s Bentley: Luxurious, plaything, grand engineering, good design, inspired, visible engineering, engineered thing	Porsche 911 (1990s): Luxurious, plaything, sculpted, refined, self-conscious design, elegant, Porsche, clear lineage, good design, inspired, bolted together	Citroën DS19: Luxurious, plaything, sculpted, refined, self-conscious design, elegant, grand engineering, god design, inspired, likely to break down, bolted together

Table 7.18 Prioritised table of cars

The first table identified sophistication, luxury and refinement, but these seem less important than historical significance. However, the Porsche 356 is preferred to the Trabant. Luxury and competence overtakes basic transport for Eastern Germans. His constructed need for aesthetics moves towards luxury and away from basic transport.

7.3.3 Discussion of repertory grids

This is one example of the Repertory Grid process.

One purpose of the grid was to see whether the participants would consistently identify key historical cars. This depended on whether they were interested in their narrow heritage or in a comprehensive spread of historical understanding. In some cases there is a sports car museum; in others a historical overview, with significant cars. Enthusiasts wanted to see their speciality rather than a historical overview. Some were torn between constructs. The example above shows an emotional tussle between luxury (Porsches, Citroën DS19, Bentley) and practicality (Mini, Trabant, Citroën 2CV, Land Rover). Historical significance beat luxury and sophistication. What seemed to be particularly important was that the interviewees were able to select their own group of cars. This immediately caused them to think deeply about what they value in cars and in car history and as a result the approach seemed to achieve its goal of coming close to uncovering their tacit constructs concerning cars and car history.

Some cars were repeatedly selected: the original Mini (six times), Land Rover, Ford Model T, Vintage Bentley (four times), Ferrari Dino (three times), Chevrolet Corvette, Austin Seven, Range Rover, Citroën DS19, Bugatti Type 57, Ford GT40, Jaguar E Type, Porsche 911, Volkswagen Beetle, Citroën 2CV (twice).

Figure 7.13 shows car dates. Interviewees tended to select cars from between 1950 and 1990, with lesser peaks in the 1920s and 1980s. For many, these were the cars of their youth, although there is a smaller peak in the 1920s, before any of them were born.

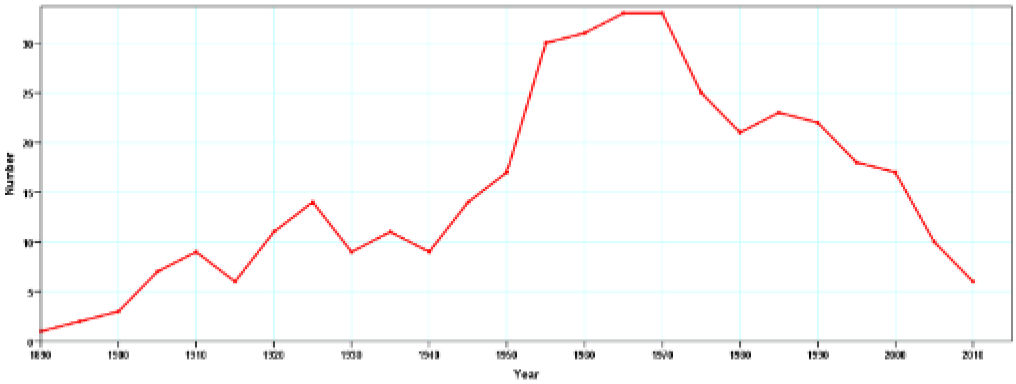


Figure 7.13 Dates of cars selected

Christian Jarrett (Jarrett, 2013), quotes a study by Schindler and Holbrook (Schindler and Holbrook, 2003):

> “Dozens of participants aged 16 to 92 rated their preference for the appearance of 80 cars, ranging from the 1915 Dodge Model 30-35 to the 1994 Chrysler Concorde. Among men, but not women, there was a clear preference for cars that dated from the participants’ youth (peaking around age 26). This was particularly the case for men who were more nostalgic and who believed that things were better in the old days. What other examples might there be? ‘Children of both sexes tend to have strong feelings about foods they like as they grow up,’ says Schindler. ‘Although we haven’t studied food, I would expect both men and women to have a lifetime fondness for foods they enjoyed during their youth.’” (page 564)

Car choices may correlate with interviewee ages. This accounts for younger interviewees uninterested in earlier car history. None of the interviewees were the 130+ years old required for cars from the 1890s, and the oldest was only seven when the Second World War started, which is somewhat younger than the 26 when interest is supposed to peak (Schindler and Holbrook, 2003).

People chose cars that were influential for them. There may have been a personal connection, like a family member who owned one, or they were seen racing, or they may have owned one, or coveted an acquaintance's. This personal connection does not beat significant history. Some cars such as the1903 Mercedes, the Lancia Lambda, the Mini and the Ford Model T identified future trends.

Figure 7.14 Mercedes 60 HP, 1903 (The Automobile)

Figure 7.15 Lancia Lambda

Figure 7.16 BMC Mini, 1959

Figure 7.17 Ford Model T, 1915

Some interviewees cited beauty as the reason for choices – Ferrari 250 SWB (“The most beautiful car in the world”), Maserati A6G 2000 Zagato and a specific 1925 Bentley.

Figure 7.18 Ferrari 250GT SWB – one person's 'most beautiful car in the world'.

Figure 7.19 Maserati A6G 2000 Zagato (Picture Supplied by interviewee)

Figure 7.20 Bentley 3-litre with Surbico body, 1925 (favcars.com)

Some selected concept cars such as the Maserati Boomerang and BMW Gina shown in Figures 7.21 and 7.22, which they said tended to influence their own designs rather than production ones.

Figure 7.21 Maserati Boomerang (favcars.com)

Figure 7.22 BMW Gina (Wikimedia Commons: ravas51)

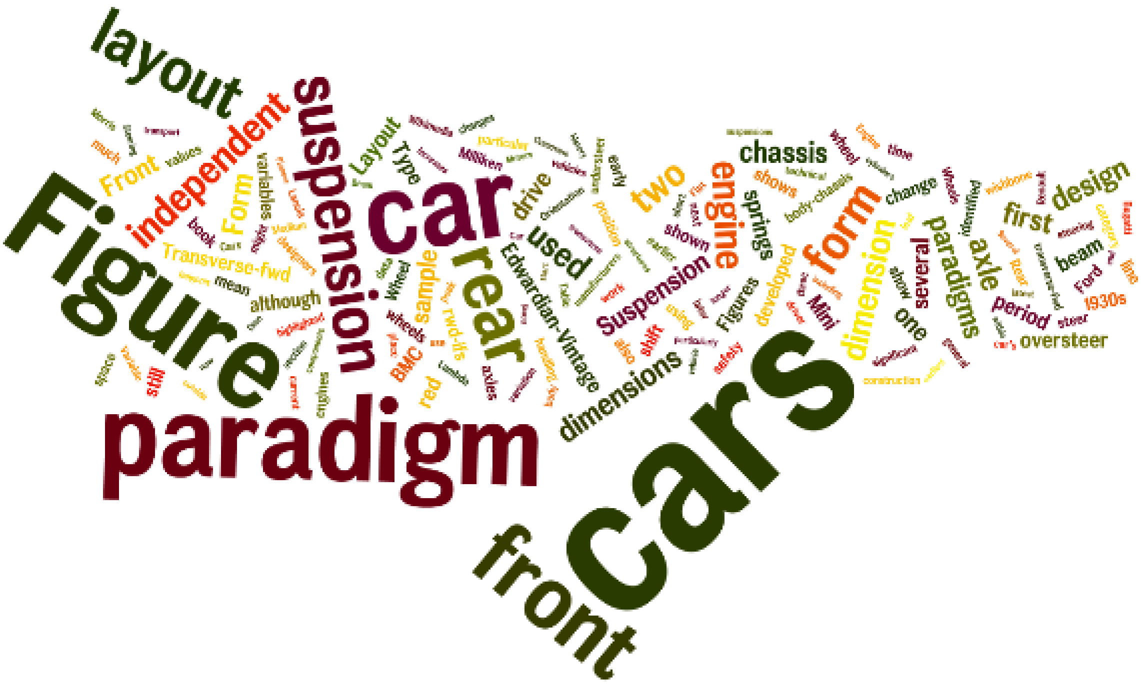
Figure 7.23 Bugatti Atlantic

The Bugatti Atlantic in Figure 7.23 might also be construed to belong to this category, although the bodywork was fitted to a few of the production Bugatti Type 57S and 57SC chassis (Adatto, 2003). These may show extremes like catwalk fashions – indicating possibilities but impractical for everyday wear.

7.3.4 Relationship to paradigms in car history

The purpose of the repertory grid work was to uncover the interviewees' subconscious car design and history constructs. It succeeded in this purpose. These constructs identified subtle perceptions of paradigmatic thinking. They uncovered tensions between transport, luxury, beauty and performance. Paradigms are exemplars utilised as models for thinking. The car museum identified significant historical cars. These cars were generally chosen because they inspired as exemplars, and hence as paradigms. In some cases it was obvious that cars were deliberately chosen to represent examples of particular eras and the design thinking that was apparent during those eras.

8 Paradigm descriptions in car history



8 Paradigm descriptions in car history

This chapter identifies car design paradigms, places them into a framework that identifies innovation and creativity in car history and identifies how and why innovations developed into effective design paradigms.

It needs to be clarified that these paradigms have been developed through this research and the descriptions and title do not necessarily correspond with paradigms that others have identified. Nor do they correspond to any descriptive titles that were used by the interviewees. In particular, the names that have been given to the paradigms do not necessarily mean the same as the meanings in general descriptive car history, although the terms themselves are used in other contexts and with slightly different meanings. The names here are simply for convenience – any terminology could have equally been used.

Four major paradigms have been identified from the analysis. These have been identified from the quantitative layout analysis. These are named as a) the Pioneer paradigm, b) the Edwardian-Vintage paradigm, c) the Transverse-front-wheel-drive paradigm (Transverse-fwd) and d) the Rear-wheel-drive-independent front suspension paradigm (rwd-ifs). These shorthand names have been invented here and are not necessarily in general usage. Others may use different terminology.

8.1 The *Pioneer* paradigm

This is not easily identified from the data. The interviewees used several names to describe this early period, such as *anything*, *inventive* and *experimental* indicating it was when people made things work. *Pioneer* was used several times, as was *horseless carriage*. The paradigm might be termed *Pioneer Paradigm* or *Horseless Carriage Paradigm*.

This paradigm developed from the transport situation at the end of the nineteenth century and from which the car arrived, seemingly at several points simultaneously. The paradigms consist of the thinking that allowed a self-propelled ‘something’ to be developed for transport and pleasure.

The paradigm cannot easily be identified from the data collected because those data were limited to ‘cars’ – i.e. self-propelled devices for private transport. The collected data is extremely varied in this paradigm. Car layout, in particular, has no particular embodiment, but the data are characterised by the large variation over broad selection of figures.

However, there is justification for identifying that a change took place which might be termed a paradigm shift from the status quo of horse-drawn vehicle to the new transport possibility. This was not well-formed in terms of layout or form variables, but nevertheless embodied a novel powered-vehicle thinking. This was not horse-drawn, but Horseless Carriage transport.

The pioneer paradigm dates from the start of car production until about 1904, although there are still some cars that exhibit a perhaps deliberate choice to remain with this ‘use of any method that works’ philosophy up until about 1914.

One interviewee said the time for a clean sheet of paper was “… *gone. You could ask that question with a clean sheet of paper in about 1890, but you can’t do it now…*” Then (1890) was when one could start with a clean sheet of paper. Nothing had gone before so whatever was designed was novel and had little relationship to beforehand. The cars in this *pioneer* period have huge variability of layout and form – and also small production, making sampling tricky. The numerical mean does not describe ‘the car of the *pioneer* period’. The extremes and the large variability do.

60% of the single-cylinder cars in the sample are from this period before 1905, and 46% of the two-cylinder cars in the sample are from this early period. Cylinders can be in-line, horizontally-opposed or Vee – cylinder arrangement for a single is irrelevant.

There is not so much variation with suspensions. These generally use forms of leaf springs with rigid axles front and rear. Earlier cars might have full-elliptic springing – 84% of cars with these are *pioneers* – but this developed into semi-elliptic by the early 20th Century. Cars in this period have varied structures. By the end of the period (about 1904) channel section chassis had been developed, but earlier cars had wooden or tubular chassis. Body construction, such as there was, almost always used coachbuilding techniques.

Although there was significant variation in this period, there are still similarities and 'ways of designing' of a paradigmatic character with the layout aspects of the car.

Pioneer car form is broad in character with significant variation, but tends towards short, tall cars (because the wooden or tubular chassis did not allow for longer constructions to be rigid enough) with multiple, separate assemblies: engine covers, front seats, rear seats, the seats following carriage practice. Most cars had no weather protection – there might be an occasional hood or an occasional saloon body. Wheels are exposed or have rudimentary mudguarding, always outside the body width.

So, despite huge variation, a design pattern still emerges which is a ‘way of designing’ and can be described as a paradigm.

Figure 8.01 De Dion vis à vis (1900) and De Dion (1902)

Figure 8.01 shows two examples of cars from this period. These are not ‘typical’ *pioneer* cars – as such a car is not able to exist – but they do display the form characteristics of separately packaged parts, little weather protection, being short and tall, and having mudguards, lights and screens as add-on accessories rather than being integrated into the car’s overall form. The earlier de Dion, on the left of the figure, has a rear engine and the driver sits at the rear, facing the front seat passengers what are facing backwards. Steering control is by what is known as a coffee grinder – a small crank handle arranged with a vertical shaft. The form of the car has no discernible bonnet, and there is no roof at all. The de Dion on the right, however, is showing far more characteristics of the next paradigm. Whilst still being short and tall, the engine is now at the front, although it still has a single cylinder, and the driver sits in the more normal position at the front of the car, steering with a wheel. The roof is still much of an afterthought and the bonnet, although present, is very short.

Innovation during that period is demonstrated by any car that used the next paradigm which others copied. That honour goes to two cars in the sample: a 1901 Renault and a 1903 Mercedes, seen in Figure 8.02. These demonstrate the next paradigm, and where car development was moving.

Figure 8.02 1901 Renault and 1903 Mercedes (Right - The Automobile)

8.2 *Edwardian-Vintage* paradigm

Figure 8.03 Peerless, 1904 (© Serious Wheels) and Bugatti Type 101, 1951

The histograms for layout, Figures 6.09 and 6.11, show three peak values for object scores in the first two layout dimensions. These indicate three particular ways of designing cars, and these three peak values are all date-related. None has been current for the whole of car history. The first peak value scores for layout are between (-0.6, -1.2) to (-0.4, -1.0). There are 57 cars in this group – almost exactly 10%. The two cars in Figure 8.02 fall just outside these scores. The earliest car inside the narrow scores is a 1904 Peerless and (apart from two cars that are deliberate replicas) the latest is a 1951 Bugatti Type 101. They are shown in Figure 8.03. Table 8.01 outlines the values of the layout variables that identify this paradigm. The numbers in brackets show how many cars within the 57 that are within this narrow band have the category stated, where there are several variations available.

Variable	Category
Engine position	Front
Crankshaft Orientation	Longitudinal
Driven Wheels	Rear
Cylinders	4 (56) 6 (1)
Cylinder Arrangement	In line
Front Suspension Form	Beam axle
Rear Suspension Form	Beam axle
Front Suspension Medium	Semi-elliptic (47) Quarter-elliptic (10)
Rear Suspension Medium	Semi-elliptic (42) Reversed quarter-elliptic (5) Quarter-elliptic (8) Cantilever (1) Unknown leaf spring (1)
Structure Type	Channel chassis (56) Unknown (1)
Body Construction	Coachbuilt

Variable	Category
Engine Type	Reciprocating (Petrol)
No of Wheels	4 wheels
Wheel Orientation	2F2R
Wheel Sizes	Same
Steering Control	Wheel
Final Drive	Shaft
Driver Position	Front, Side
Tyre Type	Pneumatic

Table 8.01 Layout parameters for *Edwardian-Vintage* paradigm cars

The paradigm was current during Edwardian years (1905 – 1918 in UK car terms) and the Vintage period (1919 – 1930) and not much after about 1934. Many layout parameters are common to all these. Each default layout parameter is the same. All these cars have the same values for the many other parameters, the exceptions being number of cylinders (one car with six cylinders all the rest (56) four), front suspension medium (ten cars quarter-elliptics, the rest (46) semi-elliptics), rear suspension medium (one car is unknown, one cantilever springs, eight quarter-elliptics, five reversed quarter-elliptics and the rest (42) semi-elliptics) and structure type: all with channel section chassis except one.

A wider category including cars with layout dimensions ± 0.2 (not ± 0.1), the number of cars increases to 127 (22.2%). The earliest in this broader category is the 1901 Renault in Figure 8.02 and the latest are Bugatti Royale reconstructions, from 1989 and 1995. If we ignore these, the latest is a 1951 Bugatti. Two cars differ in layout variables: a 1911 Austin Town car with a central driver, and a 1922 Bignan with unknown data.

Figures 8.04 – 8.06 show the layout dimensions of these cars from the quantitative analysis.

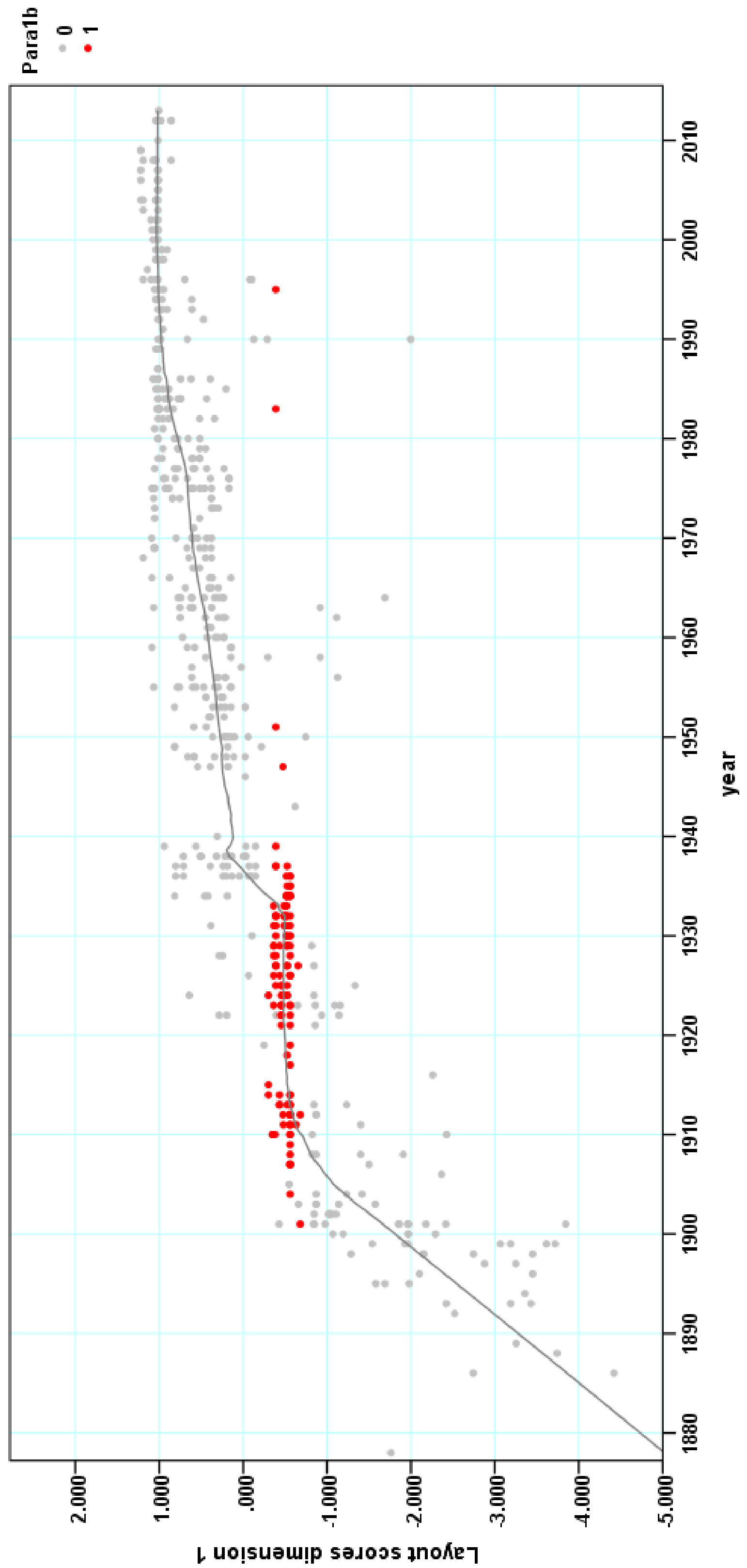


Figure 8.04 Layout dimension 1: *Edwardian-Vintage* cars are highlighted in red.

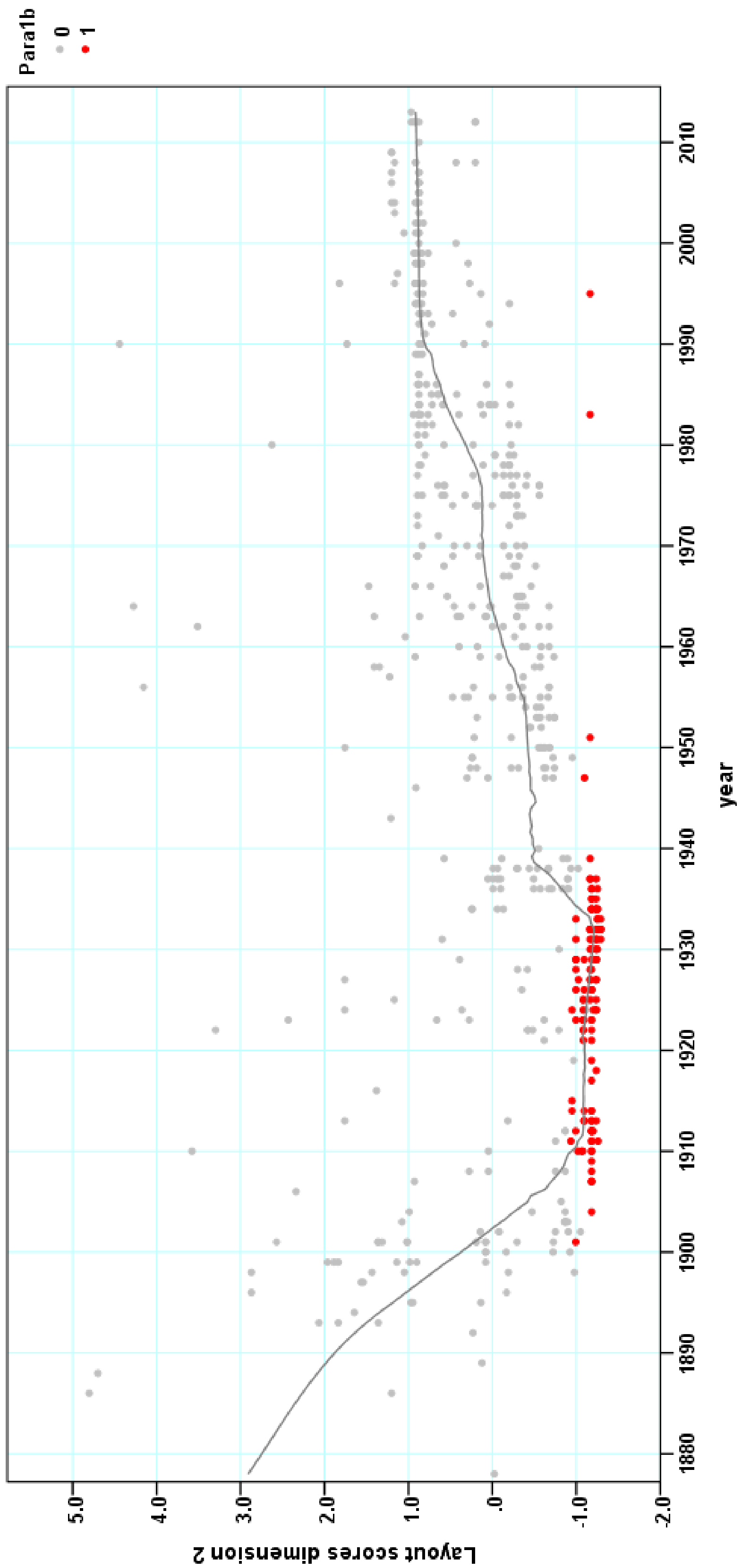


Figure 8.05 Layout dimension 2: *Edwardian-Vintage* cars are highlighted in red.

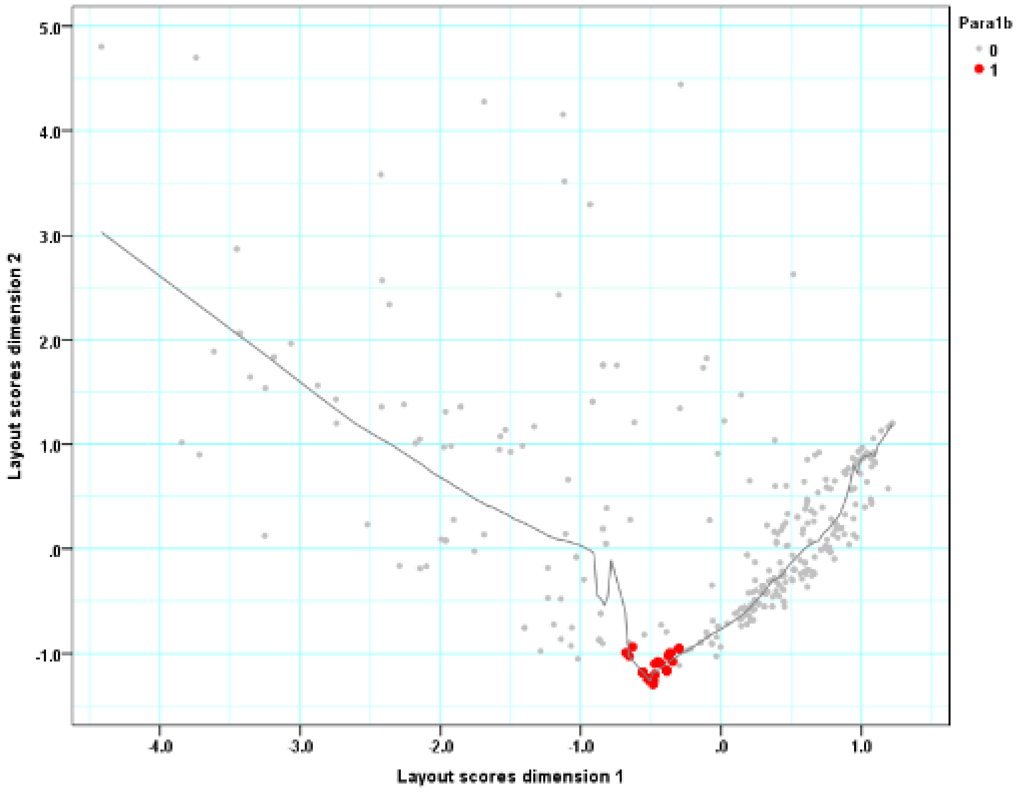


Figure 8.06 Layout dimensions 1 & 2: *Edwardian-Vintage* cars are highlighted in red.

Figures 8.07 to 8.09 show their form dimensions. These change gradually over time, and do not show the stasis and sudden shifts of the layout dimensions. In Figure 8.09 most are in the upper left quadrant.

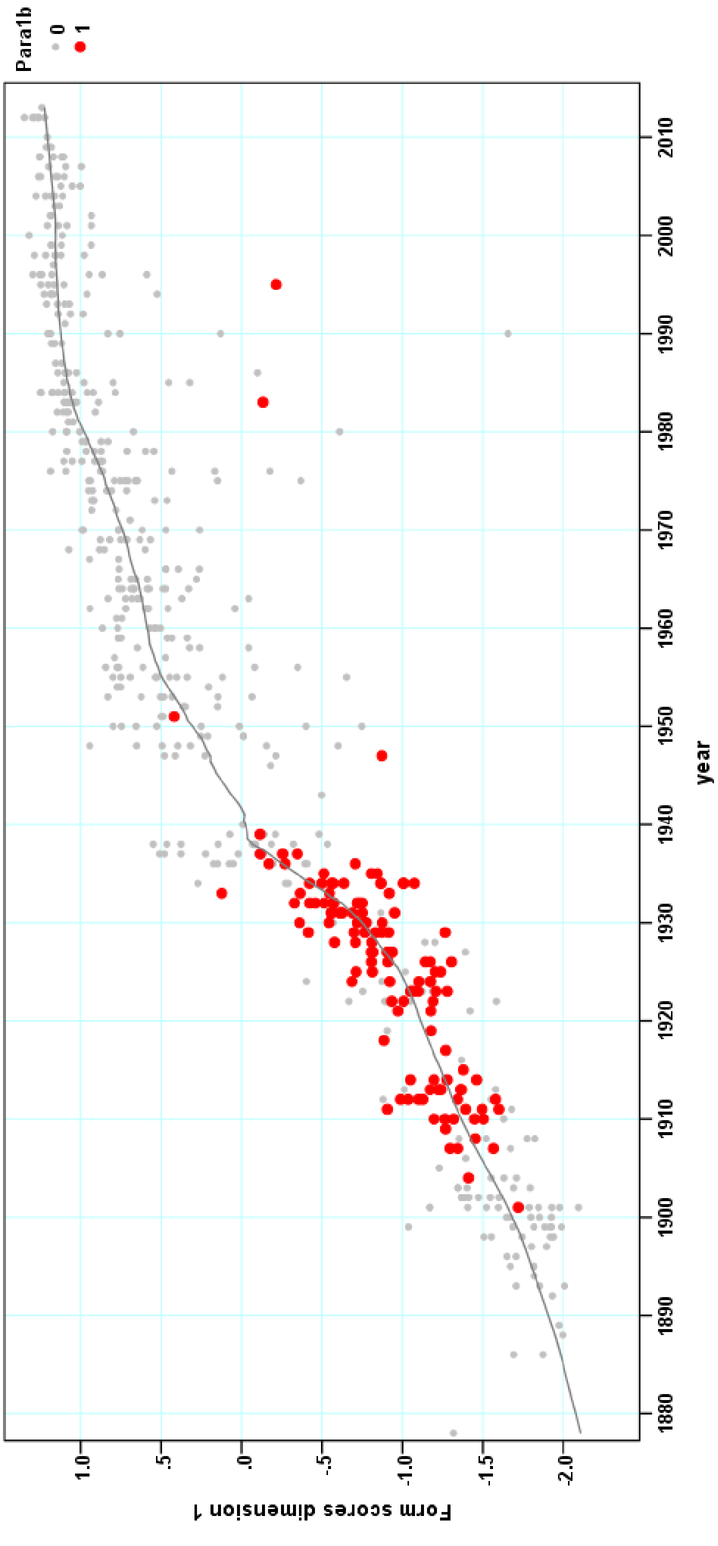


Figure 8.07 Form dimension 1: *Edwardian-Vintage* cars are highlighted in red.

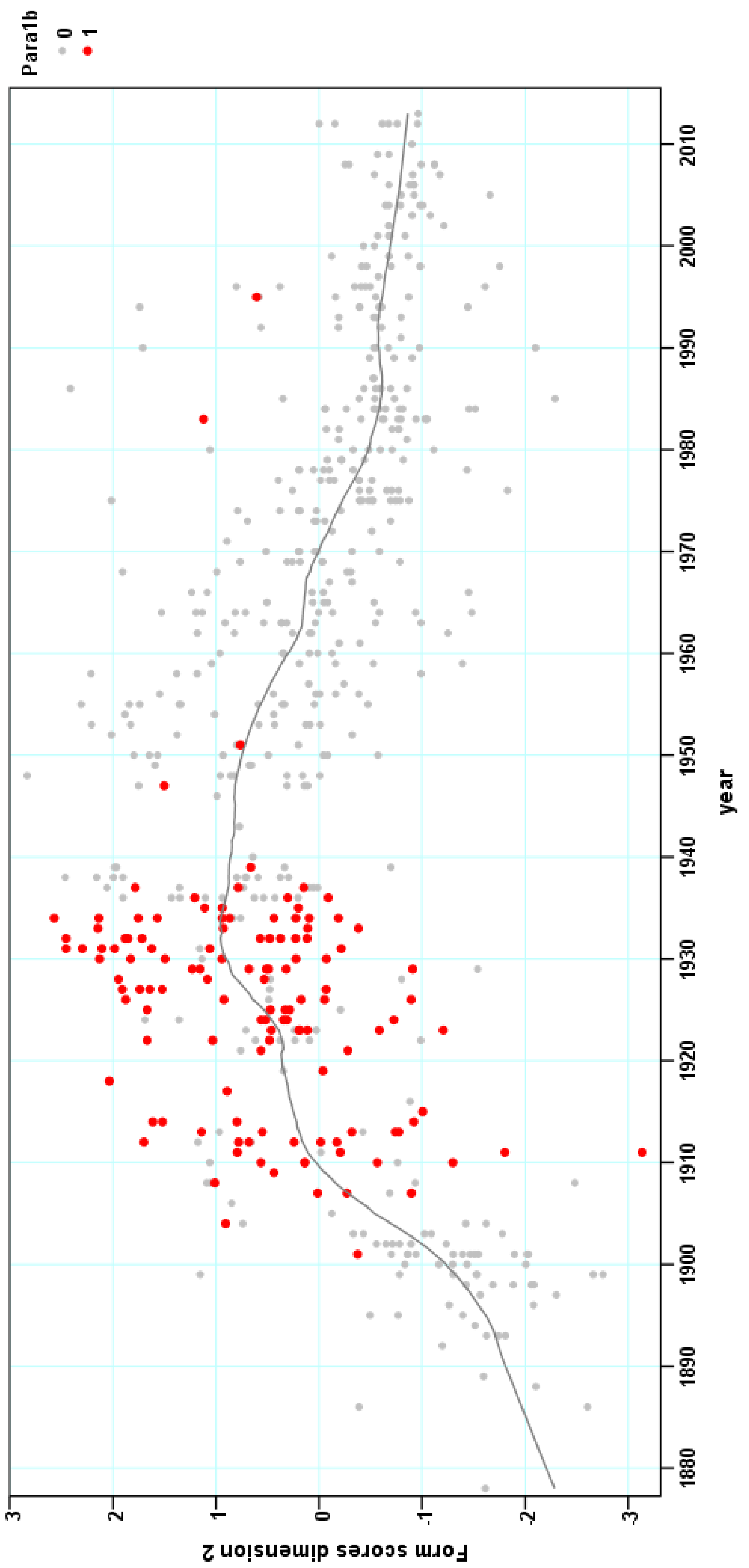


Figure 8.08 Form dimension 2: *Edwardian-Vintage* cars are highlighted in red.

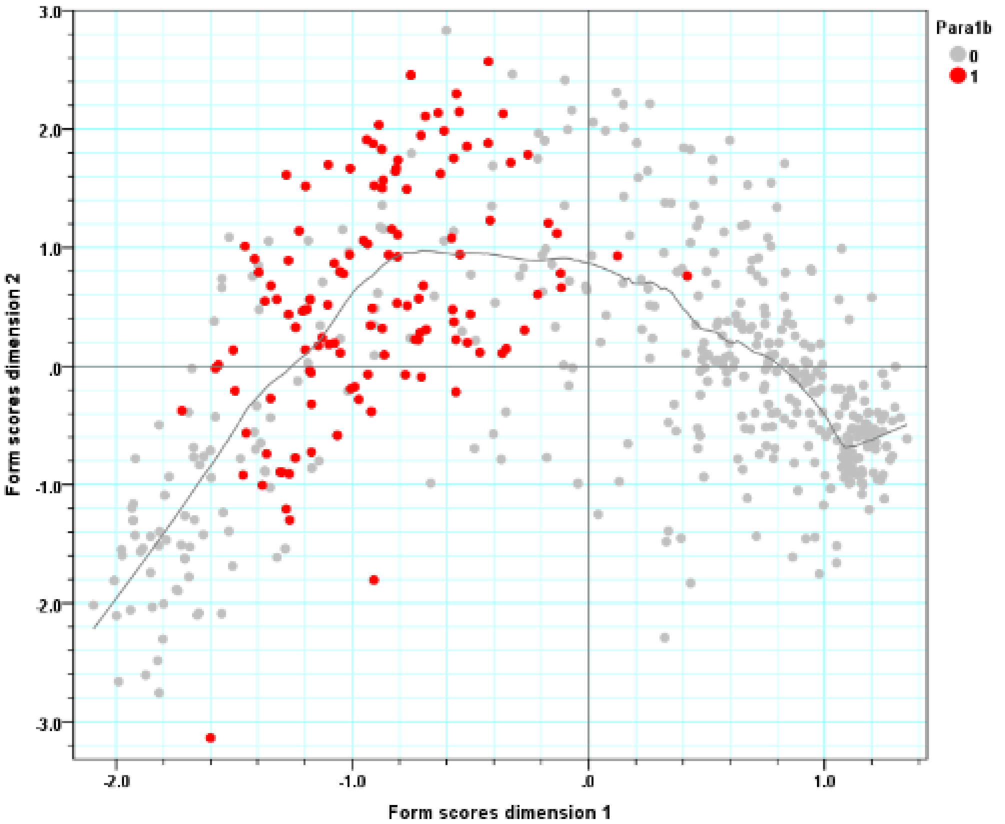


Figure 8.09 Form dimensions 1 & 2: *Edwardian-Vintage* cars are highlighted in red.

Typical of this paradigm are the seven cars in Figures 8.10 to 8.12.

Figure 8.10 Renault, 1912: Alva, 1913

Figure 8.11 Stutz Bearcat, 1916 (favcars.com): Morris Cowley, 1923

Figure 8.12 Alvis 12/50 (1928), Austin Seven (1933), Bugatti Type 57 Galibier (1939)

Innovative cars in this paradigm are all above the mean layout line in Figure 8.04 and below it in Figure 8.05. Cars demonstrating innovative form are above the mean line in Figure 8.11. The two Renaults are here, as is the

Bugatti 57 shown in Figure 8.12, and a 1933 Pierce Silver Arrow, in Figure 8.13. This shows how integrative form was developing in the 1930s.

Figure 8.13 Pierce Silver Arrow, 1933 (Wikimedia Commons: James Emery)

8.3 *Transverse-front-wheel-drive* paradigm

There are two other peak values for layout dimensions.

The next gives layout values of (+1.1, +0.9) ± 0.1. The earliest car of these is a 1959 Morris Mini-Minor, and there are 73 cars in the category, the latest being a 2013 Ford Fiesta. This paradigm is still in general use (2016).

Table 8.02 gives the values for the layout variables. The default variables are much the same as the previous paradigm. This paradigm is named after its important variables; the transverse engine and front wheel drive. Suspension is now mostly coils but occasionally hydro-pneumatic or rubber (for the British Leyland Mini and its descendants). The structure is mostly monocoque pressed steel, but one car has a fibreglass body on a platform chassis (the Mini-derived Ogle SX100). Beam axles are replaced by independent suspension, mostly struts at the front and torsion beams at the rear, although some have front double wishbones and rear trailing arms, and others have more sophisticated multi-link arrangements. Engines still have four cylinders; six have six cylinders and two have three. Two six-cylinder engines are Vee arrangements.

This is 12.7% of the sample with 73 cars. Extending the category to ±0.2 increases it to 96 cars – rather narrower than the *Edwardian-Vintage*. The widening is only in one direction.

Variable	Value
Engine position	Front
Crankshaft Orientation	Transverse
Driven Wheels	Front
Cylinders	3 (2) 4 (67) 6 (4)
Cylinder Arrangement	In line (71) Vee (2)
Front Suspension Form	Double wishbone (14) Strut (59)
Rear Suspension Form	Multi-link (18) Torsion Beam (41) Trailing Arm (14)
Front Suspension Medium	Coil (59) Hydro-pneumatic (11) Rubber (3)
Rear Suspension Medium	Coil (59) Hydro-pneumatic (11) Rubber (3)
Structure Type	Monocoque (72) Platform (1)
Body Construction	Steel (72) Fibreglass (1)

Variable	Default category
Engine Type	Reciprocating (Petrol)
No of Wheels	4 wheels
Wheel Orientation	2F2R
Wheel Sizes	Same
Steering Control	Wheel
Final Drive	Shaft
Driver Position	Front, Side
Tyre Type	Pneumatic

Table 8.02 Layout variables for the second peak layout value cars

With these cars the mean line of both layout dimensions takes time to reach the *Transverse-fwd* line. Another paradigm was still current and these two overlapped from 1960 to 1985. Innovators here were BMC cars including the Mini and its developments – the 1100-1300 and larger 1800. Fiat launched the Autobianchi Primula in 1964 and the 128 in 1969 (neither is in the sample). Figures 8.14 to 8.16 show the first and second layout dimensions for these cars plotted against time and against each other.

Form development for *Transverse-fwd* paradigm cars behaves similarly to *Edwardian-Vintage* car form; it changes gradually, Figures 8.17 to 8.19 show the graphs for the first and second form dimensions against time and against each other. In Figure 8.19 it can be seen that practically all these cars are in the lower right quadrant. These results are time-related. Attempts to manufacture pastiche ‘vintage’ cars using *Transverse-fwd* underpinnings are not particularly successful visually as the bonnet form is too short and the proportions are thus incorrect.

Figures 8.20 to 8.24 show examples of *Transverse-fwd* cars.

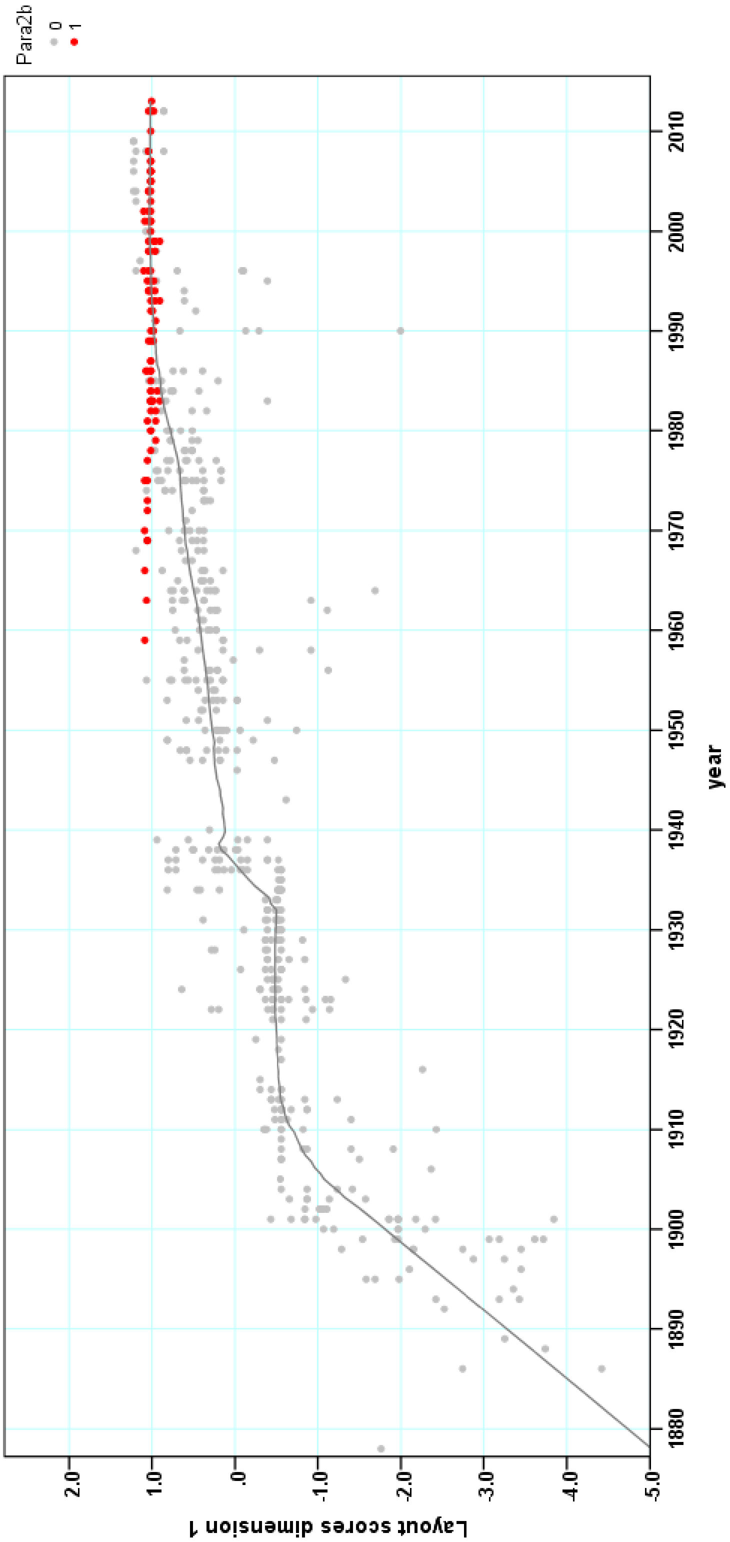


Figure 8.14 Layout dimension 1: *Transverse-fwd* cars shown in red.

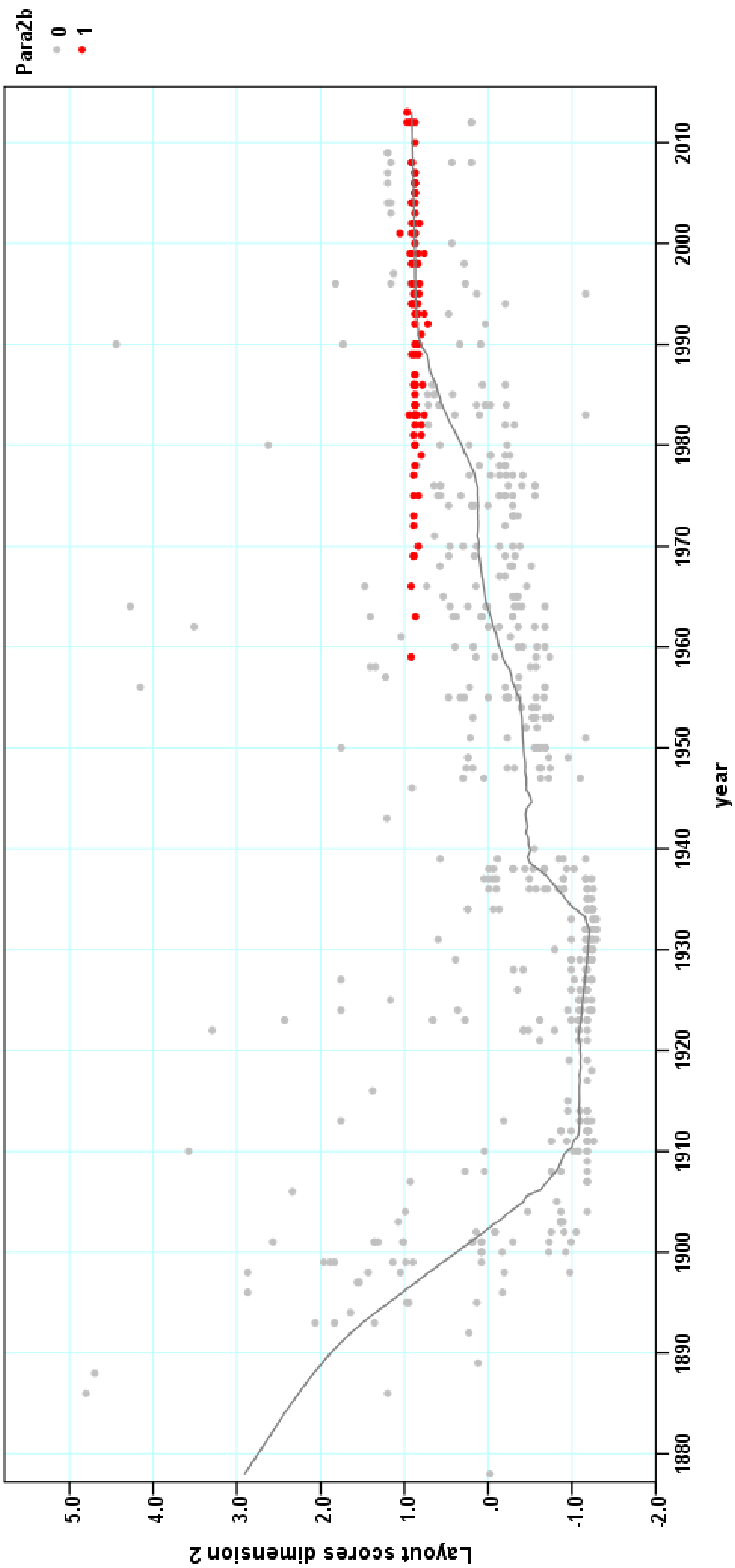


Figure 8.15 Layout dimension 2: *Transverse-fwd* cars shown in red.

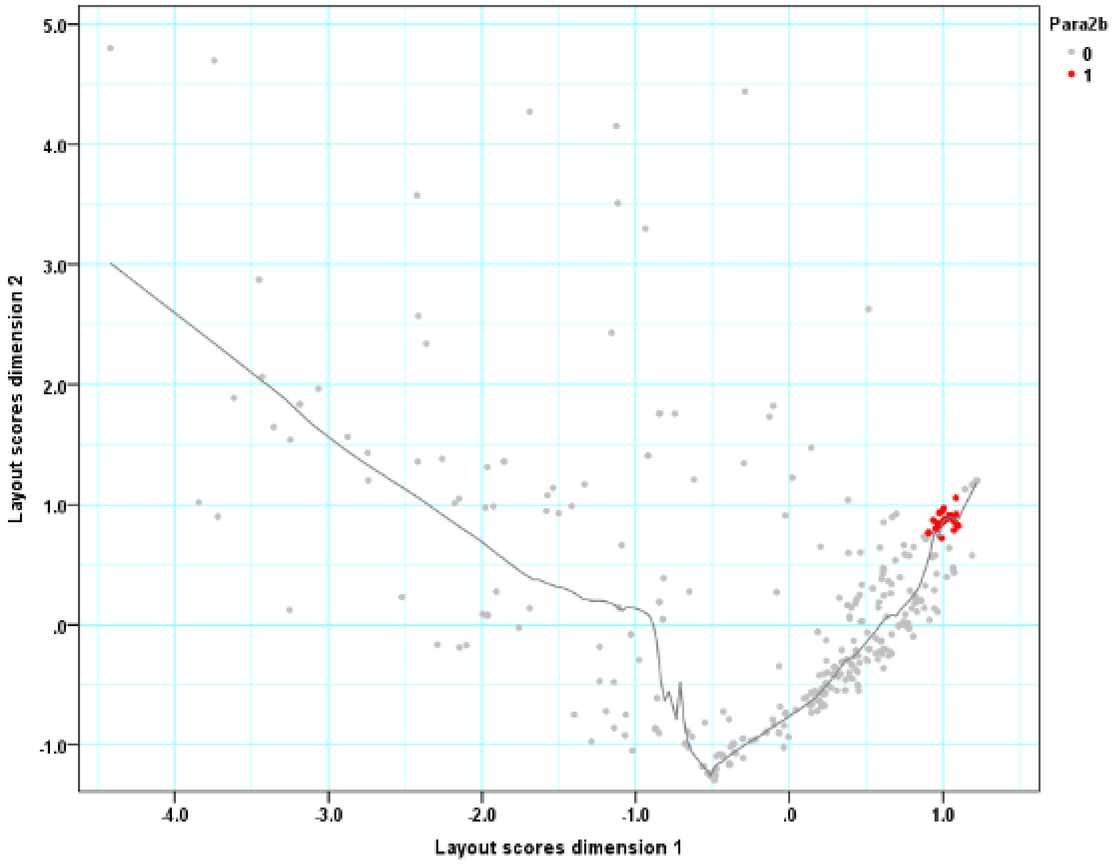


Figure 8.16 Layout dimensions 1 & 2: *Transverse-fwd* cars shown in red.

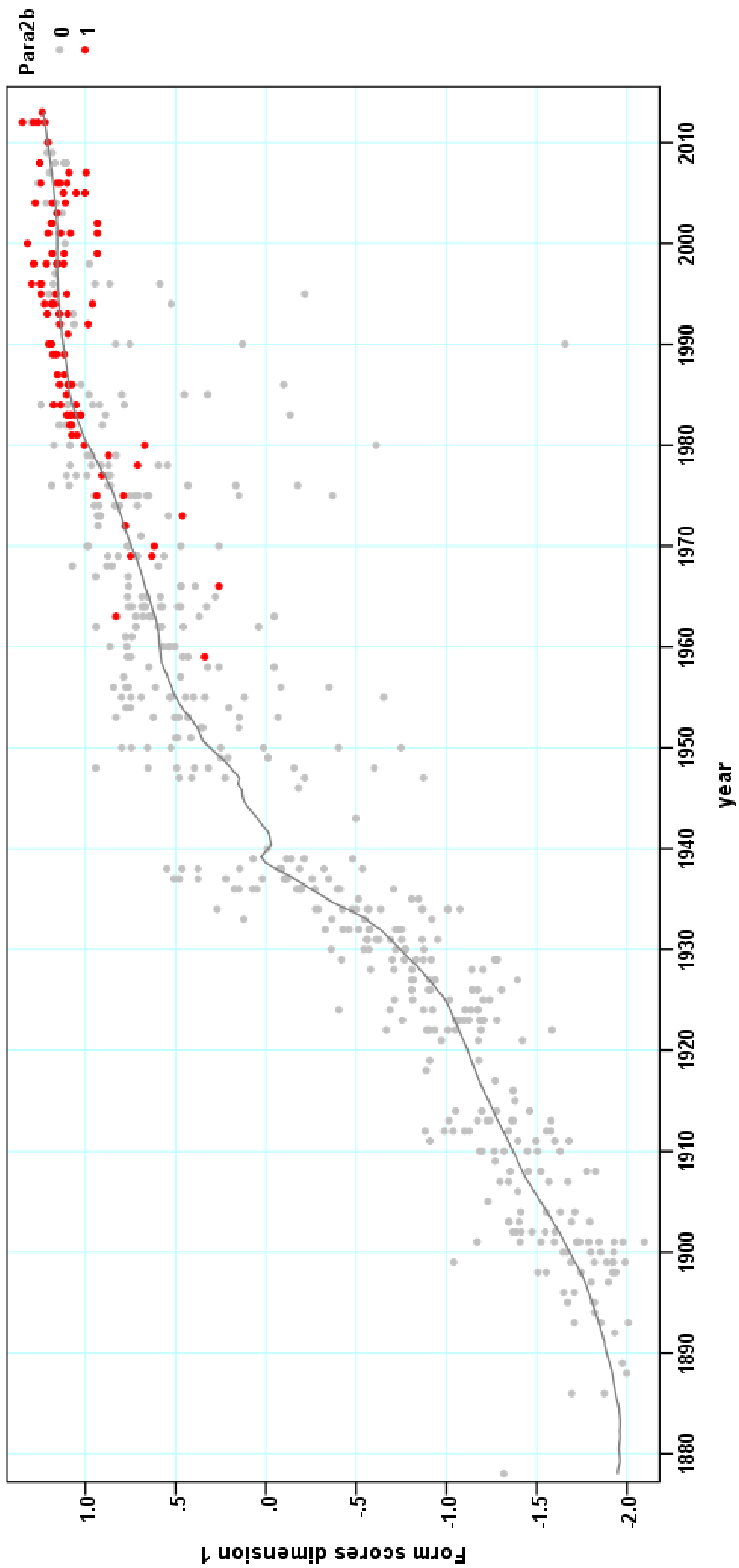


Figure 8.17 Form dimension 1: *Transverse-fwd* cars shown in red.

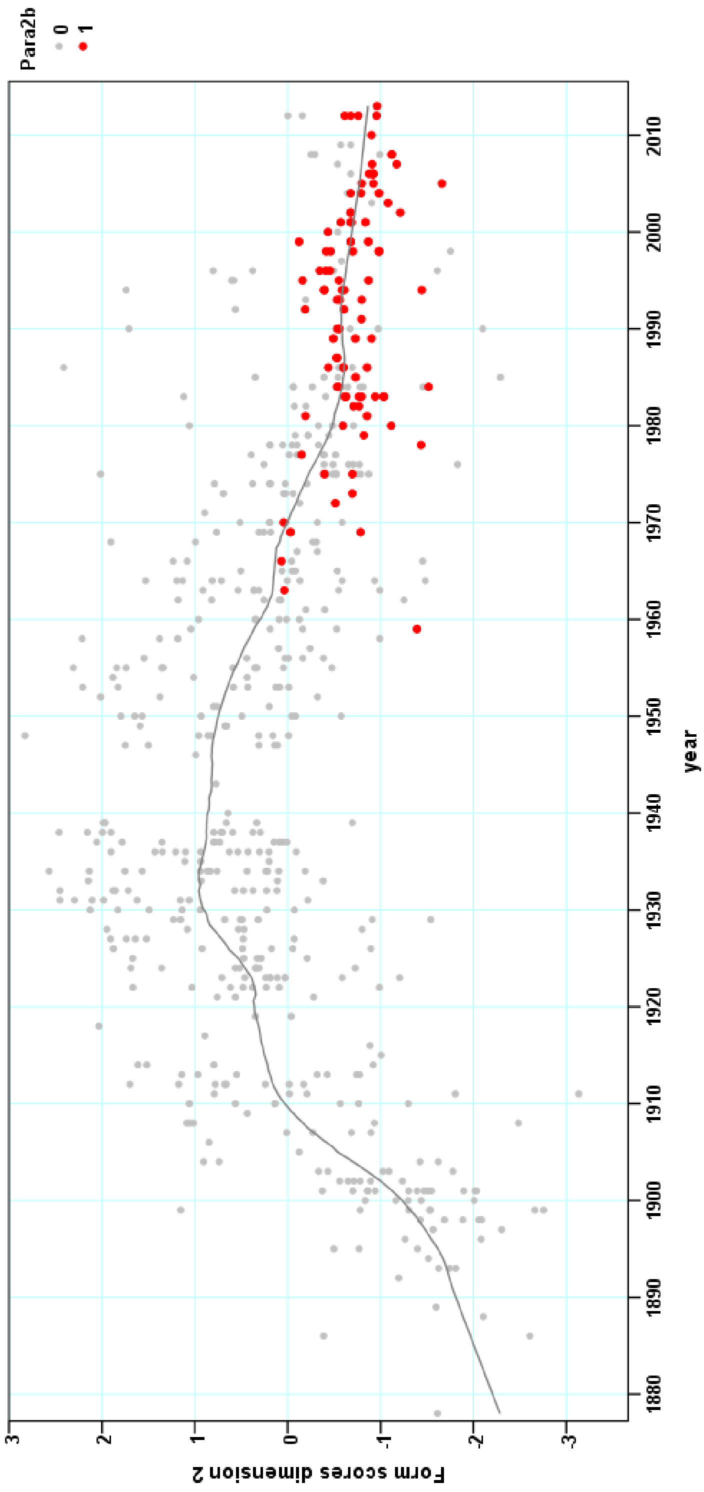


Figure 8.18 Form dimension 2: *Transverse-fwd* cars shown in red.

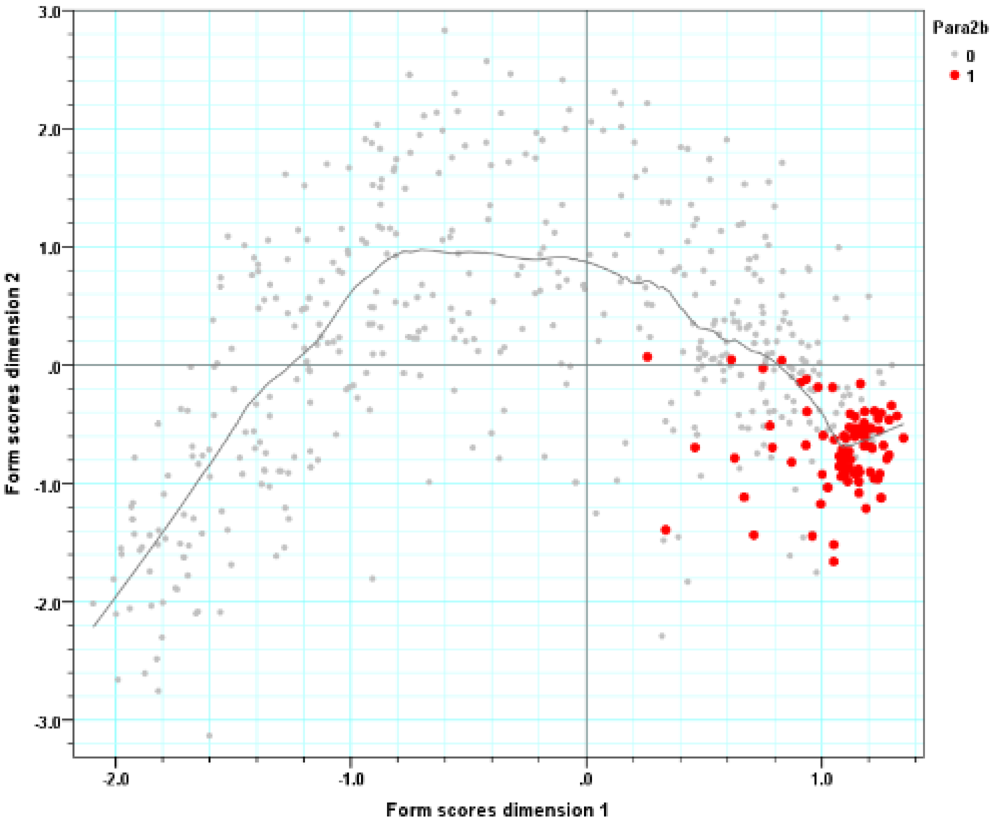


Figure 8.19   Form dimensions 1 & 2: *Transverse-fwd* cars shown in red.

Figure 8.20:   Morris Mini-Minor,1959, MG ADO 34, 1966

Figure 8.21 Wolseley Six, 1970 (Wikimedia Commons: deFacto): Vanden Plas Princess 1300, 1975

Figure 8.22 Volkswagen Golf Mk 1, 1980, Opel Corsa 1983 (Wikimedia Commons: Ecogarf)

Figure 8.23 MG Montego Turbo, 1986, Ford Escort, 1992 (Wikimedia Commons: Rudolf Stricker)

Figure 8.24 Renault Twingo, 1995, Ford Focus 1998 (favcars.com)

Figure 8.25 Vauxhall Zafira, 2005 (Autocar): Ford Fiesta, 2009 (favcars.com)

Most of these are UK best-sellers and are a familiar sight on the roads of 2016. It is how designers design cars now, particularly best-sellers that are the current median cars. In 1959 the Mini was novel and innovative, and the Morris 1100 was so perceived in the 1960s (Adams, 2012, Autocar, 1962, Hutton, 1985). The mean layout dimension lines do not reach this paradigm until the mid-1980s, and it was felt suitable only for small cars until then. Most of these cars up to about 1980 were felt to be innovative and novel – even Ford Fiestas. These cars follow the mean form development line fairly closely and do not deviate much – the Mini is probably furthest from it and shows the greatest form as well as layout innovation. One follows the other.

8.4 *Rear-wheel-drive-independent-front-suspension* paradigm

This title is somewhat of a mouthful and is better abbreviated to the rwd-ifs paradigm. This is a third layout dimension peak, but is smaller than the other two. When the narrower (± 0.1) definition of layout dimensions is taken into account this contains 23 cars and it contains 47 for the broader definition (±0.2). This is 8.2% of the sample. It is between the other two peaks in both values and dates. The earliest car here is a 1922 Lancia Lambda and the latest a 1985 Volvo 360.

Table 8.03 gives the layout dimension variables for this group of cars. The cars have longitudinally-mounted front engines, rear wheel drive, live rear axles with semi-elliptic springs and steel monocoque structures. Front suspension is independent, with coil springs and double wishbone geometry. They form a stable position between the two other paradigms. This is termed the *rwd-ifs* paradigm to indicate rear wheel drive and independent front suspension. Although both suspension and structural developments appear to be concurrent, monocoque structures arrived somewhat after independent front suspension, and several cars with separate chassis are here.

Figures 8.26 to 8.28 are the graphs of the first two layout components plotted against time and against each other, and Examples are shown in Figures 8.29 to 8.33

Variable	Value
Engine position	Front (44) Mid-rear (1)
Crankshaft Orientation	Longitudinal
Driven Wheels	Front (2) Rear (44)
Cylinders	4 (37) 6 (6) 8 (2) 12 (1)
Cylinder Arrangement	Horizontal (1) In line (38) Vee (7)
Front Suspension Form	Don't know (3) Double wishbone (24) Dubonnet (1) Sliding Pillar (3) Strut (15)
Rear Suspension Form	Beam Axle (38) Don't know (1) Double wishbone (1) De Dion (2) Swing Axle (4)
Front Suspension Medium	Coil (34) Don't know (1) Torsion bar (9) Transverse Leaf (2)
Rear Suspension Medium	Cantilever (3) Coil (2) Don't know (1) Reversed quarter elliptic (1) Semi-elliptic (33) Torsion bar (2) Transverse leaf (4)
Structure Type	Backbone (1) Channel chassis (1) Monocoque (33) Space frame (1) Tube chassis (10)
Body Construction	Steel (38) Aluminium (4) Coachbuilt (2) Fibreglass (1) Don't know (1)

Variable	Default category
Engine Type	Reciprocating (Petrol)
No of Wheels	4 wheels
Wheel Orientation	2F2R
Wheel Sizes	Same
Steering Control	Wheel
Final Drive	Shaft
Driver Position	Front, Side
Tyre Type	Pneumatic

Table 8.03 Layout variables for *rwd-ifs* paradigm cars

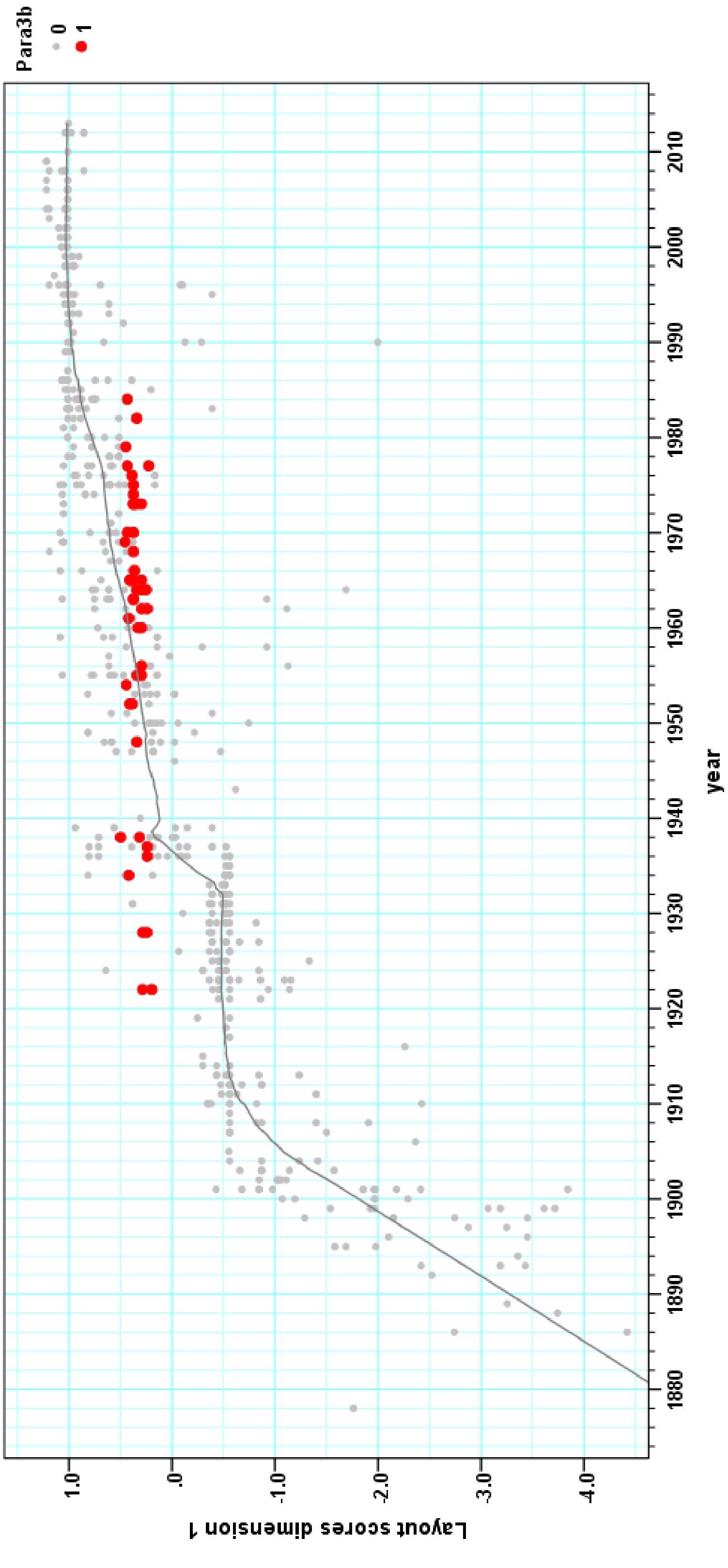


Figure 8.26 Layout dimension 1: rwd-ifs cars

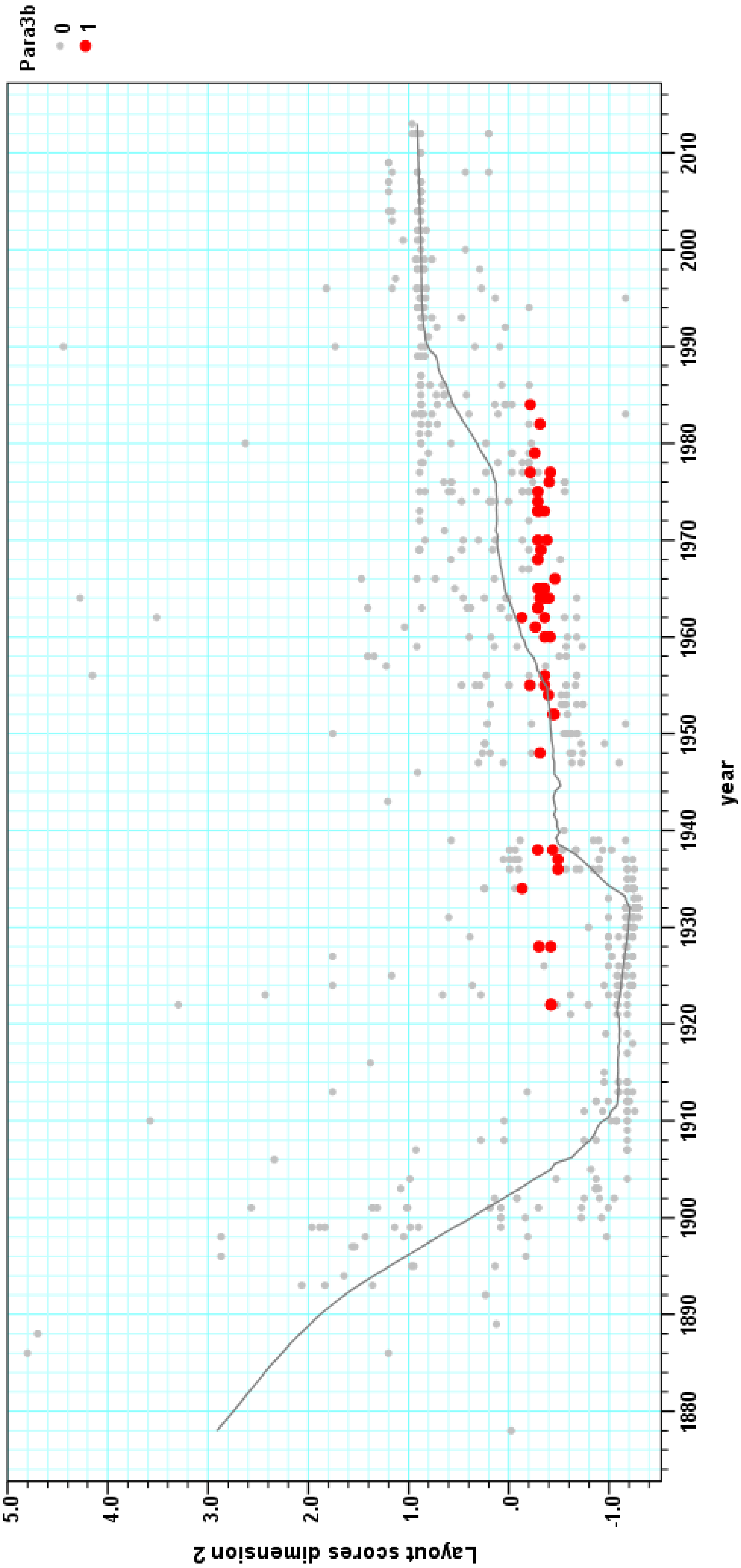


Figure 8.27 Layout dimension 2: rwd-ifs cars

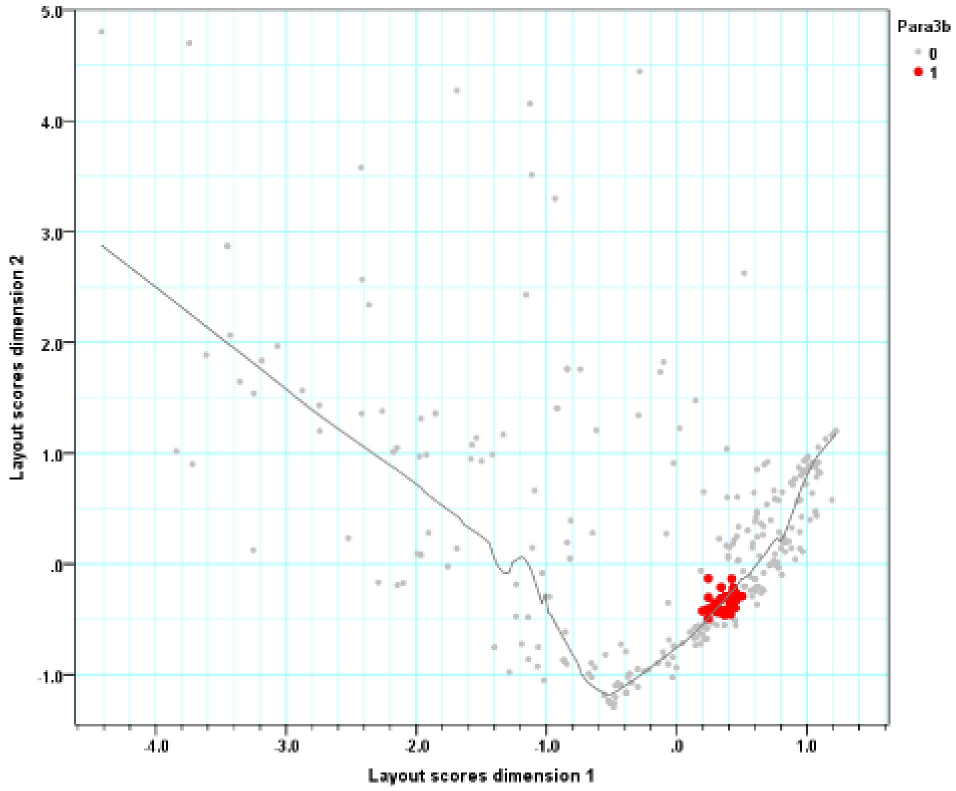


Figure 8.28 Layout dimensions 1 & 2: rwd-ifs cars

Figure 8.29 Lancia Lambda, 1922 (Mark Dowlen), Peugeot 402, 1936 (Wikimedia Commons: MartinHansV)

Figure 8.30 Morris Minor, 1948, Ford Vedette, 1954

Figure 8.31 Vauxhall Cresta, 1960, Ford Cortina, 1966

Figure 8.32 Triumph Vitesse 1967 (Wikimedia Commons: Oxyman), Morris Marina 1976 (Wikimedia: Adrian Pingstone)

Figure 8.33 Datsun Sunny 1980 (Motorbase.com), Volvo 360, 1985 (Wikimedia Commons: Ljmdbw)

Cars at the start of the paradigm have innovative and novel layouts; those at the end are perceived as staid.

The graphs for the first two form dimensions against time and against each other are shown in Figures 8.34 to 8.36. Car form shows more variety than form for the other paradigms, including family and sports cars, although it follows the first form dimension mean curve. The second form dimension curve shows greater variation and greater spread. The car that shows greatest form deviation (dimension 1) is the Ford Vedette (Figure 8.30), showing its US-inspired, integrative, rounded form was innovative in 1954.

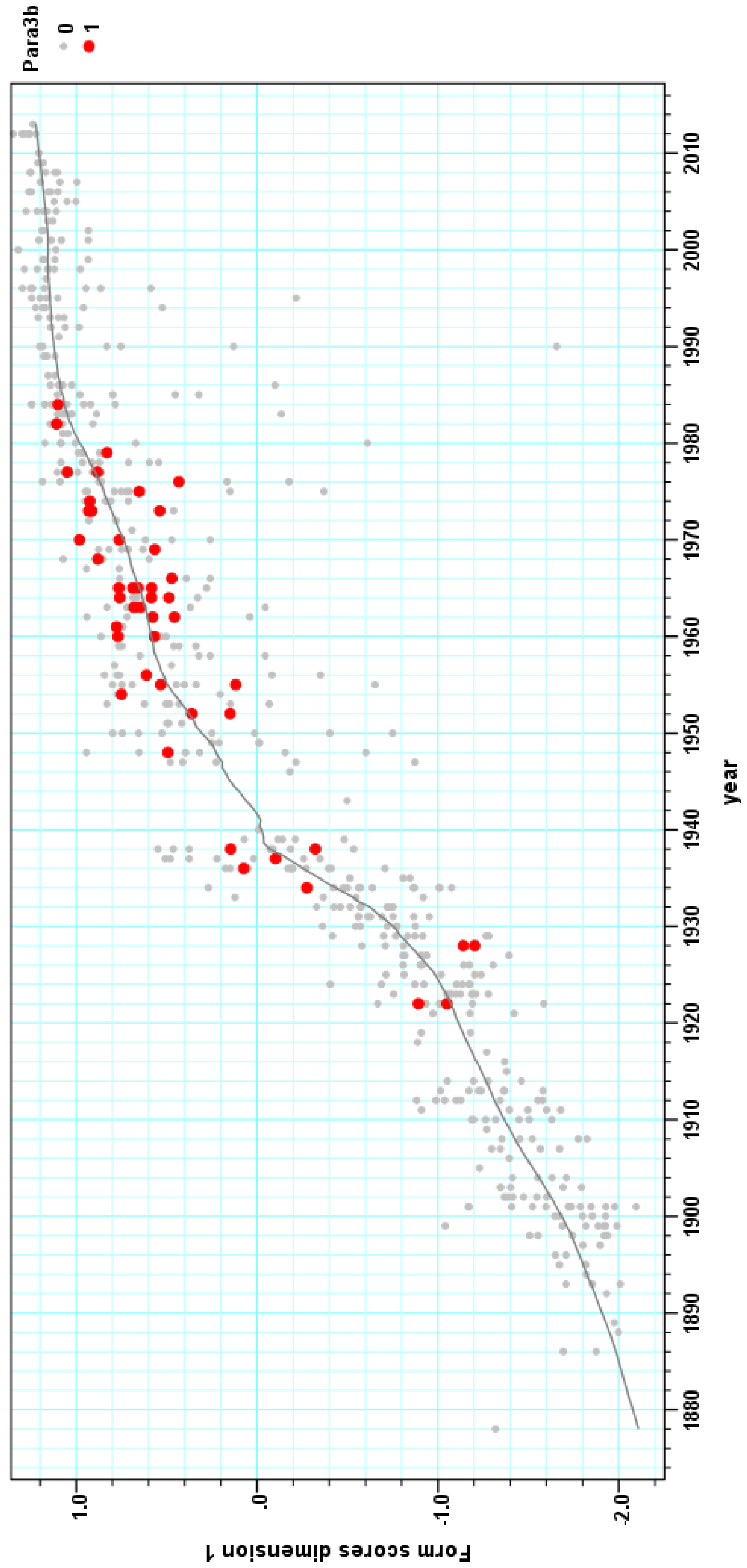


Figure 8.34 Form dimension 1: *rwd-ifs* cars

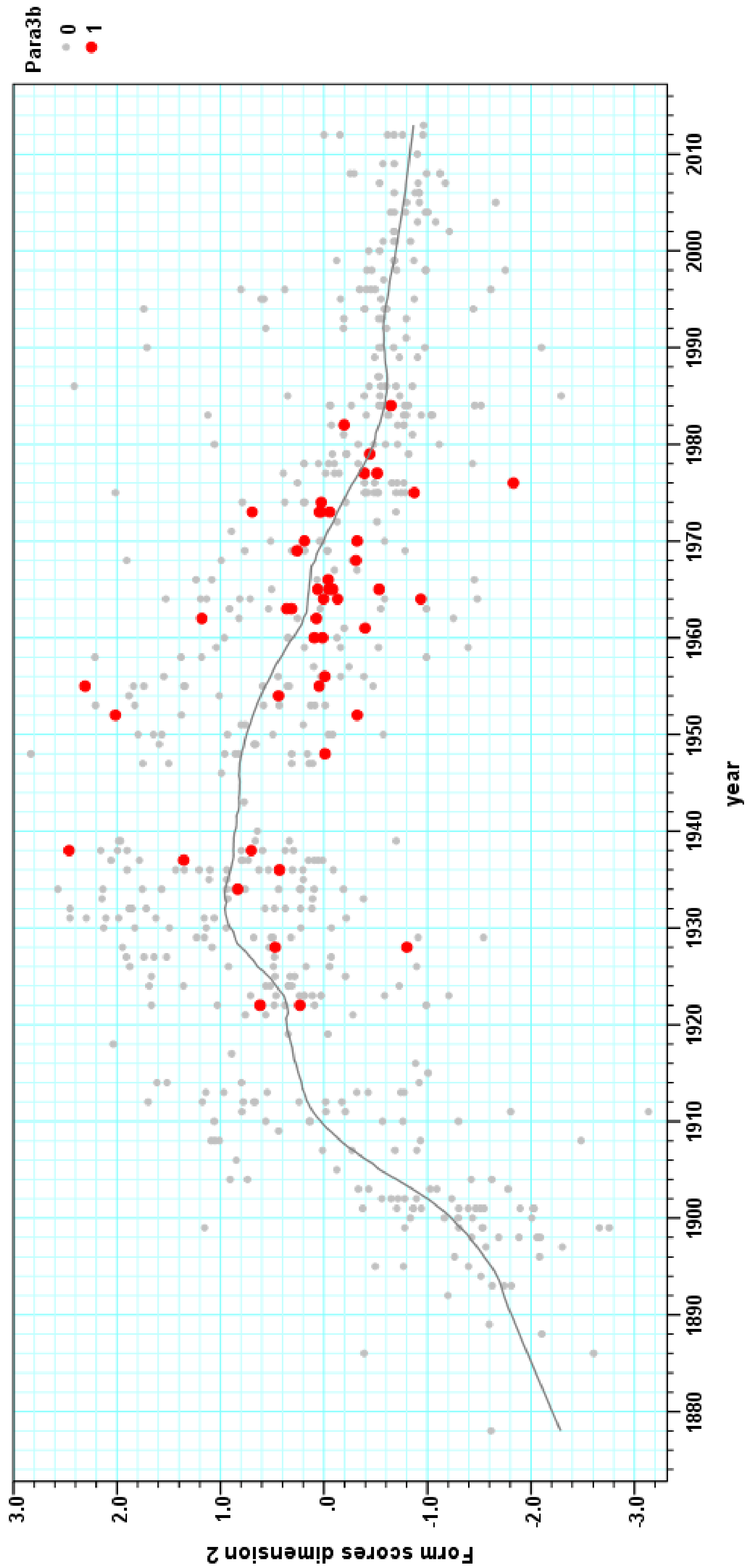


Figure 8.35 Form dimension 2: *rwd-ifs* cars

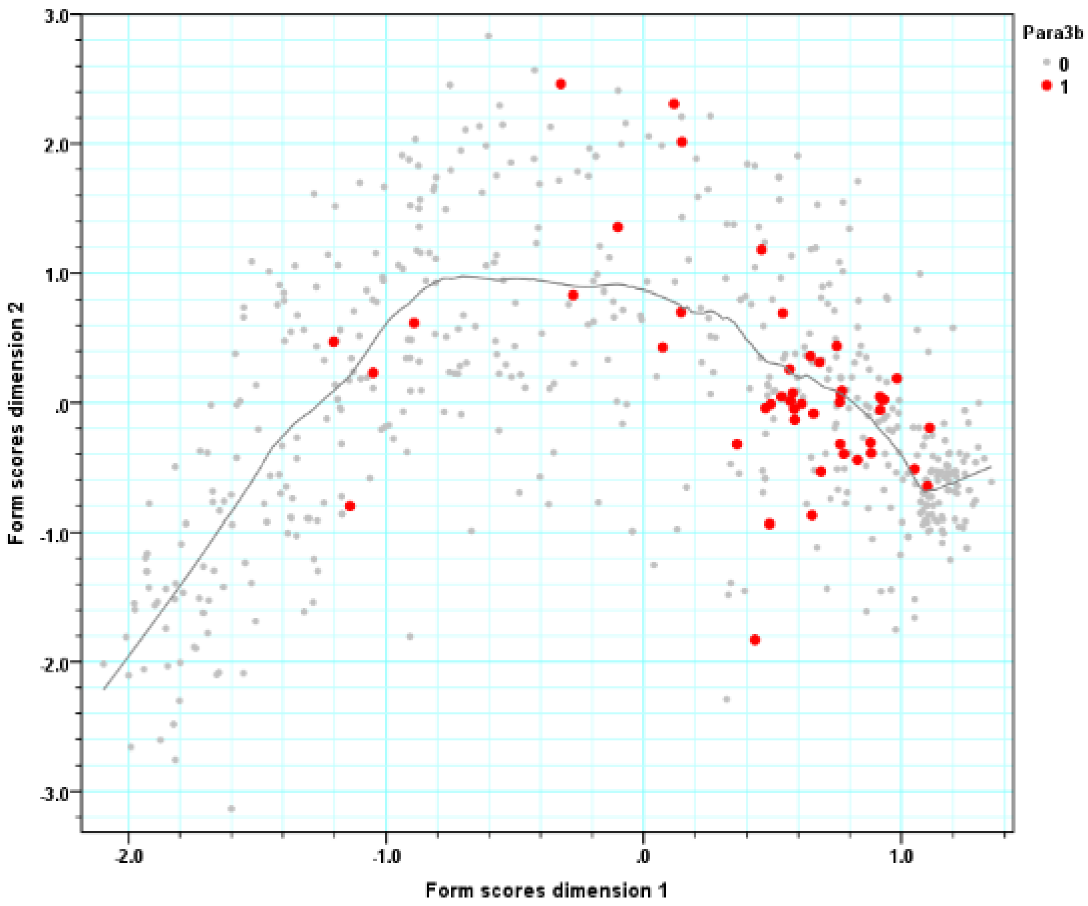


Figure 8.36 Form dimensions 1 & 2: *rwd-ifs* cars

8.5 Lesser paradigms

8.5.1 *US Mid-engined pioneers*

Several mid-engined cars were built in the US between 1895 and 1908. This paradigm is described in *Great Automobile Designers and their work* (Barker and Harding, 1992), in the chapter on Henry Leland (Hendry, 1992). Several layout features are associated with this: mid-rear engines with one or two cylinders – steam-powered earlier but petrol-powered later – transverse crankshafts, and rear-wheel drive with final drive by chain. Some had full-elliptic springs, pram frames and epicyclic transmissions (not measured as a layout variable). There is too much general variability for the paradigm to be identified clearly from the layout data. It developed into the US High Wheeler – a vehicle for rural America with rough roads and agricultural communities.

Figure 8.37 Black High-wheeler, 1908: Stanley, 1911

Eighteen cars in the sample have this paradigm. Figure 8.37 shows two later examples – a 1908 Black high wheeler and 1911 Stanley. The Stanley is steam-powered and has its boiler under the 'bonnet'. The engine is on the rear axle. Suspension on both is full-elliptics on a pram frame.

8.5.2 *Mid-engined sports car* paradigm

Sports cars are always a minority. *Mid-engined sports cars* trace their lineage to 1940s 500cc racers. There are twelve in the sample. Layout variables, particularly non-default, are not tightly grouped, although all the sample cars except one have double wishbone suspension at front and rear (the other has struts) and all except one have coil springs (the other has hydropneumatic suspension). Figure 8.38 shows two, one from the 1960s and the other from the 1990s.

Figure 8.38 Matra-Bonnet Djet (1966): MG F (1995)

8.5.3 Four-wheel drive utility vehicles

Four-wheel drive utility vehicles originated from the WWII Jeep. They are omitted from the sample as early ones were not always considered cars – early Land Rovers had fabric tilts at the rear and no side windows behind the drivers' seat and were considered commercial, agricultural or multi-purpose vehicles in the UK until 1971 when Purchase Tax ended and they attracted VAT. The UK market is dominated by family cars; 4x4s are a (significant) minority so were not part of the sample. Early examples have live axles at front and rear on half-elliptic leaf springs and separate chassis, channel section (Jeep) or welded tube (Land Rover and others). This was developed in the 1970s with the Range Rover having coil springs and live axles, still with separate chassis. The next development was independent suspensions and monocoque structures in the 1990s, years after their adoption by best-selling family cars.

8.5.4 Cars with rear engines

A significant minority of cars has been produced with rear engines. By this is meant cars with the engine arranged substantially behind the rear axle. This includes cars such as the Tatra, Volkswagen Beetle, Porsche, several Škodas, Fiats 500, 600 and 850, Renault 4CV and Dauphine, Hillman Imp, Tucker Toledo and the Chevrolet Corvair. Significantly, a large number of these cars not only had an overhung rear engine but also used the same kind of rear suspension – the swing axle. Why these two arrangements – the engine position and the rear suspension form – should tend to be combined is not clear. This combination of the rearward mass bias inherent with the engine position and the handling that is related to the suspension form led to several of these cars having notoriety for their handling. This, in particular refers to the larger cars: the Tatra and the Chevrolet Corvair. (In passing it might be noted that a rear engine does not necessarily indicate that the car will oversteer).

With these two cars in particular this combination of a large and relatively heavy rearward engine and the swing axle rear suspension led to the tendency for them to oversteer and produce somewhat uncontrollable behaviour in the limit, leading to German Army reports of Tatras overturning (Eckermann, 2001) and to the publication of Ralph Nader's book *Unsafe at any Speed* (Nader, 1972). Whilst the general public perception of this book was that it was against the specific handling difficulties of the Chevrolet Corvair, it in fact aims criticism at the Motor Industry much more generally, and in particular attacks its record on a number of safety issues, including passive safety, emissions control and its relationship to US government legislators. A critique of the book was published in the December 2016 issue of *The Automobile* (Ludvigsen, 2016) which suggests that the book did not close the chapter on the Corvair, but strengthened the reserve of General Motors to prolong its life in order to save face, and that in retrospect the book may have little effect on the direction of car design from the mid-1960s onwards. However, the general text and tenor of the book certainly indicates that it did indeed cause a shift in the design approach of the motor industry, particularly towards safety issues and allowed the public to support the separation of motor industry from government regulation. This meant that the safety work started by Ford in the 1950s (and quoted by Nader) started to bear fruit in terms of incorporation into both active and passive safety considerations in car design. It has probably also led to the introduction of such mandatory safety features into cars as front and rear crumple zones, side impact bars, anti-lock braking, air bags and multiple other features.

The unstable behaviour of some rear-engined cars has meant not that rear-engined cars have been effectively outlawed, but that car designers have had to think very carefully before they incorporate rear engines into cars. In a technical sense the work did not close the chapter on rear engine cars, but it certainly caused designers to think more carefully about issues of safety, including the primary safety of designing cars with inherently safe handling characteristics. There is further discussion of these handling characteristics in the next section.

8.6 Moving from one paradigm to another

Between the three main paradigms there are variations as manufacturers developed what they regarded as the ‘definitive’ car design. A manufacturer might initiate the change process by moving further from the previously-accepted paradigm than the later stable position. In the 1930s with the move from beam axle suspension at front and rear some manufacturers developed independent suspensions at front and rear before the later paradigm with front independent suspension and rear beam axle. This is seen in Figures 8.05 and 8.006 where the mean line shows an overshoot similar to an underdamped second-order response. The rear suspension on these cars tends to be by swing axle, which is not seen on independently sprung cars of later paradigms. Suspension media develop, with earlier independently-sprung cars frequently using transverse leaves. There was a short period when torsion bars were in vogue, and then the paradigm using front coil springs and rear semi-elliptic springs became accepted.

Similarly, the first *transverse-fwd* car in the sample, the Mini-Minor, used rubber as suspension medium. (Note – this was not the first *transverse-fwd* car – several used that arrangement earlier.) This was only used by manufacturers using BMC components. It developed into the Hydrolastic and Hydragas systems, but only Citroën and BMC used this in popular car ranges. It has also been used by Rolls-Royce, Cadillac, Mercedes-Benz and Maserati in luxury cars. The Mini had the gearbox underneath the engine, but later cars used a simpler arrangement with the gearbox end-on to the engine, pioneered by the 1964 Autobianchi Primula. The Mini seems to have produced a small ‘overshoot’ in layout, but is within the narrow paradigm boundary. The *rwd-ifs* paradigm was current when the *transverse-fwd* paradigm started which obscures developments. These two paradigms existed concurrently for some time, producing a bimodal distribution from 1970 to 1990.

Literature is written differently before and after the changes in the 1930s.

Donkin’s book on elements of motor vehicle design (Donkin, 1926) assumes cars have beam axles with leaf springs, three sorts: semi-elliptic, cantilever and quarter elliptic. Donkin mentions that some vehicles have chain final drive, stating that it is now (1926) obsolete for passenger cars. He describes car chassis as pressed or rolled steel C section. He does not mention other structures. He does not expect designers to think outside the *Edwardian-vintage* paradigm box.

The AA Book of the Car, first published in 1970 (Jacobsen, 1973), contrasts with this. It pictures its generic car with front engine and rear-wheel drive, but describes “transmissions without propeller shafts” – with a front engine and front wheel drive or rear engine and rear wheel drive, giving six layout sketches. It states “In the search for improved ride and handling designers have adopted independent front suspension and, in some cars, independent suspension is also used at the rear instead of a beam axle” – the only reference to front beam axles. Double wishbone and strut suspension are described, as are swing axles, trailing links and wishbone suspension using a longitudinal upper link. The book describes independent rear suspensions. The book outlines unit-construction and chassis construction techniques, with examples. Although clearly from when the rwd-ifs paradigm was clearly current, it is mindful that significant layout variations existed.

The resultant dominance of the *transverse-fwd* paradigm was not unexpected in 1970 although the only proponents were BMC and Fiat / Autobianchi.

That describes ‘what’ took place and how the paradigms are identified. More interesting is ‘why’ they changed.

8.6.1 The *Edwardian-vintage* paradigm

Why did this paradigm start? Several reasons seem to have come together as viable directions. One is the benefit of introducing some standardisation. Not necessarily exchangeable components per se, but of the technologies and manufacturing expertise. Spring manufacturers, having learnt to produce, say, leaf springs, found they could supply several car manufacturers. The technologies were transferable. Secondly, some design decisions, such as using pneumatic tyres, produced more effective cars. Pneumatics allow faster speeds as they have lower rolling resistance than solids and heat up less (Hart-Davis, 2008). Channel section chassis meant longer frames than simple tubular chassis and cars could carry more people. Culturally and psychologically, having a front engine simply replaced the horse. Explorations of more esoteric design features seemed to be unsuccessful. It might be obvious why cars should not place the driver behind the passengers when it is obvious that a front driver sees the road better, and why cars should not have a diamond-arrangement for the wheels which makes drive systems and passenger accommodation difficult.

8.6.2 The *rwd-ifs* paradigm

The 1930s paradigm shift is clearer. The beam front axle was flawed. Bastow cites seven reasons (Bastow, 1987), but then omits the most important. This was to avoid wheel shimmy. Cars were getting faster, many late 1920s cars being capable of over 60mph, and this dangerous dynamic oscillation takes place at speed. The 1920s brought in four-wheel braking. Attaching brake drums to the front wheels increased their inertia, reducing the shimmy's natural frequency and making it worse as the amplitude increased. If shimmy occurred it could only be cured by slowing the car using rear brakes only – the handbrake – or coasting to come to rest without braking, which may be dangerous and counter-intuitive. A technical description is in *Chassis Design* (Milliken and Milliken, 2002). This states: "The most dangerous form of unsprung oscillation was an old-fashioned classic 'shimmy', occurring with the front axle." Several possible cures are described before stating "The cure which can be rated as 'commercially complete' is the change to independent front suspension, which suppresses shimmy by connecting the mountings of the two wheels through the entire sprung mass of the front of the car." (p331)

Another major reason to replace the beam axle, in Bastow's list, is to improve the car's ride. It does this by producing a step-change in the moment arm resisting the car's roll in corners. A beam axle's roll-resisting moment arm is the distance of the spring base: that of an independent suspension is the track – i.e. distance between the wheels. To achieve the same roll stiffness the vertical springing must be significantly stiffer for a beam axle. The improvement with independent suspension is not trivial. Independent front suspension also allows the engine to be further forward between the front wheels, giving more space to the passengers. This leads to a form change, with shorter bonnets, shorter wheelbases, longer front overhangs and longer passenger sections. The change of proportion changes the second form dimension – but not immediately.

Replacing the beam axle changes the car's handling, moving it towards understeer. Understeer and oversteer describe the relationship between car steer angle and where the car actually travels. Steering around a corner is achieved by the side force generation due largely to wheel slip angle changes. Cars do not usually go where they are pointed – the relationship between steer angle and the car's yaw rate determines the direction of travel. Understeer and oversteer were defined by Maurice Olley in the early 1930s and are reported by Milliken and Milliken as being:

> "… when the rate of change of the front slip angle steer with lateral acceleration is greater than that of the rear, in a constant radius test where the lateral acceleration is varied by the speed change, the vehicle is [said to] understeer. When the opposite is true it is [said to] oversteer and when the rates of change are equal [the vehicle has] neutral steer." (Milliken and Milliken, 2002) [The grammar is different – hence the difficulty with the quote] (page 50)

If the front ploughs onwards and sends the car towards the kerb on the outside, the car understeers (terminally, if it comes off the road). If the rear swings out on a corner and threatens a spin, then it is oversteering – terminally if it spins. Figure 8.39 shows the yaw rate responses relative to steer angle for understeer, oversteer, and neutral steer.

A car will either be too slow or will show terminal understeer or oversteer. Terminal understeer gives a zero response to a steering input; terminal oversteer means an infinite response. Terminal neutral steer means going too slowly.

With terminal understeer, the natural response is to slow. This returns to where the steering responds, and control is regained. With terminal oversteer there is an infinite response and the car spins uncontrollably – not a desirable situation and to be avoided. A spin is avoided by removing the lock and steering into the spin. On the adhesion limit this results in 'opposite lock' cornering where the driver controls imminent spin by expert steering and throttle to control adhesion at the (rear) driving wheels.

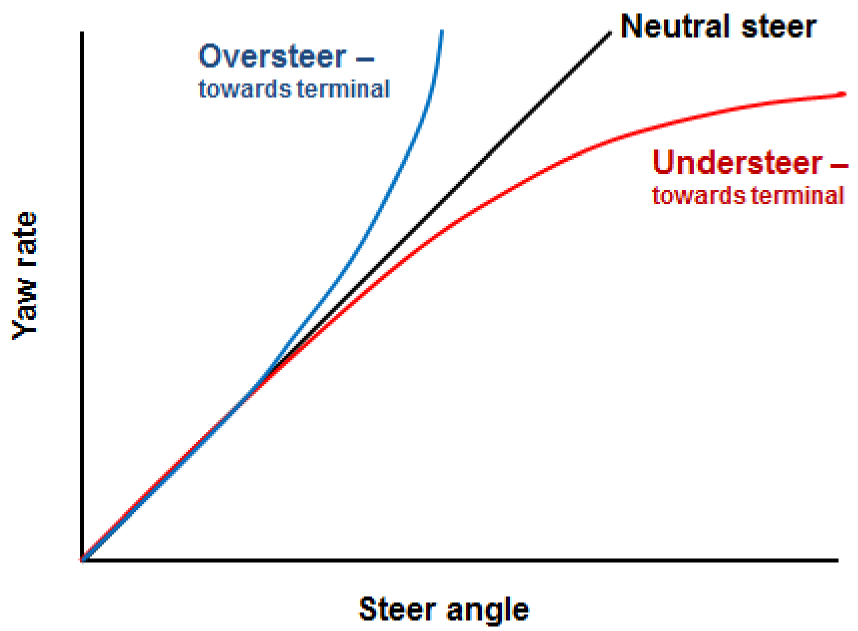


Figure 8.39 Understeer, oversteer and neutral steer responses

Independent suspension at either end of the car increases the tendency of that end to lose grip and hence independent front suspension increases the tendency to understeer. Similarly, independent rear suspension increases the tendency to oversteer. With beam axles at both ends or independent suspension at both ends, careful design and tuning are required to produce terminal stability, usually through incorporation of bump-steer and careful geometry. Bastow links this with low anti-roll resistance of the beam axle, "The narrow spring track implied by half-elliptic springs and front wheel lock clearance imply a low front anti-roll resistance and a consequential oversteer effect unless an anti-roll rod is provided." (Bastow, 1987, page 173)

These issues were first explored by Maurice Olley in the early 1930s, although Frederick Lanchester had suggested it earlier. (Private communication with Professor Fred Hales in the 1970s). This technical exploration by Olley resulted in the paradigm shift, as he worked for General

Motors and was the key engineer who introduced their range of cars with independent front suspension in 1934 (Milliken and Milliken, 2002). It is not clear whether Vincenzo Lancia identified the advantages of independent front suspension when he introduced the Lambda in 1922 (Figure 8.40). Jamieson is unclear why it was done, simply saying that Lancia decided his next car would have independent front suspension (Jamieson, 2001). Another early user of independent front suspension was Morgan, using sliding-pillars on all his cars from 1909. Discussion with Chris Booth, at the Morgan museum, suggested he designed the front suspension because it looked right and little technical reasoning would have taken place (Booth, 2009).

The other feature of the 1930s paradigm shift is unitary body-chassis construction. All-welded construction for car body shells was patented by Edward Budd in 1913, although he was responsible for all-welded car body shells at Hale and Kilburn when they were approached by the Hupp Auto Company in about 1910. In 1914 Dodge was the first major company to use Budd's patents (Cobb, 2010). It was used by several US manufacturers, with a separate chassis. Several pioneers of combined body-chassis were Lanchester in the early 20th Century, Lancia's Lambda in 1922 (Figure 8.40) and Citroën in 1934 (Figure 8.41). Citroën had used Budd patents since 1925, but in 1934 combined this with a body-chassis unit.

Figure 8.40 Lancia Lambda body-chassis (Jamieson, 2001)[5]

Figure 8.41 Citroën 7A body-chassis (Autocar, 1935)

General Motors introduced body-chassis units in the 1930s on European ranges, the Opel Olympia in 1935 and Vauxhall 10 in 1937. These both claim to be the first cars in their respective countries with body-chassis units. In the US, some claim the Nash 600 in 1941 as first, but Chrysler's Airflow

[5] Figure 8.40 also appears in Eckermann (2001). Reprinted with permission by SAE © 2017 SAE International. Further distribution of this material is not permitted without prior permission from SAE

range had framed stressed-skin from 1934, which sounds similar to unitary construction.

Combined body-chassis unitary construction was introduced to improve manufacturing: there are fewer operations, although careful tolerancing is needed. The car becomes significantly lighter than a body-on-chassis car, with fewer components. It is more difficult to include body variations, and thus unitary system was not used much in the US before the 1960s and is still not used for commercials, where chassis-cabs allow for different configurations of the load space. Commercial vehicles are different products from cars, and design paradigms lag considerably behind car design paradigms.

The key reasons for the 1930s paradigm shift were technical. There were significant technical limitations to the *Edwardian-Vintage* paradigm and the development of effective independent front suspensions within several popular car ranges led this paradigm shift. The prime instigator of the shift was Maurice Olley in his work at General Motors, particularly in the USA but this also filtered relatively quickly through to the General Motors plants in Germany and Britain with the production of the Opel Olympia and the Vauxhall 10.

8.6.3 The *transverse-fwd* paradigm

The paradigm shift to the *transverse-fwd* paradigm was also due to one person, Alec Issigonis, the BMC Mini designer, the earliest with that paradigm. Yes, there were several earlier front-wheel drive cars with transverse engines, like the German DKW, Figure 8.42, and a de Dion-engined combination of 1899, (Figure 8.43). Here the engine pivots with the front axle when steering. Both these are in the sample. What Issigonis brought to car designers' attention was how a car's components could be arranged to give more space for occupants. This is known in the Motor Industry as 'packaging'. The BMC Mini was a cleverly-arranged package, with details such as sliding windows and door bins adding to the feeling of interior space. It was reputedly known as the Tardis, after Dr Who's Police box that was larger on the inside than the outside. However, the story is apocryphal because the Mini was on the market before Dr Who reached television.

Figure 8.42 DKW F1, 1931

Figure 8.43 De Dion-engined Combination, 1899 (Derek & Gwyneth Harper)

The thinking change is spatial. The car became conceived in spatial terms with people-space the priority and engineering fitted to enable the space to be mobile. The car became an architectural product rather than an engineering one. Sparke suggests that Issigonis at BMC and Giacosa at Fiat were the first car designers to employ architectural thinking and to conceive the car from the inside out (Sparke, 2002). This explains why Issigonis' favourite design was the larger BMC 1800 which gave more space within a compact outline. It is this thinking that has been copied and became the design paradigm rather than simply the transverse engine and front-wheel drive. Issigonis' intended Mini replacement, the 1969 9X, is also in the sample, Figure 8.44.

Figure 8.44 BMC 9X, 1969

Its overall length is 100mm shorter than the Mini, but the passenger space is 100mm longer. This has been achieved by careful design of the engine and its ancillaries to use as little longitudinal space as possible.

Why did the 1960s shift take place? This was after Suez and the perceived need for economy vehicles. These were marginal bubble-cars with single and twin-cylinder engines, ingenious solutions for entry and exit and low performance. BMC wished to market a real car, but improved and perceived as a car. Take-up of the paradigm was slow, with first tentative followers the Fiat offshoot, Autobianchi in 1964 and Fiat itself in 1968, which is nine years after the BMC Mini launch. The Fiat doesn't start a followers' landslide, but a slow, stealthy takeover. This contrasts with the 1930s changes. It does not contrast with the original take-up, where there is a considerable time-gap between the Lancia Lambda and Maurice Olley's work, but following Olley's work there was speedy dissemination of independent front suspension through the industry: several major firms were on-board from the mid-1930s.

9 Interpretation and critical discussion

9 Interpretation and critical discussion

The initial questions were

What is the nature of the design paradigms that can be identified in car history?

2 *How are car design, car history and car heritage viewed by car designers, historians and enthusiasts?*

3 *How do the answers to these two questions relate to each other?*

This was expanded into a quest to *describe and analyse design paradigms in car history.*

The question was then expanded to include a selection of *what, how and where* questions, and expanded further to consider how historical design paradigms are construed by designers, historians and enthusiasts.

Several paradigms have been identified, described and analysed.

The analysis process, particularly the layout analysis process, identified major paradigms. These have been termed, in this research, as being the *pioneer*, *Edwardian-vintage*, *rwd-ifs* and *transverse-fwd* paradigms. For each of these three paradigms the layout dimensions remained constant for a period – a clear indication of their existence.

Lesser paradigms have been posited: the *US mid-engined pioneers* and the *mid-engined sports car* paradigm. These have not been identified through in the same manner due to their diverse character and their non-mainstream nature. They form separate clusters. Four-wheel-drive utility vehicles have been discussed.

The desire to produce an effective numerical timeline has been created, although this is more realistically a series of timelines, one for each of (two) dimensions for layout and form.

In a separate process, constructs have been sought from a number of experts, some of whom are designers, some historians and some enthusiasts – although these categories overlap significantly.

9.1 Discussions from each analysis process

9.1.1 Numerical analyses

Numerical analyses produced four timeline curves. They rely on a large and representative sample with sufficient information. Whilst the sample size was on the low side, the results are reliable; extra data do not disrupt the curve forms or the analysis conclusions significantly, as was shown in the small differences between the results from the initial sample and the comparison between these results and the later results from the complete database. The curves indicate periods of static behaviour for layout variables, showing that these are different to form variables. Layout curves clearly identified three paradigms in car history.

Form curves show that form (or perhaps fashion?) changes more gradually. They but they demonstrate time-based movement and identify a car's approximate date by placing it on the graph. This demonstrates that designers, form designers, design form that is related to current practice, which is indicative of paradigmatic thinking. But this may be unfair on the designers. Martindale suggests that the reason that he did not consider that car history could be analysed in the same way as the art that he chose to explore (Martindale, 1990) was that car design was affected significantly by the need to produce a saleable product, and an alternative reason for the gradual changes in car form could be the need to produce products with forms that will sell, rather than those that the designer simply appreciates. General Motors' approach to developing customer interest in design changes in the 1950s was to build concept cars and show them to the public so that they might anticipate less gradual form changes, thus removing some of the pressure on designers to design for a market that they may not have related to. Car appearance is likely to be modulated by customer acceptance.

These numerical processes demonstrate paradigmatic thinking, demonstrate when layout paradigms became current, when they stopped being current and how quickly changes took place.

Categories need to be sequenced carefully and logically.

Figure 9.01 Leyat Helicar, 1922

Results might still be spurious. One example highlights this. With the *rwd-ifs* paradigm one car was within the tight layout values that was clearly not of that paradigm. This was a 1922 Leyat, Figure 9.01. This car might be expected to be an outsider as it has airscrew drive, and is the only car in the sample powered this way. It has a wooden monocoque structure, which loads high on structure and body types, and is where the *rwd-ifs* paradigm is moving. The behaviour of the airscrew may make little difference in moving the car in the opposite direction – driven wheels load in the opposite direction – because this is the only car driven by an airscrew, which gives a small step in the driven wheels variable value due to the non-linear probability behaviour inherent in the analysis.

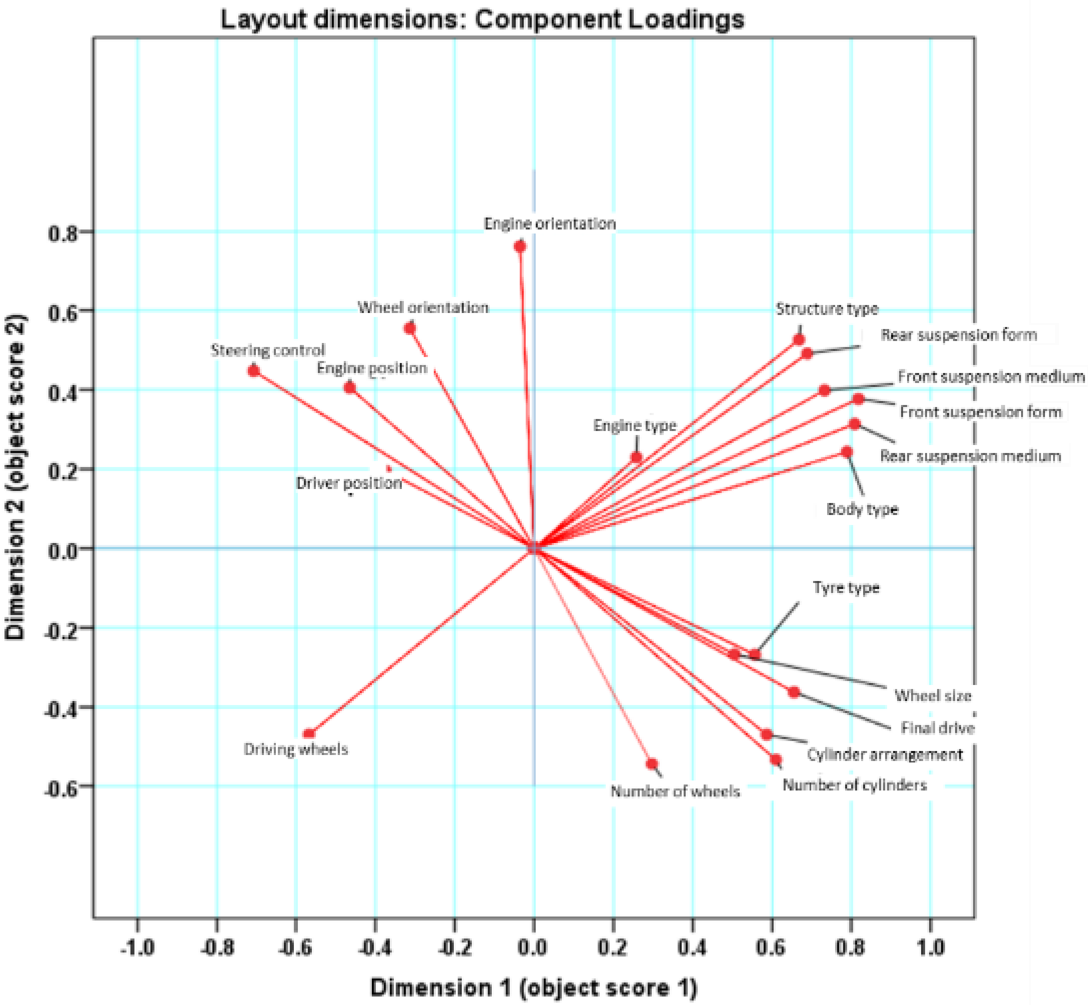


Figure 9.02 Layout variables: Component loadings (a repeat of Figure 6.08)

Figure 9.02 (which is the same as Figure 6.08) shows how the layout variables load. From Figure 9.02 it can be seen that the categorised drive wheels variable, is the only variable that loads negatively on both dimensional axes. The front suspension form variable and structure type variable load opposite, positively on both axes. These variables are the major changes from *Edwardian-vintage* to *rwd-ifs*. Normally the suspension form variable moves first, but here the structure type did. The result is not as spurious as it first appears.

The process can identify innovation in car history. This uses outliers of layout and form dimensions and classified them into a) always outsiders (i.e. for all time), b) outsiders looking backwards to previous thinking, or c) outsiders that started new design thinking – i.e. innovators. This identified several innovatory cars; 1904 Mercedes, 1922 Lancia Lambda, 1931 DKW F1, Citroën Traction Avant. These four are shown in Figure 9.03. Surprisingly, it failed to identify the BMC Mini as innovative although it is the first *transverse-fwd* paradigm car (Dowlen, 2012b).

Figure 9.03 Innovative cars: Mercedes, 1903 (The Automobile); Lancia Lambda, 1922; Citroën 7A, 1934; DKW F1, 1931

9.1.2 Interviews

Interviews complemented the numerical data, providing extra information. Although semi-structured and interesting in themselves, producing much data, they did not identify the paradigms so clearly although several interviewees talked about paradigms.

They identified issues that could not be discovered by measuring cars, such as outside issues, societal links, other manufacturing industries like aircraft, links with world events like wars and depressions. They showed that tax policy affects how products develop (e.g. after WWII in the UK). The interviewees suggested different car history eras, but most concluded the pioneer period was important even though several were not interested in it, claiming developments prior to WWII to be before their particular interest. They could identify eras that could not be identified with numerical analysis such as how Japanese companies grew in Europe and America: this did not result in physical change to car design practices, although it affected how cars were manufactured, marketed and their durability, which could not be measured numerically. This demonstrates that their perceived constructs are somewhat different from the numerically-derived perceptions of historical car periods and paradigms.

All interviewees identified that car dates identify and categorise them. Most clustered the cars using date-related clusters, even when they said they used personal preference and when they didn't identify the cars. This indicates time-based similarities are more significant than other categorisation possibilities, suggesting that they do, indeed, utilise unspoken car design paradigms when categorising cars.

Interviewees tended to use decades as a shorthand for car history categories. They mentioned 'the sixties' with tacit suggestion that car design changed on 1st January 1960 and on 31st December 1969, although they all quite clearly knew that this was not the case. Decades are convenient ways to structure time, even before the individuals were born. World events like World Wars and the 1929 Depression created memorable time punctuations. Car design changed with WWI in terms of the social behaviour of car purchasers, though the physical layout did not change. WWII did not change social structures, but cemented car design concepts, burying the beam front axle, even if the main transition occurred previously.

Designers had a narrower outlook than historians; those who were neither but were enthusiasts had the narrowest outlook. They tended to decide that what was outside their specific interests was not something they could comment on. The breadth of knowledge of some people from the car industry was salutary; immersion within the industry and interest builds up significant tacit knowledge.

Repertory grids identified personal thinking processes, constructs and attachments to cars and to car history and played a fascinating part in understanding how individuals construe car history worlds and what excites and interests them about car history. For some it was an enthusiastic approach, for others an interest in history and vehicles and for others a mixture of interests, emotions and personal recollections came into play. For some, ‘play’ was the interest: for others, cars relationship with culture was more important and car history formed part of a greater insight into social or product history.

The repertory grids identified several cars that could be called iconic – Ford Model T, Mini, Land Rover, Vintage Bentley, Ferrari Dino. Austin Seven, Range Rover, Porsche 911, Chevrolet Corvette, Volkswagen Beetle, Citroën DS19, Bugatti Type 57, Ford GT40, Jaguar E Type and Citroën 2CV were also-rans. For a nine-car exhibition, this fourteen would have to be pared down – but it would miss out favourites like the Ferrari 250 SWB so beloved of one interviewee. The reasons for these being iconic are variable. Some reasons relate to layout paradigms – the Mini, Ferrari Dino and Vintage Bentley – but others are there for eccentricity – Citroëns – or for perceived beauty – Bugatti and E Type and perhaps the Citroën DS19. Whether icons are, in general, perceived as representative of paradigms was not necessarily identified, although the Mini and Ford Model T seem to be construed as representative of the transverse-fwd paradigm and a mass-production paradigm. The Repertory Grid process might hold promise for the design and assessment of car collections. The interviewees thought about what were the most representative cars and about their personal themes, in the same way that collections tend to have themes and interests.

Upon reflection, the success of the repertory grid work seems to have relied on the need for the interviewees to identify their own cars for the collection and on the strength of their connections to them. The process is mainly to be used to identify constructs and not for the purpose of building up collections of the objects. It might also have been more profitable to have carried out the affinity diagram after the repertory grid, using the nine cars that they had selected and for them to arrange and categorise them, rather than the set of cars they had been given. Similarly, this will relate the work to their personal constructs rather than the clustering of the selected cars.

9.1.3 Subsequent literary analyses

The interviews and numerical analyses were augmented by literature to identify reasons for paradigm shifts. To identify the causes of changes from the *Edwardian-vintage* paradigm to the *rwd-ifs* paradigm, technical suspension information was found. Technical data can identify the causes of the changes, and the most instructive literature was technical and not historical; Bastow and Olley identifying reasons for the 1930s technical changes (Bastow, 1987, Milliken and Milliken, 2002). Bastow does not relate historical design changes, only noting some forms as ‘early’ or ‘obsolete’. Sedgwick (Georgano et al., 2001) identified car design paradigms, calling them *shibboleths*. Few other car history texts identified thinking paradigms, although most identified eras and design trends. These were identified through outside events or by date-changes e.g. decades that artificially provide constructs.

9.2 Evaluation and utilisation

Wake (Wake, 2000) suggests that design paradigms are primarily shorthand methods of thinking that enable design to be carried out more easily. Petroski (Petroski, 1994) develops that thinking beyond the practical, where design paradigms cease to be useful tools and become liabilities when stretched beyond their intended purpose and technical remit. In one case design paradigms are formidable tools for (on behalf of) design and in the other they become negative, holding back the development of effective novel problem solutions by their presence.

Design paradigms in car history demonstrate both aspects. In the first case they can be usefully used to develop effective car models – others have done a significant amount of the hard work in the evolution of that original paradigm. It can be picked up and utilised. In some cases familiarity with both layout and form paradigms ensures customer acceptance and relatively easy maintainability. The aspect of customer acceptance is what was used usefully by Mazda, for instance, in the development of its original MX5 sports car in the late 1980s. As outlined in section 2.9, this car was developed to deliberately utilise a specific paradigm of both form and layout in order to achieve its significant success in the market. This was down to careful concept and detail design and the development of a coherent customer profile and set of requirements that went beyond the simple listing process.

In a similar way there is almost certainly scope for the deliberate development of paradigm-based thinking in the development of new car designs. This both ties into the aspects of heritage that several companies rely on and the aspects of customer delight – beyond simple acceptability (Cohen, 1995).

These aspects of the current research have not been developed, leaving scope for this synthesis aspect to be developed significantly.

9.3 Statements of contribution to knowledge

Numerical car history overview and quantitative study have produced data not available prior to the analysis. This had not taken place previously and this process has determined the direction of the research.

Prior to the analysis few commentators identified that the suspension changes in the mid-1930s created changes of the order of a paradigm shift in design thinking.

No numerical car history analyses have utilised product measurements. This approach holds promise for developing other product histories, which may not have extant literature explaining or describing thinking processes.

Numerical analysis can identify historical changes provided a small number of common variables are used. A similar approach has been carried out with popular music, using timbre, rhythm and harmony as major quantified areas rather than layout and form used in this study (Mauch et al., 2015), and Martindale used numerical processes when investigating creativity theories (Martindale, 1990). Mauch’s study was from 1960 to 2010. The later limit may have created an artificial time constraint on an unfinished study, and data before 1960 may not have been able to produce effective trends – similar to UK car sales data being unreliable before then.

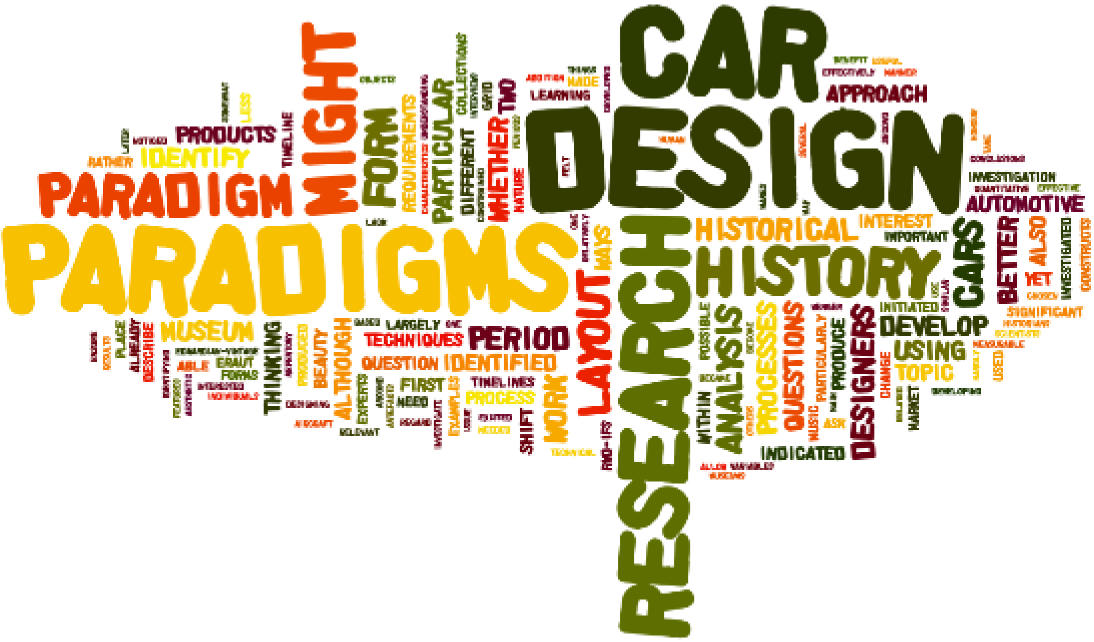
The approach is, firstly, to identify what to measure and measure it. Then to produce timelines of how those measures change over time. Changes over time are then identified by their dates and their nature, and lastly the literature is searched to identify the causes of the changes.

This may sound simplistic. Mauch used 7000 items, using an automated process to develop measurements.

The numerical process removes the narrative aspects of design history to a secondary investigation, identifying situations where narrative is crucial and placing the narratives into context with conceptual framework. What it does not do is to remove altogether the need for narrative exploration. Whilst numerical processes can answer how things changed and when things changed, and can start to point towards where to investigate narratives, they are not able to answer the reasons why changes were made, to describe what the process was for making the changes, or identifying exactly what the thinking was behind the changes. Narrative exploration is required to answer those crucial questions.

The process of eliciting, developing and understanding experts' constructs on car history and design using repertory grid techniques is one that has been used in other spheres (usually in marketing) but which has not been used in this precise fashion to seek to understand perceptions of product history. This is a novel application of the method.

10 Conclusions



10 Conclusions

The main purpose of the research project was to investigate design paradigms in car history as a broad exemplar of how historical design paradigms might be evidenced, identified, and what their characteristics might be. Chapter 3 introduced the topic of the research questions.

The first, rather broad questions were whether design paradigms exist and whether they can be demonstrated. The research has effectively demonstrated that they do exist and the lack of paradigms is not an issue.

The first research question was:

1. *What is the nature of the design paradigms that can be identified in car history?*

Car layout design paradigms and form design paradigms have been shown to have different characteristics. Layout design paradigms have a tendency to be evidenced as collections of variables that are chosen together for a particular time period, and these then change in a significant shift to a new layout paradigm. At some later point a further layout paradigm makes a further shift. With car form paradigms there is a more gradual change rather than a sudden shift. The changes are based on what might best be termed an accumulated wealth of historical car form which are seen to be related to recent car forms.

Several layout design paradigms have been described and named: the Pioneer paradigm, the Edwardian-Vintage paradigm, the rwd ifs paradigm and the fwd transverse engine paradigm, along with some lesser layout paradigms. It is not possible to describe form paradigms in a similar manner as they do not form constant lines on the timeline graphs.

An analysis of these layout paradigms indicated why they evolved and why they became obsolete, but these questions had to be resolved using a narrative process subsequent to the numerical analysis.

The topic of design paradigms was also investigated from a constructivist viewpoint. This led to a further two research questions

2 *How are car design, car history and car heritage viewed by car designers, historians and enthusiasts?*

3 *How do the answers to these two questions relate to each other?*

The interview process, although clearly identifying the research topic, did not specifically ask the interviewees about paradigms, although several talked about them. They indicated that they were designing cars and not things that met disembodied lists of requirements. They indicated that designing cars *ab initio* was no longer possible – that car paradigms already existed and that they felt bound to honour car history, thereby determining that they consciously identified that they were using design paradigms. They also indicated that they chose car examples and previous designers' work as their influences rather than the engineering design 'experts' who largely produce design work to meet a list of disembodied requirements. Another factor in their need to honour car history was their need to maintain the market requirement to design a *car* – that is, a specific thing – because that was how the market requirements were couched and what the market was expecting from their work.

All the experts had high regard for the historical traditions. The historians and industry professionals said that a good understanding of the pioneer period was important to the overall view of car history, but this was less important to some of the designers who preferred to concentrate their design history interest in the post-Second World War period. Enthusiasts might have less regard for an overview of car history, being primarily interested in their particular specialist interest, whatever that might be, and preferring to ignore what is outside of that interest.

One of the other desirable outcomes of the investigation was to produce an effective, measurable, timeline or sets of timelines that describe car history. These have been done, although it was not possible to develop an effective single timeline as multiple approaches produced beneficial results. Timelines were produced for layout and form design, using the first two dimensional variables from each analysis to produce a total of four measurable timelines.

The car came of age in the early twentieth century. The *Edwardian-vintage* paradigm started about 1904 with tightly constrained layout features. The reasons are connected with standardisation and designers' desires to produce a *car*. This paradigm remained in widespread use until around 1934. Then its technical inadequacies became too great and it was replaced by the *rwd-ifs* paradigm. From the mid-1960s the *transverse-fwd* paradigm developed alongside, largely replacing the *rwd-ifs* paradigm from the 1980s onwards. These two paradigms also contain a constrained set of layout features. During the *Edwardian-vintage* period other paradigms existed but were hardly noticed, but other ways to design cars are noticed in the later post-Second-Word-War period.

The moves to the *rwd-ifs* and *transverse-fwd* paradigms were initiated by individuals. The first paradigm shift was initiated by Maurice Olley and the second one was initiated by Alec Issigonis. These two individuals were hugely influential, each within one company which was the major car manufacturer in their country. In both cases others were reticent to follow, but this was hastened in the 1930s as General Motors is a world-wide organisation.

10.1 Suggestions for further work

10.1.1 Developing this piece of research

The research is unfinished by nature. In particular, the numerical analysis can be improved by increasing the sample size. This is particularly important where there are few individual examples in the population. These examples need careful selection to ensure range coverage and ensure significant numbers near median values – although all data provide useful contributions. If five-year periods were chosen, then 750+ samples would be needed. For single-year periods this increases to 3750+. Larger samples allow better identification of sub-paradigms using clustering techniques.

Literature from 1950 to the mid-1970s needs more investigation to identify how paradigm shifts developed during that period.

These graphical timelines have not yet been used to illustrate car history in car museums and identifying themes for historical car collections would be a welcome addition.

The affinity diagram work in section 7.2 produced somewhat inconclusive results and this indicates that the perception of historical car form would benefit from further analysis, in particular to identify whether this inconclusive nature is a generic issue or whether it might be able to be overcome by further work such as allowing the participants to derive their own items for the arrangement.

Repertory grid techniques might effectively identify key automotive museum exhibits. This could lead to ways of guiding visitors and develop museum and collection management. Contact has been made with a number of museum researchers but discussion has yet to take place.

10.1.2 Expanded research questions

An extra part of the second main research question might be to critically evaluate design paradigms in car history. This question can also be expanded into question of the usefulness or otherwise of the research as a whole. It would ask in what ways might the research be further applied to develop design thinking and in what ways does the research identify shortcomings within the processes of automotive design. It might ask whether the research identified novel ways of developing automotive design processes. These possibilities have yet to be investigated and they remain tasks for a follower to develop.

An aspect of design paradigms that has not specifically been addressed in this research is the manner in which they form in the individual designers – i.e. to investigate their learning process. It is surmised that this is likely to be by using non-traditional learning processes such are described in Singleton's compiled book *Learning in Likely Places* (Singleton, 1998), by Michael Eraut (Eraut, 2009) and by Etienne Wenger (Wenger, 1998) through community learning processes. Eraut describes these processes as being largely tacit and undocumented. Documenting them would be a useful addition to this research.

10.1.3 Wider car design topics for research

The research does not describe how to design better cars. Historical research does not change how designers think but merely identifies how they thought at the time. Designers might be able to reflectively identify their constructs and paradigms and try to enlarge their thinking, particularly in layout and technical design, which determines initial requirements for form development. The position of design paradigms as a positive, conscious influence for automotive designers has yet to be investigated.

A recurring theme in the interviews was that cars would be better if they were not boring, and that beauty should be rediscovered. One interviewee criticised current car design: “we’re currently in a period of relatively gross styling that over-aggressives what should be quiet recessive products and makes them look hideous”. Ways to develop and assess beauty are needed.

Attempts at determining exactly what construes beauty within cars and whether (or how) it might be measured links with other work into the quantification of both novelty and beauty which has been taking place using things such as the Wundt curves as a starting point for measuring aesthetic perceptions (Baxter, 1995). No attempt has been made in this research to carry out a comprehensive literature search in this topic as it is hardly related to the investigation of historical design paradigms and thinking.

10.1.4 Other products and uses

Other products would benefit from similar timely analyses. Many consumer durables lend themselves to the approach. Commercial vehicles, motor-cycles, railways and aircraft have similarities and generally have enthusiastic followings. The process may require modification to allow for disruption for trains and aircraft (Christensen, 1997, Constant, 1980). Electronic products like computers would also be suitable.

The repertory grid museum suggestion is broader than automotive museums and could result in more accessible collections: visitors become overwhelmed and this could focus them on what has interest in the museum and why. Museum curators’ constructs are valuable in developing museum essence and branding.

This quantitative approach has already been taken in several areas by Martindale (Martindale, 1990) and in particular with music (Mauch et al., 2015). They contrast their approach with that of philosophers, sociologists, journalists and pop stars; “Their accounts, though rich in vivid musical lore and aesthetic judgements, lack what scientists want: rigorous tests of clear hypotheses based on quantitative data and statistics Economics-minded social scientists studying the history of music have done better, but they are less interested in music than the means by which it is marketed.” (page 1) They suggest their approach is more amenable to analysis.

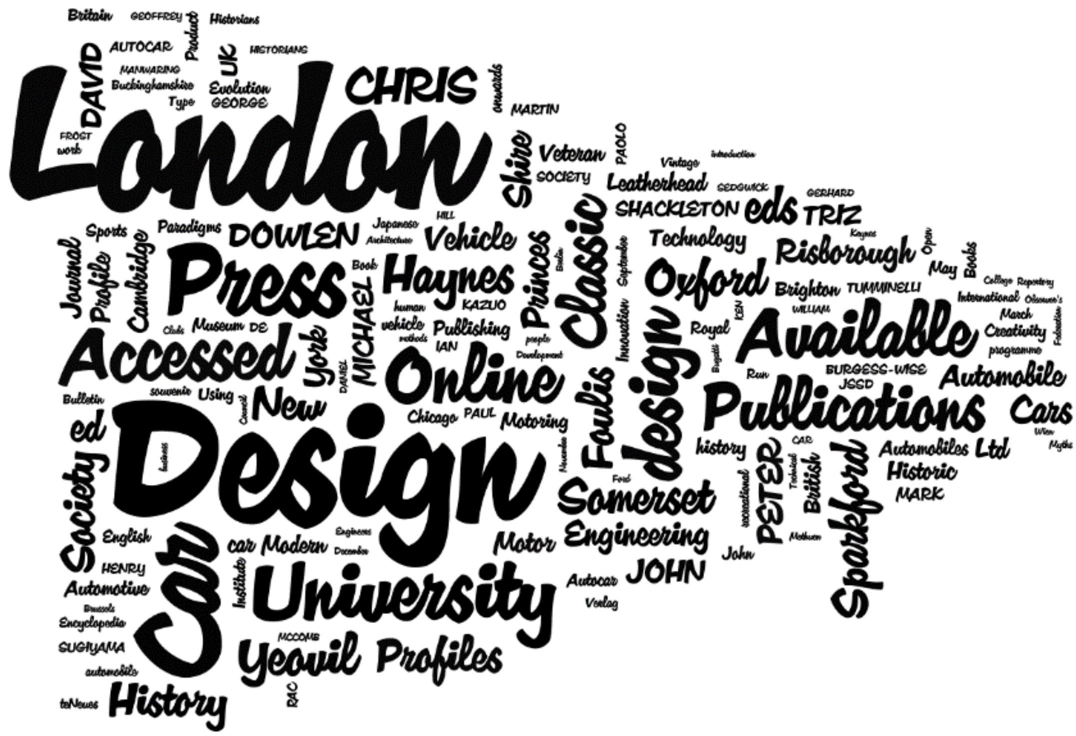
Other artistic forms might be measured and trends and styles identified through the processes, although interplay of function and style may not be so pronounced as with cars.

Repertory grids have already been used to develop reflective product-related thinking for first-year design students. They were asked to use them as a self-reflective tool to uncover their relationships with designed objects. They selected nine objects that they felt were particularly relevant for themselves, and then carried out a triadic analysis on them, some better than others.

This particular technique might have wider applications, not just in relation to design research. It stands alongside techniques like Delphi (Baxter, 1995) that might be used to identify thinking paradigms for groups of experts in any sphere, resulting in a relatively speedy development of the topic of understanding for the interviewer. Interviews play a significant role within journalism, and it might be worthwhile for a journalist to take a repertory grid approach towards eliciting the constructs of their interviewee. Such interviews would, of course, have different rules for privacy.

Human history is somewhat larger than cars. These have only been around in the last hundred and thirty years or so and form a minute proportion of the greater body of historical artefacts. Human loves, lives and products will continue with different layouts and forms in different eras. The analysis techniques will still be relevant long after the artefacts have become ancient history. Is the world made a better place because of cars? Only the future judgement of history will be able to decide.

11 References



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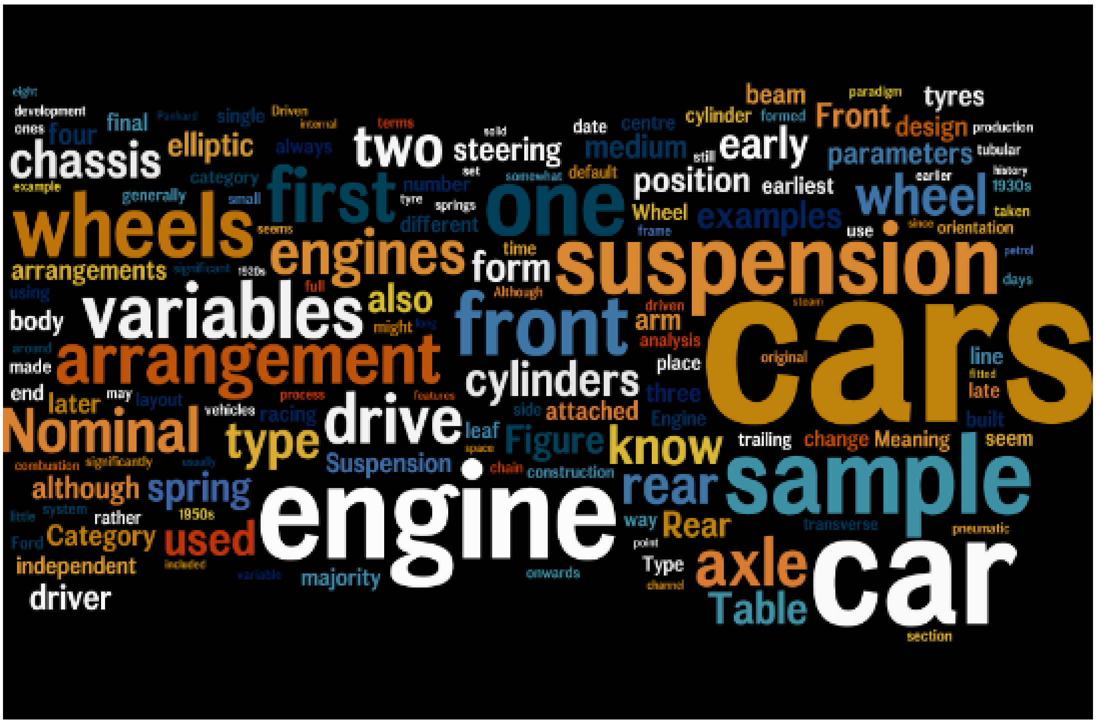
Design Paradigms in Car History

APPENDICES

Chris Dowlen

A1 Expanded Layout analysis



A1 Expanded Layout analysis

A1.1 Layout Variables

Nineteen layout variables were chosen. These are listed as follows:

Parameter	**Type**	**Parameter**	**Type**	**Default**
Engine position	Nominal	Engine Type	Nominal	Reciprocating (Petrol)
Crankshaft Orientation	Nominal	No of Wheels	Nominal	4 wheels – category 5
Driven Wheels	Nominal	Wheel Orientation	Nominal	2F2R
Cylinders	Numeric	Wheel Sizes	Nominal	Same
Cylinder Arrangement	Nominal	Steering Control	Nominal	Wheel
Front Suspension Form	Nominal	Final Drive	Nominal	Shaft
Rear Suspension Form	Nominal	Driver Position	Nominal	Front, Side
Front Suspension Medium	Nominal	Tyre Type	Nominal	Pneumatic
Rear Suspension Medium	Nominal			
Structure Type	Nominal			
Body Construction	Nominal			

Table A1.1: Layout parameters

The reasons for the choice were that these were generally seen as variables or parameters that were essential features of a car, rather than features of, say, an engine. There could have been more parameters that were included. More engine design features and characteristics could have been identified such as valve arrangements, induction and ignition arrangements, for instance, and things such as the type of transmission, braking, steering and fuel systems could have been included. In some senses the parameters chosen were somewhat arbitrary. Initially it was felt that selecting too many parameters to analyse might simply have indicated that some were irrelevant, but without actually carrying out that analysis the relevance of a particular non-analysed parameter cannot be ascertained.

It should be noted that in terms of a steam engine, the engine position is that of the engine and not of the boiler which takes up a considerable extra space. Although none of the analysed cars have the arrangement, it is quite possible that a car might be a hybrid with electric motors dispersed and a single internal combustion engine located elsewhere. It is the location of the internal combustion engine that would be noted as the engine position in this case.

Of these nineteen parameters, six refer to engine-related design parameters, including where the engine is to be located, four refer to suspension parameters, four to the wheels and tyres in some way, two to physical construction issues, two to control parameters and one to the transmission arrangements. The number of wheels, their arrangement, where the engine is placed and where the driver is placed also have physical arrangement properties, although the physical space arrangements are perhaps implicit in the choices of several other parameters. For instance, if an engine is to be placed transversely, then the number of cylinders and their arrangement is normally limited to an arrangement that will fit into the space between the wheels, although some ingenious detail design solutions have been used to try to fit large engines transversely. Whilst all the parameters are deemed to be fundamental parameters, some are not what might be termed top level parameters: ie their choice is dependent on a choice made in one of the others. Thus the number of cylinders to be chosen is only relevant if the designer has first decided to use a reciprocating engine, and the cylinder arrangement is only relevant if the decision has been made to have more than one cylinder.

A1.2 Default variables

The parameters on the right of Table A1.1 were largely set up relatively early on in car history and it was decided that having a default value was a sensible way to deal with them. It doesn't mean that they have remained constant after the particular date that they seem to have been adopted, but that the vast majority of cars follow the default value.

It makes sense to discuss these variables first. These are not givens for all cars: simply variables that tend to be the norm for them. The norms can and do change, however, as witness the growing numbers of cars sold in the UK with diesel engines rather than petrol engines from the late 1990s onwards.

Parameter	**Type**	**Default**
Engine Type	Nominal	Reciprocating internal combustion engine (Petrol)
No of Wheels	Nominal	4 wheels
Wheel Orientation	Nominal	2F2R
Wheel Sizes	Nominal	Same
Steering Control	Nominal	Wheel
Final Drive	Nominal	Shaft
Driver Position	Nominal	Front, Side
Tyre Type	Nominal	Pneumatic

Table A1.2 A subset of Table A1.1 to include only the variables that have default numbers.

A1.2.1 Engine type

Category	Meaning
0	Don’t know
1	Steam
2	Reciprocating (Petrol)
3	Electric
4	Gas Turbine
5	Rotary (Petrol)
6	Reciprocating (Diesel)
7	Electric (Solar)

Table A1.3: Engine type

In the New Oxford English Dictionary the definition of a car (Pearsal and Hanks) states that it is powered by an internal combustion engine. So this aspect of the default is put firmly into place. The conventional inventors of the car were Gottlieb Daimler and Karl Benz, both of whose contribution was largely to add internal combustion engines to road vehicles. Private vehicles powered by other power sources had been built before that, so technically neither Daimler nor Benz built the first cars.

This may seem to be the most important parameter for any car designer – but it is also one of those parameters that does have different norms during the life of the car, and the way that the rest of the car is designed is essentially determined by the engine type that has been decided early in the conceptual process, arguably before even an inkling of the design has been carried out. It is fundamental.

The very earliest cars were steam powered. But there were very few of them, so the steam era does not figure very large in car history, and although Olley mentions that early car designers were familiar with steam technology (Milliken and Milliken, 2002), this familiarity seemed to have been ignored after around 1905. From then on, cars were powered by internal combustion engines burning petrol, ignited by a spark. Yes, until Dr Diesel's invention found its way into cars. The first diesel-engined car was reputedly a Mercedes-Benz in 1936 (Lengert et al., 2006) but this did not herald a stampede to put diesel engines in cars and the process of so doing was a very slow one, with 50% of the UK car market only being reached in July 2010 (Wray, 2010). In the 1960s and 1970s the piston engine was challenged by the rotary engine in the form of the Wankel engine. Rotary-engined cars have been put into production from the NSU Spider onwards and although development has continued, primarily by Mazda in Japan, the rotary engine does not look as if it will challenge the default piston engine. At least for the moment. Since the late 1990s, however, there seem to have been other challenges to the straightforward petrol-powered piston-engined car from cars using hybrid technology and from electric propulsion. A few hybrid and electric cars have found their way into the Car of the Year lists since the first version of the Toyota Prius in 2001, but sales are not a high proportion of cars in the UK market – yet. There are a few (usually earlier) electric cars in the current sample, but no hybrid ones.

The categories were originally ordered on logical considerations. The general process is that categories should be ordered with the earliest first. 'Don't know' was always taken as 0, as this means that that will be ignored by the calculation. There are no cars with no engine as this is taken as fundamental (if the photograph was of a model car then the decision as to the engine type was that of the real car). Steam was placed at 1 because that was before anything else. Electric came next as that was generally an earlier form of engine type, and then petrol engines came in at 3. Reciprocating diesel engines were set at 4 as there is a similarity to the reciprocating petrol engine, with the rotary engine at 5 and gas turbine at 6 being different forms of an internal combustion engine. Solar power is definitely not a serious production suggestion and so it has been placed at 7. In the case of this variable, there are no cars that have no engine at all and so 'no engine' is not an option. They were then reordered in terms of the date of their first appearance in general usage, as in Table A1.3 above. This was a more consistent decision that was able to be applied to several of the variables. Steam is the first category in time terms, in that steam cars were generally around before petrol-powered ones. Reciprocation engines powered by petrol then come next, followed by the electrical cars. The first (few) cars with gas turbine engines appeared in the 1960s, as did the first cars with rotary engines. Although the first diesel engine was probably fitted to a car by Mercedes-Benz in the 1930s (Lengert et al., 2006), the earliest car in the sample fitted with a diesel engine is a Mercedes-Benz 190D of 1985, as that type of fuel was starting to be used more and more. Finally, the first solar powered cars were built in the 1990s, and two of these were in the original sample, if marginalised.

A1.2.2 Number of wheels

The New Oxford English Dictionary (Pearsal and Hanks) says that cars typically have four wheels. Very few cars have been built with three wheels, but a few of them find their way into the sample – usually from photographs taken for curiosity value or interest rather than from any attempt at effective representation. A few cars have been made with different numbers of wheels, but none of them appear in the survey.

It was difficult to discover how many wheels one car had from the original 453 cars, so the 0 position had to be filled originally, although it was later discovered that it has 4 wheels, with the rear ones closely spaced. Category 1 is for cars with three wheels and category 2 for the vast majority with four wheels.

Three-wheeled cars have always seemed to be a subset of cars – looked down upon by those who feel that every car needs to have four. There is a story of an American who came to Britain and when he saw a Reliant for the first time made some comment about “Of all the things that might be left off a car, only the English would think about removing one of the wheels”. It’s probably apocryphal. The reality is that they do not seem to offer very much, if anything, in the way of benefits. They may offer lower rolling resistance and have fewer components, but as they are produced in such small numbers this last does not offer price advantages. The space utilisation of a four-wheeler is much better, as is the cornering and the handling. And the engineering required to get them to behave at least respectably is unconventional. Few people have novelty high on their list of attributes when buying a car.

In the original set of cars there was one car in the analysis that needed a category to itself. This was a Citroën Kegresse from 1925. It is debatable whether it is a car at all, and it was removed from the database analysis later. It has two wheels at the front and has tracks at the rear – a half-track. However, the body shell indicates that it has been based on a car and thus it was originally included.

Category	Meaning
0	Don’t know
1	3 wheels
2	4 wheels
3	2 wheels and 2 tracks, originally

Table A1.4 Number of wheels

A1.2.3 Wheel orientation

For the vast majority of cars, this is two at the front and two at the back – as one might expect from general experience of cars. Three-wheeled cars have a choice of wheel orientation, usually between two at the front with one at the back and one at the front, two at the back. But there are two cars in the survey with two wheels on one side and one on the other, like a motorcycle combination. One is the Scott Sociable of 1921 and the other the solar-powered car built by Monash University in 1990. There is one car with a diamond arrangement of four wheels – the 1901 Sunbeam Mabley, which looks a bit like a mobile Victorian sofa and has a number of other unconventional details

.

Figure A1.01 Scott Sociable, 1921:

Figure A1.02 Monash University solar car, 1990

Figure A1.03 Sunbeam Mabley, 1901

Whether the most common category should be 1 rather than 4 is debatable.

A revised set of categories based on date is suggested.

Category	Meaning
0	Don’t know
1	2 Front, 2 Rear
2	1 Front, 2 Rear
3	2 Front, 1 Rear
4	Diamond
5	One on one side, 2 on the other
6	2 front, tracks to the rear

Table A1.5 Wheel arrangement

A1.2.4 Wheel sizes

In the early days cars had smaller wheels at the front than at the rear. This arrangement was probably a hangover from coaching days where smaller front wheels were required as horse-drawn carriages used centre point steering systems with the requirement that the rotation of the front wheels needs to place the wheels under part of the body. Although this part of the body was normally higher for exactly this purpose, smaller diameter front wheels lessened the need for excess height. This arrangement quickly changed so that cars had equal sized wheels at the front and rear. The adoption of equal sized wheels front and rear seems to have been effectively complete by about 1900.

Figure A1.04 Daimler from 1900 showing a clear difference in wheel sizes. This also shows a chaincase for the final drive chain just forward of the rear mudguard and solid tyres.

Category	Meaning
0	Don't know
1	Rear larger
2	Same (and nearly the same)

Table A1.6 Wheel sizes

A1.2.5 Steering Systems and Steering Control

As noted above, centre point steering systems have not generally been used in cars. Although a fundamental decision of early car manufacturers might have been whether they had stub axle or centre point steering the decision was made not to include this as one of the parameters, largely because, apart from three wheelers with a single steered front wheel, there are only six cars in the sample that have this arrangement. As a subsidiary note, centre point steering systems are still used for trailer arrangements for cars and small vans pulling trailers where the trailer hitch forms the steering pivot, for articulated heavy goods vehicles using what is called a fifth wheel pivot for the semi-trailer, and for several earth moving vehicles using what is known as pivot steering.

The topic of how the steering is controlled, however, was included as one of the parameters. The vast majority of cars are steered using a steering wheel. But when the change from horse-drawn vehicles occurred, the need for steering control was novel – it hadn’t been necessary where the horse steered the carriage round the corners by pulling it, and it wasn’t necessary on railways or tramways where the tracks guide the vehicle.

In the early days there were all sorts of different ways of steering a car round a corner. By about 1904 this was largely resolved and most cars since then have had steering wheels, although there were a few that persisted with tillers for longer and a few marginal cars such as the 1950s Messerschmitt have had handlebars. There were two cars where the steering control was not known. One was a 1955 Nardi Le Mans car that was built on a twin-boom arrangement: it was later found to have a conventional steering wheel, but flattened at the bottom. The other car was a German Solar Car where very little of the cockpit could be seen, and it wasn't possible to find out what they had done, although most solar cars have had steering wheels simply because the driver is familiar with how to use one to turn corners.

Category	Meaning
0	Don’t know
1	Wheel
2	Four-spoked control
3	Coffee Grinder
4	Tiller
5	Handlebars
6	Rear Tiller
7	Horizontal Coffee Grinder
8	Side Tiller

Table A1.7 Steering control

Figure A1.05 Cars without steering wheels: De Dion Bouton (1901) with a coffee grinder

Figure A1.06 Cars without steering wheels: Oldsmobile (1904) with a tiller

A1.2.6 Final Drive

The majority of cars have shaft final drive. This was adopted as a standard a little later than most of the other defaults and there have been more cars built with other forms of drive from time to time, particularly if the car is a little on the margins of conventionality – perhaps it's a three wheeler using motorcycle components, for instance.

There are three major systems of final drive used in cars: shaft, chain and belt. Chain drive was the norm until about 1904: it was superseded gradually from before the turn of the century. Surprisingly, in mainstream cars, it was the larger cars where chain drive held on longest and there are examples of large chain drive cars in the sample as late as the 1912 Bugatti Black Bess. But chain drive has always been used for cyclecars and in the 1920s cars such as the GN (in the sample) and Frazer Nash (not in the sample) were chain drive until the 1930s. Three wheelers that are driven by a single wheel (such as Morgans and bubble cars) almost always have chain drive. In the 1950s the Dutch company DAF developed a belt-driven continuously-variable transmission system for the final drive of their cars and used this until after they were taken over by Volvo in the 1970s, since when variations of it have been developed into continuously variable transmissions for small cars, but using steel belts rather than rubber ones, and usually encased within the main transmission housing rather than in the final drive arrangements, which will still normally be by shaft.

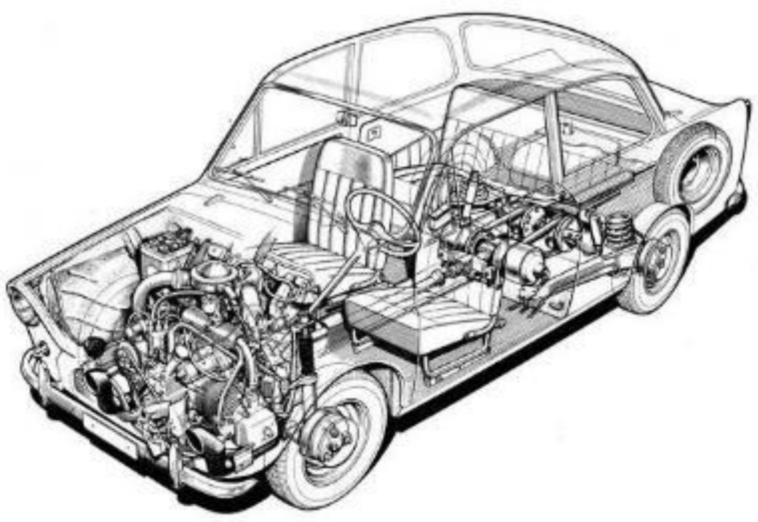


Figure A1.07 DAF 600 (1955) clearly showing belt final drive (Fair use: courtesy of The Society of Automotive Historians, source: SAH Journal #242)

Figure A1.08 Bédélia (1913) clearly showing belt final drive

There are a few oddities in the sample: apart from the 1955 DAF, the Bédélia cyclecar used belt drive transmission and the Nef Nef (about 1906) and its variations also used it – these are really hang-overs from the early days. Steam driven and electric cars frequently connect the engine directly to the drive wheels and may not have a final transmission at all, or use a ring gear as was used by Stanley in the 1900s.There is one car using a propeller drive – the Leyat Helicar from 1922. But not a majority arrangement, and the Amphicar supplements its rear wheel drive for road use with a pair of screws for use in water.

Category	Meaning
0	Don’t know
1	Chain
1	Probably chain
2	ring gear
3	Shaft
3	Probably shaft
4	Belt
5	Shaft plus propeller

Table A1.8 Final Drive

A1.2.7 Driver Position

The conventional place for a driver is to be at the front and on one side, giving space for a passenger alongside. But not all cars have the driver at the side – Grand Prix racing cars are required to be single-seaters and it is normal on these for the driver to be central (but it isn’t always the case). Single seater racing cars have been removed from the analysis as they are not road cars and their development arguably takes a different course as they are significantly constrained by racing regulations. There are some other examples in the sample where the driver sits in the centre: some early taxis, the 1930s Panhard Dynamique, the tandem-seat Leyat, Bédélia, Messerschmitt and Scootacar and the 1990s Elswick Envoy that was driven from a wheelchair in the centre. It may be a bit surprising to know that there were some cars that were driven from the rear set of seats. These were mostly vis à vis cars from the early years, but even as late as the first world war there were some American electric cars such as the Detroit Electric which had this arrangement. Another arrangement with the driver at the rear was where the forecar, usually based on bicycle technology with a basket chair or similar at the front of a cycle-seated driver at the rear. This arrangement is still used for cycles where children are seated in a front compartment – it is akin to pushing a pram in front. There were apparently a number of cars from the early years where the driver sat behind the main passenger compartment in the manner of the driver of the horse-drawn Hansom Cab, but there were none of these in the sample. Note that if the driver simply sits behind a rather long bonnet rather than in the second set of seats this is still perceived as located at the front. There is also the assumption that the driver sits. Other arrangements are possible, but no cars in the sample have them.

Category	Meaning
0	Don’t know (no cars fitted into this category!)
1	Front, centre
2	Front – not sure whether this is centre or side
3	Front, side
5	Rear, centre
4	Rear, side

Table A1.9 Driver position

Figure A1.09 Top left: Detroit Electric – driver at the rear: Top right: Bédélia – driver in the centre at the rear: Lower left: Panhard Dynamique – driver in the centre: Lower right: De Dion Bouton Vis à vis – driver at the rear

A1.2.8 Tyre Type

Early cars had solid tyres. In the very early days some cars had iron tyres – three in this sample, the latest being the Panhard of 1893 – but most had solid rubber tyres. The development of the pneumatic tyre is described in Bijker's book which includes the development of the bicycle (Bijker, 1997). However, the pneumatic tyre quickly became adopted for cars. The first car with pneumatic tyres was reputed to be a Peugeot of 1895 that was fitted with pneumatic tyres by Michelin. From that date the adoption of pneumatics seems to have been very swift, such that after 1900 it is a rarity to see cars with solid tyres at all, although these continued to be used by commercial vehicles for some considerable time – well into the 1920s. The only three cars in the sample after 1900 with solid tyres are a 1908 Black – an American High-wheeler (these were noted as being somewhat behind the times in their approach) and the 1922 Trojan, where Leslie Hounsfield, the designer, argued that the suspension was so soft that it didn't need pneumatics, although many were sold with them. The half-track, of course, has a category to itself.

Category	Meaning
0	Don't know (no cars fitted into this category!)
1	Iron
2	Solid rubber
4	Pneumatic
5	Pneumatic tyres and rubber tracks

Table A1.10 Tyre type

The changeover to pneumatic tyres from solids took a surprisingly short time as far as cars were concerned. Despite the fragility of early pneumatic tyres and their susceptibility to punctures, they show several considerable advantages over solid tyres. The main advantage is that they allow a car to go faster. This may not be immediately obvious so an explanation is helpful. The reason is that with a solid tyre, minor road imperfections require the wheel to be lifted to pass over them. With a pneumatic tyre the tyre deflects and the wheel does not need to be lifted. Thus less energy is required to propel the vehicle. Solid tyres also start to heat up significantly due to eddy currents in the rubber beyond a speed to about 20mph, which also limits their use on road vehicles. The other advantage of pneumatic tyres is the more obvious one that they provide a cushioning effect for the occupants and also for the rest of the mechanical components and vehicle structure, which means less fatigue damage to both.

The changeover from iron tyres took place earlier and only the first few cars in the sample were fitted with iron tyres. They have the obvious disadvantage of sliding on the majority of relatively flat road surfaces, and this affects adhesion for traction, braking and cornering.

A1.2.9 Default variables - summary

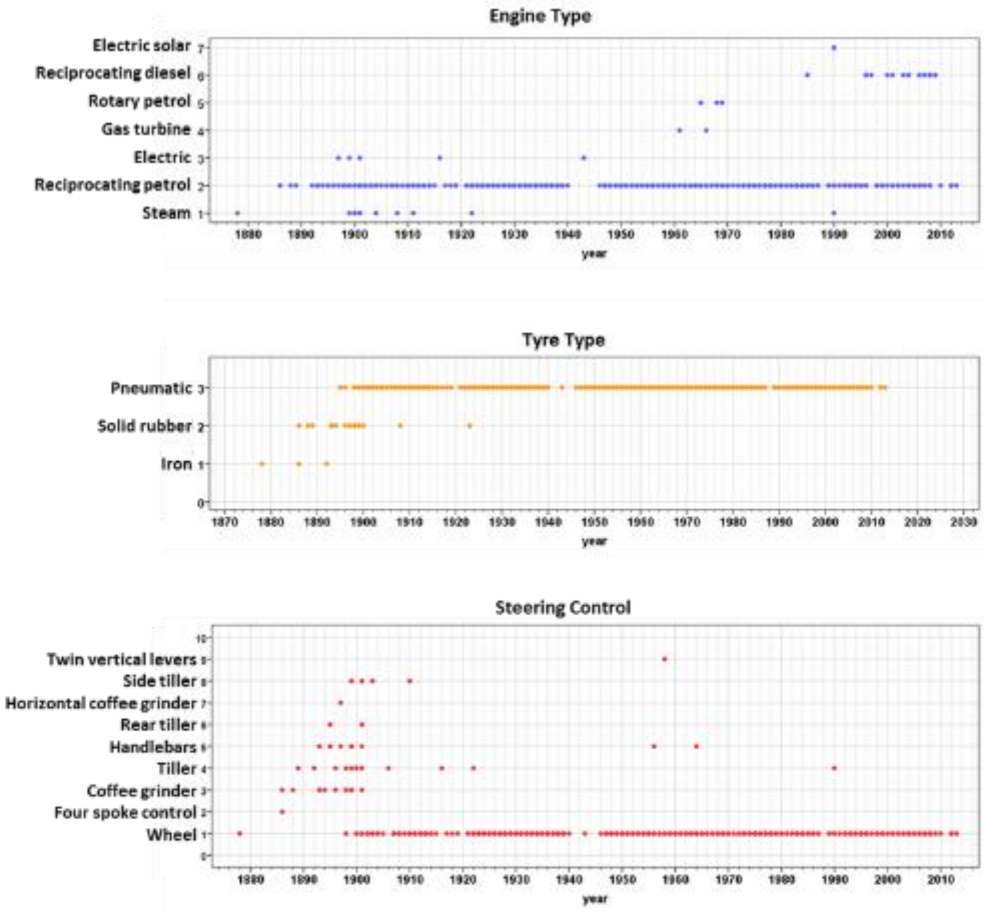


Figure A1.10 Default variables plotted against date

The above plot shows all of these default variables plotted over the top of each other, which admittedly shows a somewhat confused picture. However, it is clear when each of the variables stabilised and how this took place from looking at the fit lines for each variable. There are three variables that indicate that the default position has at some point in time not necessarily been the reigning paradigm. These are the engine type, final drive and the tyre type. The later variations of engine type and the inclusion of significant challenges to the position of the petrol engine can be seen on the right of the diagram in the mid-blue markers at number 6 - cars with diesel engines. The final drive type seems to have changed paradigm from chain final drive in the earlier periods to shaft drive between 1905 and 1915. From the somewhat confused plot of tyre type, the changeover comes as a step rather than the gradual change line shown above and it occurs between 1995 and 1900. All the other variables seem to have had a number of choices before they settled into a normal paradigm. Final drive and steering control seem to have stabilised last in this group of variables at 1915 and 1909 respectively; the stabilisation for wheel sizes and tyre type was earlier, at around 1901. Number of wheels and their orientation seem to have always been at their default levels from the earliest days, and the driver position seems to have generally been the same, but there is some variation seen before 1920, with a few examples of cars with a central driver in the 1930s, one in the 1950s, one in the 60s and one in the 1980s - the Elswick Envoy car driven from a central wheelchair.

Figure A1.11 Elswick Envoy, 1985

It has perhaps been noticed that if a car deviates from one of the default parameters in some way, then it is reasonably likely that it will also deviate from one of the others – in other words, unconventional thinking in one particular area tends to make it more likely in another.

A1.3 Other layout variables

These were not determined so early on in car history and there is significantly more variation in them throughout car history.

Parameter	Type	Zero	Parameter	Type	Zero
Engine position	Nominal	Don't know	Front Suspension Form	Nominal	Don't know
Crankshaft Orientation	Nominal	Don't know	Rear Suspension Form	Nominal	Don't know
Cylinders	Numeric	Don't know	Front Suspension Medium	Nominal	Don't know
Cylinder Arrangement	Nominal	Don't know	Rear Suspension Medium	Nominal	Don't know
Structure Type	Nominal	Don't know	Driven Wheels	Nominal	Don't know
Body Construction	Nominal	Don't know			

Table A1.11 Other layout variables – a subset of Table A1.1

The eleven other variables above were chosen for analysis. Four of these relate to the engine design, four relate to suspension design, two what might loosely be called to the structure, and the last to which wheels are driven.

A1.3 Other variables

A1.3.1 Engine design variables

These four variables are basic ones that relate to the engine design. Many other variables could have been added to the list such as the location and type of valvegear, arrangements for lubrication, and so on. These basic ones were chosen because they are among the first ones that the designer considers, and they are fundamental to how the car is arranged and how the engine behaves. The first two of these, engine location and crankshaft orientation, relate to how the engine is arranged in the vehicle and the other two, the number and arrangement of the cylinders, are the province of the engine designer but have larger overall consequences.

A1.3.1.1 Engine position

Category	Meaning
0	Don’t know
0	No engine
1	Front
2	Mid
3	Mid-rear
4	Rear

Table A1.12 Engine position

The ordering here is not done by date order, but by the position of the engine in the car. Most cars have the engine at the front – over 250 out of the original 453 in the sample. This has been the predominant position throughout the history of the car, with the first car in the sample with a front engine (in this case a steam one) being the earliest overall – La Mancelle by Amedée Bollée, built in 1878. The overall concept of having an engine at the front and driving the rear wheels is generally called the Système Panhard after the second earliest in the sample with this arrangement, the 1892 Panhard. Although most cars have had the engine in the front throughout car history, in fact the engine position behaves a little like one of the default variables in that there were significantly more cars with the engine elsewhere before about 1900. The mid-engine position is determined, in this sample, as being an engine that is fitted under the front seat position. There were a significant number of American cars with engines in either this position – or slightly further aft – at the turn of the century, and these combined with other specific features to become, effectively, a ‘design cluster’ or design paradigm, although there are some detail differences between them as a group. They developed into the High wheelers of the early years of the century, but were a dead group by about 1910. In the 1920s the Trojan had its engine under the driver’s seat even though it looked conventional enough. The TARF twin-boom car also has its engine in this sort of position – but on one side – and the Fiat-Ford BDA drag car has been included in this category as although the engine could technically be called at the front, it is hidden under the main part of the lift-up body shell with the driver seated just above the rear axle line. What is called the mid-rear engine position, where the engine is substantially in the rear but is in front of the rear axle line, was only used by the Detroit Electric (which arguably harks back to the early American cars in concept), the 1924 Rumpler, Auto Union Grand Prix car of the late 1930s and some bubble cars before being taken up by the racing fraternity in the 1950s as providing a better solution for racing – a lower polar moment of inertia and lower overall car than with a front engine. Although this approach was really started by the Cooper in the late 1940s and 1950s the first car in this sample with the arrangement is a Ferrari sports-racing car: somewhat paradoxically because Ferrari was one of the last Grand Prix companies to espouse the arrangement. The first production car in the sample (as opposed to a racing car or sports-racing car) is the Matra-Bonnet Djet of 1966, which was introduced in 1962 and beat the more commonly quoted Lamborghini Miura to it (and also beat the de Tomaso Vallelunga by one year – this is not in the sample). This layout is now commonplace for performance cars. The ‘full’ rear engined layout, where the engine is either over the rear wheels or behind them, was the favoured arrangement in the very early days of the car, but was quickly taken over by the front location from about 1901 onwards. The cars with rear engines have since then been either somewhat marginal – small, motorcycle-engined devices – or were generally a group of cars emanating from the work of Porsche and his disciples in the 1920s and 1930s – but hanging on until the 1980s and since, with some still being produced with the engine in this position, notably the Porsche 911. There are three exceptions in the sample – an Alpine, Hillman Imp and the De Lorean. The Alpine and the Imp might justifiably claim to be descended from a group of European Post-Second World War economy cars, while the De Lorean’s ancestry is somewhat strange and it seems to have had features that were simply the particular whims of its creator.

A1.3.1.2 Crankshaft orientation

Category	Meaning
0	Don’t know
0	No engine
1	Longitudinal
2	Transverse
3	Vertical

Table A1.13 Crankshaft orientation

Or more technically, engine drive shaft orientation. For all reciprocating engines this will be the crankshaft orientation.

The sequencing of this variable is done in order of frequency of occurrence.

The majority of cars have longitudinal crankshafts. In the sample, this is more prevalent than front engines, with more than 350 having this arrangement. The earliest car in the sample with a longitudinal crankshaft is Amedée Bollée’s La Mancelle of 1878 – in other words, the earliest car in the sample. The 1892 Panhard, after which the Système Panhard is named, is the second earliest. This arrangement, with a longitudinal engine crankshaft and rear wheel drive is the majority arrangement, but a significant number of cars with front wheel drive and with rear and mid-rear engines also have longitudinal engines. There were always a few cars, usually with small engines and motorcycle derived mechanical arrangements, with transverse engines before the Morris Mini-Minor was introduced in 1959 to set a revised paradigm in which transverse engines and front wheel drive was the norm. The transverse mid-rear engine was effectively introduced through the motorcycle-derived 500cc racing cars from the late 1940s and early 1950s, with the first cars in the original sample with this arrangement being the BMC Zanda styling exercise using Austin Maxi mechanicals – but this was never built into a running vehicle – and the production Lamborghini Miura which somehow managed to arrange a 4-litre V12 engine transversely behind the driver. The original sample did not really contain enough cars from the later years to track the development of the transverse engine adequately and more data needed to be added to pick up the date that this arrangement became part of a design paradigm for cars. This becomes more obvious when the data for the UK best sellers is added.

There are only two cars in the sample with the crankshaft arranged vertically, both of them very early Benz examples from before 1890. There have been a few other cars with this arrangement since, but it has always been extremely rare. Apparently Karl Benz felt that arranging the crank otherwise might have caused some vibrations to affect the behaviour of the car as a whole, so the first few cars he made had this arrangement.

A1.3.1.3 Number of cylinders

Category	**Meaning**
0	Don’t know
1	0 – this car does not have cylinders or rotors in its engine
2	1
3	2
4	3
5	4
6	5
7	6
8	8
9	12
10	16
11	1 rotor
12	2 rotors
13	3 rotors

Table A1.14 Number of cylinders

The majority of cars in the sample have four cylinders. There are 295 in the sample with four and 85 with six, giving 380 with either. There are 111 cars with less than four, which tends to signify some kind of marginal car even though significant numbers of some of these were made. In Europe, cars with five or more cylinders may be considered as either some form of luxury or as racing cars: in the United States and Australia, however, six and eight cylinders are considered normal. The latest US car in the sample with four cylinders is the Ford Model T of 1924: this doesn't mean that later four-cylinder cars were not made, simply that they were not included in the sample.

There is one car in the sample with sixteen cylinders: the V16 Cadillac of 1932. Few cars have had this many cylinders, and even fewer of these have been series production cars for sale to customers. There are 17 examples of twelve cylinder cars in the sample, with examples from Pierce, Daimler, Packard, Maybach (2), Delahaye, Ferrari (7), Jaguar (2), Lamborghini and Voisin. Some of these were designed for racing purposes and the others are luxury road cars, including luxury sports cars.

In terms of dates, the first cars had single-cylinder engines, and these remained common until about 1910, although there were fewer proportionally from 1900 onwards. After 1910 the only cars in the sample with single cylinder engines are the Hanomag Kommisbrot and Aero from the 1920s, the bubble cars of the 1950s and 60s and the JDM Orane Microcar from 1996. The first twin-cylinder car in the sample is the Daimler Stahlradwagen from 1889, and they were quite common during the Edwardian period. From the end of the First World War onwards twin-cylinder cars seem to have been related to motorcycle technology rather than car technology, with frequent use of air cooling, Vee-type arrangements and two stroke engines, although not all at once. The current Fiat 500 is available in a two-cylinder version.

Three cylinder engines have always been in a minority, and the sample only has seven examples of these: a Scott Sociable from 1921, a Saab 93 from

1953, Auto Union 1000SP from 1963, BL Technology ECV3, Citroen Eco 2000, Vauxhall Corsa and a Ford Focus. The ECV3 and the Citroen were never intended as production cars. The Scott has a number of other features about it that render it un-car-like as it has three wheels with one on one side and two on the other and was, in any case, made by a motorcycle company. The Saab used a development of the DKW engine, which was essentially the same as the one in the Auto Union 1000SP. The Scott, Auto Union and Saab are all two-strokes – another minority in car design. The BL Technology ECV3 was built to demonstrate possible directions for the then British Leyland car companies, and the Citroen was likewise built to demonstrate future possible developments. Essentially the cars used a number of unconventional design features that it was felt might be able to be included in future cars such as an aluminium body shell and three-cylinder engine. These have both been taken up since by car manufacturers – the Audi A2 from 2001 – 2004 used both (not in the sample). The Vauxhall and the Ford demonstrate a recent development in economy cars where the idea is that the smaller-engined cars should still retain cylinders of a particular size as these are shown to be more efficient – the previously unconventional three-cylinder is starting to become more accepted, following the research.

The first cars in the sample with four-cylinder engines are from 1900: the Napier and Gardner-Serpollet, in this instance. The Gardner Serpollet is a complicated example of a steam car, but the Napier seems to show the way forwards for car design, Wolseley, Panhard-Levassor, Mors, Mercedes and Peerless all being examples from pre-1905 and there being five examples in the sample from the second half of the decade.

The only examples of cars with five-cylinder engines are two Audis from the 1980s and 1990s. Although five cylinders have now been accepted and are produced by a few manufacturers there are still few of them in production.

The first six-cylinder car in the later sample is a 1910 Lanchester. The six-cylinder engine has inherently good balance characteristics and hence is smoother – an important point for a luxury car. There are significant numbers of six cylinder cars from most periods in the sample. From the 1930s onwards there are very few four cylinder cars in the USA and the six is felt to be at the lower end of the market: there is a contrast with Europe where sixes are generally at the mid to upper end of the range.

The first eight-cylinder car in the original sample is a Duesenberg from 1921, with a straight eight engine. This was a racing car and was thus removed from the later sample. Not quite such a racing car (and therefore allowed in the later sample) is the next earliest car with eight cylinders - a Bugatti 35 from 1925. Until the Ford V8s (of which the only example in the sample is the French-built Ford Vedette from 1954), eight cylinders are definitely considered to be a luxury items or developed initially for racing. There are four cars with eight cylinders in the sample that are perhaps not in the luxury or racing classes: the Ford Vedette of 1954, the Buick from 1950, a Ford Mustang from 1966 and a 1976 Triumph Lynx prototype.

A1.3.1.4 Cylinder arrangement

Category	Meaning
0	Don’t know
0	0 – this car does not have cylinders
1	This car is a single cylinder. The arrangement is not applicable.
2	In line
3	Vee
4	Horizontally opposed
5	Square
6	W

Table A1.15 Cylinder arrangement

406 out of the 568 cars have their cylinders arranged in line, making it the most common arrangement. The Vee arrangement is the next most common, with 76 examples, and there are 27 examples of cars with horizontally opposed cylinders. There are also two examples of cars with the

cylinders arranged in a square – both Trojans from the 1920s and a single example of the W formation – the Rumpler Tropfenwagen from 1922.

The in line arrangement is perhaps the most obvious, but Vee arrangements for engines came in surprisingly early on, with the first example in the sample being the Daimler Stahlradwagen from as early as 1889. The Vee-twin has the advantage of only needing a single crankpin, and of being reasonably compact. Early Panhards and Peugeots also used the Daimler Vee-twin engine built under licence. Later Vee-twin engines signify motorcycle influence: there are examples of Bédélia, GN, Morgan and Phänomobil in the sample from the 1910s and 20s and no later examples. In contrast, the first example of the V4 engine is the Lancia Lambda from about the same date, and the only other examples are other pre-war Lancias, the 1970s Saab which used a German Ford V4 and two British Fords from the 1960s and 1980s. This rather late start is to do with the complex balancing problems of such engines and the desire to make quiet cars. The first V6 in the sample is also a Lancia, from as late as 1955. The arrangement is also quite difficult to balance successfully. Other examples are from Peugeot, Renault and De Lorean who used the same engine; Ford, Honda, Rover, Honda, Volkswagen and Nissan, all from the 1970s or later. Eight cylinder in-line engines are difficult to accommodate as they are long and this length also makes them susceptible to torsional vibration and hence fractured crankshafts, unless the engine speed is kept down. The latest straight eight engines in the sample is a Bugatti, dating from 1951 but being a bit of a throwback to pre-war days. Hence, the V8 engine was developed relatively early. Although the first examples date from the early years of the 20th Century, the earliest in the sample are three Cords from the late 1930s, together with three Tatras and a Packard from the pre-war years. They are more common in the post-war era, with 17 examples in the sample. Twelve cylinder in-line engines are extremely rare but at least one has been deemed to have existed. The normal arrangement for the 12 cylinders is in a Vee, as it is for 16 cylinders, although other arrangements such as 12 W engines existed (and still do).

There is one example of a flat-12 in the sample – a Ferrari from 1992. The horizontally-opposed engine would seem to be the obvious way to avoid balance problems, but they are more complicated and costly to make than in-line engines and hence are not used significantly. In terms of twin-cylinder engines, however, the out of balance of a parallel twin four stroke is significant so the horizontally-opposed arrangement becomes advantageous. The first example in the sample is a Lanchester from 1896, and it is then used by several manufacturers in all periods for small cars, frequently with air cooling as it provides good airflow around the cylinders. The earliest example of the horizontally-opposed four-cylinder in the sample is a Wolseley from 1902. There are no other examples from before the Second World War, and the next earliest is the Volkswagen from 1947, and then there are examples from Tatra, Jowett, Hotchkiss-Grégoire, Porsche and Lancia. There is only one horizontally opposed six in the sample – a Chevrolet Corvair from 1960 - and one car with a horizontally-opposed twelve-cylinder engine – the Ferrari Testarossa from 1992 mentioned earlier.

Square and W arrangements of cylinders are considerably rarer. There are two examples of square layouts in the sample; both are Trojans from the 1920s. These engines were somewhat unusual in that they were uniflow two-strokes as well, and had a single combustion chamber for each pair of cylinders, with the inlet ports controlled by one of the pair of the cylinders, and the exhaust port controlled by the other. The only car with a W arrangement in the survey is a Rumpler from 1922.

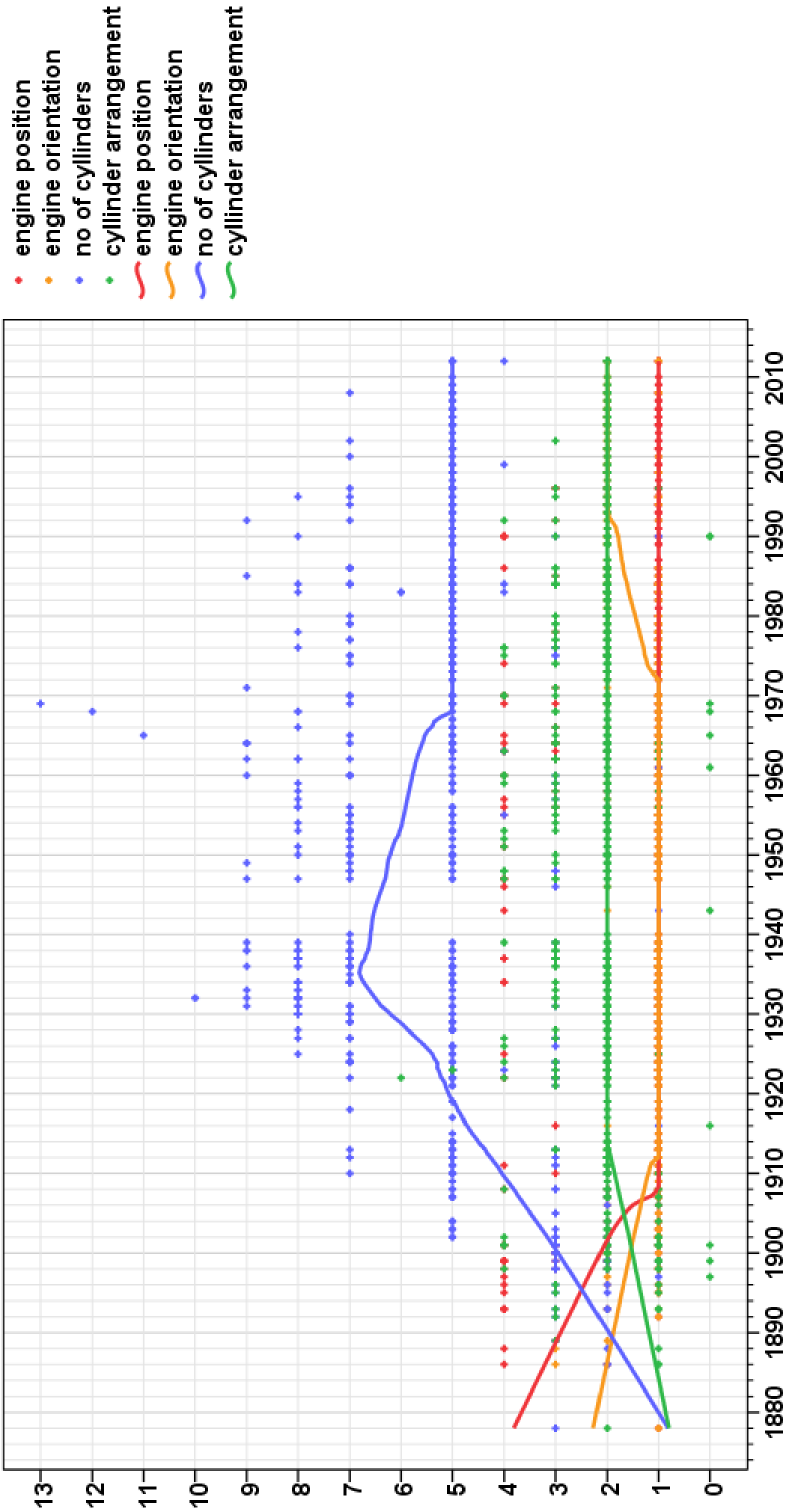


Figure A1.12 Basic engine design variables

A1.3.2 Suspension design variables

There are four of these in the layout analysis. It is argued that there are essentially two descriptive variables that are used for suspensions at either end of the car – the form or geometry and the medium. Of these the geometry probably has the greater influence, as it dictates the way in which the car corners and rides far more than the medium which is there simply to provide some resistance, although some types of medium are more suited to larger deflections than others, and the amount of space taken up by the suspension medium can be significant. Thus the suspension form and suspension medium at each end of the car are used as variables. Both of these fit into categorical variables, and the process of determining the sequence of these is largely down to when they first became popular.

Category	Front suspension form	Rear suspension form	Front suspension medium	Rear suspension medium
0	Don't know	Don't know	Don't know	Don't know
1	None	None	None	None
2	Sprung seat only	Sprung seat only	Leaf spring (unknown type)	Leaf spring (unknown type)
3	Pram frame	Pram frame	Full elliptic	Full elliptic
4	Beam axle	Beam axle	Transverse full elliptic	Transverse full elliptic
5	Driven beam axle	De Dion	¾ elliptic	¾ elliptic
6	de Dion	Non-driven beam axle	Semi-elliptic	Semi-elliptic
7	Independent	Independent	Semi-elliptic with transverse helper	Quarter elliptic
8	Sliding Pillar	Trailing arm, trailing spring	Quarter elliptic	Cantilever
9	Double wishbone	Swing axle	Cantilever	Transverse leaf
10	Dubonnet	Double wishbone	Transverse leaf	Reversed quarter elliptic
11	Leading arm	Semi-trailing arm	Coil	Torsion bar
12	Strut	Strut	Torsion bar	Coil

13	Swing axle	Torsion beam	Interconnected coil	Interconnected coil
14	Trailing Arm	Multi-link	Hydro-pneumatic	Hydro-pneumatic
15	Multi-link		Rubber	Rubber
16			Sulcated grp	Sulcated grp

Table A1.16 Suspension variables

Suspension variables were found to be, perhaps surprisingly, significant variables in the analysis.

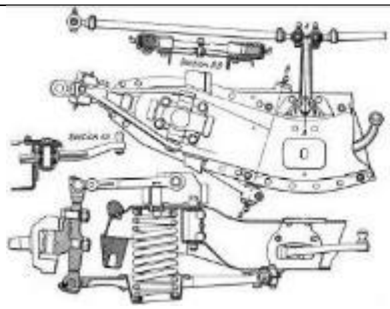
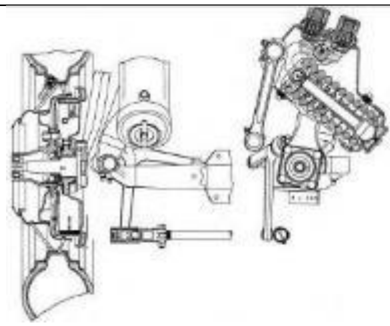
Table A1.16 is effectively written in a code – a shorthand form and those who know can understand it, others cannot. This means that the different arrangements need some sort of explanation in the way of an illustrated glossary. The different suspension forms also have different geometries and hence different ride and handling characteristics.

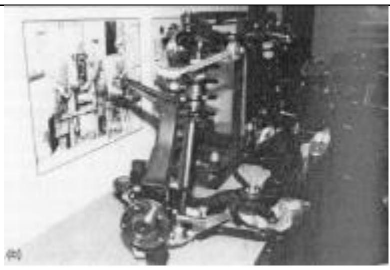
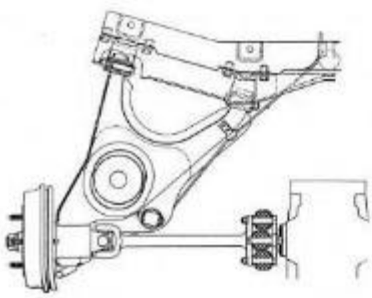
In terms of ordering the variables, the general approach is that non-independent suspensions have lower values than independent ones, and then ordering is done on a date basis.

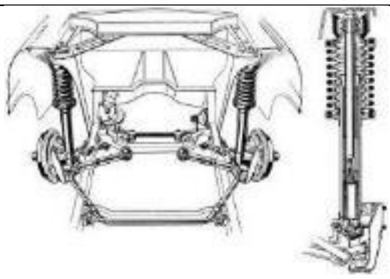
A1.3.2.1 Suspension glossary

A1.3.2.1.1 Suspension form

Term	Description	Picture
Beam axle	An axle where the two wheels are rigidly attached to each other by some form of axle. This is in contrast to an independent suspension system where the wheels are free to move independently of each other.	 Wikimedia Commons: Gede~commonswiki
Driven beam axle	A beam axle with wheels that drive the car. Sometimes known as a live axle. A live axle will normally have the final drive suspended with the axle.	 Rankin Kennedy (1912)

Non-driven beam axle	A beam axle with wheels that do not drive the car. Sometimes known as a dead axle.	
Dead axle	Non-driven beam axle.	
De Dion	A driven beam axle where the final drive is not attached directly to the axle.	
Double wishbone	An independent suspension with upper and lower hinged links and with the wheel attached to an upright connected to the outer ends of the links at top and bottom.	 Newcomb and Spurr (1989) p298
Dubonnet	A complex independent suspension arrangement using trailing arms and including coil springs in a compact space. On a front axle the whole of the suspension is connected to the kingpin and turns with the front wheels.	 Newcomb and Spurr (1989) p297
Independent	A suspension where each wheel can move without affecting the movement of the one opposite. A generic term is used when the precise type of suspension may not be known.	

Leading arm	An independent suspension where the wheel is attached to a forward-pointing arm that is hinged transversely on the chassis.	 http://costajulio.tripod.com/ citroen/chassis1.jpg
Live axle	A beam axle with the drive to it and where the final drive is also mounted on the axle.	 Rankin Kennedy (1912)
Multi-link	A form of independent suspension that consists of several links that enable sophisticated geometric behaviour to take place when cornering, braking and accelerating.	 Eckermann (2001)
Pram frame	A non-independent suspension system where both axles are part of a frame that also connects both front and rear axles.	 Yalcin Kiliclar
Semi-trailing arm	An independent suspension where the wheel is attached to an arm that pivots in front of the wheel and at an angle to the transverse direction.	

		Newcomb and Spurr (1989)
Sliding Pillar	An independent suspension system where each wheel slides vertically on a pillar. For front suspension systems the pillar is normally the steering axis (ie the kingpin).	
Sprung seat only	A suspensions system where the car is unsprung and the seat is sprung instead. This system is commonly used on tractors.	
Strut	An independent suspension arrangement where the wheel is attached to a telescopic strut that is pivoted at the top and where the bottom of the strut is constrained by a link such as a wishbone. For front suspensions the strut commonly forms the steering axis.	 Newcomb and Spurr (1989)
Swing axle	An independent suspension arrangement where the wheel is rigidly attached to the axle which pivots about a fore and aft axis. If the wheel is driven, this pivot is commonly formed by a universal joint in the driveshaft (but isn't always).	 www.imps4ever.info
Torsion beam	A semi-independent suspension system where each wheel on an axle is attached to a trailing arm that is connected to the trailing arm on the other side of the car by an open-section member that is deliberately weak in torsion, allowing the wheels to move reasonably independently. The	 Wikimedia Commons: Springs

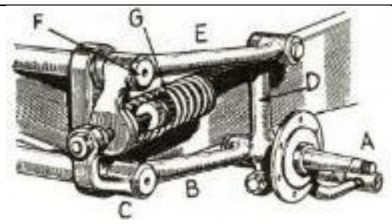
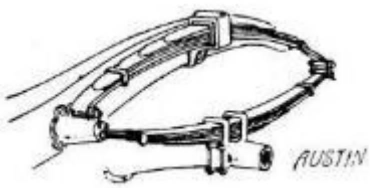
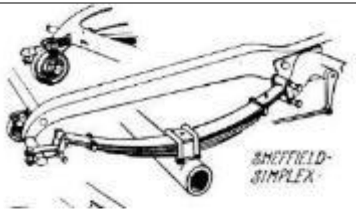
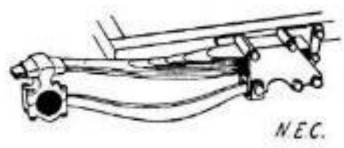
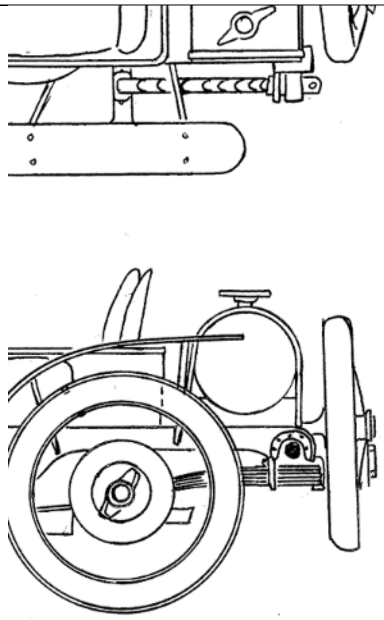
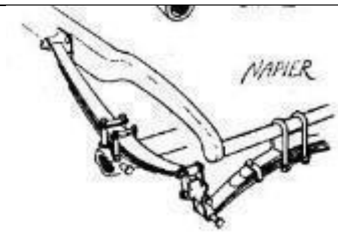
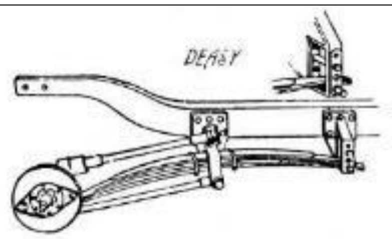
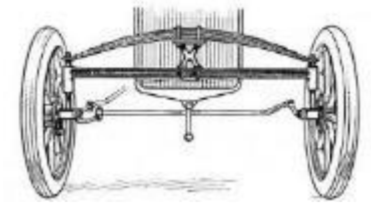
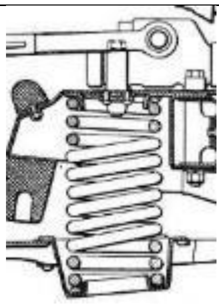
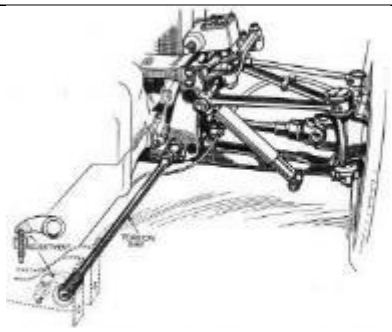
	beam and arm assembly is only pivoted at each end.	
Trailing arm	An independent suspension where the wheel is attached to an arm that pivots in a transverse plane and which faces towards the rear of the vehicle. There can on occasions be more than one trailing arm with the wheel mounted on a vertical link that joins the two trailing arms: this may be termed a double trailing arm suspension but the category is combined with the single trailing arm category for the analysis.	 Newcomb and Spurr (1989) p299
Trailing spring	A trailing link-type independent suspension where the trailing arm is formed of a quarter-elliptic leaf spring (or two of them). The spring is rigidly attached to the chassis at its front end and is not pivoted.	 Silverstone Auctions

Table A1.17 Glossary of suspension form

A1.3.2.1.2 Suspension medium

Term	Description	Picture
Leaf spring	A spring formed of one or more pieces of thin, springy sheet metal.	
Full elliptic	A suspension medium formed of two leaf springs one above the other to appear as if they are in a full ellipse.	 Newcomb and Spurr (1989)
¾ elliptic	A suspension medium formed of two leaf springs one above the other where one of the springs is only half the length of the other. The axle is attached at the	 Newcomb and Spurr (1989)

	mid-point of the long spring. This looks like a quarter elliptic spring above a semi-elliptic spring.	
Semi-elliptic	A suspension medium formed of a single leaf spring attached at each end with the axle attached at its centre point.	 Newcomb and Spurr (1989)
Quarter elliptic	A suspension medium formed of a single leaf spring with the axle at one end and attached to the chassis at the other.	 Newcomb and Spurr (1989)
Reversed quarter elliptic	A quarter elliptic spring where the chassis attachments are nearer the car extremities than the axle. Mostly used by Bugatti.	 Car Blueprints.info/
Transverse full elliptic	A full elliptic spring mounted transversely.	

Semi-elliptic with transverse helper	A semi-elliptic spring combined with a transverse leaf spring at one end.	 Newcomb and Spurr (1989)
Cantilever	A single leaf spring pivoted on the chassis in its middle, attached to the axle at one end and to the chassis at the other. It allows for more flexibility.	 Newcomb and Spurr (1989)
Transverse leaf	One or more leaf springs mounted across the chassis.	 Newcomb and Spurr (1989)
Coil	A spring formed of spirally-wound (coiled) material.	 Newcomb and Spurr (1989)
Torsion bar	A spring formed from a bar that is twisted to provide the suspension.	 Newcomb and Spurr (1989)

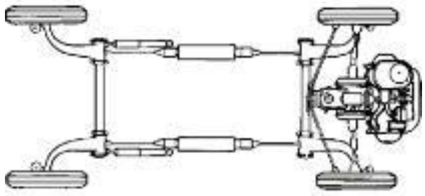
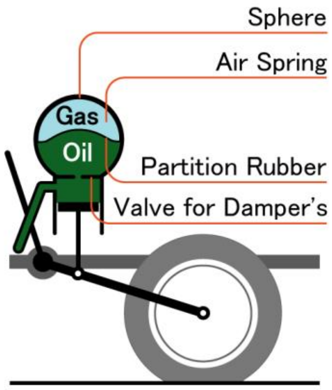
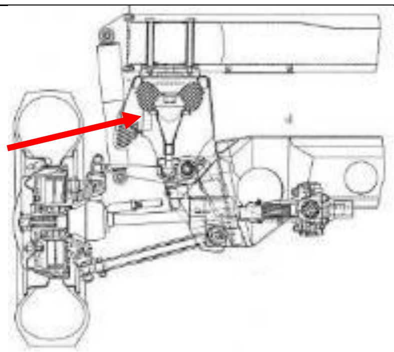
Interconnected coil	Coil springs where there is a connection between the front and rear suspension. Used to change bounce and pitch frequencies (such as on the Citroën 2CV range.	 Citroenet.org.uk
Hydro-pneumatic	Suspension using compressed air as the suspension medium, connected to the wheels through hydraulic fluid. Hydro-pneumatic suspensions frequently (but not always) allow for connection between the front and rear systems and self-levelling.	 Wikimedia Commons: Teccirio
Rubber	Use of rubber as the suspension medium. This is usually in a compression form, but may be in torsion.	 Newcomb and Spurr (1989)
Sulcated grp	A grp spring that is wave-shaped. The picture shows the form but it is not in grp.	

Table A1.18 Glossary of suspension media

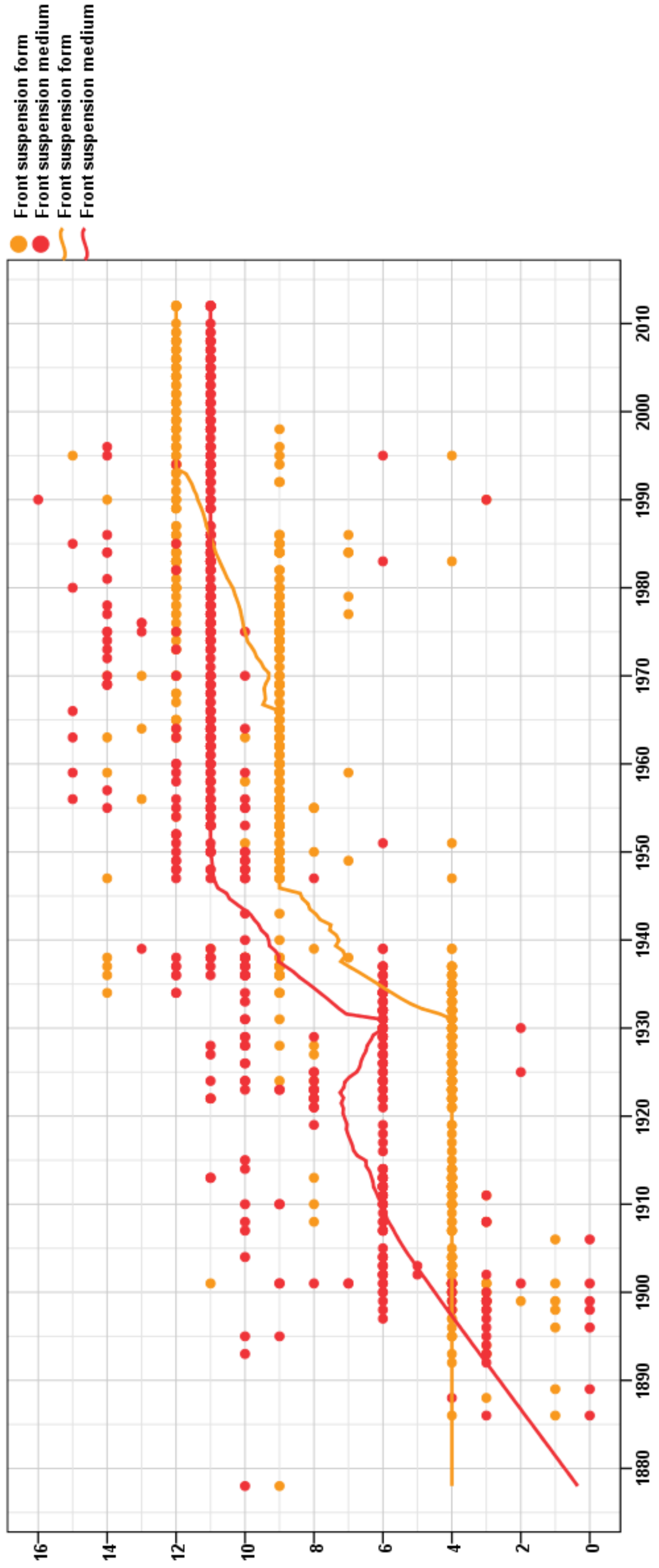


Figure A1.13 Front suspension form and medium.

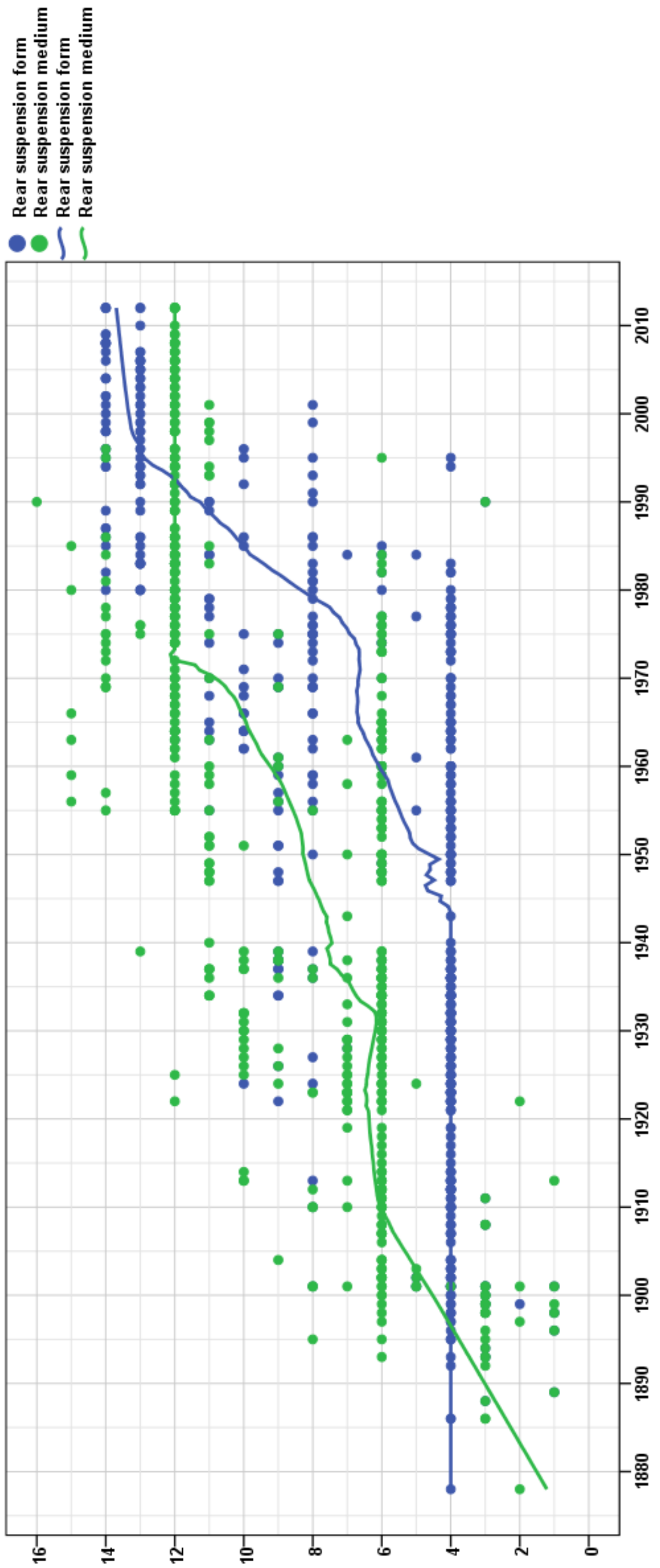


Figure A1.14 Rear suspension form and medium.

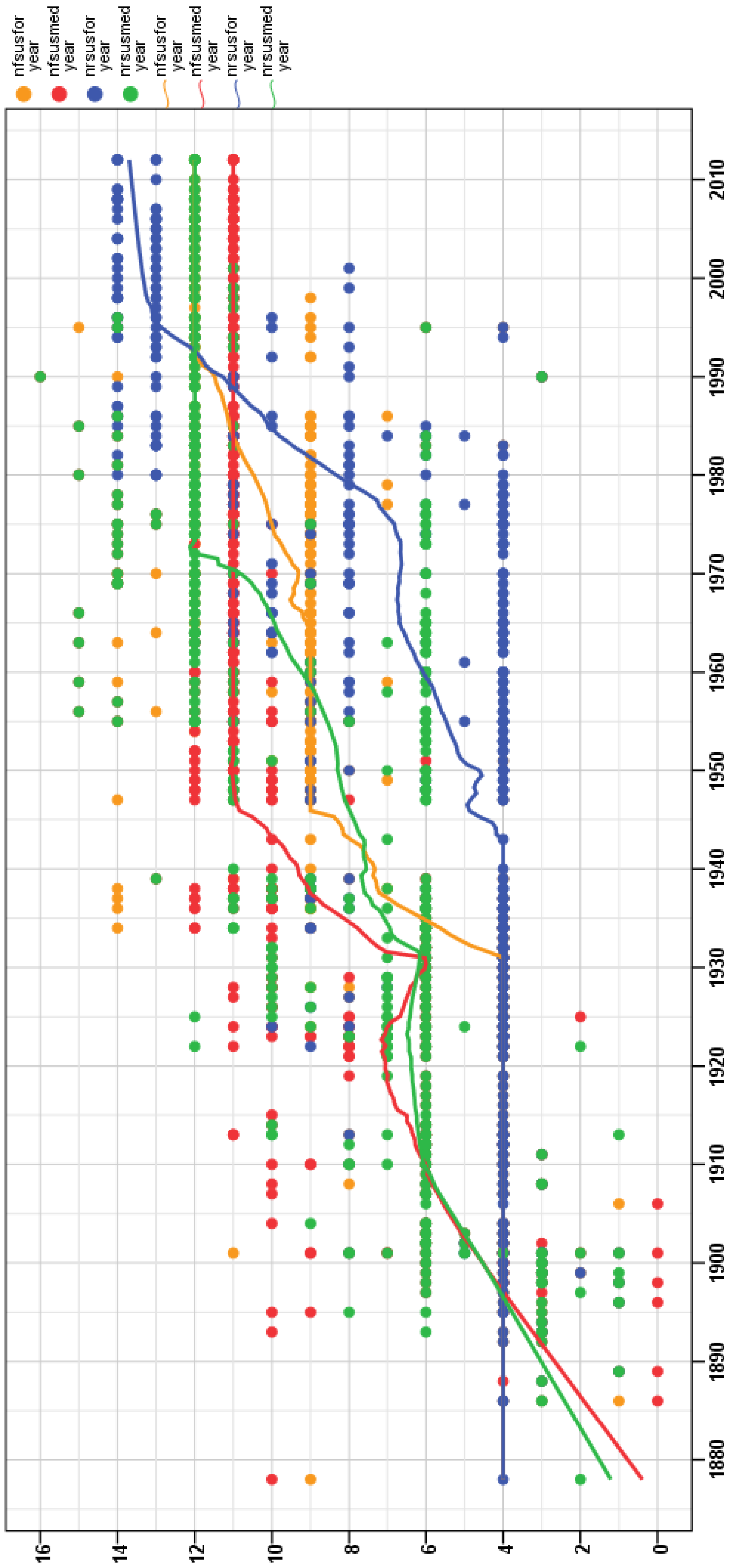


Figure A1.15 Suspension form and medium

It is easier to see behaviour from the two separate graphs for front and rear suspension than from the combined one.

Both graphs demonstrate paradigmatic behaviour, in that there are long lines of points where the majority of car designs do not change and that when a change occurs it goes immediately, it would seem, from one kind of suspension to another without a lot of vacillation, although there is a small amount of that. With the front suspension form there are essentially three long lines. The first is from as early as 1890 and lasts until about 1938. From a little earlier than this we see the next line starting to form, and then this goes from then until roughly 1985. During the end of this period we see the third line start – probably around 1965 – and this continues until the latest cars in the sample. The first line is at 4, which is the front non-independent beam axle. The second is at 9, the double wishbone arrangement, and the third at 12, the strut-type front suspension. With front suspension media we also have a similar picture of long lines, of which there are again three. The first is a short one, from about 1892 to 1900, and is at 3, which is for full elliptic leaf springs. Taking over from this from about 1896 to 1938 is a line at 6, the semi-elliptic leaf spring. The final line is from about 1936 and is at 11, which is the coil spring, which reigns supreme from then onwards. With front suspension it would appear that the arrangements on pre-war cars are generally significantly different from post-war ones – but the evidence suggests that the change takes place just a little before that, in the mid-1930s, and it would seem to be happening very quickly. We have, here, an effective paradigm shift.

With rear suspension there is a similar pattern but it is significantly different. Rear suspensions also display the long lines and changes that signify paradigmatic thinking, but the first line, at 4 – beam axle, again – lasts longer than with the front beam axle and goes from 1893 or so up to about 1982, although by that time this is being encroached by the next line, at 8, which effectively starts taking over from about 1970 onwards. This is for the trailing arm independent suspension. From the 1980s onwards the major form of rear suspension geometry is 13, the torsion beam, with a bit of a foray into 14, the sophisticated multi-link suspension. Rear suspension media, similarly to the front suspension media, show three lines. The first is at 3 from 1892 to 1900, exactly the same as for the front suspension, and is for the full elliptic spring. From 1896 to 1983 the semi-elliptic, 6, reigns. Coil springs start around 1955 and continue to be the norm at the end of the sample.

The possible reasons for these paradigm shifts will be explored later.

A1.3.3 Structure and body type

These two could claim to be related. Both are categorical variables.

Category	**Structure type**	**Category**	**Body type**
0		0	
1	Wooden chassis	1	No body or virtually no body
2	Channel chassis	2	Coachbuilt
3	Tube chassis	3	Steel
4	Backbone chassis	4	Aluminium
5	Platform chassis	5	Wood
6	Punt chassis	6	Aluminium and steel
7	Monocoque body shell	7	Fibreglass; Steel and fibreglass
8	Space frame	8	Thermoplastic
9	Space frame / monocoque hybrid		
10	Unit frame		

Table A1.19 Structure and body type variables

There is more than a certain amount of difficulty in determining exactly what structure and body construction some cars had, so in some cases the information given is a matter of the best guess: and in some cases the construction is a little difficult to describe, - particularly the case for hybrid constructions.

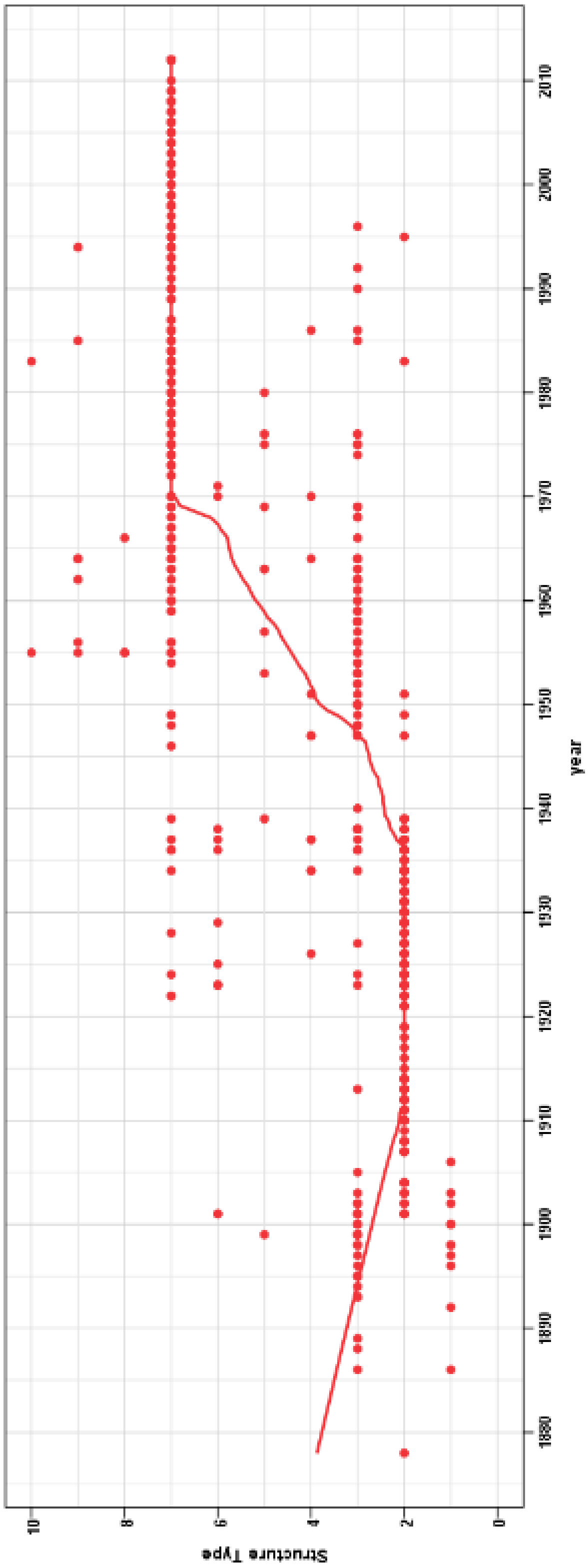


Figure A1.16 Structure type

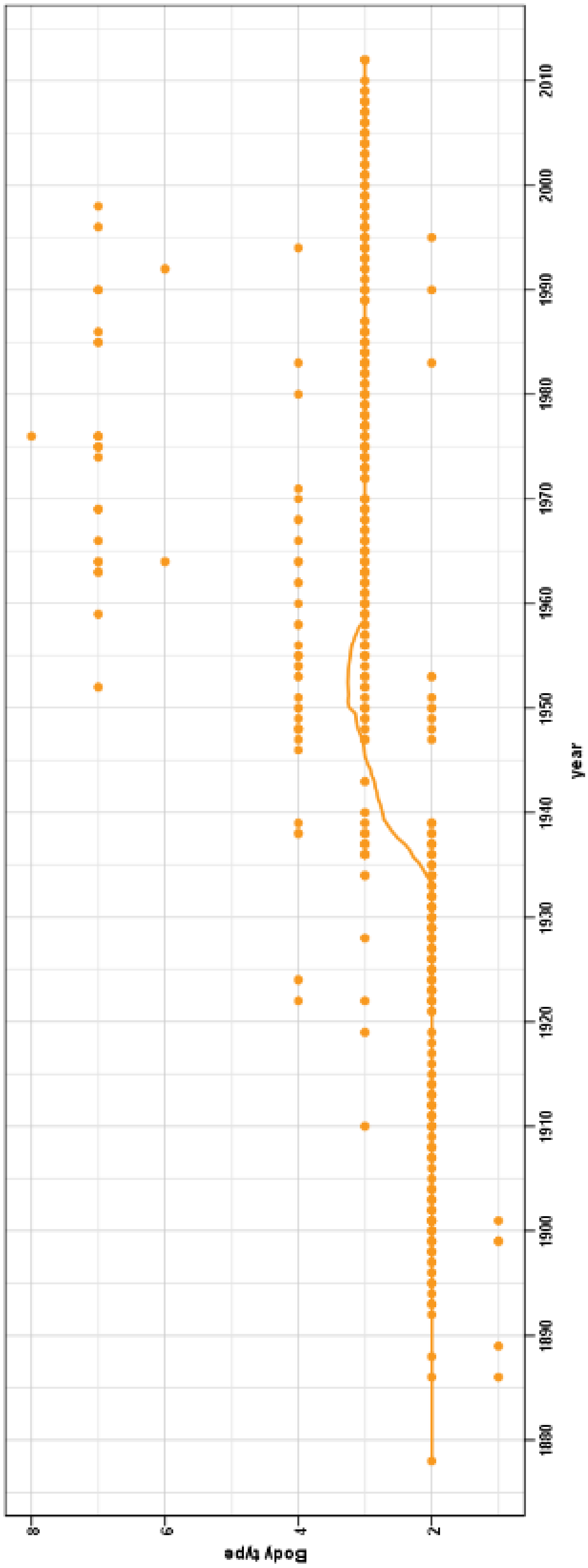


Figure A1.17 Body type

With structure type we see some paradigmatic behaviour. The shifts occur from early tubular chassis to channel section chassis, back to tubular chassis and then to monocoque construction. Interestingly, the changes from one type of structure to another seem to take place at around the same time that other changes are taking place. So the first change from the early tubular structures to the channel section chassis takes place between about 1900 and 1905 and the change from channel section chassis takes place in the late 1930s. The change from channel section chassis is a two-part one: the first change is to a tubular form of chassis, and then the second is to the full monocoque, integrated construction. It should be noted that the tubular form of chassis at this later time is significantly different from the earlier tubular chassis, which tended to be made from small round tubes which limited the length of the wheelbase because of their poor behaviour in bending. This was corrected with the channel section chassis, where the depth of the chassis varied according to the loadings. The later tubular chassis continued the depth of the channel section chassis and tended to become effectively a boxed-in form of chassis with the same depth as the channel section, but with the improved torsional behaviour of the closed tubular section. In some instances, further tubular members are added to give increased bending stiffness – perhaps adding depth to the chassis in the central tunnel section, for instance. This is particularly true of small-production cars in the 1950s.

In terms of body construction, there is a similar picture but there are fewer variations. Essentially, the construction moved from a coachbuilt body with metal panels on a wooden frame to a steel welded construction. Much of the change took place during that most productive of times – the late 1930s. There were generally two stages to the process. First, the coachbuilt body was replaced with a similar construction in welded steel, and then the welded steel body was developed into a monocoque construction, doing away with the separate structural chassis. The use of materials such as glass reinforced plastic (alias fibreglass) came in from the 1950s, but has only been used for low-volume production vehicles, normally in conjunction with a separate steel chassis.

A1.3.4 Driven wheels

The last of the layout variables is the fairly fundamental one of which wheels are driven.

Category	**Meaning**
0	Don’t know
1	Front
2	Rear
3	Four
4	Propeller
5	Rear plus screw

Table A1.20 Driven wheels

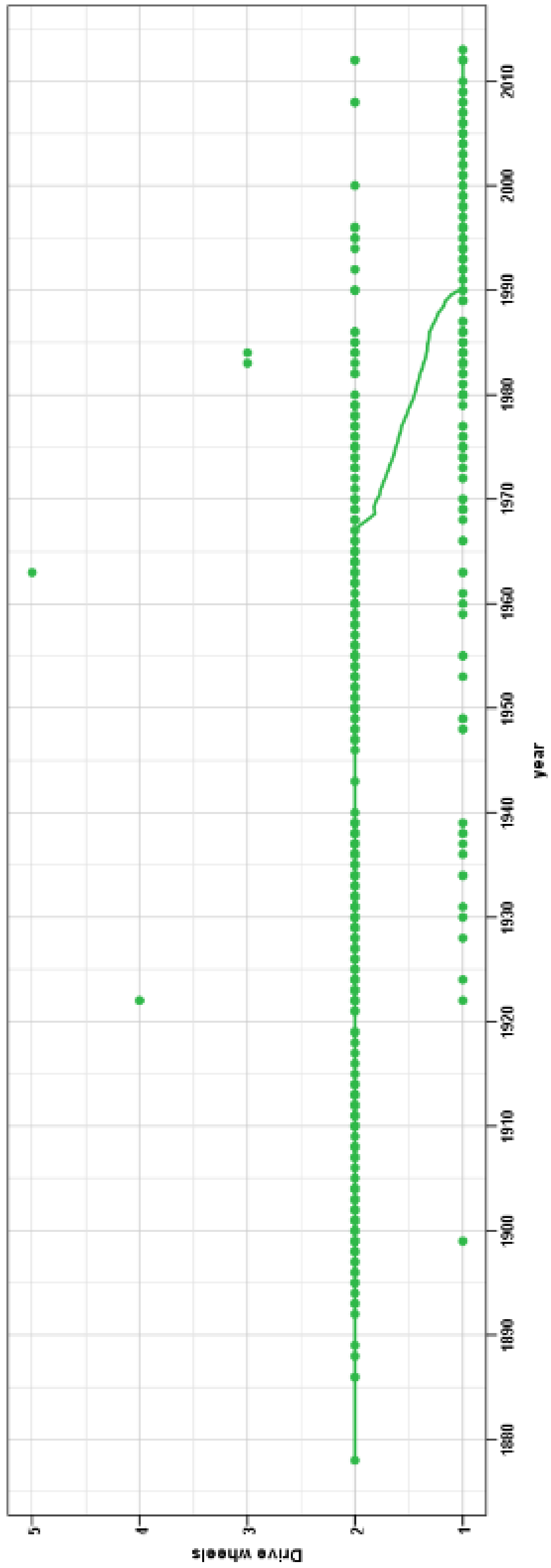


Figure A1.18 Driven wheels

Cars started with the drive to the rear wheels. Front wheel drive had been around from the earliest days for a few cars, but not many. The catalyst for the widespread adoption of front wheel dive seems to have been the BMC Mini in the 1960s, but this didn’t really seem to make its presence known in terms of people copying the layout. The first transverse engine / front wheel drive developments by other manufactures seems to have started with the Autobianchi Primula in 1965 and the Fiat 128 in 1968, but this development didn’t become popular until the mid-1970s when the Volkswagen Golf was introduced and Ford the Fiesta. By 1990 there were sufficient cars with the layout for the graph above to move from the rear wheel drive majority to the front wheel drive majority. As can also be seen by the graph above, four wheel drive has always been for a minority of cars – in spite of the current apparent popularity of 4 x 4 vehicles, they are still only a small part of the market.

There are two cars in the survey with other arrangements. One, the Leyat Helicar from 1922 has an airscrew driving it and the other, the Amphicar from 1963, has a screw for use in water in addition to its rear wheel drive for use on land.

Figure A1.19 Leyat Helicar, 1922: Amphicar, 1963

A1.4 The analysis

Correlations in the movements of variables were obtained using categorical principal components analysis (CATPCA). This uses probabilities to determine a non-linearity for each variable based on the probability of a particular categorical value. The process then investigates correlations between the variables to produce a number of object score variables which are combinations of the different variables and the process is essentially a means of discovering how important the individual variables are. Object score variables behave as a set of mutually orthogonal dimensions – ie, each dimension is independent of the others. There are actually as many dimensions as there are variables, but the majority of the variation is accounted for the first few variables and it therefore makes most sense to obtain results for only two variables (or dimensions).

Variable description	**Variable name**	**1**	**2**
Engine Position	nengpos	-.464	.405
Engine Crankshaft Orientation	nendror	-.039	.760
Driven wheels	ndrwhe	-.564	-.468
No of cylinders	ncylno	.608	-.534
Cylinder arrangement	ncyllarr	.586	-.469
Front suspension form	nfsusfor	.817	.383
Rear suspension form	nrsusfor	.687	.499
Front suspension medium	nfsusmed	.734	.403
Rear suspension medium	nrsusmed	.804	.335
Structure type	nstructy	.662	.526
Body type	nbodytyp	.751	.224
Engine type	nengtyp	.257	.234
Wheel orientation	nwheor	-.310	.557
Wheel sizes	nwhesz	.507	-.265
Steering control system	nsteerco	-.707	.447
Final drive type	nfindri	.655	-.363

Driver position	ndrpos	-.373	.197
Tyre type	ntyrtyp	.559	-.265
No of wheels	nwheels	.294	-.546

Table A1.21 Component loadings for layout variables

Exactly what each variable is principally made up from is difficult to identify and what the two dimensions are actually measuring is fairly difficult to discern, but Table A1.21 identifies how each is constituted and the angles in the following diagram indicate how each of the original nineteen categorical variables behaves and is measured – although it has to be remembered that the distances along each variable's axis are non-linear and derived from the probabilities that each encounters. Thus, for instance, it can be seen that the engine crankshaft orientation, nendror, has little effect on dimension 1 and effectively only affects dimension 2 as it loads principally in that direction (-0.039, 0.760). This is the clearest variable to describe. The line representing that variable is nearly vertical in the diagram.

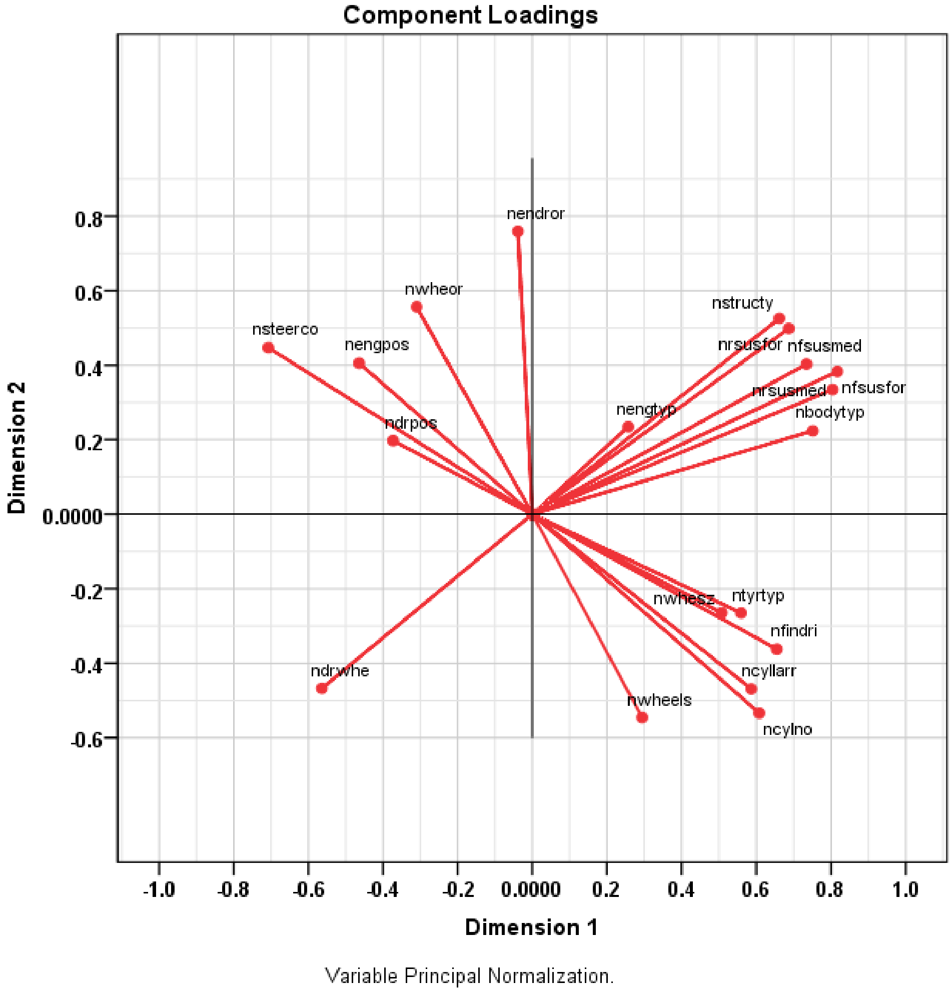


Figure A1.20 Dimensional angles and lengths for each of the categorical variables

Now investigating how each of these two layout dimensions (or object scores) varies for the date of each car we have Figures A1.21 to A1.24:

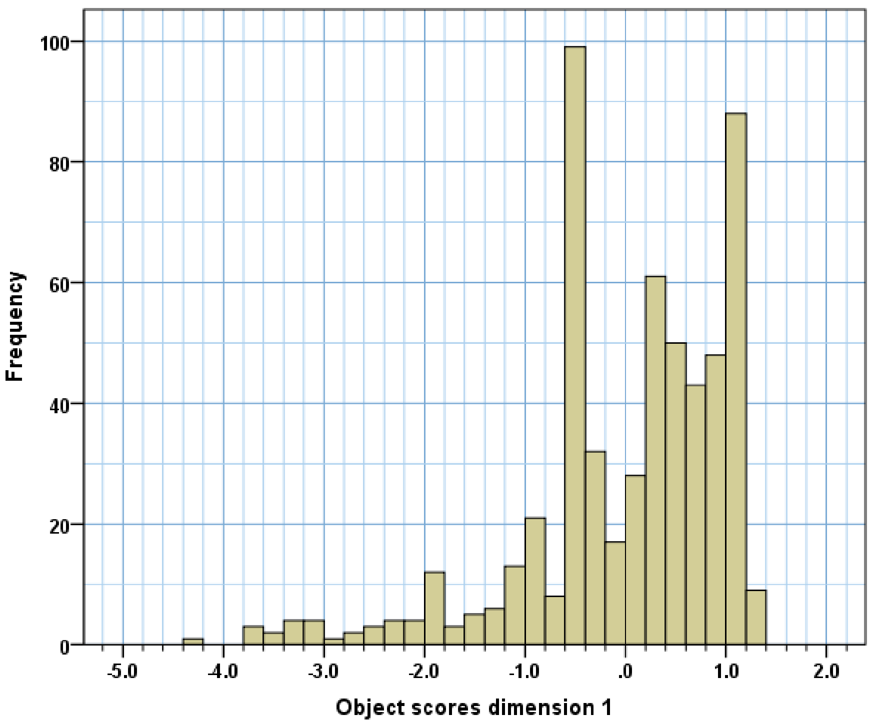


Figure A1.21 Dimension 1 histogram

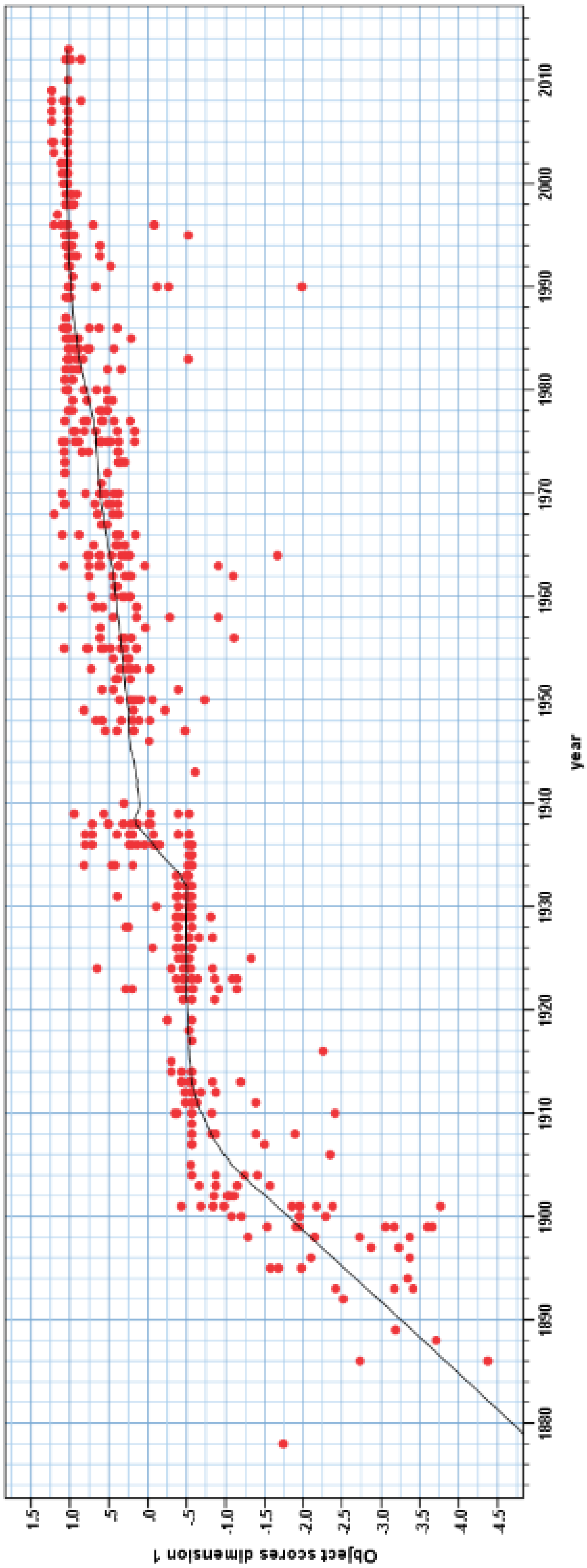


Figure A1.22 Object scores for dimension 1

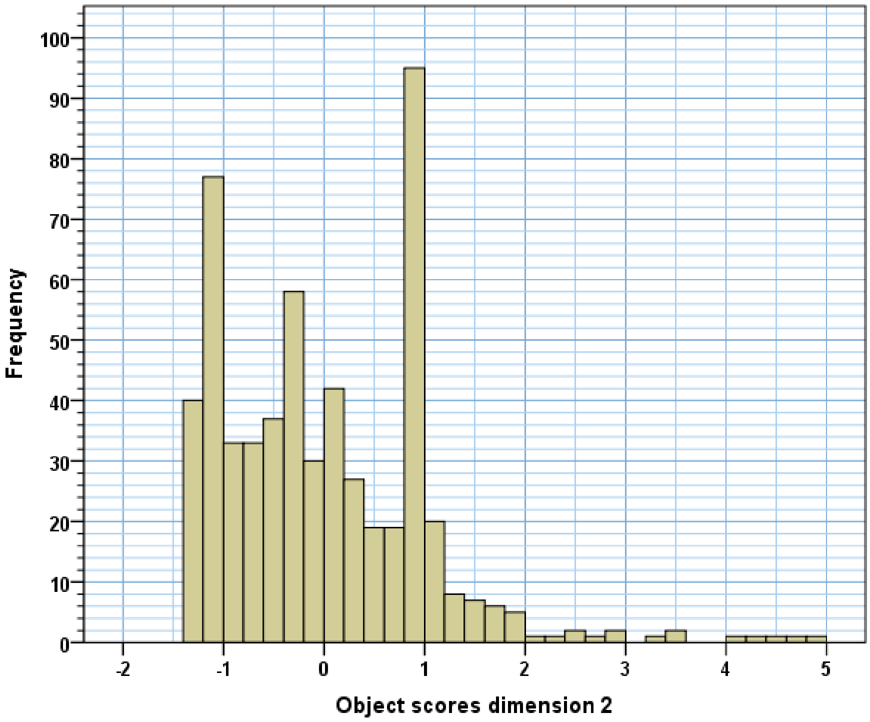


Figure A1.23 Histogram for dimension 2

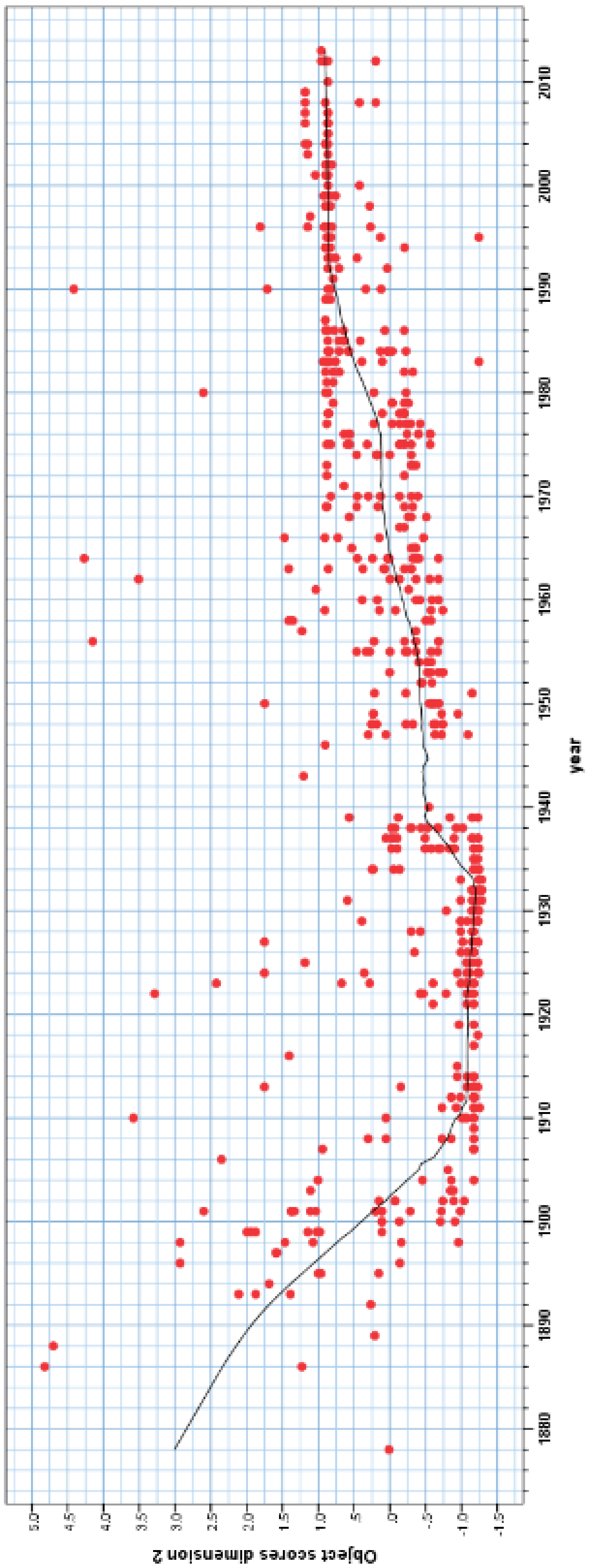


Figure A1.2 Object scores for dimension 2

If these two object scores are plotted against each other, Figure A1.25 results

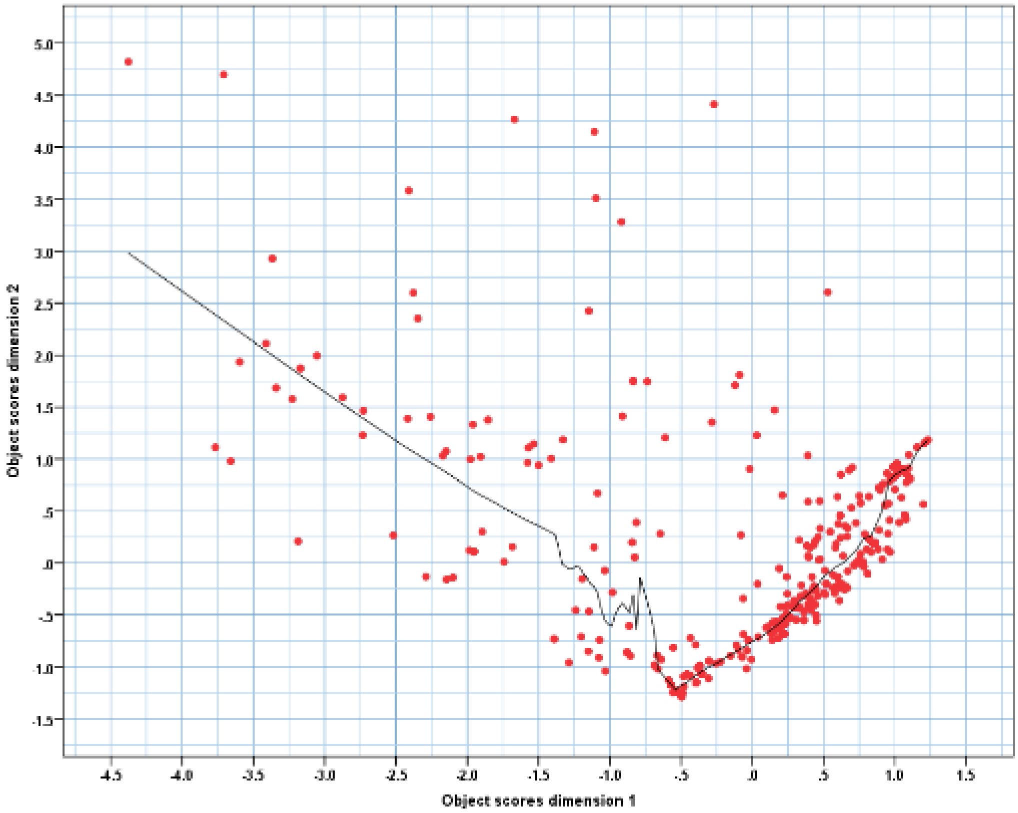


Figure A1.25 Object score dimensions plotted against each other

Implications and discussion of these scores and the implications of these for the investigation of Design Paradigms in car history is to be found in the main text.

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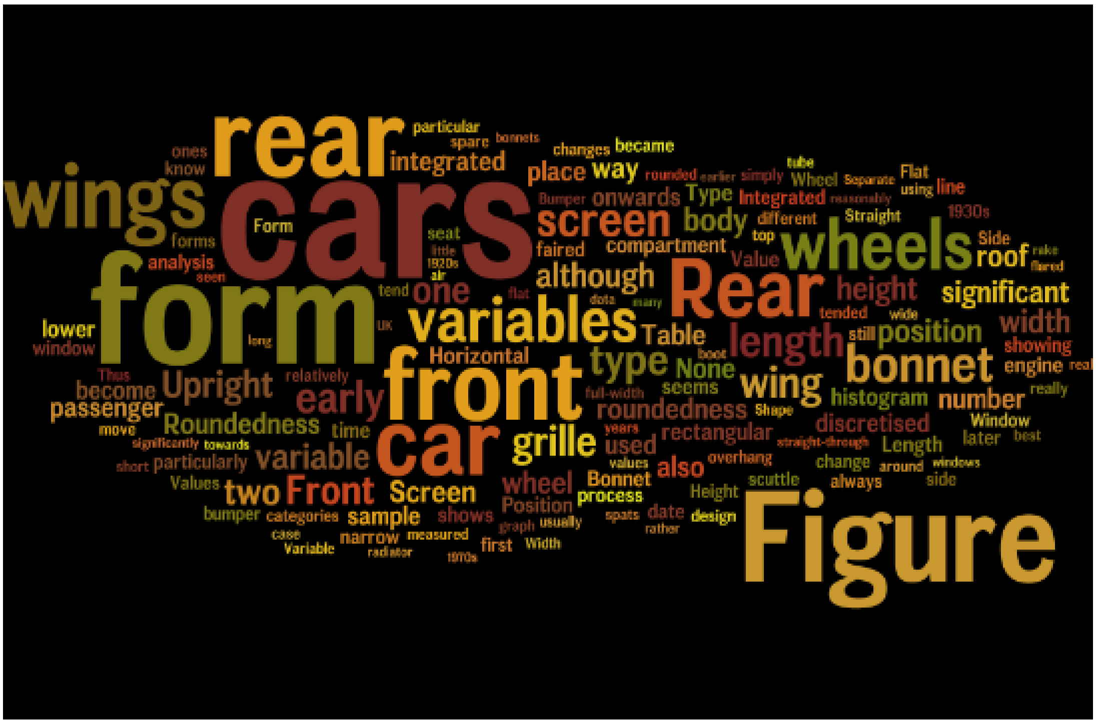
A2 Expanded Form analysis



A2 Expanded Form analysis

Two different form analyses were carried out. An initial analysis was carried out using a large number of variables. This number was reduced for a subsequent analysis as it was felt that a number of them were irrelevant.

A2.1 Form Variables

46 form variables were selected initially. Some of the logic behind selecting them was related to variables that John Shackleton had used in his analysis of Japanese recreational vehicles (Shackleton and Sugiyama, 1996b, Shackleton and Sugiyama, 1996a, Shackleton et al., 1996, Shackleton et al., 1997); others were found useful variables to introduce and others were thought to yield useful material.

Variable	**Variable**	**Variable**	**Variable**
Length	Rear Form	C Post	Rear Window Rake
Width	Bonnet Length	D Post	Rear Window Roundedness
Height	Front Roundedness	Edge Roundedness	Rear of Cockpit Position
Front Overhang length	Front Wing Shape	Panel Roundedness	Boot Length
Rear overhang length	Screen Type	Roof Roundedness	Boot Slope
Headlight Shape	Screen Rake	Running Board	Rear Bumper Type
Headlight Number	Side Doors	Side Window Base Height	Rear Light Position
Headlight Position	Seat Rows	Side Window Form	Rear Light Shape
Front Bumper Type	Wheel Type	Rear Wing Shape	Rear Light Number

Grille Shape	Wheel Width	Screen Position	Rear Number Plate Position
Bonnet Plan	Roof Type	Rear Window Type	Rear Roundedness
Bonnet Profile	B Post		

Table A2.1 Initial form parameters

In the initial analysis they were all taken as being categorical numbers rather than real numbers: this resulted in a significant degree of guesswork in assigning the categories and in future work use of some real numbers would be perhaps more suitable for things such as length and width where real numbers are fairly easy to obtain for quite a few cars (probably not for all of those in the survey, though).

These variables split into a number of groups. There are the fairly obvious overall size variables of length, height and width. Connected with these are the fundamental physical dimensions of the front and rear overhangs. It was decided that measuring the wheelbase, although frequently defined in vehicle data, was not fundamental. It can be derived from a combination of overhangs and length in any case, but it also tends to correlate significantly with length. It has been measured physically for many of the cars in the sample, but has not been categorised or analysed as the other variables have been. The number of seat rows is connected to these physical variables. Several of these are in fact ordinal rather than nominal: these are Length, Width, Height, Front Overhang Length, Rear Overhang Length, Bonnet Length, Front Roundedness, Screen Rake (although not all cars have a screen and therefore it can’t be measured for some), Side doors (although some don’t have any), Seat Rows, Wheel Width, Edge Roundedness, Panel Roundedness, Roof Roundedness, Side Window Base Height, Screen Position, Rear Window Rake, Rear Window Roundedness, Rear of Cockpit Position, Boot Length, Boot Slope, Rear Light Number and Rear Roundedness. A number of these were later translated into real numbers rather than categorical ones, using direct views where possible (which they are for many cars). The real numbers were then categorised to line up the information with that obtain using the earlier estimation process – they happened to show up some weaknesses in the earlier estimation process: in particular, that the estimation process is coloured by a time-based perception.

The quantities that were measured and then categorised were all measured in inches apart from the rake angle which was measured in degrees and the discretisation was carried out as in Table A2.2.

Variable Value	Very small 1	Small 2	Medium 3	Large 4	Very Large 5
Length	<= 120	120 <= 150	150 <= 180	180 <= 210	210 < =
Width		<= 60	60 <= 70	70 <=	
Height	<= 45	45<= 50	50 <= 60	60 <= 70	70 <=
Front overhang	<= 20	20 <=30	30 <= 40	40 <=50	50 <=
Rear overhang	<= 20	20 <=30	30 <= 40	40 <=50	50 <=
	Very short 2	Short 3	Medium 4	Long 5	Very long 6
Bonnet length (no bonnet = 1)	<= 20	20 <=30	30 <= 40	40 <=50	50 <=
Side window base height (no side window base = 1)	<= 20	20 <=30	30 <= 40	40 <=50	50 <=
	Reverse 1	Upright 2	Raked 3	Very raked 4	
Screen rake (no screen = 0)	110° =<	75° =< 110°	45° =<75°	<45°	
	Forward control	Front wheel centreline	Rear of front wheels	Medium	Rearwards
Screen position (relative to front axle)	<= -10	-10 <= 10	10 <= 20	20 <= 30	30 <=
		Front of rear wheels	In line with rear wheels	Rear of rear wheels	
Rear of cockpit position (relative top rear axle)		< -10	-10 > 10	10 <	

Table A 2.2 Discretisation of numerical values for different dimensions (inches)

The only justification for using the imperial measure for distances was the size of the figures that resulted there would have been no particular difficulty in using a metric measure instead. There would have been some slight differences in that distances would have to be rationalised to be measured in ‘metric inch’ equivalents where one ‘metric inch’ is defined as being exactly 25mm. Thus a car with a length between 4.5m and 180” would move from being defined as ‘medium’ to ‘long’. This particular instance would have affected as many as ten cars in the sample, which perhaps demonstrates that the length variable does not cluster and that the discretisation process is arbitrary in nature.

It was felt that having 46 variables was too many for the analysis: many were perceived to have little bearing on the overall analysis. Thus the number was reduced to 27 variables:

Variable	**Variable**	**Variable**	**Variable**
Length	Height	Width	Seat Rows
Front Overhang length	Rear overhang length	Front Bumper Type	Rear Bumper Type
Front Wing Shape	Rear Wing Shape	Screen Position	Screen Rake
Screen Type	Bonnet Length	Bonnet Plan	Grille Shape
Headlight Position	Headlight Shape	Side Window Base Height	Roof Type
Rear of Cockpit Position	Rear Form	Rear Roundedness	Rear Window Roundedness
Edge Roundedness	Wheel Type	Wheel Width	

Table A2.3 Final set of form variables

A2.1.1 Overall dimension variables (discretised)

These are the overall length, width and height of the car. Whilst the current market seems to categorise cars with such titles as ‘mini’, ‘supermini’, ‘medium range’, ‘large’, executive and so on, these categories do not necessarily relate effectively to a specific length range, although a ‘mini’ car is expected to be shorter than an 'executive' car. The histogram for car lengths shows a very clear pattern that approaches a normal distribution (superimposed on the histogram).

A2.1.1.1 Length

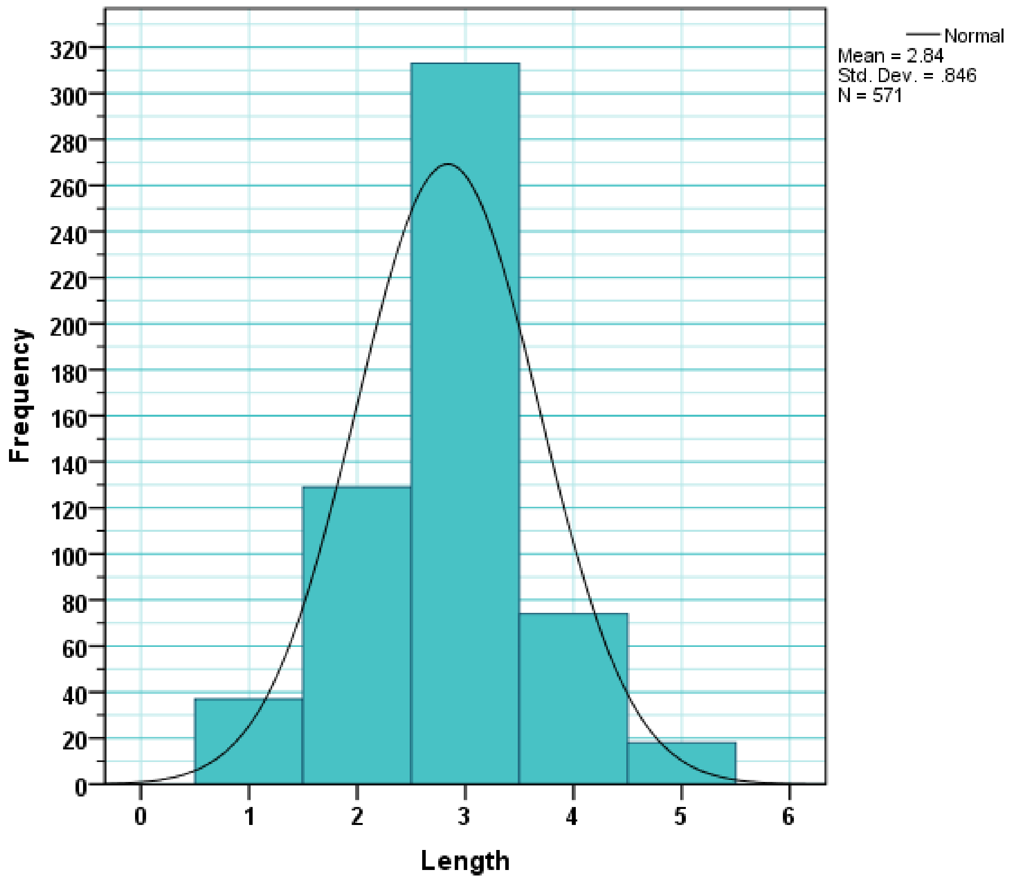


Figure A2.1 Histogram for car lengths (discretised)

The only real differences from normal are that there are more cars on the short side of the histogram than there are on the long side of the histogram.

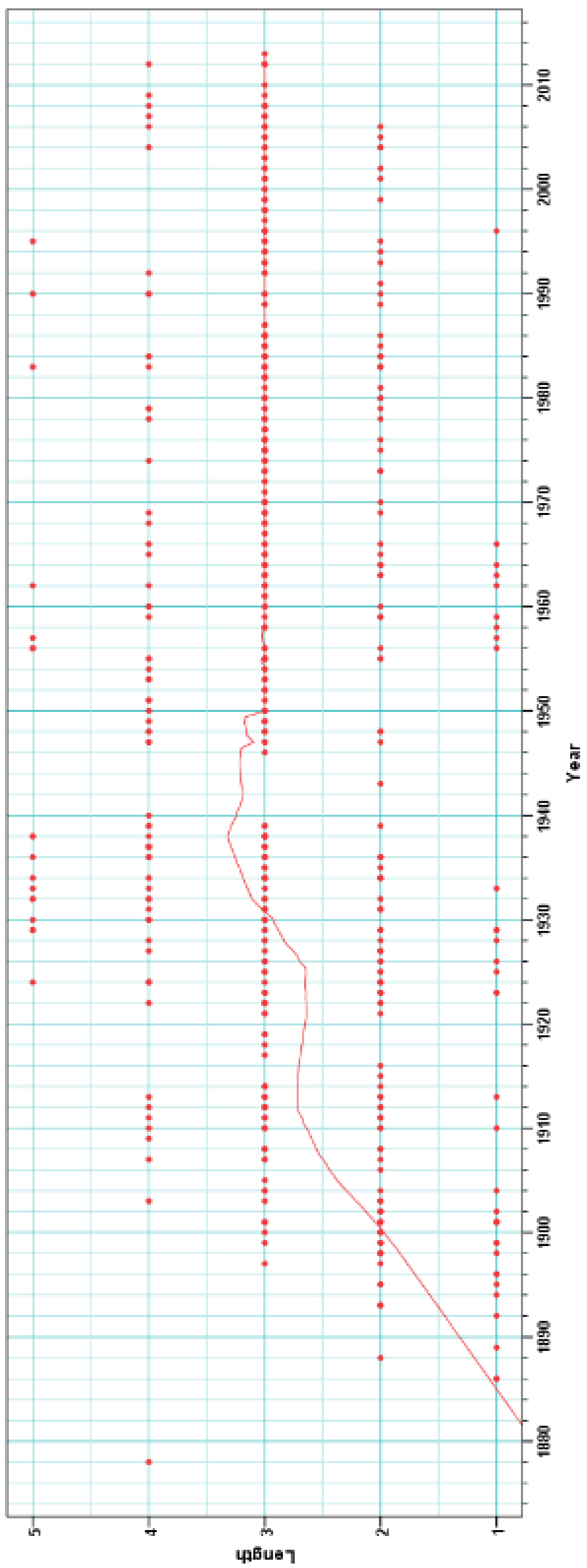


Figure A2.2 Length (discretised) plotted against date

The graph of length against date identifies that earlier cars tended to be shorter. This is particularly noticeable in that there are a significant number (20) of early cars dating from before the 1905 layout paradigm was formed that are very short, and only about the same number (19) in the whole sample dating from after this date. Only one of these cars is from the sample of UK best-selling cars – the BMC Mini, which was in the top ten UK best-selling list from 1965 to 1981 inclusive. Part of the reasoning for this significant change is that very early cars frequently had a single tube chassis, which was not particularly stiff in the bending mode, and this tended to limit the wheelbase, which in turn limited the length.

A2.1.1.2 Width

In contrast with the length of a car, the width does not vary so much. There are few cars designed for a single person abreast, and also few cars designed to seat three people abreast. This means that most cars are of what has been termed 'normal' width. The histogram for width is therefore not a particularly interesting one. The histogram is slightly skewed towards the lower end, and the narrower cars tend to be from early periods than the later ones – yes, cars are getting slightly fatter, but this is not particularly apparent from the rather crude discretisation that was carried out.

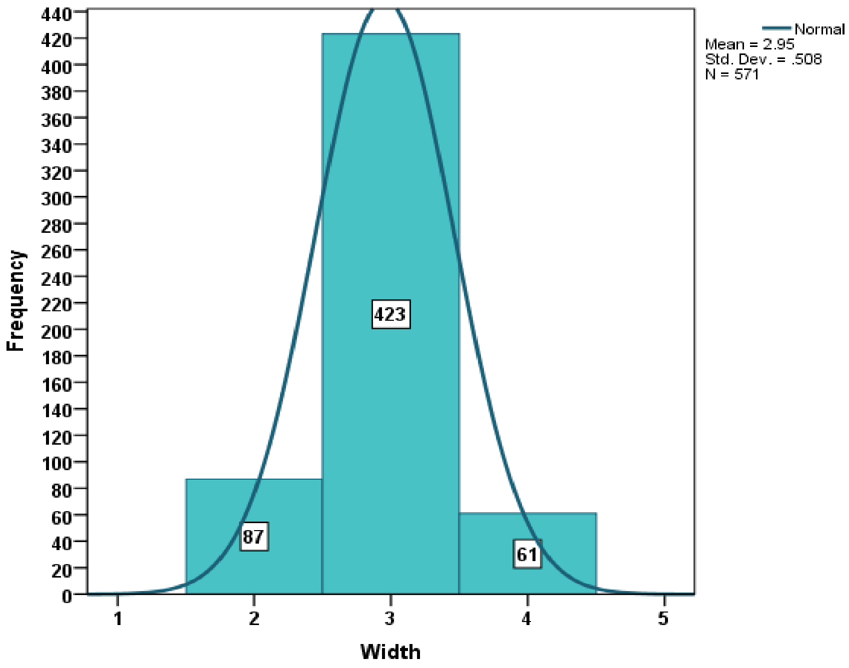


Figure A2.3 Car width histogram

A2.1.1.3 Height

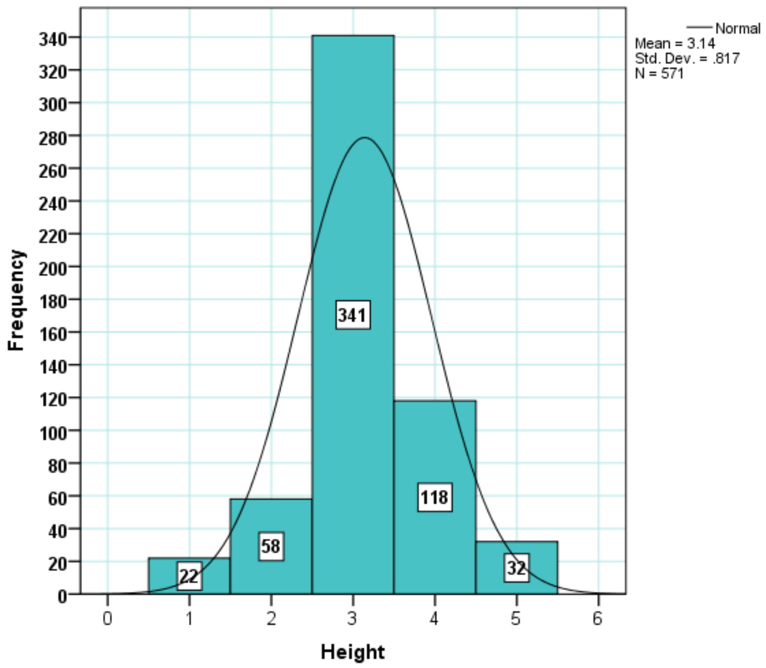


Figure A2.4 Height histogram

The histogram for height shows, not unexpectedly, a reasonably normal distribution of heights. When this histogram is coloured with the car periods it is reasonably easy to see that the tall and very tall cars are from the earlier periods, and that the lower cars were from the later periods from 1935 onwards.

The scatter plot confirms this, clearly showing that early cars were taller, with the mean trace reaching the ‘medium height’ line by around 1930.

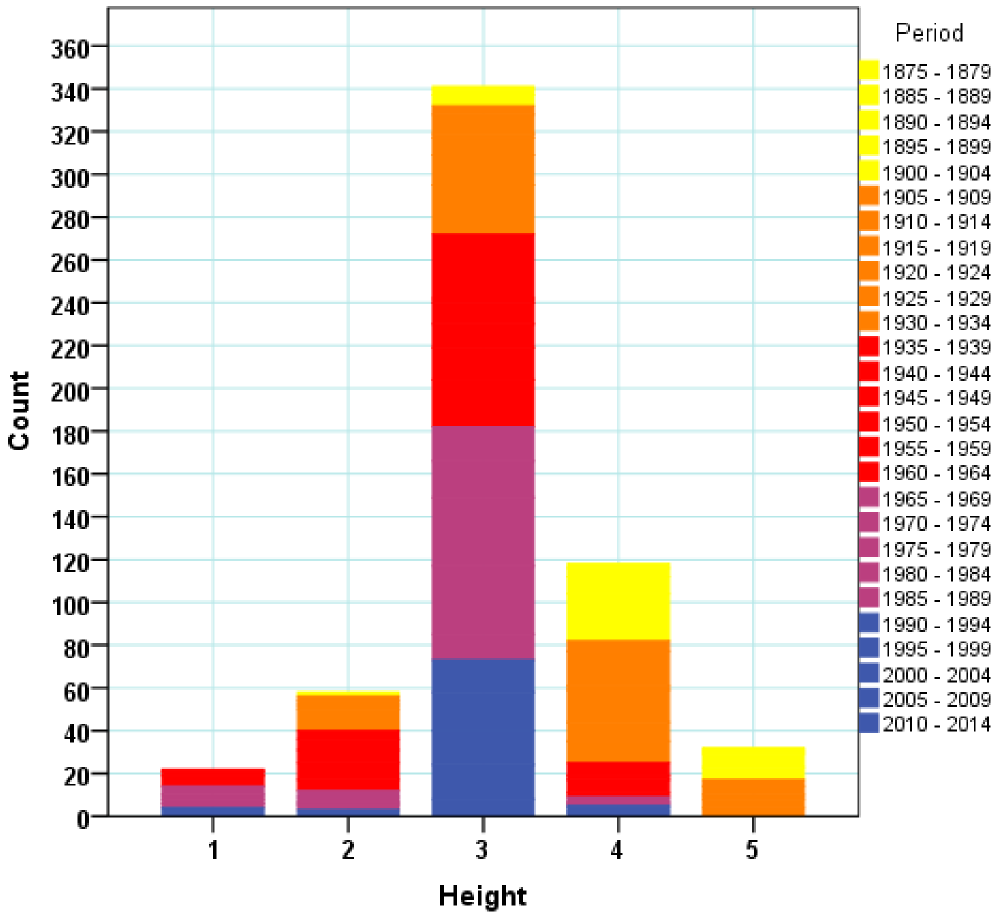


Figure A2.5 Height histogram with periods coloured

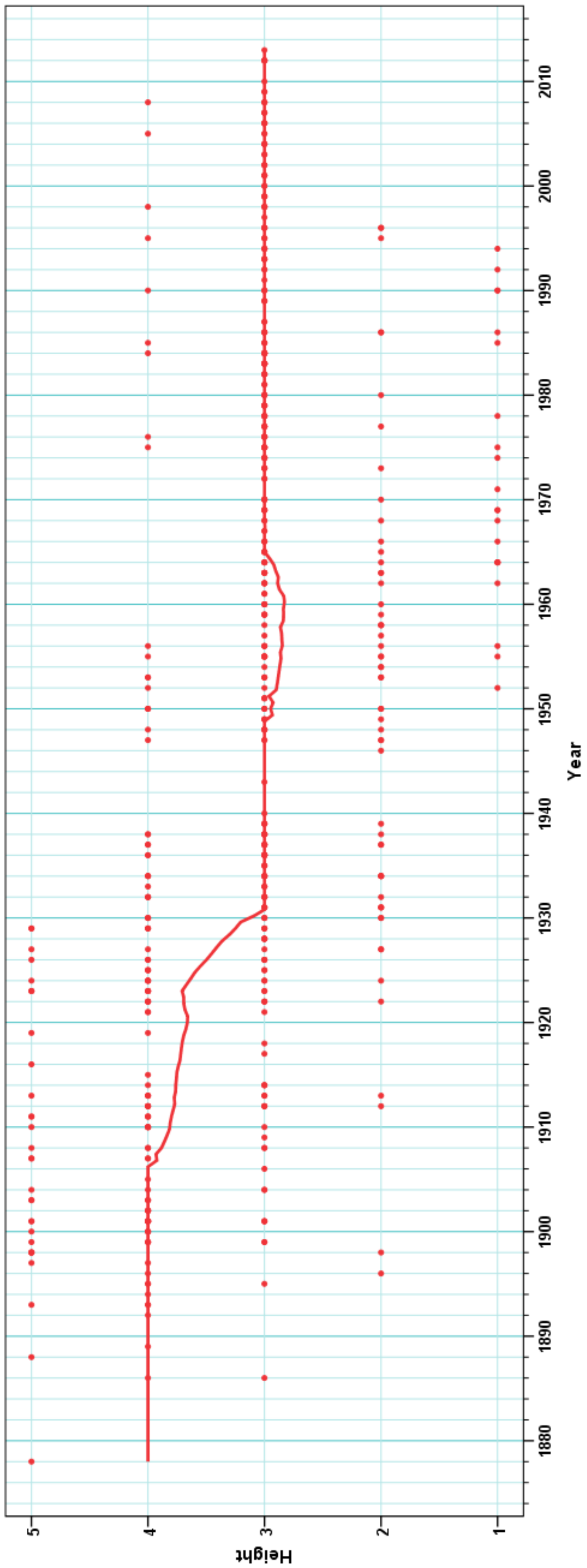


Figure A2.6 Scatter plot of height for date

A2.1.2 Seat rows

This variable was included as it specifies the type of car form. It seems to be more suitable for this than the number of doors that a car has, which is not necessarily very consistent with the form. Having said that, the majority of cars, particularly those which sold well, tend to have two seat rows: any fewer and the car is either an early car or a sports car as very few cars have a single row of seats if they are not sports cars - although some economy cars were built that way, like the Smart (which is not in the sample) and the bubble cars (which are as they were among the early photographs that were taken). Any more than two rows of seats and the car is a people-carrier, and there are very few of these in the sample, as they have not really featured in the UK best sellers, apart from the Vauxhall Zafira. A graph of seat rows taken against the year a car was built shows little information as there is little correlation. All it shows is that the best selling cars virtually all have two rows of seats and the cars in the original survey, which were a bit of an arbitrary selection, included more sports cars, which never find their way into the best sellers.

A2.1.3 Front and rear overhangs

These are discretised variables. The front overhang shows distinct historical movement. Early cars had very short front overhangs – in some cases the front of the car was formed by the front tyres – and this did not change until the significant shifts of layout design in the 1930s. The scatter plot of front overhang shows very short until about 1933, and then increased as independent front suspension started to become the norm and the engine started to move forwards between the front wheels from behind it, as dictated by the need to have movement for a solid front beam axle. The ability to move the engine forwards for more passenger room was linked to improved roll and ride behaviour gained by independent front suspension.

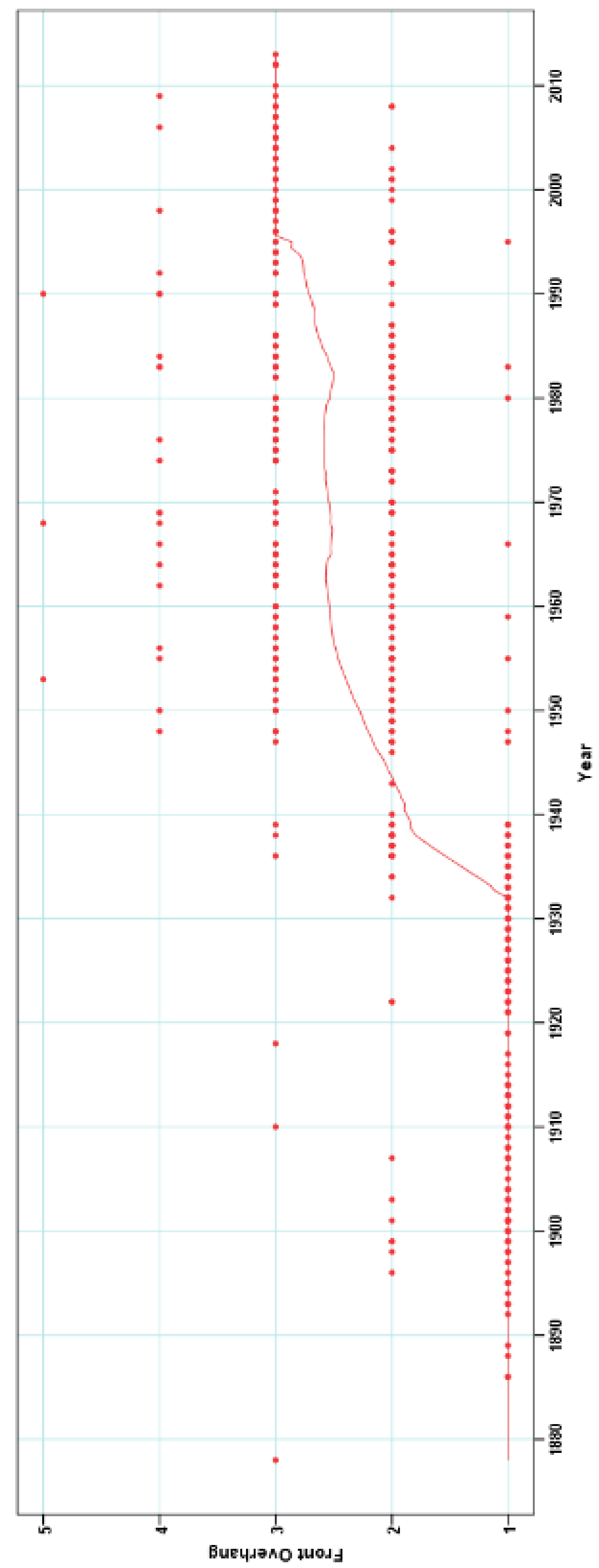


Figure A2.7 Front overhang plotted against date

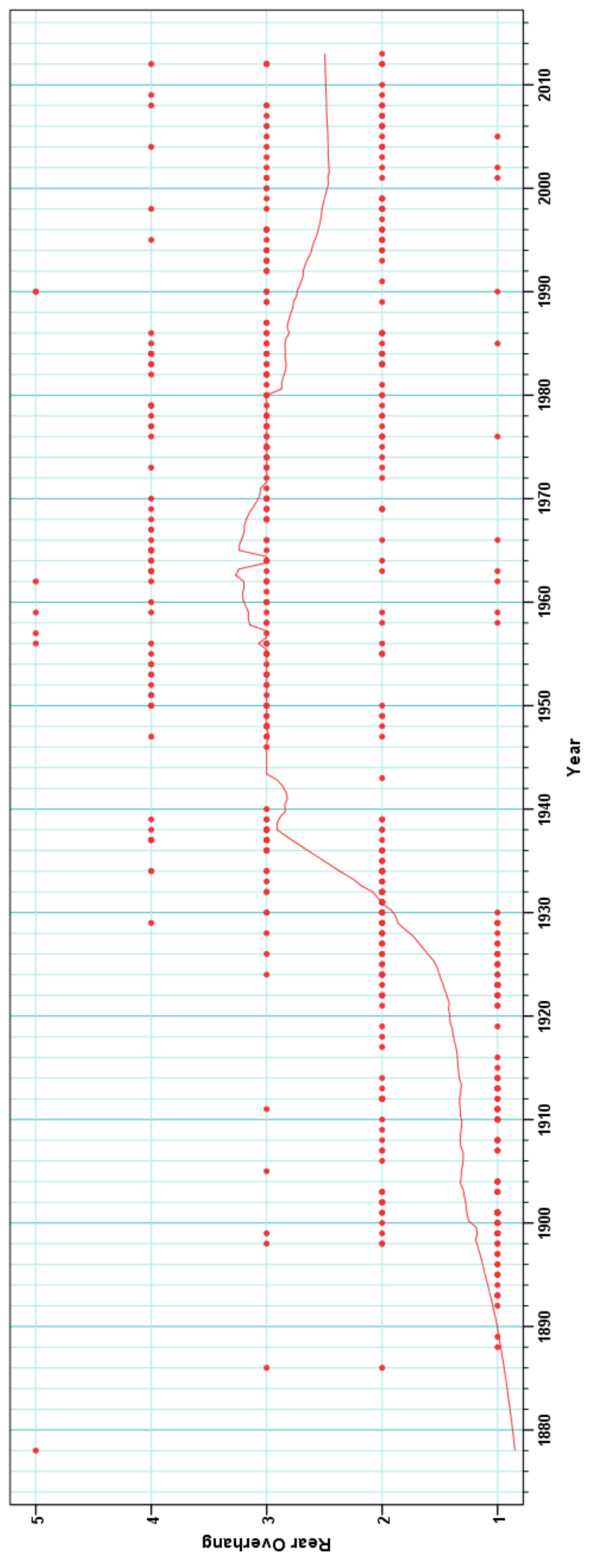


Figure A2.8 Rear overhang plotted against date

With the rear overhang the situation is more complex in that although there was a similar, if short-lived, movement to implement independent rear suspension in the 1930s the passenger compartment did not significantly move to between the rear wheels, although the rear overhang did increase, generally speaking, between the 1930s and the 1980s, only returning to a shorter distance with the popular arrangement of putting a ‘wheel in each corner’ that was perhaps started with the BMC Mini in the 1960s.

A2.1.4 Front and rear bumpers

These are truly categorical variables as they are descriptive ones. They also vary together, in that the front and rear bumper types tend to match each other.

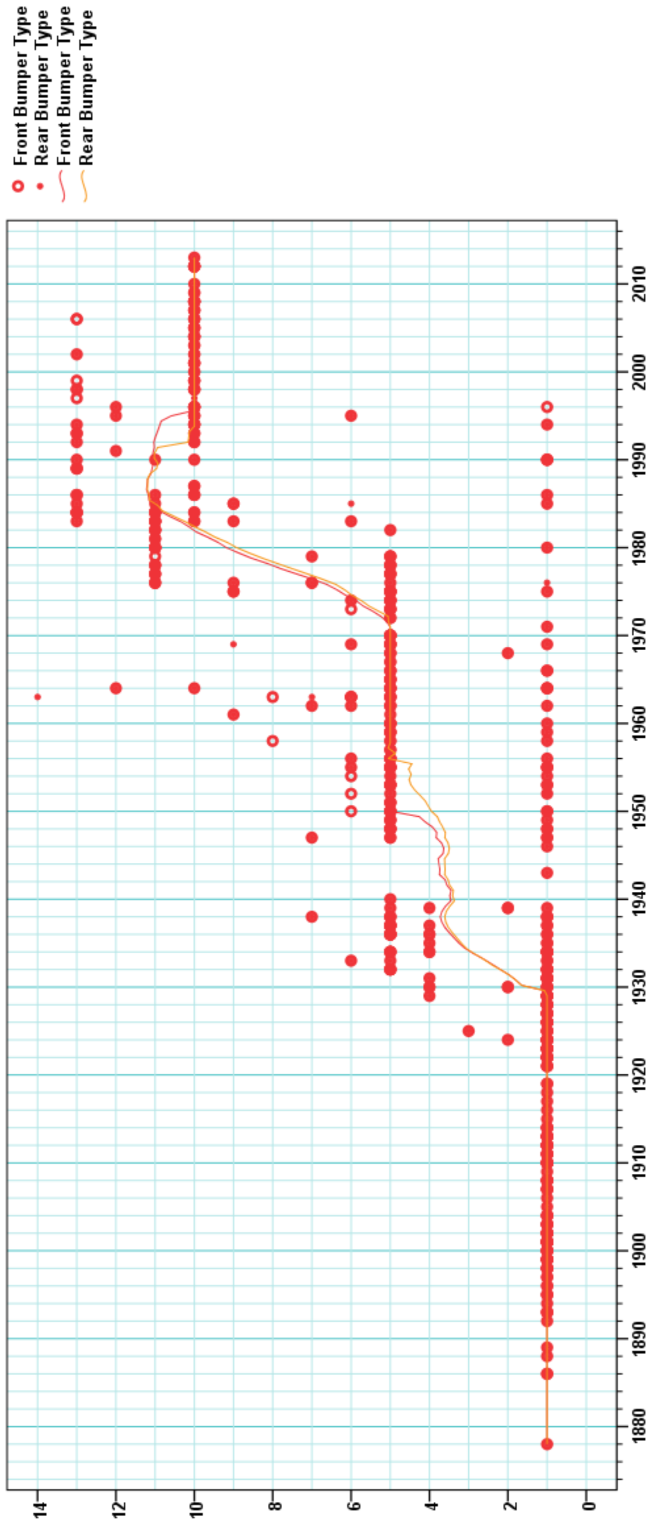


Figure A2.9 Front and rear bumper type. Note: small points are for rear bumper type only; unfilled circles are for front bumper type only. If the types are the same, the larger circle is filled in.

For this reason a table of values is helpful:

Value	Front Bumper type description	Rear Bumper type description
0	Don’t know	Don’t know
1	None	None
2	Tubular	Tubular
3	Wooden	Wooden
4	Blade	Blade
5	Chrome	Chrome
6	Quarter	Quarter
7	Painted	Painted
8	Tubular quarter	
9	Separate colour-coded	Separate colour-coded
10	Integrated colour-coded: Integrated colour coded with insert	Integrated colour-coded: Integrated colour coded with insert
11	Separate black	Separate black
12	Integrated grey	Integrated grey
13	Integrated black	Integrated black
14	Overriders only	Overriders only

Table A2.4 Values for bumper type

What we see is that bumpers were rarely attached to cars before about 1930. From that point onwards something, whatever it might have been, was attached to cars to cushion very minor blows either to the car or by the car. These generally consisted, initially, of simple tubular structures attached to the front and rear of the chassis, quickly moving to a vertical blade-like structure, usually, but not always, with curled ends. This was quickly succeeded by a chromed structure that became decorative as well as functional. Early chromed bumpers tended to be developments of the blade form, without much in the way of three-dimensional forming, and it is sometimes difficult to place a structure in one category or another. From the 1980s the chrome gave way to a black structure, either painted steel or rubber of some sort, particularly for vehicles being sold into the United States which brought in a 5mph impact requirement at around that date, and a simple chrome structure would not succeed in performing that role easily. From the 1990s the form of the bumper changed, to become significantly integrated into the form of the car, with the body-coloured bumper winning against the black version. This development tended to rely on the development of paintable polymers that would take the loads required of the impact system: the integration took place largely because the integrated system could fit effectively within the body structure whereas a separate system, to be effective in the higher-speed 5mph no-damage impacts would need to be proud of the body form by a considerable amount. It should also be said that there have always been a few specialist cars without bumpers, as these are necessarily heavy items and if not required by careless drivers (always the other ones) or legislation a car will always perform better without the extra weight. Of course the drawback is extra expense in slow-speed parking mishaps.

A2.1.5 Wing form

Car wings are not the variety of wings that allow them to fly! That is obvious, perhaps. The US term is *fender*, which although reasonably distinctive, tends, at least in the UK, to indicate a structural purpose of preventing minor accidents, which is not the case with these structures. Car wings are the structures that cover the wheels.

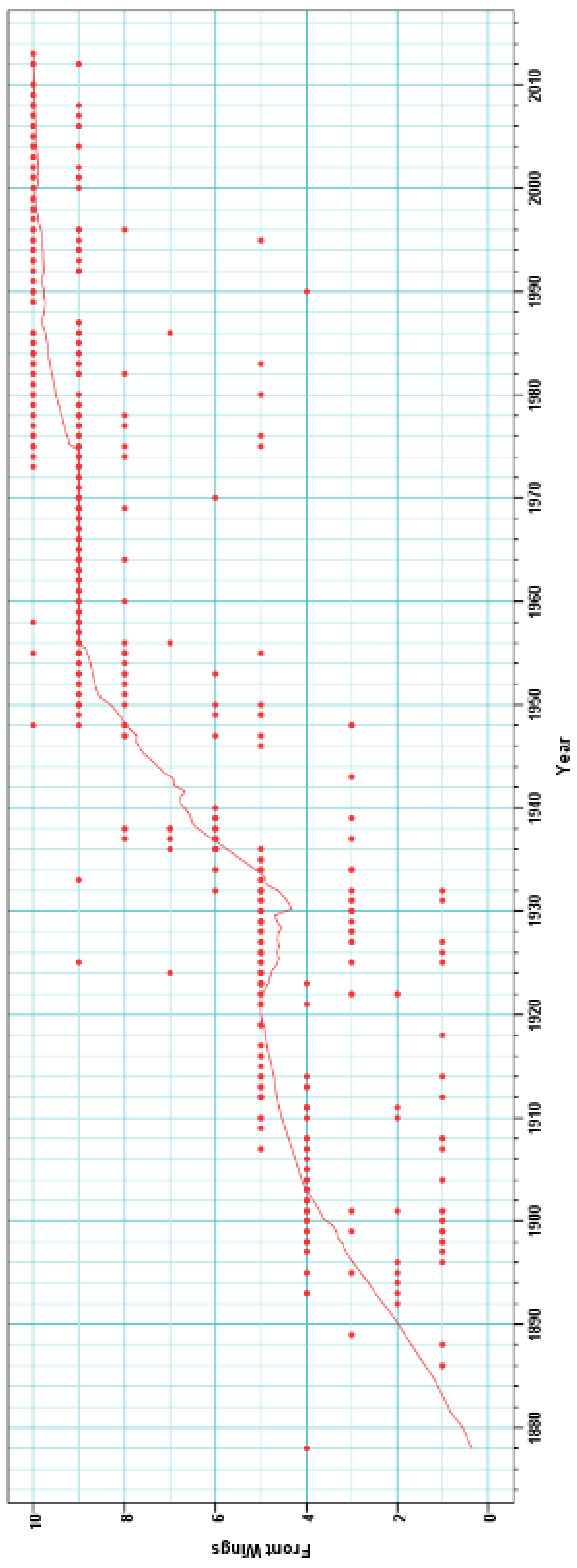


Figure A2.10 Front wing form

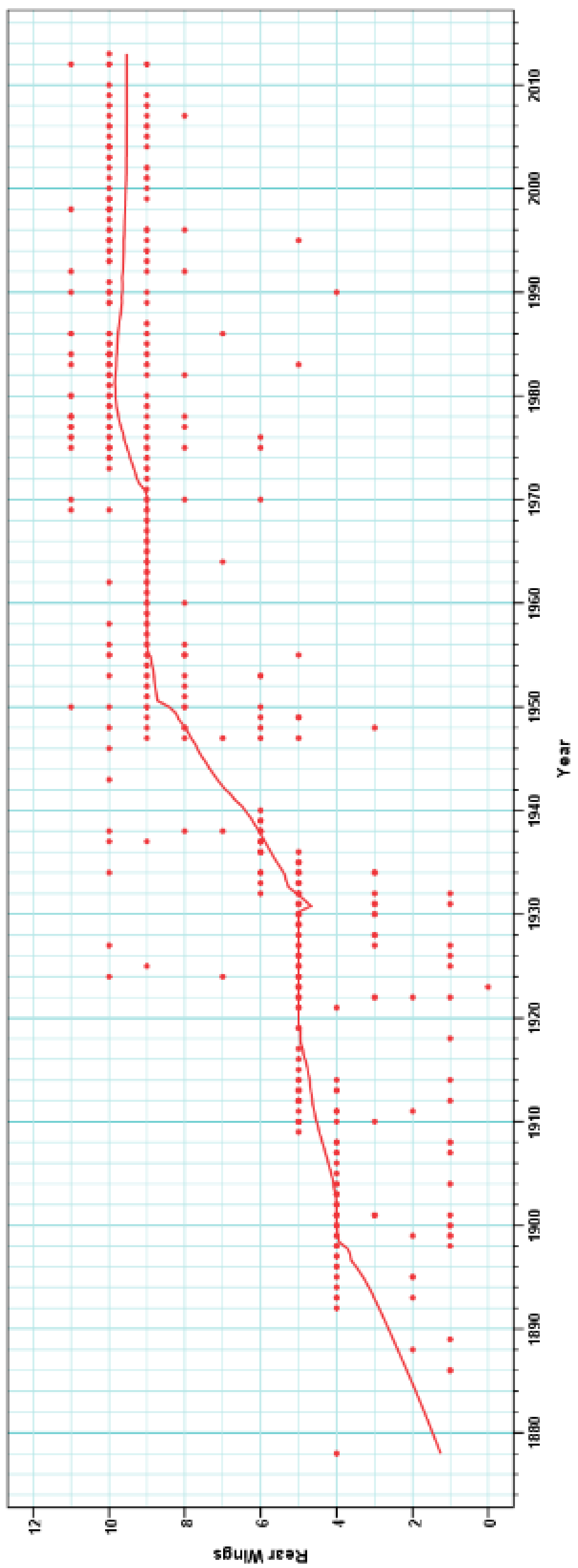


Figure A2.11 Rear wing form

Both these variables are categorical ones. In contrast to the bumper variables, however, the front and rear wing forms do not always follow each other.

Value	Front wing form	Rear wing form
0	Don't know	Don't know Flared one side, integrated the other
1	No wings – exposed wheels	No wings – exposed wheels
2	Flat board Angular board	Flat board Angular board
3	Cycle wings Attached cycle wings	Cycle wings: Attached cycle wings
4	Flared	Flared
5	Flared with rear valances Flared with spare and rear valances	Flared with rear valances
6	Valanced Valanced, with spare Valanced, with spats	Valanced Valanced, with spats
7	Pod Pod, joined	Pod Pod, joined
8	Merged	Merged Merged with spats Suggested Suggested with fins
9	Straight through Straight through but interrupted at passenger compartment Straight through with wheel bulges Straight through with spats	Straight through Straight through with wheel bulges Straight through with fins Straight through but interrupted at passenger compartment Straight through with spats Straight through with wheel bulges and fins Interrupted behind passenger compartment: wheel bulges
10	Integrated Integrated with spats	Integrated Integrated with spats
11		Rear quarter, Rising

Table A2.5 Values for wing form

There are some details that only feature on rear wings – fins, in particular, and some that only feature on front wings – a spare wheel nestled into the wing. There is one car in the sample that is an oddity with different wings on each side at the rear – this is the Scott Sociable, which is a three wheeler with two wheels on one side and one on the other. This was given a score of zero for its rear wing form as it really didn't fit into any sensible category and didn't have much effect on a historical development of cars' wing forms, although it could be argued that its left side is an early example of an integrated form. The other car with two wheels on one side and one on the other, the Monash University Solar Car, has all its wheels safely tucked underneath everything – integrated wings, of course.

The historical changes in wing form are significant. It is fairly clear that these are linked with the historical changes to passenger compartment width, which widened significantly between 1940 and 1950 or thereabouts. For instance, a narrow body is not possible with straight-through wings as the two are contradictory.

By 1900 or so the flared wing style (4) was introduced and became the most popular for a time – until people decided that there really needs to be some sort of protection between the wing and the rest of the body, when a rear valance was added between the wing and the chassis or body, depending on what was the nearest useful piece of structure to attach it to. This occurred from about 1910 onwards and after this date few people were happy to have road muck and spray coming at them between the wings and the chassis. This style is defined as being a flared wing with a valance (5). In the 1930s the flared wings tended to have valances at the front as well as the back: defined above as being valanced (6). This style did not last particularly long, as it was overtaken by the more significant paradigm shift that took place after the 1930s with movements towards full-width body shells, with the wings developing eventually into the straight-through form (9). This did not occur immediately, and what we find is that the long flared front wings of the 1920s which grew valances in the 1930s joined the rear wings at a higher and higher point to become, eventually, the single line of the straight-through form. A series of pictures might best demonstrate this change.

Figure A2.12 1908 Sizaire-Naudin clearly showing the flared wings with no rear valances.

Figure A2.13 A very similar Sizaire-Naudin, but from 1910 (two years later) clearly showing the valancing behind the flared wings.

Figure A2.14 A 1932 Bugatti Type 55 showing the flowing front and rear flared wings joining each other in a smooth curving form.

Figure A2.15 This is a car with a very short manufacturer's name – Z. It dates from 1934, and shows the flared wings starting to get the hint of valances on the outer edge, with added depth of the shaping.

Figure A2.16 Talbot 150C, from 1939, showing valanced wings, with spats at the rear.

Figure A2.17 1937 Tatra 87 showing the front wings merging into a full-width body. Classic and Sports Car says that ‘to think that the T87 was made at the same time as … Western car, however, takes a considerable feat of imagination. Every detail of the Tatra stands out…” (Roberts, 2015).

Figure A2.18 A Maybach: this is a 1938 car that was rebodied in the 1950s by Spohn. It shows the front wings flowing rearwards to join the rear wings about half way up the lower part of the body.

Figure A2.19 A 1955 Humber Hawk showing wings that merge with the rear wings a little higher up the body.

Figure A2.20 Citroën DS, probably from the mid-1970s. Here the front wings merge almost imperceptibly into the front doors – and the rear wings disappear, integrated into a full-width rear form with only a very narrow ledge on the outside of the windows.

Figure A2.21 A 1933 Pierce Silver Arrow showing straight-through front wings, but separate spatted valanced wings at the rear. (Wikimedia Commons: James Emery)

Figure A2.22 1955 Lancia Aurelia Spider with straight-through front wings and merged rear ones.

Figure A2.23 A Tatraplan from 1951 showing a true straight-through wing lines from front to rear, also with spats at the rear.

Figure A2.24 Ford Anglia showing straight-through wings with small fins at the rear. This example dates from 1967.

From the 1970s an integrated form becomes apparent, where there is a discontinuous line from front to rear and the windows are nearer to the outside of the car form. In some cases the window lower edge is below the top edge of the front wing line, which itself has become integrated into the bonnet top.

Figure A2.25 The British Leyland Princess range of the 1970s shows a clear break in the wing line at the front pillar, as does the Vauxhall Cavalier from the early 1980s (see below): (Wikimedia Commons: Charles01)

Figure A2.26 Vauxhall Cavalier, 1983

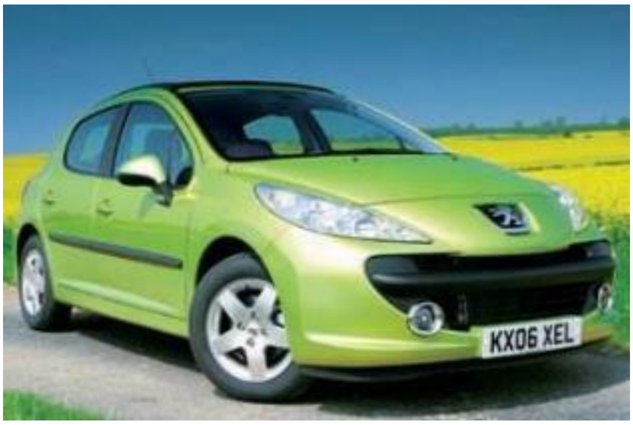


Figure A2.27 Peugeot 207 (2006) showing very clearly how the wing line is split with the lower line of the door windows being considerably lower than the bonnet line (Autocar).

This integrated form does not totally replace the form with the straight-through wing line – or has not done so yet.

A2.1.6 Screen position, screen rake and screen type

These three related variables determine significant characteristics of the form of the screen.

Value	Screen type	Screen Rake	Screen position
0		None Reverse Fold Flat	
1	None Leather screen	Upright	Forward control
2	Single Aero Monocle Twin Aero	Raked	Front wheel centreline
3	Flat Flat screen to rear compartment Flat with corner windows Flat with curved corner windows	Very raked	Rear of front wheels
4	Double mesh grilles Vee	Raked and upright	Medium
5	Curved		Rearward
6	Wrap around Wrap around multi piece		

Table A2.6 Values for screen type

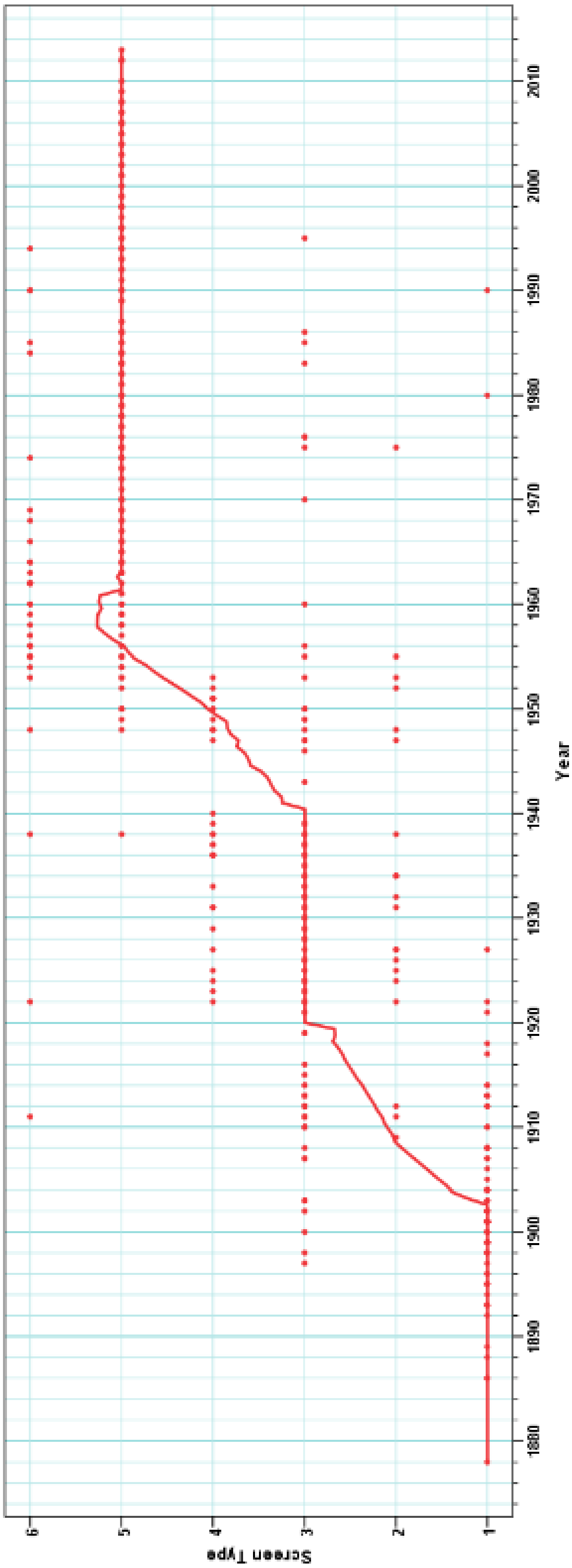


Figure A2.28 Screen type

Early cars had no weather protection at all, and this also applied to their having no screen at all. Although there are two cars with no screen at all, one from 1980 and 1990, these are both replica-type cars and this is certainly not what would be expected from their date of manufacture. The lack of any windscreen at all had virtually died out by 1920: a few cars had the token aero-type screen or a monocle screen from about 1910 – monocles and double monocles (very rare) before 1920 and aero screens after then – most cars had at least some forward protection from the elements from about 1906 onwards. Screens were flat until the Second World War. From then on some curving was introduced. This was not because curved glass could not be produced at all before then, but more because it was thought that it would cause distortion. The 1911 Alfa Ricotti demonstrates that it was perfectly possible, if somewhat eccentric, to produce a curved screen.

Figure A2.29 Alfa Ricotti from 1911 – a one-off body shell (Coachbuild.com).

Several cars built after the second world war still had flat screens, usually because they are significantly cheaper to manufacture and perhaps cheaper to provide in out-of-the way situations (which is the reason that several 4x4 vehicles have used them relatively recently). Amongst the UK best sellers, the latest with a flat screen is the Volkswagen Beetle, a best seller in 1970, which introduced a curved screen in 1973 – although the flat screen was still available at the end of production in Mexico in 2003.

Figure A2.30 A 2003 Volkswagen Beetle – not in the sample.

The difference between a curved screen and a wrap-around screen is not always easy to determine: a wrap-around screen is simply described as a screen with significantly more curvature than a curved one: it may in addition have screen pillars at a very different angle from the screen rake: in some cases these are reverse-rake pillars, such as in the 1955 Lancia Aurelia Spyder seen earlier in the discussion on wing forms or in the 1960 Vauxhall Cresta.

Figure A2.31 Vauxhall Cresta, 1960

There was what looks like a fashion for wrap-around screens from the mid-1950s to the mid-1960s.

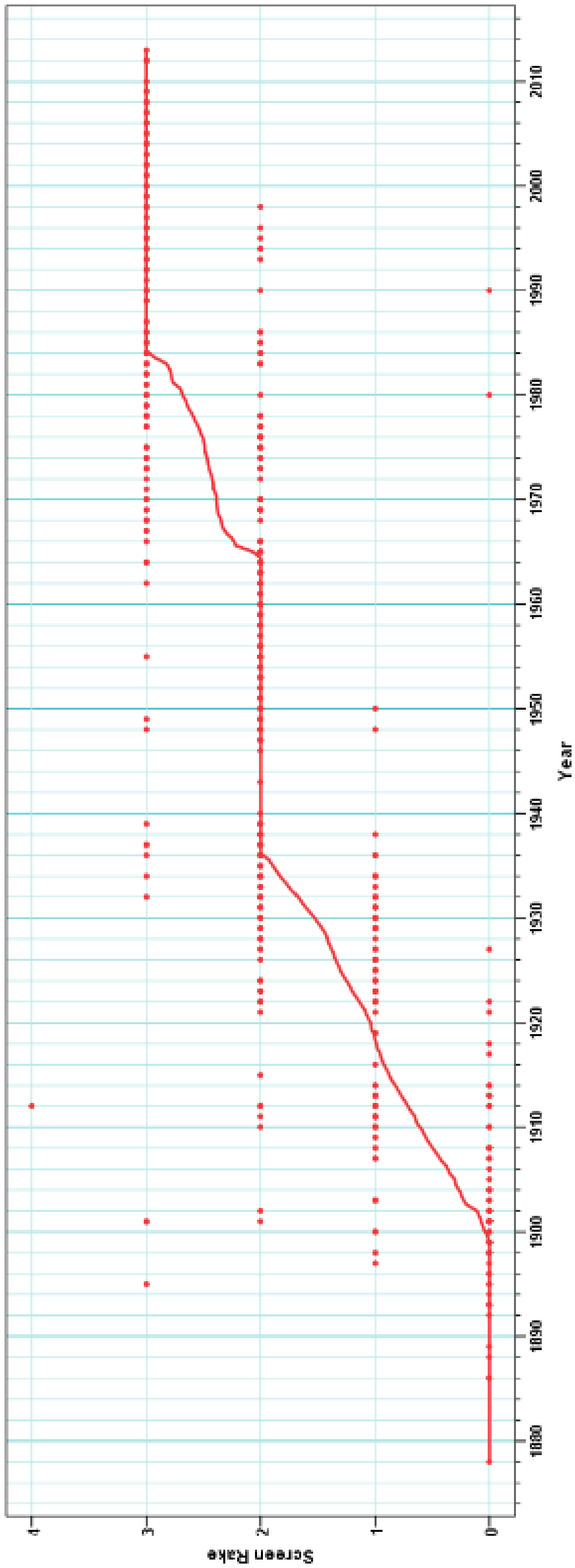


Figure A2.32 Screen rake (discretised)

Clearly, from Figure A2.32, screen rakes increase with date and become more extreme. This increase in rake is associated not just with fashion, but also with the desire to produce a car with low fuel consumption, which tends to result from a more raked screen. Today’s screens would almost certainly be thought to be very extreme by someone transported suddenly from, say the 1950s. The discretisation process for this variable is somewhat crude, although it does actually produce the result that says that screens are more raked than they were, suggesting that the scale is a stepped one is simply not true: the reality is that the change is a smooth curve.

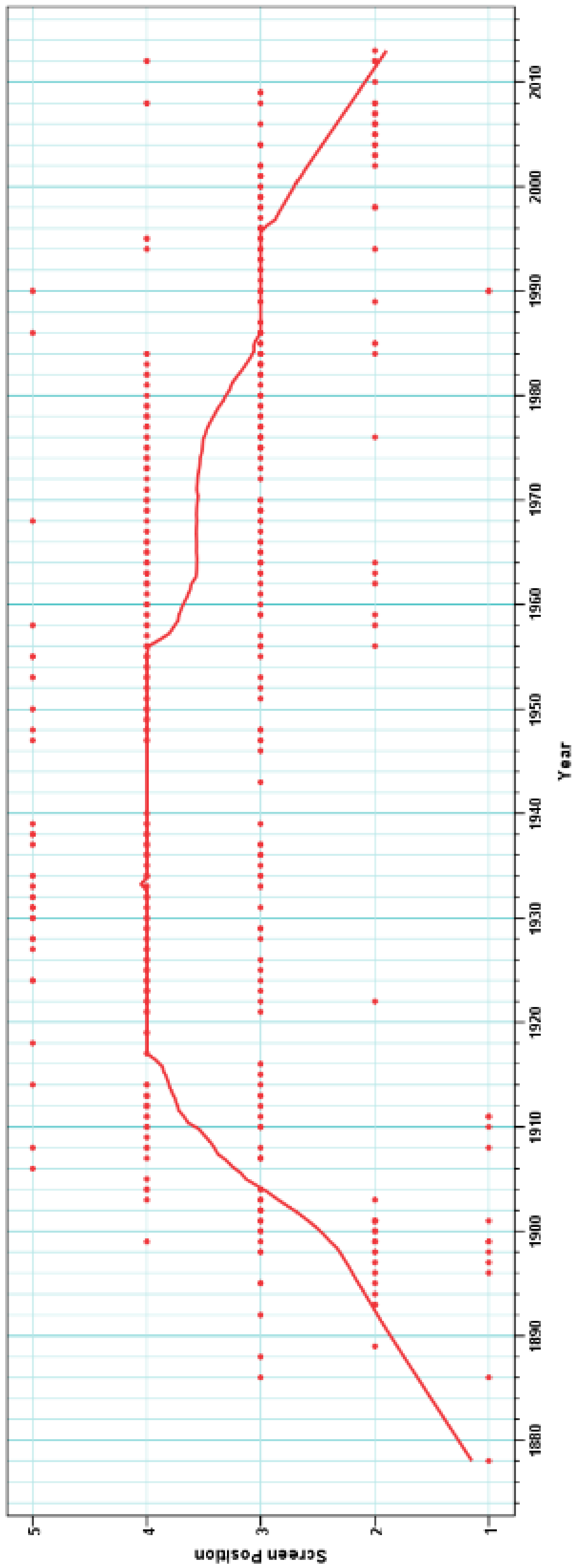


Figure A2.33 Screen position (discretised)

The data for this discretised variable also show that the discretisation is relatively crude. However, it is clear that the screen position starts off relatively close to the front axle position and increases until about the 1920s or 1930s, then decreasing. Looking at the non-discretised data, it would appear that this decrease does not continue but has a small dip and then increases to become reasonably flat. It might be surmised from the concept that the form data follows the layout data, that there would have been a step function in these data from about the mid-1930s, but it is not clear whether this takes place or not – the suggestion is that it does not and that the reduction in value of the variable is gradual rather than stepped. The graph of the non-discretised data does not extend back far enough currently to identify this information.

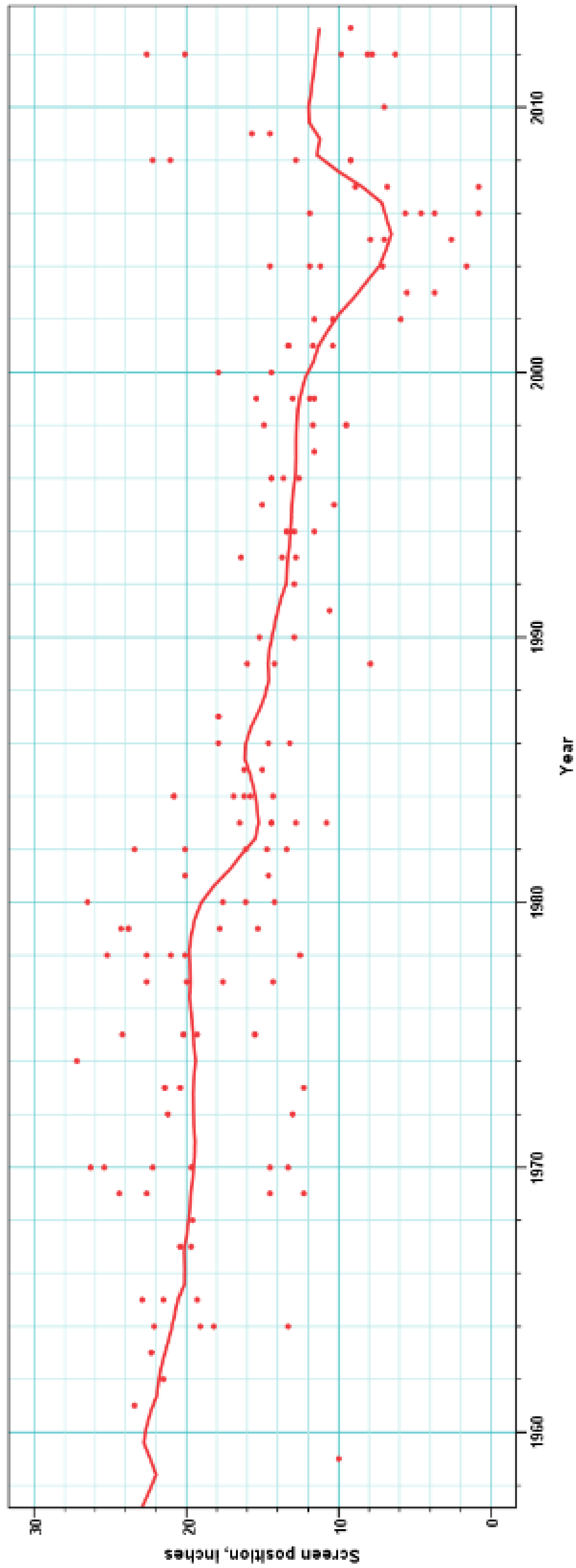


Figure A2.34 Screen position: not discretised

A2.1.7 Bonnet length and bonnet plan

Value	Bonnet length	Bonnet plan
0	Don't know (!)	None
1	None	Rectangular narrow
2	Very short	Tapered narrow
3	Short	Tapered wide Tapered, faired to wings
4	Medium	Rectangular wide
5	Long	Twin boom
6	Very long	

Table A2.7 Values for bonnet length and bonnet plan

The bonnet length variable has been discretised, again reasonably crudely. The first discussion here is that a zero bonnet length is the same as having no bonnet at all.

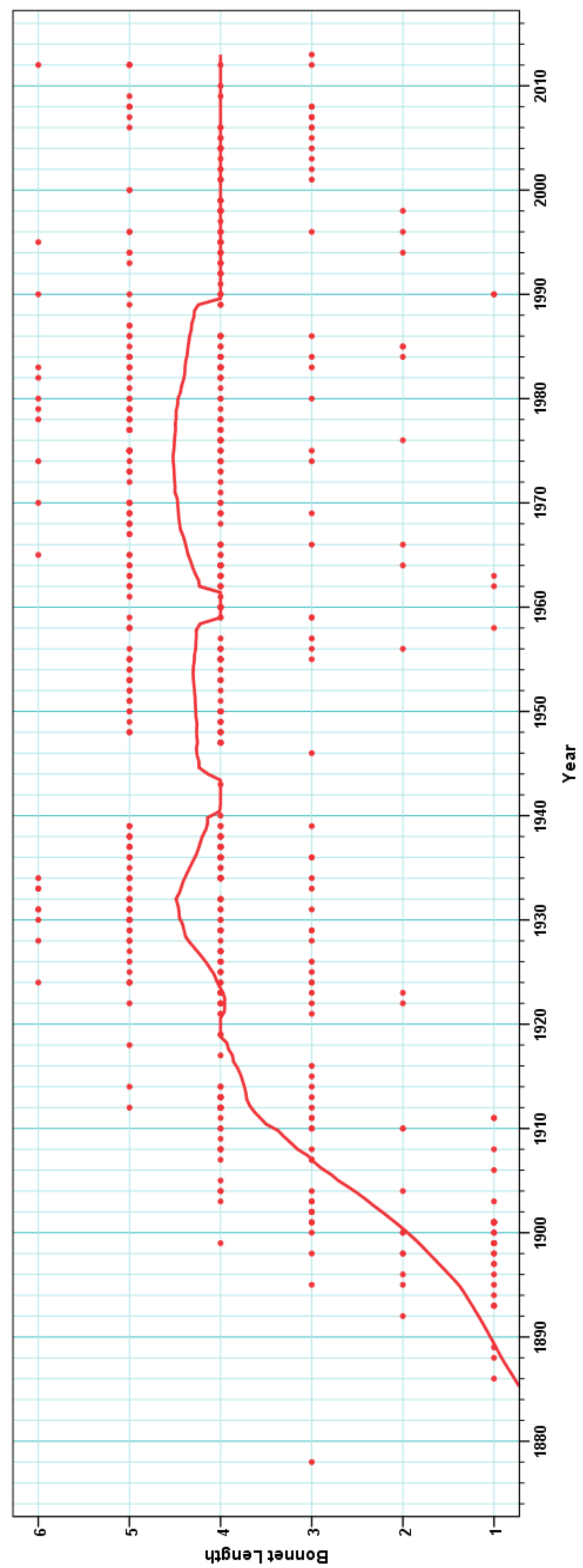


Figure A2.35 Bonnet length (discretised)

This variable simply shows shorter bonnets giving way to longer ones. Whilst it might have been anticipated that the shorter bonnets would return significantly, the mean trace suggests that this is not yet really taking place and that there are still a relatively large number of cars with longer bonnets that are popular in the UK. This reversion of position is probably well illustrated by a series of Mercedes-Benz cars: the three different generations of A Class cars (these are not in the sample).

Figure A2.36 Mercedes-Benz A Class cars from 1997 – 2003, 2004 – 2012 and 2013 onwards. The lengthening bonnet can be seen, as can the ‘retreat’ from the two-box form that felt like an innovation when it was first introduced in 1997 (Wikimedia Commons: Matthias93).

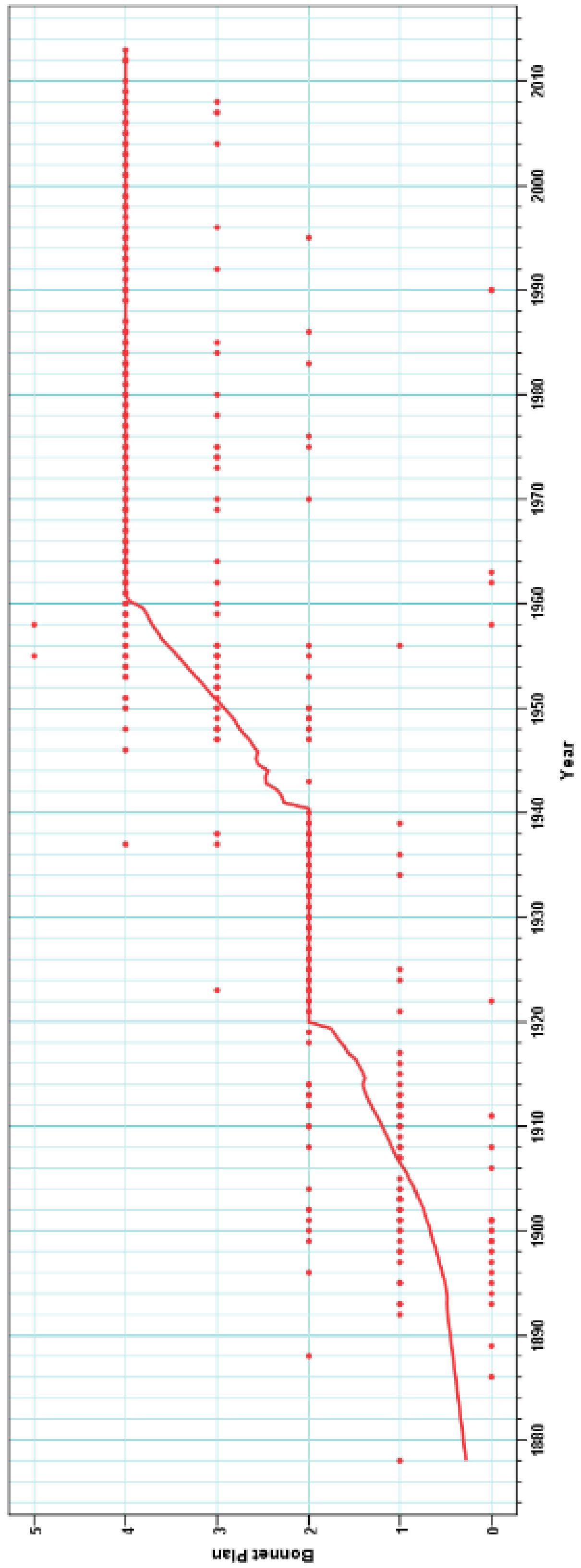


Figure A2.37 Bonnet plan

A number of early cars had no bonnet at all. Sometimes this was because they had no body at all: in other cases this was because the front of the car consisted of a seated passenger facing forwards (known as a forecar) with the driver sitting (usually) on some form of saddle arrangement behind, in others because the front consisted of a rearwards-facing bank of seats (a vis-à-vis arrangement) and in yet others there was simply a vertical panel. This category also includes two bubble cars from the late 1950s and early 1960s which have front-opening doors, effectively replacing any bonnet. Apart from these bubble cars, these various arrangements were all replaced from about 1895 with a rectangular narrow bonnet. This covered the engine, and was a different width from the passenger compartment behind. The next stage, from about 1920, was for this form to become wider at the rear to the same width as the passenger compartment. This is, at this stage, still classed as a ‘narrow’ bonnet because the passenger compartment is not full-width. The next stage, from the late 1940s, was to widen the passenger compartment to full width and thus to widen the rear of the bonnet to full-width also. Whilst the front of the car was usually also full-width at this point, the bonnet front remained narrow with a narrow radiator. From the early 1950s there were a significant number of cars where the bonnet front was widened to become full width, usually including a horizontal form of air-intake grille rather than the earlier vertical form – although some cars still had a narrow form of grille with the rectangular wide bonnet form.

A2.1.8 Grille Form

Thus, connected with the bonnet plan is the grille form. This is significantly more difficult to determine than the bonnet plan, and it tends to form a means of identifying the car’s branding. In some of the UK best seller descriptions the car definition covered several differently branded cars under the same heading – badge engineered cars. These usually have different grille forms to identify the different branding. Hence, for instance, the BMC 1100 / 1300 range from 1962 to 1974 included examples branded as Austin, Morris, MG, Wolseley, Riley and Vanden Plas.

Figure A2.38 Clockwise from top left: Austin 1300 (1972) (Wikimedia Commons: Charles01), Morris 1100 (1963) (aronline.com), Wolseley 1300 (1969) (Wikimedia Commons: Charles 01), Vanden Plas 1300 (1968), Riley Kestrel (1969) (Wikimedia Commons: Charles01), MG 1300 (1972) (Wikimedia Commons: Charles01),

Value	Grille Form	Amalgamation
0	Don’t know	
1	None	None
2	Gilled tube	Gilled tube
3	Coal scuttle; Coal scuttle with rear radiator; Coal scuttle with gilled tube	Coal scuttles
4	Rectangular; Rectangular, chamfered corners; Rectangular, rounded; Trapezium; Round;	Approximately equal height and width
5	Set of louvres in rounded bonnet	Not really there
6	Upright, rectangular, rounded corners; Upright, rectangular, rounded top; Upright, rectangular, vee; Upright, rectangular, rounded corners, vee; Upright, rectangular, pitched top; Upright, pitched top, Vee; Upright, horseshoe; Upright, horseshoe, Vee; Upright, tapered, rounded corners; Upright, bullnose; Upright, shield; Upright, oval; Upright, rounded, faired; Upright, rectangular, faired; Upright, double slot, faired; Upright, shield, faired; Upright, horseshoe, faired	Vertical forms
7	Upright, oval, faired with flanking ovals; Upright shield with horizontal rectangles; Upright rectangular with flanking rectangles	Combination of horizontal and vertical forms
8	Horizontal Ellipse, Horizontal semi-ellipse, Horizontal semi-ellipse with teeth, Horizontal double nostril, Horizontal rectangular, Horizontal rectangular with pitched top, Horizontal rectangular with teeth, Horizontal slot, Horizontal double slot, Horizontal trapezoidal	Horizontal forms
9	Horizontal slot with bumper intake; Bumper intake	Bumper intakes – these seem to be amalgamated with the bumper in some way.

Table A2.8 Values for Grille Form

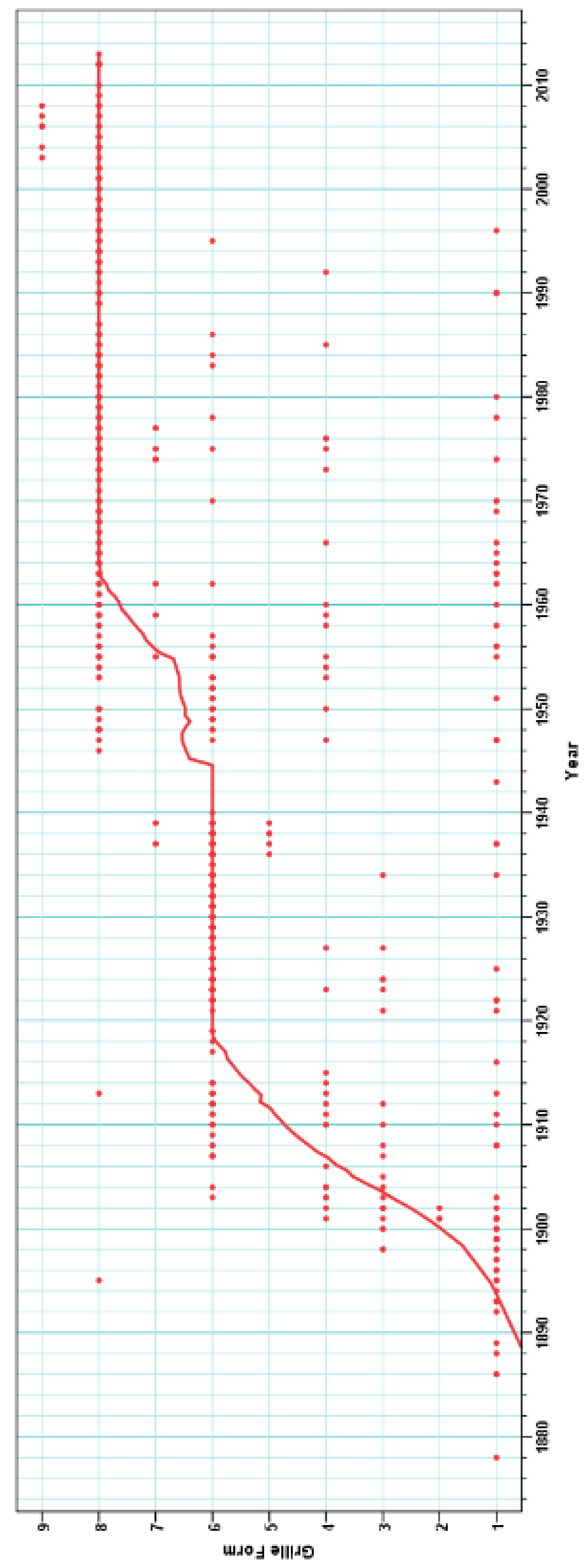


Figure A2.39 Grille Form

In Table A2.8 many different overall shapes have been amalgamated into some general categories. The existence of a grille on a car is as a result of the engine needing to be cooled in some way. All heat engines reject heat to their surroundings, and internal combustion engines therefore all do this. Internal combustion car engines are cooled either by liquid, usually water (but just occasionally air), or by gas, almost always air in practice. Some early liquid-cooled cars may have relied on the spare water in a large tank to cool the engine. Others placed some form of heat exchanger somewhere near the engine and some used air, with finning on parts of the engine that got hot. One or two cars had a combination of air and water cooling, with parts of the engine being cooled by each (there is an argument that all cars are, in fact, air cooled and some just intersperse liquid between the air and the engine to aid the process). An early process of cooling was simply to have a long tube with fins on it and to zigzag this around to form something like a grille. This is the gilled tube system. The next process was to combine tubes into some form of radiator, which came to form the grille, which generally tended to be placed in front of the engine.

After some time this radiator became the form by which car brands became recognised and the radiator was a distinctive feature. The feature remained, and the radiator itself then became covered by a grille form, which then turned into a more designed air circulatory system on some cars. Thus the very early cars simply had no grilles (1), and there have always been some cars, typically those with air-cooled and rear engines, which had no need for a front grille, and thus there are always a few cars scoring 1 for all dates. The next process was to use one or more zigzag finned (gilled) tube (2), or this in combination with what is known as a coal-scuttle form of bonnet (3). Some cars, notably Renault, continued to use coal scuttle bonnets with the radiator at the rear of the engine until the late 1920s, and in this case the bonnet shape became a distinguishing feature for the marque. The latest car in the sample with a coal scuttle type bonnet is a 1934 Mercedes-Benz with a rear engine – although one could argue that the Volkswagen Beetle form is a development of the coal scuttle.

The coal scuttle form was replaced from the early years of the 20th century by the vertical grille form. In some cases even air-cooled cars added a vertical grille form at the front, even though they didn't really use the grille as an air intake. This vertical form of grille is still used by some manufacturers as a brand distinction, sometimes in combination with a broader grille to give more cooling area. See the above pictures to see how it was used to differentiate and badge-engineer the BMC 1100 / 1300 ranges in the 1960s and 1970s. The significant change from the more narrow, upright grille occurred as car bodies became full width – or slightly later. Although there are two early examples of what are termed a wide grille in the sample, the first car in the sample that demonstrates the start of the trend is a 1947 De Soto (seen in somewhat decrepit condition on the banks of the Bosporus in Istanbul)

Figure A2.40 De Soto Diplomat, 1947

The changes in grille form might be best seen by seeing pictures of typical examples that show the changes.

Figure A2.41 No grille – Panhard, 1892: Gilled tube – Wolseley 1901 (© British Motor Industry Heritage Trust)

Figure A2.42 Coal scuttle with gilled tube – Georges Richard 1903

Figure A2.43 Coal scuttles – Clement Bayard 1909, Renault 40CV 1927

Figure A2.44 Horizontal louvres – Cord, 1936

Figure A2.45 Vertical grille – Citroën, 1925

Figure A2.46 Horizontal grille – Cadillac, 1962

A2.1.9 Headlight position and type

These two variables tend to be the visible signs of changes in cars' ancillary systems. For several cars, lights have always been optional. Some cars, such as racing cars, may not have been driven on public roads or travelled at night. For others, lights were an add-on extra, to be placed on the car if night travel was envisaged. In early days, if lights were required they were required they oil lamps, usually shaped like carriage lamps with a rectangular casing and attached at suitable positions – which may have been on the side of the bonnet, at the sides of the scuttle, on the sides of the seat, and so on. In the very early years of the 20th Century the Carbide or acetylene lamp was invented, burning acetylene produced from the reaction of calcium carbide with water. These were a more integrated accessory, although frequently still portable, and were used from about 1905 onwards, although it is difficult to tell exactly when they were first fitted as they are able to be relatively easily added later. Electric lighting was first fitted to cars from around 1908, and became commonplace from the 1920s. The lighting fittings became non-detachable and the whole system wired in (or in the case of carbide lamps plumbed-in) from about 1910 onwards. Headlights were generally round from then until the 1960s

Value	**Headlamp Form**	**Headlamp Position**
0	None	None
1	Carriage	Side of bonnet
2	Round	Back of seat
3	Round Faired;	Scuttle
4	Round under Elliptical fairing	Separate in front of front panel
5	Rectangular	Above front wings
6	Trapezoidal: Square	Separate above wings
7	Elliptical	Front in middle
8	Semi-Elliptical	Centre in front and back of seat at sides

9	Ovoid faired	Separate on wings
10	Rectangular faired	Separate between grille & wings
11	Trapezoidal faired: Irregular faired	Behind grille
12	Pop-up	Faired between grille and wings
13		In wings
14		Front panel
15		In wings and front panel
16		Bonnet top
17		Bumper
18		Faired into corners

Table A2.9 Values for headlamp form and position

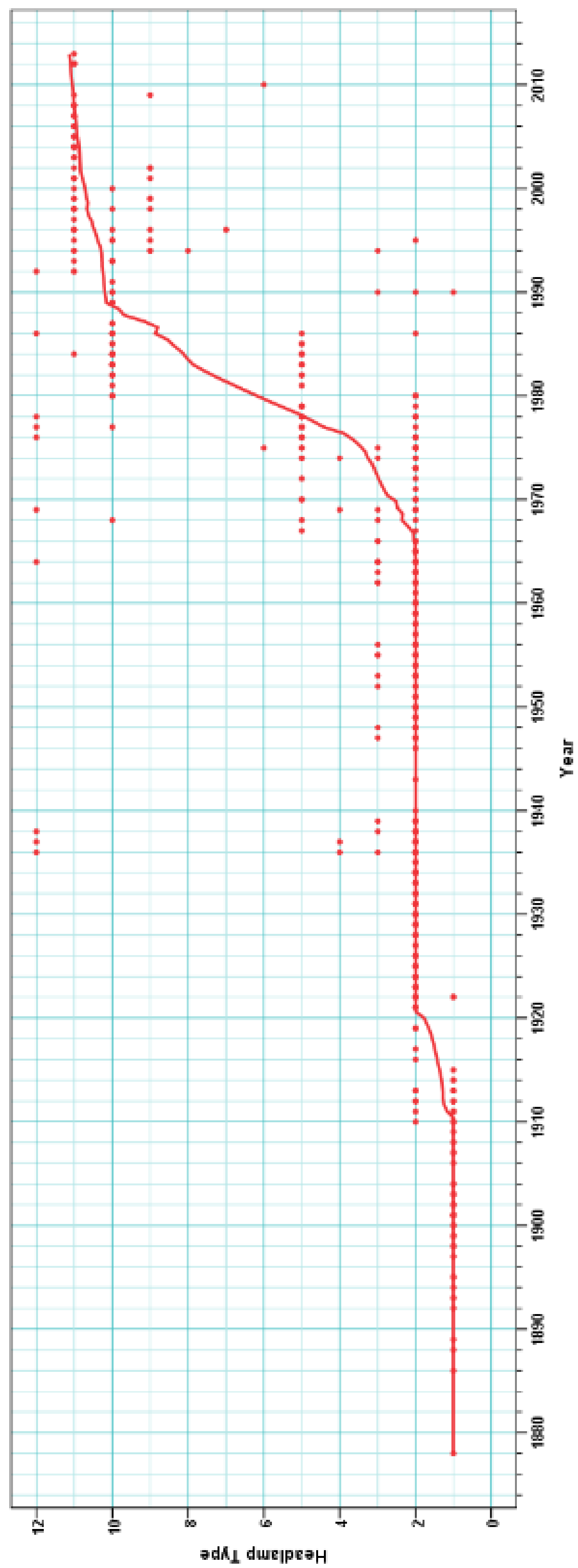


Figure A2.47 Headlamp type

Figure A2.47 shows that significant changes in headlamps occurred not during the late 1930s or the Second World War, but at two or three other points. Firstly, between 1910 and 1920 with the introduction of electric lighting, when round headlights replaced the carriage lamp form, secondly from around 1970 when the first change took place from the round headlamp to the rectangular one, and then to a faired form of lamp where the external surface followed the body contours, firstly keeping the previous form and then from the 1990s onwards with complex, irregular forms. These changes to headlight form tended to follow changes in headlamp technology which enabled the form changes to take place.

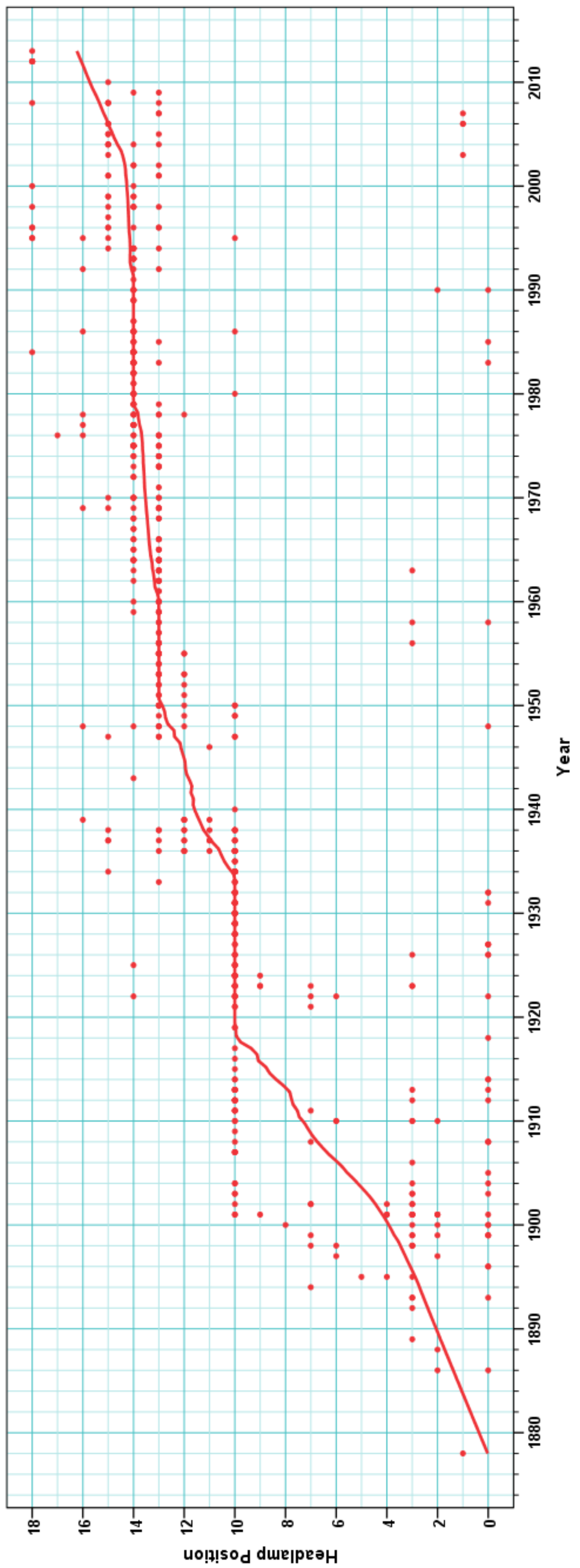


Figure A2.48 Headlamp Position

The graph for headlamp position looks somewhat messy in character. The major players in the position are attached to the scuttle (3), separate headlights between the grille and the wings (10), in the wings (13), in the front panel (14) and in the wings and front panel (15). The change from scuttle mounted lights tended to take place when electric lighting was introduced, although some cars such as the Austin 7 had electric scuttle-mounted headlamps: the next change from separate lights mounted between the grille and wings took place with the move to full-width body shells in the 1940s, and the later changes tended to take place when the body shells were squaring up and becoming more integrated in the 1960s and later in the 1990s. The positioning of headlamps during the late1930s seems somewhat confused, and it almost looks as if no designer could quite tell what was going on – they seem almost to have tried everything then before the full-width body shells were really introduced and the headlamps found a natural place in the front of the wings.

A2.1.10 Side Window Base Height

Value	**Side window (wing) base height**
0	None
1	Very low
2	Low
3	Medium
4	High
5	Very high

Table A2.10 Discretised values for side window base height

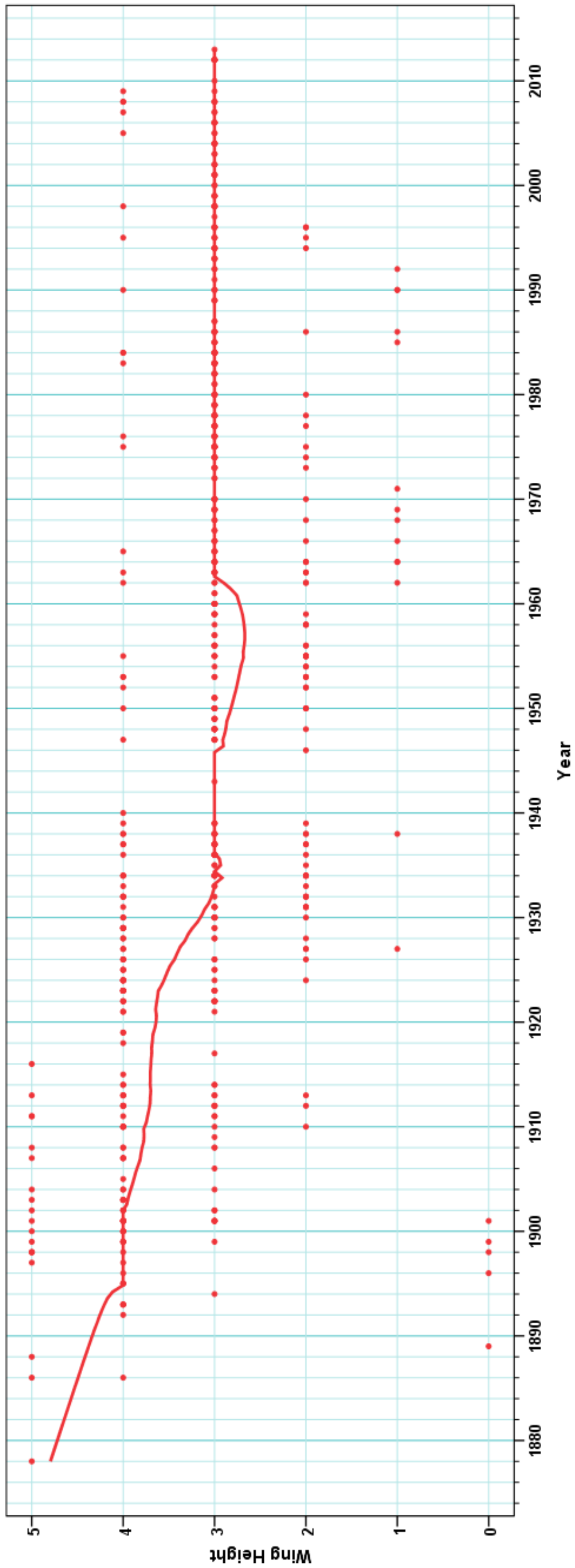


Figure A2.49 Side window base height (or wing height)

The two heights are taken as being the same thing, although in some cases they are not. The height that was actually measured was the side window base height. This is a discretised variable. Early cars are taller, and not surprisingly, their window base height is also higher. This lowers through time and there seems to be a bit of a jump from 1940 onwards to what is described as being a ‘medium’ height, although there are still some cars with high wing lines after that. In the 1950s and early 1960s there was a bit of a trend towards lower cars – and there are some sports cars in the sample at this sort of date, which do not ever figure in the best sellers and tend to pull the figure down slightly at this point. There does seem to be a very slow rise in values taking place, but this is not seen because of the significant discretisation.

A2.1.11 Roof Type

Value	**Roof type**
0	Don’t know
1	None
2	Fabric Convertible to rear only
3	Coupe de Ville with glass roof
4	Fabric Convertible
5	Removable Hard Top
6	Landaulet with no front roof
7	Coupe de Ville
8	Surrey with fringe
9	Fabric sun roof
10	Sliding sun roof; Removable sun roof; Clear canopy
11	Landaulet with front roof
12	Rigid roof
13	Rigid roof with luggage grid

Table A2.11 Values for roof type

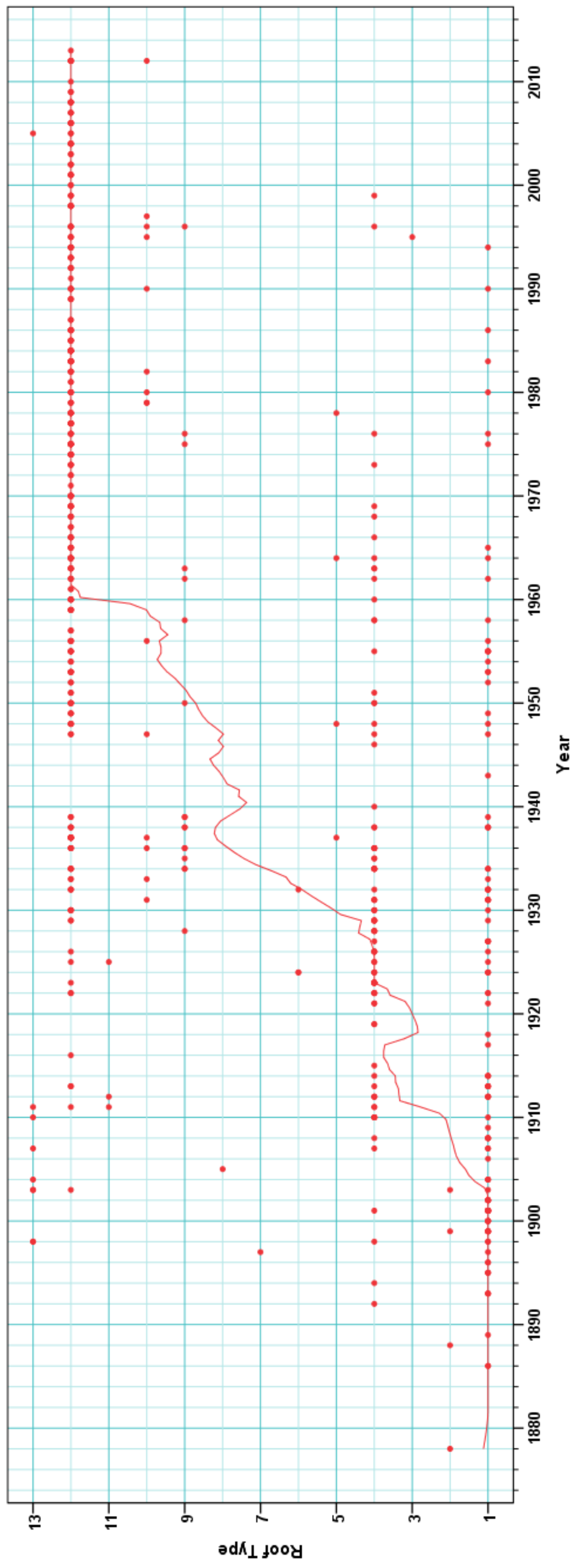


Figure A2.50 Roof type

There are some fairly large categories here: most cars have no roof (1), a fabric convertible roof (4) or a rigid roof (12). The lack of any weather protection at all is apparent for the majority of cars up to about 1910. The convertible fabric roof was, of course, used for horse-drawn vehicles earlier and so its introduction is not a novel technology. It starts to become fitted to a significant number of cars around 1910, although the earliest car in the sample with any form of convertible roof, in this case just to the rear passengers, is the earliest one of all – Amedée Bollée’s La Mancelle from 1878. This is followed by another of the earliest cars, the 1892 Panhard, that has a convertible fabric roof. Cars are still made with convertible fabric roofs, and a few are still made without any weather protection at all – usually for racing or for specialist track-type cars where the emphasis is not on comfort at all. The earliest car in the survey with a rigid roof is the Georges Richard from 1903, but the rigid roof doesn’t start to become common until the 1920s.A small number of cars with (mostly) rigid roofs are fitted with sun roofs, either fabric ones or rigid sliding ones.

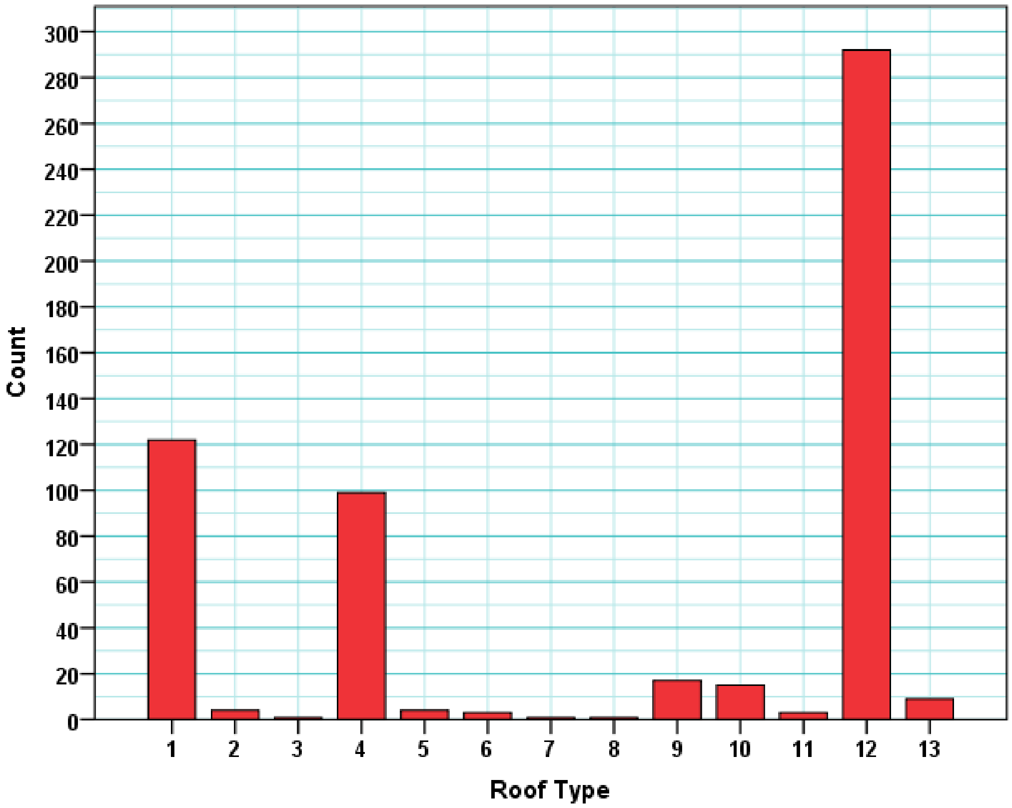


Figure A2.51 Histogram of roof type showing popularity in the survey.

A2.1.12 Rear of Cockpit Position

Value	Rear of cockpit position
0	None: in front of front wheels!
1	Front of rear wheels
2	In line with rear wheels
3	Rear of rear wheels

Table A2.12 Values for the position of the rear of the cockpit (passenger space)

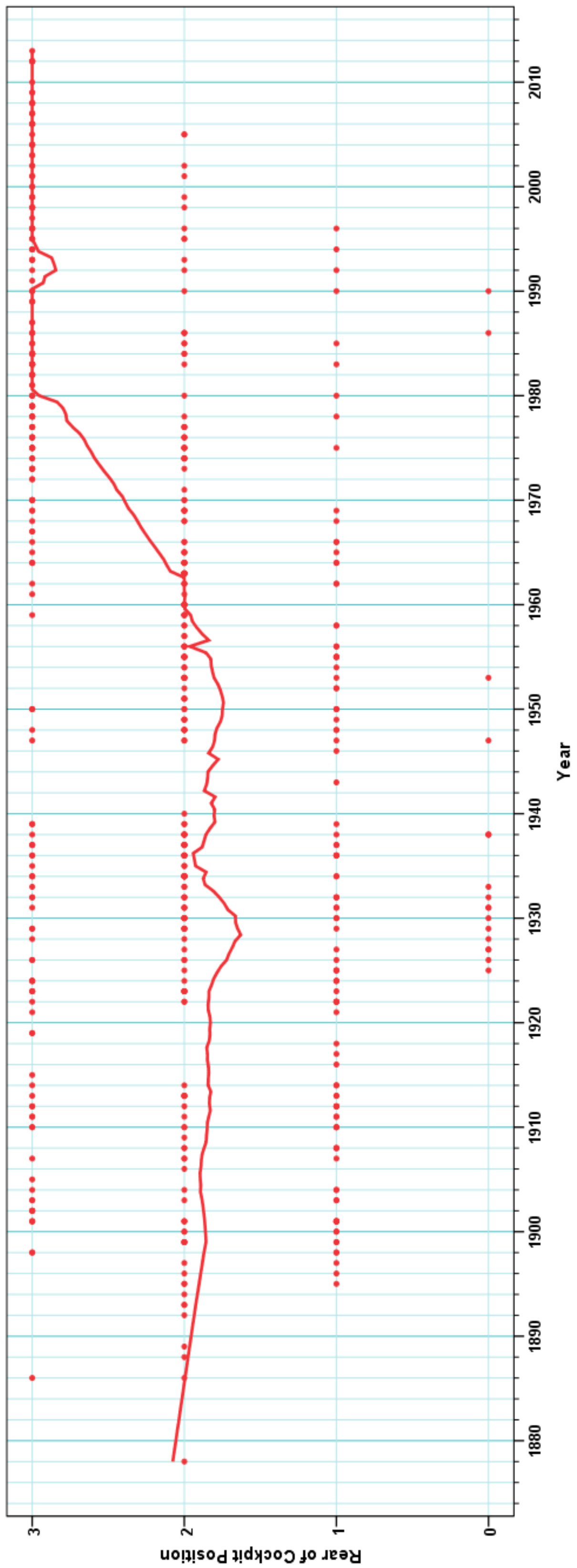


Figure A2.52 Rear of cockpit position

Naming this variable was not particularly easy. Some cars have what they call a cockpit – for others this simply means the rear of the passenger compartment. For an estate car or a hatchback, this is likely to be very close to the rear of the car. The value given to the variable is related to the position of the rear wheels – with one exception, in that one car is forward control, seats but one person and that person sits in front of the front wheel (a single on in this case). Thus the rear of the passenger compartment is actually in front of the front wheel.

The graph shows that this variable is relatively slow to move and in spite of the crude discretisation, it seems to show some movement towards cars having a longer passenger area if they are later, which takes into account the popularity of the hatchback revolution since the 1970s and 1980s. The variable doesn’t seem to move in a paradigmatic manner.

2.1.13 Rear form

Value	Rear Form
0	Don’t know
1	Exposed spare: Exposed Trunk: Fuel Tank and Spare(s): Fuel Tank / Trunk and Spare(s): Fuel Tank only: No bodywork, just exposed engine & transmission: Rear seat plus sloping radiator
2	Narrow boot: Narrow boot with Dickie Seat: Narrow boot with spare
3	D Back: D Back with spare
4	Rear Entrance Tonneau: Rear Entrance Saloon
5	Large square luggage box: Tapered tail: Tapering tail with dickie seat & exposed spares
6	Wide boot: Wide boot with exposed spare: Wide boot with fairing & fin
7	Tapered wide boot
8	Fastback
9	Estate car
10	Sloping Hatchback: Sloping Hatchback with bustle
11	Solar array: Twin boom: Vertical boiler with stoking platform: Vertical rear panel

Table A2.13 Values for rear form

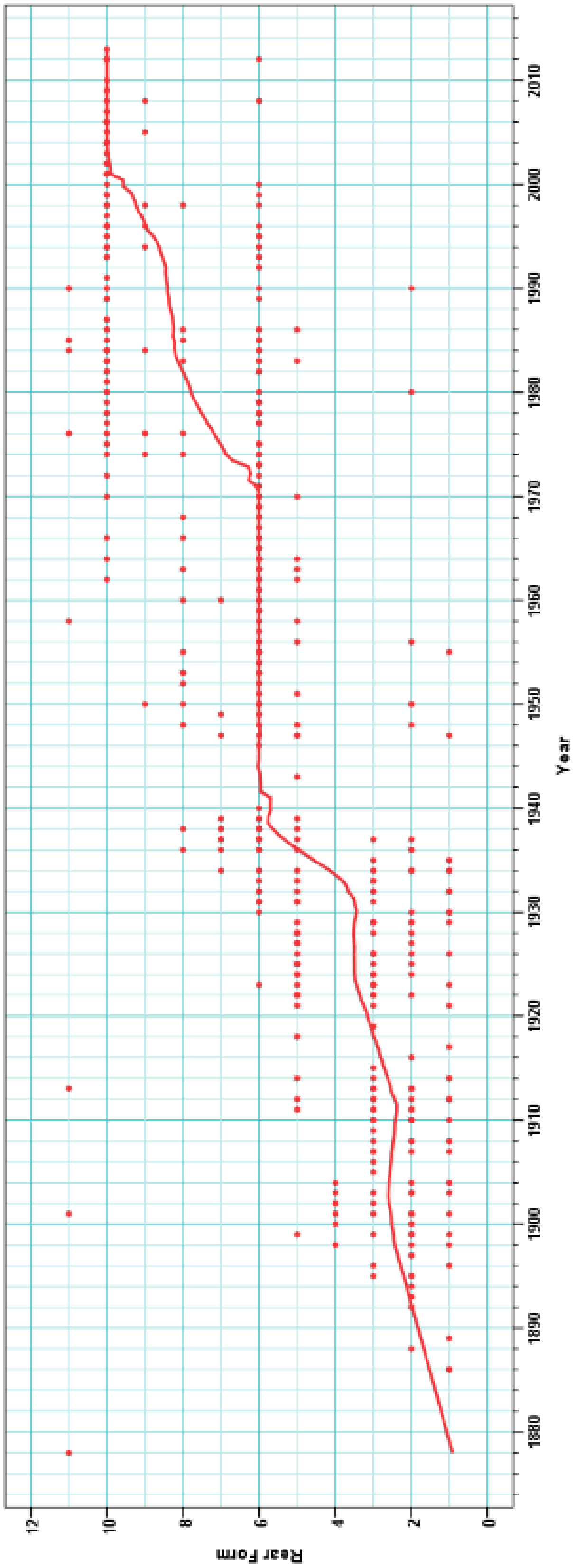


Figure A2.53 Rear form

The values are aggregated here: the existence of a dickie seat and a spare wheel are disregarded. The descriptions of category 1 is for cars where it would appear that the existence of any rear bodywork seems to have been forgotten and the rear of the car approximates to a pile of useful things that are attached in some way to the outside of the car. These may be a fuel tank, a spare wheel, a separate trunk strapped on, and any combination of these. Category 11 is used for anything which really doesn't fit into any other category. There are about five categories which most cars fit into. The narrow boot and D back forms are current from the early days until 1940, when they change, relatively quickly, into the wide boot forms with the introduction of full-width body shells. These remain current until the 2000s, but the hatchback form takes over in the popularity stakes, starting from the 1970s, to become the dominant rear form from about 1980 onwards.

A2.1.14 Roundedness variables

Three roundedness variables have been brought into the smaller analysis from the five roundedness variables that were originally analysed. These are edge roundedness, rear roundedness and rear window roundedness (or curvature). They are, to some extent, discretised variables. It might be mooted that a real measure of the roundedness could be measured and thus computed. However, this would be an extremely difficult process to accomplish and the results may not be particularly useful in terms of the length of time expended for the amount of output that was achieved. Thus the real data were not measured, but cars were placed into categories. This process is similar to the use of something like a Likert scale, where there are a few reasonably easy to define categories which effectively form a discretised continuum, but which no-one expects to measure with any more formal degree of accuracy. Thus the categories that are used are Don't know, None, Flat / angular, a little, moderate and rounded. Some extra categories were found to be necessary. For edge roundedness a few cars had conflicting roundedness with the wings being rounded but the body being flat or angular and vice versa. These were effectively removed from the calculations by being allocated the value of 0. This increases the values by 1. There were a few cars that had concave rear windows; thus this had to be given a value (1) so the categories for the rear window roundedness are also increased by 1.

Value	**Edge roundedness**	**Rear roundedness**	**Rear window roundedness (curvature)**
0	Conflicting: round bonnet & angular wings: Conflicting: angular bonnet & round wings	None	None
1	None	Flat / angular	Concave
2	Flat / angular	A little	Flat / angular
3	A little	Moderate	A little
4	Moderate	Rounded	Moderate
5	Rounded		Rounded

Table A2.14 Values for roundedness parameters

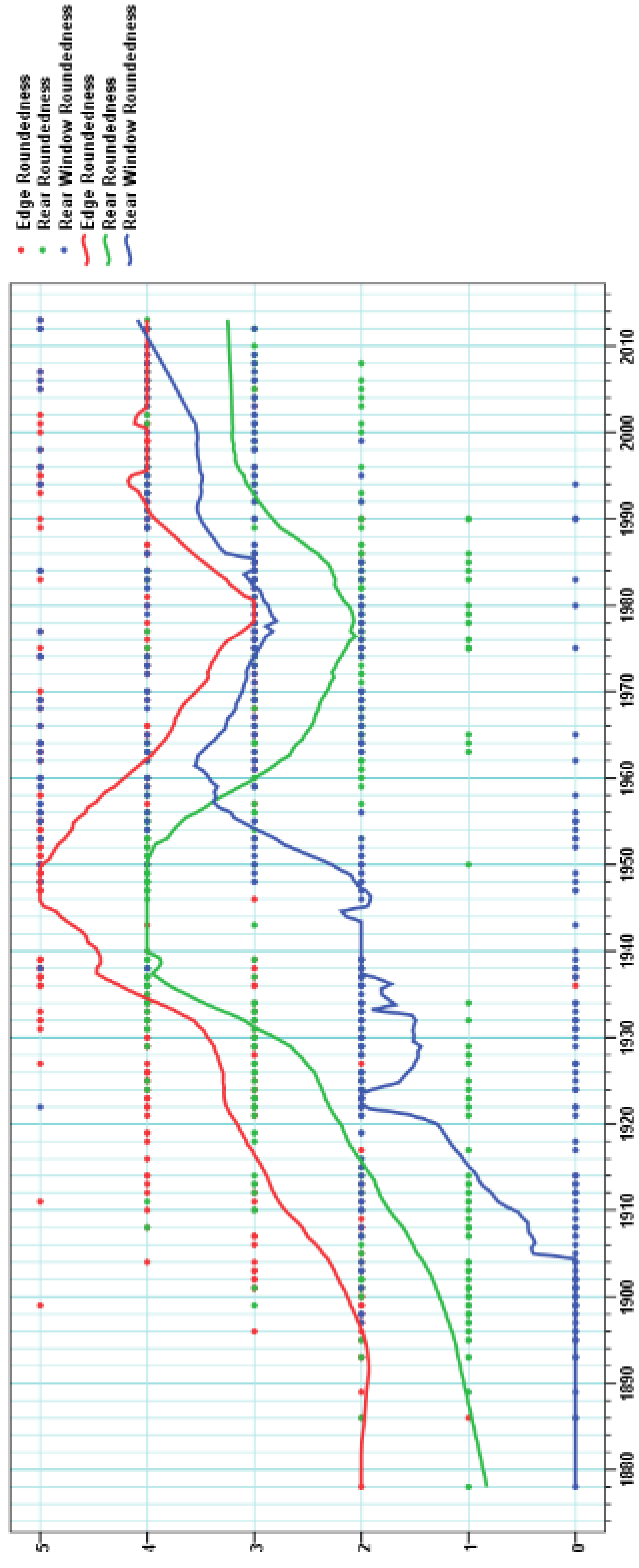


Figure A2.54 Roundedness graphs

The results for the roundedness show some considerable variations over time, which probably indicates that these tend to be fashion variables and not particularly related to technological factors. The early figures tend to indicate that there are a certain number of early cars that really do not possess any body shell at all, and therefore which produce the value of 1 for edge roundedness and 0 for the other two variables. A few cars of later periods also have no roofs and therefore no back windows, also producing the value of 0. There can be seen that there is reasonably strong correlation between these variables, which is what is perhaps anticipated. The dip in values for all three variables between 1970 and 1990 is of interest, demonstrating that the angularity of those dates is measurable, and that it affects the form of the rear window slightly less than the body measurements – windows remain with some effective curvature through the period and do not return to using flat glass. There seems to be a tendency, though, to move towards cars having a moderate roundedness – not quite the tendency that Setright noted towards a completely spherical car, however (Setright, 2002).

A2.1.15 Wheel type and width

It could be argued that these two variables are not form variables but layout ones. Wheel type is clearly a categorical variable, but wheel width is a discretised variable, but has very few values.

Value	Wheel Type	Wheel Width
0	Don't know	Don't know
1	Spoked	Narrow
2	Wire	Normal
3	Disc	Wide
4	Pressed: Pressed with hubcaps	Narrow front, wide rear
5	Cast Cast brake drums with attached rims	
6	Wire front, cast rear	

Table A2.15 Values for wheel type and width

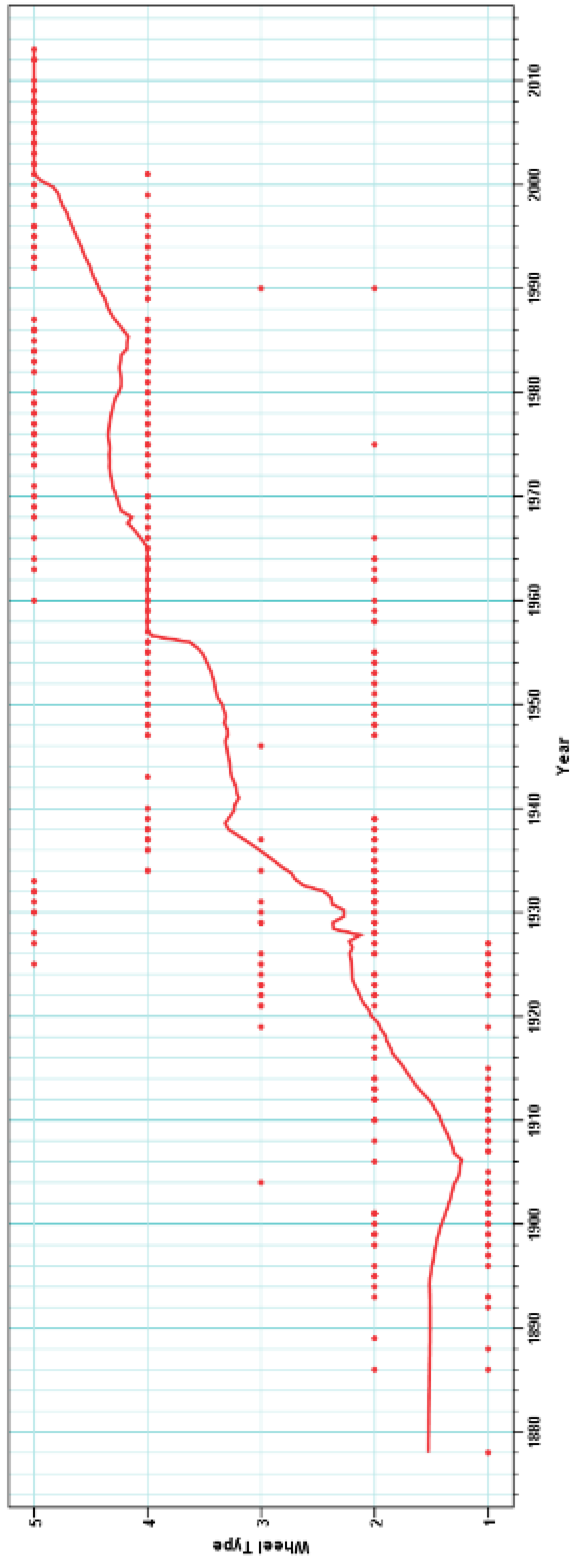


Figure A2.55 Wheel type

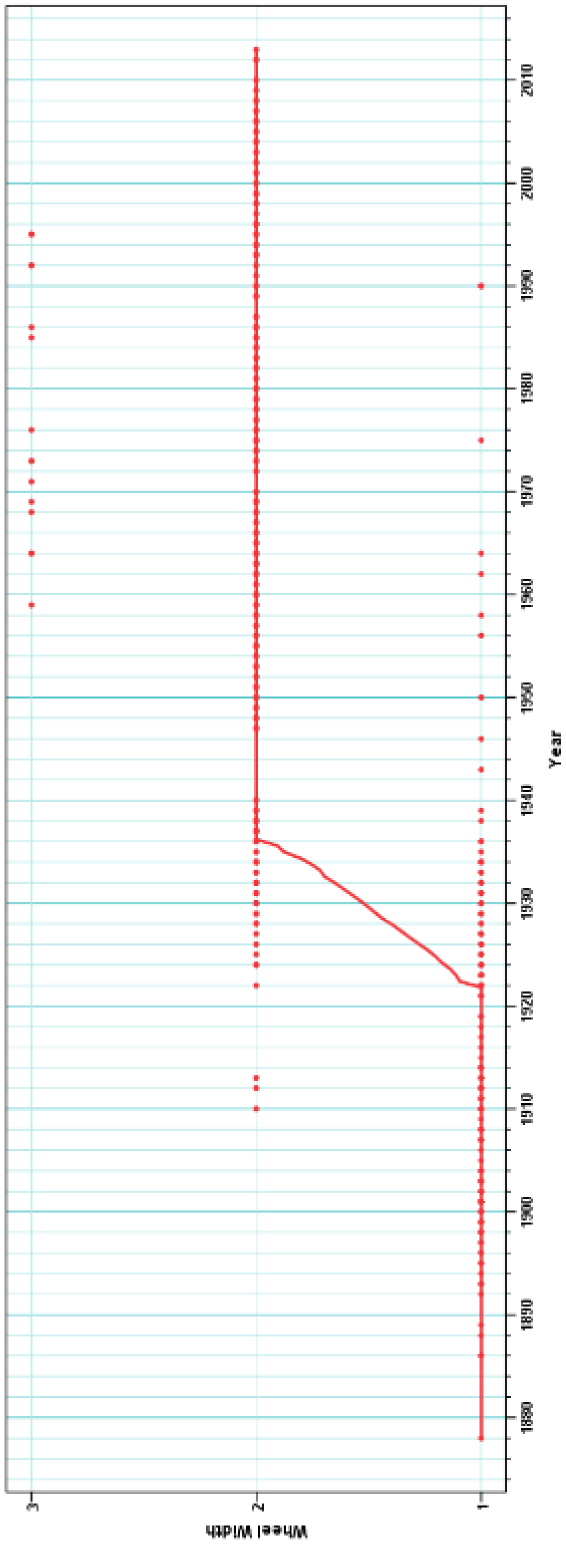


Figure A2.56 Wheel width

The wheel width graph is distinctly boring, simply indicating that up to the 1930s cars had narrow wheels and then they became wider, with a few cars in the 1960s and 1970s with what are termed as ‘wide’ wheels. These tend to be performance cars or in a couple of cases, beach buggy type vehicles.

Figure A2.57 Otosan Böçek, 1976 A beach buggy with wide wheels (Simge Erdoğan)

The wheel type curve demonstrates distinct movement through time, with spoked wheels being replaced by wire wheels which in turn are replaced by pressed wheels and then, from about the 1990s onwards, by cast wheels. Spoked wheels using wooden construction were used by carriages and were manufactured by skilled wheelwrights, and this tradition continued with cars. The information does not distinguish between wooden spoked wheels and iron or steel spoked wheels, made by riveting members together or by a single piece manufacture. By the late 1920s the wooden spoked wheels on cars such as the Renault 40 were seen as somewhat anachronistic.

A significant number of cars from the earliest years, however, used wire spoked wheels. A few very early ones of these were simply using wire to replace the wooden spokes, but even some early cars used the wire in tension principle for their wheels. They tended to be used, initially, on lighter cars, but they found themselves employed relatively quickly on even heavy cars, probably from the early years of the 20th Century. Lanchesters, for instance, always used wire-spoked wheels. Sports cars continued to use wire-spoked wheels well into the 1970s, but they were not really used on family cars much after the 1930s. Several companies, particularly in France, used steel disc wheels from about the 1920s onwards for light cars, and these were replaced by pressed steel wheels in the 1930s by many manufacturers, taking over from the wire wheel for family cars from the Second World War onwards in Britain.

Figure A2.58 Renault 40 with wooden spoked wheels, 1927

The first cars in the sample with cast aluminium wheels are 1920s Bugattis. The cast wheel became relatively common from the 1970s onwards, and although some manufacturers still use pressed steel wheels on the lower models in their range, these have now been replaced with cast wheels for the majority of cars. The move seems to have taken place from the 1990s onwards, and seems to have been driven more by fashion than by technical performance – having light wheels does not make very much difference in performance of a family car. Cast wheels are not any cheaper or easier to produce, either.

A2.2 Categorical Principal Components Analysis

In a similar way to the layout analysis, a categorical principal components analysis was carried out for form. Two dimensions were considered sufficient for the analysis. In this case it seems to be possible, by inspection, to have some idea of what each variable denotes in terms of form. The first dimension seems to be indicating some relationship to the degree of integration of the form – the one that Setright (Setright, 2002) suggested would eventually become completely integrated and spherical – with the higher figures representing more integration of form. The second variable seems to have something to do with the proportion of the car. In this case the higher figures tend to a form that is longer and with the bonnet taking a larger proportion of the overall length. A few years ago it was mooted that this might result in shorter and shorter bonnets on cars, but this trend seems to have changed and the second variable now looks as if it is flat and not changing much.

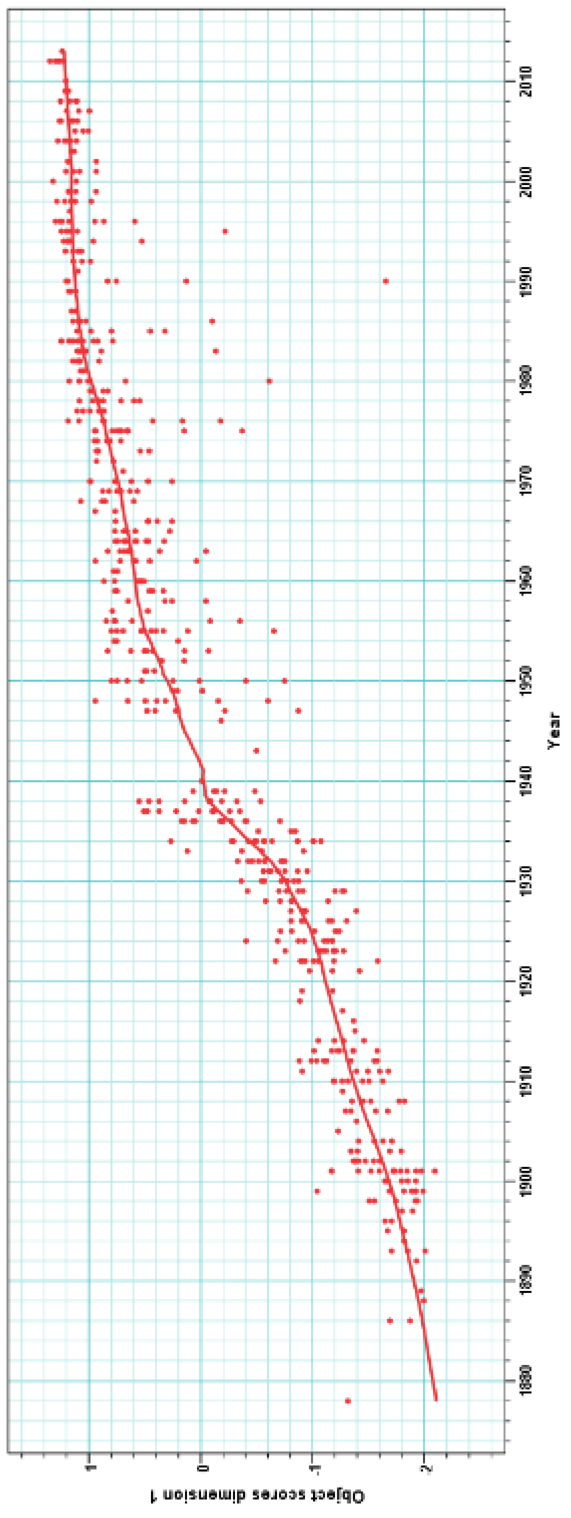


Figure A2.59 The first form variable from the Categorical Principal Components Analysis

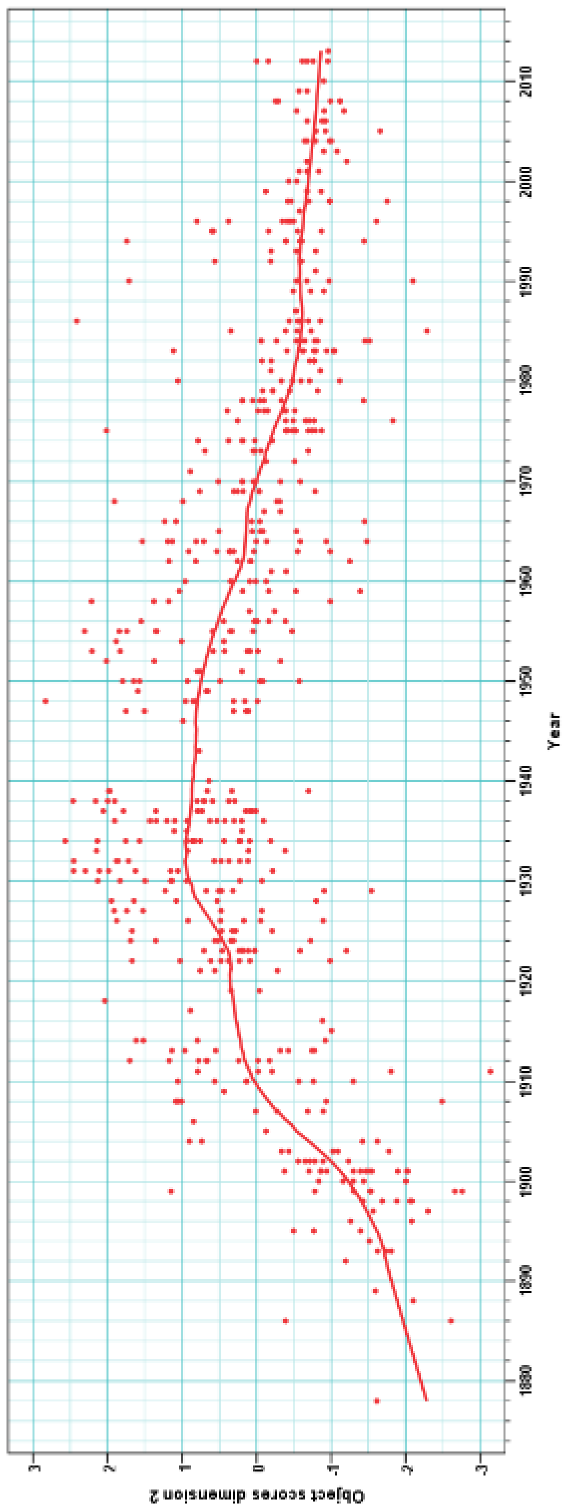


Figure A2.60 The second form variable from the Categorical Principal Components Analysis

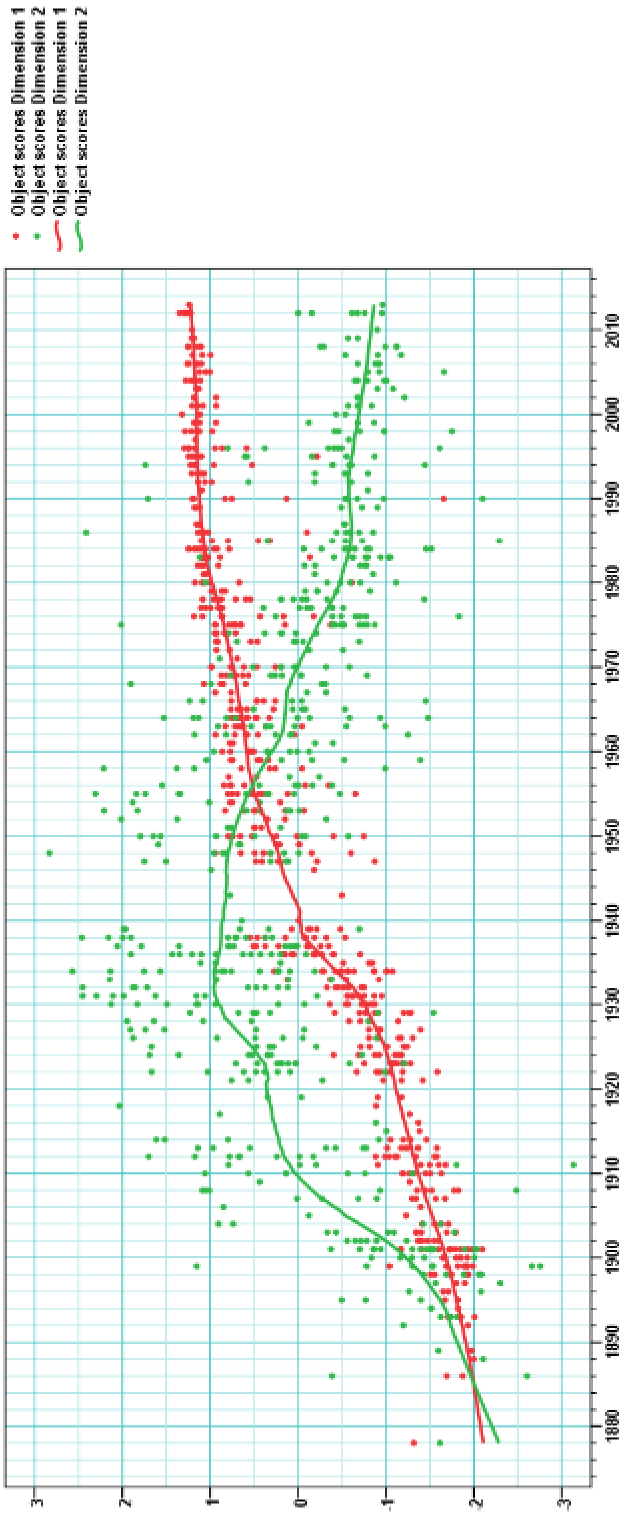


Figure A2.61 Both variables from the Categorical Principal Components Analysis plotted on the same graph

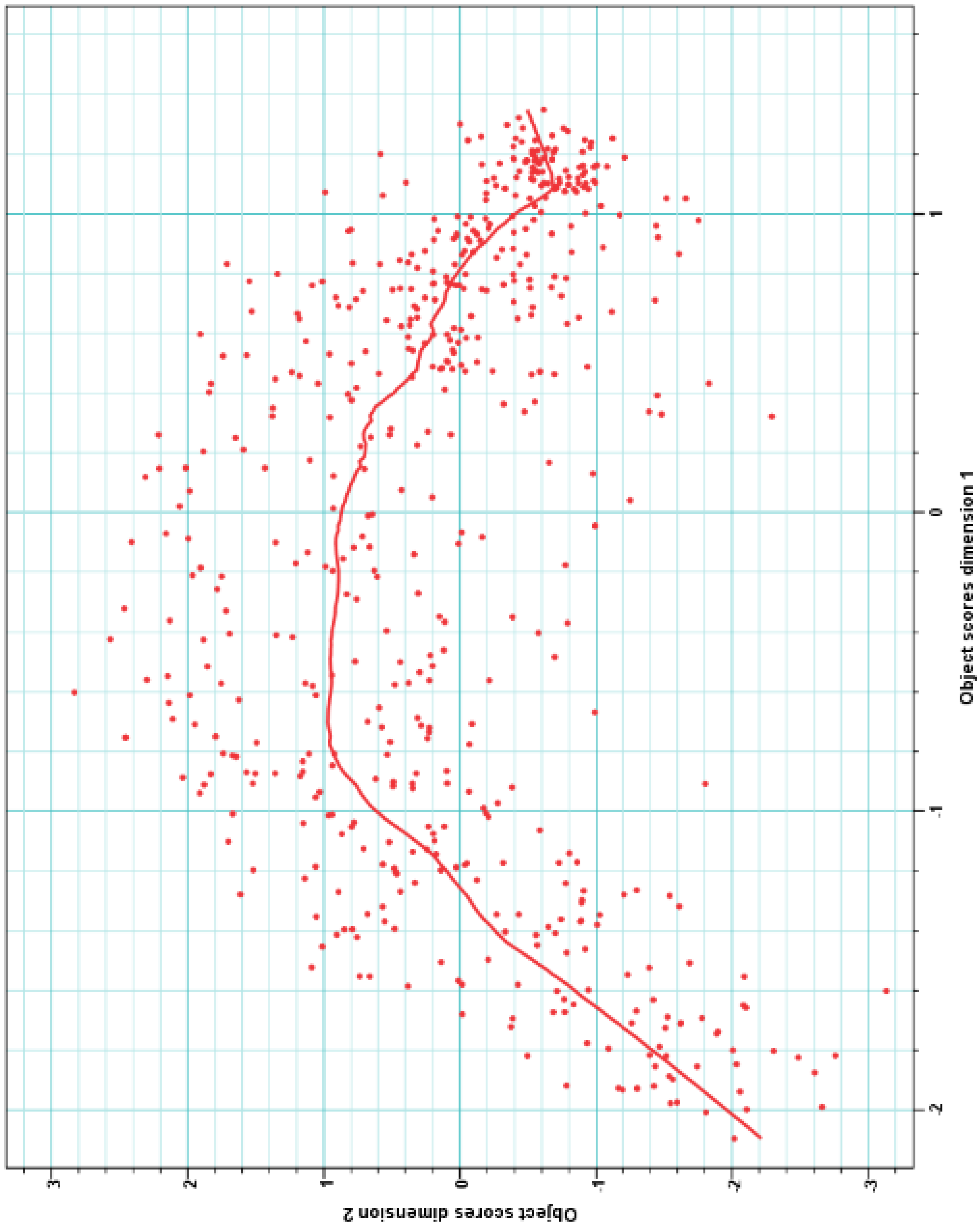


Figure A2.62 The two form variables plotted against each other

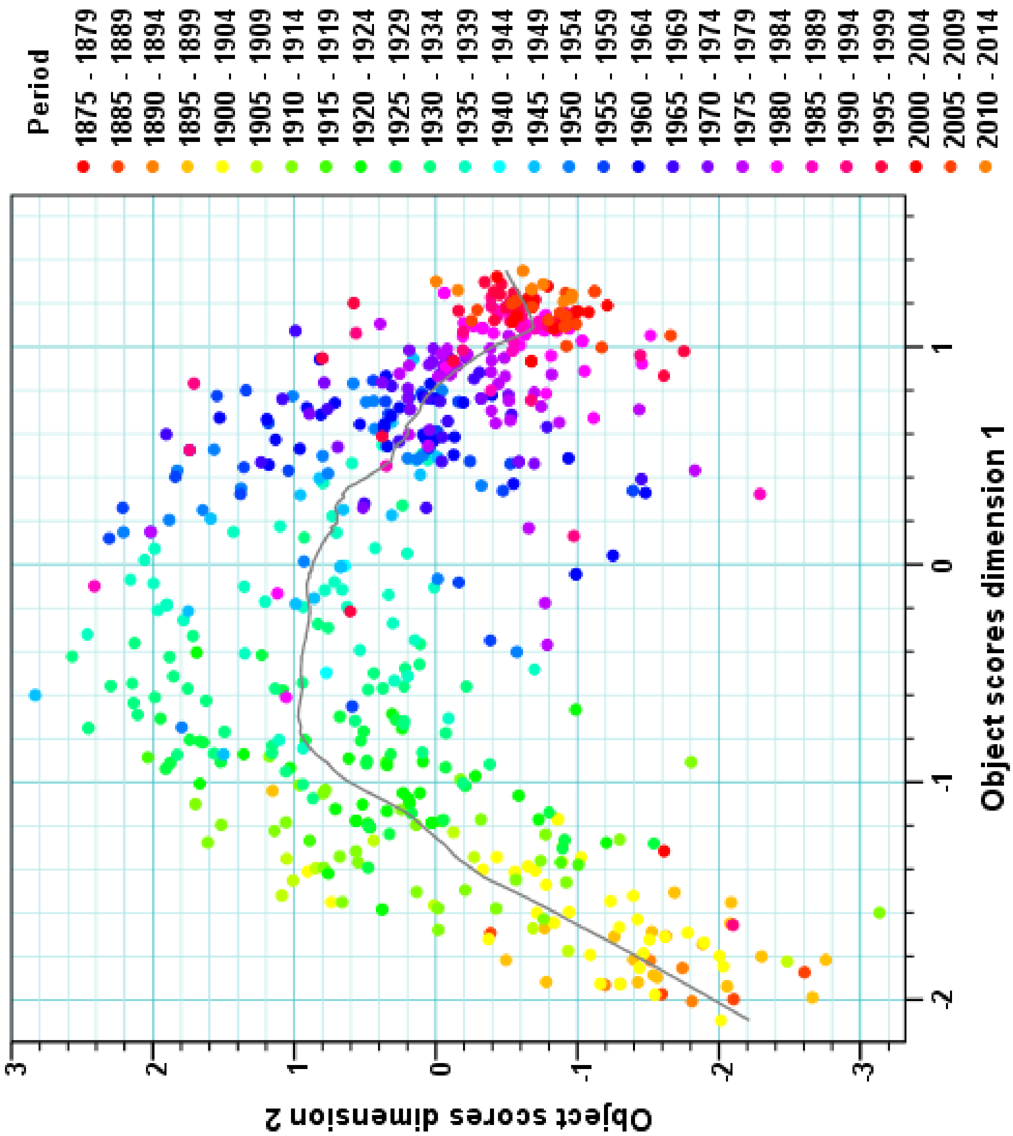


Figure A2.63 The two form variables plotted against each other with the periods coloured. Each period is five years, with period 1 being from 1875 to 1879.

Figure A2.63 demonstrates the way in which the two dimensions change with time, starting in the lower left quadrant and moving towards the upper left one: then moving across to the upper right quadrant and lastly to the lower right one. The axes on the graph are not actually labelled in any way to suggest this time dependency – it is partly caused by the way in which the variables have been ordered so that the lower numbers are earlier, but in the case of form, quite a few of these variables are discretised real variables and hence this criticism is not totally valid.

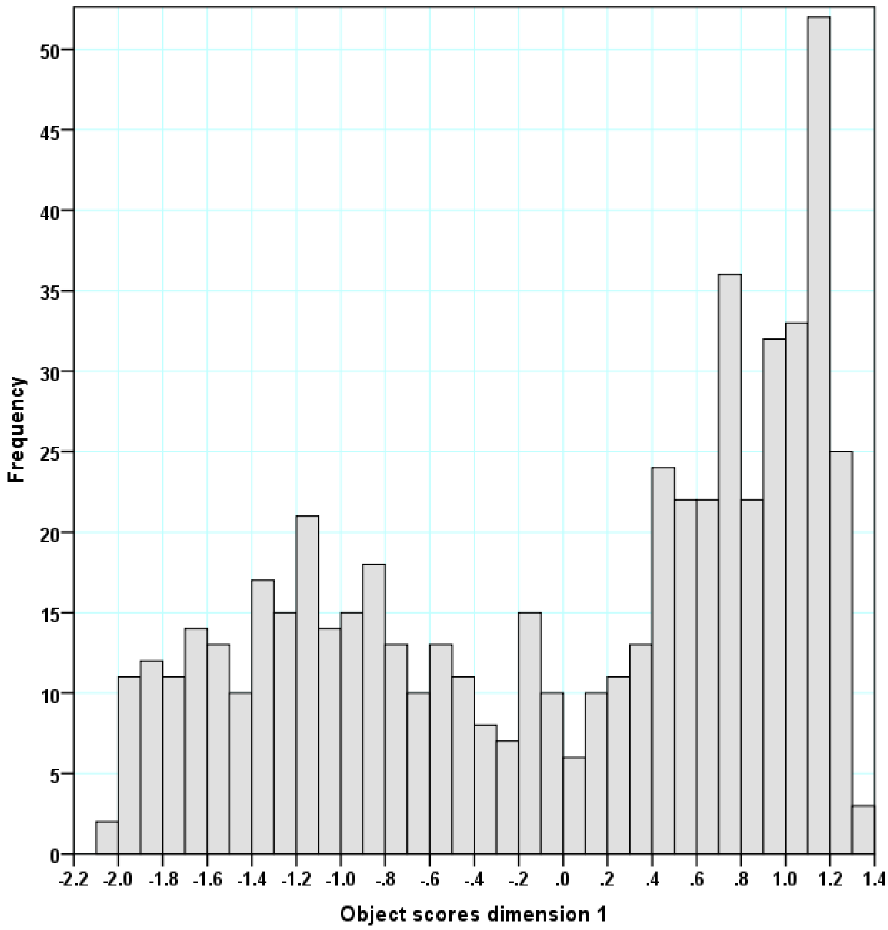


Figure A2.64 Histogram of scores for dimension 1

The histogram of scores indicates that there are a few scores that may demonstrate paradigmatic thinking – in particular the scores between 1.1 and 1.2 and between 0.7 and 0.8. However, the histogram also indicates that there is a flattening of the curve at the lower values between (say) -1.6 and -0.6, followed by a relatively steep section between about -0.4 and +0.4, with a flat section from 0.4 upwards to the maximum seen at between 1.3 and 1.4. It should be noted that if the binning interval is lower than the histogram does not display the same elongated point between 1.1 and 1.2, indicating that there is a certain amount of variation within this particular point.

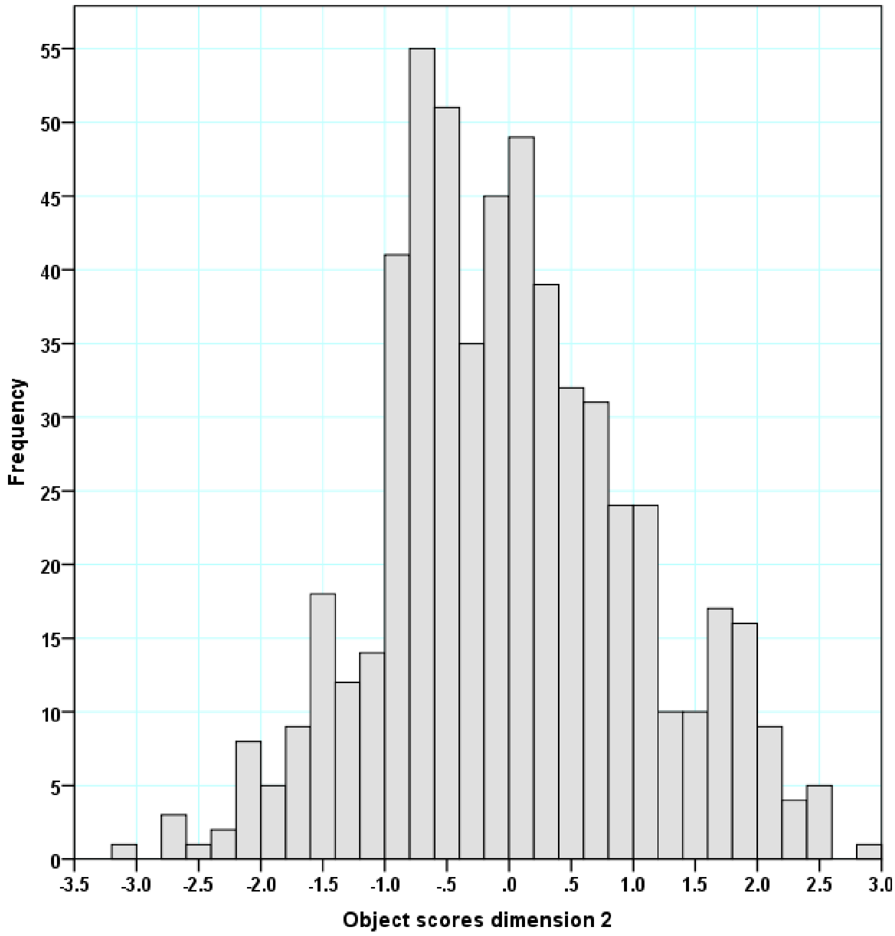


Figure A2.65 Histogram of scores for dimension 2

Figure A2.65 simply indicates a flattening off at a particular value, between -0.8 and -0.6 or even between -0.8 and -0.4 rather than the perception of a particularly paradigmatic form design process taking place. Yes, car designers recognise the particular forms that are reasonably current, in that the form curve does not jump around with time, but this is not quite the same as saying that they have a particular form paradigm in either their conscious or subconscious mind.

Figure A2.66 indicates that dimension 2 primarily contains the Front of Cockpit variable (ie the position of the screen) with significant loadings from the bonnet length, overall length and two of the roundedness variables.

Negatively, the height, wing height seat rows and rear of the cockpit position load onto it. Thus it can be seen that this variable is to do with the car's proportion, and in particular, the proportion of the length that is bonnet.

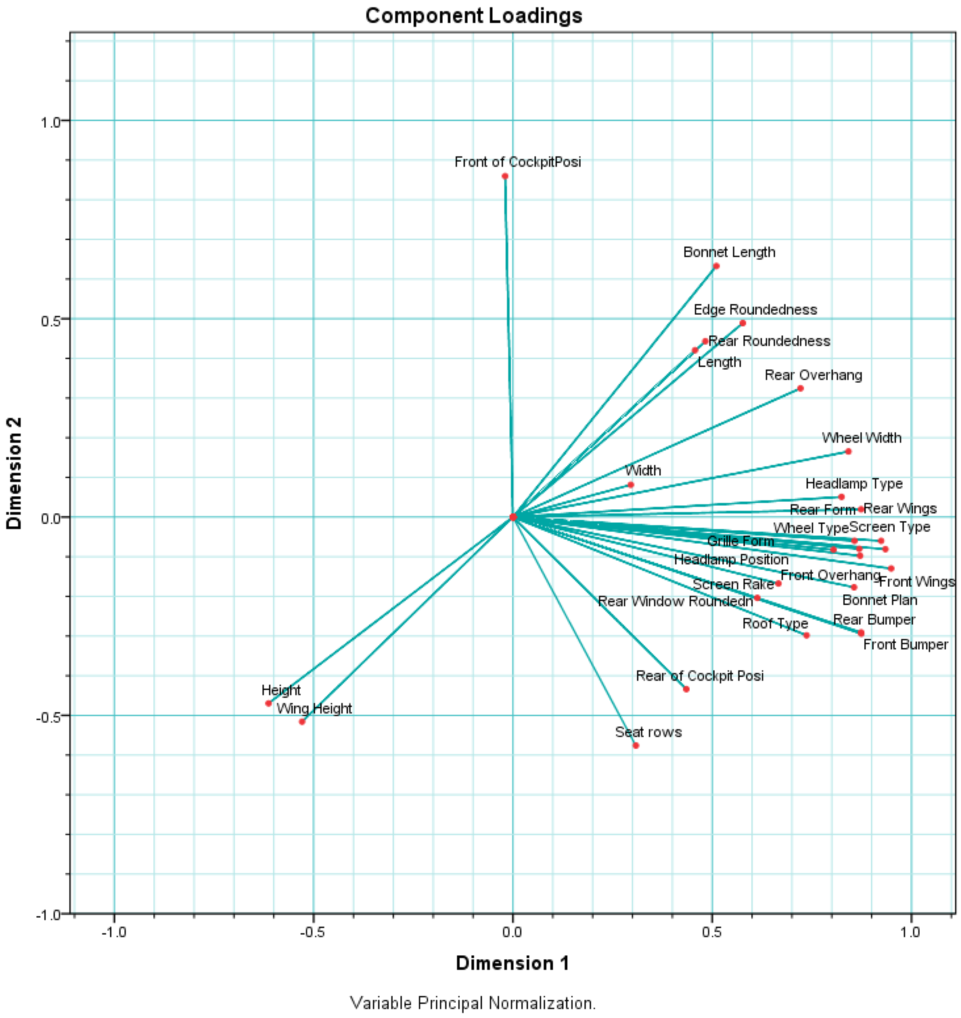


Figure A2.66 Component loadings

The other variables load onto the first component, mostly in a positive direction, with height and wing height being the only two that load in the negative direction. In practice, this component appears to be related to the way that the car becomes integrated in some way, as many of the categorical variables (such as wing form, bumper type screen rake and headlamp type) tend to increase as integration takes place.

Thus, early cars, generally in the lower left quadrant, are likely to be a discrete collection of components assembled together in a less than integrated fashion and to be generally short and tall, with short bonnets. As they move into the next quadrant, cars become slightly more integrated but a lot longer, with longer bonnets generally. In the third quadrant they become more integrated, keeping the long bonnets, and lastly the passenger compartment moves further forwards and they become slightly taller again in later years.

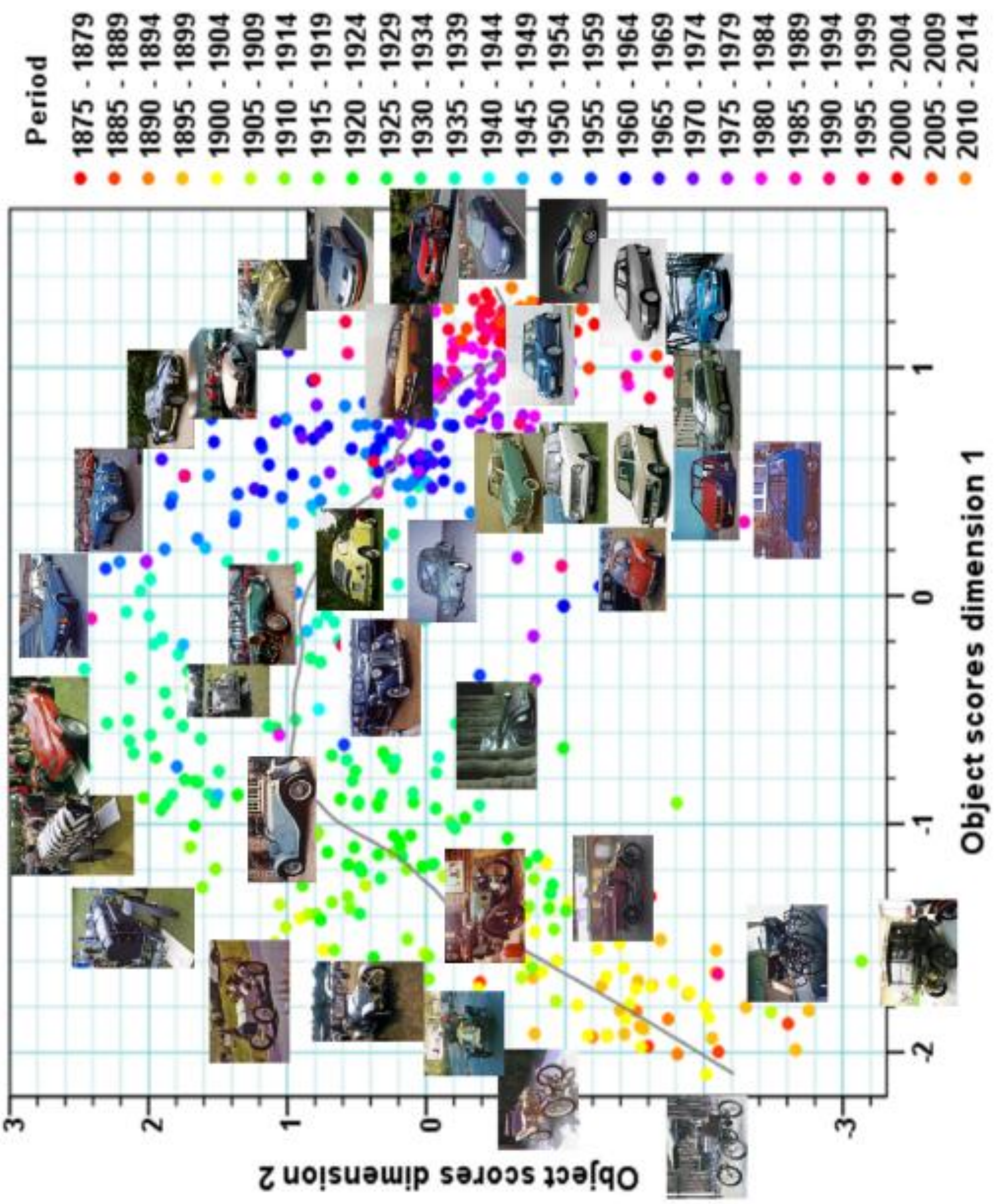


Figure A2.67 Object scores graph with pictures of cars added

So the end result and the question that needs an answer? Does the form analysis demonstrate that paradigmatic thinking is taking place where car form design is concerned? The graphs do not demonstrate the same kind of linear form as the layout graphs showed. This means that designers are not copying each other in the same way: that they do not have the same blinkered approach to form design as they have to layout design. However, it is clear that there is a significant time-based element to the graphs: that a car designer from the 1920s, say, would not consider a form similar to the car of the 1980s, and that even with the heritage of over a hundred years of car design, designers from the 1990s do not seek to emulate designs from the past to any great extent. They do, however, create pastiche-like designs from time to time, but there are significant elements of the form of the designs that locate them in the period that they were actually designed, rather than the period that they are trying to emulate – with the significant exception of some cars that have been deliberately designed to be faithful replicas of older cars.

Figure A2.68 Comparison of copy and original Volkswagen Beetles (lower, favcars.com)

For instance, the new Volkswagen Beetle was never designed to be a faithful copy of the old Beetle – merely to pick up significant characteristics of its form. A comparison of the profiles of the two cars immediately identifies that the different screen rakes clearly shows that the later car comes from a more recent era, even if the separate wings hark back deliberately to the 1940s that the original Beetle was put into production.

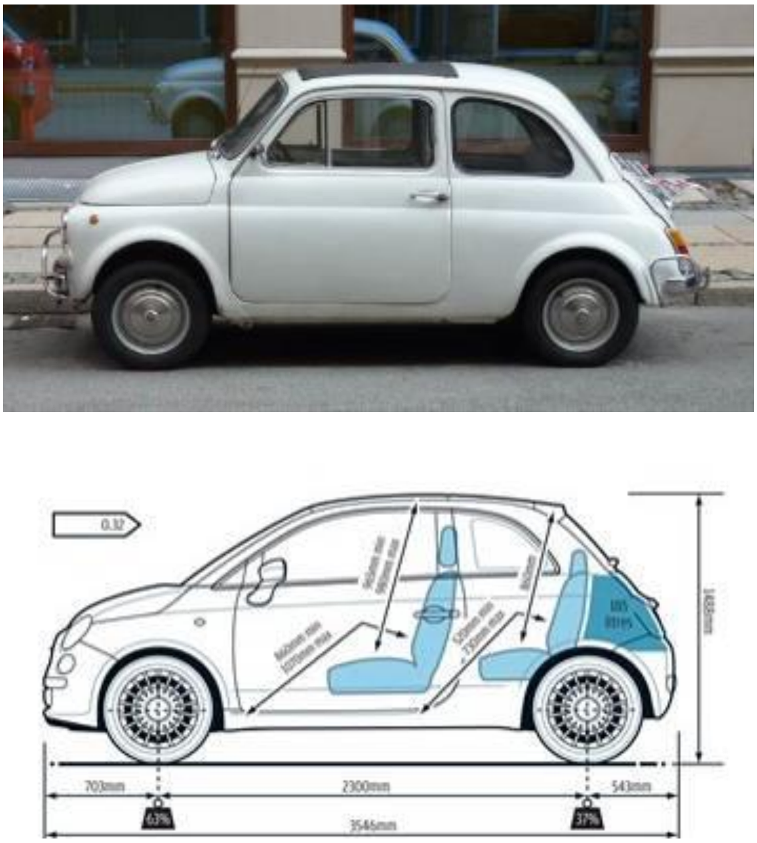


Figure A2.69 Comparison of Fiat 500 profiles old and new (lower: Autocar)

A similar thing occurs with the Fiat 500 – the major form difference that is evident is the screen rake.

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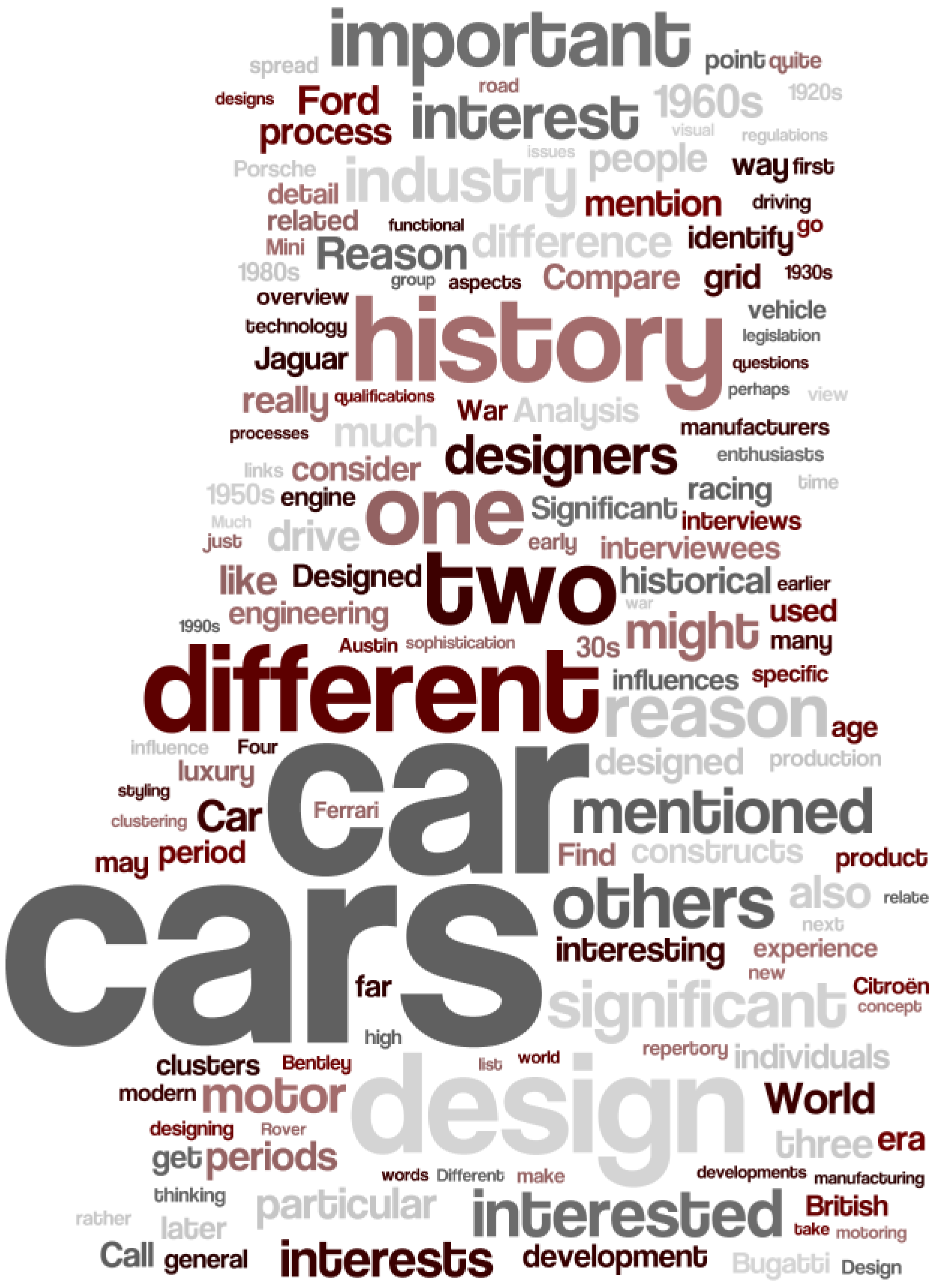
A3 Expanded Interview information



A3 Expanded Interview information

A3.1 Interview Questions

Design History of the Car

Chris Dowlen

Interview questions

Part 1: General information

In this section most of the questions are designed to be closed questions in that there is one right or wrong answer – and they are personal!

Date (this is for reference)

Name

Age & gender

Part 2: Your relationship to car design and history

Education

What subject areas are covered by your specialist education?

Engineering?

Design?

History?

In what way does your education specifically relate to cars?

What professional qualifications and associations do you have?

In what ways (if any) do these specifically relate to cars?

Background

What relationship did you have with cars when you were growing up? In what way (if any) were your family members interested in engineering, design, history or cars?

How did your interest in cars develop?

Can you tell me which of these categories you fit into?

Car historian?

Car designer?

Car enthusiast?

Other?

What is your current interest in cars, in their design and in their history?

Do you have a particular interest in an era, a manufacturer style or design feature?

What is it that excites you about that particular interest?

Part 3: Car Design

If you were part of a team starting to design a new mass-produced car, where would you start from?

And what information would be provided for you as you started?

What would you want to incorporate into the next models of car that might be designed – assuming you had a clean sheet to work from?

What do you think have been the greatest influences on your (car) designing and interest?

Part 4: Car History

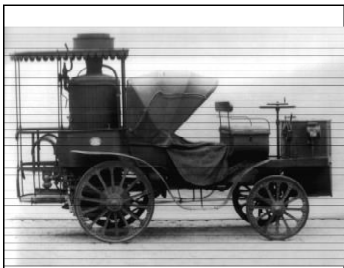
Looking back into car history, what particular periods can you identify and what is it connected with each that you would say most effectively describes them?

What particular events may have precipitated changes from one era of car history to the next?

Part 5: Arrangements of cars

Affinity diagram

Please rearrange these examples of cars into a pattern that shows how you might relate them to each other. You may remove the pictures from the table and move them anywhere in two dimensions – if I was interviewing you in person we would arrange them on a table top. Also feel free to add lines, headings and notes around them to clarify any arrangement.

 (Kupélian, 1997. © Autoworld)		
		
		
		
		

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	 (Wikimedia Commons: Rudolf Stricker)	 (Wikimedia Commons: Rudolf Stricker)
 (Autocar)	 (Autocar)	 (Autocar)

Part 6 Repertory Grid

Select any nine cars that interest you and which you feel you could use to describe your interests in cars and car history. These do not have to be any of the cars in the previous exercise. Number them 1 to 9 in any way you wish. It may help to arrange them in a square like this:

1	2	3
4	5	6
7	8	9

I would like you to compare them in threes with each other: there will be twelve sets of questions which are repetitive as I am trying to get an overall map of your interests.

1

1	2	3

Compare cars 1, 2 and 3.

Which car do you consider to be most different from the other two?

For what reason?   Call this reason A

Which of these three cars is the most important or significant?

2

4	5	6

Compare cars 4, 5 and 6.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from A   Call this reason B

Which of these three cars is the most important or significant?

3

7	8	9

Compare cars 7, 8 and 9.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from A or B   Call this reason C

Which of these three cars is the most important or significant?

4

1
4
7

Compare cars 1, 4 and 7.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from A, B and C. Call this reason D

Which of these three cars is the most important or significant?

5

2
5
8

Compare cars 2, 5 and 8.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from the others so far.   Call this reason E

Which of these three cars is the most important or significant?

6

3
6
9

Compare cars 3, 6 and 9.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from the others so far. Call this reason F

Which of these three cars is the most important or significant?

7

1	2	3
4	5	6
7	8	9

Compare cars 1, 5 and 9.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from the others so far. Call this reason G

Which of these three cars is the most important or significant?

8

1	2	3
4	5	6
7	8	9

Compare cars 2, 6 and 7.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from the others so far. Call this reason H.

Which of these three cars is the most important or significant?

9

1	2	3
4	5	6
7	8	9

Compare cars 3, 4 and 8.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from the others so far. Call this reason I

Which of these three cars is the most important or significant?

10

1	2	3
4	5	6
7	8	9

Compare cars 1, 6 and 8.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from the others so far. Call this reason J

Which of these three cars is the most important or significant?

11

1	2	3
4	5	6
7	8	9

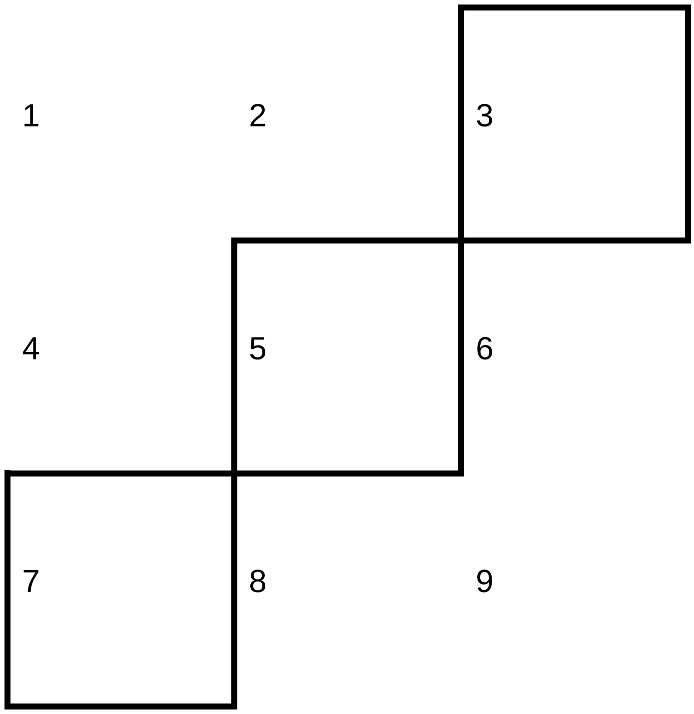
Compare cars 2, 4 and 9.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from the others so far. Call this reason K

Which of these three cars is the most important or significant?

12



Compare cars 3, 5 and 7.

Which car do you consider to be most different from the other two?

Find a reason for this that is different from the others so far.   Call this reason L

Which of these three cars is the most important or significant?

Summary Tables:

Cars	
1	
2	
3	
4	
5	
6	
7	
8	
9	

Reasons	
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	

A 3.2 Interview Wordles

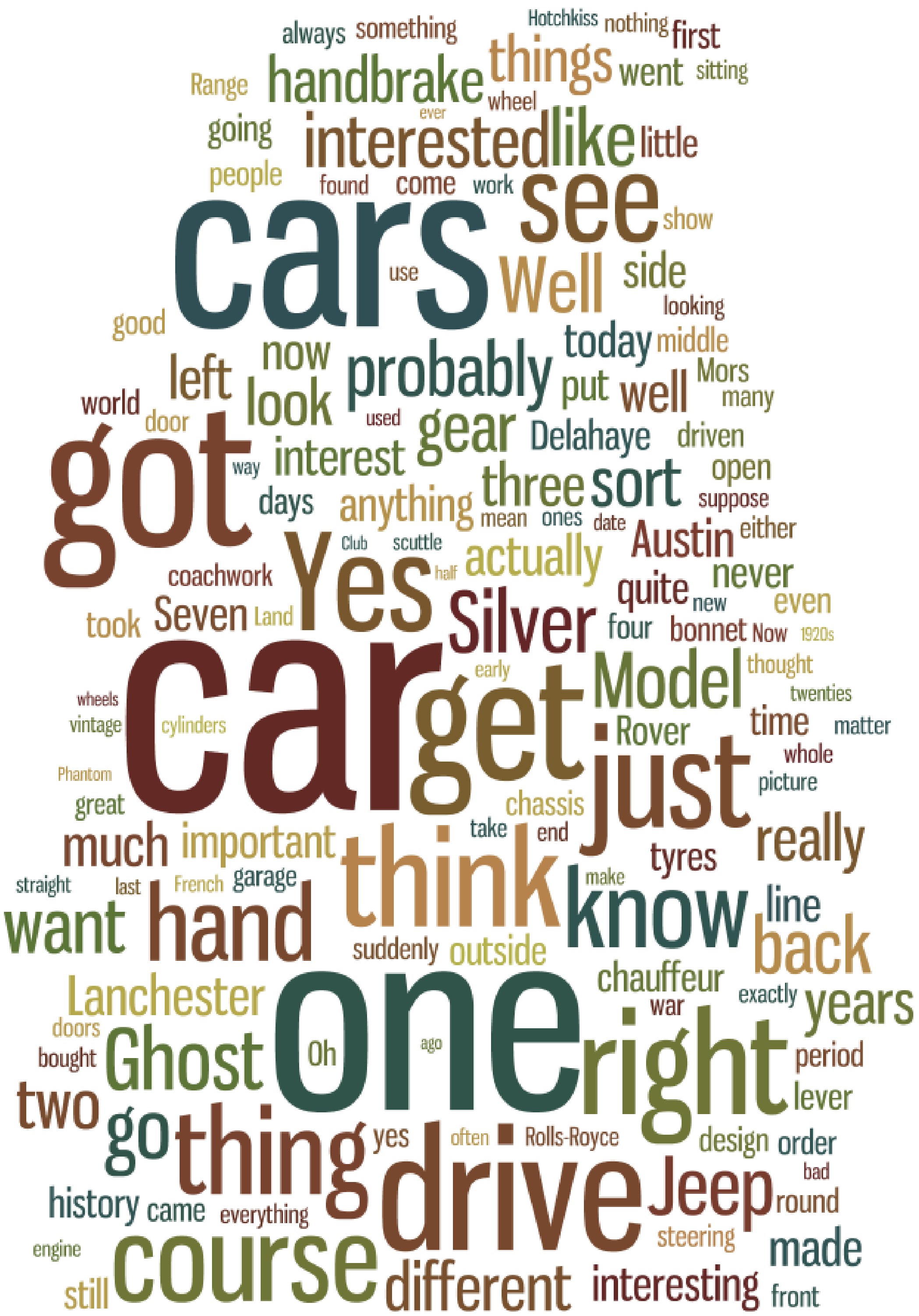
These identify the major words from each interview without disclosing the confidential information that was in them.


car
cars
architecture
identity
timeline
work
trends
design
research
year
pioneers
PhD
shape
experience
first
visual
age
Brazil
things
favourite
now
Porsche
models
Started
find
one
speed
group
designers
years
Architecture
Paolo
like
much
WWII
lot
Need
see
just
Many
new
materials
body
space
use
shared
aesthetics
Design team
others
know
used
changes
start
want
convertible
clever
necessary
behind
sheet
better
pre-war
bodyshells
information
1950s

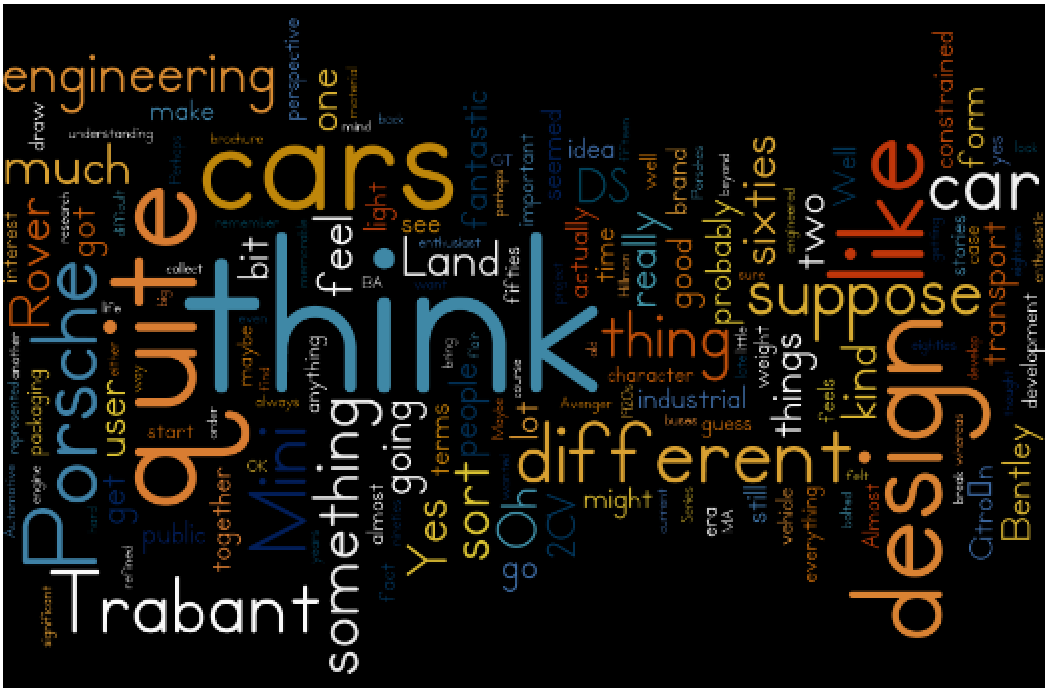

CARS
DIFFERENT
BIT
ONE
GET
REALLY
CAR
LIKE
DESIGN
MUCH
THINK
MIGHT
PRODUCTION
CONSTRUCTION
HISTORY
CITROEN
OTHERS
EVEN
OLD
MODEL
TIME
EARLY
FORD
ALWAYS
WORK
EMPHASIS
LANCIA
WELL
TOGETHER
ENGINE
MINI
DESIGNED
ALSO
BODY
ERA
FORM
USED
SEE
WAY
LATER
TATRA
ROAD
JUST
PANHARD
SCHOOL
TOP
MASERATI
PEOPLE
STARTED
QUITE
LEFT
INTERESTED
WORLD
FIRST
MAKE
INTEGRATION
MECHANICAL
AUTOMOTIVE
PROBABLY
DONE
ENGINEERING
PARTICULAR
REMEMBER
RATHER
BETTER
MONOCOQUE
FRONT-WHEEL
TRANSVERSE
MAINSTREAM
DRIVE
THINKING
SOMETHING
CYLINDER
DEGREE
ALTHOUGH
INDEPENDENT
TEND
PUT


got
think
going
just
Ford
actually
time
Jaguar
like
one
know
get
different
things
two
well
much
go
people
something
design
lot
cars
years
Aston
Martin
Car
business
Saab
Alfa
Romeo
sport
quite
industry
really
racing
strategy
thought
motor
involved
deal
put
called
months
good
started
sort
stuff
thing
market
great
three
era
day
aerospace
brand
board
first
drive
trying
automotive
Europe
nineteen
wonderful
probably
period
huge
States
around
Well
awful
still
Oh
look
back
better
went
want
interesting
need
engineering
finance
bit
big
yes
start
share
make
needed
suppose
Club
job
Fiat
interest
beautiful
upmarket
Just
end
money
later
rather
Maserati
absolutely
way
round
come
work
buy
Lucas
reason
guy
designers
used
next
turn
talk
never
thirties
looked
whereas
call
early
looking
concept
done
execution
working
styling
Italian
pretty
see
discussions
now
sort-of
less
right
another
remember
Victor
Monza
OK
always
John
Yes
along
Ferrari
even
style
role
Chris


think
cars
car
quite
different
really
much
Bugatti
Type
know
Well
one
racing
Morgan
actually
just
two
sort
built
bought
got
design
mean
like
early
going
club
Ferrari
whereas
involved
world
Porsche
Bugattis
way
BMW
GT3
GT40
see
today
perhaps
time
thought
interest
history
modern
point
Brescia
motor
although
suppose
went
little
hugely
experience
put
years
back
desirable
period
motor-racing
bit
three
tend
Napier
look
go
good
used
fact

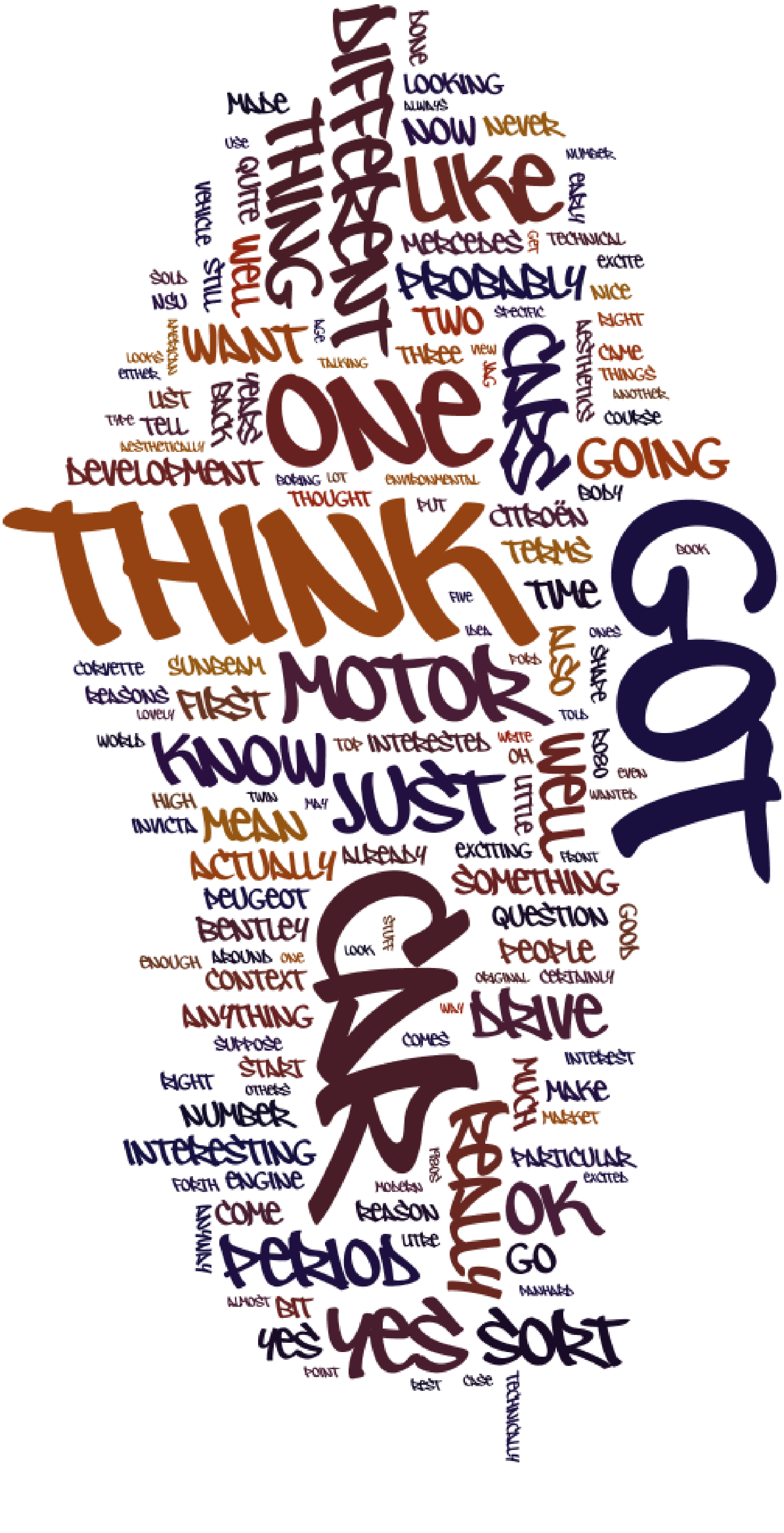

always
something
Hotchkiss
nothing
first
Range
handbrake
things
went
sitting
wheel
ever
going
interested
like
little
people
found
come
work
see
cars
show
use
Well
side
good
looking
today
middle
now
left
probably
Mors
look
put
well
many
world
door
used
got
gear
Delahaye
driven
way
interest
open
three
sort
days
anything
suppose
mean
ones
date
Club
scuttle
Austin
either
actually
coachwork
Yes
half
never
quite
Silver
new
even
took
Seven
Land
four
bonnet
Now
1920s
car
early
Model
thought
wheels
get
twenties
vintage
cylinders
Rover
time
matter
just
whole
Phantom
picture
chassis
great
take
end
much
important
really
tyres
straight
last
French
garage
think
make
want
hand
know
line
suddenly
outside
back
chauffeur
Lanchester
exactly
war
years
doors
one
ago
bought
Ghost
Oh
right
period
two
lever
go
thing
yes
often
Rolls-Royce
design
order
bad
drive
Jeep
history
came
everything
round
steering
engine
made
course
still
different
interesting
front

amount
rather
take
People
power
interesting
marketing
factory
war
now
huge
things
make
course
also
way
one
Land
world
luxury
year
much
use
quarter
lot
think
engineering
great
Fellow
went
pioneering
moved
Daimler
want
Jaguar
different
look
Road
ground-breaking
Golf
brakes
steering
something
design
cars
transportation
sixties
family
Defender
industry
number
company
tremendous
sort
management
University
terms
always
market
business
just
crash
second
armaments
built
get
nk
car
still
going
like
money
days
Royal
good
idea
yes
important
answer
start
early
suppose
got
Rover
ones
give
manufacturing
mass
Pressed
case
Steel
made
customer
thirties
Aston
away
Well
trying
Manchester
engine
everything
need
wheels
question
late
price
two
trains
back
whole
worked
first
clear
part
electric
sense
know
obviously
put
quite
used
go
Martin
life
time
Brighton
drive
Th
four
every
Model
probably
whether
version
took
production
difficult
many
customers
structures
build
people
period
point
Ford
well
years
right
wheel
thing

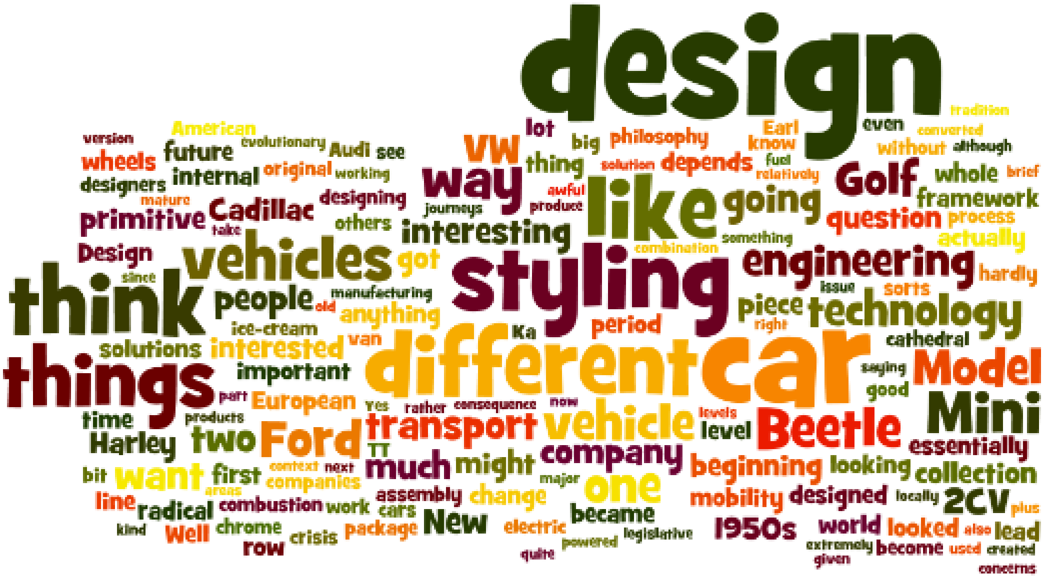


think
quite
design
like
cars
car
Porsche
Trabant
different
suppose
engineering
much
Land
Rover
something
Mini
thing
sixties
feel
sort
Yes
going
Bentley
transport
form
constrained
kind
things
probably
good
really
fantastic
industrial
Oh
lot
2CV
DS
two
make
one
people
terms
user
public
together
fifties
character
guess
might
idea
time
brand
well
seemed
important
weight
Well

design
car
styling
different
vehicles
think
Mini
things
like
Beetle
technology
engineering
vehicle
Ford
Model
transport
Golf
way
one
people
two
VW
interesting
company
want
going
much
Harley
primitive
question
interested
important
Cadillac
New
Design
beginning
future
mobility
European
designed
chrome
1950s
wheels
assembly
electric
period
actually
world
depends
essentially
first
solutions
collection
combustion
cathedral
ice-cream
radical
framework
change
might
2CV
others
designing
thing
cars
level
became
looking
looked
lead
American
anything
crisis
package
piece
internal
original
row
lot
line
Audi
philosophy
companies
time
know
got
Well
whole
hardly
designers
process
big
become


THINK
GOT
CAR
ONE
MOTOR
DIFFERENT
THING
LIKE
KNOW
JUST
YES
SORT
PERIOD
REALLY
DRIVE
OK
WELL
WANT
GOING
CARS
PROBABLY
LOOKING
NOW
NEVER
MADE
MERCEDES
TECHNICAL
EXCITE
NICE
TWO
THREE
RIGHT
CAME
THINGS
ANOTHER
COURSE
AESTHETICS
YEARS
BACK
LIST
TELL
DEVELOPMENT
THOUGHT
ENVIRONMENTAL
CITROËN
BODY
TERMS
TIME
BOOK
SUNBEAM
FIRST
CORVETTE
REASONS
WORLD
INTERESTED
ALSO
SHAPE
MEAN
HIGH
INVICTA
ACTUALLY
ALREADY
EXCITING
SOMETHING
QUESTION
PEUGEOT
BENTLEY
PEOPLE
CONTEXT
ENOUGH
AROUND
CERTAINLY
ANYTHING
SUPPOSE
START
NUMBER
INTERESTING
ENGINE
COME
REASON
MAKE
PARTICULAR
MUCH
INTEREST
MARKET
GO
BIT
POINT
CASE
TECHNICALLY
DONE
ALWAYS
VEHICLE
QUITE
STILL
SOLD
NSU
LITTLE
FRONT
GOOD
LOOK
ORIGINAL
COMES
OTHERS
FORTH
MODERN
PANHARD
ALMOST
BEST


package period Design things Harley line
technology manufacturing part
like Golf engineering vehicle
philosophy relatively might
world think car Audi although
powered interested
lead framework
evolutionary designers given
sorts different TT depends awful
products hardly
cars even used combination VW time
design future
van bit whole see
version next kind process
old issue saying designed
crisis ice-cream Model Beetle without
converted
2CV people interesting designing
context fuel something
tradition created solutions
major one primitive levels companies
know
got New Ka collection looking
anything combustion
legislative question change first
American beginning wheels
right internal company looked
consequence important also European journeys
become take way two concerns lot
want original
Well now cathedral row
going Ford piece thing produce
quite became level
electric transport assembly others
big radical styling
mobility
Cadillac chrome
Yes mature
brief vehicles actually since
Earl
work essentially Mini 1950s
rather working solution good plus
extremely much areas locally

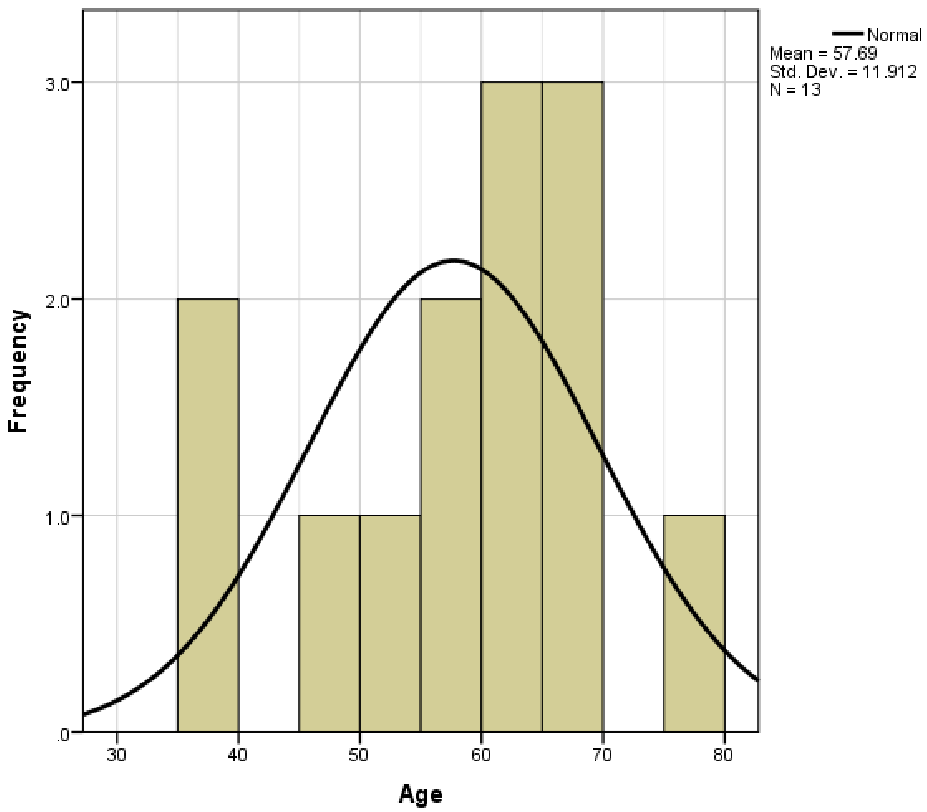

design
styling
different
car
think
things
like
vehicles
engineering
technology
Model
Mini
Beetle
transport
vehicle
Ford
way
VW
Golf
going
interesting
people
company
one
two
want
much
might
beginning
collection
2CV
1950s
New
Harley
Cadillac
primitive
question
framework
whole
philosophy
depends
Design
interested
anything
solutions
important
European
time
first
essentially
looking
mobility
designed
world
looked
lead
became
change
assembly
combustion
radical
Well
chrome
crisis
package
electric
line
wheels
future
internal
designers
original
designing
American
evolutionary
Audi
see
lot
thing
big
Earl
know
even
without
tradition
actually
hardly
piece
period
cathedral
Ka
van
good
level
got

Austin
Seven
one
different
Rover
Bentley
Land
just
got
Turbo
basic
XJRS
Mini
cars
important
always
Rolls-Royce
two
like
actually
car
Eight
now
really
went
basically
old
use
Jaguars
Club
stop
Range
bought
completely
interest
Jaguar
Silver
Shadow
XJ6
Jags
others
meetings
never
people
drive
ones
nothing
well
liked
heater
three
reason
boneshaker


BMW
GTS
design
cars
Countach
Lamborghini
Mangusta
Esprit
Boomerang
Lotus
Tomaso
Lagonda
Maserati
Martin
Aston
Envision
Gina
Ferrari
Dino
De
Design
different
origami
research
windshield
Automotive
Center
technology
mirrors
view
rear
engine
cabriolet
door
attend
year
interest
Car
wings
shows
split
Art
glass
side
skin
mid
toy
since
books
plastic
ship
automotive
wheels
friends
hybrid
performance
spoiler
body
designer
magazines
gull
fabric
car

A3.3 The interviewees

Thirteen individual interviews were carried out. Twelve of these were face-to-face interviews and one was carried out via email discussion, as the interviewee was not in Britain. The process of selecting suitable people to interview was not taken at random and those selected were not chosen from the general public because the general public does not have the knowledge that was required. The candidates were chosen because of their qualifications and interests. There was an uneven spread of ages and all of the interviewees were male – this does not imply any lack of knowledge or interest on the part of females, many of whom design cars or who have interests in cars and their history. Two were not British and one was British but not English. The candidates have been anonymised and are known by letters – A, B, C, D, E, J, L, M, N, P, R, S and T. However, some of them have significant publications on car history and mentioned these in the process of the interview. Four had engineering qualifications, but one of these had abandoned engineering for the more lucrative financial sector. Four were automotive historians, but without formal qualifications in that area. Seven were designers – not all car designers. Five had experience in the Motor Industry, two at a senior level. Four had specific automotive-related qualifications. Eleven would describe themselves as car enthusiasts. The two that did not describe themselves as enthusiasts were nevertheless knowledgeable on car history. They preferred to take a more balanced perspective on that history than an enthusiast might have done, and they still seemed to have some sort of passion for cars, despite wishing to take a non-enthusiast's position. Three of the interviewees had competed in car events of some sort – rallies or racing. Three of the others had also taken part in historical events – classic car shows or the Veteran Car Club's annual London to Brighton Run. Six were from academia, including one who was a visiting professor. Five had PhDs of some sort. Eight were owners of what might best be called historic cars and five had restored cars themselves.



Histogram of interviewee ages

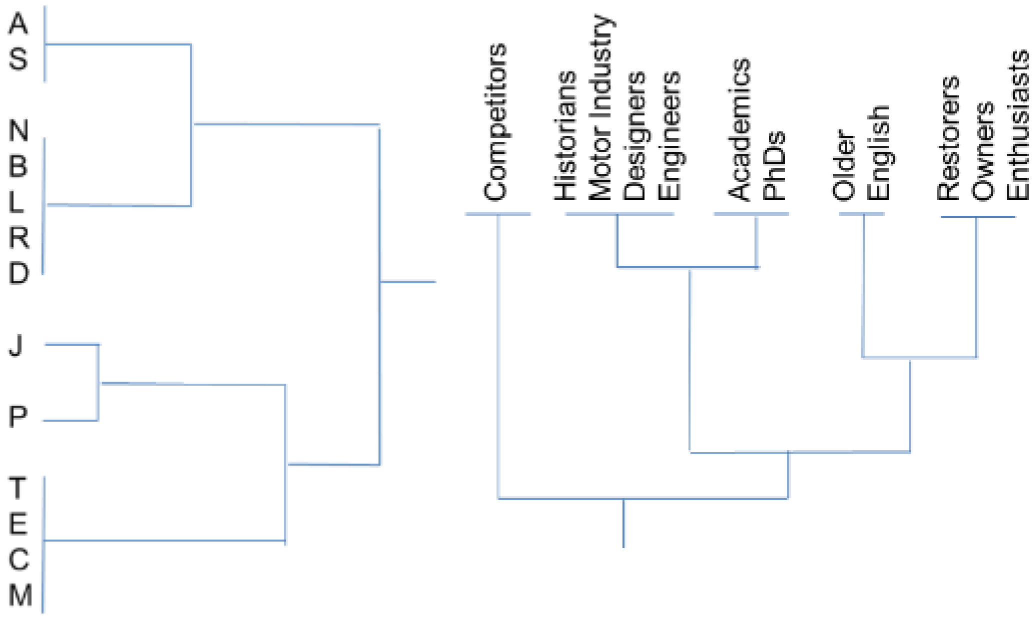
A repertory grid was produced to seek to understand and summarise the combinations and complexities of the individuals who were interviewed. This is the same process as that used later to elucidate the interviewees' constructs on car history and heritage, but at this point in the process the repertory grid was used to seek to understand the results of the interviews. The process of the repertory grid was developed largely from the discipline of psychology. It was originally intended to identify individuals' constructs and thinking processes in a qualitative manner. The suggested process used originally was to identify a series of 'objects' which might include people or anything that an individual particularly relates to, depending on how the process needs to be constructed, and what thinking constructs they have that relate to that particular 'object'. The method of elucidating the constructs was initially to use a process of triads in which three of the 'objects' are compared with each other; the one with the difference is identified and the reason for that difference found. This difference is then termed a 'construct'.

Each ‘object’ is compared with each of the other two in this process and hence a grid of the constructs can be built up. This process is used later to identify the interviewees’ constructs on particular cars (objects) to which they relate, but at this point in the process the individuals were identified as the ‘objects’ and these basic descriptors of them became the ‘constructs’. A repertory grid was able to be constructed to identify the ways in which the individuals’ expertise and interests related to each other. It should be noted that the positive direction for the measures is to the left of the grid.

		A	S	N	B	L	R	D	J	P	T	E	C	M	
18	Competitors	0	2	0	1	0	1	0	6	5	2	7	1	1	Non-competitors
49	Historians	5	4	4	4	4	3	5	2	0	1	3	7	7	Uninterested in history
44	Motor Industry	2	7	3	7	5	3	5	7	0	2	0	0	3	No industry experience
52	Designers	7	7	7	5	7	5	7	2	0	0	0	1	4	No design experience
55	Engineers	4	5	5	7	4	6	7	2	0	5	4	1	5	No interest in engineering
53	Academia	4	6	7	6	7	3	7	4	7	0	0	0	2	No links with academia
58	PhDs	7	7	7	5	7	4	4	4	7	0	3	0	3	No qualifications
61	Older	2	3	6	6	2	4	5	6	6	4	4	7	6	Younger
75	English	0	1	7	7	7	7	6	5	7	7	7	7	7	Not European
48	Restorers	2	2	0	2	3	5	4	2	2	5	7	7	7	No experience of restoring
54	Owners	5	2	0	0	6	2	3	6	5	7	7	7	7	Non-owners
75	Enthusiasts	5	7	2	2	6	6	7	6	7	7	7	6	7	Not enthusiasts
		A	S	N	B	L	R	D	J	P	T	E	C	M	

Repertory Grid of individual interviewees’ background and experience

The primary divisions of the grid are also identified and the clustering of both individuals and their backgrounds is able to be noted.



Clusters for individuals and their backgrounds

The analysis program produced up to five clusters for individuals and for their backgrounds. The primary division is between two major clusters with designers on one side (A, S, N, B, L, R and D) and non-designers (J, P, T, E, C and M) on the other. The next division occurs between the first two, J and P and the other four, T, E, C and M. None of these six are designers. These last four are all enthusiasts and none of them are in academia or have PhDs. They have no experience in the motor industry. The next division occurs between the designers, and sets A and S apart from the others. Neither A nor S is British, both are working outside Europe, and they are both at the younger end of the age spectrum of those interviewed.

In terms of the descriptors, these cluster, firstly, into the competitors and the rest, and then the cluster of the rest splits with historians, motor industry, designers and engineers academics and PhDs on one side and the age, nationality, restorers, owners and enthusiasts on the other – ie those things that are essentially occupational in character on one side and those that are not occupational on the other. Then the two characteristics that are related to being – age and nationality – spilt from those that are more to do with doing and are more related to cars – owning, restoring and enthusing. Lastly, and not too surprisingly, perhaps, the academics and PhDs show some synergy and split from the other occupational characteristics.

A3.4 The interviews

A3.4.1 Questions

The interviews split into several sections. Initially some broad overview questions were used to find out how the interviewees had developed their interests in cars and what form this took. Following that they were asked about their perceptions of car history and how they could identify periods and themes, and then asked about how they might go about designing cars and what influences they might have when they were considering how to do that. Then they were presented with pictures of cars from every five-year period from 1875-1879 to 2010-2014 and asked to arrange these in whatever way they chose, with the additional aim that they might cluster them in some way and then identify those clusters – an affinity diagram using pictures rather than themes. Lastly a variation of the repertory grid technique was used. They were asked to choose nine cars to form their personal car museum and their constructs were identified using a process of triads and in the general discussion that followed from that task. This meant that there were usually more than the anticipated twelve constructs that result from a straight triadic differentiation. As an aside, if a questionnaire approach had been taken then a bare twelve constructs would probably have resulted and some of the answers may have been banal in nature.

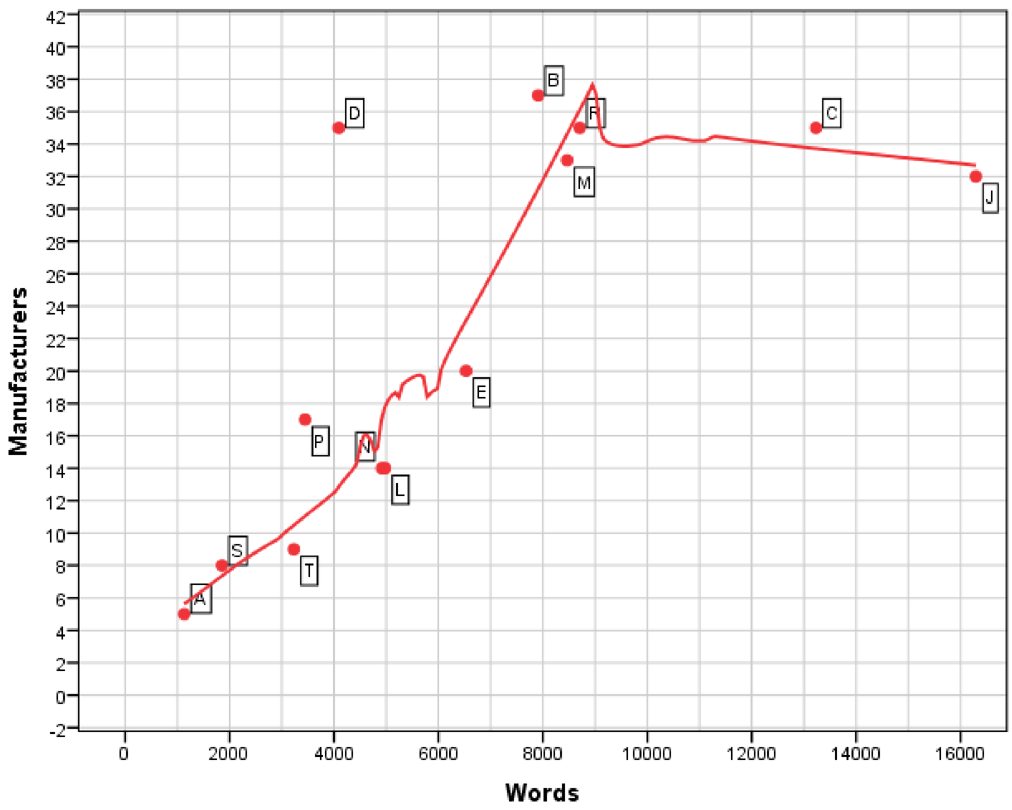
A3.4.2 Analysis processes

The interviews were transcribed, and were from 1000 words to as long as 16000 words. A large proportion of the longer interviews was not in direct answer to the questions, but these tended to be the more fascinating interviews – yes, but fascination isn't one of those things measured, unfortunately. As might have been expected, the longer interviews also tended to wander off the subject from time to time and were filled with interesting anecdotes and comments.

Car history is about different makes and what the manufacturers did, so how many mentions did each person give to different manufacturers?

Not surprisingly, the longer the interview the more manufacturers were mentioned. The distance from the linear equation may indicate the breadth of somewhat obscure knowledge that can be attributed to the individual. T, for instance, being enthusiastic for a particular group of manufacturers and knowing or caring little about a broader spectrum is somewhat below that line, whilst D and B who have a very broad spread of the multinational nature of the industry's history and find interest and enjoyment in the obscure are significantly above that line. There might expect to be a levelling off of the line as people manage to include references to all the manufacturers that they know – how close the points are to that position will never be known, of course.

The interviewees seem to fall into a group who mention a lot of manufacturers, over 30 different ones each, and another group who mention a much smaller number. This second group could possibly be divided again into two: those who mention fewer than ten manufactures and those who mention between fourteen and twenty. It is interesting that there is a clear gap between these lower two groups and the other group and it seems to indicate a broader understanding of the overall spread of the motor industry and its history, with perhaps less enthusiasm or loyalty for a particular manufacturer.

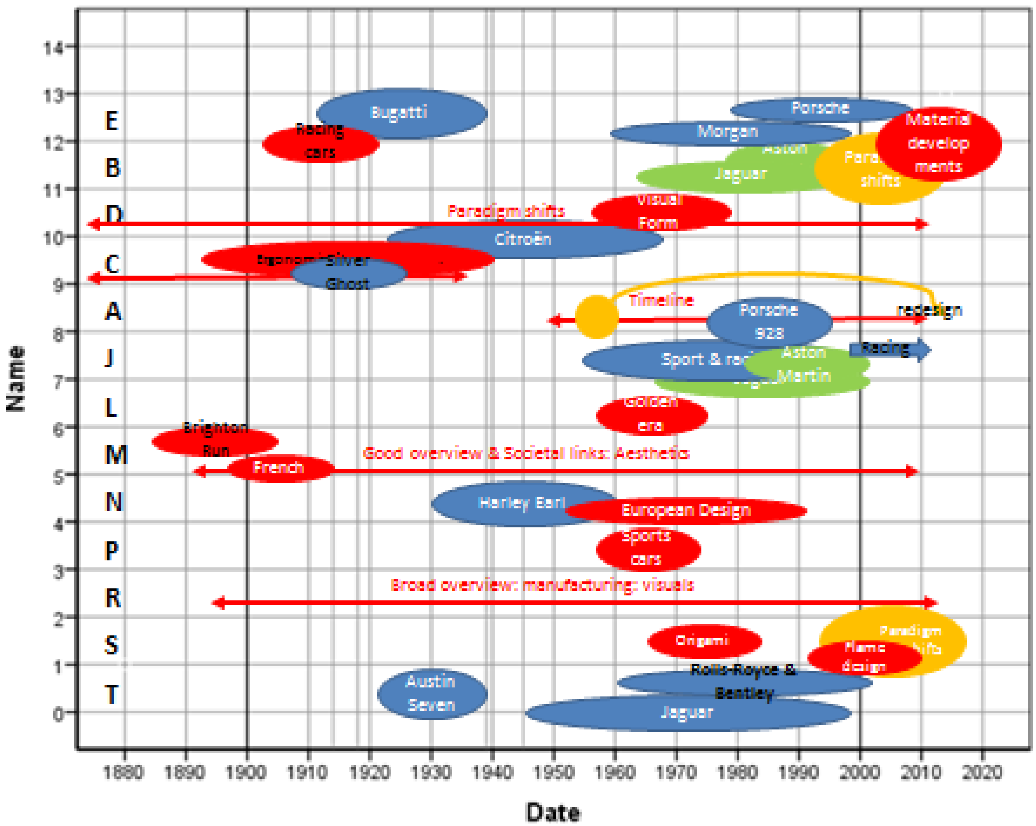


Graph of number of words against number of different manufacturers mentioned

A3.4.3 Interests

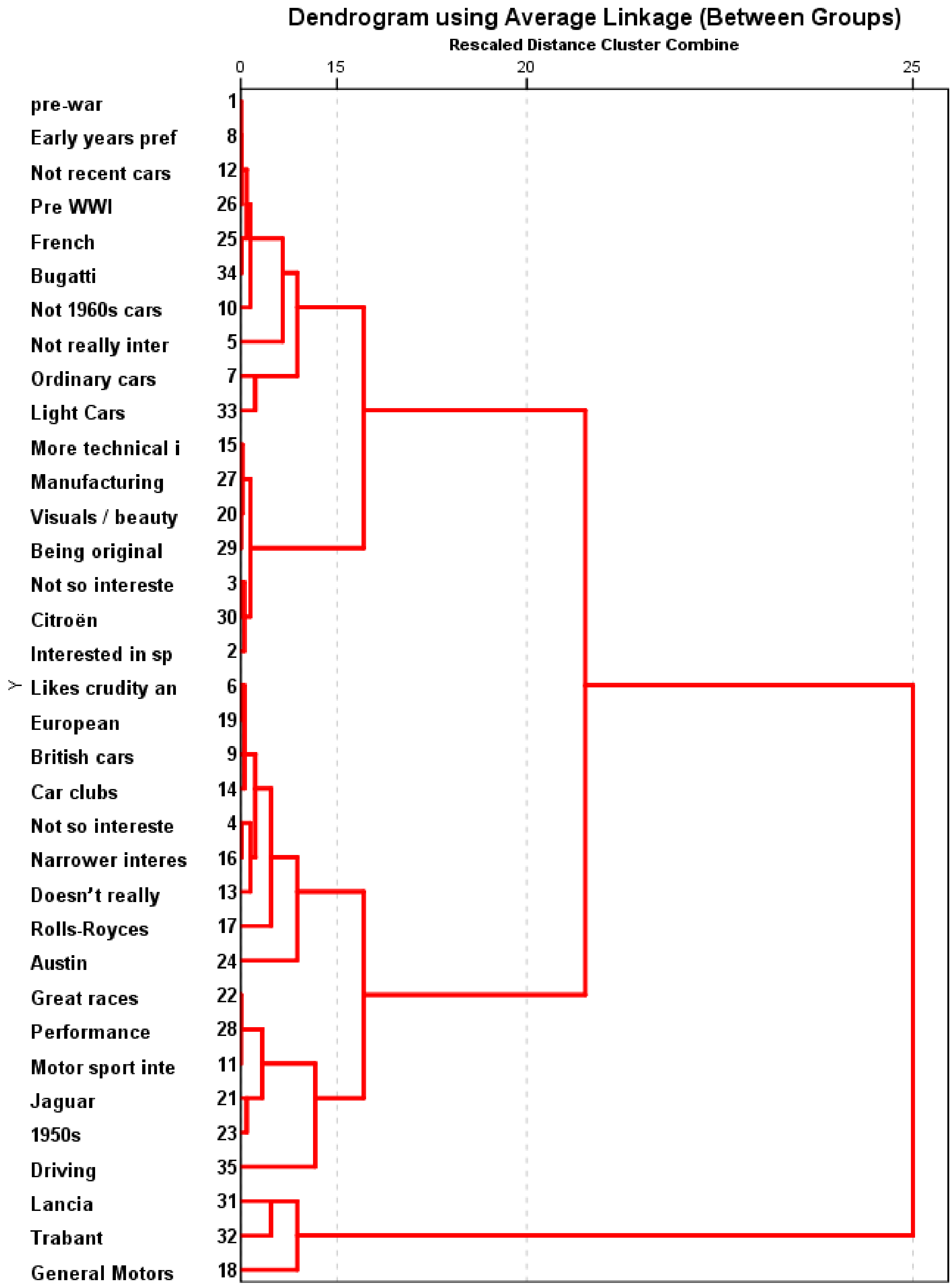
In the early section of the interview each interviewee was asked about their particular interests, and whether this related to periods, particular manufacturers, styles or design features. There was a very varied set of answers – some people gave very quick answers whilst others took a long time to talk over many ideas with illustrative examples and some off the subject discussion. The picture probably describes the interests quite well, placing them on a timeline. Several mentioned the idea of investigating paradigm shifts, although quite what they meant by them wasn't always clear. Certainly the designers amongst the group seemed to want to use the term, but they were not the only ones. In some cases this was a major change of direction, in others more the utilisation and incorporation of a particular novel manufacturing technique – but as this was a change from the status quo of the stamped steel bodyshell, perhaps he should be forgiven this.

The youngest three (which may be significant) did not find pre-Second World War cars to be of particular interest, whilst the oldest limited himself the other way in that he said that he wasn't interested in anything after 1939, but later in the discussion indicated that he did seem to be interested in later cars after all. He also happened to have owned one of the earliest cars of the interviewees – a 1900 Benz.



Timeline of interviewees' interests in cars

A repertory grid approach was also carried out on these data. This produces a somewhat more complex result than the previous grid, as there are far more constructs to deal with. A clustering analysis produces the two pictures: first, clustering the constructs:



Two Clusters:

a) Lancia, Trabant and General Motors

b) The rest!

Three Clusters:

a) pre-war, early years preferred, not recent cars, pre WWI, French, Bugatti, not 1960s cars, not really interested in Porsches, ordinary cars, light cars, more technical, manufacturing, visuals / beauty, being original, not so interested in specific makes, Citroën, interested in spread of history:

b) likes crudity and starkness, European, British cars, Car clubs, Not so interested in history, narrower interests, doesn’t really do paradigms, Rolls-Royces, Austin, Great races, performance, motor sport interest, Jaguar, 1950s, driving

c) Lancia, Trabant, General Motors (still)

Five Clusters:

a) pre-war, early years preferred, not recent cars, pre WWI, French, Bugatti, not 1960s cars, not really interested in Porsches, ordinary cars, light cars

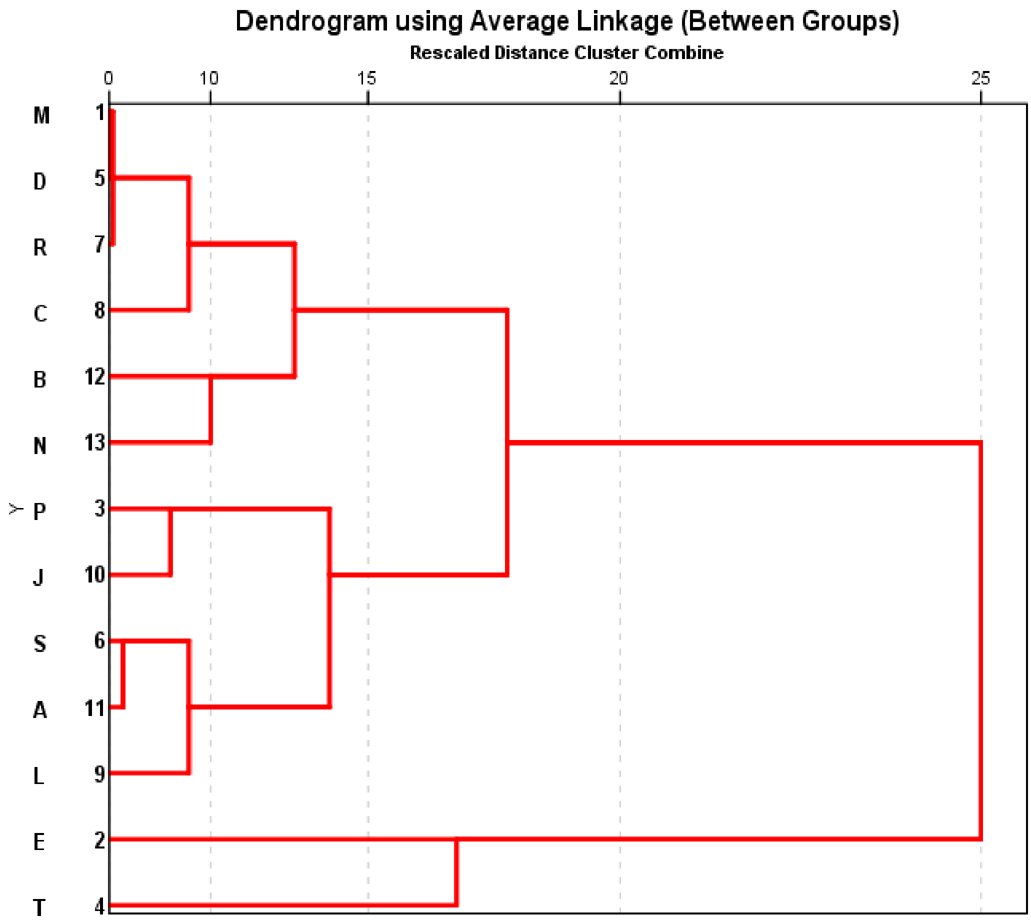
b) more technical, manufacturing, visuals / beauty, being original, not so interested in specific makes, Citroën, interested in spread of history

c) likes crudity and starkness, European, British cars, Car clubs, Not so interested in history, narrower interests, doesn’t really do paradigms, Rolls-Royces, Austin

d) Great races, performance, motor sport interest, Jaguar, 1950s, driving

e) Lancia, Trabant, General Motors

Second, clustering the interviewees



Two clusters:

a) E & T Two owners and enthusiasts with less historical knowledge

b) M, D, R, C, B, N, P, J, S, A & L the rest

Three clusters:

a) M, D, R, C, B & N Interested in a broad spread

b) P, J, S, A & L A narrower set of interests

c) E & T See above

Four clusters:

a)	M, D, R, C, B & N	Interested in a broad spread
b)	P, J, S, A & L	A narrower set of interests
c)	E	Bugatti owner!
d)	T	Owns lots of British cars…

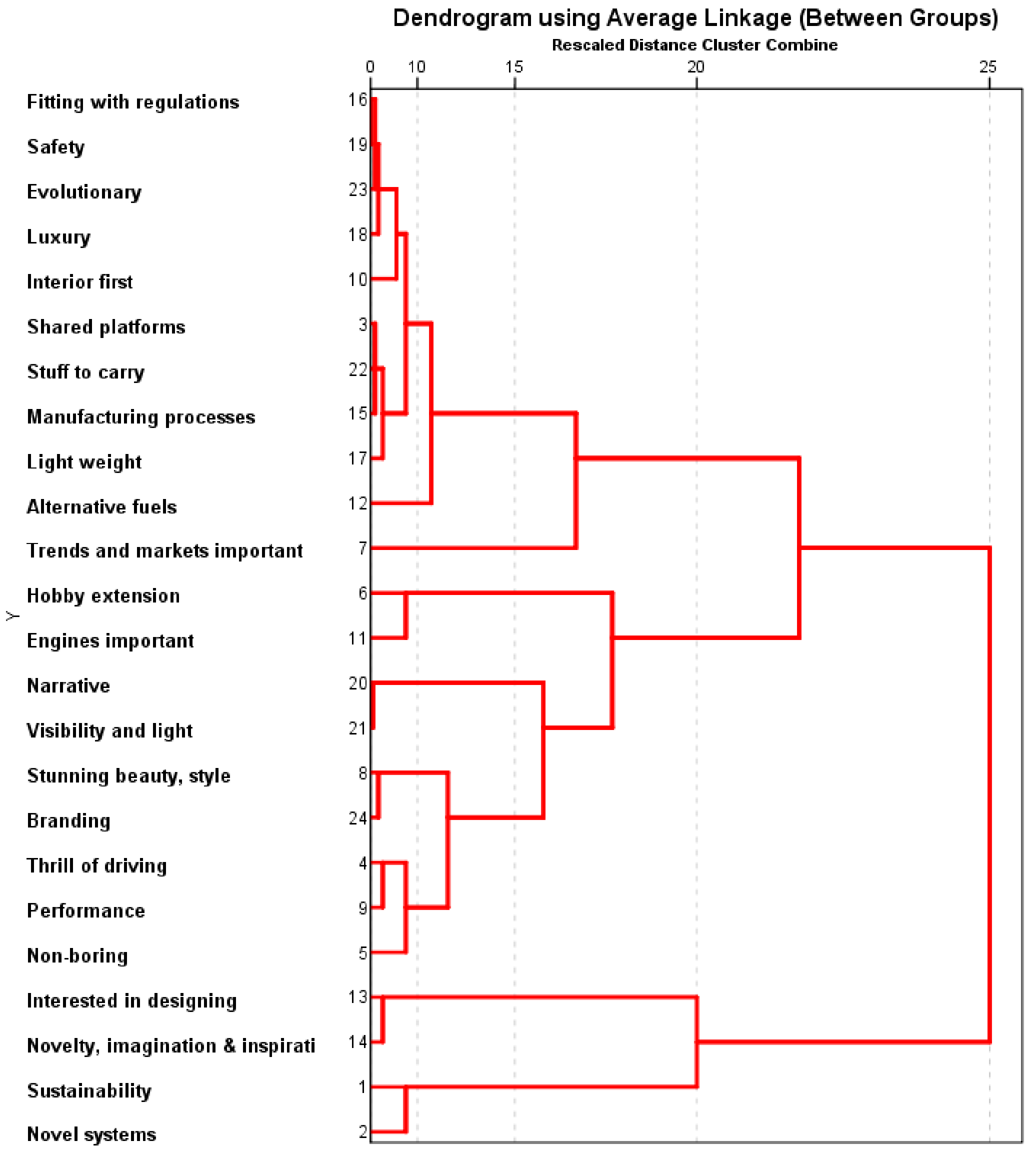
Five clusters:

a)	M, D, R, C, B & N	Interested in a broad spread
b)	P & J	Racing enthusiasts
c)	S, A & L	Younger Designers with later interests
d)	E	Bugatti owner
e)	T	Owns lots of British cars …

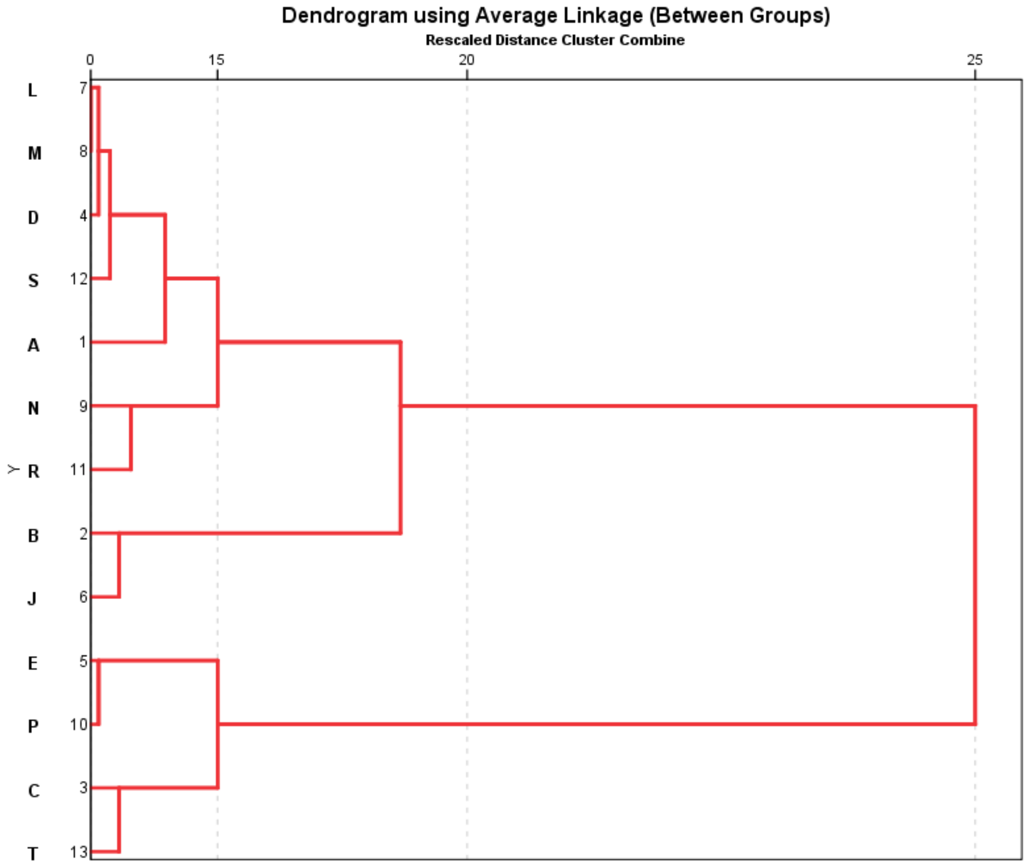
The interests expressed here do not necessarily relate to the individual's knowledge of car history – simply to their interests.

A3.4.4 Car design thoughts

The next question was more specific and related to their design thoughts if they were part of a team and how they might start on a new car design and what they might want to incorporate – this was as a practical design and one that was meant to include current constraints rather than to generate blue-sky thinking. A list of the important points mentioned was gathered and rated – what did they think was important? What was it that they would like to see incorporated into cars?



Top of the list was to design non-boring cars – 85% rating. There is then a small gap before there is a long list that doesn't really show a lot of differentiation, right down to the bottom, and which is therefore difficult to categorise effectively. Small gaps in the list do occur, however which just about separate them into categories. So perhaps they could be graded like students on courses – A, B, C etc priorities. Maybe.



Priority Rating	Design requirement
A	Non boring
B	Stunning beauty, style, Performance, Trends and markets important, Manufacturing processes, Visibility and light, Interested in designing, Branding, Thrill of driving, Novelty, imagination & inspiration
C	Evolutionary, Sustainability, Engines important, Fitting with regulations, Safety, Interior first, Stuff to carry, Hobby extension, Narrative, Light weight
D	Alternative fuels, Shared platforms, Luxury, Novel systems

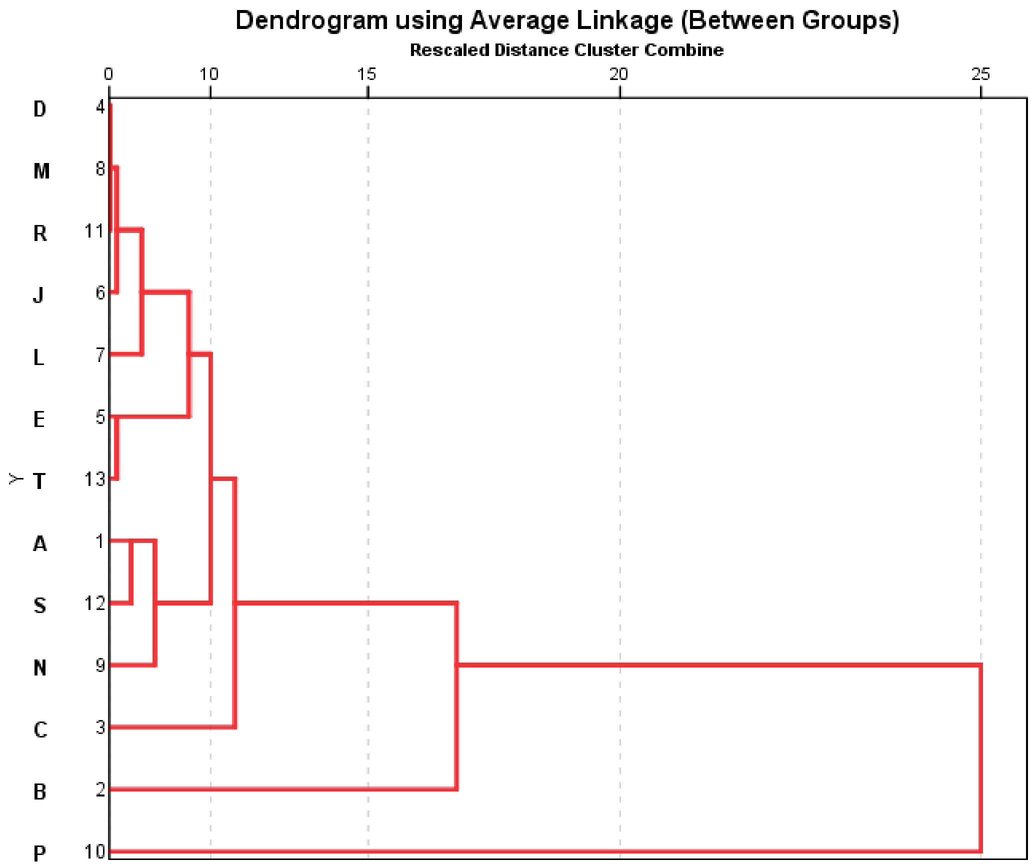
As each scale was a bi-categorical one the opposites were thus also below these as each was measured on the same scale – these are the losers. Perhaps these are aspects that designers would prefer to ignore!

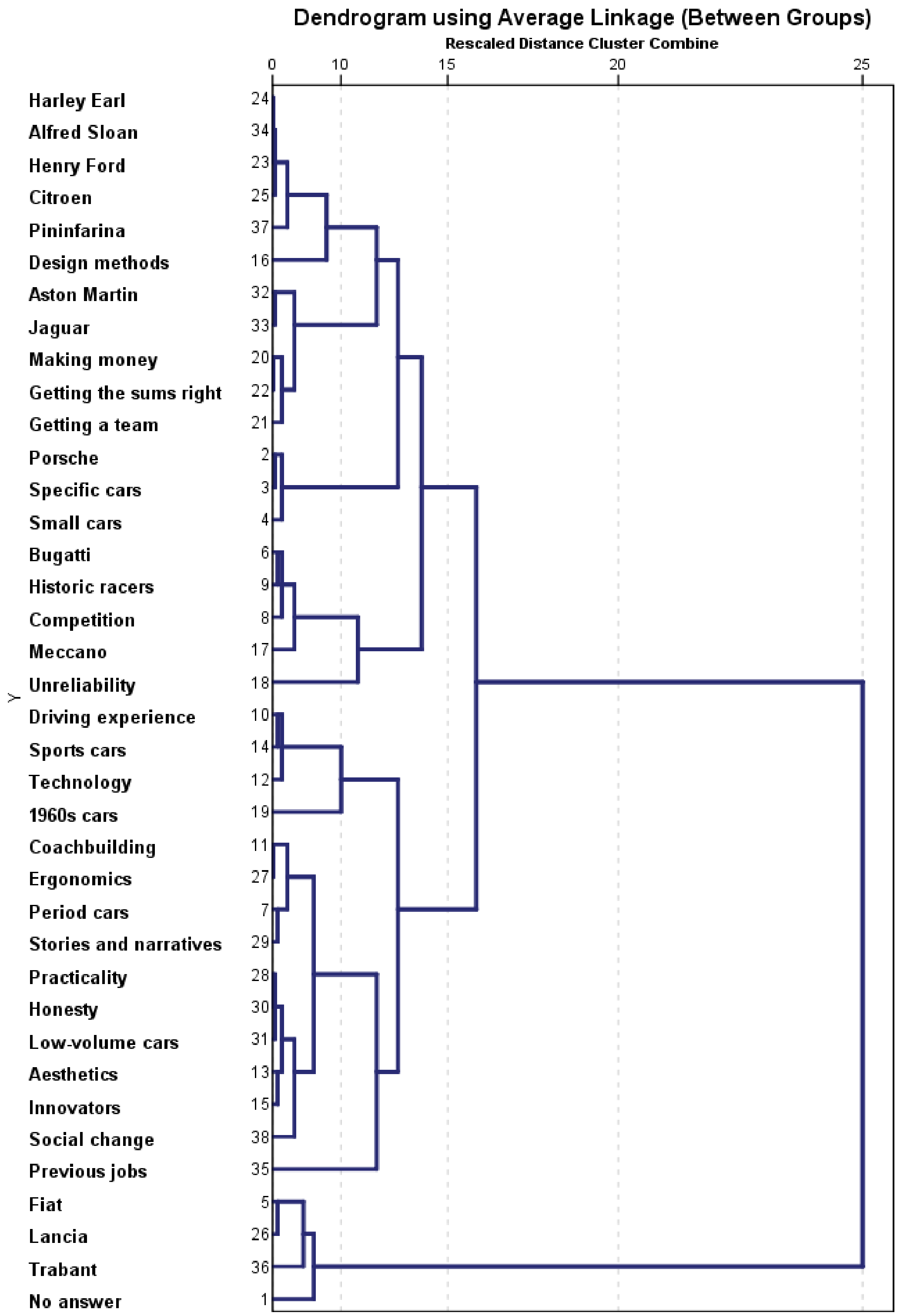
Priority Rating	
E	No novel systems, Starkness, No sharing, Stick with oil-based
F	Weight not so important, Not narrative, Ignoring safety, Interior less important, Carrying capacity sorted out later, Simply an intellectual exercise, Developing new regulations, Engines sorted out later, Ignoring sustainability, reversing trends
G	Lack of novelty, Anonymity, Basic transport, Processes come later, Ignoring visibility and light, Not interested in designing, Car more important than its market, Utilitarian, Concentrating on transport aspects
H	Boring

The differences shown between what designers would like to design and what they are required to design seems to be significant. More designers would like to design interesting sports cars, whereas in practice most car design is of the replacement for the current super-mini or similar. However, car history suggests that some of the interesting cars can indeed be small, economic family cars. The later question where they were identifying the nine cars for their personal museums indicated that these small cars can indeed become significant ones for museums.

A3.4.5 Greatest influences

This was to ask them what or who would be their greatest influences in carrying out a car design task. For some this would be hypothetical but for others it would be the real influence that they have used. For some who are not actually designers, they may have been car specifiers and would therefore also have used some specific influences to make those decisions about which design preferences to support and encourage.


Dendrogram using Average Linkage (Between Groups)
Rescaled Distance Cluster Combine
0
10
15
20
25
D 4
M 8
R 11
J 6
L 7
E 5
Y T 13
A 1
S 12
N 9
C 3
B 2
P 10



Priority rating	Influences

A	Low-volume cars, Honesty, Sports cars, Innovators
B	Previous jobs, Driving experience, Practicality, Aesthetics, Technology
C	Period cars, 1960s cars, Social change
D	Jaguar, Getting the sums right, Porsche, Unreliability, Design methods, Coachbuilding, Making money, Stories and narratives
E	Specific cars, Competition, Henry Ford
F	Small cars, Bugatti, Ergonomics, Historic racers, Harley Earl, Aston Martin, Pininfarina, Citroën
G	Alfred Sloan, Getting a team, Meccano
H	Lancia, Trabant, Fiat

This is interesting in that, in the main, large volume producers are not particularly influential. Most of the influences seem to be targeted at ‘pin-up’ type cars – low-volume ones, sports cars and innovators. These cars could also be termed as dreamlike or perhaps slightly wild in character, and not necessarily practical ones. The inclusion of low-volume cars is interesting in that it suggests that car designers look to the edges of what is going on to establish interesting directions for future design work. This also indicates that designers may be actively thinking about changing paradigms if they can, and making car history shift its perceived direction. The influence of honesty is seen as also being very important: the need to tell the public exactly what the car you’re designing is and not to pretend about it. This seems to imply that a high degree of positive ethics is expected of car designers, although this might be tempered with a certain amount of cynicism once the dream car moves towards being a concrete proposal for action.

Next in the list come some strong influences from experience – previous jobs and driving experience. The need for there to be a strong emphasis on practicality, aesthetics and technology – ie all intangible influences – is also very important.

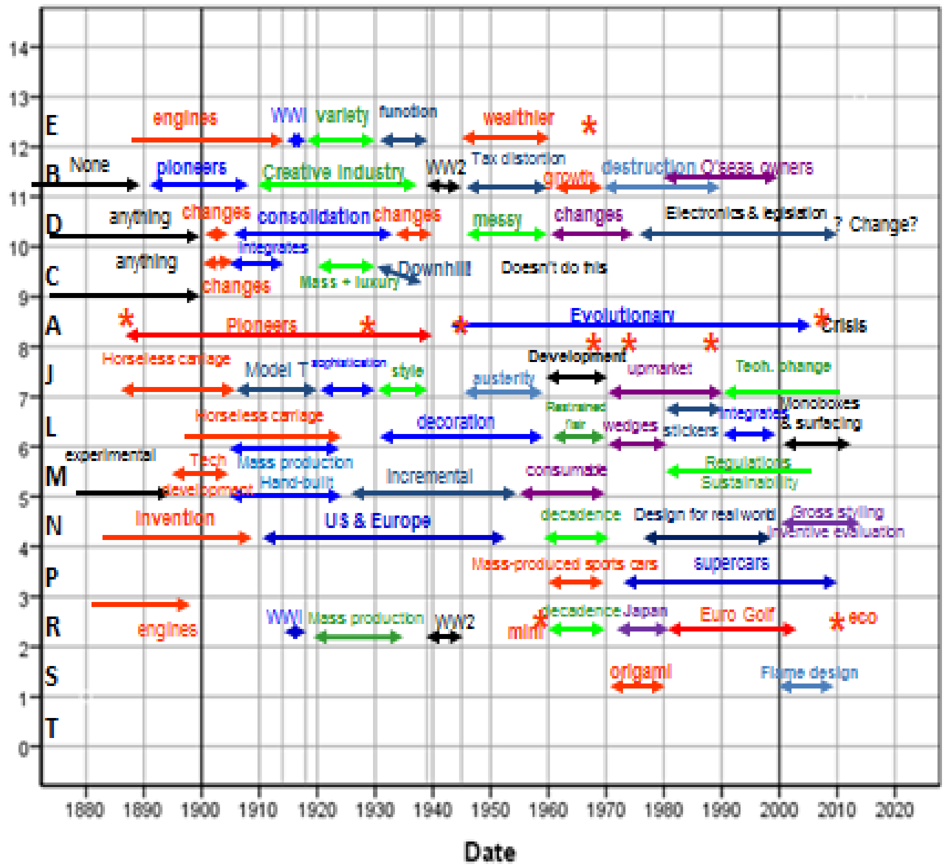
The C rate category of period cars, 1960s cars and social change indicates that these individuals appreciate the historical aspects of cars when designing new ones, and some seem to hark back to the specific 1960s era, perhaps their teenage years. Investigating the non-design aspect of social change as an inspiration is interesting and shows a broader outlook for designers than might have sometimes been felt to have been the case.

The first specific vehicles or designers mentioned are only down at a D rating – Jaguar and Porsche. As these people were also interested in car history, the historical aspects of design come through this list quite strongly, although how they might be interpreted in currently designing cars is quite another matter. One of the designers in the survey suggested that deliberately including historical cues might result in a bastardised style that failed in its honesty. He felt this was a significant design trend and therefore included one of these cars in his selected nine – one that Tumminelli calls a 'Remake' rather than simply a 'Retro' (Tumminelli, 2004). At this level we also see the significant influence of economic issues, indicating that car designs might start with less consideration of these and then move towards significant consideration of these issues before the design is finalised. The consideration of unreliability here is interesting – the point being made was that current vehicles' unreliability influences the changes that they would like to see implemented.

A3.4.6 Car history periods

The next question asked how they thought of car history, by asking what periods of car history they could identify. In the picture sets of coloured lines indicate similarities. Some of (mostly) the designers didn't really want to indicate that much took place before the Second World War – A, L, P and S chose not to mention very much before then. Some had little to say on this question, including one (T) who chose not to answer it at all.

Initially it was felt that carrying out a repertory grid approach on this question was counter-productive, but later it was realised that this was probably exactly what was required, as this obtained the differences in opinion, perceptions and historical interests of individuals. The overall grid looks like the table below the time-scale diagram:

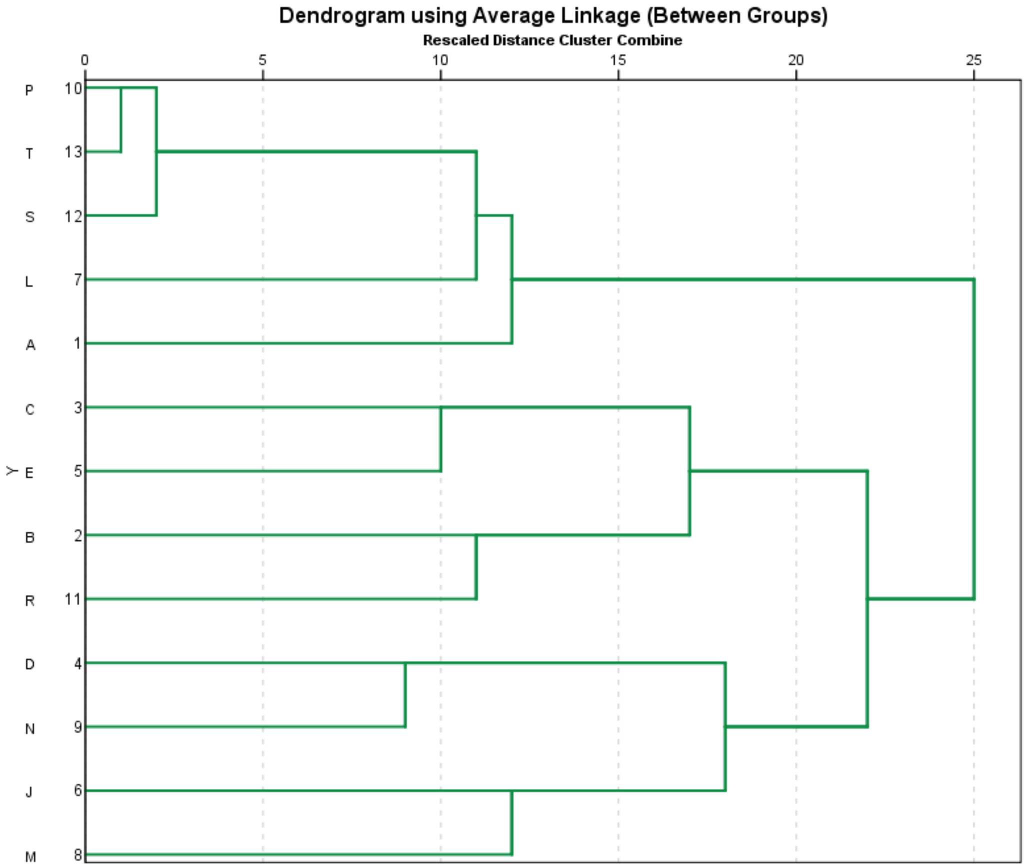


Car history periods

1	overview of all periods	Limited overview	no overview
2	World Wars make breaks	Wars mentioned but don't change things	don't mention the war!
3	Pioneering age earlier and mentioned in detail	Pioneering age to 1945	No mention of pioneers
4	interest in pre-Second World War		No interest in pre-WW2
5	growth of mass-produced product		Mass production not mentioned
6	detail before WW1		No detail before WW1
7	interested from an industry point of view rather than the product	As much interest in industry as the product	Product interest
8	fabulous designs from the 1930s		Fabulous design of the 1930s not mentioned
9	sustainability a big influence and a driver for history		Sustainability ignored
10	electronics developments from 1975 (or so)		No mention of electronics
11	UK motor industry from 1960s rise through 1980s decline and then overseas ownership.		Doesn't mention British industry
12	development of general luxury and sophistication from 1990s.		Growth of sophistication not mentioned
13	interested in visual aesthetics		Not interested in visual aspects
14	exuberance of 1950s US design		US exuberance ignored
15	links from aircraft industry	Any other industrial links mentioned?	No industry links mentioned
16	luxury cars in the 20s and 30s related to societal issues		No mention of 1920s and 30s luxury
17	functional design from 1920s and 30s		No mention of 1920s and 30s functionality
18	regulations and legislation from 1980s		Ignores legislation!
19	Early inventive period		Doesn't mention early invention
20	Japanese development	Little mention of global aspects	Doesn't like Japanese
21	Veteran, Edwardian, Vintage mentioned		Terms not mentioned

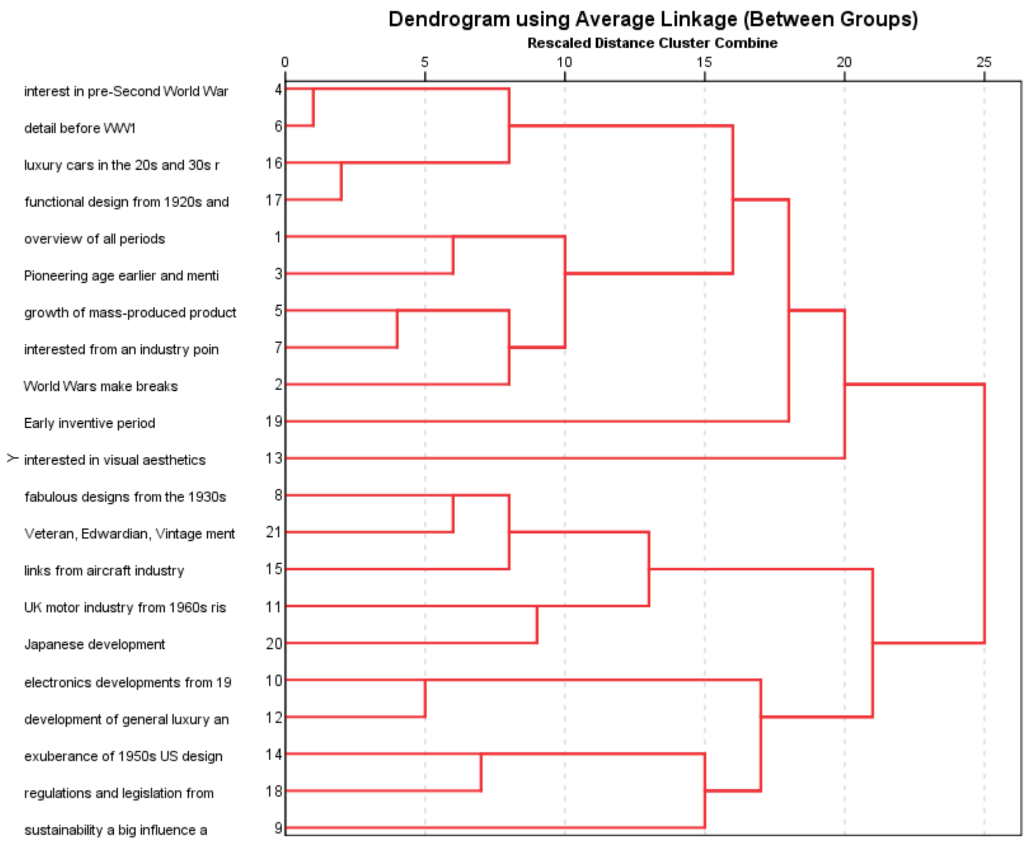
	M	J	N	D	R	B	E	C	A	L	S	T	P
4	5	3	1	5	2	6	6	9	1	4	0	0	0
6	6	1	2	4	2	6	4	10	0	5	0	0	0
16	10	6	0	0	7	3	5	10	0	0	0	0	0
17	8	6	2	2	7	7	7	10	0	0	0	0	0
1	10	10	7	10	10	10	7	5	5	10	1	0	2
3	9	9	7	9	7	7	6	10	4	5	0	0	0
5	7	5	5	5	7	8	6	5	7	1	0	0	4
7	7	7	6	4	7	10	2	4	3	2	0	0	1
2	4	9	3	7	10	10	8	8	7	4	0	0	0
19	5	0	10	10	2	10	4	10	5	3	0	0	0
13	6	4	7	5	2	0	3	7	5	9	6	0	0
8	0	6	3	0	4	1	7	3	0	3	0	0	0
21	0	0	0	3	0	0	6	3	0	0	0	0	0
15	0	0	0	0	8	5	7	0	0	3	0	0	0
11	2	3	4	4	8	10	0	0	0	0	0	0	0
20	0	6	0	0	8	2	0	0	0	0	0	0	0
10	7	8	0	8	3	0	0	1	7	0	0	0	0
12	5	10	0	4	0	1	0	0	1	0	0	0	0
14	3	0	10	8	0	0	0	0	0	2	0	0	0
18	8	8	10	8	0	0	0	0	0	0	0	0	0
9	7	0	9	3	7	0	0	0	8	0	0	0	0

Tables showing historical interest of individuals – the coding from the top table is needed to comprehend the lower one.



Individual clustering based on historical perceptions

This clustering is interesting. If two clusters are envisaged, then P, T, S, L and A would be in one corner with C, E, B, R, D, N, J and M in the opposite one. The first cluster does not really investigate history much before the Second World War. The other one does. It is this second cluster that splits next, with C, E, B and R heading to a third corner, leaving D, N, J and M. C and E would be happy talking about very old cars. B and R would talk about manufacturing processes and their incorporation in the car and when that took place. D and N would be happy talking for hours (and do – they know each other) about various influences and periods and their enjoyment of historical design and J and M would carry on a conversation about legislation, the pioneering age and their general enjoyment of historical beauty.



Clustering of historical themes

If the historical themes are clustered, then splitting into two clusters puts

4, 6, 16, 17, 1, 3, 5, 7, 2, 19, 13	interest in pre-Second World War: detail before WW1: luxury cars in the 20s and 30s related to societal issues: functional design from 1920s and 30s: overview of all periods: Pioneering age earlier and mentioned in detail: growth of mass-produced product: interested from an industry point of view rather than the product: World Wars make breaks: Early inventive period: interested in visual aesthetics
8, 21, 15, 11, 20, 10, 12, 14, 18, 9	fabulous designs from the 1930s: Veteran, Edwardian, Vintage mentioned: links from aircraft industry: UK motor industry from 1960s rise through 1980s decline and then overseas ownership: Japanese development: electronics developments from 1975 (or so): development of general luxury and sophistication from 1990s: exuberance of 1950s US design: regulations and legislation from 1980s: sustainability a big influence and a driver for history

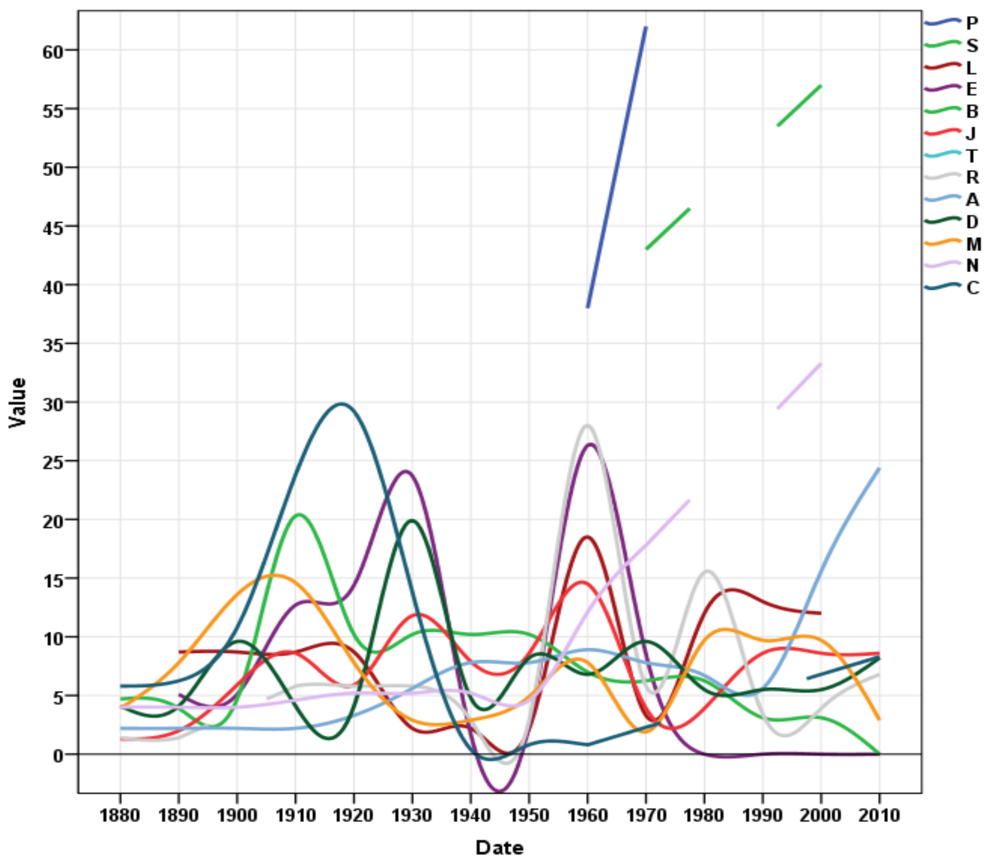
Splitting this into five clusters we have:

4, 6, 16, 17, 1, 3, 5, 7, 2	interest in pre-Second World War: detail before WW1: luxury cars in the 20s and 30s related to societal issues: functional design from 1920s and 30s: overview of all periods: Pioneering age earlier and mentioned in detail: growth of mass-produced product: interested from an industry point of view rather than the product: World Wars make breaks
19	Early inventive period
13	interested in visual aesthetics
8, 21, 15, 11, 20	fabulous designs from the 1930s: Veteran, Edwardian, Vintage mentioned: links from aircraft industry: UK motor industry from 1960s rise through 1980s decline and then overseas ownership: Japanese development
10, 12, 14, 18, 9	electronics developments from 1975 (or so): development of general luxury and sophistication from 1990s: exuberance of 1950s US design: regulations and legislation from 1980s: sustainability a big influence and a driver for history

Listing the factors in order of priority – ie which people thought were the most important and therefore gave high marks to these aspects of car history, we get:

Category	**Marks**	**No**	**Aspect of car history**
A	87, 73, 70	1, 3, 2	overview of all periods: Pioneering age earlier and mentioned in detail: World Wars make breaks
B	60, 59, 54, 53	5, 19, 13, 7	growth of mass-produced product: Early inventive period: interested in visual aesthetics: interested from an industry point of view rather than the product
C	49, 42, 41, 40	17, 4, 16, 6	functional design from 1920s and 30s: interest in pre-Second World War: luxury cars in the 20s and 30s related to societal issues: detail before WW1
D	34, 34, 34, 31, 27	10, 18, 9, 11, 8	electronics developments from 1975 (or so): regulations and legislation from 1980s: sustainability a big influence and a driver for history: UK motor industry from 1960s rise through 1980s decline and then overseas ownership: fabulous designs from the 1930s
E	23, 23, 21	15, 14, 12	links from aircraft industry: exuberance of 1950s US design: development of general luxury and sophistication from 1990s
F	16, 12	20, 21	Japanese development, Veteran, Edwardian, Vintage mentioned

Thus, despite a number of the ‘specialists’ tending to ignore the early period, it is felt to be very important, by the collective wisdom, to get a thorough overview of all periods of car history, and it is very important that the pioneering age (whenever that might be considered to be) be described in detail, and be determined as being earlier – in other words, it is beneficial to identify the early developments clearly and not to combine early periods too much in one’s mind. World wars have a tendency to create breaks in history. Partly this is a perception of history, but in fact they cause disruption to industry, which then develops at a different pace and following a war there are various different processes that seem to take place to put industry back onto its feet again, and these interfere with and affect the way in which developments take place. On some occasions technology develops hugely due to the war efforts – but in other instances the rebuilding of industries takes time and effort, sometimes on the part of both winners and losers where the winners assist the losers in their development processes as took place in Germany after the Second World War.



Emphasis on each decade from each individual

The process of creating this graph was that the percentage of each person's answer that related to each decade was measured in terms of the number of words, and this graph indicates the result. Yes, individuals have their own emphases, but there are some general comments that could be made. The Second World War period from 1939 to 1945 is one where much of the world's car production shut down, and thus there is little to talk about, so people don't. It is clear that the favourite decade for our individuals is the 1960s. Some people are particularly interested in the 1910s decade, some in the 1920s and some in the 1930s – this reflects particular interests, and shows that there was something of interest in all of these periods that could be discussed. In contrast, the 1950s, 1970s and 1990s are not mentioned as much as the 1960s and 1980s, for some reason.

A3.4.7 Affinity Diagrams

A3.4.8 Repertory Grid Cars

R Grid

1 Works D Type Jaguar  (Wikimedia Commons: Writegeist)	2 Bentley 4½ litre supercharged 	3 Pre First World War French racing car (with aircraft engine) (1908 Brasier)  (Fair use: Available from Norton.uk.com)
4 Austin Seven trials  (imcdb.org)	5 Jaguar E type coupé  (Autocar)	6 Land Rover LWB 1960s  (Wikimedia Commons: Cestes)
7 Fiat 500 Twin Air (new)  (Autocar)	8 Volkswagen Beetle 1950s  (Wikimedia Commons: Pfan70)	9 DUKW  (Dave Ahl)

R Analysis

	No	Reason for difference	No	Reason for Significance
123	1	Designed from scratch as a precursor for roadsters.	1	It uses more modern manufacturing techniques
456	4	Stripped down version for a specific purpose	6	Set the scene for 4wd and off-road
789	9	It's amphibious	8	Set the scene for German reconstruction
147	1	A non-production vehicle	1	Precursor to modern manufacturing techniques
258	8	Air-cooled flat 4: application as peoples' car.	8	
369	3	Almost designed (but not quite?) A put-together vehicle	6	Sets the scene for off-road vehicles: created desire for Range Rovers and Toyotas
159	9	Amphibious: a heavy-duty carrier and not a sports car!	5	Commercially. Set the standard for the affordable sports car.
267	2	Not a mass-market vehicle	6	
348	3	A one-off vehicle	8	Mass market appeal: Application of design life from the 1940s into the 1970s
168	1	Not really a production vehicle	6	Because it influenced more vehicle designs than the others.
249	4	Super lightweight: low technology and for a very pointed purpose.	4	For its significance to the British motor industry
357	3	Almost a custom car	5 7	Historically. This has extended the design life of the petrol engine. But too new to really know its significance.

E Grid

1 Bugatti Type 13 	2 Bugatti 18 	3 Bugatti Type 35 
4 BMW 328 	5 Napier 1903 	6 Bugatti 57S 
7 Porsche GT3  (Wikimedia Commons: Brian Snelson)	8 Ferrari F40  (Autocar)	9 Ford GT40 

E Analysis

	No	Reason for difference	Significant
123	2	Rarity	2
456	5	The earliest one	4

789	9	Ford’s attempt to get one over Ferrari	9
147	1	Much cruder: function over design, almost	4
258	8	Much more modern	5
369	9	Much more modern, recent: different owner: no fettling	3
159	9	The era is so different	5
267	7	It’s a car to aspire to today	6
348	4	Not built especially for racing	3
168	8	Much more recent	1
249	2	A pre first-world war car: not so proficient	2
357	7	Most capable: most usable: most fuel-efficient: not an out and out racer	5

P Grid

1 Ferrari F40  (Autocar)	2 AC Cobra  (favcars.com)	3 Lotus Elan (early) 
4 Lotus 7 (Caterham)  (favcars.com)	5 Austin Healey 100M  (Bonhams)	6 MGA Twin Cam  (Wikimedia Commons: Mr Choppers)
7 Ferrari Dino 	8 BMW Z4 Motorsport  (automotiveaddicts.com)	9 Mercedes-Benz SLS  (Wikimedia Commons: WikiABG)

P Analysis

	No	Reason for difference	Significant
123	1	A different concept The other two have separate chassis The other two are front-engine rear-wheel-drive A little V8 at the back	1
456	4	Just purely a driving car. Not for comfort	5
789	7	First attempt at a production rear-engined car	8

		More refinement in the other two	
147	4	Rear wheel drive and affront engine	1
258	8	Not of the same period Comfortable	2
369	9	A modern car Has a V8 and not a 4-cylinder engine Doors Others are not that fast or comfortable	3
159	9	Comfortable, fast touring car Others designed for racing Mercedes is designed for bankers	1
267	7	It has a rear engine	2
348	8	The others were designed by Colin Chapman	3
168	1	Not a front engine A pure racing car that found its way onto the street	1
249	9	Not designed as a racing car	2
357	7	A rear engined car The others race quite a bit The Healey M was built for racing	3

B Grid

1 Land Rover Defender  (Buckers at English Wikipedia)	2 Original Mini  (John Baker)	3 Model T Ford 
4 Jaguar C Type 	5 Mercedes-Benz 300SL 	6 Corvette  (Chevrolet Press Release)
7 Ford Galaxy  (Wikimedia Commons: Rudolf Stricker) / Renault Espace 	8 Th!nk 	9 Bentley Speed Six  (favcars.com)

B Analysis

	No	Reason for difference	Significant	

123	1	Four wheel drive Low and high range gearbox Designed to do everything and go anywhere Other two are personal transportation Others give best possible value	3	
456	6	The first big-volume blue-collar sports car	4	Jaguar was so pioneering in terms of its focus on winning one motor-car race First to use disc brakes (no it was the D type) First to use gearbox-driven power brakes (no it was the D type)
789	8	Electric	8	You can get two people in reasonable comfort
147	4	Designed to win one motor race	1	Designed to win one motor race
258	8	Electric	2	Redefined motoring for so many people and made it affordable
369	3	Mass motoring for so many people Ground-breaking Epicyclic gearbox Built down to a price: the price reduced instead of going up each year	3	Mass motoring for so many people Ground-breaking Epicyclic gearbox Built down to a price: the price reduced instead of going up each year
159	1	Four wheel drive Low and high range gearbox Designed to do everything and go anywhere From ploughing a field to climbing a mountain	1	Four wheel drive Low and high range gearbox Designed to do everything and go anywhere From ploughing a field to climbing a mountain
267	2	The others are a two-seater sports car and a people mover It's a different class of car	2	
348	8	Electric	3	
168	8	Electric A newer way of thinking about transportation	1	In a sense this was also a new way of thinking

				It allowed you to go to places that other things couldn’t get you to
249	2	A ground-breaking layout Fantastic packaging The best piece of work Issigonis did	2	
357	7	You got this idea of a cross between a car and a bus	3	Brought motoring to the masses

D Grid

1 Lancia Lambda 	2 Maserati A6G 2000 Zagato  (Interviewee)	3 Ford Model T 
4 Citroën DS19 	5 Mini 	6 Citroën Light 15 
7 Sizaire-Naudin 	8 Panhard Dyna Z  (Brian Shorey)	9 Tatra T87 

D Analysis

	No	Reason for difference	Significant	
123	2	Much more integrated than the others The form is more together	3	Because it put the world in cars
456	5	A very different size of car The focus was on making it small	5	It acted as an exemplar for so many other cars
789	7	It isn't integrated in its form It has no emphasis on streamlining at all	9	It's the model for the VW

147	4	Hydraulic systems have overtaken the mechanical in importance	1	A pioneer of independent suspension A pioneer of integral body shell
258	2	Designed as a racer and then prettied up to become a road car	5	It’s the exemplar for so many other cars
369	3	Designed to get the world on the road	3	Designed to get the world on the road
159	9	Different arrangements of just about everything	5	It’s more significant than the Lancia was
267	6	It’s designed as a family conveyance	6	In the history of cars the others don’t really figure. This one may not have been copied but it was admired even if it got it wrong
348	3	Different philosophy No attempt at integration Direction was production and not sophistication	3	It made far more impact on the world and was a more mainstream changer
168	8	A combination of reasons Air-cooled Transverse twin engine Emphasis on lightness Emphasis on streamlining	6	Introduced front wheel drive and demonstrated it was practical
249	2	Not designed for any real sort of production Designed just for effect	4	Designed for production much more Could act as an example. Perhaps admired more than copied
357	5	Architectural design Emphasis on space utilisation and integration	5	It has more of a following in terms of its design thinking and acting as a model for others

C Grid

1 Rolls-Royce Silver Ghost  (Courtesy RM Sotheby's)	2 Austin Seven 	3 Ford Model T 
4 Lanchester 	5 Mors 1898  (Mr and Mrs T Watson)	6 Delahaye 135 
7 Bentley Chinese Eye or similar 1950s or 1960s  (favcars.com)	8 Range Rover 	9 Jeep 

C Analysis

	No	Reason for difference	Significant	Reason
123	3	You couldn't drive it	1 3 2	Best of the British Most significant in terms of history Important in England only
456	6	I could go out in it. It's usable. I'd still love to have one.	4	Because it went on and on and the Mors didn't.
789	9	The others do everything very well.	8	Probably from the point of view of history

		The Jeep doesn't do anything very well. But I would take it to go round the world. The Jeep is repairable.		
147	4	Silver Ghost and a modern Bentley don't really compare. Its difference is in the controls. It's just different to drive.	1	It was an incredible car. It went through the war as a war vehicle.
258	5	You couldn't just get in and drive it. The other two you or I could get in and drive.	2	It's one of those cars which sort of put the world on wheels.
369	3	Because you couldn't just get in and drive it.	6	Just because we want it in the collection. It's the most beautiful.
159	5	It's probably much more difficult to drive. The Silver Ghost is difficult to drive well.	1	
267	2	Because it's little and cheap The other two are expensive and luxurious.	2	Most important historically
348	3	Not a luxury car Very different in its conception. It's like driving a lawn mower.	3	From a historical point of view
168	1	Difficult to answer this one. Different in conception - somehow.	1	
249	4	Because my interest is in driving	9	
357	3	Different in class Different to drive You wouldn't go out in a Model T for pleasure	3	

J Grid

1 Bugatti Atalante 	2 Jaguar E type 	3 Mini 
4 Ferrari 250 GT SWB  (favcars.com)	5 Alfa Romeo 1750 Monza Note that the Monza was a 2600 8C – not a 1750 	6 Mercedes 300SLR 
7 Chevron B16  (Wikimedia Commons – Mutari)	8 Aston Martin DBR1 300  (Wikimedia Commons: Brian Selsdon)	9 Maserati 250F 

J Analysis

	No	Reason for difference	Significant	Reason
123	3	A totally different design concept – novelty and space efficiency	3	A benchmark Novelty Impact on future design direction. Impact on designers

456	5	All similar concepts – high performance cars usable on the road and in competition. All iconic Alfa Romeo from an earlier era	4	Most beautiful car – Looks exactly like it what should be
789	9	All racing cars Open wheeler From an earlier era but not by much	9	Epitomises a wonderful era of motor sport / Grand Prix cars Towards the end of the front-engined oversteering cars
147	7 1	Can only be used on a racetrack Purely a road car – designed for its aesthetic appeal and not performance	4	Most favourite car of all time!
258	2	Predominantly a road car with greater market appeal	8	Personal association with Aston Martin Epitomised a wonderful style in that period
369	6	The only one to have won the Mille Miglia Only ne seen racing in period	3	
159	1	Most breath-taking execution of 1930s era Design concept about form and not function Others both had significant functional requirements in their concept.	9	Tough to judge! Epitomised a particular era Hesitated because it's true of the other two as well. (but the era is different for 9)
267	7	Much more of a specialist Less well-known Partly because it looks nice and partly personal	2	Most significant design statement.
348	3	Nothing to do with racing but an important design statement.	4	Wins over Mini because of its beauty
168	1	Form over function	1	Represents a different era
249	9	No pretence at anything other than a focused racing role	4	This one wins every time!
357	3	Most innovative design statement and a benchmark	7	Personal association. Would quite like it back!

L Grid

1 Porsche 911(1960s)  (favcars.com)	2 Trabant 601s 	3 Porsche 356 
4 Mini Cooper (original)  (Wikimedia Commons: Writegeist)	5 Land Rover Series 1 	6 Bentley 1920s 
7 Porsche 911 (1990s)  (Wikimedia Commons: Wistar Rinearson, Landmark Extra)	8 Citroën DS19 	9 Citroën 2CV  (Wikimedia Commons - Thomas Forsman)

L Analysis

	No	Reason for difference	Significant
123	2	It's the ultimate vehicle you make when you have nothing. Everything is constrained: material, labour, technology	1
456	6	The grand engineering	5
789	8	It's more likely to break down	9

147	4	The other two are Porsche and there's clear lineage between them.	4 It would beat the other two.
258	8	It's a designed, luxurious thing. It's inspired. It's a good design. It has an elegance.	5
369	3	It feels as if it's been sculpted. The other two feel as if they're kind of bolted together. The other two have been engineered	9
159	1	The others are kind of bolted together engineering, like Meccano. The Porsche is more refined.	5
267	2	Feels more different Low engineering: the others are high engineering	2
348	4	But they're all unconventional! It may be a scale thing - it's much smaller	4
168	6	It's that visible engineering	1
249	4	It's the one that had the most profound effect on cars.	4
357	5	It's a functional object. It's not a plaything almost	5

M Grid

1 1890s Peugeot V twin 	2 Mercedes 18/22 1903  (The Automobile)	3 Sunbeam 12/16 Sports 2-seater 1913  (Interviewee)
4 3-litre Bentley 1925  (favcars.com)	5 Invicta 4½ litre low chassis 	6 Corvette 1960 
7 Citroën SM 	8 Ferrari Dino 1960s 	9 NSU Ro80 

M Analysis

	No	Reason for difference	Significant	Reason
123	1	It's much more primitive	2	It's really the first modern motor car. The car itself and the associations.
456	6	Different mechanically. It's American in concept. American in styling	5	Because I've driven it. Ownership affiliations
			4	A particular car with a body by Surbico

				Very attractive aesthetically Was Louis Holland's
789	9	It has a rotary engine	7	Wonderful! Aesthetically attractive Technically very interesting Ultimate development of DS19
147	7	Front wheel drive	4	It's unique and very special
258	8	A body styled by an independent outfit. It's got shape. It's got elegance. It's quite small.	2	A lovely car to drive Its associations
369	9	The purity of the body shape. Very distinctive Aesthetically satisfying	9	Nobody else really developed a car as a rotary. It's also something about that shape in the 1960s
159	1	Engineering quality relative to the date in which it was made.	1	It represents the earliest practical motor cars.
267	6	Multi-cylinder engine	2	It's a key car in the development of the motor car
348	8	Engine in the rear – or at least behind the people	4	Unique and very special
168	6	Front engined	1	Represents the earliest practical motor cars.
249	4	Unique	2	The first modern motor car
357	3	Two-seater	7	Hydropneumatic suspension
	3	12/16s are rare anyway. A super example of a coachbuilt 12/16		

T Grid

1 Jaguar XJ6 	2 Jaguar XJR-S  (Clarkes XJS World)	3 Austin 7 
4 Austin 8  (Beds and Herts Vintage & Classic Car Club)	5 Range Rover 	6 Rolls-Royce Silver Shadow 
7 Bentley Turbo R  (Wikimedia Commons: Mr choppers)	8 Mini 	9 Land Rover 

T Analysis

	No	Reason for difference	Significant
123	3	So basic Cable brakes Doesn’t stop	2
456	4	Still basic motoring	4
789	8	Still a bit basic in spite of being much later	7
147	4	Basic motoring from that era	7

258	8	It’s a boneshaker	2
369	6	Too far advanced	3
159	1	Not an off-road vehicle It can’t do so much	5
267	7	So many extras for the year	2
348	8	It has a heater! More luxurious than the others	3
168	8	It’s basic	1
249	9	It’s a workhorse	2
357	3	Cable operated brakes Doesn’t stop Can’t be used on the road	7

S Grid

1 Maserati Boomerang  (favcars.com)	2 Ferrari Daytona Spyder  (favcars.com)	3 Lagonda  (Wikimedia Commons: Charles01)
4 BMW Gina  (Wikimedia Commons: ravas51)	5 de Tomaso Mangusta  (Wikimedia Commons: Gonzalo de Velasco)	6 Lotus Esprit 
7 BMW i8 concept  (Wikimedia Commons: WikiABG)	8 Lamborghini Countach  (Wikimedia Commons: Karrmann)	9 Ferrari Dino 

S Analysis

	No	Reason for difference	Significant
123	3	It has four doors	2
456	4	It has a fabric skin	5
789	7	It is a hybrid	8

147	1	It has gull-wing doors	7
258	2	It is a cabriolet	5
369	3	It is not mid-engined	9
159	1	Origami design	5
267	6	Plastic bodied	7
348	8	It has a rear spoiler	4
168	1	The doors are glass	8
249	4	It has a split windshield	4
357	7	No side view mirrors	7

N Grid

1 Ford Model T 	2 1950s Cadillac 	3 VW Beetle 
4 2CV  (Wikimedia Commons - Thomas Forsman)	5 Mini  (John Baker)	6 Golf 
7 Ford Ka  (Autocar)	8 New Mini  (Autocar)	9 Audi TT  (Wikimedia Commons: OSX)

N Analysis

	No	Reason for difference	Significant
123	2	It embodies a design philosophy of exuberant styling at the expense of function	1
456	4	It was designed for an unusual collection of purposes - and as a consequence looked different from anything before or since.	6
789	8	Because it used the visual language of an engineering package-based design and converted it to attractive styling: the Ford Ka and the Audi TT were both original in both packaging and styling.	8

147	1	It's such an old primitive thing. It is designed for an assembly line but hardly production engineered. There's a combination of assembly line and blacksmith technology.	1
258	2	It's a chrome cathedral on wheels: a bit like and ice-cream van.	5
369	3	It's a manifestation of heroic, pioneering but still relatively primitive technology	6 against 3
159	1	It's such a primitive thing and outdistances all the others in the way it's different	1
267	2	A chrome cathedral on wheels	6
348	8	It was a very successful market-oriented piece of styling. The other two are engineering plus.	3
168	8	Because it was conceived in the context where marketing and styling could take over - the quality of the technology was a given.	1 but 6 is also very important.
249	4	In its conception, the appearance hardly matters. Getting a consistent design is important but it comes from other factors.	4
357	3	The others are manifestations of a philosophy partly created by the Beetle but are latter-day versions. The vocabulary is of its time, but more mature.	3 wins - just.

O Grid

1 Lotus Carlton  (favcars.com)	2 Mustang Boss 302 Mach 1 (about 1967)  (Wikimedia Commons: Bill Doser)	3 Lotus Cortina Mk 1  (Wikimedia Commons: Sicnag)
4 Ford Corsair 2000E  (Wikimedia Commons: Charles 01)	5 Ford RS 200 (Cosworth Rally car ~ 1986)  (Wikimedia Commons: Morven)	6 Ford Capri Tickford Turbo  (H& H Classics)
7 Ford GT40 	8 Ford Sierra Cosworth RS 500  (Wikimedia Commons: Rocknrollmancer)	9 Renault Clio Trophy  (Autocar)

References

TUMMINELLI, P. 2004. *Car Design,* Düsselsorf, teNeues.

A4 Detailed description of database information

A4 Detailed description of database information

The intention for the project was that it should not become a software development project. Thus all software used is proprietary software. It may not be used as economically or as effectively as it might be, but the only other option would have been to develop software especially for the project, which would have detracted significantly from the main thrust of the project into what would have been a development of little use outside the project itself.

The data for the project has been stored on two linked FileMaker Pro databases. One is for the cars in the sample – called the ‘Cars’ database – and the other is a more general database containing details of car pictures, rather predictably called the ‘Car Pictures’ database. This second database allows pictures to be identified and a record kept of their source and also enables correct attribution to be added to each picture used in any publication.

The ‘Cars’ database holds all the data on the individual cars (perhaps technically termed participants). It holds formulae to convert descriptive variables into numerical categorised variables and further calculated variables as appropriate for the numerical analyses and is able to hold more ephemeral information on each car. It can select cars on any parameter and is able to sort and arrange the data on any particular data item or sets of data items. The data from the FileMaker Pro database is transferred via Excel into an SPSS input file that enables it to be used in the SPSS analysis. Calculated data from the analysis are able to be transferred back to the FileMaker Pro database.

This is a somewhat cumbersome procedure but avoid the need to develop specific software.

A4.1 Car pictures database

Each record in this database is allotted a unique Reference that is created when the record is created. It may be linked to a record in the Cars database by a Car Reference number. There may be more than one picture for any specific Car in the database.

Field names for the Car picture database are shown in Table A4.1

Field Name	Type	Options and Comments
Reference	Number	Auto-enter Serial, Numeric Only, Allow Override
Vehicle Type	Text	Identifies whether the picture is of a car or what else. There is a selection of other vehicle types included in the pictures for convenience.
Manufacturer	Text	
Model	Text	
Type	Text	This tends to be used for a body style or coachbuilder.
Year (of manufacture)	Number	
Ref No	Calculation	A random integer number used for some sequencing
Description	Text	Allowing space for some sort of description of the picture
Picture	Container	This is a reference to the picture which is a file stored – it shows as the picture itself when the records are viewed. All records are stored in the Car Pictures folder which is a sub-folder of the Car Research folder which holds both databases.
Picture Quality	Number	To identify good and poor quality pictures
Picture?	Text	Used originally to identify the type of source. Subsequently all pictures were brought into one folder as digital files. A file

		of photographs still exists but they haven't been scanned as yet.
Car Reference	Number	This refers to the reference number in the Cars database
Picture Title	Text	
Period	Calculation	= Int (Year/5) -374 Allows car pictures to be allotted to a five-year period. Period 1 is from 1875 – 1879.
Cutting Ref	Text	
Max Cutting	Summary	=Maximum of Cutting No
Cutting No	Calculation	Right (Cutting Ref: Length (Cutting Ref – 1))
Picture Source	Text	
Picture Location	Text	
Car Reference max	Summary	= Maximum of Car Reference This is used when working out what value needs to be put on the next value for Car Reference (which cannot be automatic)
Filename	Text	The picture filename (held in the Car Pictures Folder)

Table A4.1 Field names in Car Pictures database

A number of Value lists were also defined within the database. Table A4.2 lists these and their values. The Picture Source and the Picture Location are editable for individual pictures, allowing for other values to be input for maximum flexibility whilst still being able to input common values for the data.

Value List Name	Values
Slide List	"", "Y"
Picture Quality List	"1", "2", "3", "4", "5"
Picture? List	"Slide", "JPEG", "Cutting", "Compilation", "GIF", "TIFF"
Vehicle Type	Car, Van, Truck, {Pick up, Van with Windows, Motor Caravan, 4x4, Cyclecar, Amphibious Vehicle, Taxi, Steam Cart, Gas Cart, Bus, Motorcycle, Tricycle, Half Track, Fire Truck, Pedal Car, Miniature, Model, Engine, Transmission, Axle / Suspension, Chassis, Body Shell, Mascot, Detail, Component, Vies, Multiple

	Vehicles, Compilation, Pastiche, Sculpture, Drawing, Photograph, Railcar, Text, Motoring Infrastructure
Car Record	Yes, No – Duplicate, No – General View, No – Model, No - engine only, You cannot be serious
Source	Autocar, Autocar Beautiful Cars, Autocar Road Test, Autocar website, Book, Car Blueprints.info/, Carfolio.com, Car of the year, The Automobile (Car of the Century), Chris Dowlen, Classic & Sports Car, Company website, Deborah Andrews, Motor Industry Heritage Trust, Motorbase.com, National Motor Museum, Octane car specs, Telegraph Beautiful Cars, Telegraph website, The Automobile, Unknown website, VCC, Wikimedia Commons With the ability to add and edit
Location	Autoworld, Brussels, Bentley Motor Museum, Sussex, Blackhawk Motor Museum, Booth Museum, Rolvenden, Brooklands Motor Museum, Cotswold Motor Museum Bourton on the Water, Coventry Transport Museum, Egeskov Slot, Denmark, Gaydon Motor Museum, Glasgow Transport Museum, Great Dorset Steam Fair, Holker Hall Museum, La Reole, France, London to Brighton Run, Louis Vuitton Concours, Louwman Museum, Luzern Verkehsverein, Mercedes-Benz Museum Stuttgart, Mobilia Kangasala Finland, National Motor Museum Beaulieu, Paris, Porsche Stuttgart, Prague Technical Museum, Redhill Steam Rally, Regent Street, Retromobile Paris, Schlumpf Collection Mulhouse, Science Museum London, Science Museum Wroughton, Streatham, Technical Museum Munich, Technical Museum Vienna, Udaipur India, Vehoniemen Museum Finland With the ability to add and edit

Table A4.2 Value lists in the Car Pictures database

The database links with the Cars database as an external FileMaker Pro file.

Several layouts have been developed on a pragmatic basis. Figure A4.1 shows the most useful one which contains most of the information.

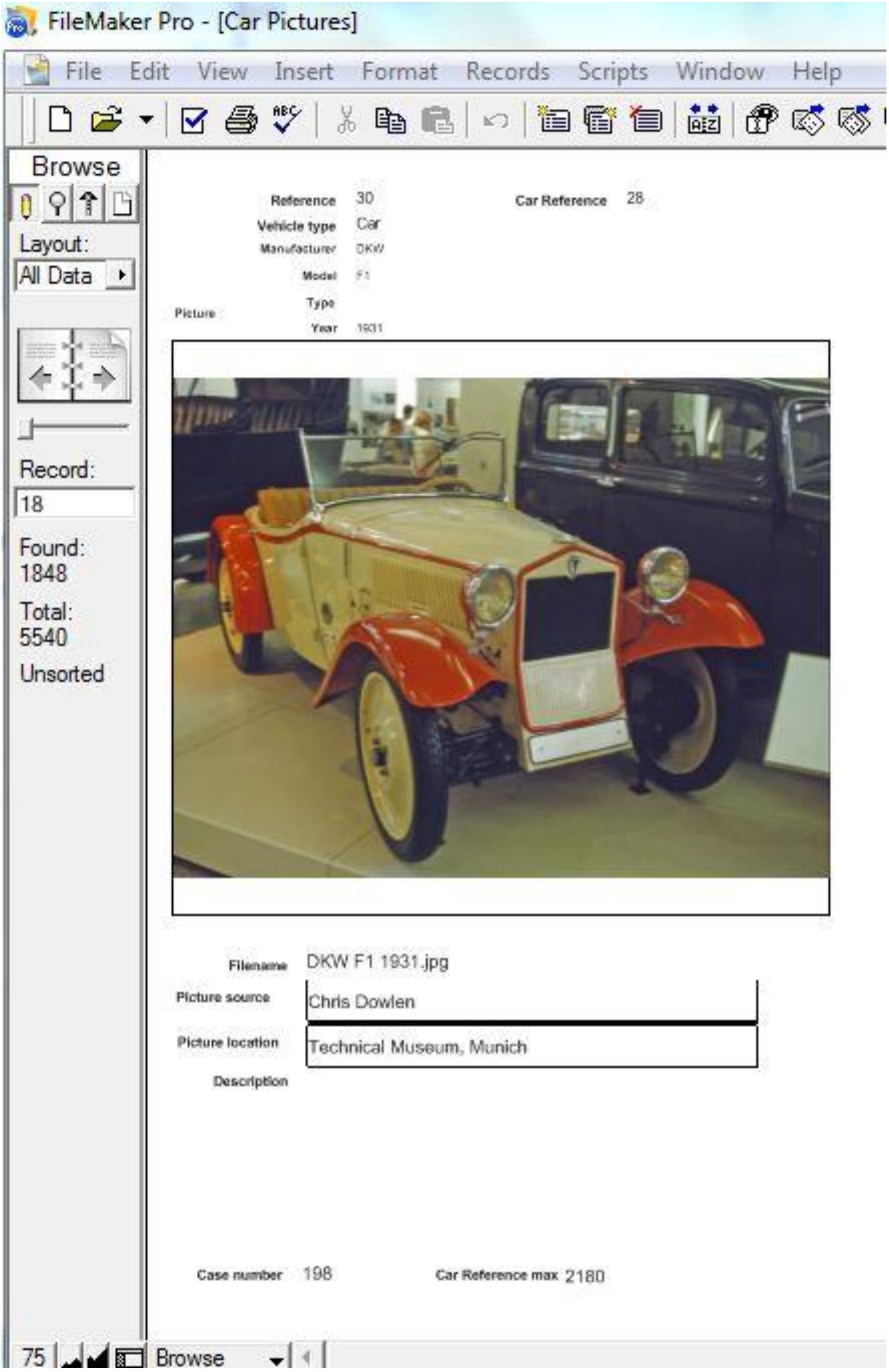


Figure A4.1 Car Pictures Database – picture layout

A list layout has also been developed that simply provides a list of the Reference, Manufacture, Model and Type with a thumbnail picture, and a layout that simply gives the picture on a black background with the manufacturer, title and date. This last is designed to work with a script that scrolls the pictures through as a slide show.

A4.2 Cars Database

This is linked to the car pictures database and is the main database that contains the data for the numerical analyses. In contrast to the Car Pictures database, this database contains a large number of fields for the different analysis purposes. Table A4.3 contains a list of the administrative fields for the database.

Field Name	Type	Options / Comments
Car Reference	Number	Unique, Numeric only
Manufacturer	Text	
Model	Text	
Type	Text	
Year	Number	
Ref No	Calculation	=Round (Random * 100; 1) Used to create a random number for each car
Country of Origin	Text	Value list
Year Confirmed	Text	Used to put a marker on when needed
Analysis	Text	Value List Used to identify which sample sets the car belongs to
Analysis number	Calculation	= Length (Analysis) Used to create a number for the combination of analysis sets that the car belongs to

Table A4.3 Administrative Field names

The car reference is not entered automatically. It is the same as the number in the Car Pictures database. There may be more than one picture of the car. While the cars are being entered onto the database there may be no pictures of the car, and the car reference is left blank until a picture or pictures are identified and then provided with a unique reference that is then applied to each of the relevant pictures.

The random number is used simply to produce a listing in a random order based on the allotted random number. It has no relevance for the analysis.

The value list of countries is used to identify local trends and paradigms of a local nature. The infrastructure conditions are different in different countries and this has, from time to time, led to different designs being developed specifically for those conditions. The country list, in alphabetical order is: Australia, Austria, Belgium, Britain, Czechoslovakia, Czech Republic, France, Germany, Holland, Italy, Japan,

Korea, Romania, Russia, Spain, Sweden, Switzerland, Turkey, USA. There is also a ‘Don’t know’ category. This is used in two circumstances. Firstly, it has the genuine meaning of being unsure of where the particular car was designed and built, and secondly it is used for cars where the design and manufacture may be carried out in several countries in such a way that one is unsure of which particular country an individual car is designed in. The country of origin may be defined more by the country of origin of the company rather than the actual country of manufacture, which makes for a certain amount of complexity. For instance, Nissan is deemed to be a Japanese company even though the later Nissan cars have been designed and manufactured in Britain. Audi and Volkswagen are generally identified as being of German origin, but conversely Škoda is Czech and both Rolls-Royce and Bentley are deemed to be British. However, some Fords are seen to be British, German or French despite the company being of American origin. Since the mid-1970s the origins of Ford and General Motors’ European offerings has been harder to identify and these have tended to have a ‘Don’t know’ origin applied to them. Opel and Vauxhall models have generally been almost identical from that time onwards – in the case of the models sold in the UK and thus on the UK best-sellers lists, these are the Vauxhall branded ones and not the Opel brand.

This is not an exhaustive list of countries that have manufactured cars over the years. The Car Pictures database does not contain this field, but does contain cars with other origins.

The text for the Analysis was used to set up groups of analyses. More than one can be selected, and several have found their way into the database despite only two analyses being carried out. The samples analysed only contain the original set plus the UK best sellers. However, the database contains several other sets. They are known by the code names shown in Table A4.4. A number was used to identify the various combinations of different analysis lists – created from the length of the title, but it doesn't always result in a unique number for various of the more complex combinations where cars find themselves in several sample lists.

Value	Meaning
453	The original sample set which included a few spurious entries such as bare chassis and a pedal car. It contained 453 samples, hence the name.
453 minus	The modified original sample set that removed the spurious entries. This set contains 434 samples.
UK Best seller top 10	This is the list of UK best selling cars from the 1965 best-selling table onwards. There are 157 cars in this lists.
Car of the Year	A list of cars that have been in the Car of the Year lists since they commenced in 1963. There are 259 cars in this list.
Car of the Century	The collection of cars identified by the journalist group tasked with locating the most influential cars of the 20th Century. The list contains 100 cars.
Paolo Tumminelli	This is a list from his 2004 book. He identifies 309 cars in this list, although he says that he has analysed a much larger number.
Telegraph 100 beautiful cars	The list published in the Telegraph in 2008.
Autocar 100 beautiful cars	A similar list published by the Autocar magazine in 2002.

Table A4.4 The list of analyses

Layout input data are shown in Table A4.5. These data were transformed into variable names that SPSS recognises and the values transformed into categorical variables using calculations built into the database. The categorical values are described in appendix A1. Some of them have default values as well as an associated value list. The value list is able to override the default value when this is necessary.

Field Name	Type	Options / Comments	SPSS name
Engine Position	Text	Value List	nengpos
Engine Drive Shaft Orientation	Text	Value List	nendror
Driven Wheels	Text	Value List	ndrwhe
Cylinders	Text	Value List	ncylno
Cylinder Arrangement	Text	Value List	ncylarr
Front Suspension Form	Text	Value List	nfsfor
Front Suspension Medium	Text	Value List	nfsmed
Rear Suspension Form	Text	Value List	nrsusfor
Rear Suspension Medium	Text	Value List	nrsusmed
Structure Type	Text	Value List	nstructy
Body Construction	Text	Value List	nbodytyp
Engine Type	Text	Auto-enter Data – default value Reciprocating, Petrol	nengtyp
No of Wheels	Text	Auto-enter Data – default value 4	nwheels
Wheel Orientation	Text	Auto-enter Data – default value 2F2R	nwheor
Wheel Sizes	Text	Auto-enter Data – default value Same	nwhesz
Steering Control	Text	Auto-enter Data – default value Wheel	nsteerco
Final Drive	Text	Auto-enter Data – default value Shaft	nfindri
Driver Position	Text	Auto-enter Data – default value Front, Side	ndrpos
Tyre Type	Text	Auto-enter Data – default value Pneumatic	ntyrtyp

Table A4.5 Layout Data Field names

The variables that SPSS uses for the layout analyses are calculated automatically from the layout input variables.

Variable	Calculation
nengpos	Case (Engine Position = "don't know"; ""; Engine Position = "No engine"; "0"; Engine Position = "Front"; 1; Engine Position = "Mid-rear"; 3; Engine Position = "Mid"; 2; Engine Position = "Rear"; 4;"")
nendror	Case (Engine drive shaft Orientation = "Don't know"; ""; Engine drive shaft Orientation = "no engine"; 0; Engine drive shaft Orientation = "Longitudinal"; 1; Engine drive shaft Orientation = "Transverse"; 2; Engine drive shaft Orientation = "Vertical"; 3; "")
ndrwhe	If (Driven Wheels = "Four"; 3; If (Driven Wheels = "Front"; 1; If (Driven Wheels = "Propeller"; 4; If (Driven Wheels = "Rear"; 2; If (Driven Wheels = "rear plus screw"; 5; "")))))
ncylno	If (Cylinders = "1 rotor"; 11; If (Cylinders = "2 rotor"; 12; If (Cylinders = "3 rotor"; 13; If (Cylinders = "6?"; 6; If (Cylinders = "8?"; 8; If (Cylinders = "Don't know"; ""; If (Cylinders = 8; 8; If (Cylinders = 12; 9; If (Cylinders = 16; 10; Cylinders + 1)))))))))
ncyllarr	If (Cylinder Arrangement = "No cylinders"; 0; If (Cylinder Arrangement = "Single Cylinder"; 1; If (Cylinder Arrangement = "In Line"; 2; If (Cylinder Arrangement = "Vee"; 3; If (Cylinder Arrangement = "Horizontally Opposed"; 4; If (Cylinder Arrangement = "Square"; 5; If (Cylinder Arrangement = "W"; 6; "")))))))

Table A4.6 Examples of calculations for five layout variables

Examples of the calculations used to calculate five of the layout variables are shown in Table A4.6. The other calculations used are similar in character to these.

Figure A4.2 shows the layout input screen from the database.

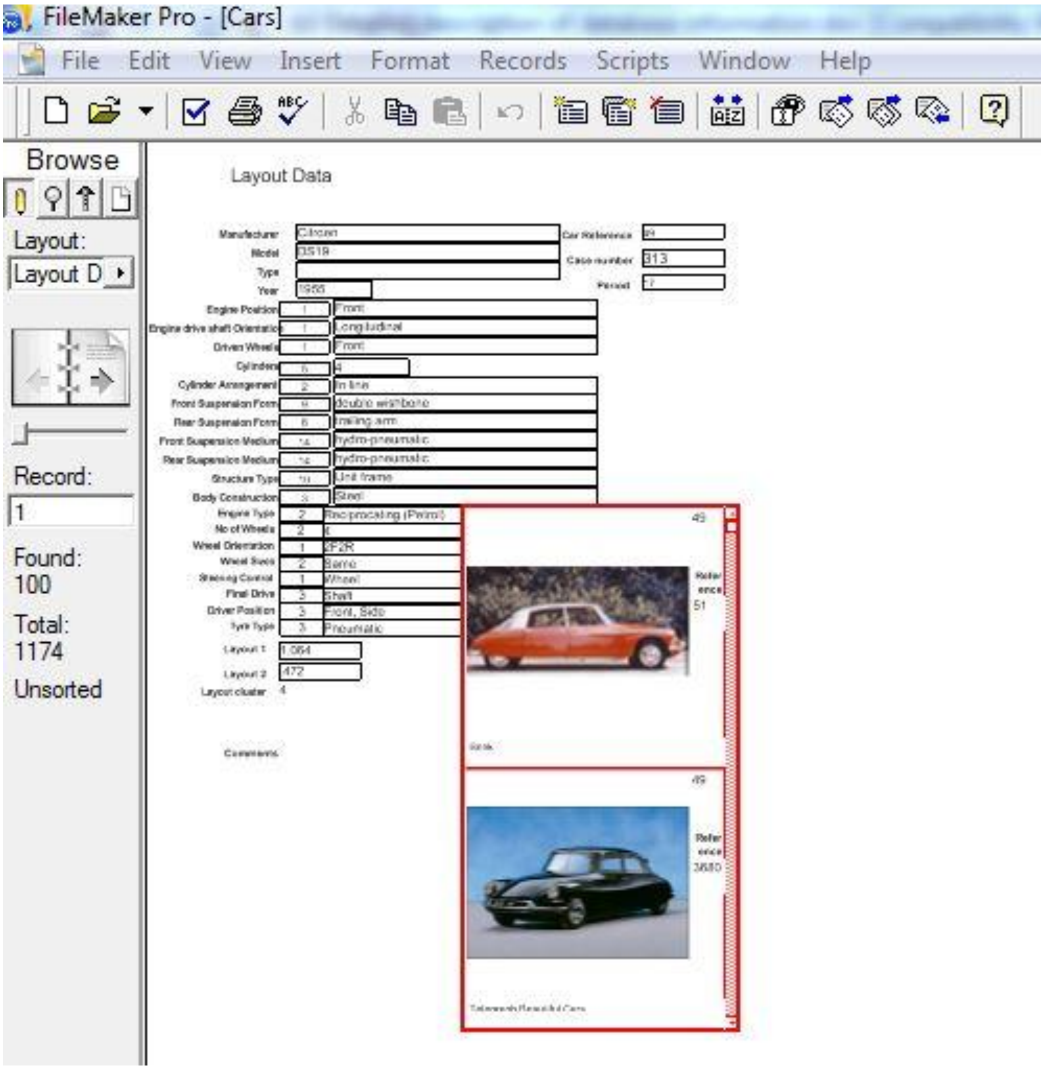


Figure A4.2 Layout input screen from the database

Following a layout analysis, the two layout variables can be returned to the database as the variables Layout 1 and Layout 2.

The variables input for the Form analyses are shown in Table A4.7. These particular variables are all categorical text ones and are transferred to categorical numerical ones for the SPSS analyses. This shows the complete list rather than the later shorter list. For using the short form of the form analysis the variables that are not used are simply not output to SPSS and thus do not form part of the analysis.

A significant number of these variables are taken as being categorical ones although they are real numbers. The real numbers are used also and calculations are used to identify the category for each. Rather than automatically calculate the variables that SPSS uses these figures are compared and the category chosen manually. This allows for the cars where the dimension values have not been measured where these are not able to be input as real numbers.

Variable	Type	Options / Comments	SPSS Name
Length	Text	By Value List	nlength
Width	Text	By Value List	nwidth
Height	Text	By Value List	nheight
Headlight Shape	Text	By Value List	nhltype
Headlight Number	Number	By Value List	nhno plus
Headlight Position	Text	By Value List	nhlposn
Grille Shape	Text	By Value List	ngrillef
Bonnet Plan	Text	By Value List	nbonplan
Bonnet Profile	Text	By Value List	nbonprof
Bonnet Length	Text	By Value List	nbonleng
Front Wing Shape	Text	By Value List	nfwings
Front Bumper Type	Text	By Value List	nfbumper
Screen Type	Text	By Value List	nscretyp
Screen Rake	Text	By Value List	nscrerak
Side Doors	Text	By Value List	ndoor
Seat Rows	Number	By Value List	nseatr
Roof Type	Text	By Value List	nrootyp
B Post	Text	By Value List	nbpost
Wheel Type	Text	By Value List	nwhetyp
C Post	Text	By Value List	ncpost
Front Overhang Length	Text	By Value List	nfohang
Rear overhang Length	Text	By Value List	nrohang
Edge Roundedness	Text	By Value List	nedroun
Panel Roundedness	Text	By Value List	npanroun
Roof Roundedness	Text	By Value List	nroorou
Running Board	Text	By Value List	nrunbrd

Side Window Base Height	Text	By Value List	nwinheig
Side Window Form	Text	By Value List	nwinfrm
Rear Wing Shape	Text	By Value List	nrwings
D Post	Text	By Value List	ndpost
Wheel Width	Text	By Value List	nwheid
Front of Cockpit position	Text	By Value List	nfcockpi
Rear window type	Text	By Value List	nrwintyp
Rear window rake	Text	By Value List	nrwinrak
Rear window curvature	Text	By Value List	nrwinrou
Boot length	Text	By Value List	nbootlen
Rear of cockpit position	Text	By Value List	nrcockpi
Boot slope	Text	By Value List	nbootslo
Rear bumper type	Text	By Value List	nrbumper
Rear light number	Number	By Value List	nrlighno
Rear light shape	Text	By Value List	nrlighsh
Rear light position	Text	By Value List	nrlighpo
Rear number plate shape	Text	By Value List	nrnoplsh
Rear roundedness	Text	By Value List	nrround
Front roundedness	Text	By Value List	nfround
Rear form	Text	By Value List	nrform
Body width form	Text	By Value List	nbodywid

Table A4.7 Form variables

A set of calculations similar to those used for the layout analysis is inbuilt into the database to produce the form numerical values for analysis by SPSS.

Figure A4.3 shows the screen used to input the data for the smaller (later) form analysis.

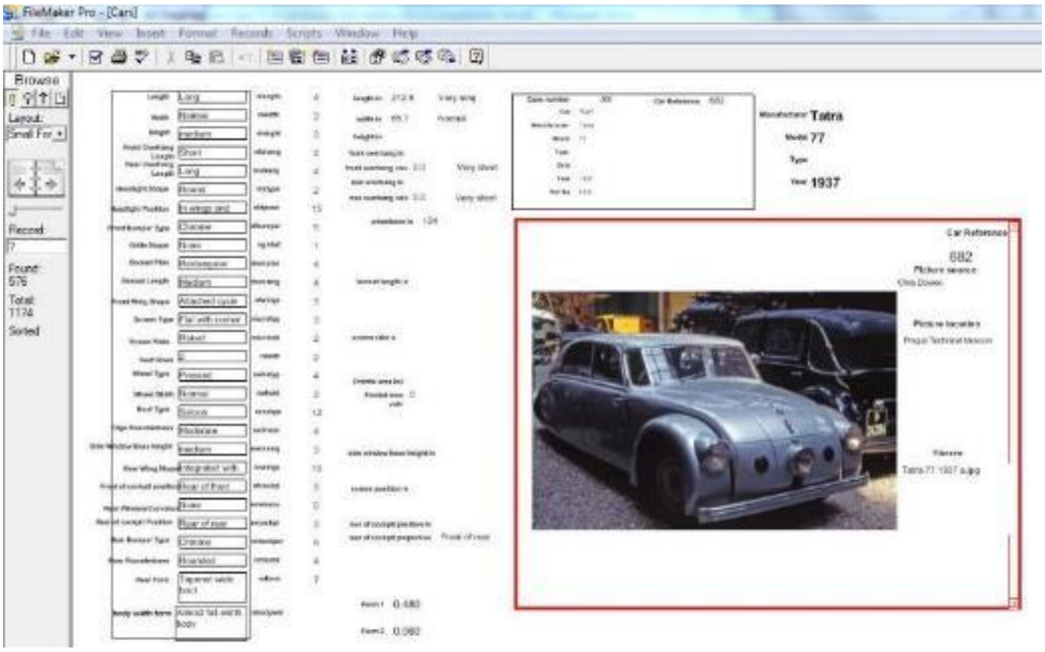


Figure A4.3 Screen layout for inputting the form data for the later form analysis with the smaller number of variables

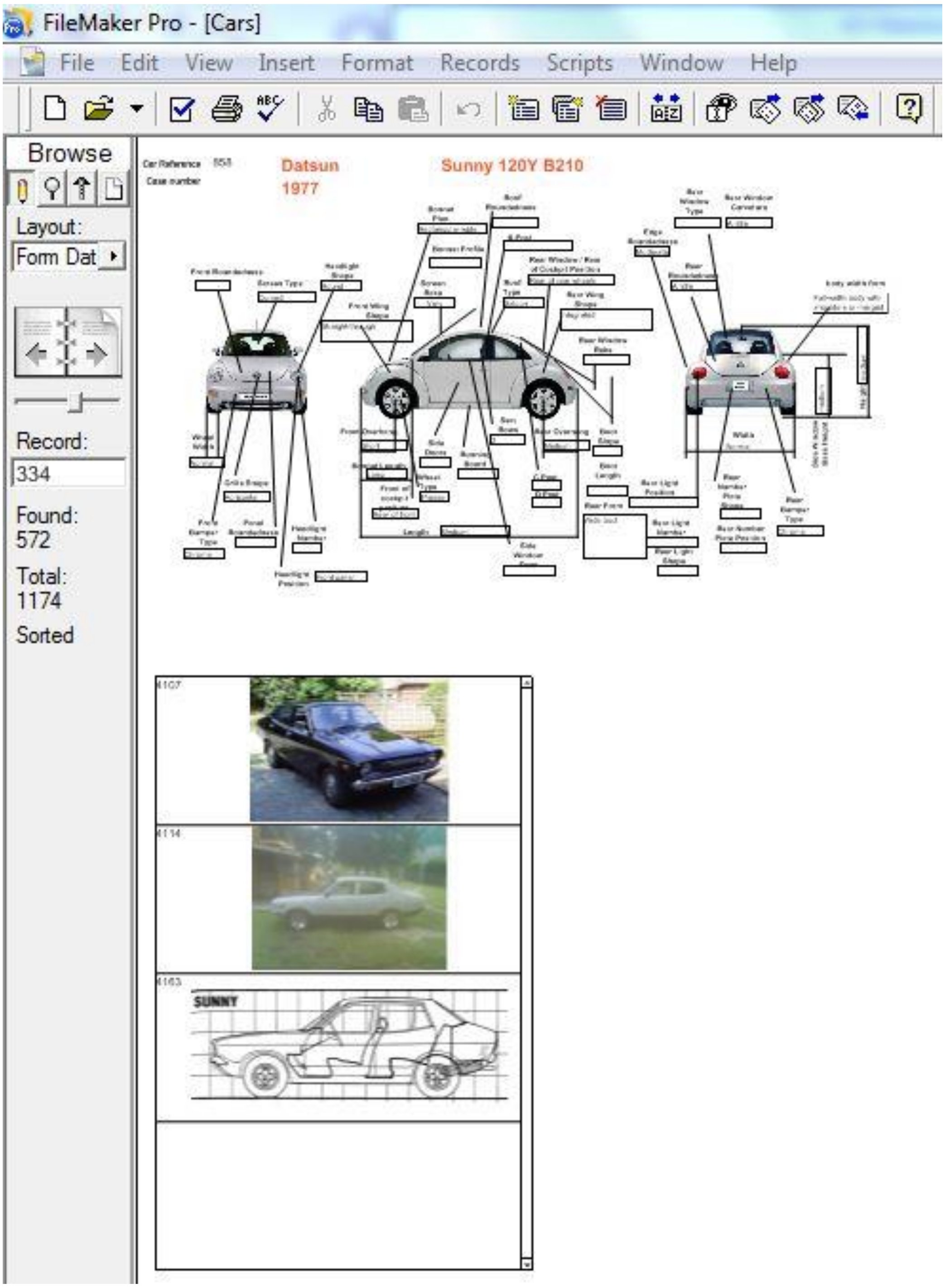


Figure A4.4 Screen layout used for inputting the form data for the original form analysis. Note the blank fields: this particular car (Datsun Sunny 120Y, 1977) is part of the 'UK Best Sellers' sample

Figure A4.4 shows the input screen for the earlier, larger Form analysis. The database allows for up to three Form dimension results to be read back in as the real numbers Form 1, Form 2 and Form 3.

The database holds several items of real number data for each car. Some of these are the non-categorised form dimensions: others are published data that have been used for other analyses. They are listed in Table A4.8.

Variable	Meaning	Units used
Engine cc	Swept engine capacity. This is not in SI units but these are the ones commonly used.	cc
Bore mm	Engine bore	mm
Stroke mm	Engine stroke	mm
Power bhp	Maximum engine power (given in published data)	bhp
Power revs	Engine speed for the maximum power (given in published data)	rpm
Torque lbf	Maximum engine torque (given in published data)	lbf
Torque revs	Engine speed for the maximum torque	rpm
Length in	Overall length (given in published data)	inches
Width in	Overall width (given in published data)	inches
Height in	Overall height (usually given in published data)	inches
Wheelbase in	Wheelbase (given in published data)	inches
Front overhang in	Front overhang (measured from side elevation)	inches
Rear overhang in	Rear overhang (measured from side elevation)	inches
Bonnet length in	Bonnet length (measured from side elevation)	inches
Screen rake o	Screen rake. Measured from side elevation on centreline of car.	degrees
Side window base height in	Approximate mean side window height	inches
Screen position in	Distance from the centre of the front axle to the position of the front of the windscreen	inches
Rear of cockpit position in	Distance from the centre of the front axle to the rear of the glasshouse part of the car	inches

Weight kg	Unladen mass of the car (not really weight)	Kg
Max speed mph	As given in published data. This could have been in m/s or in Km/Hr, but the mph figure relates to UK practice	mph
0-? sec	A time from 0 to the speed for 0-? (given in published data)	seconds
Acceleration s	A speed in mph used for the published acceleration figure	mph
Cd	Non-dimensional constant given in published data (sometimes)	
Frontal area in2	Either from published information or calculated and copied into the data item. Other units could have been used	in^2

Table A4.8 Real number data

The database also calculates a number of parameters for each car. There are various reasons why these values are calculated. The first two calculation values are used to obtain some semblance of the correct overhang values – these can be slightly different from reality when they are measured from a side elevation and the attempt is to get the figures to be as close as they can be to the reality, even if they are discretised as well.

The acceleration figures given in published data are to a number of different speeds. In the UK this had been 60mph for quite a long time, but cars which may not be capable of 60 mph may have a figure quoted from zero to 50mph instead. Those cars that are not even capable of a 50 mph maximum do not have a quoted figure. To give some idea of the acceleration in real, SI acceleration units (m/s2) the average acceleration over the quoted time is calculated. Of course this will only relate to one position on the acceleration curve.

The next calculations are to discretise and categorise the measured figures. This is needed because a significant number of cars do not have pictures of the side elevation and hence the categories are approximated for them. A manual process is required to input the calculated data into the data fields that are used for the form analysis.

Frontal area is calculated to give some approximate idea of the figure that would need to be used to calculate the car's drag from the Cd figure, or to calculate the Cd figure if that is missing. The figure was not actually used in any calculations, but could be.

The calculation for the period is to identify a five-year period for each car. This is simply a convenience for the analysis as this provides a reasonable (but not always sufficient) number of samples for a time period. Five years seems an effective compromise for the numbers of cars in the sample and enables effective analysis to take place. Each five-year period arbitrarily starts with either a year starting in a zero or in a five. The first period is from 1875 to 1879 and contains one car. The second period, from 1880 to 1884 does not contain any. This is not because none were made, but because there are none in the sample – there were few made in that period in any case.

The last calculated variable is an augmented one to obtain a single set of information on each car combined with a description of particular aspects (when simply described). This is simply a concatenated variable.

Variable	Formula
Front overhang calc	front overhang in / (front overhang in + rear overhang in) * (length in - wheelbase in)
Rear overhang calc	rear overhang in / (front overhang in + rear overhang in) * (length in - wheelbase in)
Acceleration m/s2	acceleration s / ${0-? sec} * .446944444
Length calc	If (length in ≤ 120; "Very short"; If (length in ≤ 150; "Short"; If (length in ≤ 180; "Medium"; If (length in ≤ 210; "Long"; "Very long")))
Width calc	If (width in ≤ 60; "Narrow"; If (width in ≤ 70; "Normal"; "Wide"))
Height calc	If (height in ≤ 45; "Very low"; If (height in ≤ 50; "Low"; If (height in ≤ 60; "Medium"; If (height in ≤ 70; "High"; "Very High"))))
Front overhang calc	If (front overhang calc ≤ 20;"Very short"; If (front overhang calc ≤ 30; "Short"; If (front overhang calc ≤

	40; "Medium"; If (front overhang calc ≤ 50; "Long"; "Very Long"))))
Rear overhang calc	If (rear overhang calc ≤ 20; "Very short"; If (rear overhang calc ≤ 30; "Short"; If (rear overhang calc ≤ 40; "Medium"; If (rear overhang calc ≤ 50; "Long"; "Very long"))))
Bonnet length calc	If (bonnet length in ≤ 20; "Very short"; If (bonnet length in ≤ 30; "Short"; If (bonnet length in ≤ 40; "Medium"; If (bonnet length in ≤ 50; "Long"; "Very long"))))
Side window base height calc	If (side window base height in ≤ 20;"Very low"; If (side window base height in ≤ 30; "Low"; If (side window base height in ≤ 40; "Medium"; If (side window base height in ≤ 50; "High"; "Very High"))))
Screen rake calc	If (screen rake o < 45; "Very Raked"; If (screen rake o ≤ 75; "Raked"; If (screen rake o ≤ 110; "Upright"; If (screen rake o > 110; "Reverse"; "None"))))
Screen position calc	If (screen position in ≤ -10; "Forward Control"; If (screen position in ≤ 10; "front wheel centreline"; If (screen position in ≤ 20; "Rear of front wheels"; If (screen position in ≤ 30; "Medium"; "Rearwards"))))
Rear of cockpit proportion	If (rear of cockpit position in > wheelbase in + 10; "Rear of rear wheels"; If (rear of cockpit position in > wheelbase in - 10;"In line with rear wheels"; "Front of rear wheels"))
Frontal area calc	width in * height in / 1.2
Period	Int (Year/5) – 374
Interview data	"Origins of the Design " & Origins of the design & " Exterior Form " & Exterior form & " The mechanics "& The mechanics & " Manufacture and structure "& ${Manufacture and structure} & " Accessories "& Accessories & " Reference Material "& Reference material & " Description " & Description

Table A4.9 Calculated values

Other data are held in the database for convenience – these data fields can be added to as and when required so the lists is a little fluid in character.

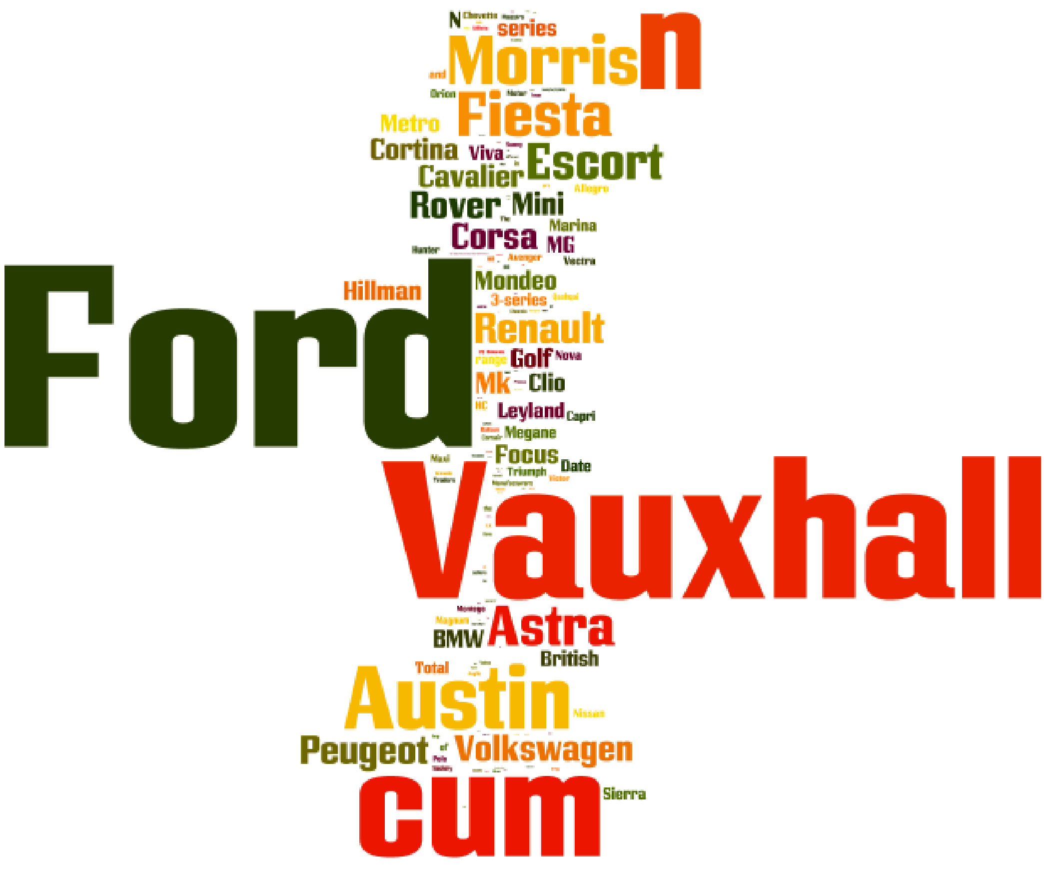
The Design year is held because this is unlikely to be the year that the car was manufactured. Some cars (such as the Volkswagen Beetle and the Ford Model T) were in production for a long time. But they will have changed during that time, so this date is not necessarily an indication of the totality of the car’s design which probably underwent facelifts during its manufacturing life. Where cars changed significantly (eg different Marks of the Volkswagen Golf). The Era variable is used to cluster several of the periods together to create a larger range of years that is known as an ‘Era’.

Variable	Type	Reason
Design year	Number	Unlikely to be the year that the car was manufactured
Era	Calculation	Choose (Period; 0; 1; 1;1;1;1;1;2;2;2;3;3;4;4;5;5;5;5;6;6;6;7;7;7;7)
Date	Date	An arbitrary date
Car	Text	Identifies whether the vehicle is a car or something else (eg a cyclecar or tricycle)
Case number	Number	A number brought in from the SPSS analysis to identify the individual car in the analysis
Predicted layout group	Number	A prediction variable that was calculated by SPSS and input.
Predicted layout era	Number	A prediction variable that was calculated by SPSS and input.
Predicted form group	Number	A prediction variable that was calculated by SPSS and input.
Predicted form era	Number	A prediction variable that was calculated by SPSS and input.
Description	Text	Descriptive data
Comments	Text	Descriptive data
Origins of the design	Text	Descriptive data
Exterior Form	Text	Descriptive data
The mechanics	Text	Descriptive data
Manufacture and structure	Text	Descriptive data
Accessories	Text	Descriptive data
Reference material	Text	Identifies a list of references that contain the descriptive (and other) data.
Layout cluster	Number	Data from an SPSS layout clustering process

Table A4.10 Other data held in the database

The descriptive data are used simply to provide for descriptive information to be input. They are concatenated to form the calculated variable called 'Interview data' – the idea of this was that each car would be 'interviewed' and would provide its own qualitative data for later use and analysis.

A5 UK best sellers



A5 UK best sellers

The spreadsheet of UK Best sellers from 1965 is shown in the tables. The data are from the SMMT (Society of Motor Manufacturers and Traders, 1926 - 2007) and for later dates, from their website (Society of Motor Manufacturers and Traders, 2015).

The cars listed in red in the table are substantial new models and therefore count as being different entries in the Cars database and therefore as different samples. Note that this includes significant facelifts as well as models that are totally new.

Date	2014	2013	2012	2011	2010
Total	2476435	2264737	2044609	1941253	2030846
1	Ford	Ford	Ford	Ford	Ford
	Fiesta	Fiesta	Fiesta	Fiesta	Fiesta
n	131254	121929	109265	96112	103013
%	5.30%	5.38%	5.34%	4.95%	5.07%
2	Ford	Ford	Vauxhall	Ford	Vauxhall
	Focus	Focus	Corsa	Focus	Astra
n	85140	87350	89434	81832	80646
%	3.44%	3.86%	4.37%	4.22%	3.97%
cum %	8.74%	9.24%	9.72%	9.17%	9.04%
3	Vauxhall	Vauxhall	Ford	Vauxhall	Ford
	Corsa	Corsa	Focus	Corsa	Focus
n	81783	84275	83115	77751	77804
%	3.30%	3.72%	4.07%	4.01%	3.83%
cum %	12.04%	12.96%	13.78%	13.17%	12.87%
4	Volkswagen	Vauxhall	Vauxhall	Volkswagen	Vauxhall
	Golf	Astra	Astra	Golf	Corsa
n	73880	68070	63023	63368	77398
%	2.98%	3.01%	3.08%	3.26%	3.81%
cum %	15.02%	15.97%	16.87%	16.44%	16.69%
5	Vauxhall	Volkswagen	Volkswagen	Vauxhall	Volkswagen
	Astra	Golf	Golf	Astra	Golf
n	59689	64951	62021	62575	58116
%	2.41%	2.87%	3.03%	3.22%	2.86%
cum %	17.43%	18.84%	19.90%	19.66%	19.55%
6	Nissan	Nissan	Nissan	Vauxhall	Volkswagen
	Qashqai	Qashqai	Qashqai	Insignia	Polo
n	49909	50211	45675	46324	45517
%	2.02%	2.22%	2.23%	2.39%	2.24%
cum %	19.45%	21.05%	22.13%	22.05%	21.79%
7	Volkswagen	BMW	BMW	Volkswagen	Peugeot
	Polo	3-series	3-series	Polo	207

n	48004	43494	44521	45992	42185
%	1.94%	1.92%	2.18%	2.37%	2.08%
cum %	21.39%	22.97%	24.31%	24.41%	23.87%
8	Audi	Volkswagen	Volkswagen	BMW	BMW
	A3	Polo	Polo	3-series	3-series
n	45581	42609	41901	42471	42020
%	1.84%	1.88%	2.05%	2.19%	2.07%
cum %	23.23%	24.85%	26.36%	26.60%	25.93%
9	Fiat	BMW	Mercedes-Benz	Nissan	BMW
	500	1-series	C-Class	Qashqai	Mini
n	44005	41883	37261	39406	41883
%	1.78%	1.85%	1.82%	2.03%	2.06%
cum %	25.01%	26.70%	28.18%	28.63%	28.00%
10	Nissan	Peugeot	BMW	BMW	Nissan
	Juke	208	1-Series	MINI	Qashqai
n	39263	38616	34488	35845	39048
%	1.59%	1.71%	1.69%	1.85%	1.92%
cum %	26.59%	28.41%	29.87%	30.48%	29.92%

Date	2009	2008	2007	2006	2005
Total	1994999	2131795	2404007	2344864	2439717
1	Ford	Ford	Ford	Ford	Ford
	Fiesta	Focus	Focus	Focus	Focus
n	117296	101593	126928	137694	145010
%	5.88%	4.77%	5.28%	5.87%	5.94%
2	Ford	Vauxhall	Vauxhall	Vauxhall	Vauxhall
	Focus	Corsa	Astra	Astra	Astra
n	93517	99574	113894	105296	108461
%	4.69%	4.67%	4.74%	4.49%	4.45%
cum %	10.57%	9.44%	10.02%	10.36%	10.39%
3	Vauxhall	Ford	Ford	Ford	Vauxhall
	Corsa	Fiesta	Fiesta	Fiesta	Corsa

n	84478	94989	102872	103856	89463
%	4.23%	4.46%	4.28%	4.43%	3.67%
cum %	14.80%	13.89%	14.30%	14.79%	14.06%
4	Vauxhall	Vauxhall	Vauxhall	Vauxhall	Renault
	Astra	Astra	Corsa	Corsa	Megane
n	67729	90641	94120	73923	87093
%	3.39%	4.25%	3.92%	3.15%	3.57%
cum %	18.20%	18.14%	18.21%	17.94%	17.63%
5	Volkswagen	Volkswagen	Volkswagen	Renault	Ford
	Golf	Golf	Golf	Megane	Fiesta
n	57187	65029	68843	62069	83803
%	2.87%	3.05%	2.86%	2.65%	3.43%
cum %	21.06%	21.19%	21.08%	20.59%	21.06%
6	Peugeot	Peugeot	Peugeot	Volkswagen	Volkswagen
	207	207	207	Golf	Golf
n	48037	53462	67185	62011	67749
%	2.41%	2.51%	2.79%	2.64%	2.78%
cum %	23.47%	23.70%	23.87%	23.24%	23.84%
7	BMW	BMW	BMW	Renault	Peugeot
	Mini	3-series	3-series	Clio	206
n	39866	49384	58544	57192	67450
%	2.00%	2.32%	2.44%	2.44%	2.76%
cum %	25.47%	26.02%	26.31%	25.67%	26.60%
8	BMW	Ford	Renault	BMW	Ford
	3-series	Mondeo	Megane	3-series	Mondeo
n	39029	44150	55468	50248	57589
%	1.96%	2.07%	2.31%	2.14%	2.36%
cum %	27.43%	28.09%	28.61%	27.82%	28.96%
9	Vauxhall	Vauxhall	Renault	Ford	Renault
	Insignia	Zafira	Clio	Mondeo	Clio
n	36040	43169	53907	48021	65538
%	1.81%	2.03%	2.24%	2.05%	2.69%
cum %	29.23%	30.12%	30.86%	29.87%	31.65%

10	Ford	Vauxhall	Vauxhall	Vauxhall	BMW
	Mondeo	Vectra	Vectra	Zafira	3-series
n	34418	42555	50983	47527	44844
%	1.73%	2.00%	2.12%	2.03%	1.84%
cum %	30.96%	32.11%	32.98%	31.89%	33.49%

Date	2004	2003	2002	2001	2000
Total	2567269	2579050	2563631	2458769	2221647
1	Ford	Ford	Ford	Ford	Ford
	Focus	Focus	Focus	Focus	Focus
n	141021	131684	151209	137074	114512
%	5.49%	5.11%	5.90%	5.57%	5.15%
2	Vauxhall	Vauxhall	Vauxhall	Vauxhall	Vauxhall
	Corsa	Corsa	Corsa	Astra	Astra
n	101625	108387	105199	98999	93263
%	3.96%	4.20%	4.10%	4.03%	4.20%
cum %	9.45%	9.31%	10.00%	9.60%	9.35%
3	Ford	Vauxhall	Vauxhall	Ford	Ford
	Fiesta	Astra	Astra	Fiesta	Fiesta
n	89625	96929	102107	98221	91783
%	3.49%	3.76%	3.98%	3.99%	4.13%
cum %	12.94%	13.07%	13.98%	13.60%	13.48%
4	Peugeot	Ford	Peugeot	Peugeot	Vauxhall
	206	Fiesta	206	206	Corsa
n	86605	95887	96938	97887	84514
%	3.37%	3.72%	3.78%	3.98%	3.80%
cum %	16.32%	16.78%	17.77%	17.58%	17.29%
5	Renault	Renault	Ford	Vauxhall	Peugeot
	Megane	Clio	Fiesta	Corsa	206
n	86569	83972	93591	93792	80991
%	3.37%	3.26%	3.65%	3.81%	3.65%
cum %	19.69%	20.04%	21.42%	21.39%	20.93%

6	Vauxhall	Peugeot	Renault	Ford	Vauxhall
	Astra	206	Clio	Mondeo	Vectra
n	85087	82667	86337	86559	70704
%	3.31%	3.21%	3.37%	3.52%	3.18%
cum %	23.00%	23.25%	24.78%	24.91%	24.12%
7	Renault	Renault	Volkswagen	Renault	Ford
	Clio	Megane	Golf	Clio	Mondeo
n	72412	71660	72362	79843	69377
%	2.82%	2.78%	2.82%	3.25%	3.12%
cum %	25.82%	26.02%	27.61%	28.16%	27.24%
8	Volkswagen	Volkswagen	Ford	Renault	Renault
	Golf	Golf	Mondeo	Megane	Megane
n	69784	67226	72016	73577	64666
%	2.72%	2.61%	2.81%	2.99%	2.91%
cum %	28.54%	28.63%	30.42%	31.15%	30.15%
9	Ford	BMW	Renault	Volkswagen	Renault
	Mondeo	3-series	Megane	Golf	Clio
n	60441	65489	69530	67099	61209
%	2.35%	2.54%	2.71%	2.73%	2.76%
cum %	30.90%	31.17%	33.13%	33.88%	32.90%
10	Peugeot	Ford	Ford	Citroen	Volkswagen
	307	Mondeo	Ka	Xsara	Golf
n	58742	60046	62863	65681	57359
%	2.29%	2.33%	2.45%	2.67%	2.58%
cum %	33.18%	33.50%	35.58%	36.55%	35.49%

Date	1999	1998	1997	1996	1995
Total	2197615	2247402	2170725	2025450	1945366
1	Ford	Ford	Ford	Ford	Ford
	Focus	Fiesta	Fiesta	Fiesta	Escort
N	103228	116110	119471	139552	137760
%	4.70%	5.17%	5.50%	6.89%	7.08%

2	Ford	Ford	Ford	Ford	Ford
	Fiesta	Escort	Escort	Escort	Fiesta
N	99830	113560	113522	128760	129574
%	4.54%	5.05%	5.23%	6.36%	6.66%
cum %	9.24%	10.22%	10.73%	13.25%	13.74%
3	Vauxhall	Ford	Ford	Ford	Ford
	Astra	Mondeo	Mondeo	Mondeo	Mondeo
n	92050	99729	107239	100725	118040
%	4.19%	4.44%	4.94%	4.97%	6.07%
cum %	13.43%	14.66%	15.67%	18.22%	19.81%
4	Vauxhall	Vauxhall	Vauxhall	Vauxhall	Vauxhall
	Corsa	Vectra	Vectra	Vectra	Astra
n	86779	92719	93778	88224	100709
%	3.95%	4.13%	4.32%	4.36%	5.18%
cum %	17.38%	18.78%	19.99%	22.58%	24.99%
5	Vauxhall	Renault	Vauxhall	Vauxhall	Vauxhall
	Vectra	Megane	Astra	Astra	Cavalier
n	77479	82998	89537	86068	73978
%	3.53%	3.69%	4.12%	4.25%	3.80%
cum %	20.90%	22.48%	24.12%	26.83%	28.79%
6	Ford	Vauxhall	Vauxhall	Vauxhall	Vauxhall
	Mondeo	Astra	Corsa	Corsa	Corsa
n	77183	81494	79898	75777	72502
%	3.51%	3.63%	3.68%	3.74%	3.73%
cum %	24.42%	26.10%	27.80%	30.57%	32.52%
7	Renault	Vauxhall	Peugeot	Rover	Rover
	Megane	Corsa	306	400	200 series
n	65127	75673	66888	63847	68141
%	2.96%	3.37%	3.08%	3.15%	3.50%
cum %	27.38%	29.47%	30.88%	33.72%	36.02%
8	Renault	Peugeot	Rover	Peugeot	Peugeot
	Clio	306	200 series	306	306
n	63991	70169	62365	58916	56112

%	2.91%	3.12%	2.87%	2.91%	2.88%
cum %	30.29%	32.59%	33.75%	36.63%	38.90%
9	Volkswagen	Rover	Rover	Renault	Renault
	Golf	200	400 series	Clio	Clio
n	63715	64928	61913	53826	52576
%	2.90%	2.89%	2.85%	2.66%	2.70%
cum %	33.19%	35.48%	36.61%	39.28%	41.61%
10	Peugeot	Rover	Renault	Rover	Rover
	206	400	Clio	200 series	100 (alias Metro)
n	58788	57318	58033	53562	52392
%	2.68%	2.55%	2.67%	2.64%	2.69%
cum %	35.86%	38.03%	39.28%	41.93%	44.30%

Date	1994	1993	1992	1991	1990
Total	1910933	1778426	1593601	1592326	2008934
1	Ford	Ford	Ford	Ford	Ford
	Escort	Escort	Escort	Fiesta	Fiesta
N	144089	122002	121140	117181	151475
%	7.54%	6.86%	7.60%	7.36%	7.54%
2	Ford	Ford	Vauxhall	Ford	Ford
	Mondeo	Fiesta	Cavalier	Escort	Escort
N	127144	110449	108818	110302	141985
%	6.65%	6.21%	6.83%	6.93%	7.07%
cum %	14.19%	13.07%	14.43%	14.29%	14.61%
3	Ford	Vauxhall	Ford	Vauxhall	Vauxhall
	Fiesta	Astra	Fiesta	Cavalier	Cavalier
n	123723	108204	106595	109545	138357
%	6.47%	6.08%	6.69%	6.88%	6.89%
cum %	20.67%	19.15%	21.12%	21.17%	21.49%
4	Vauxhall	Vauxhall	Vauxhall	Ford	Ford
	Cavalier	Cavalier	Astra	Sierra	Sierra
n	100115	104104	86858	93650	128705

%	5.24%	5.85%	5.45%	5.88%	6.41%
cum %	25.91%	25.01%	26.57%	27.05%	27.90%
5	Vauxhall	Ford	Ford	Vauxhall	Vauxhall
	Astra	Mondeo	Sierra	Astra	Astra
n	98098	88660	77253	71437	101087
%	5.13%	4.99%	4.85%	4.49%	5.03%
cum %	31.04%	29.99%	31.42%	31.53%	32.93%
6	Rover	Rover	Rover	Rover	Rover
	200 series	200 series	200 series	200 series	Metro
n	80313	77745	77214	68122	81064
%	4.20%	4.37%	4.85%	4.28%	4.04%
cum %	35.24%	34.37%	36.26%	35.81%	36.97%
7	Vauxhall	Rover	Rover	Rover	Rover
	Corsa	Metro	Metro	Metro	200
n	78739	57068	56713	60361	62487
%	4.12%	3.21%	3.56%	3.79%	3.11%
cum %	39.36%	37.57%	39.82%	39.60%	40.08%
8	Rover	Peugeot	Peugeot	Peugeot	Vauxhall
	Metro	405	405	205	Nova
n	58565	52184	48482	46615	54786
%	3.06%	2.93%	3.04%	2.93%	2.73%
cum %	42.43%	40.51%	42.86%	42.53%	42.81%
9	Renault	Vauxhall	Vauxhall	Vauxhall	Ford
	Clio	Corsa	Nova	Nova	Orion
n	49337	51608	42779	44751	51404
%	2.58%	2.90%	2.68%	2.81%	2.56%
cum %	45.01%	43.41%	45.55%	45.34%	45.36%
10	Peugeot	Renault	Renault	Peugeot	Peugeot
	306	Clio	Clio	405	205
n	48802	45269	34701	41296	50205
%	2.55%	2.55%	2.18%	2.59%	2.50%
cum %	47.56%	45.96%	47.73%	47.93%	47.86%

Date	1989	1988	1987	1986	1985
Total	2300944	2215574	2013693	1882474	1832408
1	Ford	Ford	Ford	Ford	Ford
	Escort	Escort	Escort	Escort	Escort
N	181218	172706	178001	156895	157269
%	7.88%	7.80%	8.84%	8.33%	8.58%
2	Ford	Ford	Ford	Ford	Vauxhall
	Sierra	Sierra	Fiesta	Fiesta	Cavalier
N	175911	162684	153453	143712	134335
%	7.65%	7.34%	7.62%	7.63%	7.33%
cum %	15.52%	15.14%	16.46%	15.97%	15.91%
3	Ford	Ford	Ford	Ford	Ford
	Fiesta	Fiesta	Sierra	Sierra	Fiesta
n	149358	144991	139878	113861	124143
%	6.49%	6.54%	6.95%	6.05%	6.77%
cum %	22.01%	21.68%	23.41%	22.02%	22.69%
4	Vauxhall	Austin MG	Austin MG	Vauxhall	Austin MG
	Cavalier	Metro	Metro	Cavalier	Metro
n	130615	116811	108223	113475	118817
%	5.68%	5.27%	5.37%	6.03%	6.48%
cum %	27.69%	26.95%	28.78%	28.05%	29.17%
5	Vauxhall	Vauxhall	Vauxhall	Austin MG	Ford
	Astra	Astra	Cavalier	Metro	Sierra
n	115294	98086	98490	109351	101642
%	5.01%	4.43%	4.89%	5.81%	5.55%
cum %	32.70%	31.38%	33.67%	33.85%	34.72%
6	Rover	Vauxhall	Vauxhall	Vauxhall	Vauxhall
	Metro	Cavalier	Astra	Astra	Astra
n	99373	96462	88637	80067	76553
%	4.32%	4.35%	4.40%	4.25%	4.18%
cum %	37.02%	35.74%	38.07%	38.11%	38.90%
7	Vauxhall	Ford	Ford	Austin MG	Austin MG
	Nova	Orion	Orion	Montego	Montego

n	71047	67713	69262	62658	73955
%	3.09%	3.06%	3.44%	3.33%	4.04%
cum %	40.11%	38.79%	41.51%	41.44%	42.93%
8	Ford	Austin MG	Austin MG	Ford	Ford
	Orion	Montego	Montego	Orion	Orion
n	68598	63649	56238	55255	65363
%	2.98%	2.87%	2.79%	2.94%	3.57%
cum %	43.09%	41.66%	44.31%	44.37%	46.50%
9	Rover	Rover	Rover	Austin MG	Vauxhall
	200 series	200 series	200 series	Maestro	Nova
n	68316	58890	50254	51465	61358
%	2.97%	2.66%	2.50%	2.73%	3.35%
cum %	46.06%	44.32%	46.80%	47.10%	49.85%
10	Rover	Vauxhall	Peugeot	Vauxhall	Austin MG
	Montego	Nova	205	Nova	Maestro
n	57835	56937	49127	48465	57527
%	2.51%	2.57%	2.44%	2.57%	3.14%
cum %	48.57%	46.89%	49.24%	49.68%	52.99%

Date	1984	1983	1982	1981	1980
Total	1749650	1791699	1555027	1484713	1513761
1	Ford	Ford	Ford	Ford	Ford
	Escort	Escort	Escort	Cortina Mk 5	Cortina Mk 5
N	157340	174190	166942	159804	190281
%	8.99%	9.72%	10.74%	10.76%	12.57%
2	Vauxhall	Ford	Ford	Ford	Ford
	Cavalier	Sierra	Cortina Mk 5	Escort	Escort
N	132149	159119	135745	141081	122357
%	7.55%	8.88%	8.73%	9.50%	8.08%
cum %	16.55%	18.60%	19.47%	20.27%	20.65%
3	Ford	Austin MG	Austin	Ford	Ford
	Fiesta	Metro	Metro	Fiesta	Fiesta

n	125851	137303	114550	110753	91661
%	7.19%	7.66%	7.37%	7.46%	6.06%
cum %	23.74%	26.27%	26.83%	27.73%	26.71%
4	Austin MG	Vauxhall	Ford	Austin	Austin / Morris
	Metro	Cavalier	Fiesta	Metro	Mini
n	117442	127509	110165	110283	61129
%	6.71%	7.12%	7.08%	7.43%	4.04%
cum %	30.45%	33.38%	33.92%	35.15%	30.75%
5	Ford	Ford	Vauxhall	Morris	Morris
	Sierra	Fiesta	Cavalier	Ital	Marina
n	113071	119602	100081	48490	59906
%	6.46%	6.68%	6.44%	3.27%	3.96%
cum %	36.91%	40.06%	40.35%	38.42%	34.70%
6	Austin MG	Austin MG	Vauxhall	Vauxhall	Vauxhall
	Maestro	Maestro	Astra	Chevette	Chevette
n	83072	65328	46412	36838	46059
%	4.75%	3.65%	2.98%	2.48%	3.04%
cum %	41.66%	43.70%	43.34%	40.90%	37.75%
7	Vauxhall	Vauxhall	Triumph	Vauxhall	Vauxhall
	Astra	Astra	Acclaim	Cavalier	Cavalier
n	56511	62570	42188	33631	41119
%	3.23%	3.49%	2.71%	2.27%	2.72%
cum %	44.89%	47.20%	46.05%	43.17%	40.46%
8	Vauxhall	Triumph	Volvo	Datsun	Austin
	Nova	Acclaim	300 series	Cherry	Allegro
n	55442	38406	30412	32874	39612
%	3.17%	2.14%	1.96%	2.21%	2.62%
cum %	48.06%	49.34%	48.01%	45.38%	43.08%
9	Ford	Nissan	Datsun	Vauxhall	Ford
	Orion	Sunny	Sunny	Astra	Capri
n	51026	36781	28744	30854	31187
%	2.92%	2.05%	1.85%	2.08%	2.06%
cum %	50.98%	51.39%	49.85%	47.46%	45.14%

10	Volvo	Volvo	Ford	Austin Morris	Renault
	300 series	300 series	Granada	Mini	18
n	35034	36753	28590	28772	30958
%	2.00%	2.05%	1.84%	1.94%	2.05%
cum %	52.98%	53.44%	51.69%	49.40%	47.19%

Date	1979	1978	1977	1976	1975
Total	1716275	1591939			
1	Ford	Ford	Ford	Ford	Ford
	Cortina Mk 5	Cortina Mk 4	Cortina Mk 4	Escort	Cortina Mk 3
N	193784	139204	120601	133959	106787
%	11.29%	8.74%			
2	Ford	Ford	Ford	Ford	Ford
	Escort	Escort	Escort	Cortina Mk 4	Escort
N	131667	114415	103389	126238	103817
%	7.67%	7.19%			
cum %	18.96%	15.93%			
3	Austin Morris	Morris	Morris	British Leyland	British Leyland
	Mini	Marina	Marina	Mini	Mini
n	82938	82638	66088	81107	84688
%	4.83%	5.19%			
cum %	23.80%	21.12%			
4	Morris	Austin / Morris	Austin / Morris	British Leyland	British Leyland
	Marina	Mini	Mini	Marina	Marina
n	62410	72617	60337	71288	78632
%	3.64%	4.56%			
cum %	27.43%	25.68%			
5	Austin	Ford	Austin	British Leyland	British Leyland
	Allegro	Fiesta	Allegro	Allegro	Allegro
n	59985	68723	56175	55218	63339

%	3.50%	4.32%			
cum %	30.93%	30.00%			
6	Ford	Austin	Vauxhall	Vauxhall	Vauxhall
	Fiesta	Allegro	Chevette	Chevette	Viva / Magnum HC
n	58681	61535	51763	43827	54792
%	3.42%	3.87%			
cum %	34.35%	33.87%			
7	Ford	Vauxhall	Ford	Ford	Hillman
	Granada	Cavalier	Capri	Capri	Avenger
n	52089	55373	42816	36098	38877
%	3.04%	3.48%			
cum %	37.38%	37.34%			
8	Ford	Vauxhall	Vauxhall	Vauxhall	Triumph
	Capri	Chevette	Cavalier	Viva / Magnum HC	Dolomite
n	49147	52327	41128	33901	30119
%	2.86%	3.29%			
cum %	40.24%	40.63%			
9	Vauxhall	Ford	Ford	Austin	British Leyland
	Cavalier	Granada	Fiesta	Maxi	Princess / 18.22
n	46517	38099	40934	33476	29067
%	2.71%	2.39%			
cum %	42.95%	43.02%			
10	Vauxhall	Datsun	Datsun	British Leyland	Hillman
	Chevette	Sunny	Sunny	Princess	Hunter
n	44197	37923	35257	31702	28966
%	2.58%	2.38%			
cum %	45.53%	45.41%			

Date	1974	1973	1972	1971	1970
Total			1662856	1301667	1097219
1	Ford	Ford	Ford	Austin Morris	Austin Morris

	Cortina Mk 3	Cortina Mk 3	Cortina Mk 3	1100 / 1300	1100 / 1300
N	131234	181607	187159	133527	132965
%			11.26%	10.26%	12.12%
2	Ford	Morris	Ford	Austin Morris	Ford
	Escort	Marina	Escort	Mini	Cortina Mk 3
N	91699	115041	140837	103180	123256
%			8.47%	7.93%	11.23%
cum %			19.72%	18.18%	23.35%
3	British Leyland	Ford	Morris	Ford	Ford
	Mini	Escort	Marina	Cortina Mk 3	Escort
n	89682	114296	104986	102214	95837
%			6.31%	7.85%	8.73%
cum %			26.04%	26.04%	32.09%
4	British Leyland	Vauxhall	Vauxhall	Vauxhall	Austin Morris
	Marina	Viva / Magnum HC	Viva HC	Viva / Magnum HC	Mini
n	81439	97893	104778	98982	80740
%			6.30%	7.60%	7.36%
cum %			32.34%	33.64%	39.44%
5	Vauxhall	British Leyland	Austin Morris	Ford	Vauxhall
	Viva / Magnum HC	Mini	1100 / 1300	Escort	Viva / Magnum HC
n	71852	96383	102449	89143	76838
%			6.16%	6.85%	7.00%
cum %			38.50%	40.49%	46.45%
6	British Leyland	Hillman	Austin Morris	Hillman	Hillman
	Allegro	Avenger	Mini	Avenger	Avenger
n	60619	78644	96314	63476	50133
%			5.79%	4.88%	4.57%
cum %			44.29%	45.37%	51.02%
7	Hillman	Hillman	Hillman	Austin Morris	Ford
	Avenger	Hunter	Avenger	1600 range / Maxi	Capri
n	60244	65500	78729	42867	38176
%			4.73%	3.29%	3.48%

cum %			49.03%	48.66%	54.50%
8	Triumph	British Leyland	Austin Morris	Hillman	Austin Morris
	Dolomite	1100 / 1300	1600 range / Maxi	Hunter	1600 range / Maxi
n	45008	59198	53984	41996	36752
%			3.25%	3.23%	3.35%
cum %			52.27%	51.89%	57.85%
9	Ford	Triumph	Hillman	Morris	Austin Morris
	Capri	Dolomite	Hunter	Marina	1800, 2200, 3 litre
n	37530	57439	50342	41164	32927
%			3.03%	3.16%	3.00%
cum %			55.30%	55.05%	60.85%
10	Hillman	Austin	Ford	Austin Morris	Volkswagen
	Hunter	Maxi	Capri	1800, 2200, 3 litre	Beetle
n	37158	52853	42437	39163	25480
%			2.55%	3.01%	2.32%
cum %			57.85%	58.06%	63.17%

Date	1969	1968	1967	1966	1965
Total	987441	1116894	1116702	1065423	1122477
1	Austin Morris	Austin Morris	Ford	Austin Morris	Austin Morris
	1100 / 1300	1100 / 1300	Cortina Mk 2	1100 / 1300	1100 / 1300
N	133455	151146	165300	151946	157679
%	13.52%	13.53%	14.80%	14.26%	14.05%
2	Ford	Ford	Austin Morris	Ford	Ford
	Cortina Mk 2	Cortina Mk 2	1100 / 1300	Cortina Mk 1	Cortina Mk 1
N	116186	137873	131382	127037	116985
%	11.77%	12.34%	11.77%	11.92%	10.42%
cum %	25.28%	25.88%	26.57%	26.19%	24.47%
3	Ford	Vauxhall	Vauxhall	Austin Morris	Austin Morris
	Escort	Viva HB	Viva HB	Mini	Mini

n	85156	101067	100220	91624	104477
%	8.62%	9.05%	8.97%	8.60%	9.31%
cum %	33.91%	34.93%	35.54%	34.78%	33.78%
4	Vauxhall	Ford	Austin Morris	Ford	Ford
	Viva HB	Escort	Mini	Anglia	Anglia
n	75354	98218	82436	68209	84589
%	7.63%	8.79%	7.38%	6.40%	7.54%
cum %	41.54%	43.72%	42.92%	41.19%	41.31%
5	Austin Morris	Austin Morris	Ford	Vauxhall	Vauxhall
	Mini	Mini	Anglia	Viva HB	Victor FC
n	68330	86190	55735	59731	60854
%	6.92%	7.72%	4.99%	5.61%	5.42%
cum %	48.46%	51.44%	47.92%	46.79%	46.73%
6	Hillman	Hillman	Hillman	Austin Morris	Vauxhall
	Minx (Arrow)	Minx / Hunter(Arrow)	Imp / Chamois / Stiletto	1600 range	Viva HA
n	36094	48198	38807	48077	58884
%	3.66%	4.32%	3.48%	4.51%	5.25%
cum %	52.11%	55.75%	51.39%	51.31%	51.98%
7	Ford	Vauxhall	Vauxhall	Vauxhall	Austin Morris
	Capri	Victor FD	Victor FD	Victor FC	1600 range
n	33047	34772	38517	46537	52503
%	3.35%	3.11%	3.45%	4.37%	4.68%
cum %	55.46%	58.87%	54.84%	55.67%	56.66%
8	Austin Morris	Ford	Ford	Hillman	Triumph
	1600 range / Maxi	Corsair	Corsair	Imp / Chamois / Stiletto	Herald, Vitesse
n	30784	31014	35993	38870	46626
%	3.12%	2.78%	3.22%	3.65%	4.15%

cum %	58.58%	61.64%	58.06%	59.32%	60.81%
9	Austin Morris	Hillman	Morris	Ford	Morris
	1800, 2200, 3 litre	Imp / Chamois / Stiletto	Minor	Corsair	Minor
n	29005	30707	34565	38412	44905
%	2.94%	2.75%	3.10%	3.61%	4.00%
cum %	61.51%	64.39%	61.16%	62.93%	64.81%
10	Vauxhall	Austin Morris	Austin Morris	Triumph	Ford
	Victor FD	1600 range	1600 range	Herald, Vitesse	Corsair
n	28688	30284	34498	38076	44463
%	2.91%	2.71%	3.09%	3.57%	3.96%
cum %	64.42%	67.10%	64.25%	66.50%	68.77%

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A6 Cars of the Year

A6 Cars of the Year

The European Car of the Year lists are shown in the following tables and figures.

Year	1964	1965	1966	1967	1968	1969
Winner	Rover	Austin	Renault	Fiat	NSU	Peugeot
	2000	1800	16	124	Ro80	504
	76	78	98	61	197	119
Second	Mercedes-Benz	Autobianchi	Rolls-Royce	BMW	Fiat	BMW
	600	Primula	Silver Shadow	1600	125	2500 / 2800
	65	51	81	61	133	77
Third	Hillman	Ford	Oldsmobile	Jensen	Simca	Alfa Romeo
	Imp	Mustang	Toronado	FF	1100	1750
	31	18	59	61	94	76

Year	1970	1971	1972	1973	1974
Winner	Fiat	Citroen	Fiat	Audi	Mercedes-Benz
	128	GS	127	80	450S
	235	233	239	114	115
Second	Autobianchi	Volkswagen	Renault	Renault	Fiat
	A112	K70	15 / 17	5	X1/9
	96	121	107	109	99
Third	Renault	Citroen	Mercedes-Benz	Alfa Romeo	Honda
	12	SM	350SL	Alfetta	Civic
	79	105	96	95	90

Year	1975	1976	1977	1978	1979
Winner	Citroen	Simca	Rover	Porsche	Simca - Chrysler
	CX	1307 - 1308	3500	928	Horizon
	229	192	157	261	251
Second	Volkswagen	BMW	Audi	BMW	Fiat
	Golf	316 - 318	100	7 Series	Ritmo
	164	144	138	231	239
Third	Audi	Renault	Ford	Ford	Audi
	50	30TS	Fiesta	Granada	80
	136	107	135	203	181

Year	1980	1981	1982	1983	1984
Winner	Lancia	Ford	Renault	Audi	Fiat
	Delta	Escort	9 - 11	100	Uno
	369	326	335	410	346
Second	Opel	Fiat	Opel	Ford	Peugeot
	Kadett	Panda	Ascona	Sierra	205
	301	308	304	386	325
Third	Peugeot	Austin	Volkswagen	Volvo	Volkswagen
	505	Metro	Polo	760	Golf
	199	255	225	157	156

Year	1985	1986	1987	1988	1989
Winner	Opel	Ford	Opel	Peugeot	Fiat
	Kadett	Scorpio	Omega	405	Tipo
	326	337	275	464	356
Second	Renault	Lancia	Audi	Citroen	Opel / Vauxhall
	25	Y10	80	AX	Vectra / Cavalier
	261	291	238	252	261
Third	Lancia	Mercedes-Benz	BMW	Honda	Volkswagen
	Thema	200 - 300 E	7 Series	Prelude	Passat

	191	273	175	234	194

Year	1990	1991	1992	1993	1994
Winner	Citroen	Renault	Volkswagen	Nissan	Ford
	XM	Clio	Golf	Micra	Mondeo
	390	312	276	338	290
Second	Mercedes-Benz	Nissan	Opel / Vauxhall	Fiat	Citroen
	SL	Primera	Astra	Cinquecento	Xantia
	215	258	231	304	264
Third	Ford	Opel / Vauxhall	Citroen	Renault	Mercedes-Benz
	Fiesta	Calibra	ZX	Safrane	C Klasse
	214	183	213	244	192

Year	1995	1996	1997	1998	1999
Winner	Fiat	Fiat	Renault	Alfa Romeo	Ford
	Punto	Bravo / Brava	Megane Scenic	156	Focus
	370	378	405	454	444
Second	Volkswagen	Peugeot	Ford	Volkswagen	Opel / Vauxhall
	Polo	406	Ka	Golf	Astra
	292	363	293	266	272
Third	Opel / Vauxhall	Audi	Volkswagen	Audi	Peugeot
	Omega	A4	Passat	A6	206
	272	246	248	265	249

Year	2000	2001	2002	2003	2004
Winner	Toyota	Alfa Romeo	Peugeot	Renault	Fiat
	Yaris	147	307	Megane	Panda

	344	238	286	322	281
Second	Fiat	Ford	Renault	Mazda	Mazda
	Multipla	Mondeo	Laguna	6	3
	325	237	244	302	241
Third	Opel / Vauxhall	Toyota	Fiat	Citroen	Volkswagen
	Zafira	Prius	Stilo	C3	Golf
	265	229	243	214	241
Fourth			Mini	Honda	Toyota
			One	Jazz	Avensis
			213	167	219
Fifth			Honda	Ford	Opel / Vauxhall
			Civic	Fiesta	Meriva
			174	161	213
Sixth			Citroen	Opel / Vauxhall	BMW
			C5	Vectra	5-series
			119	151	144
Seventh			Jaguar	Mercedes-Benz	Nissan
			X-type	E-Klasse	Micra
			96	133	111

Year	2005	2006	2007	2008	2009
Winner	Toyota	Renault	Ford	Fiat	Opel / Vauxhall
	Prius	Clio	S Max	500	Insignia
	406	256	235	385	321
Second	Citroen	Volkswagen	Opel / Vauxhall	Mazda	Ford
	C4	Passat	Corsa	2	Fiesta
	267	251	233	325	320
Third	Ford	Alfa Romeo	Citroen	Ford	Volkswagen
	Focus	159	C4 Picasso	Mondeo	Golf
	228	212	222	202	223
Fourth	Opel / Vauxhall	BMW	Skoda	Kia	Citroen

	Astra	3 series	Roomster	Cee'd	C5
	180	203	189	166	198
Fifth	Renault	Mazda	Honda	Nissan	Alfa Romeo
	Modus	5	Civic	Qashqai	MiTo
	151	198	148	147	148
Sixth	Peugeot	Citroen	Peugeot	Mercedes-Benz	Skoda
	407	C1	207	C-Klasse	Superb
	135	187	144	128	144
Seventh	BMW	Toyota	Volvo	Peugeot	Renault
	1-series	Yaris	C30	308	Megane
	83	143	141	91	121

Year	2010	2011	2012	2013	2014
Winner	Volkswagen	Nissan	Opel / Vauxhall / Chevrolet	Volkswagen	Peugeot
	Polo	Leaf	Ampera / Volt	Golf	308
	347	257	330	414	307
Second	Toyota	Alfa Romeo	Volkswagen	Subaru / Toyota	BMW
	iQ	Giulietta	Up!	BRZ / GT86	I3
	337	248	281	202	223
Third	Opel / Vauxhall	Vauxhall / Opel	Ford	Volvo	Tesla
	Astra	Meriva	Focus	V40	S
	221	244	256	189	216
Fourth	Skoda	Ford	Range Rover	Ford	Citroen
	Yeti	C-Max	Evoque	B-Max	C4 Picasso
	158	224	186	148	182
Fifth	Mercedes-Benz	Citroen	Fiat	Mercedes-Benz	Mazda
	E Class	C3/DS3	Panda	A-Class	3
	155	175	156	138	180
Sixth	Peugeot	Volvo	Citroen	Peugeot	Skoda
	3008	S60/V60	DS5	208	Octavia

	144	145	144	128	172
Seventh	Citroen	Dacia	Toyota	Hyundai	Mercedes-Benz
	C3 Picasso	Duster	Yaris	i130	S Class
Year	113	132	122	120	170

Reference

CAR OF THE YEAR ORGANIZING COMMITTEE. 2015. *Car of the Year: the official website* [Online]. Available: http://www.caroftheyear.org/ [Accessed 28 May 2015].

A7 Lists of collected cars

A7 Lists of collected cars

Table A7.1, below consists of a list of all of the cars that were included in the analysis. The cars are ordered by date, Manufacturer, Model and Type.

Ref	Manufacturer	Model	Type	Year	Code
392	Bollée	La Mancelle	(Amedée Bollée)	1878	A B
379	Benz	Tricycle		1886	A B
1	Daimler	Phaeton		1886	A B
2	Benz	Victoria		1888	A B
639	Daimler	Stahlradwagen		1889	A B
3	Panhard			1892	A B
381	Benz	Victoria	Vis-a-vis	1893	A B
380	Benz	Viktoria		1893	A B
516	Peugeot	Type 8		1893	A B
382	Benz	Velo		1894	A B
473	Lanchester			1895	A B
517	Peugeot			1895	A B
13	Renault		(replica)	1895	A B
393	Leon-Bollée	Voiturette		1896	A B
581	Panhard	Levassor	Phaetonette	1896	A B
386	Bersey	Electric Cab		1897	A B
481	Malicet et Blin			1897	A B
472	Allen			1898	A B
429	Daimler			1898	A B
437	Delahaye			1898	A B
240	Leon-Bollée	Tricar		1898	A B
511	Panhard	Levassor A2	Tonneau Fermé	1898	A B
633	Automoto	De Dion Engined	Quadricycle	1899	A B
383	Benz			1899	A B
613	Benz			1899	A B

679	De Dion engined	Combination		1899	A B
470	Jenatzy	La Jamais Contente		1899	A B
4	Locomobile	Steam Buggy		1899	A B
550	Star			1899	A B
640	Daimler			1900	A B
646	Gardner-Serpollet		Steamer	1900	A B
658	Mobile	Steamer		1900	A B
497	Napier			1900	A B
546	Skene	Steamer		1900	A B
6	Baker	Electric		1901	A B
433	de Dion Bouton			1901	A B
5	de Dion Bouton	vis-a-vis		1901	A B
431	Decauville			1901	A B
651	Lanchester			1901	A B
652	Lanchester			1901	A B
476	Locomobile	Steam Buggy		1901	A B
681	Locomobile	Steam Buggy		1901	A B
9	Oldsmobile	Curved Dash		1901	A B
665	Renault		Two seater	1901	A B
7	Royal Enfield	Quadricycle		1901	A B
8	Sunbeam	Mabley		1901	A B
583	Wolseley	10hp	Tonneau	1901	A B
384	Benz	10 HP	Tonneau	1902	A B
10	de Dion-Bouton	8hp Tonneau		1902	A B
434	de Dion-Bouton	Tonneau		1902	A B
353	James & Browne			1902	A B
512	Panhard	Levassor		1902	A B
676	Wolseley			1902	A B
11	Berliet	20 HP		1903	A B
454	Georges Richard			1903	A B
578	Mercedes	60 HP		1903	A B
518	Mors			1903	A B
513	Panhard	Levassor		1903	A B

551	Stevens-Duryea			1903	A B
14	Cadillac			1904	A B
663	Peerless	Green Dragon		1904	A B
332	White	Steam Car		1904	A B
435	de Dion-Bouton	AB	Double Phaeton	1905	A B
499	Nef Nef			1906	A B
405	Cadillac	Model K		1907	A B
12	Itala		Peking-Paris	1907	A B
525	Renault			1907	A B
535	Rover	20HP	Tourer	1907	A B
385	Benz	Grand Prix		1908	A B
388	Black	'10/20	High Wheeler	1908	A B
526	Renault	20-30 PK Type V		1908	A B
544	Sizaire-Naudin			1908	A B
548	Stanley	Steamer		1908	A B
630	American Underslung		Raceabout	1909	A B
355	AC	Sociable		1910	A B
424	Clement-Bayard			1910	A B
460	Hupmobile	Model 20		1910	A B
16	Isotta-Fraschini			1910	A B
17	Lanchester	28 HP	Tourer	1910	A B
474	Lanchester	38 HP	Open-drive Limousine	1910	A B
545	Sizaire-Naudin	12 CV		1910	A B
358	Alfa	Ricotti		1911	A B
363	Austin	Town Car		1911	A B
632	Austro-Daimler			1911	A B
436	de Dion-Bouton			1911	A B
222	Stanley	Steamer	Roadster	1911	A B
595	Bugatti	Type 18		1912	A B
479	Lorraine-Dietrich	Vieux Charles III		1912	A B
220	Mercer	Type 35 F	Raceabout	1912	A B
18	Peugeot	Bébé		1912	A B
138	Renault	AX		1912	A B

533	Rolls-Royce	Silver Ghost		1912	A B
536	Rover	12HP	Landaulet	1912	A B
261	Stutz	Bearcat		1912	A B
359	Alva	Type C	Doctor's Coupe	1913	A B
178	Bédélia			1913	A B
395	Bugatti	Type 13		1913	A B
236	Bugatti	Type 13	Torpedo	1913	A B
430	Daimler	30hp	Saloon	1913	A B
492	Morgan		3 wheeler	1913	A B
19	Vauxhall	C Type	Prince Henry	1913	A B
396	Bugatti	Type 17 Brescia	Torpedo	1914	A B
571	Ford	Model T	Tourer	1914	A B
483	Mercedes	Grand Prix		1914	A B
611	Sunbeam	TT		1914	A B
15	Ford	Model T	Tourer	1915	A B
570	Detroit Electric			1916	A B
610	Stutz	Bearcat	with engine	1917	A B
673	Straker-Squire	X2		1918	A B
20	Citroen	Model A		1919	A B
442	Fiat	501		1919	A B
408	Citroen	5CV	Torpedo Cabriolet	1921	A B
573	GN	Vitesse		1921	A B
527	Renault	Type IG 10HP		1921	A B
344	Amilcar	CGS		1922	A B
387	Bignan	AL		1922	A B
409	Citroen	5CV		1922	A B
23	Lancia	Lambda		1922	A B
606	Leyat	Helicar		1922	A B
523	Phänomobil			1922	A B
670	Rumpler	Tropfenwagen		1922	A B
549	Stanley	Steamer		1922	A B
365	Austin	Seven	Chummy	1923	A B
217	Citroen	B2 10CV		1923	A B

411	Citroen	B2 10CV	Saloon	1923	A B
410	Citroen	Type C	Torpedo	1923	A B
21	GN	Touring		1923	A B
282	Morris	Oxford	Tourer	1923	A B
528	Renault	MT	Torpedo	1923	A B
541	Scott	Sociable		1923	A B
22	Trojan	Chummy		1923	A B
586	Trojan	Chummy		1923	A B
445	Ford	Model T	Tourer	1924	A B
457	Hispano-Suiza	H6C	Tulipwood	1924	A B
493	Morgan		3 wheeler	1924	A B
660	Opel	Laubfrosch		1924	A B
529	Renault	18CV	Coupe de Ville	1924	A B
245	Renault	40CV NM	Landaulet	1924	A B
582	Rolls-Royce	Silver Ghost		1924	A B
671	Schwabische Hutten Werke GmBh	Wunibald Kamm	Prototype	1924	A B
98	Bugatti	Type 35		1925	A B H G
413	Citroen	5CV		1925	A B
414	Citroen	Type C		1925	A B
438	FN			1925	A B
225	Hanomag	2/10 PS	Kommisbrot	1925	A B
24	Austin	Seven	Chummy	1926	A B
375	Bentley	3 litre		1926	A B
182	Bugatti	Type 37		1926	A B
25	Morris	Cowley	Bullnose Doctors' Coupe	1926	A B
588	Morris	Oxford	Bullnose Tourer	1926	A B
555	Tatra			1926	A B
631	Amilcar	C6	Sports	1927	A B
397	Bugatti	Type 35C		1927	A B
399	Bugatti	Type 38		1927	A B
427	Darmont	Type DS		1927	A B

471	Jowett	7/17		1927	A B
609	Renault	40CV	Phaeton	1927	A B
629	Alvis	'12/50	Beetle Back	1928	A B
194	Alvis	Front Wheel Drive		1928	A B
389	BMW	Dixi		1928	A B
596	Bugatti	Type 43 Grand Sport		1928	A B
475	Lancia	Lambda	Torpedo	1928	A B
357	Aero			1929	A B
367	Austin	Seven	Box Saloon	1929	A B
366	Austin	Seven	Chummy	1929	A B
269	Bugatti	Type 40		1929	A B
648	Hispano-Suiza	H6B	Torpedo Galle Sport	1929	A B
580	Packard		Coupe	1929	A B
534	Rolls-Royce	Phantom I ?		1929	A B
563	Voisin	13CV Type C14		1929	A B
26	Bentley	4.5 Litre	Supercharged	1930	A B H
394	Bucciali	TAV8		1930	A B
180	Bugatti	Type 41 Royale		1930	A B
400	Bugatti	Type 49	Saloon	1930	A B
352	Invicta	4.5 Litre	S Type	1930	A B
491	Minerva	40CV Type AL		1930	A B
564	Voisin	13CV Type C14	Berline	1930	A B
239	Alfa Romeo	6C-1750	Touring	1931	A B H
627	Alfa Romeo	8C 2.3	Zagato Spyder	1931	A B
159	Austin	Seven	Swallow	1931	A B
597	Bugatti	Type 51		1931	A B
177	Daimler	Double Six		1931	A B
28	DKW	F1		1931	A B E
106	MG	M Type Midget		1931	A B
97	Talbot	105		1931	A B
598	Bugatti	Type 54		1932	A B
271	Bugatti	Type 55		1932	A B

637	Bugatti	Type 55		1932	A B H
349	Cadillac	V16		1932	A B
272	Duesenberg	J		1932	A B
114	Duesenberg	J	Hibberd & Darrin Convertible	1932	A B
134	Morris	Minor	2-door saloon	1932	A B
508	Packard	45 HP		1932	A B
565	Voisin		Sports Coupe	1932	A B
590	Alfa Romeo	8c 2300	spider	1933	A B
368	Austin	Seven	Box Saloon	1933	A B
402	Bugatti	Type 41 Royale	Park Ward Limousine	1933	A B
221	Pierce	Silver Arrow		1933	A B
369	Austin	Sixteen		1934	A B
415	Citroen	7A	Traction	1934	A B F
642	Duesenberg	SJ	Phaeton	1934	A B
52	Mercedes-Benz	130H	Convertible	1934	A B
488	MG	Midget		1934	A B
656	MG	NA	Special	1934	A B
31	MG	PB Midget		1934	A B
496	Morris	10/4		1934	A B
667	Riley	Imp		1934	A B
556	Tatra	77		1934	A B
675	Triumph	Dolomite		1934	A B
27	Voisin	17CV C14		1934	A B
612	Voisin	C27		1934	A B
567	Z			1934	A B
579	MG	PB Midget		1935	A B
302	Morris	8	Series 1	1935	A B
672	Singer	Le Mans		1935	A B
360	Alvis	Speed 25		1936	A B
348	Auburn	851	Speedster	1936	A B H G
370	Austin	Ten		1936	A B
35	BMW	328		1936	A B

600	Cord	810	Sportsman	1936	A B
32	de Soto	Airflow		1936	A B
92	Fiat	500	Topolino	1936	A B
446	Ford	10		1936	A B
96	Hillman	Aero Minx		1936	A B
333	Packard	V12	Roadster	1936	A B
33	Panhard	Dynamique	Coupe	1936	A B
123	Peugeot	402		1936	A B
270	Bugatti	Type 57		1937	A B
404	Bugatti	Type 57		1937	A B
638	Cord	812 Beverly	Sedan	1937	A B
510	Packard	V8?		1937	A B
514	Panhard	Dynamique		1937	A B
664	Peugeot	402	Eclipse	1937	A B
668	Rolls-Royce	25/30?		1937	A B
683	Talbot	Lago T 150 C Teardrop		1937	A B G
682	Tatra	77		1937	A B
557	Tatra	87		1937	A B
356	Adler	Trumph	Junior	1938	A B
593	Alfa Romeo	6C 2500		1938	A B
591	Alfa Romeo	8c 2900		1938	A B
628	Alfa Romeo	8C 2900B	Spyder	1938	A B
390	BMW	328		1938	A B
636	BMW	328	Wendler	1938	A B
34	Cord	810	Sedan	1938	A B
654	Maybach	Zeppelin		1938	A B
655	Maybach	Zeppelin	(rebodied in 1950s)	1938	A B
519	Peugeot	202	Cabriolet	1938	A B
403	Bugatti	Type 57C	Galibier	1939	A B
37	Citroen	2CV	Prototype	1939	A B
641	Delahaye	T165		1939	A B
36	Lancia	Aprilia		1939	A B
674	Talbot	Lago T 150 C Teardrop		1939	A B

391	BMW	326	Cabriolet	1940	A B
520	Peugeot	Electric	Runabout	1943	A B
524	Rapid			1946	A B
38	De Soto			1947	A B
587	Ferrari	125		1947	A B
575	HRG	1500	Sports 2-seater	1947	A B
216	Tatra	87		1947	A B
39	Volkswagen	Beetle		1947	A B F
594	Alfa Romeo	6C 2500		1948	A B
376	Bentley	Mark 6 Pininfarina	(& MGA)	1948	A B
42	Cisitalia	1100	Coupe	1948	A B
40	Morris	Minor	MM	1948	A B
659	Nardi	Alfa-Romeo		1948	A B
662	Panhard	Dyna X	Coupe	1948	A B
515	Panhard	Dynavia Prototype		1948	A B
30	Citroen	11BL	Traction	1949	A B F
417	Citroen	Light 15	Traction	1949	A B F
343	Delahaye	135M		1949	A B
141	Ferrari	166 MM	Barchetta	1949	A B
45	Buick			1950	A B
342	Gordini	21S		1950	A B
462	Jaguar	XK120		1950	A B F
494	Morgan	F Type	3 wheeler	1950	A B
542	Simca	6		1950	A B
44	Standard	Vanguard	Phase I	1950	A B
552	Studebaker	Champion	Coupe	1950	A B F
43	Triumph	1800	Renown	1950	A B
336	Alfa Romeo	6C 2500	Touring Villa d'Este	1951	A B
260	Bugatti	Type 101	Cabriolet	1951	A B
558	Tatra	Tatraplan		1951	A B
1074	Jaguar	C Type	Special / replica	1952	A B H
47	Jaguar	XK120	Coupe	1952	A B F
74	Jowett	Javelin		1952	A B

377	Bentley	R Type		1953	A B
212	Bentley	R Type	Continental	1953	A B F H G
455	Gordini	23S		1953	A B
459	Hotchkiss-Gregoire		Saloon	1953	A B
661	OSCA	MT4-2AD		1953	A B
48	Studebaker	Commander	Coupe	1953	A B F
188	Sunbeam-Talbot	90		1953	A B G
447	Ford	Vedette		1954	A B
650	Jaguar	XK120	Ghia	1954	A B
608	OSCA	MT4		1954	A B
49	Citroen	DS19		1955	A B F G
256	Fiat	600		1955	A B F
649	Humber	Hawk		1955	A B
466	Jaguar	D Type		1955	A B
605	Lancia	Aurelia	Spider	1955	A B
607	Lister-Bristol			1955	A B
484	Mercedes-Benz	300SL	Gullwing	1955	A B F H G
657	MG	TF	Midget	1955	A B
498	Nardi	Le Mans Racer		1955	A B
137	SAAB	93		1955	A B
406	Cadillac	Sedan de Ville		1956	A B
467	Jaguar	XKSS		1956	A B H G
91	Messerschmitt	KR200	Kabin Scooter	1956	A B
174	MG	Magnette	ZB	1956	A B
568	Packard	Patrician		1956	A B
185	Renault	4CV	Affaires	1956	A B
53	Cadillac	Eldorado		1957	A B F
647	Goggomobil	TS300 Coupe		1957	A B
305	BMW	507		1958	A B F H G
576	Isetta	300+		1958	A F B

677	MG	A	(see Bentley slide)	1958	A B F G
554	Tarf	1		1958	A B
426	DAF	600		1959	A B
54	Edsel	Ranger		1959	A B F
602	Morris	Mini-Minor		1959	A B C F G
547	Standard	Vanguard	Phase III	1959	A B
165	TVR	Grantura	Mk1	1959	A B
55	Chevrolet	Corvair	Convertible	1960	A B
286	Chrysler	Valiant		1960	A B
643	Ferrari	250GT	SWB	1960	A B
249	Metropolitan	1500	Hard top	1960	A B F
50	Panhard	PL17		1960	A B
105	Vauxhall	Cresta		1960	A B
537	Rover	T4 Gas Turbine Car		1961	A B
559	Triumph	Herald	1200	1961	A B C
407	Cadillac		Convertible	1962	A B
601	Facel Vega	Facel II		1962	A B G
603	Ferrari	248 SP		1962	A B
577	Jaguar	E Type	Fixed Head Coupe	1962	A B F H
173	Riley	'4/72		1962	A B C
82	Trojan	200	Cabin Scooter	1962	A B
361	Amphicar	770		1963	A B
374	Auto Union	1000SP	Roadster	1963	A B
825	Ford	Cortina	Mk 1	1963	C
826	Ford	Cortina Lotus		1963	C
51	Isetta			1963	A B
56	Lotus	Elite		1963	A B F H G
503	Ogle	SX1000		1963	A B
85	Porsche	356B		1963	A B F G
644	Ferrari	250GT	Berlinetta Lusso	1964	A B
645	Ferrari	250LM		1964	A B
923	Hillman	Imp		1964	C D F

57	Jaguar	E Type Cunningham	Lightweight Le Mans	1964	A B
468	Jaguar	XJ13		1964	A B H
205	Lotus	Elan		1964	A B H
831	Morris	Minor	1000	1964	C
540	Scootacar			1964	A B
827	Vauxhall	Victor 101	FC	1964	C
828	Vauxhall	Viva	HA	1964	C
371	Austin	A60		1965	A B C
58	Ford	Anglia	105E	1965	A B C F
832	Ford	Corsair		1965	C
448	Ford	Zodiac	Mk III	1965	A B
502	NSU	Wankel	Spider	1965	A B
372	BMC	9X		1966	A B
60	Ford	Mustang	Notchback	1966	A B D F
312	Matra-Bonnet	Djet		1966	A B
489	MG	Mini ADO 34	sports car	1966	A B
538	Rover-BRM	Gas Turbine	Coupe	1966	A B
449	Ford	Lotus-Cortina	Mark 2	1967	A B C
833	Vauxhall	Viva	HB	1967	C
190	AC	Cobra	427	1968	A B G E
635	Bizzarini	5300 GT	Strada	1968	A B
837	Hillman	Hunter		1968	C
61	NSU	Ro80		1968	A B D F G E
787	Alpine	A110		1969	A B
821	Austin	1300	GT	1969	C
838	Austin /Morris	1800		1969	C D
418	Citroen	DS21		1969	A B
487	Mercedes-Benz	C111		1969	A B
830	Triumph	Vitesse	Convertible	1969	C
836	Vauxhall	Victor	FD	1969	C
815	Ford	Capri	3000 GT Mk 1	1970	C H
835	Ford	Cortina	Mk 2	1970	C

824	Hillman	Avenger		1970	C
834	Hillman	Imp		1970	C D
653	Lancia	Flavia	Zagato	1970	A B
847	Volkswagen	Beetle	1500	1970	C F
839	Wolseley	Six		1970	C
83	Lamborghini	Miura	P400	1971	A B H G E
842	Austin	Maxi		1972	C
820	Vauxhall	Viva	HC 2300 SL	1972	C
817	Ford	Escort		1973	C
450	Ford	Escort	Mexico	1973	A B C
509	MG	Midget	(on de Dion slide)	1973	A B
819	Morris	Marina	1.3 saloon	1973	C
822	Vanden Plas	1300		1973	C
187	Alpine	A110		1974	A B
419	Citroen	DS21		1974	A B
428	Datsun	240Z		1974	A B H E
849	Ford	Capri	1600	1974	C
291	SAAB	95 V4	Estate	1974	A B
539	SAAB	96 V4		1974	A B
851	British Leyland	18-22		1975	C
420	Citroen	Dyane 6		1975	A B F
64	Ford	Cortina	Mark 3	1975	A B C
850	Ford	Escort	Mk II 1600 Ghia	1975	C
463	Jaguar	C Type	Special / replica	1975	A B
505	Otosan	Anadol		1975	A B
59	Renault	16	Hatchback	1975	A B D
125	Trabant			1975	A B
840	Triumph	Dolomite		1975	C
841	Triumph	Dolomite	Sprint	1975	C
852	Wolseley	2200		1975	C
421	Citroen	Jyane 602		1976	A B
422	Citroen	Mehari		1976	A B
506	Otosan	Anadol	Estate Car	1976	A B

65	Otosan	Böçek		1976	A B
507	Otosan	STC-16		1976	A B
521	Peugeot	304	Estate	1976	A B
561	Triumph	Lynx		1976	A B
848	Austin	Allegro		1977	C
858	Datsun	Sunny 120Y B210		1977	C
869	Ford	Cortina 2.3 Ghia	Mark 4	1977	C
522	Peugeot	504	Coupe	1977	A B G
66	SAAB	99	Turbo	1977	A B F
560	Triumph	TR7		1977	A B F
872	Volvo	343		1977	C
67	Fiat	X1/9		1978	A B D F
871	Ford	Capri		1978	C
451	Ford	Cortina	Mark 4	1978	A B C
669	Rolls-Royce	Silver Shadow		1978	A B D F
854	Vauxhall	Chevette	Hatchback	1978	C
853	Vauxhall	Chevette	Saloon	1978	C
974	Volkswagen	Golf	3-door	1978	A B D F E
857	Datsun	Sunny B310	Saloon	1979	C
856	Ford	Fiesta		1979	C D
859	Ford	Granada		1979	C D F
972	Ford	Granada		1979	C D
855	Vauxhall	Cavalier	Saloon	1979	C
452	Ford	Capri		1980	A B C
861	Ford	Escort	Mk III	1980	C D
495	Morgan-type	mini-based	Three-wheeler	1980	A B
862	Renault	18		1980	C F
866	Vauxhall	Astra		1980	C
63	Volkswagen	Golf	5-door	1980	A B D F E
863	Austin	Metro		1981	C D
865	Datsun	Cherry N10		1981	C
870	Datsun	Sunny	1.5DX	1982	C

860	Ford	Cortina	Mk V	1982	C
973	Ford	Escort	Mk III	1982	C D
864	Morris	Ital		1982	C
562	Vauxhall	Cavalier		1982	A B C
68	Audi	100		1983	A B D F
69	Audi	Quattro		1983	A B G E
874	Austin	Maestro		1983	C
72	BL Technology	ECV3		1983	A B
401	Bugatti	Type 41 Royale	Esders Reproduction	1983	A B
877	Opel	Corsa	hatchback	1983	C
876	Opel	Corsa	saloon	1983	C
879	Peugeot	205		1983	C D
867	Triumph	Acclaim		1983	C
875	Vauxhall	Nova	hatchback	1983	C
378	Bentley	Eight		1984	A B
423	Citroen	Eco 2000	SL10	1984	A B
873	Ford	Fiesta	1.1 Ghia	1984	C
878	Ford	Orion		1984	C
572	Ford	Sierra	2000	1984	C D F
818	Ford	Sierra	4X4	1984	A B C
482	Mazda	MX02		1984	A B
500	Nissan	Prairie		1984	A B
71	Opel	Kadett		1984	A B C D
530	Renault	25		1984	A B D
868	Volvo	340	Saloon	1984	C
441	Elswick	Envoy		1985	A B
465	Jaguar	XJR5	(with D type)	1985	A B
70	Mercedes-Benz	190D		1985	A B F
884	Rover	213		1985	C
585	Vauxhall	Astra		1985	A B C D
975	Austin	Metro		1986	C D
73	Austin Rover	CCV		1986	A B
569	de Lorean			1986	A B

A	Ford	Eltec		1986	A B
883	Ford	Orion		1986	C
425	Kougar			1986	A B
490	MG	Montego	turbo	1986	A B C
881	Ford	Escort		1987	C
882	Ford	Escort		1987	C
888	Ford	Fiesta		1989	C D
887	Rover	216 GS1		1989	C
886	Vauxhall	Cavalier	Saloon	1989	C D
814	Ford	Escort		1990	C
477	Locomobile	Steam Buggy	Replica	1990	A B
589	Monash University	Solar Car II		1990	A B
294	Tatra	613		1990	A B
666	TH Darmstadt	Renn Solarmobil	Pinky	1990	A B
885	Vauxhall	Cavalier		1990	C D
893	Renault	Clio		1991	C D
604	Ferrari	Testarossa		1992	A B
890	Ford	Orion		1992	C
574	Honda	Prototype	Saloon	1992	A B
149	Mazda	Xedos		1993	A B
880	Peugeot	205 GTI		1993	C
892	Peugeot	405		1993	C D
891	Vauxhall	Astra		1993	C D
894	Ford	Escort		1994	C
895	Ford	Mondeo 1.8LX	Saloon	1994	C D
979	Ford	Mondeo 1.8LX	Saloon	1994	C D
464	Jaguar	D Type	Lynx	1994	A B
899	Peugeot	306	3-door	1994	C
531	Renault	Twingo		1994	A B F
362	Audi	TT	Coupe Concept	1995	A B
599	Bugatti	Type 41 Royale	Reconstruction	1995	A B
902	Ford	Fiesta		1995	C
501	Nissan	300ZX		1995	A B F G

903	Rover	100		1995	C
900	Ford	Escort		1996	C
905	Ford	Mondeo	Hatchback	1996	C
906	Ford	Mondeo ST200	Hatchback	1996	C
469	JDM	Orane	Microcar	1996	A B
584	MG	F		1996	A B
532	Renault	Fiftie		1996	A B
901	Rover	200	SD1	1996	C
898	Peugeot	306	5-door	1997	C
957	Ford	Focus	3-door	1998	C D
794	Ford	Focus	5-door	1998	C D F
614	Ford	Puma		1998	A B
897	Peugeot	306	GTi	1998	C
615	Renault	Espace		1998	A B
908	Rover	400	Saloon	1998	C
896	Peugeot	306	Cabriolet	1999	C
806	Renault	Megane	1.6 RT Hatchback	1999	C
805	Vauxhall	Corsa	1.0	1999	C F
808	Volkswagen	Golf	2.0 FSI 5dr	1999	C D
774	BMW	330d M Sport	Saloon	2000	C
907	Vauxhall	Vectra	Hatchback	2000	C
809	BMW	Mini Cooper		2001	C D F
807	Citroen	Xsara	HDi	2001	C
804	Ford	Fiesta	1.3 Hatchback	2001	C
803	Vauxhall	Astra	Hatchback	2001	C D
2136	BMW	Mini One		2002	C D F
775	Renault	Megane	1.6 Privilège Hatchback	2002	C D F
781	Volkswagen	Golf	R32	2002	C
773	Ford	Fiesta	1.25 LX Hatchback	2003	C D
784	Peugeot	307	1.6 HDi 90	2003	C D
763	Ford	Focus	1.6 Ti-VCT Zetec Hatchback	2004	C D
777	Ford	Mondeo	ST TDCi Hatchback	2004	C D
782	Peugeot	206	GTi HDi 110 3-door	2004	C D

783	Renault	Clio	Renault sport 182	2004	C
780	Volkswagen	Golf	2.0 FSI 5dr	2004	C D
795	Ford	Ka	1.3i	2005	C D
776	Renault	Clio	1.4 16v Dynamique Hatchback	2005	C D
771	Vauxhall	Zafira	1.6i 16v Club 5dr MPV	2005	C
779	Peugeot	207	1.4 (90bhp) Sport 5dr hatch	2006	C D
2138	Peugeot	307	1.6 HDi 90	2006	C
766	Vauxhall	Astra	1.6 16v SXi Hatchback	2006	C D
778	Vauxhall	Corsa	1.2 SXi 5dr	2006	C
772	Vauxhall	Vectra	1.9 CDTi 16v Club Hatchback	2006	C D
770	Ford	Mondeo	2.0 TDCi Hatchback	2007	C D
768	Peugeot	207	GTi 3-door hatch	2007	C D
764	Vauxhall	Corsa	1.4i 16v Club 3dr Hatchback	2007	C D
769	BMW	3-series	330d M Sport Saloon	2008	C D
765	Ford	Fiesta	1.4i Zetec Hatchback	2008	C D
982	Ford	Fiesta	1.4i Zetec Hatchback	2008	C D
988	Mercedes-Benz	C-Klasse	180 Kompressor Blue Efficiency	2008	D C
925	Nissan	Qashqai	+2 2.0	2008	C D
802	Vauxhall	Insignia	2.0 CDTi ecoFLEX Exclusiv (160bhp) 5d	2009	C D
767	Volkswagen	Golf	2.0 TDI 140 GT	2009	C D
796	Volkswagen	Polo	1.4	2010	C D
987	BMW	1-series	114i	2012	C
986	BMW	3-series	320i	2012	C
930	Ford	Focus	1.0 Ecoboost	2012	C D
992	Peugeot	208	1.2 VTi Active 5dr	2012	C D
2151	Vauxhall	Astra	1.7 CDTI	2012	C D
985	Volkswagen	Golf	1.4 TSI Blue Motion	2012	C D
2028	Ford	Fiesta		2013	C

Table A7.1 List of cars in the analysis

Code	Meaning
A	In the original sample
B	The original sample without the racing cars, non-cars and partial cars
C	UK Best selling cars
D	Car of the Year
E	Car of the Century
F	Paolo Tumminelli's list
G	Daily Telegraph 100 most beautiful cars
H	Autocar 100 most beautiful cars

Table A7.2 Analysis codes referred to in Table A7.1

Table A7.2 lists the meaning of the codes in Table A7.1. The list in Table A7.1 includes the cars that were analysed: the database also includes the full list of cars from the Car of the Year lists, cars from the Car of the Century list, Paolo Tumminelli's list of cars used in his books, the Daily Telegraph list of 100 most beautiful cars and the Autocar list of 100 most beautiful cars.

Illustrations of the cars can be seen in Table A7.3. It should be noted that there are frequently more pictures of each car. The one shown is the first one that the database picks up, which may not be the most photogenic illustration in the databases.

A8 List of Relevant Published Articles and Papers

A8 List of Relevant Published Articles and Papers

1. Structural Design: Three Alternative Paradigms; Proceedings of International Conference on Engineering Design, Prague, August 1995; WDK, Zürich.

2. Using Car History for Teaching Engineering and Design; in Explorations in Motoring History, Oxbow Books, Oxford, 1997, pages 57 - 64. ISBN 1 900188 48 1.

3. Using Car History for Teaching Engineering and Design; International Conference on Engineering Design, ICED'97, Tampere, Finland, pages 763 - 768. ISBN 951-722-788-4.

4. Development of Design Paradigms: ICED'99: International Conference on Engineering Design, Technical University, Munich, 1999.

5. The Evolution of the Car: An investigation into Product History. Similarities, contrasts and questions. Design and Nature 2002, Udine, Italy, WIT Press, 2002

6. Early Car History – Investigation of the Establishment of a 'Design Paradigm'. Common Ground conference, Brunel University, Design Research Society, 2002

7. Design History of the Car: An Empirical Overview of the Development of Layout and Form, with John Shackleton, Brunel University; ICED'03, Stockholm: Design Society, 2003:

8. Patterns of car history. A teaching aid that developed into a research project: International conference on engineering and product design education: September 2010, Norwegian University of Science and Technology, Trondheim, Norway

9. Measuring history: Does historical car performance follow the TRIZ performance S curve? International conference on engineering design, ICED11. August 2011, Technical University of Denmark

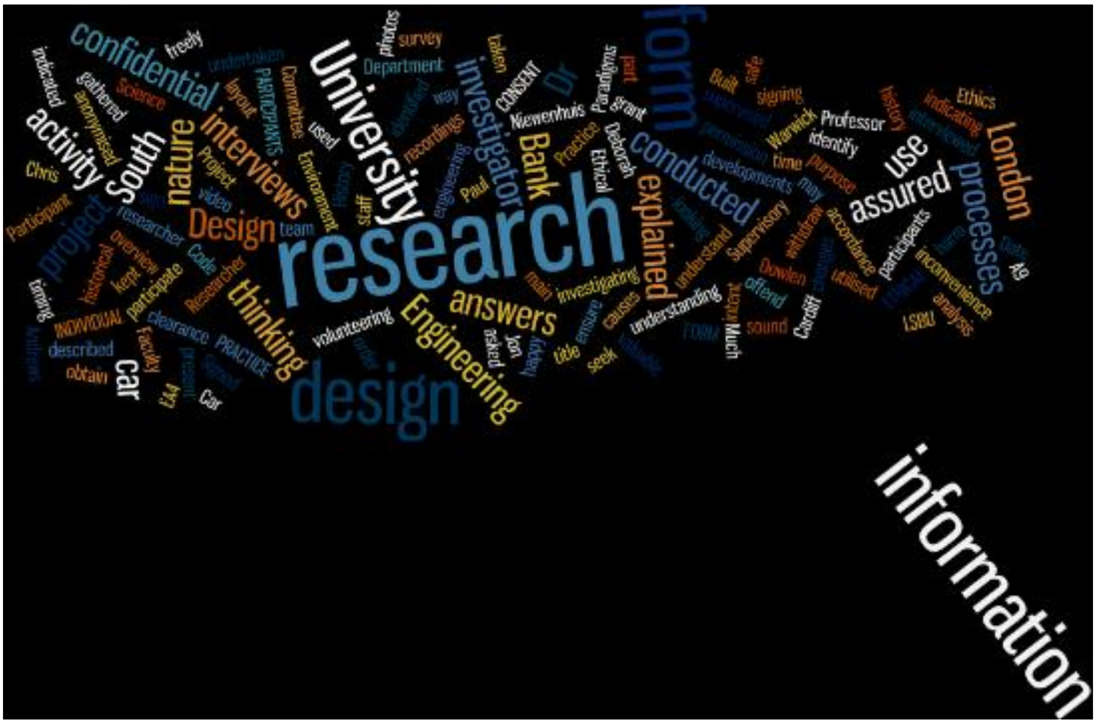
10. (Perceptions of Product History: NordDesign 2012, Aalborg University. Written and accepted but not published)

11. Creativity in car design – the behaviour at the edges: The 2nd International Conference on Design Creativity (ICDC2012), September 2012, Glasgow.

12. Automobile design history – what can we learn from the behavior at the edges? Journal of Design Creativity, 2012.

13. The United Kingdom's best-selling cars: SAHB Times, Issue 81, Summer 2015, The Society of Automotive Historians in Britain.

A9 Ethical clearance



A9 Ethical clearance

Each of those who were interviewed were asked to sign the form below that explained how the answers to their interviews would be utilised and that they were happy that the research should be undertaken. The main purpose of the form was to ensure the participants that their answers would be kept confidential.

EA4. ETHICAL PRACTICE

INDIVIDUAL CONSENT FORM FOR PARTICIPANTS

Design and Engineering Department

Faculty of Engineering, Science and the Built Environment

London South Bank University

Researcher	**Chris Dowlen**
Project title and overview	**Design Paradigms in Car History**

The research is investigating design thinking processes in car history. Much of the research is an analysis of car layout and form design from 1878 to the present in order to obtain information about changes and developments, their timing, nature and causes. This part of the research is to use interviews to seek to identify design thinking processes and historical understanding.

Supervisory team

Professor Jon Warwick, Dr Deborah Andrews (LSBU) and Dr Paul Niewenhuis (Cardiff University)

I understand that I am volunteering freely to participate in this survey and design / engineering project, which will be conducted by the researcher and supervised by the staff indicated.

By signing this form I am indicating that the investigator

1 has identified himself

2 has explained the nature of the project, his intent and what he is looking for

3 has described how this information will be used and why it's valuable

4 has assured me that the research activity is safe and will not inconvenience, offend or harm me in any way and that I may withdraw at any time

5 assured me that all the information gathered is confidential and will be anonymised

I grant permission for the investigator to use the information and any photos and / or video or sound recordings taken

Participant

Signed Date

This research activity is being conducted in accordance with London South Bank University Ethics Committee Code of Practice.