The history, development and construction of the car body

1.1 Development of the motor car body

1.1.1 Brief history

The first motor car bodies and chassis frames, made between 1896 and 1910, were similar in design to horse-drawn carriages and, like the carriages, were made almost entirely of wood.

The frames were generally made from heavy ash, and the joints were reinforced by wrought iron brackets which were individually fitted. The panels were either cedar or Honduras mahogany about 9.5 mm thick, glued, pinned or screwed to the framework. The tops, on cars which had them, were of rubberized canvas or other fabrics. Some bodies were built with closed cabs, and the tops were held in place by strips of wood bent to form a solid frame. About 1921 the Weymann construction was introduced, in which the floor structure carried all the weight of the seating, and the body shell, which was of very light construction, was attached to the floor unit. Each joint in the shell and between the shell and the floor was made by a pair of steel plates, one on each side of the joint and bolted through both pieces of timber, leaving a slight gap between the two pieces. The panelling was of fabric, first canvas, then a layer of wadding calico and finally a covering of leather cloth. This form of construction allowed flexibility in the framing and made a very light and quiet body frame, but the outer covering had a very short life.

As the demand for vehicles increased it became necessary to find a quicker method of production. Up to that time steel had been shaped by hand, but it was known that metal in large sheets could be shaped using simple die tools in presses, and machine presses were introduced to the steel industry to form steel sheets into body panels. Initially the sheets were not formed into complex shapes or contours, and the first bodies were very square and angular with few curves. The frame and inner construction was still for the most part made of wood, as shown in Figure 1.1. About 1923 the first attempts were made to build all-steel bodies, but these were not satisfactory as the design principles used were similar to those which had been adopted for the timber-framed body. The real beginning of the all-steel body shell came in 1927, when presses became capable of producing a greater number of panels and in more complex shapes; this was the dawn of the mass production era. During the 1930s most of the large companies who manufactured motor vehicles adopted the use of metal for the complete construction of the body shell, and motor cars began to be produced in even greater quantities.

Owing to the ever-increasing demand for private transport, competition increased between rival firms, and in consequence their body engineers began to incorporate features which added to the comfort of the driver and passenger. This brought about the development of the closed cars or saloons as we know them today. The gradual development of the shape of the motor car body can be clearly seen in Figure 1.2, which shows a
Repair of Vehicle Bodies

The inner construction of the head roof of these saloons was concealed by a headlining. Up to and including the immediate post-war years, this headlining was made from a woollen fabric stitched together and tacked into position on wooden frames. However, the more recently developed plastic and vinyl materials were found to be more suitable than fabric, being cheaper and easier to clean and fit. They are fitted by stretching over self-tensioning frames which are clipped into position for easy removal, or alternatively the headlining is fastened into position with adhesives.

Comfort improved tremendously with the use of latex foam rubber together with coil springs in the seating, instead of the original plain springing. The general interior finish has also been improved by the introduction of door trim pads, fully trimmed dash panels and a floor covering of either removable rubber or carpeting.

Then came the general use of celluloid for windows instead of side curtains, and next a raising and lowering mechanism for the windows. Nowadays the windscreen and door glasses are made of laminated and/or toughened safety glass. The window mechanism in use today did not begin to develop until well into the 1920s.

Mudguards, which began as wooden or leather protections against splattered mud, grew into wide splayed deflectors in the early part of the twentieth century and then gradually receded into the body work, becoming gracefully moulded into the streamlining of the modern motor car and taking the name of wings. Carriage steps retained on earlier models gave place to running boards which in their turn disappeared altogether.

Steering between 1890 and 1906 was operated by a tiller (Figure 1.3). This was followed by the steering wheel which is in current use. The position of the gear lever made an early change from the floor to the steering column, only to return to some convenient place on the floor.

Some of the first vehicles, or horseless carriages as they were known, carried no lights at all; then carriage candle lamps made their appearance. Later came oil lamps, acetylene lamps and finally the electric lighting system, first fitted as a luxury extra and ultimately becoming standard and finally obligatory equipment which must conform with legislation of the day.

When windscreens were first introduced such accessories as windscreen wipers and washers were unknown. Then came the single hand-operated wiper, followed by the suction wiper and finally electrically driven wipers.

The design of the wheels was at first dictated by fashion. It was considered necessary for the rear wheels to be larger than the front, a legacy from the elegant horse-drawn carriages. Wooden spokes and iron tyres were the first wheels to appear, and with both rear and front wheels of the same dimensions. Then came the wooden-spoked artillery wheel with pneumatic tyre (Figure 1.4). The artillery wheel gave way to the wire-spoked wheel, and this in turn to the modern disc wheel with tubeless tyres.

Great strides have been made in the evolution of the motor car since 1770, when Cugnot’s steam wagon travelled at 3 mile/h (4.8 km/h), to the modern
1909 The first Baby Austin

1922 Austin Tourer

1932 Austin Saloon

1946 Austin 16

Figure 1.2  Development of the Austin car body 1909 to 1992, from Edwardian to modern construction methods
4 Repair of Vehicle Bodies

Figure 1.2 (continued)
The history, development and construction of the car body

1963 Austin 1100

1964 Austin 1800

1970 Austin Maxi 1800

1973 Austin Allegro

Figure 1.2 (continued)
6 Repair of Vehicle Bodies

Figure 1.2 (continued)
The history, development and construction of the car body

1984 Austin Montego

1986 Austin Rover 200

1987 Austin Rover Sterling

1988 Rover 820 Fastback

1989 Mini Flame

Figure 1.2 (continued)
vehicle which can carry driver and passengers in silence, comfort and safety at speeds which at one time were thought to be beyond human endurance; indeed, special vehicles on prepared tracks are now approaching the speed of sound.

It must be borne in mind that the speed of the vehicle is governed by (a) the type of power unit, (b) its stability and manoeuvring capabilities and (c) its shape, which is perhaps at present one of the most important features in high-speed travel. Whatever the mechanical future of the car, we may rest assured that the shape of the motor car body will continue to change as technical progress is made (Figure 1.5).

### 1.1.2 Highlights of motor vehicle history

The idea of a self-propelled vehicle occurs in Homer’s *Iliad*. Vulcan, the blacksmith of the gods, in one day made 20 tricycles which ‘self-moved obedient to the beck of the gods’. The landmarks in more modern motor vehicle history are as follows:

1688 Ferdinand Verbiest, missionary in China, made a model steam carriage using the steam turbine principle.
1740 Jacques de Vaucansen showed a clockwork carriage in Paris.
1765 Watt developed the steam engine.
1765 Nicholas Joseph Cugnot, a French artillery officer, built a steam wagon which carried four people at a speed of 2.25 mile/h. It overturned in the streets of Paris and Cugnot was thrown into prison for endangering the populace.
1803 Richard Trevithick built a steam carriage and drove it in Cornwall.
1831 Sir Charles Dance ran a steam coach (built by Sir Goldsworthy Gurney) on a regular
service from Gloucester to Cheltenham. Sometimes they did four round trips a day, doing 9 miles in 45 minutes. The steam coaches were driven off the road by the vested interests of the stage coach companies, who increased toll charges and piled heaps of stones in the roads along which the steam coaches passed. This, combined with the problems of boilers bursting and mechanical breakdowns and the advent of the railways, contributed to the withdrawal of the steam coaches.

**Figure 1.4** 1905 and 1909 Vauxhalls with wooden spoked artillery wheels with pneumatic tyres
(*Vauxhall Motors Ltd*)

**Figure 1.5** Twin concept car with interchangeable engines (petrol/electric motor drive module)
(*Vauxhall Motors Ltd*)

1859 Oil was discovered in USA.
1865 The Locomotive Act of 1865 (the Red Flag Act) was pushed through by the railway and coach owners. One of the stipulations was...
that at least three people must be employed to conduct the locomotive through the streets, one of whom had to walk 60 yards in front carrying a red flag. Speeds were restricted to 2–4 mile/h. This legislation held back the development of the motor vehicle in Great Britain for 31 years, allowing the continental countries to take the lead in this field.

1885 Karl Benz produced his first car. This is recognized as being the first car with an internal combustion engine as we know it.

1886 Gottlieb Daimler also produced a car.

1890 Panhard and Levassor began making cars in France.

1892 Charles and Frank Duryea built the first American petrol-driven car, although steam cars had been in use long before this.

1895 First motor race in Paris.

1896 The repeal of the Red Flag Act. This is commemorated by the London to Brighton veteran car run. The speed limit was raised to 12 mile/h and remained at that until 1903, when the 20 mile/h limit in built-up areas was introduced. There was much persecution of motorists by police at this time, which led to the formation of the RAC and the AA.

1897 The RAC was formed, largely through the efforts of F. R. Simms, who also founded the SMMT in 1902.

1899 Jenatzy set world speed record of 66 mile/h.

1900 Steering wheel replaces tiller.

1901 Front-mounted engine. Mercedes car produced.

1902 Running board.

1903 Serpollet did a speed of 74 km/h in a steamcar.

1903 Pressed steel frames.

First windshield.

The Motor Car Act resulted in considerable persecution of the motorist for speeding, number plates and lights, so much so that the motoring organizations paid cyclists to find police speed traps.

1904 Folding windshield.

Closed saloon-type body.

A petrol car reached 100 mile/h and, in the same year, a Stanley steam car achieved a speed of 127 mile/h. Stanley steam cars used paraffin in a multtube boiler and had a chassis made from hickory.

Rolls-Royce exhibited their first car in Paris. The motoring press were impressed with its reliability.

Veteran cars are cars up to and including this year.

1.1.3 Terms used to describe early vehicle body styles

In the history of the motor car there has been some ambiguity in the names used to describe various types of body styles, built by coach builders from different countries. The following terms relate to the vehicles produced during the period 1895 to 1915, and show the derivation of the terminology used to describe the modern vehicle.

**Berlina** Rarely used before the First World War. A closed luxury car with small windows which allowed the occupants to see without being seen.

**Cab** A term taken directly from the days of the horse-drawn carriages. Used to describe an enclosed vehicle which carried two passengers, while the driver was situated in front of this compartment and unprotected.

**Cabriolet** Used towards the end of the period. Describes a car with a collapsible hood and seating two or four people.

**Coupé** A vehicle divided by a fixed or movable glass partition, behind the front seat. The driver’s position was only partially protected by the roof whilst the rear compartment was totally enclosed and very luxurious.

**Coupé cabriolet or double cabriolet** A long vehicle having the front part designed as a coupé and the rear part designed as a cabriolet. There were often two supplementary seats.

**Coupé chauffeur** A coupé with the driving position completely covered by an extension of the rear roof.

**Coupé de ville** A coupé having the driving position completely open.

**Coupé limousine** A vehicle having a totally enclosed rear compartment and the front driving position closed on the sides only.

**Double Berlina** A longer version of the Berlina but having the driving position separated from the rear part of the vehicle.
Double landaulet A longer version of the landaulet. It had two permanent seats plus two occasional seats in the rear and a driving position in front. 
Double phaeton A phaeton which had two double seats including the driver’s seat.
Double tonneau A longer version of the tonneau in which the front seats were completely separated from the rear seats.
Landau A cabriolet limousine having only the roof behind the rear windows collapsible.
Landaulet or landaulette A small landau having only two seats in the closed collapsible roof portion.
Limousine A longer version of the coupé with double side windows in the rear compartment.
Limousine chauffeur A limousine with an extended rear roof to cover the driving position.
Phaeton A term from the days of the horse-drawn carriage. In early motoring it was used to describe a lightweight car with large spoked wheels, one double seat and usually a hood.
Runabout An open sporting type of vehicle with simple bodywork and two seats only.
Tonneau An open vehicle having a front bench seat and a semicircular rear seat which was built into the rear doors.
Glass saloon A large closed vehicle similar to a double Berlina but with enlarged windows.
Saloon A vehicle having the driving seat inside the enclosed car but not separated from the rear seat by a partition.
Torpedo A long sports vehicle having its hood attached to the windscreen.
Victoria Another term derived from the era of horses. The Victoria was a long, luxurious vehicle with a separate driving position and a large rear seat. It was equipped with hoods and side screens.
Wagon saloon A particularly luxurious saloon used for official purposes.

1.1.4 Vehicle classification

There are many ways in which motor vehicles may be classified into convenient groups for recognition. Much depends on such factors as the manufacturer, the make of the car, the series and the body type or style. Distinctive groups of passenger vehicle bodies include the following:

1 Small-bodied mass-produced vehicles
2 Medium-bodied mass-produced vehicles
3 Large-bodied mass-produced vehicles
4 Modified mass-produced bodywork to give a standard production model a more distinctive appearance
5 Specially built vehicles using the major components of mass-produced models
6 High-quality coach-built limousines (hand made)
7 Sports and GT bodywork (mass-produced)
8 Specially coach-built sports cars (hand made).

Styling forms include the following:

Saloon The most popular style for passenger vehicles is the two-door or four-door saloon. It has a fully enclosed, fixed-roof body for four or more people. This body style also has a separate luggage or boot compartment (Figure 1.6a).
Hatchback This body style is identified by its characteristics sloping rear tailgate, which is classed as one of the three or five doors. With the rear seats down there is no division between the passenger and luggage compartments and this increases the luggage carrying capacity of the vehicle (Figure 1.6b).
Estate This type of vehicle is styled so that the roof extends to the rear to give more luggage space, especially when the rear seats are lowered (Figure 1.6c).
Sports coupé and coupé A sports coupé is a two-seater sports car with a fixed roof and a high-performance engine. A coupé is a two-door, fixed-roof, high-performance vehicle with similar styling but with two extra seats at the rear, and is sometimes referred to as a ‘2-plus-2’ (Figure 1.6d).
Convertible or cabriolet This can have either two or four doors. It has a soft-top folding roof (hood) and wind-up windows, together with fully enclosed or open bodywork (Figure 1.6e).
Sports This is a two-seater vehicle with a high-performance engine and a folding or removable roof (hood) (Figure 1.6f).
Limousine This vehicle is characterized by its extended length, a high roofline to allow better headroom for seating five passengers comfortably behind the driver, a high-quality finish and luxurious interiors (Figure 1.6g).

1.1.5 The evolution of design

When the first motor cars appeared, little attention was paid to their appearance; it was enough that they ran. Consequently the cars initially sold
Figure 1.6  Vehicle styling forms: (a) saloon (b) hatchback
The history, development and construction of the car body

Figure 1.6  (c) estate (d) coupé (e) convertible
Repair of Vehicle Bodies

14

Figure 1.6 (f) sports (g) limousine

to the public mostly resembled horse-drawn carriages with engines added. Henry Ford launched his Model T in 1908, and it sold on its low price and utility rather than its looks. However, the body design of this car had to be changed over its 19 year production span to reflect changes in customer taste.

The 1930s saw greater emphasis on streamlining design. Manufacturers began to use wind tunnels to eliminate unnecessary drag-inducing projections from their cars. One of the dominant styling features of the 1950s and 1960s was the tail fin, inspired by the twin tail fins of the wartime Lockheed Lightning fighter aircraft. Eventually a reaction set in against such excesses and the trend returned to more streamlined styling.

In creating cars for today’s highly competitive car market, designers have to do far more than just achieve a pleasing shape. National legal requirements determine the positions of lamps, direction indicators and other safety-related items, while the buying market has become much more sophisticated than before. Fuel economy, comfort, function and versatility are now extremely important.

1.2 Creation of a new design from concept to realization

The planning, design, engineering and development of a new motor car is an extremely complex process. With approximately 15 000 separate parts, the car is the most complicated piece of equipment built using mass production methods.
Every major design project has its own design team led by a design manager, and they stay with the project throughout. The size of the team varies according to the progress and status of the project. The skill and judgement of the trained and experienced automotive designer is vital to the creation of any design concept.

To assist in the speed and accuracy of the ensuing stages of the design process (the implementation), some of the most advanced computer-assisted design equipment is used by the large vehicle manufacturers. For example, computer-controlled measuring bridges that can automatically scan model surfaces, or machines that can mill surfaces, are linked to a computer centre through a highly sophisticated satellite communication network. The key terms in computer equipment are as follows:

- **Computer-aided design (CAD)**: Computer-assisted design work, basically using graphics.
- **Computer-aided engineering (CAE)**: All computer-aided activities with respect to technical data processing, from idea to preparation for production, integrated in an optimum way.
- **Computer-aided manufacturing (CAM)**: Preparation of production and analysis of production processes.
- **Computer-integrated manufacturing (CIM)**: All computer-aided activities from idea to serial production.

The use of CAE is growing in the automotive industry and will probably result in further widespread changes. Historically, the aerospace industry was the leader in CAE development. The three major motor companies of GM, Ford and Chrysler started their CAE activities as soon as computers became readily available in the early 1960s. The larger automotive companies in Europe started CAE activities in the early 1970s – about the same time as the Japanese companies.

Each new project starts with a series of detailed paper studies, aimed at identifying the most competitive and innovative product in whichever part of the market is under review. Original research into systems and concepts is then balanced against careful analysis of operating characteristics, features performance and economy targets, the projected cost of ownership and essential dimensional requirements. Research into competitors’ vehicles, market research to judge tastes in future years, and possible changes in legislation are all factors that have to be taken into account by the product planners when determining the specification of a new vehicle.

The various stages of the design process are as follows:

1. Vehicle styling, ergonomics and safety
2. Production of scale and full-size models
3. Engine performance and testing
4. Wind tunnel testing
5. Prototype production
6. Prototype testing
7. Body engineering for production

### 1.2.1 Vehicle styling

**Styling**

Styling has existed from early times. However, the terms ‘stylist’ and ‘styling’ originally came into common usage in the automotive industry during the first part of the twentieth century.

The automotive stylist needs to be a combination of artist, inventor, craftsman and engineer, with the ability to conceive new and imaginative ideas and to bring these ideas to economic reality by using up-to-date techniques and facilities. He must have a complete understanding of the vehicle and its functions, and a thorough knowledge of the materials available, the costs involved, the capabilities of the production machinery, the sources of supply and the directions of worldwide changes. His responsibilities include the conception, detail, design and development of all new products, both visual and mechanical. This includes the exterior form, all applied facias, the complete interior, controls, instrumentation, seating, and the colours and textures of everything visible outside and inside the vehicle.

Styling departments vary enormously in size and facilities, ranging from the individual consultant stylist to the comprehensive resources of major American motor corporations like General Motors, who have more than 2000 staff in their styling department at Detroit. The individual consultant designer usually provides designs for
organizations which are too small to employ full-time stylists. Some act as an additional brain for organizations who want to inject new ideas into their own production. Among the famous designers are the Italians Pininfarina (Lancia, Ferrari, Alfa), Bertone (Lamborghini), Ghia (Ford) and Issigonis (Mini).

The work of the modern car stylist is governed by the compromise between his creativity and the world of production engineering. Every specification, vehicle type, payload, overall dimensions, engine power and vehicle image inspire the stylist and the design proposals he will make. Initially he makes freehand sketches of all the fundamental components placed in their correct positions. If the drawing does not reduce the potential of the original ideas, he then produces more comprehensive sketches of this design, using colours to indicate more clearly to the senior executives the initial thinking of the design (Figure 1.7). Usually the highly successful classic designs are the work of one outstanding individual stylist rather than of a team.

The main aim of the designer is to improve passenger comfort and protection, vision, heating and ventilation. The styling team may consider the transverse engine as a means of reducing the space occupied by the mechanical elements of the car. Front-wheel drive eliminates the drive shaft and tunnel and the occupants can sit more comfortably. Certain minimum standards are laid down with regard to seat widths, kneeroom and headroom. The interior dimensions of the car are part of the initial specifications and not subject to much modification. Every inch of space is considered in the attempt to provide the maximum interior capacity for the design. The final dimensions of the interior and luggage space are shown in a drawing, together with provision for the engine and remaining mechanical assemblies.

Ergonomics

Ergonomics is a fundamental component of the process of vehicle design. It is the consideration of human factors in the efficient layout of controls in the driver’s environment. In the design of instrument panels, factors such as the driver’s reach zones and his field of vision, together with international standards, all have to be considered. Legal standards include material performance in relation to energy absorption and deformation under impact. The vision and reach zones are geometrically defined, and allow for the elimination of instrument reflections in the windshield.

Basic elements affecting the driver’s relationship to the instrument panel controls, instruments, steering wheel, pedals, seats and other vital elements in the car are positioned for initial evaluation using the ‘Manikin’, which is a two- and three-dimensional measuring tool developed as a result of numerous anthropometric surveys and representing the human figure. Changes are recorded until the designer is satisfied that an optimum layout has been achieved.

1.2.2 Safety

With regard to bodywork, the vehicle designer must take into account the safety of the driver, passengers and other road users. Although the vehicle cannot be expected to withstand collision with obstacles or other vehicles, much can be done to reduce the effects of collision by the use of careful design of the overall shape, the selection of suitable materials and the design of the components. The chances of injury can be reduced both outside and inside the vehicle by avoiding sharp-edged, projecting elements.

Every car should be designed with the following crash safety principles in mind:

1. The impact from a collision is absorbed gradually by controlled deformation of the outer parts of the car body.
The passenger area is kept intact as long as possible.

3 The interior is designed to reduce the risk of injury.

Safety-related vehicle laws cover design, performance levels and the associated testing procedures; requirements for tests, inspections, documentation and records for the process of approval; checks that standards are being maintained during production; the issue of safety-related documentation; and many other requirements throughout the vehicle’s service life.

Primary or active safety
This refers to the features designed into the vehicle which reduce the possibility of an accident. These include primary design elements such as dual-circuit braking systems, anti-lock braking systems, high aerodynamic stability and efficient bad-weather equipment, together with features that make the driver’s environment safer, such as efficient through ventilation, orthopaedic seating, improved all-round vision, easy to read instruments and ergonomic controls.

An anti-lock braking system (ABS) enhances a driver’s ability to steer the vehicle during hard braking. Sensors monitor how fast the wheels are rotating and feed data continuously to a microprocessor in the vehicle to signal that a wheel is approaching lockup. The computer responds by sending a signal to apply and release brake pressure as required. This pumping action continues as long as the driver maintains adequate force on the brake pedal and impending wheel lock condition is sensed.

The stability and handling of the vehicle are affected by the width of the track and the position of the centre of gravity. Therefore the lower the centre of gravity and the wider the track the more stable is the vehicle.

Secondary or passive safety
If a crash does happen, secondary safety design should protect the passengers by

1 Making sure that, in the event of an accident, the occupants stay inside the car
2 Minimizing the magnitude and duration of the deceleration to which they are subjected
3 Restraining the occupants so that they are not injured by secondary impacts within the car, and, if they do strike parts of the inside of the vehicle, making sure that there is sufficient padding to prevent serious injury
4 Designing the outside of the vehicle so that the least possible injury is caused to pedestrians and others who may come into contact with the outside of the vehicle.

The primary concern is to develop efficient restraint systems which are comfortable to wear and easy to use. Manufacturers are now fitting automatic seatbelt tensioners. These automatic ‘body lock’ front seatbelt tensioners reduce the severity of head injuries by 20 per cent with similar gains in chest protection. In impacts over 12 mile/h (20 km/h) the extra tension in the seatbelt buckle triggers a sensor which tightens the lap and diagonal belts in 22 milliseconds, that is before the occupant even starts to move. In addition, because it operates at low speeds, it covers a broad spectrum of accident situations. Anti-submarining ramps built into the front seats further aid safety by reducing the possibility of occupants sliding under the belt (Figure 1.8).

There are also engineering features such as impact energy-absorbing steering columns, head restraints, bumpers, anti-burst door locks, and self-aligning steering wheels. Anti-burst door locks are to prevent unrestrained occupants from falling out of the vehicle, especially during roll-over. The chances of survival are much reduced if the occupant is thrown out. Broad padded steering wheels are used to prevent head or chest damage. Collapsible steering columns also prevent damage to the chest and abdomen and are designed to

Figure 1.8 Automatic seatbelt tensioner (Vauxhall Motors Ltd)
prevent the steering column being pushed back into the passenger compartment whilst the front end is crumpling. The self-aligning steering wheel is designed to distribute force more evenly if the driver comes into contact with the steering wheel during a crash. This steering wheel has an energy-absorbing hub which incorporates six deformable metal legs. In a crash, the wheel deforms at the hub and the metal legs align the wheel parallel to the chest of the driver to help spread the impact and reduce chest, abdomen and facial injuries.

Body shells are now designed to withstand major collision and rollover impacts while absorbing shock by controlled deformation of structure in the front and rear of the vehicle. Vehicle design and accident prevention is based on the kinetic energy relationship of damage to a vehicle during a collision. Energy is absorbed by work done on the vehicle’s materials by elastic deformation. This indicates that, to be effective, bumpers and other collision-absorbing parts of a vehicle should be made of materials such as foam-filled plastics and heavy rubber sections. Data indicates that long energy-absorbing distances should be provided in vehicle design, and the panel assemblies used for this purpose should have a lower stiffness than the central section or passenger compartment of the vehicle. The crumple zones are designed to help decelerate the car by absorbing the force of collision at a controlled rate, thereby cushioning the passengers and reducing the risk of injury (Figure 1.9). The safety cage (or safety cell) is the central section of the car body which acts as the passenger compartment. To ensure passenger safety, all body apertures around the passenger area should be reinforced by box-type profiles; seats should be secured rigidly to the floor; and heavy interior padding should be used around the dashboard areas. A strengthened roof construction, together with an anti-roll bar, afford additional protection in case of overturning (Figure 1.10).

To counteract side impact manufacturers are now fitting, in both front and rear doors, lateral side supports in the form of twin high-strength steel tubular beams, which are set 90 mm apart to reduce the risk of the vehicle riding over the beams during side collision. These beams absorb the kinetic energy produced when the vehicle is struck from the side. To further improve the body structure the BC-pillars are being reinforced at the points of attachment to the sill and roof, again giving more strength to the safety cage and making it stronger and safer when the vehicle is involved in collision (Figure 1.10).

Visibility in design is the ability to see and be seen. In poor visibility and after dark, light sources must be relied upon. The lights on vehicles now are much more efficient than on earlier models. The old tungsten filament lamp has given way to quartz-halogen lamps which provide much better illumination. The quartz-halogen lamp is able to produce a more powerful beam because the filament can be made hotter without shortening its lifespan. Hazard, reversing and fog lights are now fitted to most vehicles to improve safe driving.

In daylight, colour is probably the most important factor in enabling cars to be seen. If a vehicle is coloured towards the red end of the spectrum, it can be less obvious to other road users than a yellow one, especially in sodium vapour street lights: a red car absorbs yellow light from the street light and

![Figure 1.9 Crumple zones (Volvo Concessionaires Ltd)]
The history, development and construction of the car body

reflects little, and so appears to be dark in colour, whereas a yellow car reflects the yellow light and appears more obvious. Silver vehicles will blend into mist and fog and become difficult to see.

Blind spots can be diminished firstly by good design of front pillars, making them slim and strong, and secondly by reducing the area of rear quarter sections. This elimination of blind spots is now being achieved by using bigger windscreens which wrap round the front A-post, and rear windows which wrap round the rear quarter section, giving a wider field of vision.

Many automotive manufacturers now believe that a seatbelt/airbag combination provides the best possible interior safety system. Airbags play an important safety role in the USA since the wearing of seatbelts is not compulsory in many of the states. As competition to manufacture Europe’s safest car

Figure 1.10  Safety cage (Volvo Concessionaires Ltd)
Figure 1.11  (a) Safety features included in the safety cage (*Vauxhall Motors Ltd*) (b) Reinforced BC-pillar and anti-roll bar (*Volvo Concessionaires Ltd*)
increases, more manufacturers including those in the UK are starting to fit airbags. These Eurobags, or facebags as they are now called, since their main function in Europe and the UK is to protect the face rather than the entire body in the event of collision, are less complex than their USA counterparts.

The first automotive airbags were made more than 20 years ago using nylon-based woven fabrics, and these remain the preferred materials among manufacturers. Nylon fabrics for airbags are supplied in two basic designs depending on whether the airbag is to protect the driver or the front passenger. The driver’s airbag is housed in the steering wheel and requires special attention because of the confined space (Figure 1.12). The passenger’s airbag system has a compartment door, located in front of the passenger in the dash area, which must open within 10 milliseconds and deploy the airbag within 30 milliseconds. The vehicle has a crash sensor which signals the airbags to deploy on impact (Figure 1.13).

1.2.3 Production of models

Scale models
Once the initial designs have been accepted, scale models are produced for wind tunnel testing to determine the aerodynamic values of such a design. These models are usually constructed of wood and clay to allow for modifications to be made easily. At the same time, design engineering personnel construct models of alternative interiors so that locations of instruments can be determined.

A $\frac{1}{2}$ or $\frac{1}{3}$ scale model is produced from the stylist’s drawings to enable the stylist designer to evaluate the three-dimensional aspect of the vehicle. These scale models can look convincingly real (Figure 1.14). The clay surfaces are covered with thin colored plastic sheet which closely resembles genuine painted metal. Bumpers, door handles and trim strips are all cleverly made-up dummies, and the windows are made of Plexiglass. The scale models are examined critically and tested. Changes to the design can be made at this stage.

Full-size models
A full-size clay model is begun when the scale model has been satisfactorily modified. It is constructed in a similar way to the scale model but uses a metal, wood and plastic frame called a buck. The clay is placed on to the framework by professional model makers, who create the final outside shape of the body to an accuracy of 0.375 mm. The high standard of finish and detail results in an exact replica of the future full-size vehicle (Figure 1.15).
This replica is then evaluated by the styling management and submitted to top management for their approval. The accurate life-size model is used for further wind tunnel testing and also to provide measurements for the engineering and production departments. A scanner, linked to a computer, passes over the entire body and records each and every dimension (Figure 1.16). These are stored...
and can be produced on an automatic drafting machine. The same dimensions can also be projected on the screen of a graphics station; this is a sophisticated computer-controlled video system showing three-dimensional illustrations, allowing design engineers either to smooth the lines or to make detail alterations. The use of computers or CAD allows more flexibility and saves a lot of time compared with the more conventional drafting systems.

At the same time as the exterior model is being made, the interior model is also being produced accurately in every detail (Figure 1.17). It shows the seating arrangement, instrumentation, steering wheel, control unit location and pedal arrangements. Colours and fabrics are tried out on this mock-up until the interior styling is complete and ready for approval.

1.2.4 Engine performance and testing

Development engineers prepare to test an engine in a computer-linked test cell to establish the optimum settings for best performance, economy and emission levels. With the increasing emphasis on performance with economy, computers are used to obtain the best possible compromise. They are also used to monitor and control prolonged engine testing to establish reliability characteristics. If current engines and transmissions are to be used for a new model, a programme of refining and adapting for the new installation has to be initiated. However, if a completely new engine, transmission or driveline configuration is to be adopted, development work must be well in hand by this time.

1.2.5 Aerodynamics and wind tunnel testing

Aerodynamics is an experimental science whose aim is the study of the relative motions of a solid body and the surrounding air. Its application to the design of a car body constitutes one of the chief lines of the search for energy economy in motor vehicles.

In order to move over flat ground, a car must overcome two forces:

1. Resistance to tyre tread motion, which varies with the coefficient of tyre friction over the ground and with the vehicle’s mass.
2. Aerodynamic resistance, which depends on the shape of the car, on its frontal area, on the density of the air and on the square of the speed.

One of the objects of aerodynamic research is to reduce the latter: in other words to design a shape that will, for identical performance, require lower energy production. An aerodynamic or streamlined body allows faster running for the same consumption of energy, or lower consumption for the same speed. Research for the ideal shape is done on reduced-scale models of the vehicle. The models are placed in a wind tunnel, an experimental installation producing wind of a certain quality and fitted with the means for measuring the various forces due to the action of the wind on the model or the vehicle. Moreover, at a given cruising speed, the more streamlined vehicle has more power left available for acceleration: this is a safety factor.

The design of a motor car body must, however, remain compatible with imperatives of production, of overall measurements and of inside spaciousness. It is also a matter of style, for the coachwork must be attractive to the public. This makes it impossible to apply the laws of aerodynamics literally. The evolution of the motor car nevertheless tends towards a gradual reduction in aerodynamic resistance.

Aerodynamic drag

The force which opposes the forward movement of an automobile is aerodynamic drag, in which air rubs against the exterior vehicle surfaces and forms disturbances about the body, thereby retarding forward movement. Aerodynamic drag increases with speed; thus if the speed of a vehicle is doubled, the corresponding engine power must be increased by eight times. Engineers
Repair of Vehicle Bodies

express the magnitude of aerodynamic drag using the drag coefficient $C_d$. The coefficient expresses the aerodynamic efficiency of the vehicle: the smaller the value of the coefficient, the smaller the aerodynamic drag.

Figure 1.18 illustrates the improvements in aerodynamic drag coefficient achieved by alterations to the shape of vehicles. Over the years, the value of $C_d$ has been reduced roughly as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>$C_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>0.95</td>
</tr>
<tr>
<td>1920</td>
<td>0.82</td>
</tr>
<tr>
<td>1930</td>
<td>0.56</td>
</tr>
<tr>
<td>1940</td>
<td>0.45</td>
</tr>
<tr>
<td>1950</td>
<td>0.42</td>
</tr>
</tbody>
</table>

During the wind tunnel test all four wheels of the car rest on floating scales connected to a floor balance, which has a concrete foundation below the main floor area. The vehicle is then subjected to an air stream of up to 112 mile/h; the sensitive balances register the effect of the headwind on the vehicle as it is either pressed down or lifted up from the floor, pushed to the left or right, or rotated about its longitudinal axis. The manner in which the forces affect the vehicle body and the location at which the forces are exerted depends upon the body shape, underbody contours and projecting parts. The fewer disturbances which occur as air moves past the vehicle, the lower its drag. Threads on the vehicle exterior as well as smoke streams indicate the air flow, and enable test engineers to see where disturbance exists and where air flows are interrupted or redirected, and therefore where reshaping of the body is necessary in order to produce better aerodynamics (Figures 1.19 and 1.20).

1.2.6 Prototype production

The new model now enters the prototype phase. The mock-ups give way to the first genuine road going vehicle, produced with the aid of accurate drawings and without complex tooling and machinery. The prototype must accurately reproduce the exact shape, construction and assembly conditions of the final production body it represents if it is to be of any value in illustrating possible manufacturing problems and accurate test data. The process begins with the issue of drawing office instructions to the experimental prototype workshop. Details of skin panels and other large pressings are provided in the form of tracings or as photographic reproductions of the master body drafts. As the various detailed parts are made, by either simple press tools or traditional hand methods, they are spot welded into minor assemblies or subassemblies; these later become part of a major assembly to form the completed vehicle body.

1.2.7 Prototype testing

Whilst still in the prototype stage, the new car has to face a number of arduous tests. For these tests a mobile laboratory is connected to the vehicle by a cable, which transmits signals from various sensors on the vehicle back to the onboard computer for collation and analysis. The prototype will also be placed on a computer-linked simulated rig to monitor, through controlled vibrations, the stresses and strains experienced by the driveline, suspension and body.

Crash testing (Figure 1.21) is undertaken to establish that the vehicle will suffer the minimum of damage or distortion in the event of an impact and that the occupants are safely installed within the strong passenger compartment or safety cell. The basic crash test is a frontal crash at 30 mile/h (48 km/h) into a fixed barrier set perpendicularly
The collision is termed 100 per cent overlap, as the complete front of the car strikes the barrier and there is no offset (Figure 1.22). The main requirement is that the steering wheel must not be moved back by more than 120 mm (5 in), but there is no requirement to measure the force to which the occupants will be subject in collision. The manufacturers use anthropometric dummies suitably instrumented with decelerometers and strain gauges which collect...
relevant data on the effect of the collision on the dummies. A passenger car side impact test aimed at reducing chest and pelvic injuries will be legal in the USA from 1993. This stricter standard requires that a new vehicle must pass a full-scale crash test designed to simulate a collision at an intersection in which a car travelling at 15 mile/h is hit in the side by another car travelling at 30 mile/h. This test is called an angled side-swipe: the displacement is 27 degrees forward from the perpendicular of the test vehicle’s main axis. The test is conducted by propelling a movable deformable barrier at 33.5 mile/h into the side of a test car occupied by dummies in the front and rear seats. The dummies are wired with instruments to predict the risk potential of human injury. Volvo do a very unusual promotional crash test which involves propelling a car from the top of a tall building (Figure 1.23).
The history, development and construction of the car body

Extensive durability tests are undertaken on a variety of road surfaces in all conditions (Figure 1.24). Vehicles are also run through water tests (Figure 1.25) and subjected to extreme climatic temperature changes to confirm their durability.

As competition between the major car manufacturers increases, so does the need for lighter and more effective body structures. Until recently the choice of section, size and metal gauges was based upon previous experience. However, methods have now been evolved which allow engineers to solve problems with complicated geometry on a graphical display computer which can be constructed to resemble a body shape (Figure 1.26). The stiffness and stress can then be computed from its geometry, and calculations made of the load bearing of the structures using finite-element methods (Figure 1.27).

With the final specifications approved, the new car is ready for production. At this stage an initial batch of cars is built (a pilot run) to ensure that the plant facilities and the workforce are ready for the start of full production. When the production line begins to turn out the brand new model, every stage of production is carefully scrutinized to ensure quality in all the vehicles to be built.

1.2.9 EuroNCAP

The governments in most countries have some form of regulations covering vehicle safety. These regulations are aimed at giving both the occupants of the vehicle protection in the case of an accident, and ensuring that pedestrians and cyclists are not subject to unnecessary injury if they come into contact with a car. The regulations are in most cases very minimal. In the UK the Department for Transport (DfT) works with a number of bodies on vehicle safety, much of the DfT work is sub-contracted to Transport Research Laboratory (TRL) Ltd – formerly a wholly government funded institution. In America there is the United States Department of Transportation (DOT). There is also the EEVC (European Enhanced Vehicle-safety Committee).

The most pro-active of vehicle safety organisations is EuroNCAP. The full title is European New Car Assessment Programme. This programme is jointly funded and supported by its members which includes:

- Allgemeiner Deutscher Automobil-Club e V (ADAC), motoring organisation – Germany
- Bundesministerium fur Verker, Bau- und Wohnuwesesen, government department – Germany

The final stages are now being reached: mechanical specifications, trim levels, engine options, body styles and the feature lists are confirmed.

1.2.8 Body engineering for production

The body engineering responsibilities are to simulate the styling model and overall requirements laid down by the management in terms of drawings and specification. The engineering structures are designed for production, at a given date, at the lowest possible tooling cost and to a high standard of quality and reliability.
Figure 1.25  Water testing a prototype (Ford Motor Company Ltd)

Figure 1.26  Three-dimensional graphics display of a scale model (Ford Motor Company Ltd)

- Department for Transport (DfT), government department – UK
- Dutch Ministry of Transport, Public Works and Water Management, government department – Holland
- European Commission – Belgium
- FIA Foundation for the Automobile and Society, motoring organisation – UK
- Government of Catalonia, government department – Spain
- International Consumer Research and Testing, consumer group – UK
- Ministere de l’Equipment, government department – France
- Swedish Road Administration, government department – Sweden
- Thatcham – representing British Motor Insurers – GB

EuroNCAP have a number of tests which vehicles are subjected to, the results of the tests are then subjected to a number of calculations which lead to star ratings. Basically the more stars the safer the vehicle (Figure 1.28). The tests appear simple; but the recording of results is quite complex. Each test has a 50-page operating manual. Readings are taken from the dummies inside the vehicles as well as the photographs of the vehicle as it deforms under impact. The dummies contain electrical sensing equipment, mainly measuring acceleration rates. Each dummy costs the same amount of money as a super car such as a Ferrari.

The EuroNCAP tests are designed to encourage vehicle manufacturers to consider safety standards above and beyond those required by the government regulations.
The history, development and construction of the car body

Front impact test
Frontal impact takes place at 64 kph (40 mph) when a car strikes a deformable barrier that is offset (Figure 1.28a). This test is similar to many road accidents where one car hits another car, or another object, offset to one side.

Side impact test
This is similar to accidents where the car is hit by another on the side. The impact takes place at 50 kph (30 mph) when a trolley with a deformable front is towed into the driver’s side of the car to simulate a side-on crash (see Figure 1.28c).

Pole test
Accident patterns vary from country to country within Europe, but approximately a quarter of all serious-to-fatal injuries happen in side impact collisions. Many of these injuries occur when one car runs into the side of another. To encourage manufacturers to fit head protection devices, an optional pole or head protection test may be performed, where such safety features are fitted to the vehicle. Side impact airbags help protect the head by providing a padding effect and by preventing the head from passing through the window opening (see Figure 1.28e).

In this test, the car being tested is propelled sideways at 29 kph (18 mph) into a rigid pole. The pole is relatively narrow, like a telegraph pole of lamp post, so there is major penetration into the side of the car. In an impact without the head protecting airbag, a driver’s head could hit the pole with sufficient force to cause a fatal head injury.

Pedestrian impact test
A series of tests (Figure 1.28b) are carried out to replicate accidents involving child and adult pedestrians where impact occurs at 40 kph (25 mph) – maximum speed in build up areas in France. Impact sites are then assessed and rated fair, weak and poor. As with the other tests, these are based on EEVC guidelines.

Star ratings
Each vehicle tested is given a star rating for its protection of:
- adult occupant
- child occupant
- pedestrians
The Star Ratings are based on calculations carried out after the tests, the latest figures can be found on the EuroNCAP website: www.euroncap.com.

### 1.2.10 Computational fluid dynamics

**Definition**

Any material which flows, such as air or water, can be referred to as a fluid; ‘dynamics’ simply means moving and ‘computational’ is about calculations. Aerodynamics was for many years about observing the air flow over a vehicle, with sample calculations for specific areas of the car; the advent of computers meant that calculations could be done many times faster than by long hand. So, it became possible to carry out calculations for large sections of the car very quickly.

In the 1970s engineers became interested in the aerodynamics which were taking place both underneath and inside the car, places which could not be seen. More recently software has been developed, such as AutoCAD, 3D Studio and Pro/ENGINEER, which allows solid modeling and the facility to virtually walk through a...
design. This means that there is now no longer a need to make a buck, or a mock-up, of a car to be able to visualize the design. As an example, vehicle body engineers used to use a wooden buck of an engine to help them to design the body work, and see if it could be fitted to and removed from the initial body design. The Rover 75 is the first car to be designed without this; a solid modelling package was used for a virtual engine and body design, allowing an onscreen test fit.

Having designed the virtual car it is possible to observe it in a virtual wind tunnel and carry out calculations both internally and externally, this is what computational fluid dynamics (CFD) is all about. As you can appreciate, the cost of a virtual design and aerodynamic testing without a wind tunnel is only a fraction of the cost of building a buck and using a real wind tunnel.

**The calculations**

The following are some of the calculations which an aerodynamist may be concerned with; it should be remembered that these calculations are often carried out on about 10 000 000 (ten million) individual grid squares, or cells, on the car body, a slight change of design will need a new set of calculations. Even using the latest computer software, the slightest change may take several days; without CFD it would take months, and the level of accuracy would be much less. If you choose to use any of these formulae, remember to use SI units, metres, newtons and seconds where appropriate.

**Dynamic pressure**, which is also a kinetic energy of unit volume in terms of cubic metres, comes from the Bernoulli equations. Bernoulli was a scientist whose fluid flow theories were first used in the design of ships’ hulls.

**Dynamic pressure** = \( \frac{1}{2} \times \text{air density} \times \text{vehicle velocity squared} \)

\[
= \frac{1}{2} \rho V^2
\]

As you can see, the speed (velocity) of the vehicle is important for these calculations. Of course velocity is a vector quantity, it is related to the direction of the wind. Wind is very rarely a straight-on head wind, so calculations can be done for any of the 360 degree possible wind directions for each of the ten million grid squares. Yes, that is 3.6 billion calculations for each speed and of course the air density varies with altitude; at sea level the value is 1.226 kilogrammes per cubic metre.

**Reynolds Number** is a ratio which gives a good guide to the air flow pattern and is an important consideration of what is called scale effect.

\[
\text{Reynolds Number} = \frac{\text{air density} \times \text{air velocity}}{\text{length of flow/air Viscosity}}
\]

\[
\text{Re} = \frac{\rho vl}{\mu}
\]

**Drag** is the aerodynamic resistance of the vehicle, its resistance to pass through air. Drag in newtons force is found by the formula:

\[
\text{Drag} = \frac{1}{2} \text{air density} \times \text{velocity squared} \times \text{frontal area} \times \text{coefficient of drag}
\]

\[
= \frac{1}{2} \rho V^2 A C_D
\]

You will see that part of the formula is familiar, and part of it is the same as dynamic pressure, therefore:

\[
\text{Drag} = \text{dynamic pressure} \times \text{frontal area} \times \text{coefficient of drag}
\]

The coefficient of drag is a number which indicates the resistance of the car to pass through the air, typical values are between 0.25 and 0.35.

**Lift** is the force generated by an aerofoil section normal to the direction of fluid flow. In other words it is the upward lifting force which is generated when passing horizontally through air. For road vehicles wings are used to hold a vehicle on to the road, this can be called downthrust or negative lift.

\[
\text{Lift} = \text{dynamic pressure} \times \text{wing area} \times \text{coefficient of lift}
\]

When working with road vehicles the frontal area is often used for the wing area figure. On aircraft, the wing plan area is more appropriate. With advanced aerodynamic work the plan area is related to a reference area. For most road vehicles the frontal area and the plan area are proportional; also the coefficient of lift and the coefficient of drag are also proportional.

\[
\text{Lift} = \frac{1}{2} \rho V^2 A C_L
\]
Grid system
The vehicle body shape is broken into grid squares, or cells, see Figure 1.29. Depending on the shape of the panel, the grid cells may be of different shapes between square and oblong.

The squares are then considered as imaginary cube shapes, see Figure 1.30. A set of calculations called the Navier–Stokes equations gives a relationship between pressure, momentum and viscous forces in three-dimensional space. There is also a similar set called the Euler equations. The above calculations covered some of these concepts. The computer is used to calculate the amount of energy which is entering each cube and in turn leaving it. Obviously the two figures should balance and there will be flow between adjacent cubes.

Ahmed model
For benchmark testing of CFD systems the simplified vehicle shape, known as the Ahmed model, is used, see Figure 1.31. This is a simplified model of a hatchback car. The Ahmed model can be made from a wooden block and used in any wind tunnel.

1.3 Methods of construction
The steel body can be divided into two main types: those which are mounted on a separate chassis frame, and those in which the underframe or floor forms an integral part of the body. The construction of today’s mass-produced motor car has changed almost completely from the composite, that is conventional separate chassis and body, to the integral or mono unit. This change is the result of the need to reduce body weight and cost per unit of the total vehicle.

1.3.1 Composite construction
(conventional separate chassis)
The chassis and body are built as two separate units (Figure 1.32). The body is then assembled on to the chassis with mounting brackets, which
The history, development and construction of the car body

Figure 1.31  The Ahmed Model, a simplified shape of a hatchback vehicle (*Dr Ahmed 1984*)

Figure 1.32  Composite construction (conventional separate chassis)
have rubber-bushed bolts to hold the body to the rigid chassis. These flexible mountings allow the body to move slightly when the car is in motion. This means that the car can be dismantled into the two units of the body and chassis. The chassis assembly is built up of engine, wheels, springs and transmission. On to this assembly is added the body, which has been pre-assembled in units to form a complete body shell (Figure 1.33).

1.3.2 Integral (mono or unity) construction

Integral body construction employs the same principles of design that have been used for years in the aircraft industry. The main aim is to strengthen without unnecessary weight, and the construction does not employ a conventional separate chassis frame for attachment of suspension, engine and other chassis and transmission components (Figure 1.34). The major difference between composite and integral construction is hence the design and construction of the floor (Figure 1.35). In integral bodies the floor pan area is generally called the underbody. The underbody is made up of formed floor sections, channels, boxed sections, formed rails and numerous reinforcements. In most integral underbodies a suspension member is incorporated in both the front and rear of the body. The suspension members have very much the same appearance as the conventional chassis frame from the underside, but the front suspension members end at the cowl or bulkhead and the rear suspension members end just forward of the rear boot floor. With the floor pan, side rails and reinforcements welded to them, the suspension members become an integral part of the underbody, and they form the supports for engine, front and rear suspension units and other chassis components. In the integral body the floor pan area is usually of heavier gauge metal than in the composite body, and has one or more box sections and several channel sections which may run across the floor either from side to side or from front to rear; this variety of underbody construction is due largely to the difference in wheelbase, length and weight of the car involved. A typical upper body for an integral constructed car is very much the same as the conventional composite body shell; the major differences lie in the rear seat area and the construction which joins the front wings to the front

Figure 1.33  Composite construction showing a Lotus Elan chassis before fitting the body (Lotus Engineering)
The history, development and construction of the car body

bulkhead or cowl assembly. The construction in the area to the rear of the back seat is much heavier in an integral body than in a composite body. The same is true of the attaching members for the front wings, front bulkhead and floor assembly, as these constructions give great strength and stability to the overall body structure.

1.3.3 Semi-integral methods of construction

In some forms of integral or mono assemblies, the entire front end or subframe forward of the bulkhead is joined to the cowl assembly with bolts. With this construction, the bolts can be easily removed and the entire front (or in some cases rear) subframe can be replaced as one assembly in the event of extensive damage.

1.3.4 Glass fibre composite construction

This method of producing complex shapes involves applying layers of glass fibre and resin in a prepared mould. After hardening, a strong moulding is produced with a smooth outer surface requiring little maintenance. Among the many shapes available in this composite material are lorry cabs, bus front canopies, container vehicles, and the bodies of cars such as the Reliant Scimitar. The Italian designer, Michelotti, styled the Scimitar body so that separately moulded body panels could be used and overlapped to hide the attachment points. This allows the panels to be bolted directly to the supporting square-section steel tube armatures located on the main chassis frame. The inner body, which rests directly on the chassis frame and which forms the base for all internal trim equipment, is a complex GRP moulding. The windscreen aperture is moulded as a part of the inner body, and incorporates steel reinforcing hoops which are braced directly to the chassis. The boot compartment is also a separate hand-laid GRP moulding, as are the doors and some of the other panels. Most of the body panels are secured by self-tapping bolts which offer very positive location and a useful saving in assembly time (see Figures 1.36 and 1.37).

1.3.5 Galvanized body shell clad entirely with composite skin panels

Renault have designed a high-rise car which has a skeletal steel body shell (Figure 1.38, clad entirely with composite panels. After assembly the complete body shell is immersed in a bath of
Figure 1.34  (b) Land Rover Discovery body assembly
molten zinc, which applies an all-over 6.5 micron (millionth of a metre) coating. The process gives anti-rust protection, while the chemical reaction causes a molecular change in the steel which strengthens it. Lighter-gauge steel can therefore be used without sacrificing strength, resulting in a substantial weight saving even with the zinc added.

Skin panels are formed in reinforced polyester sheet, made of equal parts of resin, fibreglass and mineral filler. The panels are joined to the galvanized frame and doors by rivets or bonding as appropriate. The one-piece high-rise tailgate is fabricated entirely from polyester with internal steel reinforcements (Figure 1.39). Damage to panels through impact shocks is contained locally and absorbed through destruction of the material, unlike the steel sheet which transmits deformation. Accident damage and consequent repair costs are thus reduced.

1.3.6 Variations in body shape

Among the motor car manufacturers there are variations in constructional methods which result in different body types and styles. Figure 1.40 illustrates four types of body shell – a saloon with a boot, a hatchback, an estate car and a light van. Figure 1.41 shows a coach-built limousine of extremely high quality, built on a Rolls-Royce Silver Spirit chassis by the coach-builders Hooper & Co. This vehicle has been designed for the use of heads of state and world-ranking VIPs.

1.4 Basic body construction

A typical four-door saloon body can be likened to a hollow tube with holes cut in the sides. The bulkhead towards the front and rear completes the box-like form and assists in providing torsional stability. The roof, even if it has to accommodate a sunshine roof, is usually a quite straightforward and stable structure; the curved shape of the roof panel prevents lozenging (going out of alignment in a diamond shape). The floor is a complete panel from front to rear when assembled, and is usually fitted with integral straightening ribs to prevent lozenging. With its bottom sides or sill panels, wheel arches, cross members and heelboard, it is the strongest part of the whole body. The rear bulkhead, mainly in the form of a rear squab panel, is again a very stable structure. However, the scuttle or forward bulkhead is a complex structure in a private motor car. Owing to the awkward shape of the scuttle and the accommodation required for much of the vehicle’s equipment, it requires careful designing to obtain sufficient strength. Body sides with thin pillars, large windows and door openings are inherently weak, requiring reinforcing with radius corners to the apertures to give them sufficient constructional strength.
A designer in a small coach building firm will consider methods necessary to build the body complete with trim and other finishing processes. The same job in a mass production factory may be done by a team of designers and engineers all expert in their own particular branch of the project. The small manufacturer produces bodies with skilled labour and a minimum number of jigs, while the mass producer uses many jigs and automatic processes to achieve the necessary output. However, the problems are basically the same: to maintain strength and stability, a good standard of finish and ease of production.

Figure 1.42 shows the build-up details of a four-door saloon, from the main floor assembly to the complete shell assembly. In the figure the main floor
The history, development and construction of the car body

unit (1), commencing at the front, comprises a toe-board or pedal panel, although in some cases this may become a part of the scuttle or bulkhead. Apart from providing a rest for the front passengers' feet, it seals off the engine and gearbox from the body and connects the scuttle to the main floor. The main centre floor panel (2) should be sufficiently reinforced to carry the weight of the front seats and passengers. It may be necessary to have a tunnel running the length of the floor in the centre to clear

Figure 1.36  Motor body panel assembly using GRP: Lotus Elan (Lotus Engineering)

Figure 1.37  Complete Lotus Elan SE body shell (Lotus Engineering)

Figure 1.38  Espace high-rise car with galvanized skeletal steel body shell (Renault UK Ltd)
the transmission system from the engine to the rear axle, and holes may have to be cut into the floor to allow access to the gearbox, oil filler, and dipstick, in which case removable panels or large grommets would be fitted in these access holes (3).

The front end of the main floor is fixed to the toeboard panel and the sides of the main centre floor are strengthened by the bottom sills (4) and/or some form of side members which provide the necessary longitudinal strength. The transverse strength is provided by the cross members. The floor panel itself prevents lozenging, and the joints between side members and cross members are designed to resist torsional stresses.

The rear end of the floor is stiffened transversely by the rear seat heelboard (5). This heelboard also stiffens the front edges of the rear seat panel. In addition it often provides the retaining lip for the rear seat cushion, which is usually made detachable.

![Diagram of car structure](image)

**Figure 1.39** Espace high-rise car showing composite panel cladding (*Renault UK Ltd*). Plastic parts are made from a composite material based on polyester resin: pre-impregnated type (SMC) for parts 1, 4, 5, 6, 7, 8, 9, 10; injected resin type for parts 2, 3. Parts bonded to chassis: Detachable parts:

1. Body top
2. Roof
3. Tailgate lining
4. Tailgate outer panel
5. Rear wing
6. Rear door panel
7. Sill
8. Front door panel
9. Front wing
10. Bonnet

**Figure 1.40** Body shell variations: (a) saloon with boot (b) hatchback (c) estate car (d) light van (*Rover Group Ltd*)
The history, development and construction of the car body

from the body. The heelboard, together with the rear panel and rear squab panel, forms the platform for the rear seat.

The rear seat panel (6) is reinforced or swaged if necessary to gain enough strength to support the rear passengers. Usually the rear seat panel has to be raised to provide sufficient clearance for the deflection of the rear axle differential housing. The front edge of the rear seat panel is stiffened by the rear seat heelboard, and the rear edge of the seat panel is stiffened by the rear squab panel. The rear squab panel completes this unit and provides the rear bulkhead across the car. It seals off the boot or luggage compartment from the main body or passenger compartment.

The boot floor (7), which extends from the back of the rear squab panel to the extreme back of the body, completes the floor unit. In addition to the luggage, the spare wheel has to be accommodated here. The front edge of the boot floor is reinforced by the rear squab panel and the rear end by a cross member of some form (8). The sides of the floor are stiffened by vertical boot side panels at the rear, while the wheel arch panels complete the floor structure by joining the rear end of the main floor and its side members. The wheel arch panels (9) themselves seal the rear road wheels from the body.

In general the floor unit is made up from a series of panels with suitable cross members or reinforcements. The edges of the panels are stiffened either by flanging reinforcing members, or by joining to the adjacent panels. The boot framing is joined at the back to the rear end of the boot floor, at the sides to the boot side panels and at the top to the shelf panel behind the rear squab (10). It has to be sufficiently strong at the point where the boot lid hinges are fitted to carry the weight of the boot lid when this is opened. Surrounding the boot lid opening there is a gutter to carry away rain and water to prevent it entering the boot; opposite the hinges, provision is made for the boot lid lock striking plate (11) to be fixed. From the forward edge of the boot, the next unit is the back light and roof structure (12), and this extends to the top of the windscreen or canopy rail (13). The roof is usually connected to the body side frames, which comprise longitudinal rails or stringers and a pair of cantrails which form the door openings (14). Provision in the roof should be made for the interior lights and wiring and also the fixing of the interior trimming. The scuttle and windscreen unit, including the front standing pillar or A-post (15), provides the front bulkhead and seals the engine from the passenger compartment.

Accommodation has to be made for the instrumentation of the car, the wiring, radio, windscreen wipers and driving cable, demisters and ducting, steering column support, handbrake support and pedals. The scuttle (16) is a complicated structure which needs to be very strong. When the front door is hinged at the forward edge, provision has to be made in the front pillar for the door hinges, door check and courtesy light switches.

The centre standing pillar or BC-post (17) is fixed to the side members of the main floor unit and supports the cantrails of the roof unit. It provides a shut face for the front door, a position for the door lock striking plate and buffers or dovetail, and also a hinge face for the rear door; as with the front standing pillar, provision is made for the door hinges and door check. The rear standing pillar or D-post (18) provides the shut face for the rear end of the floor side members at the bottom, whilst the top is fixed to the roof cantrails and forms the front of the quarters.

The quarters (19) are the areas of the body sides between the rear standing pillars and the back light and boot. If the body is a six-light saloon there will be a quarter window here with its necessary surrounding framing, but in the case of a four-light saloon this portion will be more simply constructed. Apart from the doors, bonnet, boot lid and...
Figure 1.42 Body constructional details of Austin Rover Maestro (Austin Rover)

1. Main floor unit
2. Main centre floor panel
3. Access holes
4. Bottom sills
5. Rear seat heelboard
6. Rear seat panel
7. Boot floor
8. Cross member
9. Wheel arch panel
10. Rear squabs
11. Boot lid lock striking plate
12. Roof structure
13. Windscreen or canopy rail
14. C pillars
15. Front standing pillar (A-post)
16. Scuttle
17. Centre standing pillar (BC-post)
18. Rear standing pillar (D-post)
19. Quarter panels

Panel windshield scuttle assembly
front wings this completes the structure of the average body shell.

1.5 Identification of major body pressings

The passenger-carrying compartment of a car is called the body, and to it is attached all the doors, wings and such parts required to form a complete body shell assembly (Figure 1.43).

1.5.1 Outer construction

This can be likened to the skin of the body, and is usually considered as that portion of a panel or panels which is visible from the outside of the car.

1.5.2 Inner construction

This is considered as all the brackets, braces and panel assemblies that are used to give the car strength (Figure 1.44). In some cases the entire panels are inner construction on one make of car and a combination of inner and outer on another.

1.5.3 Front-end assembly including cowl or dash panel

The front-end assembly (Figure 1.45) is made up from the two front side member assemblies which are designed to carry the weight of the engine, suspension, steering gear and radiator. The suspension system used will affect the design of the panels, but whatever system is used the loads must be transmitted to the wing valances and on to the body panels. The front cross member assembly braces the front of the car and carries the radiator and headlamp units. The side valance assemblies form a housing for the wheels, a mating edge for the bonnet and a strong box section for attachment of front wings. Both the side frames and valance assemblies are connected to the cowl or dash panel. The front-end assembly is attached to the main floor at the toe panel.

The cowl or dash panel forms the front bulkhead of the body (Figure 1.45) and is usually formed by joining smaller panels (the cowl upper panel and the cowl side panel) by welds to form an integral unit. In some cases the windscreen frame is integral with the cowl panel. The cowl extends upwards

---

**Figure 1.43**  Major body panels

- 1 Roof panel
- 2 Bonnet panel
- 3 Boot lid
- 4 Front wing
- 5 Radiator grille
- 6 Front bumper bar
- 7 Headlamps
- 8 Sidelamps
- 9 Sill panel
- 10 Front door
- 11 Rear door
- 12 Centre pillar
- 13 Rear quarter panel
- 14 Rear bumper bar
Repair of Vehicle Bodies
The history, development and construction of the car body

(Facing page)

**Figure 1.44** Body shell assembly *(Austin Rover Group Ltd)*

1. Underbody assembly
2. Body side frame assembly
3. Windscreen upper rail assembly
4. Cowl and dash panel assembly
5. Front wheel house complete panel
6. Instrument panel assembly
7. Cowl side lower brace
8. Front body hinge pillar (A-post)
9. Roof panel assembly
10. Roof bow assembly
11. Bulkhead brace assembly
12. Rear quarter centre panel assembly (back window)
13. Back window upper rail panel assembly
14. Rear-end upper panel assembly
15. Radiator panel complete assembly
16. Centre pillar (BC-post)
17. D-post
18. Rear quarter assembly
19. Sill panel
20. Front side member assembly
21. Rear wheel arch assembly
22. Main floor assembly
23. Front valance complete assembly

(Facing page)

**Figure 1.45** Complete front-end assemblies *(Rover Group Ltd)*

1. Headlamp panel RH and LH
2. Front cross member closing panel
3. Front cross member
4. Bonnet lock panel
5. Headlamp panel reinforcement RH and LH
6. Front wing corner piece RH and LH
7. Bonnet frame extension
8. Bonnet skin
9. Bonnet frame
10. Dash panel
11. Scuttle panel
12. Front bulkhead
13. Chassis leg reinforcement RH and LH
14. Front inner wing RH and LH
15. Front chassis leg RH and LH
16. Subframe mounting RH and LH
17. Front wheel arch RH and LH
18. Front wing RH and LH
19. Battery tray
20. Chassis leg gusset RH and LH
21. Bumper mounting reinforcement RH and LH
22. Chassis leg extension RH and LH
23. A-post rear reinforcement RH and LH
around the entire windscreen opening so that the upper edge of the cowl panel forms the front edge of the roof panel. In this case the windscreen pillars, i.e. the narrow sloping construction at either side of the windscreen opening, are merely part of the cowl panel. In other constructions, only a portion of the windscreen pillar is formed as part of the cowl. The cowl is sometimes called the fire wall because it is the partition between the passenger and engine compartments, and openings in the cowl accommodate the necessary controls, wiring and tubing that extend from one compartment to the other. The instrument panel, which is usually considered as part of the cowl panel although it is a complex panel in itself, provides a mounting for the instruments necessary to check the performance of the vehicle during operation. Cowl panels usually have both inner and outer construction, but in certain constructions only the upper portion of the cowl around the windscreen is visible. On many vehicles the front door hinge pillar is also an integral part of the cowl.

1.5.4 Front side member assembly

This is an integral part of the front-end assembly; it connects the front wing valances to the cowl or dash assembly. It is designed to strengthen the front end; it is part of the crumple zone, giving lateral strength on impact and absorbing energy by deformation during a collision. It also helps to support the engine and suspension units (see Figure 1.45; key figure references 13, 15, 16, 20, 22).

1.5.5 A-post assembly

This is an integral part of the body side frame. It is connected to the front end assembly and forms the front door pillar or hinge post. It is designed to carry the weight of the front door and helps to strengthen the front bulkhead assembly (Figure 1.45).

1.5.6 Main floor assembly

This is the passenger-carrying section of the main floor. It runs backwards from the toe panel to the heelboard or back seat assembly. It is strengthened to carry the two front seats, and in some cases may have a transmission tunnel running through its centre. Strength is built into the floor by the transmission tunnel acting like an inverted channel section. The body sill panels provide extra reinforcement in the form of lateral strength. Transverse strength is provided by box sections at right angles to the transmission tunnel, generally in the areas of the front seat and in front of the rear seat. The remaining areas of flat floor are ribbed below the seats and in the foot wells to add stiffness (Figure 1.46).

1.5.7 Boot floor assembly

This is a section of the floor between the seat panel and the extreme back of the boot. It is strengthened by the use of cross members to carry the rear seat passengers. This area forms the rear bulkhead between the two rear wheel arches, forming the rear seat panel or heelboard, and in a saloon body shell can incorporate back seat supports and parcel shelf. The boot floor is also strengthened to become the luggage compartment, carrying the spare wheel and petrol tank. At the extreme back it becomes the panel on to which the door or tailgate closes (Figure 1.46).

1.5.8 Complete underbody assembly

This is commonly called the floor pan assembly, and is usually composed of several smaller panels welded together to form a single floor unit. All floor panels are reinforced on the underside by stiffening members or cross members. Most floor pans are irregular in shape for several reasons. They are formed with indentations or heavily swaged areas to strengthen the floor sections between the cross members, and foot room for the passengers is often provided by these recessed areas in the floor. Figure 1.46 shows a complete underbody assembly.

1.5.9 Body side frame assembly

On a four-door saloon this incorporates the A-post, the BC-post, the D-post and the rear quarter section. The side frames reinforce the floor pan along the sill sections. The hinge pillar or A-post extends forward to meet the dash panel and front bulkhead to provide strength at this point. The centre pillars or BC-posts connect the body sills to the roof cantrails. They are usually assembled as box sections using a top-hat section and flat plate. These are the flanges which form the attachments for the door weather seals and provide the four
The history, development and construction of the car body

Figure 1.46  Main floor assemblies and boot floor assemblies *(Proton)*

1 Reinf. parking brake lever
2 Crossmember assy backbone
3 Reinf. assy backbone
4 Bracket A-Frame LH
5 Bracket A-Frame RH
6 Pan front floor
7 Crossmember assy front floor front RH
8 Crossmember assy front floor rear LH
9 Crossmember assy front floor rear RH
10 Crossmember assy front floor front LH
11 Reinf. seat belt side LH/RH
12 Bracket anti zipper
13 Sill front floor side inner LH/RH
14 Reinf. sidemember front floor LH/RH
15 Sidemember front floor LH/RH

NOTE:
A large reinforcement has been added to the front floor backbone (Reinforcement assy backbone), and this is coupled with the side sill, sidemember and crossmember to provide increased rigidity to the total floor.

Door openings. The D-post and rear quarter section is integral with the rear wheel arch and can include a rear quarter window (Figure 1.47).

1.5.10 Roof panel

The roof panel is one of the largest of all major body panels, and it is also one of the simplest in construction. The area which the roof covers varies between different makes and models of cars. On some cars, the roof panel ends at the windscreen. On others it extends downwards around the windscreen so that the windscreen opening is actually in the roof. On some cars the roof ends above the rear window, while on others it extends downwards so that the rear window opening is in the lower rear roof. When this is the case the roof panel forms the top panel...
### Figure 1.47  Body side assemblies, roof, BC-post, front and rear door of a hatchback *(Proton)*

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Panel outer rear door</td>
</tr>
<tr>
<td>2</td>
<td>Panel inner rear door</td>
</tr>
<tr>
<td>3</td>
<td>Panel outer front door</td>
</tr>
<tr>
<td>4</td>
<td>Panel inner rear door</td>
</tr>
<tr>
<td>5</td>
<td>Panel hood</td>
</tr>
<tr>
<td>6</td>
<td>Panel cowl top inner</td>
</tr>
<tr>
<td>7</td>
<td>Panel cowl top outer</td>
</tr>
<tr>
<td>8</td>
<td>Panel assy dash</td>
</tr>
<tr>
<td>9</td>
<td>Reinf. radiator side RH</td>
</tr>
<tr>
<td>10</td>
<td>Stay hood lock</td>
</tr>
<tr>
<td>11</td>
<td>Crossmember front end</td>
</tr>
<tr>
<td>12</td>
<td>Reinf. radiator side LH</td>
</tr>
<tr>
<td>13</td>
<td>Bar front end upper</td>
</tr>
<tr>
<td>14</td>
<td>Bulkhead front pillar lower</td>
</tr>
<tr>
<td>15</td>
<td>Bulkhead front pillar side sill</td>
</tr>
<tr>
<td>16</td>
<td>Bracket crossmember front</td>
</tr>
<tr>
<td>17</td>
<td>Bracket crossmember</td>
</tr>
<tr>
<td>18</td>
<td>Reinf. pillar front inner lower</td>
</tr>
<tr>
<td>19</td>
<td>Pillar front inner lower</td>
</tr>
<tr>
<td>20</td>
<td>Sidemember front</td>
</tr>
<tr>
<td>21</td>
<td>Panel front fender</td>
</tr>
<tr>
<td>22</td>
<td>Pan front floor</td>
</tr>
<tr>
<td>23</td>
<td>Reinf. front pillar lower</td>
</tr>
<tr>
<td>24</td>
<td>Extension upper frame outer</td>
</tr>
<tr>
<td>25</td>
<td>Side structure</td>
</tr>
<tr>
<td>26</td>
<td>Reinf. front pillar centre</td>
</tr>
<tr>
<td>27</td>
<td>Pillar front inner upper</td>
</tr>
<tr>
<td>28</td>
<td>Rail roof side inner</td>
</tr>
<tr>
<td>29</td>
<td>Rail roof front</td>
</tr>
<tr>
<td>30</td>
<td>Pillar centre inner</td>
</tr>
<tr>
<td>31</td>
<td>Pillar centre outer</td>
</tr>
<tr>
<td>32</td>
<td>Pillar rear inner</td>
</tr>
<tr>
<td>33</td>
<td>Rail roof rear</td>
</tr>
<tr>
<td>34</td>
<td>Panel roof</td>
</tr>
</tbody>
</table>
around the rear boot opening. Some special body designs incorporate different methods of rear window construction, which affects the roof panel; this is particularly true for estate cars, hatchbacks and hardtop convertibles. Alternatively the top is joined to the rear quarter panel by another smaller panel which is part of the roof assembly.

The stiffness of the roof is built in by the curvature given to it by the forming presses, while the reinforcements, consisting of small metal strips placed crosswise to the roof at intervals along the inside surface, serve to stiffen the front and rear edges of the windscreen and rear window frames. In some designs the roof panel may have a sliding roof built in (Figure 1.47) or a flip-up detachable sunroof incorporated.

1.5.11 Rear quarter panel or tonneau assembly

This is integral with the side frame assembly and has both inner and outer construction. The inner construction comprises the rear wheel arch and the rear seat heelboard assembly. This provides the support for the rear seat squab in a saloon car; if the vehicle is a hatchback or estate car, the two back seats will fold flat and the seat squabs will not need support. This area is known as the rear bulkhead of the car; it gives additional transverse strength between the wheel arch sections and provides support for the rear seat. The rear bulkhead also acts as a partition between the luggage and passenger compartments (Figure 1.47).

1.5.12 Rear wheel arch assembly

This assembly is constructed as an integral part of the inner construction of the rear quarter panel. It is usually a two-piece construction comprising the wheel arch and the quarter panel, which are welded together (Figure 1.46).

1.5.13 Wings

A wing is a part of the body which covers the wheel. Apart from covering the suspension construction, the wing prevents water and mud from being thrown up on to the body by the wheels. The front wings (or the fender assembly) are usually attached to the wing valance of the front end assembly (see Figure 1.45) by means of a flange the length of the wing, which is turned inwards from the outer surface and secured by either welding or bolts. Adjustment for the front wing is usually provided for by slotting the bolt holes so that the wing can be moved either forwards or backwards by loosening the attaching bolts. This adjustment cannot be made if the wing is welded to the main body structure.

In some models the headlights and sidelights are recessed into the front wing and fastened in place by flanges and reinforcement rims on the wing. Any trim or chrome which appears on the side of the wing is usually held in place by special clips or fasteners which allows easy removal of the trim.

The unsupported edges of the wing are swaged edges known as beads. The bead is merely a flange which is turned inwards on some cars and then up to form a U-section with a rounded bottom. It not only gives strength but prevents cracks developing in the edges of the wing due to vibration, and it provides a smooth finished appearance to the edge of the wing.

In general the rear wing is an integral part of the body side frame assembly and rear quarter panel. When the wing forms an integral part of the quarter panel, the inner construction is used to form part of the housing around the wheel arch. The wheel arch is welded to the rear floor section and is totally concealed by the rear quarter panel, while the outer side of the wheel arch is usually attached to the quarter panel around the wheel opening. This assembly prevents road dirt being thrown upwards between the outer panel and inner panel construction.

1.5.14 Doors

Several types of door are used on each vehicle built, although the construction of the various doors is similar regardless of the location of the door on the vehicle, as indicated on Figure 1.47. The door is composed of two main panels, an outer and an inner panel, both being of all-steel construction. The door derives most of its strength from the inner panel since this is constructed mainly to act as a frame for the door. The outer panel flanges over the inner panel around all its
edges to form a single unit, which is then spot welded or, in some cases, bonded with adhesives to the frame.

The inner panel has holes or apertures for the attachment of door trim. The trim consists of the window regulator assembly and the door locking mechanism. These assemblies are installed through the large apertures in the middle of the inner panel. Most of the thickness of the door is due to the depth of the inner panel which is necessary to accommodate the door catch and window mechanism. The inner panel forms the lock pillar and also the hinge pillar section of the door. Small reinforcement angles are usually used between the outer and inner panel, both where the lock is inserted through the door and where the hinges are attached to the door. The outer panel is either provided with an opening through which the outside door handle protrudes, or is recessed to give a more streamlined effect and so to create better aerodynamics.

The upper portion of the door has a large opening which is closed by glass. The glass is held rigidly by the window regulator assembly, and when raised it slides in a channel in the opening between the outer and inner panels in the upper portion of the door. When fully closed the window seats tightly in this channel, effectively sealing out the weather.

1.5.15 Boot lid or tailgate

This is really another door which allows access to the luggage compartment in the rear of the car (Figure 1.46). A boot lid is composed of an outer and an inner panel. These panels are spot welded along their flanged edges to form a single unit in the same manner as an ordinary door. The hatchback and estate car have a rear window built into the boot lid, which is then known as a tailgate. Some manufacturers use external hinges, while others use concealed hinges attached to the inner panel only. A catch is provided at the lower rear edge of the boot lid or tailgate and is controlled by an external handle or locking mechanism. This mechanism may be concealed from the eye under a moulding or some type of trim. In some models there is no handle or external locking mechanism; instead the hinges are spring loaded or use gas-filled piston supports, so that when the lid is unlocked internally it automatically rises and is held in the open position by these mechanisms.

1.5.16 Bonnet

The bonnet (Figure 1.45) is the panel which covers the engine compartment where this is situated at the front of the vehicle, or the boot compartment of a rear-engined vehicle. Several kinds of bonnets are in use on different makes of cars. The bonnet consists of an outer panel and an inner reinforcement constructed in the H or cruciform pattern, which is spot welded to the outer skin panel at the flanged edges of the panels. The reinforcement is basically a top-hat section, to give rigidity to the bonnet. In some cases the outer panel is bonded to the inner panel using epoxy resins. This system avoids the dimpling effect on the outer surface of the bonnet skin which occurs in spot welding.

Early models used a jointed type of bonnet which was held in place by bolts through the centre section of the top of the bonnet into the body of the cowl and into the radiator. A pianotype hinge was used where the bonnet hinged both at the centre and at the side.

The most commonly used bonnet on later constructions is known as the mono or one-piece type, and can be opened by a variety of methods. On some types it is hinged at the front so that the rear end swings up when the bonnet is open. Others are designed so that they can be opened from either side, or unlatched from both sides and removed altogether. Most bonnets, however, are of the alligator pattern, which is hinged at the rear so that the front end swings up when opened.

The type of bonnet catch mechanism depends on the type of bonnet used. When a bonnet opens from the rear the catch mechanism is also at the rear. When it opens from either side the combination hinge and catch are provided at each side. The alligator bonnets have their catches at the front, and in most cases the catches are controlled from inside the car.

Bonnets are quite large, and to make opening easier the hinges are usually counterbalanced by means of tension or torsion springs. Where smaller bonnets are used the hinges are not counterbalanced.
and the bonnet is held in place by a bonnet stay from the side of the wing to the bonnet. Adjustment of the bonnet position is sometimes possible by moving the hinges.

1.5.17 Trims

Some details of exterior and interior trims are shown in Figures 1.48 and 1.49.

1.5.18 Complete body shell

A contemporary vehicle embracing all the latest techniques of panel assembly is shown in Figures 1.50 and 1.51. Figure 1.50 illustrates the completed structure with all panel assemblies in place. Figure 1.51 shows the completely finished vehicle ready for the road.

1.5.19 Comparative terms in common use by British, American and European car manufacturers

As manufacturers use differing terms for the various body panel assemblies and individual panels, difficulties may arise when identifying specific panels. The following are the terms in most common use:

- Bonnet, hood
- Boot lid, deck lid, trunk lid, tailgate
- Cantrail, roof side rail, drip rail
- Centre pillar, BC-post
- Courtesy light, interior light
- Cowl, scuttle, bulkhead, fire wall
- Dash panel, facia panel
- Door opening plates, scuff plates
- Door skin, outside door panel

Figure 1.48  Exterior trim (Rover Group Ltd)

73 Lower front grille  77 Front grille  84 Lower screen moulding  88 Rear door waist moulding
74 Front spoiler  81 Door mirror assembly  85 Rear bumper insert  89 Front door waist moulding
75 Front bumper  82 Scuttle grille  86 Rear bumper  90 Front wing waist moulding
76 Front bumper insert  83 Scuttle moulding  87 Rear wing waist moulding
Repair of Vehicle Bodies

system is shown in Figure 1.52. The figure also shows the paint and trim codes which are usually included on the VIN plate.

The car body number is provided separately in the engine or boot compartments.

1.6 Vehicle type approval

Many industrial sectors are subject to some form of approval or certification system but road vehicles are a special case, because of their importance to and impact upon society, and have been subject to specific technical standards almost from their first invention. Within Europe, two systems of type approval have been in existence for over 20 years. One is based around EC Directives and provides for the approval of whole vehicles, vehicle systems and separate components. The other is based around ECE (United Nations) Regulations and provides for approval of vehicle systems and separate components, but not whole vehicles.

Type approval is the confirmation that production samples of a design will meet specified performance standards. The specification of the product is recorded and only that specification is approved.

Automotive EC Directives and ECE Regulations require third party approval – testing, certification and production conformity assessment by an independent body. Each member state is required to appoint an Approval Authority to issue the approvals and a Technical Service to carry out the testing to the Directives and Regulations. An approval issued by one Authority will be accepted in all the member states. Vehicle Certification Agency (VCA) is the designated UK Approval Authority and Technical Service for all type of approvals to automotive EC Directives and ECE Regulations. The VCA also has offices in Europe, North America and the far East.

Approved parts carry the E-mark. That is a letter ‘e’ or ‘CE’ followed by a number which indicates the country of approval.

1.6.1 Single vehicle approval scheme

The Single Vehicle Approval (SVA) scheme is a pre-registration inspection for cars and light goods vehicles that have not been type-approved to British or European standards. The main purpose
The history, development and construction of the car body

of the scheme is to ensure that these vehicles have been designed and constructed to modern safety and environmental standards before they can be used on public roads.

Single Vehicle Approval checks that vehicles constructed for non-European Economic Area markets comply with British law. Even vehicles outwardly similar to European-specification models, but intended for other markets, can often be unsuitable for use in Britain without, at least some, modification. SVA recognises certain non-European technical standards as acceptable alternatives to the SVA requirements.

Figure 1.50  Complete body shell (Proton)

Figure 1.51  Proton
54 Repair of Vehicle Bodies

Vehicle Information Code Plate — for UK/EC market only

Location
Vehicle information code plate is riveted on the toe board inside the engine compartment.

CODE PLATE DESCRIPTION
The plate shown model code, engine model, transmission model and colour code.

<table>
<thead>
<tr>
<th>Position</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>VIN CODE</td>
</tr>
<tr>
<td>B</td>
<td>ENGINE</td>
</tr>
<tr>
<td>C</td>
<td>TRANS AXLE</td>
</tr>
<tr>
<td>D</td>
<td>EXTERIOR CODE</td>
</tr>
<tr>
<td>E</td>
<td>INTERIOR CODE</td>
</tr>
<tr>
<td>F</td>
<td>OPTION CODE</td>
</tr>
<tr>
<td>G</td>
<td>GROSS VEHICLE WEIGHT</td>
</tr>
<tr>
<td>H</td>
<td>GROSS COMBINATION WEIGHT</td>
</tr>
<tr>
<td>I</td>
<td>FRONT AXLE WEIGHT</td>
</tr>
<tr>
<td>J</td>
<td>REAR AXLE WEIGHT</td>
</tr>
</tbody>
</table>

Figure 1.52 Vehicle identification number

Single Vehicle Approval also checks that the construction of amateur-built vehicles, rebuilt vehicles and vehicles using parts from a previously registered vehicle meet modern safety and environmental standards. It also provides an alternative to type-approval for vehicles manufactured in very low volume; vehicles converted for the disabled prior to registration, as well as hearses and armoured vehicles for civilian use.

Most of the items inspected in the SVA scheme are those that are tested when manufacturers apply for type-approval of mass-produced vehicles. Table 1.1 lists the items inspected for cars and light goods vehicles for the two levels of SVA. All the items for Standard SVA are checked at the SVA test station. However, items for ESV A (other than seatbelts) cannot be tested at the SVA test station and therefore documentary evidence of compliance as to be produced. The SVA test station will then check that the vehicle aligns to the documentation presented.

Acceptable alternatives are listed in the SVA Inspection Manual which is produced by VOSA.

For standard SVA, all the inspections are undertaken at selected testing stations operated by the Vehicle and Operator Services Agency (VOSA), an executive agency of The Department for Transport. These tests can also be conducted by VOSA Examiners at ‘designated premises’ if certain conditions are met. Designated premises are privately owned premises that have been authorized by VOSA for their examiners to use to conduct SVA tests.

Although the same items are tested as in type-approval they are not tested in the same way. To keep the fee to a level affordable by individuals the examiner will in the case of certain items conduct an engineering assessment. This check will be in the form of either visual inspection or a simple test on the vehicle to ensure that it complies with the regulations.

The examination will be limited to parts of the vehicle which can be readily seen without dismantling. However, the presenter may be asked to open lockable compartments and remove engine covers, inspection/access panels, trims or carpeting. This is to allow access to items subject to examination. Also, because vehicles are inspected individually the tests are not destructive or damaging in any way.

A Minister’s Approval Certificate (MAC) under SVA is issued when the examiner is satisfied that the vehicle would meet the requirements of the regulations in relation to the design and construction of the vehicle. Unlike the MOT, the examination is not primarily concerned with vehicle
The history, development and construction of the car body

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard SVA</th>
<th>Additional items for enhanced SVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light goods vehicles</td>
<td>Light goods vehicles</td>
</tr>
<tr>
<td>Cars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radio interference suppression</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Doors, their latches and hinges</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Protective steering</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>Evidence of compliance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with type-approval standard or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>acceptable alternative</td>
</tr>
<tr>
<td>Exhaust emissions</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evidence of compliance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with type-approval standard or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>acceptable alternative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May require independent test</td>
</tr>
<tr>
<td>Smoke emissions (diesels only)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Lamps, reflectors and devices</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rear-view mirrors</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Anti-theft devices</td>
<td>Yes*</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evidence of compliance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with type-approval standard or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>acceptable alternative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May require independent test</td>
</tr>
<tr>
<td>Seat belts</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evidence of compliance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or visual assessment at test site</td>
</tr>
<tr>
<td>Seat belt anchorages</td>
<td>Yes*</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evidence of compliance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with full type-approval standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or acceptable alternative</td>
</tr>
<tr>
<td>Installation of seat belts</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evidence of compliance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with type-approval standard or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>acceptable alternative</td>
</tr>
<tr>
<td>Brakes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evidence of compliance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with type-approval standard or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>acceptable alternative</td>
</tr>
</tbody>
</table>
## Table 1.1 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard SVA</th>
<th>Additional items for enhanced SVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cars</td>
<td>Light goods vehicles</td>
</tr>
<tr>
<td>Noise and silencers</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass: windscreen and other windows outside</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Seats and their anchorages</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Tyres</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Interior fittings</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>External projections</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Speedometers</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Wiper and washer system</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Defrosting and demisting system</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Fuel input</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Design weights</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>General vehicle construction</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CO₂ emissions and fuel consumption (vehicles manufactured after 1 January 1997)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>CO₂ emissions and fuel consumption (vehicles manufactured after 1 January 1997)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Front impact protection (vehicles manufactured after 1 October 2003)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The history, development and construction of the car body

Table 1.1 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard SVA</th>
<th>Light goods vehicles</th>
<th>Additional items for enhanced SVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cars</td>
<td>Light goods vehicles</td>
<td>Cars</td>
</tr>
<tr>
<td>Plate for goods vehicles</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Side Impact Protection (vehicles manufactured after 1 October 2003)</td>
<td>No</td>
<td>No</td>
<td>Evidence of compliance with type-approval standard or acceptable alternative N.B. May require comparison test against EC approved vehicle</td>
</tr>
</tbody>
</table>

* Compliance with the enhanced requirements shall exempt the vehicles from these SVA items.

Questions

1. Why were the earliest motor vehicle bodies made almost entirely of wood?
2. When and why did manufacturers commence to use metal for the construction of vehicle bodies?
3. Give a brief history of the development of the vehicle body style, illustrating the significant changes which have taken place.
4. What is meant by monocoque construction, and why has it become so popular in motor vehicle manufacture?
5. With the aid of sketches, describe the general principles of monocoque construction.
6. Describe, with the aid of sketches, the general principles of composite and integral methods of body construction.
7. Draw a sketch of a vehicle body shell and name all the major body panels.
8. State the location and function on a vehicle body of the following sections: (a) BC-post (b) quarter panel (c) wheel arch (d) bonnet.
9. What is the most common form of vehicle body construction?
10. What are the alternatives to integral construction?
11. What is a load-bearing stressed panel assembly? Give examples.
12. What is a non-load-bearing panel assembly? Give examples.
13. Explain how rigidity and strength are achieved in monococonstruction.
14. Describe the location and function of the front and rear bulkheads.
15. Give a brief description of the following early vehicle body styles: coupé, cabriolet, limousine, saloon.
16. What is meant by a veteran vehicle? Name and describe three such vehicles.
17. Name two people who were associated with the early development of the motor vehicle, and state their involvement.
18. Explain what is meant by the semi-integral method of construction.
19. Explain why it is difficult to mass produce composite constructed vehicles.
20. In integral construction, what section of the body possesses the greatest amount of strength?
21. What is the front section of the body shell called, and what are its principal panel assemblies?
22. Explain the role of the stylist in the design organization.
58 Repair of Vehicle Bodies

23 Name one vehicle design stylist who has become well known during the last 25 years.

24 List the stages of development in the creation of a new vehicle body design.

25 State the definition of the symbol $C_d$.

26 Define the term CAD-CAM.

27 Explain the role of the clay modeller in the structure of the styling department.

28 With the aid of a sketch, explain what is meant by profile aerodynamic drag.

29 Explain the necessity for prototype testing.

30 Explain the use of dummies in safety research and testing.

31 Explain the difference in manufacture between a medium-bodied mass-produced vehicle and a high-quality coach-built limousine.

32 Describe the body work styling of a Sports or GT vehicle.

33 What is the difference in design between a saloon and a hatchback vehicle?

34 With the aid of a sketch, explain the body styling of a coupé vehicle.

35 Explain ABS as an active safety feature on a vehicle.

36 How are vehicles made safe against side impact involvement?

37 Explain how the airbag system works in a vehicle.

38 Explain the VIN number and why it is used on a vehicle.

39 Name the two main types of seatbelt arrangement which are fitted to a standard saloon vehicle.

40 State the letters used in design to identify the body pillars on a four-door saloon.

41 State the main purpose of a vehicle subframe.

42 Explain why seatbelt anchorages must be reinforced on a vehicle body.

43 State why GRP bodywork is normally associated with separate body construction.

44 List the design features that characterize a vehicle body as a limousine.

45 Explain the necessity for a hydraulic damper in the suspension of a motor vehicle.

46 Why is GRP not used in the mass production of vehicle body shells on an assembly line?

47 Name one of the persons who was associated with the early development of the motor vehicle and state his involvement.

48 State the purposes of the inner reinforcement members of a bonnet panel and say how they are held in place.

49 State the reasons for swaging certain areas of a vehicle floor pan.

50 Explain the importance of the use of scale models in vehicle design.

51 Why are current body shapes more rounded than previous designs?

52 Why are radiator grilles shaped differently on different makes of cars?