UNIT 1- CAR BODY DETAILS

Cars can come in a large variety of different body styles. Some are still in production, while others are of historical interest only. These styles are largely (though not completely) independent of a car's classification in terms of price, size and intended broad market; the same car model might be available in multiple body styles (or model ranges). For some of the following terms, especially relating to four-wheel drive / SUV models and minivan / MPV models, the distinction between body style and classification is particularly narrow.

Please note that while each body style has a historical and technical definition, in common usage such definitions are often blurred. Over time, the common usage of each term evolves. For example, people often call 4-passenger sport coupés a "sports car", while purists will insist that a sports car by definition is limited to two-place vehicles.

Body work

In automotive engineering, the bodywork of an automobile is the structure which protects:

- The occupants
- Any other payload
- The mechanical components.

In vehicles with a separate frame or chassis, the term bodywork is normally applied to only the non-structural panels, including doors and other movable panels, but it may also be used more generally to include the structural components which support the mechanical components.

Construction

There are three main types of automotive bodywork:

- The first automobiles were designs adapted in large part from horse-drawn carriages, and had body-on-frame construction with a wooden frame and wooden or metal body panels. Wooden-framed motor vehicles remain in production to this day, with many of the cars made by the Morgan Motor Company still having wooden structures underlying their bodywork.

- A steel chassis or ladder frame replaced the wooden frame. This form of body-on-frame construction is still common for commercial vehicles.

- Monocoque, or unibody construction, in which the "chassis" is part of, and
integrated with the metal body. It provides support to all the mechanical components, as well as protection for the vehicle occupants. Although there is no separate complete frame or chassis, many monocoque/unibody designs now often include subframes. Steel monocoque construction is now the most common form of car bodywork, although aluminum and carbon fiber may also be used.

Less common types include tube frame and space frame designs used for high-performance cars. There have also been various hybrids, for example the Volkswagen Beetle had a chassis, consisting of the floor pan, door sills and central tunnel, but this chassis relied on the stiffening provided by the bodywork, a technique sometimes called semi-monocoque construction.

Non-structural body panels have been made of wood, steel, aluminum, fiberglass and several more exotic materials.

**Body styles**

There are several common car body styles:

- Enclosed:
  - Sedan, known as a Saloon in British English.
  - Hardtop
  - Coupé
  - 2+2
  - Notchback
  - Limousine

- Open or partly enclosed:
  - Roadster
  - Convertible (or Cabriolet)
  - Stanhope body
  - Touring car
  - Town car

- Rear door designs:
  - Station wagon or Estate car
**Sedan delivery**

- **Hearse**
- **Hatchback**
- **Liftback**
- **Combi coupé**

**Other:**

- **Sport utility vehicle** (SUV)
- **Crossover**
- **Minivan**
- **Coupe Utility**

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**Sedan (Saloon)**

A sedan car or saloon car is a passenger car with two rows of seats and adequate passenger space in the rear compartment for adult passengers. The vehicle usually has a separate rear trunk for luggage, although some manufacturers such as Chevrolet, Tatra, and Volkswagen have made rear-engined models. It is one of the most common body styles for modern automobiles, and is often marketed at families under the rubric of family sedan.

- **1 Types of sedan**
  - **1.1 Notchback sedans**
  - **1.2 Fastback sedans**
  - **1.3 Two-door sedans**
  - **1.4 Hardtop sedans**
  - **1.5 Hatchback sedans**
  - **1.6 Chauffeured sedans**

**Types of sedan**

A sedan seats four or more people and has a fixed roof that is full-height up to the rear
**window.** The roof structure will typically have a fixed "B" pillar on sedan models. Most commonly it is a four-door; two-door models are rare, but they do occur (more so historically).

Notchback sedans

1962 Chevrolet Impala, a typical notchback sedan

A notchback sedan is a **three-box** sedan, where the passenger volume is clearly distinct from the trunk volume of the vehicle (when seen from the side). The roof is on one plane, generally parallel to the ground, the rear window at a sharp angle to the roof, and the trunk lid is also parallel to the ground. Historically, this has been a popular and arguably the most traditional form of passenger vehicle.

Fastback sedans

1941 Plymouth fastback sedan

A fastback sedan is a **two-box** sedan, with continuous slope from the roof to the base of the **decklid**, but excludes the **hatchback** feature. Marketing terminology is often misleading in this area - for example, Daimler AG calls the Mercedes-Benz CLS-Class sedan a **four-door coupé** because its semi-fastback design tries to give the impression of a coupé. Certain sedans are edging close to being **one-box** vehicles, where the windshield is steeply raked from the hood and the rear window slopes toward almost the end of the car, leaving just a short rear deck that is part of the trunk lid.

Typically this design is chosen for its **aerodynamic** advantages. Automakers can no longer afford the penalty in **fuel consumption** produced by the traditional notchback **three box** form.
Two-door sedans

Opel Kadett B two-door sedan

The Society of Automotive Engineers defines such a vehicle as any two-door model with rear accommodation greater than or equal to 33 cubic feet (0.93 m$^3$) in volume (a calculation made by adding the legroom, shoulder room, and headroom. By this standard, the Chevrolet Monte Carlo, Ferrari 612 Scaglietti, and Mercedes-Benz CL-Class coupés are all two-door sedans.

In the popular vernacular, a two-door sedan is defined by appearance and not by volume; vehicles with a B-pillar between the front and rear windows are generally called two-door sedans.

Hatchback sedans

Chevy Malibu Maxx hatchback sedan

Hatchback sedans typically have the fastback profile, but instead of a trunk lid, the entire back of the vehicle lifts up (using a liftgate or hatch). A vehicle with four passenger doors and a liftgate at the rear can be called a four-door hatchback, four-door hatchback sedan, or five-door sedan. An example of such is the Chevrolet Malibu Maxx. There can also be two-door hatchback sedans (three-door sedans), by the same technical explanation for two-door sedans. Examples of this design are the Volkswagen Golf, and Chevrolet Chevette.
Convertible

Jaguar XK8 c. 2008, with heatable glass rear window and fully automatic cloth top with integral top-concealing rigid tonneau

A convertible is a type of automobile in which the roof can retract and fold away, converting it from an enclosed to an open-air vehicle. Many different automobile body styles are manufactured and marketed in convertible form.

Roof designs vary widely, but a few characteristics are common to all convertibles. Roofs are affixed to the body of the vehicle and are usually not detachable. Instead the roof is hinged and folds away, either into a recess behind the rear seats or into the boot or trunk of the vehicle. The roof may operate either manually or automatically via hydraulic or electrical actuators; the roof itself may be constructed of soft or rigid material. Soft-tops are made of vinyl, canvas or other textile material; hard-top convertibles have roofs made from steel, aluminum, carbon fiber or plastic materials.

Contemporary convertibles are known and marketed under several different terms due to the convergence of body styles over the years. A soft-top convertible may also be referred to as a cabriolet or cabrio or spyder, although two-seater soft tops often retain the name roadster, referring to their body style.

1. Folding textile roof

The collapsible textile roof section (of cloth or vinyl) over an articulated folding frame may include linings such as a sound-deadening layer or interior cosmetic headliner (to hide the frame) — or both — and may have electrical or electro-hydraulic mechanisms for raising the roof. The erected top secures to the windshield frame header with manual latches, semi-manual latches, or fully automatic latches. The folded convertible top is called the stack.
Convertibles offer the flexibility of an open top in trade for:

- potentially reduced safety
- poor break-in protection
- deterioration and shrinkage of the sun-exposed textile fabric over time
- diminished rear visibility, from a large roof structure, small rear window, or obstructed rear window — or all of these: e.g., MINI convertible.
- generally poor structural rigidity. Contemporary engineering goes to great length to counteract the effects of removal of a car's roof.
- specifically poor structural rigidity, such as pronounced scuttle shake, a characteristic whereby the structural design of the bulkhead between engine and passenger compartment of a convertible suffers sufficiently poor rigidity to negatively impact ride or handling — or allow noticeable vibration, shudder or chassis-flexing into the passenger compartment.

2. Retractable hardtop roof

A Volvo C70 with retractable hardtop

A retractable hardtop, also known as coupé convertible or coupé cabriolet, is a type of convertible that forgoes a folding textile roof in favor of an automatically operated, multi-part, self-storing hardtop where the rigid roof sections are opaque, translucent or independently operable.

The retractable hardtop solves some issues with the convertible, but has its own...
compromises, namely mechanical complexity, expense and more often than not, reduced luggage capacity.

**Construction**

Retractable hardtops can vary in material (steel, plastic or aluminum), can vary from two to five in the number of rigid sections and often rely on complex dual-hinged trunk (*British: boot*) lids that enable the trunk lid to both receive the retracting top from the front and also receive parcels or luggage from the rear — along with complex trunk divider mechanisms to prevent loading of luggage that would conflict with the operation of the hardtop.

The retractable hardtop convertible trades higher initial cost, mechanical complexity and, with rare exception, diminished trunk space — for increased acoustic insulation, durability and break-in protection similar to that of a fixed roof coupe.

The retractable hardtop eliminates:

- the need for a storage-consuming, manually-from-outside-the-vehicle-installable, separate or integral, rigid or foldable.

- the need for a separate rigid hardtop requiring space-consuming off-season storage and a cumbersome twice-yearly, two-person manual installation and removal — a system popularized, for example, by the *Mercedes-Benz SL-Class* of 1963 to 1988.

- In addition to higher initial cost, diminished trunk space, and increased mechanical complexity — and thereby potentially higher repair cost.

**Limousine**

A black Lincoln Town Car "stretch" limousine at a car show in Bristol, England
A limousine is a luxury vehicle, especially one with a lengthened wheelbase or driven by a chauffeur. The chassis of a limousine may have been extended by the manufacturer or by an independent coachbuilder. These are referred to as "stretch" limousines and are traditionally black or white in color. Limousines are usually liveried vehicles, driven by professional chauffeurs. As the most expensive form of automobile ground transportation, limousines are culturally associated with extreme wealth or power, and are commonly cited as an example of conspicuous consumption. Among the less wealthy, limousines are also often hired during special events (most commonly weddings and funerals).

**Limousine types**

The limousine body style has a divider separating the driver from the rear passenger compartment. This partition usually contains a sliding (often soundproof) glass window so that conversations between passengers in the rear compartment may be kept private from the chauffeur. Communication with the driver is possible either by opening the window in the partition or by using an intercom system.

**Traditional**

Lincoln Limousine used by U. S. President Calvin Coolidge, c. 1924

Traditionally, the limousine has been an extension of a large car. A longer frame and wheelbase allow the rear passenger compartment to contain the usual forward facing passenger seat but with a substantial amount of foot room — more than is actually
needed. Usually then two "jump seats" are mounted, facing rearward behind the driver. These seats fold up when not in use. In this way, up to five persons can be carried in the aft compartment in comfort, and up to two additional persons carried in the driver's compartment, for a total capacity of seven passengers in addition to the driver.

Modern limousines

Maybach 62

Rolls Royce Phantom

Newer limousines such as the Maybach 62, Rolls Royce Phantom, Audi A8L, Volkswagen Phaeton, Mercedes-Benz S-Class, Jaguar XJ, BMW 760Li, Lincoln Town Car Edition, and the Cadillac DTS do not feature jump seats since stretch limousines are usually used to transport more than three passengers, excluding the driver. In production American limousines however, the jump seats almost always faced forward. The last production limousine, by Cadillac, with forward facing jump seats was in 1987 (with their Fleetwood Series 75 car), the last Packard in 1954, and the last Lincoln in 1939, though Lincoln has offered limousines through their dealers as special order vehicles at times. Several Lincoln Premier cars were also built, one being owned by Elvis Presley. Vehicles of this type in private use may contain expensive audio players, televisions, video players, and bars, often with refrigerators.

It is simpler to determine the effects of altering a separate chassis than it is to determine the effects of altering a load-bearing unit body. For this reason, the automobile of choice for conversion into stretch limousines is the Lincoln Town Car, whose Panther platform is one of the last remaining automotive platforms using a separate load-bearing chassis. Coach builders have built models based on SUVs with a separate load-bearing chassis,
including Hummer H2s and H3s.

A Lada "limousine" in Trinidad, Cuba. This car and the Trabant below fall more into the category of 'shuttle' than an actual luxury limousine.

Another type of vehicle modified for multiple passenger use is the motorized stage, applied to the same tasks as the earlier stagecoach. It is not considered a true limousine but rather in its design and application is between a sedan and a bus. While a bus will have a central interior aisle for access to seating, a stage has multiple doors that allow access to transverse forward facing seats. Examples of the type were constructed not only from sedans (e.g., Chrysler New Yorker, Cadillac DeVille), but also from station wagons; many of the station wagon conversions sported a large rack, running the length of the roof, for carrying the passengers' baggage.

This type of vehicle was once rather common in some locations. An example of its use was in the transport of travelers arriving by railroad at Merced, California to travel to Yosemite National Park in the first half of the 20th century and at other remote parks. In Yosemite, passengers would then stay in rustic platform tent camps or more expensive lodges and hike or rent bicycles for movement around the park. In Glacier National Park, the stages were referred to as "Jammers" in reference to the nickname of their gear-jamming drivers.

A modern version of the stage is seen in some novelty stretch Hummer or Hummer H2 vehicles. Some funeral homes maintain six-door stages to carry the family of the deceased between the church and the cemetery. These are usually not used for private hire.
Exotic limousines

A limousine based on a Ford Excursion

Sometimes a coach builder or car designer will develop the "ultimate" stretch limo, adding amenities that are somewhat impractical but which make a significant design statement. One such design includes tandem rear axles to support the weight of an operational hot tub.

These extensive limousine conversions have been performed on several luxury marques and fast cars, including: Bentley, BMW, Cadillac, Chrysler, Ford, Holden, Hummer, Infiniti, Jaguar, Lexus, Lincoln, Mercedes-Benz, Rolls-Royce and Volkswagen.

Novelty limousines
Trabant limousine

Sometimes an "inappropriate" vehicle is converted, simply for the novelty. Hummer vehicles have been converted. Another novelty conversion is the East German Trabant which was designed for a low manufacturing cost and incorporated body panels made from a rag fiber and plastic resin material. Volkswagen Beetles, Fiat Pandas and Citroen 2CV vehicles are occasionally stretched into limousines.

Station wagon (ESTATE CAR)

1957 Chevrolet 210 Station Wagon

1970's Opel Rekord D Caravan

A station wagon is a passenger car body style similar in terms of passengers to the sedan/saloon style but incorporating a full-size back cargo compartment (that can be further extended for a third passenger row in some cases) accessible via a fifth door instead of the standard sedan trunk slot. Station wagons are not to be confused with hatchbacks, whose difference lies in the size of the said compartment, with hatchbacks fitting practically as much storage as sedans, but often borrowing the fifth door of a station wagon instead of a trunk.

Also sometimes referred to simply as a wagon, the term 'station wagon' is used in United States, Australian, Canadian and New Zealand English, while the alternative term estate car or simply estate is used in British English, with 'station wagon' used occasionally for specific model names. Some manufacturers from other European countries, including Audi, BMW, and Citroën have often referred to their wagons as "Avant", "Touring", and
"Break" respectively.

Description

Most station wagons are modified sedan-type car bodies, having the main interior area extended to the near-vertical rear window over what would otherwise be the trunk (boot) of the sedan version. Many are placed on a longer wheelbase to increase the boot capacity. A hatchback car, although meeting a similar description, would not enjoy the full height of the passenger cabin all the way to the back; the rear glass of a hatchback being sloped further from vertical, and the hatch tending not to reach fully to the rear bumper, as it commonly would in a station wagon. Station wagons also have side windows over the cargo area, whereas some hatchbacks have thick "C" pillars and no cargo area windows.

The rear door is usually top-hinged, but on many four-wheel drive-style vehicles it is side-hinged. The original Range Rover, and a few traditional sedan-based wagons, have a horizontally split two-piece rear door rather than a single hatch. The Morris Minor and Mini Travellers, amongst other examples, have a vertically split pair of doors at the rear.

The popularity of the minivan in the 1980s, sport utility vehicles in the mid-1990s, and crossovers in the 2000s is credited with the decline of the traditional station wagon in North America.

Types:

All-steel wagons

1954 Plymouth Savoy Station Wagon

1957 Chevrolet Bel Air Townsman
1958 **AMC Ambassador** 4-door pillarless hardtop station wagon

**Full-size wagons**

1967 Ford Country Squire – a full size station wagon

Traditionally, full-sized American station wagons were configured for 6 or 9 passengers. The basic arrangement for seating six was three passengers in the front and three passengers in the rear, all on bench-type seats; to accommodate nine, a third bench seat – often facing backward, but sometimes facing forward or sideways – was installed in the rear cargo area, over the rear axle. In Ford and Mercury wagons built after 1964, the configuration was changed to two seats facing each other, placed behind the rear axle. According to Ford, each seat would accommodate two people, raising the total seating capacity to ten passengers; however, these seats were quite narrow in later models and could only accommodate one passenger, limiting the total capacity to eight passengers.

Newer models are usually built on smaller platforms and accommodate five or six passengers (depending on whether bucket or bench seats are fitted in front). Full-size SUVs such as the **Chevrolet Suburban** and **Ford Expedition** have similar features to the aforementioned full-size station wagons; such as 9-passenger seating with bench seating in the front.

**Two-door wagons**
1956 Chevrolet Bel Air Nomad

1958 Mercury Commuter 2-door hardtop wagon

1971 Chevrolet Vega Kammback

This was a car targeting buyers looking for economy and load space, as well as a strategy of reintroducing an old design; a business decision that has not been successfully duplicated to this day.

Station wagons around the world

2005 Chrysler 300C Touring (European)
1990 **Volvo 240**

This modified **MG ZT-T** became the world's fastest estate/station wagon in 2003. [17]

1972 **Citroën DS Break**
**Toyota Camry** wagon

Australian **Ford BA Falcon** station wagon

**Tailgate evolution**
1963 Studebaker Wagonaire

1974 Buick Estate Wagon with "clamshell" tailgate

2007 Ford Mondeo

Opel Insignia Sports Tourer

The vast majority of modern station wagons have an upward-swinging, full-width, full-
height rear door supported on **gas struts**, and a few also have a rear window that can be swung upward independently to load small items without opening the whole liftgate. Historically, however, many different designs have been used for access to the rear of car; the following summary concentrates on American models.

- The earliest common style was an upward-swinging window combined with a downward swinging tailgate. Both were manually operated. This configuration generally prevailed from the earliest origins of the wagon bodystyle in the 1920s through the 1940s. It remained in use through 1960 on several models offered by Ford.

- In the early 1950s, tailgates with hand-cranked roll-down rear windows began to appear. This was another innovation first seen on Rambler wagons.[18] Later in the decade, electric power was applied to the tailgate window – it could be operated from the driver's seat, as well as by the keyhole in the rear door. By the early 1960s, this arrangement was becoming common on both full-size and compact wagons.

- A side hinged tailgate that opened like a door was offered on three-seat wagons by American Motors to make it easier for the back row passengers to enter and exit their rear-facing seats. This was later supplanted by the dual-hinged tailgate.

- The **Studebaker Wagonaire** station wagon had a unique retractable rear roof section as well as a conventional rear tailgate which folded down. This allowed it to carry tall objects that would not fit otherwise. Water leaks, body flex and noise prevented the innovation from being adopted by other manufacturers. The concept was reintroduced in 2003 on GMC's mid-size Envoy XUV SUV, but did not last long on that vehicle either.

- The 1964–72 **Oldsmobile Vista Cruiser** and 1964–69 **Buick Sport Wagon** featured raised rooflines beginning above the second-row seat and continuing all the way to the rear tailgate. Above the second seat were plexiglas skylights in which passengers could view the outside from overhead. On the three-seat models of these wagons, the third seat faced forward as did the first and second seats, unlike the normal practice of three-seat wagons at the time in which the rearmost seat faced the rear.

- Ford's full-size wagons for 1966 took the conventional tailgate and disappearing window a step further. The rear section was made to open either downwards like a regular tailgate, or like a door, outward from the curb side. The window had to be retracted for either operation. This was called the "Magic Doorgate". For 1969, Ford made another innovation by allowing the glass to stay up when the door was opened sideways, thus creating the "Three-Way Magic Doorgate" (engineered by Donald N. Frey[19]). This versatile style quickly caught on and became a fixture on full-size and intermediate wagons from GM, Ford, and Chrysler. GM, however, added a notch in the rear bumper that acted as a step plate; to fill the
gap, a small portion of bumper was attached to the doorgate. When opened as a swinging door, this part of the bumper moved away, allowing the depression in the bumper to provide a "step" to ease entry; when the gate was opened by being lowered or raised to a closed position, the chrome section remained in place making the bumper "whole".

- Full-size GM wagons (Buick, Chevrolet, Oldsmobile, and Pontiac) built between model years 1971 and 1976 brought a completely new design to market. They had a rear window that would slide upwards into the roof as the tailgate dropped down below the load floor. This was referred to as a "clamshell" arrangement. On all full-size GM wagons, the window for the clamshell door was power operated, however the gate door itself could be had in either manual on Chevrolet models or power assist in Pontiac, Oldsmobile or Buick cars. The manual style door quickly lost favor because of the effort required to lift and swing the heavy door up from its storage area; sales tapered off after the 1972 model year and electric assist all but became standard. This was the first power tailgate in station wagon history. This system was large, heavy, and complex, and was never adopted for any other car manufacturer. After that, GM reverted to the doorgate style for its full-size wagons (the February 2008 issue of Collectible Automobile magazine detailed why this setup was phased out – the 1977 GM full-size cars had to meet the DOT-revised category of 4000 GVW; the elimination of the clamshell was the first agenda on the list, and limiting the bodystyles to the station wagon, coupe, and sedan).

- As the 1970s progressed, the need for lighter weight to meet fuel economy standards led to a simplified, one-piece liftgate on several models, particularly smaller wagons, such as is commonly seen on SUVs today. On the same principle, and quite ironically, the last generation of GM's full-size wagons returned to the upward-lifting rear window as had been used in the 1940s.

- In recent years, the Citroën C5 wagon features an upward-lifting full-height full-width rear door, where the window on the rear door can be opened independently from the rear door itself. The window is also opened upwards and is held on gas struts. The Renault Laguna II estate chassis has a similar arrangement.

- Early models of the Range-Rover had a hinging number plate attached to the lower part of the split rear door. When the lower part was folded down the plate hung down to remain readable. This was deleted on later models but the split tailgate remains to this day

Racing Cars

Auto racing
The start of a Formula One race in 2008

* TYPES:

Single-seater racing

Modern Formula One car: McLaren MP4-24. Heikki Kovalainen testing at the Circuito
In single-seater (open-wheel) the wheels are not covered, and the cars often have aerofoil wings front and rear to produce downforce and enhance adhesion to the track. In Europe and Asia, open wheeled racing is commonly referred to as "Formula", with appropriate hierarchical suffixes. In North America, the "Formula" terminology is not followed (with the exception of F1). The sport is usually arranged to follow an "international" format (such as F1), a "regional" format (such as the Formula 3 Euro Series), or a "domestic", or country-specific format (such as the German Formula 3 championship, or the British Formula Ford).

The best-known variety of single-seater racing, Formula One, involves an annual World Championship for drivers and constructors.

Formula Three car racing at the Hockenheimring, 2008

The other major international single-seater racing series is GP2 (formerly known as Formula 3000 and Formula Two). Regional series include Formula Nippon and Formula V6 Asia (specifically in Asia), Formula Renault 3.5 (also known as the World Series by Renault, succession series of World Series by Nissan), Formula Three, Formula Palmer Audi and Formula Atlantic. In 2009, the FIA Formula Two Championship brought about the revival of the F2 series. Domestic, or country-specific series include Formula Three, Formula Renault, Formula Ford with the leading introductory series being Formula BMW.

Touring car racing

World Touring Car Championship 2006: Andy Priaulx leads at Curitiba.
Touring car racing is a style of road racing that is run with production derived race cars. It often features full-contact racing due to the small speed differentials and large grids.

**sports car racing**

![Audi R8 at Road Atlanta](image)

The **Audi R8** was one of the most successful sports prototypes ever made, seen here at Road Atlanta.

In **sports car racing**, production derived versions of **sports cars** also known as grand tourers (GTs), and purpose built **sports prototype** cars compete within their respective classes on closed circuits.

Sports prototypes, unlike GT cars, do not rely on road legal cars as a base. They are closed wheel and often closed cockpit purpose built race cars intended mainly for endurance racing. They have much lower weight and more down force compared to GT cars making them much faster.

Famous sports car races include the **24 Hours of Le Mans**, the **24 Hours of Daytona**, **24 Hours of Spa-Franchorchamps**, the **12 Hours of Sebring**, and the 1,000-mile (1,600 km) **Petit Le Mans** at **Road Atlanta**. There is also the **24 Hours of the Nürburgring** on the infamous Nordschleife track and the **Dubai 24 Hour** which is aimed at GT3 and below cars with a mixture of professional and pro-am drivers.

**Stock car racing**

![Stock cars](image)
Practice for the **Daytona 500**.

**Stock car racing** is the most popular form of racing in North America.

Primarily raced on **oval tracks**, stock cars resemble production cars but are in fact purpose-built racing machines which are built to tight specifications.

The largest stock car racing governing body is **NASCAR** (National Association for Stock Car Auto Racing).

A **World of Outlaws** late model stock car on a dirt track.

There are also other stock car governing bodies, such as **Automobile Racing Club of America** and **United Speed Alliance Racing**.

**Rallying**

A **Ford Escort RS Cosworth**, driven by **Malcolm Wilson** on a stage rally.

**Rallying** at international and most national championship levels involves two classes of **homologated** road legal production based car; **Group N** Production cars and more modified **Group A** cars. Cars compete on (closed) public roads or off-road areas run on a point-to-point format where participants and their co-drivers "rally" to a set of points, leaving in regular intervals from start points.

**Targa Racing (Targa Rally)**
A Toyota MR2, driven by Adam Spence in the 2006 Targa Tasmania prologue stage.

Targa is a tarmac-based road rally which is run all around the world. This began with the Targa Florio.

Off-road racing

In off-road racing, various classes of specially modified vehicles, including cars, compete in races through off-road environments. In North America these races often take place in the desert, such as the famous Baja 1000. In Europe, "offroad" refers to events such as autocross or rallycross, while desert races and rally-raids such as the Paris-Dakar, Master Rallye or European "bajas" are called "cross-country rallies."

Kart racing

A sprint kart race in Atwater California hosted by the International Karting Federation.

Although often seen as the entry point for serious racers into the sport, kart racing, or karting, can be an economical way for amateurs to try racing and is also a fully fledged international sport in its own right.

Sports car
Lotus Super 7, a fundamental sports car

The term **sports car** has been defined as "an open, low-built, fast **motor car**.

- **Overview**

Sports cars can be either luxurious or spartan, but driving and mechanical performance is requisite. Many drivers regard brand name and the subsequent racing reputation and history as important indications of sporting quality (for example, **Porsche**, **Lotus**, or **Ferrari**), but some exotic car brands, such as **Lamborghini**, which do not race or build racing cars, are also highly regarded by sports car enthusiasts.

**Sportcar description**

An important sports feature on the Skelta G-Force is that it is made of **carbon fiber**, making it ultra-light.

A sports car does not require a large, powerful **engine**, though many do have them. Many classic British sports cars lacked powerful engines, but were known for exceptional handling due to light weight; a well-engineered, balanced chassis; and modern suspension (for example, **Lotus Seven**, **Austin 7 Speedy**). On tight, twisting roads, such a sports car may perform more effectively than a heavier, more powerful car.
Layout

**Alpine A110**, a rear-engine, rear-wheel (RR) drive sports car

1990s **Lotus Elan M100**, a front-engine, front wheel (FF) drive sports car

**Porsche Boxster**, a rear mid-engine, rear-wheel (RMR) drive sports car

The drive train and engine layout significantly influences the handling characteristics of an automobile, and is crucially important in the design of a sports car.

The **front-engine, rear-wheel drive layout** (FR) is common to sports cars of any era and has survived longer in sports cars than in mainstream automobiles. Examples include the **Caterham 7**, **Mazda MX-5**, and the **Chevrolet Corvette**.

The **RMR layout** is commonly found only in sports cars—the motor is centre-mounted in the chassis (closer to and behind the driver), and powers only the rear wheels. Some high-
performance sports car manufacturers, such as Ferrari and Lamborghini prefer this layout. Porsche is one of the few remaining manufacturers using the rear-engine, rear-wheel drive layout (RR). The motor's distributed weight across the wheels, in a Porsche 911, provides excellent traction, but the significant mass behind the rear wheels makes it more prone to oversteer in some situations. Porsche has continuously refined the design and in recent years added electronic driving aids (i.e. computerised traction-stability control) to counteract these inherent design shortcomings.

Some sport cars have used the front-engine, front-wheel drive layout (FF), e.g. Fiat Barchetta, Saab Sonett and Berkeley cars. This layout is advantageous for small, light, lower power sports cars, as it avoids the extra weight, increased transmission power loss, and packaging problems of a long driveshaft and longitudinal engine of FR vehicles. Yet, its conservative handling effect, particularly under steer, and the fact that many drivers believe rear wheel drive is a more desirable layout for a sports car make this layout atypical to high-performance sports cars.

Seating

Some sports cars have small back seats that are really only suitable for luggage or small children. Such a configuration is often referred to as a 2+2 (two full seats + two "occasional" seats).

Over the years, some manufacturers of sports cars have sought to increase the practicality of their vehicles by increasing the seating room. One method is to place the driver's seat in the center of the car, which allows two full-sized passenger seats on each side and slightly behind the driver. The arrangement was originally considered for the Lamborghini Miura, but abandoned as impractical because of the difficulty for the driver to enter/exit the vehicle. McLaren used the design in their F1.

Another British manufacturer, TVR, took a different approach in their Cerbera model. The interior was designed in such a way that the dashboard on the passenger side swept toward the front of the car, which allowed the passenger to sit farther forward than the driver. This gave the rear seat passenger extra room and made the arrangement suitable for three adult passengers and one child seated behind the driver.

DRIVER’S VISIBILITY:

In transport, driver visibility is the maximum distance at which the driver of a vehicle can see and identify prominent objects around the vehicle. [1] Visibility is primarily determined by weather conditions (see visibility) and by a vehicle's design. [2] The parts of a vehicle that influence visibility include the windshield, the dashboard and the pillars. Good driver visibility is essential to safe road traffic.

Blind spots may occur in the front of the driver when the A-pillar (also called the windshield pillar), side-view mirror, and interior rear-view mirror block a driver's view of the road. Behind the driver, there are additional pillars, headrests, passengers, and cargo, that may reduce visibility. Blind spots are affected directed by vehicular speed, since they
increase substantially the faster one goes.

**A-pillar blind spot**

1. **Forward visibility**

This diagram shows the blocked view in a horizontal-plane in front of the driver. The front-end blind spots caused by this can create problems in traffic situations, such as in roundabouts, intersections, and road crossings. Front-end blind spots are influenced by the following design criteria:

- Distance between the driver and the pillar
- Thickness of the pillar
- The angle of the pillar in a vertical plane side view
- The angle of the pillar in a vertical plane front view
- The form of the pillar straight or arc-form
- Angle of the windshield
- Height of the driver in relation to the dashboard
- Speed of the opposite car
1. Effects of A-pillar angle on visibility

Most passenger cars have a diagonal pillar as shown in this side view. The angle between the horizon and A-pillar is approximately 40 degrees with a straight pillar that is not too thick. This gives the car a strong, aerodynamic body with an adequately-sized front door.

1.1. Panoramic windshield

The sides of a panoramic windshield are curved, which makes it possible to design vertical A-pillars that give the driver maximum forward visibility. However, it is...
impossible to design an aerodynamic small car with a vertical A-pillar because the more vertical the A-pillar is, the less space the door opening has, and the greater frontal area and coefficient of drag the vehicle will have.

Examples of cars with an almost vertical A-pillar:

- Honda Step Bus Concept
- Saab 900
- School bus
- Almost all Cadillacs from 1954-1959

**A-pillar** bars reduce driver visibility

### 1.1.2 Panoramic windshield

Some modern car designs have an extremely flat A-pillar angle with the horizon. For example, the Pontiac Firebird and Chevrolet Camaro from 1993-2002 had a windshield angle of 68° with the vertical, which equals just 22° with the horizon.[1]

A flatter A-pillar's advantages include reducing the overall drag coefficient and making the car body stronger in a frontal collision, at the expense of reducing driver visibility in a 180° field of view from left to right.
Car with a "quarter glass", Visibility of short and tall drivers

1. 2. Other disadvantages of a flat windshield angle

- Other traffic can not see the driver through the reflection if the driver can see them.
- The heater needs more time to heat the bigger window surface.
- The flat windshield angle does not let snow slide off easily.
- The driver cannot reach the whole flat window to clean it easily.

2. Height of the driver

Driver height can also affect visibility.

An A-pillar that is split up and haves a small triangle window (Front Quarter glass) can give a short driver visibility problems. Some cars the windshield is fillet with the roof-line with a big radius. A fillet round A-pillar can give a tall driver visibility problems. Also sometimes the A-pillar can block the driver from seeing motorcyclists.

Also the B-pillar (car) can block the vision of a tall driver in small 4 door cars.
Turning your head reduces blind spot

A driver may reduce the size of a blind spot or eliminate it completely by turning their head in the direction of the obstruction. This allows the driver to see better around the obstruction and allows the driver better depth perception.

3. Visibility in a convertible

Because there is no roof connection between the A- and B- pillar The A-pillars of a convertible automobile have to be stronger and even thicker,

However, with the top down there are no B or C pillars, improving driver visibility behind the driver.

4. Windshield reflections
4. 1. Dashboard reflection

It is best if the dashboard has a non-reflecting dark colored surface. [3]
A small dashboard gives some reflection on the lower part of the windshield.

A big dashboard can give reflection on eye height.

4. 2. **A-pillar reflection**

It is best if the inside of the A-pillar has a non-reflecting dark colored surface. [3]

If the side of the window is curved there is less A-pillar reflection. [4]

4. 3. **Light through roof reflection**

Some new model cars have a very big roof-window. Sometimes the sunlight through the roof lights up the dashboard and gives a reflection in the windshield.

5. **Other automobile design factors**

Other design factors may prevent a manufacturer from maximizing visibility. These include safety, as narrower pillars cannot be made strong as easily as thicker pillars, and size restraints pertaining to aerodynamics, as taller, more vertical windshields create additional drag and reduce fuel efficiency.

6. **Rear-view mirror blind spots**

A vehicular blind spot is the area of the road that while driving cannot be seen when looking forward or through either the rear-view or side mirrors. Blind spots can be checked by turning one's head briefly, eliminated by reducing overlap between side and rear-view mirrors, or reduced by adding other mirrors with larger fields-of-view. Detection of vehicles or other objects in blind spots may also be aided by systems such as video cameras or distance sensors, though these are uncommon or expensive options in automobiles generally sold to the public.

**Blind spot (vehicle)**

A **blind spot** in a vehicle are areas around the vehicle that cannot be directly observed under existing circumstances. [1] Blind spots exist in a wide range of vehicles: cars, trucks, motorboats and aircraft.

**Motor vehicles**
VISIBILITY TESTS:

(1) Reversing visibility test procedure
The test procedure consists of the following:

- a laser pointing device,
- a dummy to represent an average adult size,
- a test cylinder to represent the shoulder height of an average 2 year old child, and
- a grid extended 1.8 x 15 metres to the rear of the vehicle.

The laser is directed through the rear window of each vehicle. The position where the laser is visible on the test cylinder is noted. This procedure is repeated for all positions on the grid. The results are analysed and an overall score is given. The best scores are awarded to the vehicles which have the most effective rear visibility.

A low star rating car means a driver looking out the rear window is less likely to see an object of child height, compared to a car with a better star rating. The more stars the
better.

In general, reversing sensors improve the rating by half a star.

(2) Visibility test by Motor Research Industry Association

Each of the cars was driven into the darkened lab and lights mounted in a dummy driver’s eye position were used to project shadows on to a screen which surrounded the car. The grid on the screen was marked with a scale so that the edges of the shadow could be measured in terms of their distance from the driver’s eyes.

Three sets of measurements were taken for each car. Firstly, a single bulb was used to project the shadow of both A-pillars on to the screen. Then, the coordinates of the upper and lower corners were measured to enable the area of vision obscured by the pillars to be calculated.

The dummy’s ‘head’ was then changed to one which had both left and right ‘eyes’ (bulbs) so that binocular vision and pillar thickness could be assessed. The edge of each pillar was measured using one bulb, then the other. In this way, we ensured that only the proportion of the pillar which was obscured to both eyes was measured.

Finally, the ‘critical vision area’ of the windscreen, which is four degrees above and four degrees below the driver’s straight-ahead eye position, was also measured and assessed.

The ‘H-point’ dummy which was used in the tests represents an average-sized UK male. It has a base and back which is moulded to the profile of the human body. Once installed in the driving seat, the dummy was weighted to mimic the weight distribution of a person. This ensured that it always adopted the same standard position in each car.

Aanalysing and presenting the data

A car with wide pillars and a wide screen will give a better overall field of view than a vehicle with the same thickness of pillars, but a narrower screen. Our final rating for each
car takes this into account. The ratio of the screen to pillar areas is the ‘critical vision area’ of the windscreen divided by the left and right pillar areas added together. The higher this value is, the better the score the car will receive.

Although only the screen-to-pillar ratio determines the final score, we’ve also scrutinised the area of the driver’s field of view that is obscured by the pillars, measured in metres squared. This area is projected forward to 23 metres in front of the car – the Highway Code stopping distance at 30mph.

Pillars can obscure a frighteningly wide area - the thickest A-pillars can easily obscure a whole car at a distance of 23 metres.

System for improving the visibility in vehicles

- **Laser Measuring**
  
  A system for improving the visibility in vehicles, including the following: an illumination optical system (2) for continuous radiation of infrared pulsed light; an associated receiver optical system (3) for receiving reflected components of the radiated light; a display (4) for representing information obtained by the receiver optical system (3), and a device (5, 6) for determining the presence of glare in the receiver optical system (3) from a foreign vehicle illumination optical system and
for changing the keying interval or duty cycle of the infrared pulsed light of the illumination optical system (2) driven with fixed keying interval in dependence upon the vehicle direction of travel in such a manner that the glare is eliminated. Therein the illumination optical system is driven is driven with a fixed keying interval depending upon the vehicle direction of travel or, in certain cases, the direction of illumination. In an alternative embodiment, the illumination optical system (2) is operated at a wavelength which depends upon the vehicle direction of travel or, in certain cases, the direction of illumination.

Representative Image:

- Patent Research

The invention concerns a device for improving the view in vehicles, in particular at night, bad weather and fog. In the process images of actual traffic scenes are recorded by a camera (2), which is sensitive outside the visible spectrum, and these images are
reproduced in the visible spectrum in the vehicle via a display optic (6). According to the invention the type of object which is contained in a traffic scene recorded by the camera (2) is automatically classified according to type, and depending upon the type of the recognized object it is reproduced on the display optic (6) in an intensity and/or color, which corresponds to the intensity and/or color which the associated object typically has by daylight. The process facilitates the recognition by the vehicle operator of images of traffic scenes recorded outside the visible spectrum.

Representative Image:

Automobile safety

Automobile safety is the study and practice of vehicle design, construction, and equipment to minimize the occurrence and consequences of automobile accidents. (Road traffic safety more broadly includes roadway design.)

Improvements in roadway and automobile designs have steadily reduced injury and death rates in all first world countries. Nevertheless, auto collisions are the leading cause of injury-related deaths, an estimated total of 1.2 million in 2004, or 25% of the total from
all causes. **Risk compensation** limits the improvement that can be made, often leading to reduced safety where one might expect the opposite.

- 

**Occupational driving**

Work-related roadway crashes are the leading cause of death from traumatic injuries in the U.S. workplace. They accounted for nearly 12,000 deaths between 1992 and 2000. Deaths and injuries from these roadway crashes result in increased costs to employers and lost productivity in addition to their toll in human suffering. Truck drivers tend to endure higher fatality rates than workers in other occupations, but concerns about motor vehicle safety in the workplace are not limited to those surrounding the operation of large trucks. Workers outside the motor carrier industry routinely operate company-owned vehicles for deliveries, sales and repair calls, client visits etc. In these instances, the employer providing the vehicle generally plays a major role in setting safety, maintenance, and training policy. As in non-occupational driving, young drivers are especially at risk. In the workplace, 45% of all fatal injuries to workers under age 18 between 1992 and 2000 in the United States resulted from transportation incidents.

**Active and passive safety**

The terms "active" and "passive" are simple but important terms in the world of automotive safety. "Active safety" is used to refer to technology assisting in the prevention of a crash and "passive safety" to components of the vehicle (primarily airbags, seatbelts and the physical structure of the vehicle) that help to protect occupants during a crash.[4][5]

**Crash avoidance**

Crash avoidance systems and devices help the driver — and, increasingly, help the vehicle itself — to avoid a collision. This category includes:

- The vehicle's **headlamps**, **reflectors**, and other **lights and signals**

- The vehicle's **mirrors**

- The vehicle's **brakes**, **steering**, and **suspension** systems

**Driver assistance**

A subset of crash avoidance is **driver assistance** systems, which help the driver to detect ordinarily-hidden obstacles and to control the vehicle. Driver assistance systems include:

- **Automatic Braking** systems to prevent or reduce the severity of collision.

- **Infrared night vision** systems to increase seeing distance beyond headlamp range

- **Adaptive highbeam** which automatically and continuously adapts the headlamp
range to the distance of vehicles ahead or which are oncoming

- **Adaptive headlamps** swivels headlamps around corners
- **Reverse backup sensors**, which alert drivers to difficult-to-see objects in their path when reversing
- **Backup camera**
- **Adaptive cruise control** which maintains a safe distance from the vehicle in front
- **Lane departure warning systems** to alert the driver of an unintended departure from the intended lane of travel
- **Tire pressure monitoring** systems or **Deflation Detection Systems**
- **Traction control systems** which restore traction if driven wheels begin to spin
- **Electronic Stability Control**, which intervenes to avert an impending loss of control
- **Anti-lock braking systems**
- **Electronic brakeforce distribution** systems
- **Emergency brake assist** systems
- **Cornering Brake Control** systems
- **Precrash system**
- **Automated parking** system

**Crashworthiness**
Ferrari F430 steering wheel with airbag

Crashworthy systems and devices prevent or reduce the severity of injuries when a crash is imminent or actually happening. Much research is carried out using anthropomorphic crash test dummies.

- **Seatbelts** limit the forward motion of an occupant, stretch to slow down the occupant's deceleration in a crash, and prevent occupants being ejected from the vehicle.

- **Airbags** inflate to cushion the impact of a vehicle occupant with various parts of the vehicle's interior.

- **Laminated windshields** remain in one piece when impacted, preventing penetration of unbelted occupants' heads and maintaining a minimal but adequate transparency for control of the car immediately following a collision. Tempered glass side and rear windows break into granules with minimally sharp edges, rather than splintering into jagged fragments as ordinary glass does.

- **Crumple zones** absorb and dissipate the force of a collision, displacing and diverting it away from the passenger compartment and reducing the impact force on the vehicle occupants. Vehicles will include a front, rear and maybe side crumple zones (like Volvo SIPS) too.

- Side impact protection beams.

- Collapsible universally jointed steering columns, (with the steering system mounted behind the front axle - not in the front crumple zone), reduce the risk and severity of driver impalement on the column in a frontal crash.

- **Pedestrian protection systems.**
- Padding of the instrument panel and other interior parts of the vehicle likely to be struck by the occupants during a crash.

**Post-crash survivability**

Post-crash survivability devices and systems help minimise the chances by using air bags.

**Pedestrian safety**


Since at least the early 1970s, attention has also been given to vehicle design regarding the safety of pedestrians in car-pedestrian collisions. Proposals in Europe would require cars sold there to have a minimum/maximum hood (bonnet) height. From 2006 the use of "bull bars", a fashion on 4x4s and SUVs, became illegal.

**Pregnant women**

When pregnant, women should continue to use seatbelts and airbags properly. A University of Michigan study found that "unrestrained or improperly restrained pregnant women are 5.7 times more likely to have an adverse fetal outcome than properly restrained pregnant women". If seatbelts are not long enough, extensions are available from the car manufacturer or an aftermarket supplier.

**Infants and children**

Children present significant challenges in engineering and producing safe vehicles, because most children are significantly smaller and lighter than most adults. Safety devices and systems designed and optimised to protect adults — particularly calibration-sensitive devices like airbags and active seat belts — can be ineffective or hazardous to children. In recognition of this, many medical professionals and jurisdictions recommend or require that children under a particular age, height, and/or weight ride in a child seat and/or in the back seat, as applicable. Child safety locks and driver-controlled power window lockout controls prevent children from opening doors and windows from inside the vehicle.
Infants left in cars

Very young children can perish from heat or cold if left unattended in a parked car, whether deliberately or through absentmindedness.

**Crash test dummy**

From Wikipedia, the free encyclopedia

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For the band, see Crash Test Dummies. For the series of toys, see The Incredible Crash Dummies.

It has been suggested that this article or section be merged with Crash test dummies in popular culture.

This article needs additional citations for verification. Please help improve this article by adding reliable references. Unsourced material may be challenged. (January 2009)

This article may contain original research. Please improve it by verifying the claims made and adding references. Statements consisting only of original research may be removed. More details may be available on the talk page. (February 2010)
Crash test dummies are full-scale anthropomorphic test devices (ATD) that simulate the dimensions, weight proportions and articulation of the human body, and are usually instrumented to record data about the dynamic behavior of the ATD in simulated vehicle impacts. This data can include variables such as velocity of impact, crushing force, bending, folding, or torque of the body, and deceleration rates during a collision for use in crash tests.

For the purpose of U.S. regulation and GTR's (Global Technical Regulations) — and for clear communication in safety and seating design — dummies carry specifically designated reference points, such as the H-point, also used, for example, in automotive design.

Crash test dummies remain indispensable in the development of and ergonomics in all types of vehicles, from automobiles to aircraft.

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Testing

On August 31, 1869, Mary Ward became the first recorded victim of a steam-powered
automobile accident; Karl Benz had not yet invented the gasoline-powered automobile (1886). Ward, of Parsonstown, Ireland, was thrown out of a motor vehicle and killed.[13] Thirty years later, on September 13, 1899, Henry Bliss became North America's first motor vehicle fatality when hit while stepping off a New York City trolley. Since then, over 20 million people worldwide have died to motor vehicle accidents.

The need for a means of analyzing and mitigating the effects of motor vehicle accidents on humans was felt soon after commercial production of automobiles began in the late 1890s, and by the 1930s, when the automobile a common part of daily life and the number of motor vehicle deaths was rising. Death rates had surpassed 15.6 fatalities per 100 million vehicle-miles and were continuing to climb.[citation needed]

In 1930, the interior of a car featured Dashboards of rigid metal, non-collapsible steering columns — and protruding knobs, buttons, and levers. Without seat belts, passengers in a frontal collision could be hurled against the interior of the automobile or through the windshield. The vehicle body itself was rigid, and impact forces were transmitted directly to the vehicle occupants. As late as the 1950s, car manufacturers were on public record as saying that vehicle accidents simply could not be made survivable because the forces in a crash were too great.[citation needed]

[edit] Cadaver testing

Detroit's Wayne State University was the first to begin serious work on collecting data on the effects of high-speed collisions on the human body. In the late 1930s there was no reliable data on how the human body responds to the sudden, violent forces acting on it in an automobile accident. Furthermore, no effective tools existed to measure such responses. Biomechanics was a field barely in its infancy. It was therefore necessary to employ two types of test subjects in order to develop initial data sets.

The first test subjects were human cadavers. They were used to obtain fundamental information about the human body's ability to withstand the crushing and tearing forces typically experienced in a high-speed accident. To such an end, steel ball bearings were dropped on skulls, and bodies were dumped down unused elevator shafts onto steel plates. Cadavers fitted with crude accelerometers were strapped into automobiles and subjected to head-on collisions and vehicle rollovers.

Albert King's 1995 Journal of Trauma article, "Humanitarian Benefits of Cadaver Research on Injury Prevention", clearly states the value in human lives saved as a result of cadaver research. King's calculations indicate that as a result of design changes implemented up to 1987, cadaver research has since saved 8500 lives annually. He notes that for every cadaver used, each year 61 people survive due to wearing seat belts, 147 live due to air bags, and 68 survive windshield impact.

However, work with cadavers presented almost as many problems as it resolved. Not only were there the moral and ethical issues related to working with the dead, but there were also research concerns. The majority of cadavers available were older European American adults who had died non-violent deaths; they did not represent a demographic
cross-section of accident victims. Deceased accident victims could not be employed because any data that might be collected from such experimental subjects would be compromised by the cadaver's previous injuries. Since no two cadavers are the same, and since any specific part of a cadaver could only be used once, it was extremely difficult to achieve reliable comparison data. In addition, child cadavers were not only difficult to obtain, but both legal and public opinion made them effectively unusable. Moreover, as crash testing became more routine, suitable cadavers became increasingly scarce. As a result, biometric data were limited in extent and skewed toward the older males.

**[edit] Volunteer testing**

Some researchers took it upon themselves to serve as crash test dummies. Colonel John Paul Stapp USAF propelled himself over 1000 km/h on a rocket sled and stopped in 1.4 seconds. Lawrence Patrick, then a professor at Wayne State University, endured some 400 rides on a rocket sled in order to test the effects of rapid deceleration on the human body. He and his students allowed themselves to be smashed in the chest with heavy metal pendulums, impacted in the face by pneumatically-driven rotary hammers, and sprayed with shattered glass to simulate window implosion. While admitting that it made him "a little sore", Patrick has said that the research he and his students conducted was seminal in developing mathematical models against which further research could be compared. But while data from live testing was valuable, human subjects could not withstand tests which went past a certain degree of physical injury. To gather information about the causes and prevention of injuries and fatalities would require a different kind of subject.

**[edit] Animal testing**

By the mid-1950s, the bulk of the information cadaver testing could provide had been harvested. It was also necessary to collect data on accident survivability, research for which cadavers were woefully inadequate. In concert with the shortage of cadavers, this need forced researchers to seek other models. A description by Mary Roach of the Eighth Stapp Car Crash and Field Demonstration Conference shows the direction in which research had begun to move. "We saw chimpanzees riding rocket sleds, a bear on an impact swing...We observed a pig, anesthetized and placed in a sitting position on the swing in the harness, crashed into a deep-dish steering wheel at about 10 mph." One important research objective which could not be achieved with either cadavers or live humans was a means of reducing the injuries caused by impalement on the steering column. By 1964, over a million fatalities resulting from steering wheel impact had been recorded, a significant percentage of all fatalities; the introduction by General Motors in the early 1960s of the collapsible steering column cut the risk of steering-wheel death by fifty percent. The most commonly used animal subjects in cabin-collision studies were pigs, primarily because their internal structure is similar to a human's. Pigs can also be placed in a vehicle in a good approximation of a seated human.

The ability to sit upright was an important requirement for test animals in order that another common fatal injury among human victims, decapitation, could be studied.
Additionally, it was important for researchers to be able to determine to what extent cabin design needed to be modified to ensure optimal survival circumstances. For instance, a dashboard with too little padding or padding which was too stiff or too soft would not significantly reduce head injury over a dash with no padding at all. While knobs, levers, and buttons are essential in the operation of a vehicle, which design modifications would best ensure that these elements did not tear or puncture victims in a crash. Rear-view mirror impact is a significant occurrence in a frontal collision; how should a mirror be built so that it is both rigid enough to perform its task and yet of low injury risk if struck.

While work with cadavers had aroused some opposition, primarily from religious institutions, it was grudgingly accepted because the dead, being dead, felt no pain, and the indignity of their situations was directly related to easing the pain of the living. Animal research, on the other hand, aroused much greater passion. Animal rights groups such as the ASPCA were vehement in their protest, and while researchers such as Patrick supported animal testing because of its ability to produce reliable, applicable data, there was nonetheless a strong ethical unease about this process.

Although animal test data were still more easily obtained than cadaver data, the fact that animals were not people and the difficulty of employing adequate internal instrumentation limited their usefulness. Animal testing is no longer practiced by any of the major automobile makers; General Motors discontinued live testing in 1993 and other manufacturers followed suit shortly thereafter.

[edit] Dummy evolution
Sierra Sam tested ejection seats.

The information gleaned from cadaver research and animal studies had already been put to some use in the construction of human simulacra as early as 1949, when "Sierra Sam" was created by Samuel W. Alderson at his Alderson Research Labs (ARL) and Sierra Engineering Co. to test aircraft ejection seats, aviation helmets and pilot restraint harnesses. This testing involved the use of high acceleration to 1000 km/h (600 mph) rocket sleds, beyond the capability of human volunteers to tolerate. In the early 1950s, Alderson and Grumman produced a dummy which was used to conduct crash tests in both motor vehicles and aircraft.
The mass production of dummies afforded their use in many more applications.

Alderson went on to produce what it called the VIP-50 series, built specifically for General Motors and Ford, but which was also adopted by the National Bureau of Standards. Sierra followed up with a competitor dummy, a model it called "Sierra Stan," but GM, who had taken over the impetus in developing a reliable and durable dummy, found neither model satisfied its needs. GM engineers decided to combine the best features of the VIP series and Sierra Stan, and so in 1971 Hybrid I was born. Hybrid I was what is known as a "50th percentile" male dummy. That is to say, it modeled an average male in height, mass, and proportion. The original "Sierra Sam" was a 95th percentile male dummy (heavier and taller than 95% of human males). In cooperation with the Society of Automotive Engineers (SAE), GM shared this design, and a subsequent 5th percentile female dummy, with its competitors.

Since then, considerable work has gone into creating more and more sophisticated dummies. Hybrid II was introduced in 1972, with improved shoulder, spine, and knee responses, and more rigorous documentation. Hybrid II became the first dummy to comply with the American Federal Motor Vehicle Safety Standard (FMVSS) for testing of automotive lap and shoulder belts. In 1973, a 50th percentile male dummy was released, and the National Highway Transportation Safety Administration (NHTSA) undertook an agreement with General Motors to produce a model exceeding Hybrid II's performance in a number of specific areas.[9]

Though a great improvement over cadavers for standardized testing purposes, Hybrid I and Hybrid II were still very crude, and their use was limited to developing and testing seat belt designs. A dummy was needed which would allow researchers to explore injury-reduction strategies. It was this need that pushed GM researchers to develop the current Hybrid line, the Hybrid III family of crash test dummies.

[edit] Hybrid III family
The original 50th percentile male Hybrid III's family expanded to include a 95th percentile male, 5th percentile female, and ten, six, and three-year-old child dummies.

**Hybrid III**, the 50th percentile male dummy which made its first appearance in 1976, is the familiar crash test dummy, and he is now a family man. If he could stand upright, he would be 175 cm (5'9") tall and would have a mass of 77 kg (170 lb). He occupies the driver's seat in all the Insurance Institute for Highway Safety (IIHS) [1] 65 km/h (40 mph) offset frontal crash tests. He is joined by a "big brother", the 95th percentile Hybrid III, at 188 cm (6 ft 2 in) and 100 kg (223 lb). **Ms.** Hybrid III is a 5th percentile female dummy, at a diminutive 152 cm (5 ft) tall and 50 kg (110 lb). [10] The three Hybrid III child dummies represent a ten year old, 21 kg (47 lb) six year old, and a 15 kg (33 lb) three year old. The child models are very recent additions to the crash test dummy family; because so little hard data are available on the effects of accidents on children, and such data are very difficult to obtain, these models are based in large part on estimates and approximations. The primary benefit provided by the Hybrid III is improved neck response in forward flexion and head rotation that better simulates the human. [11]

[edit] Testing procedure

Every Hybrid III undergoes calibration prior to a crash test. Its head is removed and is dropped from 40 centimetres to test calibrate the head instrumentation. Then the head and neck are reattached, set in motion, and stopped abruptly to check for proper neck flexure. Hybrids wear chamois leather skin; the knees are struck with a metal probe to check for proper puncture. Finally, the head and neck are attached to the body, which is attached to a test platform and struck violently in the chest by a heavy pendulum to ensure that the ribs bend and flex as they should.

When the dummy has been determined to be ready for testing, it is dressed entirely in yellow, marking paint is applied to the head and knees, and calibration marks are fastened to the side of the head to aid researchers when slow-motion films are reviewed later. The dummy is then placed inside the test vehicle. Forty-four data channels located in all parts of the Hybrid III, from the head to the ankle, record between 30 000 and 35 000 data items in a typical 100–150 millisecond crash. Recorded in a temporary data repository in the dummy's chest, these data are downloaded to computer once the test is complete.

Because the Hybrid is a standardized data collection device, any part of a particular Hybrid type is interchangeable with any other. Not only can one dummy be tested several times, but if a part should fail, it can be replaced with a new part. A fully-instrumented
dummy is worth about €150 000.\[^{[12]}\]

**edit** **Hybrid's successors**

Hybrid IIIIs are designed to research the effects of frontal impacts, and are less valuable in assessing the effects of other sorts of impacts, such as side impacts, rear impacts, or rollovers. After head-on collisions, the most common severe injury accident is the side impact.

The *SID* (Side Impact Dummy) family of test dummies has been designed to measure rib, spine, and internal organ effects in side collisions. It also assesses spine and rib deceleration and compression of the chest cavity. SID is the US government testing standard, EuroSID is used in Europe to ensure compliance with safety standards, and SID II(s) represents a 5th percentile female. BioSID is a more sophisticated version of SID and EuroSID, but is not used in a regulatory capacity. The WorldSID is a project to develop a new generation of dummy under the International Organization for Standardization.\[^{[13]}\]

**BioRID** is a dummy designed to assess the effects of a rear impact. Its primary purpose is to research *Whiplash*, and to aid designers in developing effective head and neck restraints. BioRID is more sophisticated in its spinal construction than Hybrid; 24 vertebra simulators allow BioRID to assume a much more natural seating posture, and to demonstrate the neck movement and configuration seen in rear-end collisions.

![BioRID dummy](image)

THOR offers sophisticated instrumentation for assessing frontal-impacts.

**CRABI** is a child dummy used to evaluate the effectiveness of child restraint devices including seat belts and air bags. There are three models of the CRABI, representing 18-month, 12-month, and 6-month old children.

**THOR** is an advanced 50th percentile male dummy. The successor of Hybrid III, THOR has a more humanlike spine and pelvis, and its face contains a number of sensors which allow analysis of facial impacts to an accuracy currently unobtainable with other dummies. THOR's range of sensors is also greater in quantity and sensitivity than those of
Further development is needed on dummies which can address the concern that, even though fewer lives are lost, there are still a hundred seriously injured passengers for every death, and crippling injuries to the legs and feet represent a great percentage of resultant physical impairments.

One important sector of the traveling public has yet to be represented in mainstream crash testing — pregnant women. The first prototype pregnant crash test dummy has been built by engineering researchers at Loughborough University UK with the aim of improving seat belt design. It has a fluid filled container above the pelvis to replicate the foetus and womb. Belts can be uncomfortable for pregnant women so some choose not to wear them, reducing their safety at a time when it should be increased. A second pregnant crash test dummy has been designed by a student at the University of Idaho.

Crash test dummies have provided invaluable data on how human bodies react in crashes and have contributed greatly to improved vehicle design. While they have saved millions of lives, like cadavers and animals, they have reached a point of reduced data return.

The largest problem with acquiring data from cadavers, other than their availability, was that an essential element of standardized testing, repeatability, was impossible. No matter how many elements from a previous test could be reused, the cadaver had to be different each time. While modern test dummies have overcome this problem, testers still face essentially the same problem when it comes to testing the vehicle. A vehicle can be crashed only once; no matter how carefully the test is done, it cannot be repeated exactly.

A second problem with dummies is that they are and will only ever be approximately human. Forty-four data channels on a Hybrid III is not even a remote representation of the number of data channels in a living person. The mimicking of internal organs is crude at best, a fact that means that even though cadavers and animals are no longer the primary sources of accident data, they must still be employed in the study of soft tissue injury. Furthermore, development of devices to simulate individual body systems is underway.

The future of crash testing has begun at the same place it all started: Wayne State University. King H. Yang is one of Wayne State's researchers involved in creating detailed computer models of human systems. The advantage of the computer is that it is unbound by physical law. A virtual vehicle crashed once can be uncashed and then crashed again in a slightly different manner. A virtual back broken can be unbroken, the seatbelt configuration changed, and the back re-broken. When every variable is controllable and every event is repeatable, the need for physical experimentation is greatly reduced.
At the beginning of the 21st century, legal certification of new car models is still required to be done using physical dummies in physical vehicles. The next generation of crash test dummies may perform their tasks entirely on a computer screen.

UNIT 2 VEHICLE AERODYNAMICS

INTRODUCTION

Aerodynamics is the study of the forces generated by the flow of air around a solid object

- Aerodynamics impacts the automobile in many ways
  - Fuel Consumption (pollution)
• Styling

• Noise & Vibration

• Control and Handling

• Fuel Consumption

  • Drag forces increase exponentially with velocity
  • More fuel is consumed to counter aerodynamic forces than any other factor
  • Better air flow management reduces fuel consumption and pollution

![Graph showing exponential increase of drag forces with velocity]

• Styling

  • Aerodynamically efficient body surfaces may interfere with the styling intent
  • The consumers may have preferences for aerodynamic features
• Noise & Vibration
  • Air flow can create wind noise
  • Turbulent airflow can deposit dirt on windows and automobile’s body (e.g., rear window)
  • Turbulent airflow can cause undesirable vibrations

• Control and Handling
  • Aerodynamic forces
    • Lift - dangerous at high speeds
    • Drag - decreases performance
    • Down force - better handling
    • Side force - better cornering
Aerodynamic forces can be optimized for local effect

**Aerodynamic Theory**

**Aerodynamic Factors**

- Streamlines
- Velocity Distribution
- Laminar Flow
- Turbulent Flow
- Viscosity
- Reynolds Number
- Boundary Layer
- Skin Friction Bernoulli’s Principle
- Pitot Tube
- Pressure Coefficient
Streamlines

- Curves associated with a pictorial representation of air flow
- Smoke is commonly used in wind tunnels to represent the streamlines
- Streamlines are used to study air flow

Velocity Distribution

- The nature of the fluid flow
- A measure of changes in air flow’s velocity close to the vehicle
Laminar Flow

- Fluid motion that is "well organized"
- Fluid with parallel velocity vectors
- Generally, laminar flow has the ideal aerodynamic properties

Turbulent Flow

- Fluid motion that is not "well organized"
- Fluid with parallel and other velocity vectors
- Generally, turbulent flow has undesirable properties
Viscosity

- The fluid’s resistance to motion
- Internal fluid forces at the molecular level

\[ F = \mu \left( \frac{V_\infty}{h} \right) A \]

- Where, \( F \) = fluid viscosity force, \( \mu \) = coefficient of viscosity, \( V_\infty \) = fluid velocity, \( h \) = separation distance, and \( A \) = contact area
- Pictorial of fluid viscosity

Example

- What is the force required to pull the upper plate at 5 m/s, if the plate
area is 2 m², and the fluid between the surfaces is water with the separation distance of 0.04 m (water’s coef. of viscosity is 1.0x10⁻³ Ns/m²)

\[ F = \mu \left( \frac{V_\infty}{h} \right) A \]

\[ F = 1 \times 10^{-3} \times (5/.04) \times 2 = 0.25 \text{ N} \]

Example

- Using the previous diagram and dimensions,
- How fast will the upper plate move, if the fluid is SAE 30 motor oil with the coef. of viscosity of 4.0x10⁻³ Ns/m² and an applied force of 2 N

\[ F = \mu \left( \frac{V_\infty}{h} \right) A \quad \therefore \quad V_\infty = \frac{hF}{\mu A} \]

\[ V_\infty = (0.04\times2)/(4\times10^{-3}\times2) = 10 \text{ m/s} \]

Reynolds Number

- Quantifies the product of speed times size
• A dimensionless number

\[ \text{Re} = \frac{\rho V L}{\mu} \]

• Where, \( \rho \) is fluid density, \( \mu \) is the viscosity, \( V \) is the velocity, and \( L \) is the length of the object

• Represents the ratio between inertial and viscous forces

• Compensates for scale differences

• Example

  • A car has a length of 4 m, travelling at 30 m/s
  
  • Air density is 1.22 Kg/m³
  
  • Air viscosity is 1.8x10⁻⁵
  
  \[ \text{Re} = \frac{1.22 \times 30 \times 4}{(1.8 \times 10^{-5})} = 8.1 \times 10^6 \]

• Re can indicate the nature of the fluid flow

• Higher values indicate turbulent flow

• Lower values indicate laminar flow

• Different flows can be considered the same if they have similar Re values

• Allows scale models to be accurately tested in wind tunnels using different fluids and or velocities

**Boundary Layer**
• The thin layer of rapid tangential velocity change close to an object’s surface
• Generally increases in thickness ($\delta$) with the length of the object

- Relative velocity
  - Zero at the object’s surface
  - $V_\infty$ at the outer edge of the boundary layer

- Example
  - At 60 mph, the boundary layer is about an inch close to the rear of a vehicle
  - A thicker boundary layer creates more viscous friction
  - A too sudden a change in thickness (transition) can cause flow separation,
  - Additional drag (skin friction)
• Loss of down force

Skin Friction

• $C_f$, skin friction coefficient

• Non-dimensional

• Indicates the level of friction between the vehicle’s skin and the air

• $\tau = \text{Friction resistance}$

$$C_f = \frac{\tau}{\frac{1}{2} \rho V_\infty^2}$$
Example

- What is the friction resistance ($\tau$) of a plate moving at 30 m/s, with coef. of friction of 0.002 through air with a density of 1.22 Kg/m$^3$?

$$\tau = C_f(0.5\rho V^2) = 0.002 \times 0.5 \times 1.22 \times 30^2$$

$$\tau = 1.098 \text{ N/m}^2$$

Dynamic Pressure

$$\frac{1}{2} \rho V_{\infty}^2$$
• Where \( V_\infty \) is the velocity, and \( \rho \) is the fluid density

• Boundary layer is thicker for turbulent flows

• Skin friction \( (C_f) \) decreases with Re

• At certain speeds, both laminar and turbulent flows are possible

• Flow separation can be delayed in turbulent flow, resulting in a preference for turbulent boundary conditions

**Bernoulli’s Principle**

- Pressure drop: \( P_1 > P_2 > P_3 \)

- Height of the fluid decreases with drop in pressure
• Fluid Velocity is greater at the neck, $V_1 > V_\infty$

• Pressure drop, $P_1 > P_3 > P_2$

• Fluid pressure drops as fluid velocity increases

• Fluid pressure is inversely proportional to fluid velocity

Impact on an airfoil
Impact on a rotating body (e.g., ball or tire)

Bernoulli’s Equation

- where, $V = \text{velocity}$, $p = \text{local static pressure}$, and $\rho = \text{density}$, for any point on a streamline

\[ \frac{p}{\rho} + \frac{V^2}{2} = \text{Constant} \]

- Usually used to compare and calculate pressure and velocity at two different points
\[ \frac{p_A}{\rho} + \frac{v_A^2}{2} = \frac{p_B}{\rho} + \frac{v_B^2}{2} \]

**Example**

- What is the pressure difference on the surface of a vehicle’s grill \( (V_{\text{grill}}=0)\), if the vehicle travels at 30 m/s. Air density is 1.22 Kg/m³

\[ \frac{p_\infty}{\rho} + \frac{v_\infty^2}{2} = \frac{p_{\text{grill}}}{\rho} + \frac{v_{\text{grill}}^2}{2} \]

\[ P_B - P_\infty = \frac{\rho}{2} \frac{V^2}{v_\infty} = \frac{1.22}{2} \times 30^2 = 549\, N / m^2 \]

**Pitot Tube**

- Bernoulli’s equation allows measuring any fluid velocity by measuring its pressure
\[
P_{\text{total}} - P_\infty = \frac{\rho}{2} V_\infty^2
\]

Therefore,

\[
V_\infty = \sqrt{\frac{2 \times (P_{\text{total}} - P_\infty)}{\rho}}
\]

Pressure Coefficient

- Non-dimensional
- Used to measure aerodynamic loads (lift, drag, and side forces)

\[
C_p = \frac{p - p_\infty}{\left(\frac{1}{2}\right) \rho V_\infty^2}
\]

Wind Tunnel

- Used to study the aerodynamic properties of an object in a stationary manner
- Motion is simulated by moving air (fluid) around the object of interest
- Properties measure in wind tunnel include pressures, forces, velocities, and vibrations
• Wind tunnel studies are not 100% accurate
• Wind tunnel pictorials:

Types of Wind Tunnels
• A basic wind tunnel (open-circuit)
• General Motors’ wind tunnel (close-circuit)

• Open-circuit wind tunnels
  • Less expensive
  • Subject to ambient conditions
  • Require more power

• Close-circuit wind tunnels
  • Avoids loss of return air’s momentum
  • Constant ambient conditions
  • Expensive
• A wind tunnel can not always simulate road conditions, e.g.,
  • Ground effect
  • Tire rotation
  • Reynolds number (scale corrections)
  • Wall interference
  • Natural variations in ambient conditions

• Challenges
  • Model size
    • The larger, the greater the wall effect
    • The smaller, the less accurate
  • Simulation of the moving road
  • Mounting of model and rotating wheels

• Wall effect
Examples of wall effect corrections

\[ \left( \frac{1}{2} \rho V_\infty^2 \right)_{\text{corrected}} = \left( 1 + \frac{1}{4} \times \frac{A}{C} \right) \times \left( \frac{1}{2} \rho V_\infty^2 \right)_{\text{measured}} \]

Where, \( A = \) frontal area, and \( C = \) cross sectional area

\[ C_{L_{\text{corrected}}} = C_{L_{\text{measured}}} \left[ \frac{1}{1 + \frac{1}{4} \times \frac{A}{C}} \right]^2 \]

Where, \( C_L = \) lift coefficient

Simulation of moving ground
● Important issue about wind tunnel studies,
  ● Understanding the aerodynamic problem is more critical than sensitive instrumentation
  ● Whatever works satisfactorily in the wind tunnel, will usually work well on the road
  ● Scale model studies are usually too conservative, and the vehicle can be further optimized

**Vehicle Aerodynamics**

**Vehicle Aerodynamic Factors**

● Aerodynamic Forces
● Laminar Separation
● Tripping of Boundary Layer
● Pressure Distribution
● Wake
● Tires
• Glass and Trim
• General Improvements
• Unconventional Features

Aerodynamic Forces

• Lift force
• Drag force
• Side force

• Effects of aerodynamic forces are profound
• Force coefficients

Coefficient of Lift

\[ C_L = \frac{L}{\frac{1}{2} \rho V_r^2 A} \]

Where, \( L \)= Lift, \( \rho \)= air density, \( V \)= velocity, and \( A \)= frontal area

Coefficient of Drag

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

Where, \( D \)= Drag, \( \rho \)= air density, \( V \)= velocity, and \( A \)= frontal area

Coefficient of Side-Force

\[ C_Y = \frac{Y}{\frac{1}{2} \rho V_r^2 A} \]

Where, \( Y \)= Side-force, \( \rho \)= air density, \( V \)= velocity, and \( A \)= frontal area

• Example

• What is a vehicle’s drag force, with a frontal area of 1.5 m², \( C_D \) of 0.4, and traveling at 30 m/s
Aerodynamic down force

- Opposite of lift in direction
- Uses an inverted airfoil
- Increases load on tires without increasing the vehicle’s weight (up to 10% of vehicle’s weight)
- Improves cornering performance with no weight penalty
- First discovered in 1960s!

Example of down force

\[ D = C_D \left( \frac{1}{2} \rho V^2 \right) = 0.4 \times \frac{1}{2} \times 1.22 \times 30^2 \times 1.5 = 329.4 \, N \]
• Example
  • Rear Spoiler (Mazda RX-7 R-2)
  • \( C_D = 0.31 \) (0.29 without spoiler)
  • \( C_{L\text{front}} = 0.10 \) (0.16 without spoiler)
  • \( C_{L\text{rear}} = 0.08 \) (0.08 without spoiler)

• Underbody improvements
  • Aerodynamic properties
  • Reduce drag
  • Increase down force
Laminar Separation

- Laminar Separation
  - Flow separation inside the boundary layer
- Laminar Bubble
  - Streamlines enclosed within the laminar separation
• Laminar bubble area is sensitive and can easily separate, resulting in excess drag

• Can appear in low Re range ($10^4$-$10^5$), and disappear as speed increases, causing severe discrepancies in flow visualization and analysis

• The rear end shape is the most critical factor in lowering the drag coefficient

• Flow separation above the rear window can cause annoying dirt deposits on the glass
Tripping of Boundary Layer

- Introduction of aerodynamic disturbances
  - Fins
  - Vortex generators
  - Strips of coarse sand paper
- Forcing laminar to turbulent flow
- Drag reduction due to delay in the onset of flow separation
Pressure Distribution

• Helps the placement of inlets and outlets
  • Lower pressure at the outlet
  • Higher pressure at the inlet

• Favorable pressure distribution
  • Prevents flow separation

• Unfavorable pressure distribution
  • Promotes flow separation
  • Promotes turbulent flow within boundary layer

• Example of inlet
- Radiator inlet configurations
Wake

- The disturbed air flow left behind the vehicle
- Usually in the form of a vortex
- Caused by merging air flows at different velocities near sharp edges
• Increases drag
• Presents danger to the following vehicles
• Can be controlled with small fins or smooth edges

Tires

• Tires influence a vehicle’s aerodynamic properties
  • Cross sectional area
  • Frontal area
  • Rotation of tires
- Effects of tire rotation
• Effect of all-wheel-steering

Glass and Trim

• Drag can be reduced by making glass and trim as flush with the body as possible
• Elimination of rain gutter improves the vehicle aerodynamics
General Improvements

1- Front spoiler
2- Ducted engine cooling
3- Shrouded windshield wiper arms
4- Aerodynamic mirrors
5- Smooth windshield transitions
6- Smooth side window transitions
7- Smooth rear window transition
8- Optimized trunk corner radii
9- Optimized lower rear panel
10 - Smooth fuel tank and underbody
11- Optimized rocker panels
12- Flush wheel covers
13- Elimination of the rain gutter
Unconventional Features

- Large rear fins promote lateral stability in the 1966 Peugeot CD

![Image of the 1966 Peugeot CD](image1.jpg)

- 1969 Chaparral 2J used auxiliary fans to create suction under the car

![Image of the 1969 Chaparral 2J](image2.jpg)
- Ford’s rear mounted transverse engine
- Fans improve aerodynamic properties and reduce drag

Wind tunnel

NASA wind tunnel with the model of a plane.
A model Cessna with helium-filled bubbles showing streamlines of the wingtip vortices.

- A wind tunnel is a research tool used in aerodynamic research. It is used to study the effects of air moving past solid objects.

**Theory of operation**

Wind tunnels were first proposed as a means of studying vehicles (primarily airplanes) in free flight. The wind tunnel was envisioned as a means of reversing the usual paradigm: instead of the air's standing still and the aircraft moving at speed through it, the same effect would be obtained if the aircraft stood still and the air moved at speed past it. In that way a stationary observer could study the aircraft in action, and could measure the aerodynamic forces being imposed on the aircraft.

Later, wind tunnel study came into its own: the effects of wind on manmade structures or objects needed to be studied, when buildings became tall enough to present large surfaces to the wind, and the resulting forces had to be resisted by the building's internal structure. Determining such forces was required before building codes could specify the required strength of such buildings.

Still later, wind-tunnel testing was applied to automobiles, not so much to determine aerodynamic forces per se but more to determine ways to reduce the power required to move the vehicle on roadways at a given speed. In these studies, the interaction between the road and the vehicle plays a significant role, and this interaction must be taken into consideration when interpreting the test results. In an actual situation the roadway is moving relative to the vehicle but the air is stationary relative to the roadway, but in the wind tunnel the air is moving relative to the roadway, while the roadway is stationary relative to the test vehicle. Some automotive-test wind tunnels have incorporated moving belts under the test vehicle in an effort to approximate the actual condition.

**Measurement of aerodynamic forces**

Ways that air velocity and pressures are measured in wind tunnels:

- air velocity through the test section is determined by Bernoulli's principle. Measurement of the dynamic pressure, the static pressure, and (for compressible flow only) the temperature rise in the airflow

- direction of airflow around a model can be determined by tufts of yarn attached to the aerodynamic surfaces

- direction of airflow approaching an aerodynamic surface can be visualized by mounting threads in the airflow ahead of and aft of the test model

- dye, smoke, or bubbles of liquid can be introduced into the airflow upstream of the test model, and their path around the model can be photographed (see particle image velocimetry)
pressures on the test model are usually measured with beam balances, connected to the test model with beams or strings or cables

pressure distributions across the test model have historically been measured by drilling many small holes along the airflow path, and using multi-tube manometers to measure the pressure at each hole

pressure distributions can more conveniently be measured by the use of pressure-sensitive paint, in which higher local pressure is indicated by lowered fluorescence of the paint at that point

pressure distributions can also be conveniently measured by the use of pressure-sensitive pressure belts, a recent development in which multiple ultra-miniaturlized pressure sensor modules are integrated into a flexible strip. The strip is attached to the aerodynamic surface with tape, and it sends signals depicting the pressure distribution along its surface.

pressure distributions on a test model can also be determined by performing a wake survey, in which either a single pitot tube is used to obtain multiple readings downstream of the test model, or a multiple-tube manometer is mounted downstream and all its readings are taken (often by photograph).

How it works

Six-element external balance below the Kirsten Wind Tunnel

Air is blown or sucked through a duct equipped with a viewing port and instrumentation where models or geometrical shapes are mounted for study. Typically the air is moved through the tunnel using a series of fans. For very large wind tunnels several meters in
diameter, a single large fan is not practical, and so instead an array of multiple fans are used in parallel to provide sufficient airflow. Due to the sheer volume and speed of air movement required, the fans may be powered by stationary turbofan engines rather than electric motors.

The airflow created by the fans that is entering the tunnel is itself highly turbulent due to the fan blade motion (when the fan is blowing air into the test section - when it is sucking air out of the test section downstream, the fan-blade turbulence is not a factor), and so is not directly useful for accurate measurements. The air moving through the tunnel needs to be relatively turbulence-free and laminar. To correct this problem, closely-spaced vertical and horizontal air vanes are used to smooth out the turbulent airflow before reaching the subject of the testing.

Due to the effects of viscosity, the cross-section of a wind tunnel is typically circular rather than square, because there will be greater flow constriction in the corners of a square tunnel that can make the flow turbulent. A circular tunnel provides a smoother flow.

The inside facing of the tunnel is typically as smooth as possible, to reduce surface drag and turbulence that could impact the accuracy of the testing. Even smooth walls induce some drag into the airflow, and so the object being tested is usually kept near the center of the tunnel, with an empty buffer zone between the object and the tunnel walls. There are correction factors to relate wind tunnel test results to open-air results.

Lighting is usually recessed into the circular walls of the tunnel and shines in through windows. If the light were mounted on the inside surface of the tunnel in a conventional manner, the light bulb would generate turbulence as the air blows around it. Similarly, observation is usually done through transparent portholes into the tunnel. Rather than simply being flat discs, these lighting and observation windows may be curved to match the cross-section of the tunnel and further reduce turbulence around the window.

Various techniques are used to study the actual airflow around the geometry and compare it with theoretical results, which must also take into account the Reynolds number and Mach number for the regime of operation.

**Pressure measurements**

Pressure across the surfaces of the model can be measured if the model includes pressure taps. This can be useful for pressure-dominated phenomena, but this only accounts for normal forces on the body.

**Force and moment measurements**

A typical lift coefficient versus angle of attack curve.

With the model mounted on a force balance, one can measure lift, drag, lateral forces, yaw, roll, and pitching moments over a range of angle of attack. This allows one to produce common curves such as lift coefficient versus angle of attack (shown).
Note that the force balance itself creates drag and potential turbulence that will affect the model and introduce errors into the measurements. The supporting structures are therefore typically smoothly shaped to minimize turbulence.

**Flow visualization**

Because air is transparent it is difficult to directly observe the air movement itself. Instead, multiple methods of both quantitative and qualitative flow visualization methods have been developed for testing in a wind tunnel.

**Qualitative methods**

- Smoke
- Tufts

Tufts are applied to a model and remain attached during testing. Tufts can be used to gauge air flow patterns and flow separation.

Compilation of images taken during an alpha run starting at 0 degrees alpha ranging to 26 degrees alpha. Images taken at the Kirsten Wind Tunnel using fluorescent mini-tufts. Notice how separation starts at the outboard wing and progresses inward. Notice also how there is delayed separation aft of the nacelle.
Fluorescent mini-tufts attached to a wing in the Kirsten Wind Tunnel showing air flow direction and separation. Angle of attack ~ 12 degrees, speed ~120 Mph.

- Evaporating suspensions

Evaporating suspensions are simply a mixture of some sort or fine powder, talc, or clay mixed into a liquid with a low latent heat of evaporation. When the wind is turned on the liquid quickly evaporates leaving behind the clay in a pattern characteristic of the air flow.

China clay on a wing in the Kirsten Wind Tunnel showing reverse and span-wise flow.

- Oil
When oil is applied to the model surface it can clearly show the transition from laminar to turbulent flow as well as flow separation.

Oil flow vis on straight wing in the Kirsten Wind Tunnel. Trip dots can be seen near the leading edge.

- **Sublimation**

If the air movement in the tunnel is sufficiently non-turbulent, a particle stream released into the airflow will not break up as the air moves along, but stay together as a sharp thin line. Multiple particle streams released from a grid of many nozzles can provide a dynamic three-dimensional shape of the airflow around a body. As with the force balance, these injection pipes and nozzles need to be shaped in a manner that minimizes the introduction of turbulent airflow into the airstream.

High-speed turbulence and vortices can be difficult to see directly, but **strobe lights** and film cameras or high-speed digital cameras can help to capture events that are a blur to the naked eye.

High-speed cameras are also required when the subject of the test is itself moving at high speed, such as an airplane propeller. The camera can capture **stop-motion** images of how the blade cuts through the particulate streams and how vortices are generated along the trailing edges of the moving blade.

**Wind tunnel classification**

There are many different kinds of wind tunnels, an overview is given in the figure below:

- **Low speed wind tunnel**
- **High speed wind tunnel**
- **Supersonic wind tunnel**
- **Hypersonic wind tunnel**
- **Subsonic and transonic wind tunnel**
UNIT3&4) VANS TRUCKS AND BUSES
A coach (also motor coach, often simply called a bus) is a type of bus used for conveying passengers on excursions and on longer distance intercity bus service between cities—or even between countries. Unlike transit buses designed for shorter journeys, coaches often have a luggage hold separate from the passenger cabin and are normally equipped with facilities required for longer trips including comfortable seats and sometimes a toilet.

The term 'coach' was previously used for a horse-drawn carriage designed for the conveyance of more than one passenger, the passengers' luggage, and mail, which is covered for protection from the elements. The term was applied to railway carriages in the 19th century, and later to motor coaches (buses).

Coaches, as they hold passengers for significant periods of time on long journeys, are designed for comfort. They vary considerably in quality from country to country and within counties. Higher specification vehicles include luxury seats and air conditioning. Coaches typically have only a single, narrow door, as an increased loading time is acceptable due to infrequent stops. Some characteristics include:

- Comfortable seats that may include a folding table, armrests, and recliner. Comfort is considered to be an important feature in coaches.
- Luggage racks above the seats where passengers can access their carry-on baggage during the journey.
- Baggage holds, accessed from outside the vehicle, often under the main floor or at the rear, where passengers' luggage can be stowed away from the seating area.
- Passenger service units, mounted overhead, on which personal reading lights and air conditioning ducts can be controlled and used by individual passengers with little disturbance to other passengers.
- On-board rest rooms fitted with chemical toilets, hand basins and hand sanitizer.
- On some buses, on-board entertainment including movies may be
shown to passengers On-board refreshment service or vending machines
Wheelchair accommodation, possibly including a wheelchair lifts for access.

**SINGLE DECKER BUS** - A single-decker bus or single-decker is a bus that has a single deck for passengers. Normally the use of the term single-decker refers to a standard two-axled rigid bus, in direct contrast to the use of the term double-decker bus, which is essentially a bus with two passenger's decks and a staircase. These types of single-deckers may feature one or more doors, and varying internal combustion engine positions.

In regions where double-deckers are not common, the term single-decker may lack common usage, as in one sense, all other main types of bus have a single deck. Also, the

urban areas, the single Decker is the standard mode of public transport bus travel, increasingly with low floor features.

With their origins in van chassis, minibuses are not usually considered single-deckers, although modern minibus designs blur this distinction. Minibuses can also be regarded as both included with and separate from standard single-deckers, in terms of full size length and vehicle weights, although again design developments have seen this distinction blurred. Some coach style buses that do not have under floor luggage space can also be correctly termed as single-deckers, with some sharing standard bus chassis designs, such as the Volvo B10M, with a different body style applied.

**DOUBLE DECKER BUS**-

A double-decker bus is a bus that has two storeys or decks. Red double-decker buses are used for mass transit in London. Double-decker buses are also used in other cities in Europe, Asia, and former British colonies and protectorates such as Hong Kong,
Singapore and Canada.
Almost all double-deckers have a single, rigid chassis.

This type of bus is often used for touring rather than for mass transit. As William Ewart Gladstone observed, "...the way to see London is from the top of a 'bus".

In India, Bangalore had double deckers for a while before discontinuing. Madras's Metropolitan Transport Corporation (MTC) has a small fleet of double-decker buses mostly in the high-density, longer distance routes. Mumbai has operated double-decker buses since 1937. They are operated by the Brihanmumbai Electric Supply and Transport undertaking. Thiruvananthapuram, Kochi, Kolkata and Hyderabad also have double-decker buses. They are mode led on the London buses. Ashok Leyland Titan double Decker buses are used in all cities. Articulated double Decker buses from Ashok Leyland were used till it was phased out in early 1990s and Volvo B9TL Wrights are now begun operating in Mumbai and Chennai since early 2010 and Enviro400s were also brought into Hyderabad since 2011.
DESIGN OF COMMERCIAL VEHICLES CHASSIS AND BODY STRUCTURE

1. Introduction

Transportation industry plays a major role in the economy of modern industrialized and developing countries. Concentrating on road transportation, the following facts are of special importance for the manufacturers of commercial vehicles:

- The total and relative volume of goods carried on trucks is high and still dramatically increasing. This results in acceptance and environmental problems.

- The transportation task itself becomes more and more specialized. Therefore, a large variety of different vehicles is required.

- Although the share of passenger transportation in buses is relatively small compared to private cars, there is also a tendency of increasing demand in some cases like limited accessible city centers and trend to specialization as well.

2. Design goals

2.1 Vehicle Design

The predominant goal for the design of a commercial vehicle is economy during its use from acquisition until disposal (minimal lifecycle cost), and it is important to know that more than 3/4 of the cost do not include the purchase. However, requirements of safety, handling, ride comfort, legal and environmental compatibility and aesthetics also to be satisfied.
Economy in a highly specialized industry means optimal production cost and diversification of the design causing a multitude of types and a sequence for the manufacturer to limit production cost a mod position of the vehicles (fig. 1 and 2).

Today, design trends are:
- increase in volume and weight capacity
- ease and speed up of loading and unloading - both causing tendency to low chassis height
- increase of average speed, thus increase of engine power and breaking capacity
- decrease of maintenance effort
- improvement of the working environment of the driver
- integration of electronics for brake, transmission, power pension control.

2.2 Truck Chassis and Body Structure
The vehicle design starts up with conceptual studies to determine number and location of undriven and drive axles, type of engine, engine power, transmission, tire size and axle reduction ratio and auxiliary equipment. The selected configuration has to be for the considered transportation tasks and should match the production line. Either a new vehicle type is generated or improvement over existing types has to be achieved. Because of fierce competition, advanced technology in engineering, marketing and service and strenuous work is required to be successful. Having defined the general configuration of a vehicle, let us concentrate on the main structural components. The most function of the "backbone" is supporting and distributing originating from...
- payload including its vessels
- axles with their fixtures
- coupling device (trailer or fifth wheel coupling)
- drive train
- truck cabin including top sleeper/windshield
- inertia forces
- forced deformation
- special service functions like cab tilt mechanism, cargo equipment a.s.o.

In addition to the primary structural functions, the chassis incorporate accessories, optional and special equipment like hy electrical wiring and piping systems.

Altogether, space is very limited and sometimes only section dimensions are usable for the main structure. The truck frame usually consists of straight or Y-shaped beams with varying bending stiffness and strength: selection of height, flange and thickness dimensions are inserts. In most cases HSLA steel with yield strength above used (fig. 3).

The vibration environment and the chassis deformation due the service area like - paved roads, - construction sites, rain. In most cases, the truck chassis is designed to allow xibility when twisted on a warped surface by use of a section beams both for longitudinal and crossmembers. reduces the wheel load differences and therefore increases in plane forces on the road surface. As a disadvantage it contribute to torsional vibration. Whaping forces being longitudinal and crossmember joints, much care has to be design of these critical fixtures. And finally, at very large and potholes, the channel structure may be overloaded be wheel looses completely its ground contact.

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Deformation of chassis must also be compatible with the superstructure, the body. Therefore either a sufficient flexibility be incorporated in the body itself (usually predominant design of box cargo container) or must be installed in special fixtures (e.g. three point elastic fixtures of liquid cargo tanks).

A different design philosophy may be applied for off road using box beams with high torsional stiffness. Such a chassis allows large suspension travel in order to keep good ground contact (fig. 4). In this case, the total torque resulting from one wheel is easily supported and there are minimal difficulties in the stiff payload containers to the frame.

In between these two general principles, a mixed chassis makes use of longitudinal channel beams and tubular crossmembers. This design gives a reduced torsional flexibility avoiding it of box beam joints (fig. 5). The torsional flexibility of this design is shown in fig. 6 in comparison with channel crossmembers. Joints are the most sensitive parts of the truck chassis, remarkable, that chassis joints of trucks are riveted or bolted, while joints of trailers usually are welded. The different design is due to different service conditions and structural damping is very important for the truck chassis as well as maintenance requirements.

2.3 Bus Structure

Only in the first years of bus body design, a flexible truck was used together with non-structural body elements of wood resulting in the true chassis design as a contrary to theBecause today, even if a channel beam chassis is used, it is properly designed floor crossmembers, sidewall and roof panels...
a fully integral structure is achieved (deflection behaviour set. Advantages of a channel beam bus chassis are simplicity fully equipped driveable vehicle, heavy duty suspension load introduction members.

The bus body as a whole is a light weight, stiff structure significant distortion of the overall stiffness occurs at the other large openings. Shear deformation at the doors is up greater than for comparable sidewall sections. Most of the on the European continent are fully welded tubular steel having similar stiffness properties. However, there are differences in the design of welded joints with respect to dimensions, application of additional stiffeners. Therefore different performance is achieved. Fig. 8 shows a sidewall strut modern low floor city bus.

3. Structural Analysis

3.1 Structural Idealization and FEA

As a standard tool, the method of finite elements is used for analysis. The stress-strain relation of different standard elements, beams, shells a. s. o. are reduced to forces and displacements at certain grid points. The structure is then represented by a set of elements being connected only at the grid points where displacements and forces are related in matrix form. By the use of modern even large systems can be analyzed economically, giving a result of applied forces and/or deformations of the structure. The structural analysis may include linear, nonlinear or behavior. Therefore, vibration natural frequencies, response characteristics and fatigue life of structures can be evaluated.
The design engineer is supported by the structures department in a preliminary stage and load assumptions as well as analysis becomes more and more sophisticated in the later product development. Loads are either computed on existing similar structures until the real part exists and can be made.

3.2 Multi Body System Simulation

FEA is very effective for investigation of structural problems mainly with small deformations. For the major parts of the vehicle and their motions, i.e., the behavior of axles, drive train, it is more convenient to use another technique, the MBSS.

Here, the complete state of motion of a specified set of bodies with their inertial properties, their joints, spings, damping, etc. is evaluated by integrating the equations of motion including the dynamic nonlinear behavior. The system is characterized by functions of forces, displacements or its derivatives at every point to be specified. Fig. 10 shows the representation of a power train with the vertical forces vs. time at the support bracket during engine speed-up. On Fig. 11, a three-axle trailer is shown passing a hump while coupling forces are measured.

MBSS is used to analyze the vibration behavior of the vehicle and its major components and includes the surface contact rating a tire model. Thus, safety related studies and characteristics can be investigated, and forces and/or displacements be obtained.
3.4 Safety
Requirements concerning safety are defined by law or associations. As a recent element, manufacturer liability is attended. For a competitive producer of commercial vehicles, the professional user is most important, thus special attention needs to be taken to avoid deficiencies and advanced technology to avoid them. Safety criterions for chassis and body structure include high fatigue life of safety related parts and above this in case of misuse a gradual deterioration instead of a sudden failure. This is achieved either by structural redundancy or by designing slow crack propagation rates, so defects can be detected in advance.

Trucks have very stiff chassis members in longitudinal direction and the driver is reasonably well protected by his position high in the cabin in case of accidents, at least in its most frequent positions. However, in order to protect those important structures, investigations and tests to improve the future of trucks.

In the case of bus structures, the rollover strength is of interest as well as the resistance against side intrusion of passengers. Safety related structural analysis usually includes fatigue simulation, nonlinear FEA and the use of special crush simulations.

3.5 System Idealization and Verification
Both FEA and MBSS may lead to very complex and expensive models. In order to limit effort and error risks, the most simplified model correct results is used in every design stage. Once the model is built, verification of measurements should be included in the procedure.
4. Structural Testing

Whereas theoretical investigations have the advantage to upon drawings, the testing can't begin before manufacturi hardware. In addition to a large number of functional, corrosions and other tests, the structural tests are of s tance in order to ensure quality products. Having analiz parts theoretically, by variation of topology, shape, dim other parameters to achieve the desired product prope final model has to be tested to verify the predicte Therefore lead time and cost can be minimized in the procedure.

4.1 Drive Tests

The complete vehicle is driven over specified test track: current loading conditions to reproduce the most severe sen pected during customer use. Even cases of overload an included. In order to be approved, a certain running distar completed. During test track driving, critical locations an links are monitored by strain gage measurements, accele displacement or other sensors, and the signals are storage. Then, well known severe customer service conditi measured to ensure the significance of the test programm Time functions of forces or local strain usually are histograms for better comparison with analytical or alte Both fatigue life or comfort criteria can be considered.

Fig. 12 shows the force excitation of an axle control an track driving, while the axle is excited at its natural frequenc
4.2 Component Tests
Critical components with safety relevant functions are usually hydraulically controlled test rigs. The fixture and the loads are such that a close imitation of service conditions to be monitored again typically by local strain measurement. On a test rig, the necessary statistical tests can be executed at high frequency (sometimes exceeding $2 \times 10^6$ load cycles). By control, the load application can follow a random sequence.

Besides the geometric tolerances and the nominal material, sometimes the production procedure even of the raw material influence the test results. Therefore in some cases, not only the material itself is defined by the documentation, but also e.g. the material sample or the ingot of a forged part has to be approved by extensive testing.

5. Service Experience

After having performed theoretical evaluations and proper tests it is much hope that a reliable, economical product with outstanding performance is achieved. And to our knowledge, in most cases this is true. But sometimes there are surprises. Our engineers are not enough phantasy to foresee all service conditions of our products. Only to mention a few cases: - a truck being supported by supports being used excessively in low gear as a drill to survey cracked due to vibrations of the main frame; - another truck loaded from the back by marble blocks using a winch in that first the front axle came high up in the air and later collapsed to the ground and was bent; - city buses were left running whole night causing vibration damage in the fan drive system.

Therefore in addition to all engineering skill, long time experience is necessary for the design of complicated products like vehicles.
### Truck Type Variation

#### Service
- Cargo
- Mixed
- Bulk
- Liquid
- Street
- On road long distance
- On road local distribution
- Construction site
- Off road
- Special operations
- Quick change control
- Crane, concrete mix
- Cargo lift platform
- Roll off cargo system
- Public services
- O.S.O.

#### Size

<table>
<thead>
<tr>
<th>Gross Vehicle Weight (t)</th>
<th>Cab</th>
<th>Number of Axles</th>
<th>Engine Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-10</td>
<td>Small</td>
<td>2 (3)</td>
<td>75</td>
</tr>
<tr>
<td>12-17</td>
<td>Long Distance</td>
<td>2, 3</td>
<td>110</td>
</tr>
<tr>
<td>17-48</td>
<td>Space</td>
<td>2, 3, 4</td>
<td>200</td>
</tr>
</tbody>
</table>

#### Body
- Dropside
- Fifth Wheel
- Tipper
- Bored, used, truck
- Forward control
- Underfloor engine

### Bus Type Variation

#### Service
- City
- Interurban
- Travel
- Special Oper.
- Handicapped

#### Size

<table>
<thead>
<tr>
<th>Gross Vehicle Weight (t)</th>
<th>Number of Axles</th>
<th>Engine Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2</td>
<td>110-130</td>
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<tr>
<td>17</td>
<td>2</td>
<td>140-180-250</td>
</tr>
<tr>
<td>28</td>
<td>3</td>
<td>180</td>
</tr>
</tbody>
</table>

#### Body
- Chassis
- Space frame
- Standard
- Low floor
- Articulated
- Double deck
- (Starred)
Light off Road Truck Chassis, Tubular Cross-Members

Truck Chassis Torsional Flexibility, Influence of Cross-Member Design
Chassis Bus and Space Frame Bus, Deformation Comparison
Finite Element Structural Analysis of Light Train

Multi-Body System Simulation, Five Cylinder Engine Power Train
Truck with Two-Wheeled Trailer Passing a Hump, MBSS

Suspension Excitation on Test Track
Types of commercial vehicle body

- covered truck
- lorry
- container truck
- fire truck
- wreck truck
- tilt truck
- tanker truck
- fire engine
- cement truck
- car transporter
- animal
- transporter
- tipper
- trailer
lorry
Drop side
Fixed side
Drop side
Sideways are dropped for loading & unloading.

Side
&
tail board is hinged for dropping

Side tail board is fitted in corner irons with
the help of cotter pin
fixed side
In this type vehicle Sides built in height and rigid loading and unloading in Tail side.

Transportation Vario
us
agriculture
goods,
industrial
goods&
various
parcels
fixed side(six wheeled)
Articulated vehicle
Flat platform
Flat platform
• **Underframe:** Longitudinals and floor bearers manufactured from steel, galvanised or aluminium, mounted to vehicle chassis with particular manufacturers recommendation.

• **Wings:** Thermoplastic wings fitted to chassis with tubular wing stays, galvanised mudguard brackets and Ken Kerr standard or spray suppression mud flaps.

• **Sideguards:** Anodised aluminium with galvanised folding sideguard arms to allow for easy access to battery and air filters.
Flat platform
• **Marker lamps:** LED type, water resistant and shock proof. Amber to side, red to rear and complying with all legal requirements.

• **Floor options:** 18, 21, 27 mm birch multi layer container deck ply board, finished with a phenol non-slip surface. 22, 28 mm keruing hardwood halflap.

• **Body side raves:** Aluminium/steel galvanised rolled channels.

• **Gantry:** Aluminium/steel angles to cab height to create ladder gantry, infilled with aluminium/steel corrugated to under window height and galvanised mesh to upper section to protect rear of cab.

• **Rope hooks:** Galvanised bolt on rope hooks to every cross-member where possible.
Box van or chassis van
Box van or chassis van
• **Underframe:** Longitudinals and floor bearers manufactured from steel, galvanised or aluminium, mounted to vehicle chassis with particular manufacturers recommendation.

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Box van or chassis van
• **Roof:** Fibreglass or aluminium roof skin on fully bonded galvanised roof sticks with aluminium standard radius cant rails.

• **Interior:** 9 mm plywood kickboards to off-side, near-side and bulkhead. Seven timber or aluminium tie rails rising at 300 mm centres. Two interior lamps fitted 600 mm from front of body and 600 mm from rear.
Tanker body
Tanker body
• tanker is used to transport like detergent, edible oil, resins, fat, sugarin solution, liquid gaseous, water, milk, fuels etc

• Elliptical tank has advantage of low centre of gravity.
Tipper body