Passive and Active Safety of the Vehicle
Road traffic injuries represent about 25% of worldwide injury-related deaths (the leading cause) with an estimated 1.2 million deaths (2004) each year.

- Major factors in accidents include driving under the influence of alcohol or other drugs;

- Inattentive driving; crash compatibility between vehicles;

- Driving while fatigued or unconscious;

- Encounters with road hazards such as snow, potholes, and crossing animals;

- Reckless driving.
**Active safety** refers to systems in a vehicle which utilize feedback, using information about a car's external environment to change the response of the vehicle and improve the safety of the vehicle in the pre-crash time period, or during the crash event.

**Passive safety** refers to built-in features of the vehicle such as crumple zones, seatbelts, and airbags, which work passively to prevent injury and do not change their action in response to crash scenario or severity.
Active safety

To make driving safer and prevent crashes from occurring, and also to better protect occupants during a crash, cars may have the following active safety features:

- Turn signals and brake lights, including Center High Mounted Stop Lamps (CHMSL);

- Rear end Collision Warning Lamps senses deceleration of lead vehicle and flashes amber warning strobe rearward to warn following vehicles of a pending braking or stopping event;

- Variable assist power steering allows assistance to the motorist while parking, but reduces steering effort assistance at motorway speeds;

- Headlight wipers/washers

- Ribbed taillights to prevent snow and grime build-up;

- Dynamic steering response (DSR) corrects the rate of power steering system to adapt it to vehicle's speed and road conditions.
- Traction control (TCS) actuates brakes or reduces throttle to restore traction if driven wheels begin to spin;

- Hill holder;

- Four wheel drive (AWD) with a center differential. Distributing power to all four wheels lessens the chances of wheel spin. It also suffers less from oversteer and understeer than front wheel drive, but more understeer than rear wheel drive. However, four wheel drive vehicles often have a higher center of gravity and are more prone to roll-over and cause injury or death to passengers;

- Reverse backup sensors, which alert drivers to nearby objects in their path, are installed in some high-end vehicles, but may also be purchased separately;

- Electronic Stability Control (ESC, also known by ESP and other numerous manufacturer-specific names). Uses various sensors to intervene when the car senses a possible loss of control. The car's control unit can reduce power from the engine and even apply the brakes to prevent the car from understeering or oversteering.
- Lateral Support: Lane Departure Warning System (LDWS).

- Directional headlights, which allow the driver to see obstacles ahead in the roadway while cornering.

- Low center of gravity and other conventional features promoting good car handling and braking, and helping to avoid rollover.

- Comfortable suspension and seating to avoid accidents from driver fatigue.

- Large (relative to weight) high performance tires, suited to the weather and road conditions, contribute to braking and handling. Soft high histeresis rubber, tread and cord design are important. See Run flat tire.

- Visibility for the driver, mirrors, elimination of blind spots and possibly other awareness aids such as radar, wireless vehicle safety communications and night vision.

- Death Brake; there is a move to introduce deadman's braking into automotive application, primarily heavy vehicles, there may also be a need to add penalty switches to cruise controls.
Four wheel steering gives, at the cost of mechanical complexity, quicker, more accurate maneuvers at high speed and/or decreased turning circle at low speed. It may also help stability.

- Adaptive cruise control (ACC).

- AWAKE and intelligent car features.

- Precrash system
- Brakes

+ Anti-lock braking system (ABS)
  - Electronic brakeforce distribution (EBD)
  - Cornering Brake Control (CBC)

+ Emergency brake assist (EBA)

+ Brake assist system (BAS)

+ Forward Collision Warning System (FCW)

+ Lane Departure Warning System (LDW)

+ Dynamic Brake Control (DBC).

+ Inboard brakes allow large fade resistant discs or drums, without contributing to unsprung weight and wheel bounce, which degrade braking, handling and ride, and increase mechanical loads.
Passive safety
When a crash is imminent, various passive safety systems work together to minimize injury to the individuals involved. Much research has been done using crash test dummies to make modern cars safer than ever.
Seatbelts (or safety belts) absorb energy and limit forward motion of an occupant, and help keep occupants from being ejected from the vehicle.

Crumple zone technology absorbs the energy of a collision by displacing the impact of a crash and diverting it from the internal (passenger compartment) critical structure of the vehicle.

- **Airbags**: There are many types of airbags, all of which should be considered supplemental restraint systems (SRS), used in addition to belts.

![Ferrari F430 drivers steering wheel with airbag](image)
+ Front airbags inflate in a medium speed head on collision to cushion the impact of the head to the steering wheel (driver) or dashboard to the (front passenger).

+ Side airbags inflate in a side impact (T-bone) collision to cushion the torso and sometimes the pelvis and head.

+ Curtain airbags protect the head and upper body of passengers in a side collision. Newer models may stay inflated for a longer period of time, and may help to keep unbelted occupants in vehicle during a rollover, but should be considered supplemental to belts and never used in place of belts.

+ Knee airbags inflate in frontal impact collisions to protect the driver's knees and are now available in many newer high end model vehicles.
- Side impact bars for protection against side on collisions

- Collapsible steering column, sometimes provided with steel sheet bellows.

- Crash compatibility can be improved by matching vehicles by weight and by matching crumple zones with points of structural rigidity, particularly for side-on collisions. Some pairs of vehicle front end structures interact better than others in crashes.

- Cage construction is designed to protect vehicle occupants. Some racing vehicles have a tubular roll cage.

- Reinforced side door structural members.

- Fuel pump shutoff devices turn off gas flow in the event of a collision for the purpose of preventing gasoline fires.
- Driver State Sensor - Research, Utilizing cutting edge video processing technology, the system remotely and unobtrusively measures 3D head pose and eyelid motion parameters of the driver.

- Padding of the instrument panel and other interior parts of the vehicle likely to be struck by the occupants during a crash. Whilst largely being supplanted by airbags, it still plays an important role in preventing injuries.

- Active pedestrian protection systems.
2 Active safety

2.1 Automotive lighting

The lighting system of a motor vehicle consists of lighting and signalling devices mounted or integrated to the front, sides and rear of the vehicle. The purpose of this system is to provide illumination for the driver to operate the vehicle safely after dark, to increase the visibility of the vehicle, and to display information about the vehicle's presence, position, size, direction of travel, and driver's intentions regarding direction and speed of travel.

2.1.1 Forward illumination

Forward illumination is provided by main- ("high") and dipped- ("low") beam headlamps, which may be augmented by auxiliary fog lamps, driving lamps, and/or cornering lamps.
a) Headlamps

Dipped beam (low beam, passing beam, meeting beam)

![Image of dipped beam](image)

E-code dipped/low beam

Main beam (high beam, driving beam, full beam)

![Image of main beam](image)

E-code high/full beam
b) Auxiliary lamps

- Driving lamps
- Fog lamps
- Cornering lamps
- Spot lights

High/full beam augmented by auxiliary lights
2.1.2 Conspicuity devices

a) Retroreflectors
b) Front position lamps (parking lamps)
c) Dim-Dip Lamps (UK Only)

Extensively redundant rear lighting installation on a tour bus
d) Rear position lamps (tail lamps)

e) Rear registration plate lamp

g) Sidemarker lights

h) Daytime running lamps

i) Rear fog lamps

2.1.3 Signalling devices

a) Turn signals
Electrical connection & Switching

Two types of dashboard turn signal telltale indicators

b) Hazard flashers

c) Stop lamps (brake lamps)

d) Reversing lamps

Centre High Mount Stop Lamp (CHMSL)

LED CHMSL retrofitted on a 1974 Valiant
2.1.4 Convenience lights

Most cars have at least one dome light located in or near the ceiling of the passenger compartment, to provide illumination by which to fasten seatbelts and enter or exit the car.

2.1.5 Construction and technology

a) Light sources
   - Incandescent light bulbs
   - Halogen
   - "Xenon"
   - Neon tubes
   - Light emitting diodes (LED)
b) Variable-intensity signal lamps

Internationalized ECE regulations explicitly permit vehicle signal lamps with intensity automatically increased during bright daylight hours when sunlight reduces the effectiveness of the brake lamps, and automatically decreased during hours of darkness when glare could be a concern.

2.2 Dynamic steering response (DSR)

This is a car safety technique that corrects the rate of hydraulic or electric power steering system to adapt it to vehicle's speed and road conditions.

2.3 Hill-Holder

Hill-Holder is a name for the mechanism that holds the brake until the clutch at the friction point, making it easier to start up hills from a stop in manual transmission automobiles.
2.4 Four-wheel drive

Four-wheel drive, 4WD, or 4x4 ("four by four") is a four-wheeled vehicle with a drive train that allows all four wheels to receive torque from the engine simultaneously.

**Design**

![Sketch of 4WD (AWD)](image)

**Differentials**

When powering two wheels simultaneously, the wheels must be allowed to rotate at different speeds as the vehicle goes around curves. When driving all four wheels, the problem is even more complicated.
The Jeep Wrangler is a 4WD vehicle with a transfer case to select low range or high range 4WD.

The Lamborghini Murciélago is a 4WD/AWD that powers the front via a viscous coupling unit if the rear slips.

The Mercedes-Benz M-Class is a 4WD/AWD that powers all wheels evenly (continuously) via a plain differential and uses traction control to recover from wheel spin.
2.5 Parking sensors

Parking sensors (also known as backup sensors, parking SONAR or just SONAR) are a technology that allows the driver of a car, truck, van or commercial vehicle to be alerted to nearby objects in their path.

2.6 Electronic Stability Control

Electronic Stability Control (ESC) is a computerized system designed to improve a vehicle's handling by intervening at the limits of traction and helping the driver maintain control of the vehicle.

2.7 Lane departure warning system

A lane departure warning system (LDW) is a mechanism designed to warn a driver when the vehicle begins to move out of its lane (unless a turn signal is on in that direction) on freeways and arterial roads.
2.8 Ride quality

Ride quality refers to the degree of protection offered vehicle occupants from uneven elements in the road surface, or the terrain if driving off-road. A car with very good ride quality is also a comfortable car to ride in. Cars which disturb vehicle occupants with major or minor road irregularities would be judged to have low ride quality.

2.9 Tire

Firestone tire
Tire structure
Fast normal consume
Fast anormal consume by convergence and divergence
Penny Test - test for safe tread depth
2.10 Telematics

-The integrated use of telecommunications and informatics, also known as ICT (Information and Communications Technology). More specifically it is the science of sending, receiving and storing information via telecommunication devices.

-More commonly, telematics have been applied specifically to the use of Global Positioning System technology integrated with computers and mobile communications technology in automotive navigation systems.

-Most narrowly, the term has evolved to refer to the use of such systems within road vehicles, in which case the term vehicle telematics may be used.
Practical applications of vehicle telematics

a) Vehicle tracking

Vehicle tracking is a way of monitoring the location, movements, status and behaviour of a vehicle or fleet of vehicles.

b) Trailer tracking

Trailer tracking is the technology of tracking the movements and position of an articulated vehicle's trailer unit, through the use of a location unit fitted to the trailer and a method of returning the position data via mobile communication network.

c) Fleet management

Fleet management includes the management of cars, vans and trucks. It can include a range of Fleet Management functions, such as vehicle financing, vehicle maintenance, vehicle telematics (tracking and diagnostics), driver management, fuel management and health & safety management.
d) Satellite navigation

Satellite navigation in the context of vehicle telematics is the technology of using a GPS and electronic mapping tool to enable the driver of a vehicle to locate a position, then route plan and navigate a journey.

e) Mobile data and mobile television

Mobile data is use of wireless data communications using radio waves to send and receive real time computer data to, from and between devices used by field based personnel.

f) Wireless vehicle safety communications

Wireless vehicle safety communications is an electronic sub-system in a car for the purpose of exchanging safety information, about such things as road hazards and the locations and speeds of vehicles, over short range radio links.
2.11 Steering

Steering is the term applied to the collection of components, linkages, etc. which will allow a vehicle to follow the desired course.

Part of steering mechanism: tie rod, steering arm, king pin.

For safety reasons all modern cars feature a collapsible steering column (energy absorbing steering column) which will collapse in the event of a heavy frontal impact to avoid excessive injuries to the driver. Non-collapsible steering columns very often impaled drivers in frontal crashes. Audi has a retractable wheel system called procon-ten.
2.12 Autonomous cruise control system

Schematic of Intelligent Cruise Control. The red car automatically follows the blue car.

These systems use either a radar or laser setup to allow the vehicle to slow when approaching another vehicle and accelerate again to the preset speed when traffic allows.
2.13 Smart car

A smart car is an automobile with some artificial intelligence (or "AI") functionality. As automation technology has progressed, especially in the decades after the invention of the integrated circuit, more and more functions have been added to automobiles, relieving the driver of much of the mundane moment-to-moment decision making that may be regarded as having made driving tedious.

2.13.1 Intelligent car

The European Commission has established a smart car development program called the Intelligent Car Flagship Initiative. The goals of that program include:

- Autonomous Cruise Control
- Lane departure warning system
- Project AWAKE for drowsy drivers
2.13.2 Examples of 'smart' features

- Computerised engine management systems
- Anti-lock braking systems and Traction Control
- Position monitoring system ESITrack
- Satellite monitoring systems, such as OnStar
- Platoon and car-train features
- Driverless car which may result in less-stressed "drivers", higher efficiency (the driver can do something else), increased safety and less pollution (e.g. via completely automated fuel control)
- Advanced Parking Guidance System, Lexus automatic parking feature

2.14 Precrash system

A precrash system is an automobile safety system designed to reduce the damage caused by a collision. Most use radar sensors to detect a credible crash; though, different systems react in different ways.
Brakes

2.15 Anti-lock braking system

An anti-lock braking system (ABS) is a system on motor vehicles which prevents the wheels from locking while braking.

- Reduced the risk of multiple vehicle crashes by 18 percent.
- Reduced the risk of run-off-road crashes by 35 percent.
• Brake resistance system < Resistance between tire and road

• Brake resistance system > Resistance between tire and road
\[ \text{sliprelation} = \frac{\text{carspeed} - \text{wheelspeed}}{\text{carspeed}} \times 100 \]
ABS SYSTEM DIAGRAM

- Rear speed sensor
- Sensor rotor
- Front speed sensor
- Sensor rotor
- Disc brake cylinder
- ABS actuator
- P. valve
- Stop light switch
- ABS ECU
Front wheel speed sensor
Signal from the sensor
ABS System Diagram
Normal braking
Pressure reduction mode
Holding mode
Pressure increase mode
2.16 Traction control

The ABS equipment may also be used to implement traction control on acceleration of the vehicle. If, when accelerating, the tire loses traction with the ground, the ABS controller can detect the situation and take suitable action so that traction is regained.

The intervention can consist of any, or all, of the following:

- Retard or suppress the spark to one or more cylinders
- Reduce fuel supply to one or more cylinders;
- Brake one or more wheels;
- Close the throttle, if the vehicle is fitted with drive by wire throttle.
Sub-throttle actuator
TRC desactivated

Valve open 50%

Valve totally closed
Sub-throttle position sensor
2.17 Vehicle stability control

VSC system
Strong understeer tendency

Strong understeer tendency
Strong understeer tendency

Locus of travel based on the target yaw rate

Strong oversteer tendency

Direction of travel of the vehicle’s center of gravity

Movement of vehicle

Slip Angle
Making a right turn

Understeering Control Moment
Overtsteering Control Moment
Making a Right Turn

Making a right turn
Deceleration Sensor

Steering Angle Sensor
Yaw rate Sensor
2.18 Lane departure warning system

A lane departure warning system (LDW) is a mechanism designed to warn a driver when the vehicle begins to move out of its lane (unless a turn signal is on in that direction) on freeways and arterial roads.

2.19 Driver State Sensor

This is a robust, automatic sensor platform that uses cutting edge face tracking techniques to deliver information on operator fatigue and operator distraction.

Fatigue in Transportation

Driver fatigue is a serious issue concerning almost all areas of fleet or large-scale transportation operations.
Benefits of Advanced Fatigue Management

There are numerous benefits from employing DSS Advanced Fatigue Management beyond in-cabin alarms:

- Raise awareness of fatigue as a key issue, resulting in employees paying more attention to their resting times.
- Identify hazard conditions: Statistics on fatigue event times, locations and drivers allow for smarter scheduling.
- Less fatigue related crashes. This means less interruption, cost, driver injury and lower insurance premiums.
3 Passive safety

3.1 Seat belt

A seat belt, sometimes called a safety belt, is a safety harness designed to secure the occupant of a vehicle against harmful movement that may result from a collision or a sudden stop.

3.1.1 Types of seat belts

Three point seat belt, Citroen BX
• Lap: Adjustable strap that goes over the waist. Used frequently in older cars, now uncommon except in some rear middle seats. Passenger aircraft seats also use lap seat belts.

• Sash: Adjustable strap that goes over the shoulder. Used mainly in the 1960s, but of limited benefit because it is very easy to slip out of in a collision.

• Lap and Sash: Combination of the two above (two separate belts). Mainly used in the 1960s and 1970s. Generally superseded by three-point design.

• Three-point: Similar to the lap and sash, but one single continuous length of webbing. Both three-point and lap-and-sash belts help spread out the energy of the moving body in a collision over the chest, pelvis, and shoulders.

• Criss-cross: Experimental safety belt presented in the Volvo SCC. It forms a cross-brace across the chest.
Harness

- Five-point harnesses: Safer but more restrictive than most other seat belt types.
- Six-point harnesses: Similar to a five-point harness but includes an extra belt between the legs, which is seen by some to be a weaker point than the other parts.
- Seven-point harnesses (5+2): Aerobatic aircraft frequently use a combination harness consisting of a five-point harness with a redundant lap-belt attached to a different part of the airframe.
Front seat outer belt with pretensioner
Construction and function

- Seat belt retracting mechanism
- ELR locking mechanism
- Safety device (M-type only)
- Pretensioner mechanism
- Pretensioner sensor (M-type only)
- Gas generator with primer

Front

Right-Hand
Pretensioner mechanism type 1
Pretensioner mechanism type 2

Type 2

- Gear clutch
- Rotor
- Key clutch
- Gas generator

Inactive

Activated

Discharge port

* Gas
3.3 AIR-BAGS

- Frontal impact without seat belt
- Frontal impact with seat belt
Electronic type

Collision → Impact → Center airbag sensor assembly

- Power source
- Center airbag sensor & ECU
- Safing sensor
- Front airbag sensors*2

Inflator
- Primer
- Gas generant

Bag (for driver)
- Nitrogen gas

Inflator*1
- Primer
- Gas generant

Bag*1 (for front passenger)
- Nitrogen gas

*1: Only models with front passenger airbag
*2: Some models only
Mecanic type
Operation

Start of Deployment  Full Deployment  During Protection  End of Collision

Frontal impact
Collision from the side

Collision from the rear

Vehicle roll-over

Frontal collision at low speed
CAUTION

Child restraint

Avoid sitting on the edge of the seat or leaning over the dashboard

Do not put objects on or in front of airbag housings
Layout of components

- Inflator and bag for front passenger
  (in passenger side dashboard)
- Front airbag sensors
- Center airbag sensor assembly
- Warning light
- Inflator and bag for driver
  (in steering wheel pad)
- Spiral cable
Inflator and bag for driver

For front passenger
Operation "for driver"

Operation "for front passenger"

Gas discharge hole
Center airbag sensor

semiconductor type

Mechanical type
Diagram

*S1: For front passenger airbag
*S2: For mechanical type center airbag sensor
*S3: For electronic type (E-type) seat belt pretensioners
*S4: For some models only
Spiral cable
3.3 Crumple zone

The crumple zone on the front of these cars absorbed the impact of a head-on collision.

Activated rear crumple zone

The crumple zone of a vehicle is a structural feature designed to compress during an accident to absorb energy from an impact.
3.4 Roll cage

A roll cage is a specially constructed frame built in or around the cab of a vehicle to protect the occupants from being injured in an accident, particularly in the event of a roll-over. Roll cages are used in nearly all purpose-built racecars, and in most cars modified for racing.

Racecar roll cage inside a Suzuki Swift
3.5 Side impact bars for protection against side collisions

Side crash tests indicate that side impact bars play an important role of providing protection to occupants during the crashing processing.

3.6 Collapsible steering column

The steering column is prepared to collapse during the frontal accident.
3.7 Fuel pump shutoff devices turn off gas flow in the event of a collision for the purpose of preventing gasoline fires.

3.8 Pedestrian safety through vehicle design

In recent years crash engineers have begun to use design principles that have proved successful in protecting car occupants to develop vehicle design concepts that reduce the injuries to pedestrians in the event of a car-pedestrian crash.

The sequence of events in a car-pedestrian accident