Design of vehicle body for safety

The safety of a vehicle and its passengers can be improved by properly designing and selecting the material for vehicle bodies. The vehicle body structure is subjected to static and dynamic service loads during the life cycle. It also has to maintain its integrity and provide adequate protection in survivable crashes. At present there are two designs of vehicle body constructions: 1. Body over frame structure and 2. Uni body structure.

Necessary features of a safe vehicle body:
1. Deformable yet stiff front structure with crumple zones to absorb the crash kinetic energy from frontal collisions
2. Deformable rear structure to safeguard rear passenger compartment and protect the fuel tank
3. Properly designed side structures and doors to minimize intrusion in side impact and prevent doors from opening due to crash loads
4. Strong roof structure for rollover protection
5. Properly designed restraint systems with working in harmony with the vehicle structure
6. Accommodate various chassis designs for different power train locations and drive train configurations.

The following design techniques/strategies are to be followed while designing a car body (especially front structure) to reduce the impact of crash and increase the safety of the car and passengers.

Desired dummy performance:
Dummy is a physical model representing humans inside a car. To model a car for safety, it should be modeled for proper crash energy management. As the human beings are to be safeguarded, the interaction of the human beings with the restraint system during a crash has to be studied first. This branch of study is widely known as bio-mechanics. The reaction of a human being for a crash pulse has to defined and studied in depth. The following steps are involved in this procedure

Stiff cage structural concept:
Stiff cage is the passenger compartment structure which provides protection for the passengers in all modes of survivable collisions. The necessary features of a good stiff cage structure are: 1. sufficient peak load capacity to support the energy absorbing members in front of it, 2. High crash energy absorption. The stiff cage structure should withstand all the extreme loads and the severe deformation.

Controlled progressive crush and deformation with limited intrusion:
To make the impact of crash less, the crush event has to be controlled and the deformation should be made such that the intrusion of other components into the passenger compartment is less. Axial mode of crush is preferred to bending mode of crush as bending mode has lower energy content. To achieve this objective three different crush zones are identified: 1. Soft front zone: Reduces the aggressively of crash in pedestrian / vehicle and vehicle / vehicle collisions
2. Primary crush zone: It consists of the main energy absorbing structure before the power train. It is characterized by a relatively uniform progressive structural collapse.

3. Secondary crush zone:
Lies between the primary zone and passenger compartment and sometimes extends into the passenger compartment up to firewall. It provides a stable platform for the primary zone and transfers the load to the occupant compartment as efficiently as possible.

4. Weight efficient energy absorbing structures:
The architecture of the structural frame (structural topology) design depends on the ability to design the primary crush zone for bending, folding, mixed folding and bending. For a given vehicle package different topologies have to be studied for the same crush energy absorption.
The steps followed are:
1. Create a simple model of vehicle front end system
2. Determine the design loads of structural members

**Energy equation**

The application of the conservation of energy principle provides a powerful tool for problem solving. Newton's laws are used for the solution of many standard problems, but often there are methods using energy which are more straightforward. For example, the solution for the impact velocity of a falling object is much easier by energy methods. The basic reason for the advantage of the energy approach is that just the beginning and ending energies need be considered; intermediate processes do not need to be examined in detail since conservation of energy guarantees that the final energy of the system is the same as the initial energy. The work-energy principle is also a useful approach to the use of conservation of energy in mechanics problem solving. It is particularly useful in cases where an object is brought to rest as in a car crash or the normal stopping of an automobile.

Kinetic energy is energy of motion. Objects that are moving, such as a roller coaster, have kinetic energy (KE). If a car crashes into a wall at 5 mph, it shouldn't do much damage to the car. But if it hits the wall at 40 mph, the car will most likely be totaled. Kinetic energy is similar to potential energy. The more the object weighs, and the faster it is moving, the more kinetic energy it has. The formula for KE is: 

\[ KE = \frac{1}{2} m v^2 \]

where \( m \) is the mass and \( v \) is the velocity.

One of the interesting things about kinetic energy is that it increases with the velocity squared. This means that if a car is going twice as fast, it has four times the energy. You may have noticed that your car accelerates much faster from 0 mph to 20 mph than it does from 40 mph to 60 mph. Let's compare how much kinetic energy is required at each of these speeds. At first glance, you might say that in each case, the car is increasing its speed by 20 mph, and so the energy required for each increase must be the same. But this is not so. We can calculate the kinetic energy required to go from 0 mph to 20 mph by calculating the KE at 20 mph and then subtracting the KE at 0 mph from that number. In this case, it would be \( \frac{1}{2} m (20)^2 - \frac{1}{2} m (0)^2 \). Because the second part of the equation is 0, the KE = \( \frac{1}{2} m (20)^2 \), or 200 m. For the car going from 40 mph to 60 mph, the KE = \( \frac{1}{2} m (60)^2 - \frac{1}{2} m (40)^2 \); so KE = 1,800 m - 800 m, or 1000 m. Comparing the two results, we can see that it takes a KE of 1,000 m to go from 40 mph to 60 mph, whereas it only takes 200 m to go from 0 mph to 20 mph.

There are a lot of other factors involved in determining a car's acceleration, such as aerodynamic drag, which also increases with the velocity squared. Gear ratios determine how
much of the engine's power is available at a particular speed, and traction is sometimes a limiting factor. So it's a lot more complicated than just doing a kinetic energy calculation, but that calculation does help to explain the difference in acceleration times.

**Engine location**

Front engine:
The large mass of an engine at the front of the car gives the driver protection in the event of a head-on collision. Engine cooling is simpler to arrange and in addition the cornering ability of a vehicle is normally better if the weight is concentrated at the front.

Rear engine:
It increases the load on the rear driving wheels, giving them better grip of the road. Most rear-engine layouts have been confined to comparatively small cars, because the heavy engine at the rear has an adverse effect on the ‘handling’ of the car by making it ‘tail-heavy’. Also it takes up good deal of space that would be used on a front-engine car for carrying luggage. Most of the space vacated by the engine at the front end can be used for luggage, but this space is usually less than that available at the rear.

Central and mid-engine:
These engine situations generally apply to sports cars because the engine sitting gives a load distribution that achieves both good handling and maximum traction from the driving wheels. These advantages, whilst of great importance for special cars, are outweighed in the case of everyday cars by the fact that the engine takes up space that would normally be occupied by passengers. The mid-engine layout shown combines the engine and transmission components in one unit. The term mid-engine is used because the engine is mounted in front of rear axle line.

![Deceleration of vehicle and passenger compartment on impact with stationary and movable obstacle.](image)

It is important to study the deceleration inside passenger compartment to know the effect of crash completely, so that the crash avoidance systems can be suitably designed. For example, if the deceleration of the passenger after crash is very high, the air bag system and the seat belt system has to be so designed that the activation time for them is reduced to a lower value. Otherwise it may lead to injuries and fatalities.

Usually tests are conducted to know the deceleration behavior after the crash with a stationary obstacle. The tests are conducted at the following speeds:

1. 15 mph (miles per hour)
2. 20 mph
3. 40 mph
4. 50 mph
15 mph test:
The following pictures show the body deformation and acceleration graph after crash. The body deformation is less as the vehicle speed is low. The crash occurs at time 0 seconds. From the graph, we can know that after the crash, deceleration occurs which is shown in the negative (lower) portion. Its value is up to 20g. After some time the acceleration slowly comes to zero (the car stops).

20 mph test:
In the 20 mph test, the body deformation is more than 15 mph test. Moreover, the acceleration has reduced to a further lower value (up to 35 g) in the negative direction. In this case the maximum deceleration is obtained in 50 milli seconds whereas for 10 mph test it was 35 milli seconds. The rebound velocity for this case is 1.7 mph whereas for 10 mph it is 1.3 mph. 40 mph test: In the 40 mph test, we can see that the acceleration curve goes down (deceleration) then suddenly goes up in the positive region (acceleration). This is due to the fact that, at 40 mph, the deformation is more and the accelerometer (sensor) mounting area has buckled and resulted in an increase in acceleration value. The body deformation is also high such that the accelerometer mounting area is also damaged. So, we have to carefully analyze the graph to study the situation. The graphs are shown below:
40 mph test:
In the 40 mph test, we can see that the acceleration curve goes down (deceleration) then suddenly goes up in the positive region (acceleration). This is due to the fact that, at 40 mph, the deformation is more and the accelerometer (sensor) mounting area has buckled and resulted in an increase in acceleration value. The body deformation is also high such that the accelerometer mounting area is also damaged. So, we have to carefully analyze the graph to study the situation.

50 mph test:
The body deformation is very high as the speed is more. The acceleration curve shows that the maximum deceleration is around 35g and happens in time duration of 45 milli seconds. The rebound velocity is 1.6 mph.

Deceleration on impact with a movable obstacle:
A movable obstacle can be another car or any other vehicle. Let us consider a car is impacting with another car. We shall study for the two cars; one car which is impacting the second car, the other car is which is being impacted. In this case the test is conducted at 40 mph.
Impacting vehicle:

The impact velocity was 40.6 mph with a separation velocity of 18.0 mph for a total velocity change (AV) of 22.6 mph. A maximum of 15 g’s deceleration was achieved at about 50 milliseconds. The total impact duration was approximately 195 milliseconds.

Impacted vehicle:

The pre-impact velocity was 0.0 mph with a separation velocity of 22.8 mph for a total velocity change (AV) of 22.8 mph. A maximum of 16.5 g’s acceleration was achieved at about 15 milliseconds. The total impact duration was approximately 195 milliseconds.
Crumple zone

The crumple zone of an automobile is a structural feature designed to compress during an accident to absorb energy from the impact. Typically, crumple zones are located in the front part of the vehicle, in order to absorb the impact of a head-on collision, though they may be found on other parts of the vehicle as well. Some racing cars use aluminum or composite honeycomb to form an ‘impact attenuator’ for this purpose.

It was an inventor Bela Barenyi who pioneered the idea that passengers were safer in a vehicle that was designed to easily absorb the energy from an impact and keep that energy away from the people inside the cabin. Barenyi devised a system of placing the car's components in a certain configuration that kept the kinetic energy in the event of a crash away from a bubble protecting the car's occupants. Mercedes obtained patent from Barenyi’s invention way back in 1952 and the technology was first introduced into production cars in 1959 in the Mercedes-Benz 220, 220 S and 220 SE models.

Function:
Crumple zones work by managing crash energy, absorbing it within the outer sections of the vehicle, rather than being directly transmitted to the occupants, while also preventing intrusion into or deformation of the passenger cabin. This better protects car occupants against injury. This is achieved by controlled weakening of sacrificial outer parts of the car, while strengthening and increasing the rigidity of the inner part of the body of the car, making the passenger cabin into a 'safety cell', by using more reinforcing beam sand higher strength steels. Volvo introduced the side crumple zone; with the introduction of the SIPS (Side Impact Protection System) in the early 1990s. The purpose of crumple zones is to slow down the collision and to absorb energy. It is like the difference between slamming someone into a wall headfirst (fracturing their skull) and shoulder-first (bruising their flesh slightly) is that the arm, being softer, has tens of times longer to slow its speed, yielding a little at a time, than the hard skull, which isn't in contact with the wall until it has to deal with extremely high pressures.

Seatbelts restrain the passenger so they don't fly through the windshield, and are in the correct position for the airbag and also spread the loading of impact on the body. Seat belts also absorb energy by being designed to stretch during an impact, so that there is less speed differential between the passenger's body and their vehicle interior. In short: A passenger whose body is decelerated more slowly due to the crumple zone (and other devices) over a longer time, survives much more often than a passenger whose body indirectly impacts a hard, undamaged metal car body which has come to a halt nearly instantaneously. The final impact after a passenger's body hits the car interior, airbag or seat belts, is that of the internal organs hitting the ribcage or skull. The force of this impact is the mechanism through which car crashes cause disabling or life threatening injury. The sequence of energy is dissipating and speed reducing technologies - crumple zone - seat belt - airbags - padded interior, are designed to work together as system, to reduce the force of this final impact. A common misconception about crumple zones is that they reduce safety by allowing the vehicle's body to collapse, crushing the occupants. In fact, crumple zones are typically located in front and behind of the main body (though side impact absorption systems are starting to be introduced), of the car (which forms a rigid 'safety cell'), compacting within the space of the engine compartment or boot/trunk. The marked improvement over the past two decades in high speed crash test results and real-life accidents also belies any such fears. Modern vehicles using what are commonly termed 'crumple zones' provide far superior protection for their occupants in severe tests than older models, or SUVs that use a separate chassis frame and have no crumple zones.
Safety sandwich construction

Sandwich panel constructions using metallic and polymeric honeycombs and foams have been used for many years in the competition and high performance sectors of the automotive industry, and there is considerable knowledge and confidence in their static, dynamic and crashworthiness properties. However, it should be noted that with regard to vehicle structures, sandwich panels have only been used to produce extremely limited numbers of product and have been essentially hand-worked.

The potential advantages of polymer composites for automotive parts (high specific strength and stiffness, corrosion resistance) are well known. Further benefits are available from the use of sandwich construction, in which a relatively stiff, strong skin is bonded either side of a much thicker, lightweight core. Sandwich panels have been widely used for structural applications in the marine, aerospace and performance automotive industries for several decades [3]. Lightweight core materials have included balsa, polymer foams and metallic, paper or polymer honeycombs. These have been used in various combinations with skins of carbon, glass and/or aramid fiber-reinforced polymer, as well as aluminium. The principle of sandwich construction is that bending loads are carried by the skins, while the core transmits shear load. They enable large gains in structural efficiency, since the thickness (and hence flexural rigidity) of panels can be increased without significant weight penalty. Some representative properties of sandwich panels are given in Table.

<table>
<thead>
<tr>
<th></th>
<th>Thickness (mm)</th>
<th>Bending stiffness per unit width (Nm/m)</th>
<th>Weight per unit area of sandwich beam (kg/m²)</th>
<th>Weight per unit area of monolithic Al. with same bending stiffness (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-board</td>
<td>13.7</td>
<td>1,100</td>
<td>3.08</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>26.4</td>
<td>4,500</td>
<td>4.21</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>52.3</td>
<td>20,500</td>
<td>7.54</td>
<td>41</td>
</tr>
<tr>
<td>M-board</td>
<td>13.9</td>
<td>3,500</td>
<td>4.67</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>26.6</td>
<td>13,500</td>
<td>5.73</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>52.0</td>
<td>52,500</td>
<td>7.84</td>
<td>56</td>
</tr>
</tbody>
</table>

In high performance car construction, most sandwich panel elements are vacuum bag/autoclave molded on a contact tool, usually in several stages (e.g. first skin; core to skin bond; second skin). Although this permits complex shapes to be produced on low cost tooling, it is necessarily a time consuming and labor intensive process. A high degree of cleanliness and sophisticated process control are required, and inspection is notoriously difficult. However, sandwich panels are also available as flat sheet, stock material. Hexcel Composites, for example, supply arrange of honeycomb cored sheets of varying specifications which is widely used for building cladding, aircraft flooring, luggage bins and bulkheads. The use of a stock material is attractive, since primary material quality and specification becomes the responsibility of the supplier, not the manufacturer. Several techniques are well established for the shaping and assembly of structural
components from flat sandwich panel. Panels may be bent to required angles by removing a defined strip of material from the inner skin, then folding and adhesively bonding the joint.

For additional strength, reinforcing material can be added at the skin joints. It is emphasized at this point that the process of shaping a panel requires no tooling, and assembly can often be arranged so that parts are self-jigging. Although panels can be machined with hand tools, a major attraction of these techniques is the potential they offer for computer control and automation. In this project we have used a general industrial CNC router/cutter; as described in Section 4, adhesives were applied manually, but this too could be readily automated.
UNIT-2 SAFETY CONCEPTS

Overall safety can be classified as given below: In this unit we are going to study about vehicle safety.

Active safety:

Prevention of accidents

Driving safety

It is the result of a harmonious chassis and suspension design with regard to wheel suspension, springing, steering and braking, and is reflected in optimum dynamic vehicle behavior.

Conditional safety

It results from keeping the physiological stress that the vehicle occupants are subjected to by vibration, noise, and climatic conditions down to as low a level as possible. It is a significant factor in reducing the possibility of misactions in traffic. Vibrations within a frequency range of 1 to 25 Hz (stuttering, shaking, etc.) induced by wheels and drive components reach the occupants of the vehicle via the body, seats and steering wheel. The effect of these vibrations is more or less pronounced, depending upon their direction, amplitude and duration. Noises as acoustical disturbances in and around the vehicle can come from internal sources (engine, transmission, prop shafts, axles) or external sources (tire/road noises, wind noises), and are transmitted through the air or the vehicle body. The sound pressure level is measured in dB(A) (see Motor-vehicle noise measurements and limits). Noise reduction measures are concerned on the one hand with the development of quiet-running components and the insulation of noise.
sources (e.g., engine encapsulation), and on the other hand with noise damping by means of insulating or anti-noise materials. Climatic conditions inside the vehicle are primarily influenced by air temperature, air humidity, rate of airflow through the passenger compartment and air pressure (see Environmental stresses for additional information).

**Perceptibility safety**

- Measures which increase perceptibility safety are concentrated
- Lighting equipment (see Lighting),
- Acoustic warning devices (see Acoustic signaling devices),
- Direct and indirect view (see Main dimensions) (Driver's view: The angle of obscuration caused by the A-pillars for both of the driver's eyes binocular must not be more than 6 degrees).

**Operating safety**

Low driver stress, and thus a high degree of driving safety, requires optimum design of the driver surroundings with regard to ease of operation of the vehicle controls.

**Passive safety:**

Reduction of accident consequences.

**Exterior safety**

The term "exterior safety" covers all vehicle-related measures which are designed to minimize the severity of injury to pedestrians and bicycle and motorcycle riders struck by the vehicle in an accident. Those factors which determine exterior safety are:

- Vehicle-body deformation behavior,
- Exterior vehicle body shape.

The primary objective is to design the vehicle such that its exterior design minimizes the consequences of a primary collision (a collision involving persons outside the vehicle and the vehicle itself). The most severe injuries are sustained by passengers who are hit by the front of the vehicle, whereby the course of the accident greatly depends upon body size. The consequences of collisions involving two-wheeled vehicles and passenger cars can only be slightly ameliorated by passenger-car design due to the two-wheeled vehicle's often considerable inherent energy component, its high seat position and the wide dispersion of contact points. Those design features which can be incorporated into the passenger car are, for example:

- Movable front lamps
- Recessed windshields wipers,
- Recessed drip rails,
- Recessed door handles.
Risk to pedestrians in event of collisions with passenger cars as a function of impact frequency and seriousness of injury (based on 246 collisions)

**Interior safety**

The term "interior safety" covers vehicle measures whose purpose is to minimize the accelerations and forces acting on the vehicle occupants in the event of an accident, to provide sufficient survival space, and to ensure the operability of those vehicle components critical to the removal of passengers from the vehicle after the accident has occurred. The determining factors for passenger safety are:

- Deformation behavior (vehicle body),
- Passenger-compartment strength, size of the survival space during and after impact,
- Restraint systems,
- Impact areas (vehicle interior),
- Steering system,
- Occupant extrication,
- Fire protection.

Laws which regulate interior safety (frontal impact) are:

- Protection of vehicle occupants in the event of an accident, in particular restraint systems
- Windshield mounting
- Penetration of the windshield by vehicle body components
- Parcel-shelf and compartment lids

**Rating-Tests:**

- New-Car Assessment Program (NCAP, USA, Europe, Japan, Australia),
- IIHS (USA, insurance test),
- ADAC, ams, AUTO-BILD.
Deformation behavior of vehicle body

Due to the frequency of frontal collisions, an important role is played by the legally stipulated frontal impact test in which a vehicle is driven at a speed of 48.3 km/h (30 mph) into a rigid barrier which is either perpendicular or inclined at an angle of up to 30° relative to the longitudinal axis of the car.

Because 50% of all frontal collisions in right-hand traffic primarily involve the left-hand half of the front of the vehicle, manufacturers worldwide conduct left asymmetrical front impact tests on LHD vehicles covering 30 ... 50% of the vehicle width. Enlarge picture Fig 3 Distribution of accidents by type of collision, Symbolized by test methods yielding equal results in a frontal collision, kinetic energy is absorbed through deformation of the bumper, the front of the vehicle, and in severe cases the forward section of the passenger compartment (dash area). Axles, wheels (rims) and the engine limit the deformable length. Adequate deformation lengths and displaceable vehicle aggregates are necessary, however, in order to minimize passenger-compartment acceleration.

Depending upon vehicle design (body shape, type of drive and engine position), vehicle mass and size, a frontal impact with a barrier at approx. 50 km/h results in permanent deformation in the forward area of 0.4 ... 0.7 m. Damage to the passenger compartment should be minimized. This concerns primarily dash area (displacement of steering system, instrument panel, pedals, toe-panel intrusion), underbody (lowering or tilting of seats), the side structure (ability to open the doors after an accident).

Acceleration measurements and evaluations of high-speed films enable deformation behavior to be analyzed precisely. Dummies of various sizes are used to simulate vehicle occupants and provide acceleration figures for head and chest as well as forces acting on thighs. Head acceleration values are used to determine the head injury criterion (HIC). The comparison of measured values supplied by the dummies with the permissible limit values as per FMVSS 208 (HIC: 1000, chest acceleration: 60 g/3 ms, upper leg force: 10 kN) are only limited in their applicability to the human being. The side impact, as the next most frequent type of accident, places a high risk of injury on the vehicle occupants due to the limited energy absorbing capability of trim and structural components, and the resulting high degree of vehicle interior
deformation. The risk of injury is largely influenced by the structural strength of the side of the vehicle (pillar/door joints, top/bottom pillar points), load-carrying capacity of floor cross-members and seats, as well as the design of inside door panels (FMVSS 214, ECE R95, Euro-NCAP, US-SINCAP). In the rear impact test, deformation of the vehicle interior must be minor at most. It should still be possible to open the doors, the edge of the trunk lid should not penetrate the rear window and enter the vehicle interior, and fuel-system integrity must be preserved (FMVSS 301). Roof structures are investigated by means of rollover tests and quasi-static car-roof crush tests (FMVSS 216). In addition, at least one manufacturer subjects his vehicles to the inverted vehicle drop test in order to test the dimensional stability of the roof structure (survival space) under extreme conditions (the vehicle falls from a height of 0.5 m onto the left front corner of its roof).

Acceleration, speed and distance traveled, of a passenger compartment when impacting a barrier impacting a barrier at 50 km/h.

**Speed and acceleration characteristics of vehicle body:**

Velocity graph for 15 mph barrier test:
Velocity graph for 20 mph barrier test:

Velocity graph for 40 mph barrier test:

Velocity graph for 50 mph barrier test:
All the graphs show the reduction in velocity (speed) of passenger compartment on impact. For 15 mph and 20 mph barrier test, we can see that the velocity comes to zero, crosses zero line, stays in the negative region afterwards. Velocity in negative region means that the car is moving in opposite direction (i.e.) after the collision it moves back. But for 40 mph test, the velocity comes close to zero and lies in the positive region. It means that after the impact, the car does not bounce back much, because most of the energy of the crash is taken by deforming the body metal. But in 15 mph and 20 mph tests, as the speed is low, the kinetic energy to deform the body metal is also less and hence the body metal does not deform and stands rigid. So, the car bounces back and velocity is slightly in the negative region.
UNIT- 3   SAFETY EQUIPMENTS

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. As part of an overall automobile passive safety system, seat belts are intended to reduce injuries by stopping the wearer from hitting hard interior elements of the vehicle, or other passengers (the so-called second impact), are in the correct position for the airbag to deploy and prevent the passenger from being thrown from the vehicle. Seat belts also absorb energy by being designed to stretch during an impact, so that there is less speed differential between the passenger's body and their vehicle interior, and also to spread the loading of impact on the passengers' body. The final, so-called 'third impact' after a passenger's body hits the car interior, airbag or seat belts, is that of the internal organs hitting the ribcage or skull. The force of this impact is the mechanism through which car crashes cause disabling or life threatening injury. The sequence of energy dissipating and speed reducing technologies - crumple zone - seat belt - airbags - padded interior, are designed to work together as system, to reduce the force of this final impact.

Types of seat belts

- Lap seat belt
- Three points seat belt

Lap:
Adjustable strap that goes over the waist. Used frequently in older cars, now uncommon except in some rear middle seats. Passenger’s aircraft seats also use lap seat belts to prevent injuries.

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.

Three-point:
Similar to the lap and shoulder, 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. Volvo introduced the first production three-point belt in 1959. The first car with three point belt was a Volvo PV 544 that was delivered to a dealer in Kristianstad on August 13, 1959. The three point belt was developed by Nils Bohlin who earlier had worked on ejection seats at Saab. Until the 1980s, three-point belts were commonly available only in the front seats of cars; the back seats had only lap belts or diagonal belts. Evidence of the potential for lap belts to cause separation of the lumbar vertebrae and the sometimes associated paralysis,
"seat belt syndrome", has led to a revision of passenger safety regulations in nearly all developed countries requiring that all seats in a vehicle be equipped with three-point belts. Since September 1, 2007, all new cars sold in the U.S. require a lap and shoulder belt in the center rear.

**Seat belts and seat-belt tighteners**

![Diagram of occupant protection systems with belt tighteners and front airbags]

Occupant protection systems with belt tighteners and front airbags: 1 Belttightener, 2 Front airbag for passenger, 3 Front airbag for driver, 4 ECU

**Function:**

The function of seat belts is to restrain the occupants of a vehicle in their seats when the vehicle hits an obstacle. Seat-belt tighteners improve the restraining characteristics of a three-point inertia-reel belt and increase the protection against injury. In the event of a frontal impact, they pull the seat belts tighter against the body and thus hold the upper body as closely as possible against the seat backrest. This prevents excessive forward displacement of the occupants caused by mass inertia.
Operating concept:

In a frontal impact with a solid obstacle at a speed of 50 km/h, the seat belts must absorb a level of energy comparable to the kinetic energy of a person in free fall from the 4th floor of a building. Because of the belt slack, the belt stretch and the delayed effect of the belt retractor ("film-reel effect"), three-point inertia-reel belts provide only limited protection in frontal impacts with solid obstacles at speeds of over 40 km/h because they can no longer safely prevent the head and body from impacting against the steering wheel or the instrument panel. An occupant experiences extensive forward displacement without restraint systems.

Deceleration to standstill and forward displacement of an occupant at an impact speed of 50 km/h. 1 Impact, 2 Firing of belt tightener/airbag, 3 Belt tightened, 4 Airbag inflated. Without/with restraint systems. In an impact, the shoulder belt tightener compensates for the belt slack and the "film-reel effect" by retracting and tightening the belt strap. At an impact speed of 50 km/h, this system achieves its full effect within the first 20 ms of the impact; and thus supports the airbag which needs approx. 40 ms to inflate completely. The occupant continues to move forward slightly until making contact with the deflating airbag and in this manner is protected from injury. A prerequisite for optimum protection is that the occupants' forward movement away from their seats remains minimal as they decelerate along with the vehicle. This is achieved by triggering the belt tighteners immediately upon initial impact to ensure that safe restraint of the occupants in the front seats starts as soon as possible. The maximum forward displacement with tightened seat belts is approx. 1 cm and the duration of mechanical tightening is 5...10 ms. On activation, a pyrotechnical propellant charge is electrically fired. The explosive pressure acts on a piston, which turns the belt reel via a steel cable in such a way that the belt rests tightly against the body.

Shoulder-belt tightener 1. Ignition cable, 2 Firing elements, 3 Propellant charge, 4 Piston, 5 Cylinder, 6 Metal cables, 7 Belt reel, 8 Belt strap.
Variants:

In addition to the above-mentioned shoulder-belt tighteners for retracting the belt reel, there are variants which pull the belt buckle back (buckle tighteners) and thus simultaneously tighten the shoulder and lap belts. The restraining effect and the protection afforded against occupants sliding forward beneath the lap belt ("submarining effect") are improved still further by buckle tighteners. The tightening process in these two systems takes place in the same period of time as for shoulder-belt tighteners. Mechanical belt tighteners are also available in addition to the pyrotechnically triggered versions. In the case of a mechanicaltightener, a mechanical or electrical sensor releases a pre tensioned spring, which pulls the belt buckle back. The sole advantage of these systems is that they are cheaper.

Air Bags, Electronic System for activating air bags:

Function:

The function of front airbags is to protect the driver and the front passenger against head and chest injuries in a vehicle impact with a solid obstacle at speeds of up to 60 km/h. In a frontal impact between two vehicles, the front airbags afford protection at relative speeds of up to 100 km/h. A belt tighter alone cannot prevent the head from hitting the steering wheel in response to severe impact. In order to fulfill this function, depending on the installation location, vehicle type and structure-deformation response, airbag shave different filling capacities and pressure build-up sequences adapted to the specific vehicle conditions. In a few vehicle types, front airbags also operate in conjunction with "inflatable knee pads", which safeguard the "ride down benefit", i.e. the speed decrease of the occupants together with the speed decrease of the passenger cell. This ensures the rotational forward motion of the upper body and head which is actually needed for optimal airbag protection, and is of particular benefit in countries where seat-belt usage is not mandatory.
Operating concept:
To protect driver and front passenger, pyrotechnical gas inflators inflate the driver and passenger airbags in pyrotechnical, highly dynamic fashion after a vehicle impact detected by sensors. In order for the affected occupant to enjoy maximum protection, the airbag must be fully inflated before the occupant comes into contact with it. The airbag then responds to upper-body contact with partial deflation in a response pattern calculated to combine "gentle" impact-energy absorption with non-critical (in terms of injury) surface pressures and decelerative forces for the occupant. This concept significantly reduces or even prevents head and chest injuries. The maximum permissible forward displacement before the driver's airbag is fully inflated is approx. 12.5 cm, corresponding to a period of approx. 10 ms + 30 ms = 40 ms after the initial impact (at 50 km/h with a solid obstacle) (see Fig. "Deceleration to standstill"). It needs 10 ms for electronic firing to take place and 30ms for the airbag to inflate.

In a 50 km/h crash, the airbag takes approx. 40 ms to inflate fully and a further 80...100 ms to deflate through the deflation holes. The entire process thus takes little more than a tenth of a second, i.e. the batting of an eyelid.
Impact detection:

Optimal occupant protection against the effects of frontal, offset, oblique or pole impact is obtained through the precisely coordinated interplay of electrically fired pyrotechnical front airbags and seat-belt tighteners. To maximize the effect of both protective devices, they are activated with optimized time response by a common ECU (triggering unit) installed in the passenger cell. The ECU’s deceleration calculations are based on data from one or two electronic acceleration sensors used to monitor the decelerative forces that accompany an impact. The impact must also be analyzed. A hammer blow in the workshop, gentle pushing, driving over a curbstone or a pothole should not trigger the airbag. With this end in mind, the sensor signals are processed in digital analysis algorithms whose sensitivity parameters have been optimized with the aid of crash-data simulations. Depending on the impact type, the first trigger threshold is reached within 5...60 ms. the acceleration characteristics, which are influenced for instance by the vehicle equipment and the body's deformation performance, are different for each vehicle. They determine the setting parameters which are of crucial importance for the sensitivity in the analysis algorithm (computing process) and, in the end, for airbag and belt-tightener firing. Depending on the vehicle-manufacturer's production concept, the trigger parameters and the extent of vehicle equipment can also be programmed into the ECU at the end of the assembly line ("end-of-line programming" or "EoL programming"). In order to prevent injuries caused by airbags or fatalities to "out-of-position" occupants or to small children in Re board child seats, it is essential that the front airbags are triggered and inflated in accordance with the particular situations. The following improvement measures are available for this purpose 1. Deactivation switches. These switches can be used to deactivate the driver or passenger airbag. The airbag function states are indicated by special lamps. 2. In the USA, where there have been approx. 130 fatalities caused by airbags, attempts are being made to reduce aggressive inflation by introducing "depowered airbags". These are airbags whose gas-inflator power has been reduced by 20...30 %, which itself reduces the inflation speed, the inflation severity and the risk of injury to "out-of-position" occupants. "Depowered airbags" can thus be depressed more easily by large and heavy occupants, i.e. they have a reduced energy-absorption capacity. It is therefore essential above all with regard to the possibility of severe frontal impacts for the occupants to fasten their seatbelts. 3. "Intelligent airbag systems". The introduction of improved sensing functions and control options for the airbag inflation process, with the accompanying improvement of the protective effect, is intended to result in a step-by-step reduction in the risk of injury.

Components:

Acceleration sensors:

Acceleration sensors for impact detection are integrated directly in the ECU (belt tightener, front airbag) and mounted at selected points on the left and right body sides (side airbag) or in the vehicle's front-end deformation area (upfront sensors for "intelligent airbag systems"). The precision of these sensors is crucial in saving lives. They are generally surface-micromechanical sensors consisting of fixed and moving finger structures and spring pins. A special process is used to incorporate the "spring/mass system" on the surface of a silicon wafer. Since the sensors only have low working capacitance (≈1 pF), it is necessary to accommodate the evaluation electronics in the same housing so as to avoid stray-capacitance and other forms of interference.

Gas inflators:

The pyrotechnical propellant charges of the gas inflators for generating the airbag inflation gas (mainly nitrogen) and for actuating belt tighteners are activated by an electrically operated
firing element. The gas inflator in question inflates the airbag with nitrogen. The driver’s airbag integrated in the steering-wheel hub (volume 35...67 l) or the passenger airbag installed in the glove box (70...150 l) is inflated approx. 30 ms after firing.

**Bumper design for safety**

The front and rear of the vehicle should be protected in such a manner that low-speed collisions will only damage the vehicle slightly, or not at all. Prescribed bumper evaluation tests (US Part 581, Canada CMVSS 215, and ECE-R 42) specify minimum requirements in terms of energy absorption and installed bumper height. Bumper evaluation tests in accordance with US Part 581 (4 km/h barrier collision, 4 km/h pendulum tests) must be passed by a bumper system whose energy absorber is of the no-damage absorber type. The requirements of the ECE standard are satisfied by plastically deformable retaining elements located between the bumper and the vehicle body structure. In addition to sheet steel, many bumpers are manufactured using fiber-reinforced plastics and aluminum sections.

![Bumpers 1. Shock-absorber system, 2 Energy-absorbing PUR-foam systems](image)

**Exterior trim, impact strips:**

Plastics have become the preferred materials for external impact strips, trim, skirts and spoilers, and particularly for those components whose purpose is to improve the aerodynamic characteristics of the vehicle. Criteria used in the selection of the proper material are flexibility, high-temperature shape retention, and coefficient of linear expansion, notched-bar toughness, resistance to scratches, and resistance to chemicals, surface quality and paint ability.

![Section through an A-pillar with trim (Principle)](image)
**Collapsible Steering Column**

The collapsible steering column, like shoulder harnesses or air bags, is a device that greatly increases driver survivability in the event of a head on collision. During a head on crash, the steering column can be pushed into the passenger compartment with tremendous force. At the same time, drivers obey Newton’s first law of motion and continue to travel at the same speed of the automobile until something acts on the driver to slow or stop them. Too frequently, it was the steering wheel that caused drivers to stop, sometimes with horrific consequences. In fact, years ago it was not unheard of for drivers to be impaled on the steering shaft. As a result, engineers began to investigate ways in which driver survivability could be increased for those unlucky enough to slam into the steering wheel. The goal was to develop a system in which the driver could safely slow down or decelerate during a front end collision. What they developed is now known as the collapsible steering column. Its design was so successful that nearly all of today’s steering columns are designed to deform under pressure from impact. Collapsible steering columns come in a number of designs. Some columns integrate a series of telescoping tubes that collapse when impacted by the driver. Others use break points in the column that will allow the bend more easily. Still others have a special joint near the steering gear that allows the column to snap down during impact. While air bags have become more prominent over the past few years, collapsible steering columns continue to play an important role in enhancing driver safety. But rather than being a primary safety feature, steering column designs have come to represent the last ring of safety behind shoulder harnesses restraints and air bags. Together, more drivers are walking away from crashes that would have certainly resulted in death, just a few years ago.
Telescopic collapsible steering tubes consist of a lower part 1, which is flattened on the outside, and a hollow part 2, which is flattened on the inside. The two will be fitted together; the two plastic bushes 3 ensure that the assembly does not rattle and that the required shear-off force in the longitudinal direction is met. The tab 4 fixed to part 1 ensures the passage of electric current when the horn is operated. The spigot of the steering wheel lock engages with the welded-on half shells 5 (illustration: Lemböder Fahrwerktechnik).
Collision Warning System

An interesting safety-related electronic system with potential for future automotive application is the anti-collision warning system. An on-board low-power radar system can be used as a sensor for an electronic collision avoidance system to provide warning of a potential collision with an object in the path of the vehicle. As early as 1976, at least one experimental system was developed that could accurately detect objects up to distances of about 100 yards. This system gave very few false alarms in actual highway tests.

For an anti-collision warning application, the radar antenna should be mounted on the front of the car and should project a relatively narrow beam forward. Ideally, the antenna for such a system should be in as flat a package possible, and should project a beam that has a width of about 2° to 3° horizontally and about 4° to vertically. Large objects such as signs can reflect the radar beam, particularly on curves, and trigger false alarm. If the beam is scanned horizontally for a few degrees, say 2.5° either side of center, false alarms from roadside objects can be reduced.

In order to test whether a detected object is in the same lane as the radar-equipped car traveling around a curve, the radius of the curve must be measured. This can be estimated closely from the front wheel steering angle for an unbanked curve. Given the scanning angle of the radar beam and the curve radius, a computer can quickly perform the calculations to determine whether or not a reflecting object is in the same lane as the protected car.

For the collision warning system, better results can be obtained if the radar transmitter is operated in a pulsed mode rather than in a continuous-wave mode. In this mode, the transmitter is switched on for a very short time then it is switched off. During the off time, the receiver is set to receive a reflected signal. If a reflecting object is in the path of the transmitted microwave pulse, a corresponding pulse will be reflected to the receiver. The round trip time, $t$ from transmitter to object and back to receiver is proportional to the range, $R$, to the object and expressed in the following equation: $t = \frac{2R}{c}$ where $c$ is the speed of light. The radar system had the capability of accurately measuring this time to determine the range to the object. It is possible to measure the vehicle speed $V$, by measuring the Doppler frequency shift if the pulsed signal reflected by the ground. This reflection can be discriminated from the object reflection because the ground reflection is at a low angle and a short, fixed range. The reflection from an object will have a pulse shape that is very nearly identical to that of the transmitted pulse. As noted, the radar system can detect this object reflection and find $R$ to determine the distance from the vehicle to the object. In addition, the relative speed of closure between the car and the object can be calculated by adding the vehicle speed, $V$, from the ground reflected pulses and the speed of the object, $S$, which can be determined from the change in range of the object’s reflection pulses.
In this system the range $R$, to the object and the closing speed, $V+S$ are measured. The computer can perform a number of calculations on these data. For example the computer can calculate the time to collision $T$. Whenever this time is less than a preset value a visual and audible warning is generated. The system could also be programmed to release the throttle and apply the brakes, if automatic control were desired.

Causes of rear end collisions

Tailgating:
One of the main things drivers can do to avoid rear-end collisions is to maintain a safe following distance. A two-second following rule is recommended for passenger vehicles. When the vehicle ahead passes a marker, such as a lamppost, the driver of the car that is following
should count "One thousand one, one thousand two." Reaching the lamppost after counting "one thousand two" means that the following car is a safe distance from the lead car. Truck drivers should use a four-second following rule, because heavier weight necessitates a longer stopping distance.

Negligence:

An increasing element of driver negligence involved in rear-end accidents involves the use of cell phones while on the road. The website Science Daily says that drivers who are talking on cell phones have doubled the odds of a fender bender. It notes that cell phone use while driving leads to mistakes such as tailgating, running red lights, speeding and failure to yield to other vehicles. Other examples of negligence leading to accidents include preoccupation with the car's radio or navigation system, or driving while under the influence of drugs or alcohol.

Not Being Alert:

Daydreaming is a prime ingredient in rear-end accidents. Being alert means forcing oneself to stay aware of potential hazards in front, behind and all around one's vehicle so that it is possible to avoid accidents. Some people call this "defensive driving." The official Honolulu website refers to it as "planning ahead" and suggests a pattern of roadway scanning that involves regular checks of all three rear-view mirrors as well as quick peeks at gauges and the speedometer. Furthermore, it says to be prepared for potential problems at intersections and for traffic signal changes.

Frontal / Rear vehicle object detection

Object detection technique is the basic technique useful for determining various objects such as cars, pedestrians, etc in the front / rear of the vehicles. The main applications are:

1. Frontal objects detection
2. Rear objects detection
3. Side objects detection
4. Parking aid system
5. Lane departure warning system
6. Collision avoidance system

The basic technology is the object detecting technology.

1. Image Sensor / Camera to capture the image
2. System to process the captured data processor
3. Software which processes the data – Edge detection algorithm
An imaged systems for a vehicle includes and imaging sensor and a control. The imaging sensor is operable to capture an image of scene occurring exteriorly of the vehicle. The control receives the captured image, which comprises an image data set representative of the exterior scene. The control may apply an edge detection algorithm to a reduced image data of the image data set. The reduced image data set is representative of a target zone of the captured image. The control may be operable to process the reduced image data set more than other image data, which are representative of areas of the captured image outside of the target zone, to detect objects present within the target zone. The imaging system may be associated with a side object detection system a lane change assist system a lane departure warning system.

Note: The technology involved in both front / rear vehicle object detection is the same. Wherever the camera /technology are used, it is known as front / rear object detection system.
The present invention is intended to provide an object detection system, such as a blind spot detection system, a lane change assist or aid system or device, a lane departure warning system, a side object detection system, a reverse park aid system, a forward park aid system, a forward, sideward or rearward collision avoidance system, an adaptive cruise control system, a passive steering system or the like, which is operable to detect and/or identify a vehicle or other object of interest at the side, front or rear of the vehicle equipped with the object detection system. The object detection system of the present invention, such as a lane change assist system, utilizes an edge detection algorithm to detect edges of objects in the captured images and determines if a vehicle is present in a lane adjacent to the equipped or subject vehicle in response to various characteristics of the detected edges, such as the size, location, distance, intensity, relative speed and/or the like. The system processes a subset of the image data captured which is representative of a target zone or area of interest of the scene within the field of view of the imaging system where a vehicle or object of interest is likely to be present. The system processes the detected edges within the image data subset to determine if they correspond with physical characteristics of vehicles and other objects to determine whether the detected edge or edges is/are part of a vehicle or a significant edge or object at or toward the subject vehicle. The system utilizes various filtering mechanisms, such as algorithms executed in software by a system microprocessor, to substantially eliminate or substantially ignore edges or pixels that are not or cannot be indicative of a vehicle or significant object to reduce the processing requirements and to reduce the possibility of false positive signals.

Edge detection algorithm:

Each and every object is having edges (sharp edges or smooth edges). These edges look in a different color from the rest of the picture. So if the edges are identified first we can easily understand the picture and tell what the object in the picture is. The software algorithm used for this purpose is called as edge detection algorithm. Suppose if a picture of the front of a car is taken, the sides of the car are in a different contrast from the rest of the car. The windshield will be of uniform color for a larger area. The outer sides of the windshield will be of a darker color
which represents an edge. Thus the edge is first determined, and then the object in the picture is found approximately. Then, the object in the whole picture is determined by following the same procedure. The basic logic is that to capture the image of the front/rear objects using an image sensor (camera). This digital sensor sends the image as digital data to the image processor (which is nothing but an electronic hardware processor). The processor is having software (edge detection algorithm software) in its memory. This software analyses the image data and determines the object in the picture. Depending upon the object type, it is informed to the driver. The next advanced system is, to integrate this system with barking system so that the brakes are automatically applied when an object, pedestrian is found close to the car.

**Object detection system with braking system interactions**

![Diagram](image)

The present invention relates to an automatic braking control system with object detection system interaction, and particularly to techniques for automatic braking control according to which a braking system is activated automatically without any driver’s braking action when a host vehicle is closing on a frontally-located obstacle or a vehicle ahead.
In recent years, there have been proposed and developed various braking control systems that determine a possibility of collisions based on both a relative distance between a host vehicle and an object, such as an obstacle in front and a preceding vehicle running ahead of the host vehicle, and a relative velocity of the host vehicle to the preceding vehicle, for the purpose of automatic activation of a braking system, collision avoidance, slippage control of steered wheels, or

Accordingly, it is an object of the invention to provide an automatic braking control system with object detection system interaction, which avoids the aforementioned disadvantages.

It is another object of the invention to provide an automatic braking control system with object detection system interaction, which is capable of precisely determining the presence or absence of a driver's intention for obstacle-avoidance or a driver's intention to pass the preceding vehicle, in other words, the presence or absence of a driver's intention for lane-changing, so as to optimally control a shift to an automatic braking mode and to prevent an undesirable shift to the automatic baking mode.

In order to accomplish the aforementioned and other objects of the present invention, a braking control system with object detection system interaction comprises a relative-distance detector that detects a relative distance of a frontally positioned object relative to a host vehicle, a vehicle speed sensor that detects a host vehicle speed of the host vehicle, an automatic braking control unit configured to be electronically connected to at least the relative-distance detector and the vehicle speed sensor for automatically controlling, depending on both the relative distance and the host vehicle speed, a braking force needed for an automatic braking operation without driver's braking action when the host vehicle is approaching the frontally positioned object, the automatic braking control unit comprising a detection section that detects the presence or absence of a driver's intention for lane-changing, the automatic braking control unit limiting the automatic braking operation in the presence of the driver's intention for lane-changing.
According to another aspect of the invention, a braking control system with object detection system interaction comprises an object detection means for detecting a relative distance of a frontally positioned object relative to a host vehicle, a vehicle speed detection means for detecting a host vehicle speed of the host vehicle, an automatic braking control means configured to be electronically connected to at least the object detection means and the vehicle speed detection means for automatically controlling, depending on both the relative distance and the host vehicle speed, a braking force needed for an automatic braking operation without driver's braking action when the host vehicle is approaching the frontally positioned object, the automatic braking control means comprising means for detecting the presence or absence of a driver's intention for lane-changing, the automatic braking control means limiting the automatic braking operation in the presence of the driver's intention for lane-changing.

According to a further aspect of the invention, an automatic preliminary braking control system with object detection system interaction comprises a relative-distance detector that detects a relative distance of a frontally positioned object relative to a host vehicle, a vehicle speed sensor that detects a host vehicle speed of the host vehicle, a brake switch whose signal indicates if a brake pedal is depressed, an accelerator stroke sensor that detects an accelerator opening, an automatic braking control unit configured to be electronically connected to at least the relative-distance detector, the vehicle speed sensor, the brake switch and the accelerator stroke sensor for automatically controlling, depending on the relative distance, the host vehicle speed, the signal from the brake switch and the accelerator opening, a braking force needed for preliminary braking control initiated prior to driver's braking action when the host vehicle is approaching the frontally positioned object, the automatic braking control unit comprising a target deceleration rate calculation section that calculates a target deceleration rate, needed to avoid the host vehicle from being brought into collision-contact with the frontally positioned object, from an expression $Gx^* = \frac{V_m^2 - (V_m - dL/dt)^2}{2L}$,
where $Gx^*$ is the target deceleration rate, $Vm$ is the host vehicle speed, $L$ is the relative distance, and $dL/dt$ is a time rate of change of the relative distance, a comparison section that determines whether the target deceleration rate is greater than or equal to a predetermined deceleration-rate threshold value, and a detection section that detects the presence or absence of a driver's intention for lane-changing, the automatic braking control unit inhibiting the preliminary braking control, when either of a condition that the brake pedal is undepressed, a condition that the accelerator opening is less than or equal to a predetermined threshold value substantially corresponding to a closed position of an accelerator, a condition that the target deceleration rate is greater than or equal to the predetermined deceleration-rate threshold value, and a condition that the driver's intention for lane-changing is absent, is unsatisfied.

According to a still further aspect of the invention, an automatic supplementary braking control system with object detection system interaction comprises a relative-distance detector that detects a relative distance of a frontally positioned object relative to a host vehicle, a vehicle speed sensor that detects a host vehicle speed of the host vehicle, a pressure sensor that detects an actual braking pressure, an automatic braking control unit configured to be electronically connected to at least the relative-distance detector, the vehicle speed sensor and the pressure sensor for automatically controlling, depending on the relative distance, the host vehicle speed and the actual braking pressure, a braking force needed for supplementary braking control through which a value of a controlled quantity is brought closer to a target deceleration rate needed for collision-avoidance when the host vehicle is approaching the frontally positioned object, the automatic braking control unit comprising a target deceleration rate calculation section that calculates the target deceleration rate, needed to avoid the host vehicle from being brought into collision-contact with the frontally positioned object, from an expression $Gx^* = \frac{Vm^2 - (Vm - dL/dt)^2}{2L}$, where $Gx^*$ is the target deceleration rate, $Vm$ is the host vehicle speed, $L$ is the relative distance, and $dL/dt$ is a
time rate of change of the relative distance, a computation section that computes a target braking pressure based on the target deceleration rate.

According to another aspect of the invention, a method for automatically controlling a braking force needed for an automatic braking operation without driver’s braking action when a host vehicle is approaching a frontally positioned object, the method comprises detecting a host vehicle speed, detecting a relative distance of the frontally positioned object relative to the host vehicle, detecting a signal from a brake switch, detecting an accelerator opening, detecting an actual braking pressure, calculating a time rate of change of the relative distance, calculating a target deceleration rate based on the host vehicle speed, the relative distance, and the rate of change of the relative distance, computing a target braking pressure based on the target deceleration rate, based on the host vehicle speed, the relative distance, and the rate of change of the relative distance, computing a target braking pressure based on the target deceleration rate, detecting the presence or absence of a driver’s intention for lane-changing, inhibiting preliminary braking control initiated prior to driver’s braking action, when either of a condition that the brake pedal is undepressed, a condition that the accelerator opening is less than or equal to a predetermined threshold value substantially corresponding to a closed position of an accelerator, a condition that the target deceleration rate is greater than or equal to a predetermined deceleration-rate threshold value, and a condition that the driver’s intention for lane-changing is absent, is unsatisfied, and decreasingly compensating for the target braking pressure for limiting supplementary braking control, when a condition that the actual braking pressure is less than the target braking pressure and a condition that the driver’s intention for lane-changing is present, are both satisfied.
Steering and mirror adjustment

Electrically-adjustable steering columns are also seeing increased use as yet another means of enhancing driver comfort. The adjustment mechanism, consisting of a single electric motor and self-arresting gear set for each adjustment plane, forms an integral part of the steering column. The gear set for telescopic adjustment must be capable of absorbing any and all impact forces (crash forces) which might be applied to the steering column. The adjustment can be triggered in either of two ways, using the manual position switch or with the programmable seat adjustment. Also available is a provision for tilting the column upward to facilitate driver entry and degrees.

Central Locking System

Either pneumatic or electric actuators can be used to power central locking systems for vehicle doors, luggage compartments and fuel-filler flaps. In pneumatic systems, an electric motor drives the reversible dual-pressure pump which provides the required system pressure (positive or vacuum). The system can be switched on and off by a central position switch inside the vehicle and by the ignition switch. As an optional feature, the system can be operated from a number of points (driver door, front-seat passenger door, and trunk lid).
More widespread than the pneumatic systems are those which depend on electric motors for central locking. Although various technologies are used, according to function range and lock type, the basic principle remains constant: a small electric motor featuring a reduction-gear drive unit powers the actuating lever responsible for opening and closing the lock. Provision must be made to ensure that the door can always be unlocked with the key and the interior handle in the event of a power failure. Central locking systems incorporating special theft-deterrence features must be designed to preclude deactivation of the security system using any means other than the vehicle key. Ultrasonic or infrared remote control provide increased convenience. Such systems permit remote operation of the central locking system when the driver is still some distance away from the vehicle.

![Diagram of central locking system](image)

1 Wiring connection, 2 Flexible end-position coupling, 3 Gear unit, 4 Electric motor, 5 Actuating lever, h - Travel range

**Tire Pressure Control system**

Another interesting electronic system that is slowly finding use in automobiles is a warning system for low tire pressure that works while the car is in motion. This application is motivated in part by an act of Congress that among other things requires that new vehicles have tire pressure monitoring capability by the 2004 model year. A potentially dangerous situation could be avoided if the driver could be alerted to the fact that a tire has low pressure. For example, if a tire develops a leak, the driver could be warned in sufficient time to stop the car before control becomes difficult. There are several pressure sensor concepts that can be used. A block diagram of a hypothetical system is shown in Figure 11.13. In this scheme, a tire pressure sensor continually measures the tire pressure. The signal from the sensor mounted on the rolling tire is coupled by a link to the electronic signal processor. Whenever the pressure drops below a critical limit, a warning signal is sent to a display on the instrument panel to indicate which tire has the low pressure. The difficult part of this system is the link from the tire pressure sensor mounted on the rotating tire to the signal processor mounted on the body. Several concepts have the potential to provide this link. For example, slip rings, which are similar to the brushes on a dc motor, could be used. However, this would require a major modification to the wheel-axle
assembly and does not appear to be an acceptable choice at the present time. Another concept for providing this link is to use a small radio transmitter mounted on the tire. By using modern solid-state electronic technology, a low-power transmitter is mounted in the tire valves. The transmitter sends a signal to a receiver in the car body. The distance from the transmitter to the receiver is a few feet, so only very low power is required.

One problem with this method is that electrical power for the transmitter would have to be provided by a self-contained battery. However, the transmitter need only operate for a few seconds and only when the tire pressure falls below a critical level. Therefore, a tiny battery could theoretically provide enough power. The scheme is illustrated schematically for a single tire in the following figure. The sensor switch is usually held open by normal tire pressure on a diaphragm mechanically connected to the switch. Low tire pressure allows the spring-loaded switch to close, thereby switching on the micro transmitter. The receiver, which is directly powered by the car battery, receives the transmitted signal and passes it to the signal processor, also directly powered by the car battery. The signal processor then activates a warning lamp for the driver, and it remains on until the driver resets the warning system by operating a switch on the instrument panel. One reason for using a signal processing unit is the relatively short life of the transmitter battery. The transmitter will remain on until the low-pressure condition is corrected or until the battery runs down. By using a signal processor, the low-pressure status can be stored in memory so the warning will still be given even if the transmitter quits operating. The need for this feature could arise if the pressure dropped while the car was parked. By storing the status, the system would warn the driver as soon as the ignition was turned on. Still another scheme for monitoring tire pressure is to have a transmitter/receiver mounted on the car. In this scheme, the tire pressure sensor is a form of passive transponder that is interrogated by the transmitter/receiver system.

![Wireless Link Diagram](image)

### Rain Sensors

The rain sensor recognizes rain droplets on the windshield, so that the windshield wipers can be triggered automatically. The unit thus frees the driver to concentrate on other tasks by making the various control operations used to activate conventional wiper systems redundant. For the
Time being the driver can still use the manual controls; if desired, the automatic system must be manually selected when the vehicle is started. The sensor consists of an optical transmission and reception path (similar to the dirt sensor). In this application, the light is directed toward the windshield at an angle. A dry outer surface reflects (total reflection) it back to the receiver, which is also mounted at an angle. When water droplets are present on the outer surface, a substantial amount of the light is refracted outward, thus weakening the return signal. This system also responds to dirt once the activation threshold is exceeded.

Rain sensor 1 Windshield, 2 Optical coupling, 3 Heater, 4 Rain droplets, 5 Light conductor, 6 LED, 7 Electronics, 8 Photodiode, 9 Shield

Garage door opening system

A garage door opener is a motorized device that opens and closes garage doors. Most are controlled by switches on the garage wall, as well as by remote controls carried in the garage owner's cars. The typical electric garage door opener consists of a power unit that contains the electric motor. The power unit attaches to a track. A trolley connected to an arm that attaches to the top of the garage door slides back and forth on the track, thus opening and closing the garage door. The trolley is guided along the track by a chain, belt, or screw that turns when the motor is operated. A quick-release mechanism is attached to the trolley to allow the garage door to be disconnected from the opener for manual operation during a power failure or in case of emergency. Limit switches on the power unit control the distance the garage door opens and closes once the motor receives a signal from the remote control or wall push button to operate the door. The entire assembly hangs above the garage door. The power unit hangs from the ceiling and is located towards the rear of the garage. The end of the track on the opposite end of the power unit attaches to a header bracket that is attached to the header wall above the garage door. The power head is usually supported by punched angle iron. The first garage door opener remote controls were simple and consisted of a simple transmitter (the remote) and receiver which controlled the opener mechanism. The transmitter would transmit on a designated frequency; the receiver
would listen for the radio signal, then open or close the garage, depending on the door position. The basic concept of this can be traced back to World War II. This type of system was used to detonate remote bombs. While novel at the time, the technology ran its course when garage door openers became widely available and used. Then, not only did a person open their garage door, they opened their neighbor’s garage door as well. While the garage door remote is low in power and in range, it was powerful enough to interfere with other receivers in the area. The second stage of the wireless garage door opener system deals with the shared frequency problem. To rectify this, systems required a garage door owner to preset a digital code via dip switches on the receiver and transmitter. While these switches provided garage door systems with $28 = 256$ different codes they were not designed with high security in mind; the main intent was to avoid interference with similar systems nearby. The third stage of garage door opener market uses a frequency spectrum range between 300-400 MHz and most of the transmitter/receivers rely on hopping or rolling code technology. This approach prevents perpetrators from recording a code and replaying it to open a garage door. Since the signal is supposed to be significantly different from that of any other garage door remote control, manufacturers claim it is impossible for someone other than the owner of the remote to open the garage. When the transmitter sends a code, it generates a new code using an encoder. The receiver, after receiving a correct code, uses the same encoder with the same original seed to generate a new code that it will accept in the future. Because there is a high probability that someone might accidentally push the open button while not in range and desynchronize the code, the transmitter and receiver generate look-a-head codes ahead of time. The fourth stage of garage door opener systems is similar to third stage, but it is limited to the 315 MHz frequency.