Traffic Collision & Automobile Safety

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Traffic Collision

Vehicle Collision

A head-on collision of two cars

ICD-10	V99.
ICD-9	E810 - E819

A **traffic collision**, also known as a **traffic accident**, **motor vehicle collision**, **motor vehicle accident**, **car accident**, **automobile accident**, **Road Traffic Collision** (RTC) or **car crash**, occurs when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree or utility pole. Traffic collisions may result in injury, death and property damage.

A number of factors contribute to the risk of collision including; vehicle design, speed of operation, road design, and driver skill and/or impairment. Worldwide motor vehicle collisions lead to significant death and disability as well as significant financial costs to both society and the individuals involved.

Terminology

Many different terms are commonly used to describe vehicle collisions. The World Health Organization use the term *road traffic injury*, while the U.S. Census Bureau uses the term *motor vehicle accidents (MVA)* and Transport Canada uses the term "motor vehicle traffic collision". Other terms that are commonly used include *auto accident*, *car accident*, *car crash*, *car smash*, *car wreck*, *motor vehicle collision (MVC)*, *personal injury collision (PIC)*, *road accident*, *road traffic accident (RTA)*, *road traffic collision (RTC)*, *road traffic incident (RTI)*, *road traffic accident* and later *road traffic collision*, as well as more unofficial terms including *smash-up* and *fender bender*.

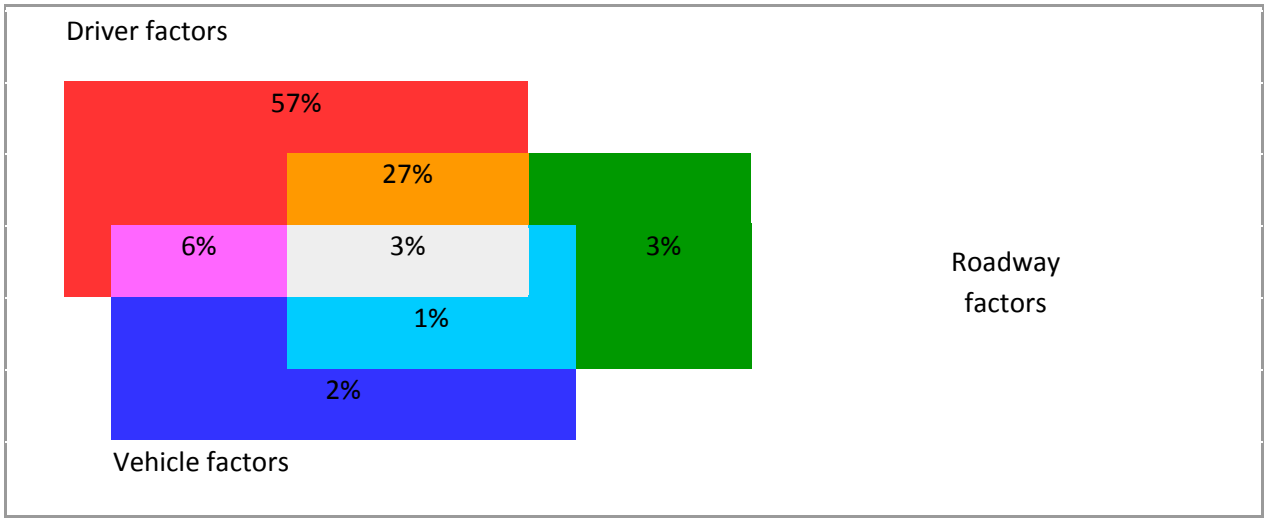
Some organizations have begun to avoid the term "accident". Although auto collisions are rare in terms of the number of vehicles on the road and the distance they travel, addressing the contributing factors can reduce their likelihood. For example, proper signage can decrease driver error and thereby reduce crash frequency by a third or more. That is why these organizations prefer the term "collision" rather than "accident".

However, treating collisions as anything other than "accidents" has been criticized for holding back safety improvements, because a culture of blame may discourage the involved parties from fully disclosing the facts, and thus frustrate attempts to address the real root causes.

Classification

Motor vehicle collisions can be classified by mechanism. Common mechanisms include head-on collisions, run-off-road collisions, rear-end collisions, side collision, and rollovers.

Causes



Breakdown of British and American crash causes

A 1985 study by K. Rumar, using British and American crash reports as data, found that 57% of crashes were due solely to driver factors, 27% to combined roadway and driver factors, 6% to combined vehicle and driver factors, 3% solely to roadway factors, 3% to combined roadway, driver, and vehicle factors, 2% solely to vehicle factors and 1% to combined roadway and vehicle factors.

Human factors

Human factors in vehicle collisions include all factors related to drivers and other road users that may contribute to a collision. Examples include driver behavior, visual and auditory acuity, decision-making ability, and reaction speed.

A 1985 report based on British and American crash data found driver error, intoxication and other human factors contribute wholly or partly to about 93% of crashes.

An RAC survey found most British drivers think they're better drivers than non-British drivers. Nearly all drivers who'd been in a crash did not believe themselves to be at fault. One survey of drivers reported that they thought the key elements of good driving were:

- controlling a car including a good awareness of the car's size and capabilities
- reading and reacting to road conditions, weather, road signs and the environment
- alertness, reading and anticipating the behaviour of other drivers.

Although proficiency in these skills is taught and tested as part of the driving exam, a 'good' driver can still be at a high risk of crashing because:

...the feeling of being confident in more and more challenging situations is experienced as evidence of driving ability, and that 'proven' ability reinforces the feelings of confidence. Confidence feeds itself and grows unchecked until something happens – a near-miss or an accident.

An AXA survey concluded Irish drivers are very safety-conscious relative to other European drivers. However, this does not translate to significantly lower crash rates in Ireland.

Accompanying changes to road designs have been wide-scale adoptions of rules of the road alongside law enforcement policies that included drink-driving laws, setting of speed limits, and speed enforcement systems such as speed cameras. Some countries' driving tests have been expanded to test a new driver's behavior during emergencies, and their hazard perception.

There are demographic differences in crash rates. For example, although young people tend to have good reaction times, disproportionately more young male drivers feature in accidents, with researchers observing that many exhibit behaviors and attitudes to risk that can place them in more hazardous situations than other road users. This is reflected by actuaries when they set insurance rates for different age groups, partly based on their age, sex, and choice of vehicle. Older drivers with slower reactions might be expected to be involved in more accidents, but this has not been the case as they tend to drive less and, apparently, more cautiously. Attempts to

impose traffic policies can be complicated by local circumstances and driver behaviour. In 1969 Leeming warned that there is a balance to be struck when "improving" the safety of a road:

Many places that look dangerous have few or no accidents. Conversely, a location that does not look dangerous may have a high crash frequency. This is, in part, because if drivers perceive a location as hazardous, they take more care. Accidents may be more likely to happen when hazardous road or traffic conditions are not obvious at a glance, or where the conditions are too complicated for the limited human machine to perceive and react in the time and distance available. (This fact can be used to improve safety, by putting up signs in accident-prone locations, like ones stated above.)

This phenomena has been observed in risk compensation research, where the predicted reductions in accident rates have not occurred after legislative or technical changes. One study observed that the introduction of improved brakes resulted in more aggressive driving, and another argued that compulsory seat belt laws have not been accompanied by a clearly attributed fall in overall fatalities.

In the 1990s Hans Monderman's studies of driver behavior led him to the realization that signs and regulations had an adverse effect on a driver's ability to interact safely with other road users. Monderman developed shared space principles, rooted in the principles of the woonerven of the 1970s. He found that the removal of highway clutter, while allowing drivers and other road users to mingle with equal priority, could help drivers recognize environmental clues. They relied on their cognitive skills alone, reducing traffic speeds radically and resulting in lower levels of road casualties and lower levels of congestion.

Motor vehicle speed

The U.S. Department of Transportation's *Federal Highway Administration* review research on traffic speed in 1998. The summary states:

- That the evidence shows that the risk of having a crash is increased both for vehicles traveling slower than the average speed, and for those traveling above the average speed.
- That the risk of being injured increases exponentially with speeds much faster than the median speed.
- That the severity of a crash depends on the vehicle speed change at impact.
- That there is limited evidence that suggests that lower speed limits result in lower speeds on a system wide basis.
- That most crashes related to speed involve speed too fast for the conditions.
- That more research is needed to determine the effectiveness of traffic calming.

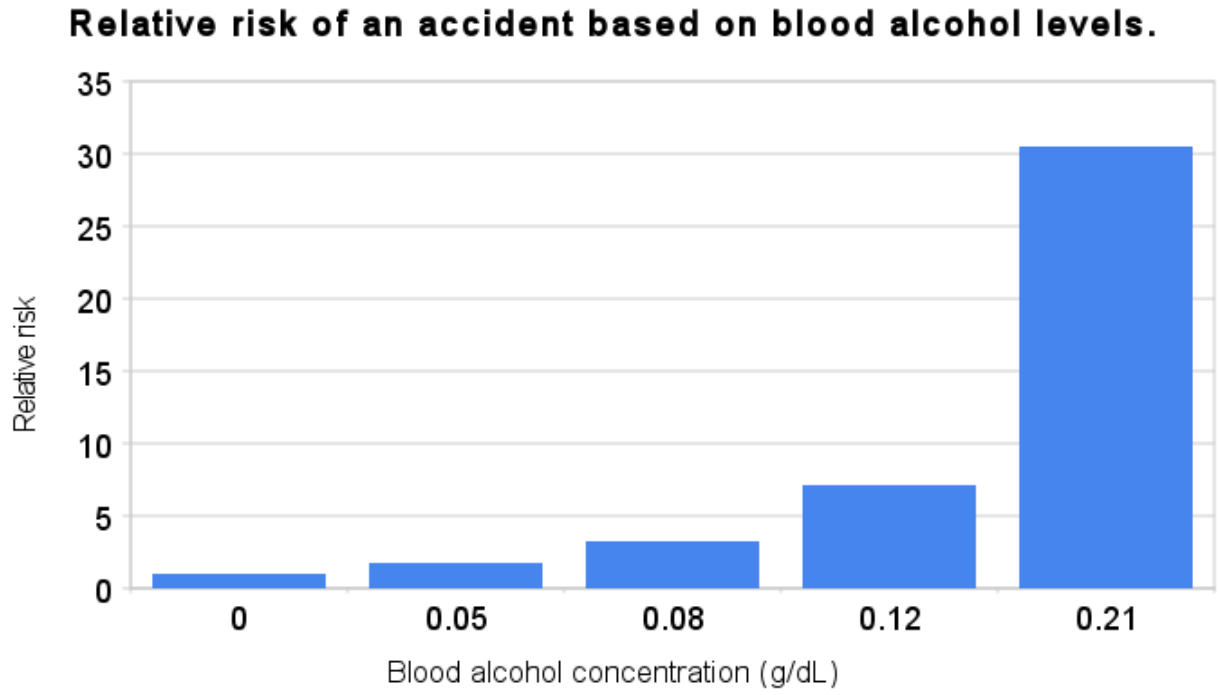
The *Road and Traffic Authority* (RTA) of the Australian state of New South Wales (NSW) asserts speeding (travelling too fast for the prevailing conditions or above the posted speed limit) is a factor in about 40 percent of road deaths. The RTA also say speeding increases the risk of a crash and its severity. On another webpage, the RTA qualify their claims by referring to one specific piece of research from 1997, and stating "research has shown that the risk of a crash causing death or injury increases rapidly, even with small increases above an appropriately set speed limit."

The contributory factor report in the official British road casualty statistics show for 2006, that "exceeding speed limit" was a contributory factor in 5% of all casualty crashes (14% of all fatal crashes), and that "travelling too fast for conditions" was a contributory factor in 11% of all casualty crashes (18% of all fatal crashes).

Driver impairment

Driver impairment describes factors that prevent the driver from driving at their normal level of skill. Common impairments include:

Alcohol



Relative risk of an accident based on blood alcohol levels

In Canada 33.8% of motor vehicle deaths were associated with alcohol use

Physical impairment

Poor eyesight and/or physical impairment, with many jurisdictions setting simple sight tests and/or requiring appropriate vehicle modifications before being allowed to drive;

Old age

Old age, with some jurisdictions requiring driver retesting for reaction speed and eyesight after a certain age;

Sleep deprivation

Fatigue;

Drug use

Including some prescription drugs, over the counter drugs (notably antihistamines, opioids and muscarinic antagonists), and illegal drugs.

Distraction

Research suggests that the driver's attention is affected by distracting sounds such as conversations and operating a mobile phone while driving. Many jurisdictions now restrict or outlaw the use of some types of phone within the car. Recent research conducted by British scientists suggests that music can also have an effect; classical music is considered to be calming, yet too much could relax the driver to a condition of distraction. On the other hand, hard rock may encourage the driver to step on the acceleration pedal, thus creating a potentially dangerous situation on the road.

Combinations of factors

Several conditions can work together to create a much worse situation, for example:

- Combining low doses of alcohol and cannabis has a more severe effect on driving performance than either cannabis or alcohol in isolation, or
- Taking recommended doses of several drugs together, which individually do not cause impairment, may combine to bring on drowsiness or other impairment. This could be more pronounced in an elderly person whose renal function is less efficient than a younger person's.

Thus there are situations when a person may be impaired, but still legally allowed to drive, and becomes a potential hazard to themselves and other road users. Pedestrians or cyclists are affected in the same way and can similarly jeopardize themselves or others when on the road.

Road design

A potential long fall stopped by an early guardrail, ca. 1920. Guardrails, median barriers, or other physical objects can help reduce the consequences of an accident or minimize damage.

A 1985 US study showed that about 34% of serious crashes had contributing factors related to the roadway or its environment. Most of these crashes also involved a human factor. The road or environmental factor was either noted as making a significant contribution to the circumstances of the crash, or did not allow room to recover. In these circumstances it is frequently the driver who is blamed rather than the road; those reporting the accident have a tendency to overlook the human factors involved, such as the subtleties of design and maintenance that a driver could fail to observe or inadequately compensate for.

Research has shown that careful design and maintenance, with well-designed intersections, road surfaces, visibility and traffic control devices, can result in significant improvements in accident rates. Individual roads also have widely differing performance in the event of an impact. In Europe there are now EuroRAP tests that indicate how "self-explaining" and forgiving a particular road and its roadside would be in the event of a major incident.

In the UK, research has shown that investment in a safe road infrastructure programme could yield a ⅓ reduction in road deaths saving as much as £6billion per year. A consortium of 13 major road safety stakeholders have formed the Campaign for Safe Road Design, which is calling on the UK Government to make safe road design a national transport priority.

Vehicle design and maintenance

A Chevrolet Malibu involved in a rollover crash

Seatbelts

Research has shown that, across all collision types, it is less likely that seat belts were worn in collisions involving death or serious injury, rather than light injury; wearing a seat belt reduces the risk of death by about two thirds. Seat belt use is controversial, with notable critics such as Professor John Adams suggesting that their use may lead to a net increase in road casualties due to a phenomenon known as risk compensation.

Maintenance

A well-designed and well-maintained vehicle, with good brakes, tires and well-adjusted suspension will be more controllable in an emergency and thus be better equipped to avoid collisions. Some mandatory vehicle inspection schemes include tests for some aspects of roadworthiness, such as the UK's MOT test or German TÜV conformance inspection.

The design of vehicles has also evolved to improve protection after collision, both for vehicle occupants and for those outside of the vehicle. Much of this work was led by automotive

industry competition and technological innovation, leading to measures such as Saab's safety cage and reinforced roof pillars of 1946, Ford´s 1956 *Lifeguard* safety package, and Saab and Volvo's introduction of standard fit seatbelts in 1959. Other initiatives were accelerated as a reaction to consumer pressure, after publications such as Ralph Nader's 1965 book *Unsafe at Any Speed* accused motor manufacturers of indifference towards safety.

In the early 1970s British Leyland started an intensive programme of vehicle safety research, producing a number of prototype experimental safety vehicles demonstrating various innovations for occupant and pedestrian protection such as: air bags, anti-lock brakes, impact-absorbing side-panels, front and rear head restraints, run-flat tyres, smooth and deformable front-ends, impact-absorbing bumpers, and retractable headlamps. Design has also been influenced by government legislation, such as the Euro NCAP impact test.

Common features designed to improve safety include: thicker pillars, safety glass, interiors with no sharp edges, stronger bodies, other active or passive safety features, and smooth exteriors to reduce the consequences of an impact with pedestrians.

The UK Department for Transport publish road casualty statistics for each type of collision and vehicle through its Road Casualties Great Britain report. These statistics show a ten to one ratio of in-vehicle fatalities between types of car. In most cars, occupants have a 2–8% chance of death in a two-car collision.

Center of gravity

Some crash types tend to have more serious consequences, Rollovers have become more common in recent years, perhaps due to increased popularity of taller SUVs, people carriers, and minivans, which have a higher center of gravity than standard passenger cars. Rollovers can be fatal, especially if the occupants are ejected because they were not wearing seat belts (83% of ejections during rollovers were fatal when the driver did not wear a seat belt, compared to 25% when they did). After a new design of Mercedes Benz notoriously failed a 'moose test' (sudden swerving to avoid an obstacle), some manufacturers enhance suspension using stability control linked to an anti-lock braking system to reduce the likelihood of rollover. After retrofitting these systems to its models in 1999–2000, Mercedes saw its models involved in fewer crashes

Now about 40% of new US vehicles, mainly the SUVs, vans and pickup trucks that are more susceptible to rollover, are being produced with a lower center of gravity and enhanced suspension with stability control linked to its anti-lock braking system to reduce the risk of rollover and meet US federal requirements that mandate anti-rollover technology by September 2011.

Motorcycles

Motorcyclists have little protection other than their clothing; this difference is reflected in the casualty statistics, where they are more than twice as likely to suffer severely after a collision. In 2005 there were 198,735 road crashes with 271,017 reported casualties on roads in Great Britain. This included 3,201 deaths (1.1%) and 28,954 serious injuries (10.7%) overall. Of these

casualties 178,302 (66%) were car users and 24,824 (9%) were motorcyclists, of whom 569 were killed (2.3%) and 5,939 seriously injured (24%).

Prevention

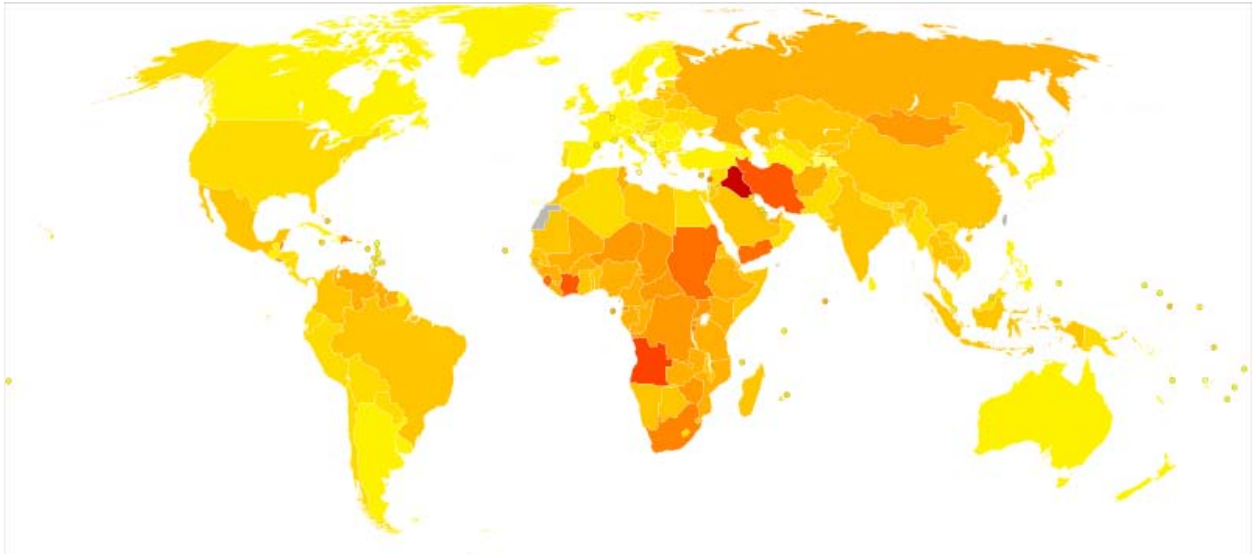
A large body of knowledge has been amassed on how to prevent car crashes, and reduce the severity of those that do occur.

United Nations response

Owing to the global and massive scale of the issue, with predictions that by 2020 road traffic deaths and injuries will exceed HIV/AIDS as a burden of death and disability, the United Nations and its subsidiary bodies have passed resolutions and held conferences on the issue. The first United Nations General Assembly resolution and debate was in 2003 The World Day of Remembrance for Road Traffic Victims was declared in 2005. In 2009 the first high level ministerial conference on road safety was held in Moscow.

The World Health Organization, a specialized agency of the United Nations Organization, in its Global Status Report on Road Safety 2009, states that over 90% of the world's fatalities on the roads occur in low-income and middle-income countries, which have only 48% of the world's registered vehicles, and predicts that road traffic injuries will rise to become the fifth leading cause of death by 2030

Epidemiology



Deaths for road traffic accidents per 100,000 inhabitants in 2004

no data

< 5

5-12.5

12.5-20

20-27.5

27.5-35

35-42.5

42.5-50

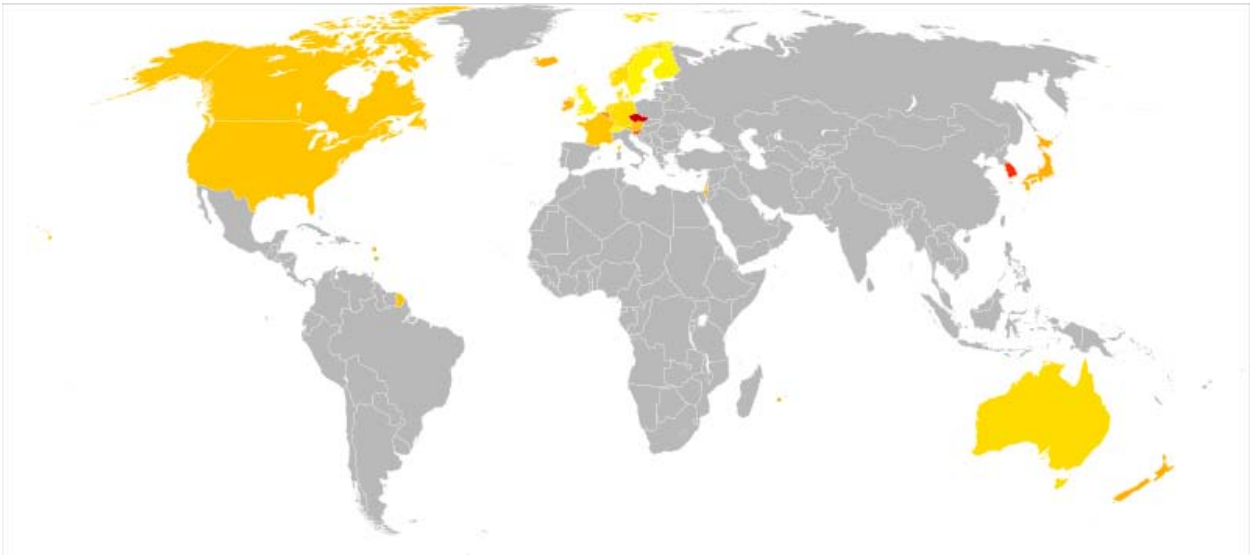
50-57.5

57.5-65

65-72.5

72.5-80

> 80



Road fatalities per vehicle-km (fatalities per 1 billion km)

no data

< 5.0

5.0-6.5

6.5-8.0

8.0-9.5

9.5-11.0

11.0-12.5

12.5-14.0

14.0-15.5

15.5-17.0

17.0-18.5

18.5-20.0

> 20.0

Worldwide it was estimated in 2004 that 1.2 million people were killed (2.2% of all deaths) and 50 million more were injured in motor vehicle collisions. India recorded 105,000 traffic deaths in a year, followed by China with over 96,000 deaths. This makes motor vehicle collisions the leading cause of injury death among children worldwide 10 – 19 years old (260,000 children die a year, 10 million are injured) and the sixth leading preventable cause of death in the United States (45,800 people died and 2.4 million were injured in 2005). In Canada they are the cause of 48% of severe injuries.

Crash rates

The safety performance of roadways are almost always reported as rates. That is, some measure of harm (deaths, injuries, or number of crashes) divided by some measure of exposure to the risk of this harm. Rates are used so the safety performance of different locations can be compared, and to prioritize safety improvements.

Common rates related to road traffic fatalities include the number of deaths per capita, per registered vehicle, per licensed driver, or per vehicle mile or kilometer traveled. Simple counts are almost never used. The annual count of fatalities is a rate, namely, the number of fatalities per year.

There is no one rate that is superior to others in any general sense. The rate to be selected depends on the question being asked – and often also on what data are available. What is important is to specify exactly what rate is measured and how it relates to the problem being addressed. Some agencies concentrate on crashes per total vehicle distance traveled. Others combine rates. The U. S. state of Iowa, for example, selects high accident locations based on a combination of crashes per million miles traveled, crashes per mile per year, and value loss (crash severity).

Fatality

The definition of a road-traffic fatality varies from country to country. In the United States, the definition used in the Fatality Analysis Reporting System (FARS) run by the NHTSA is a person who dies within 30 days of a crash on a US public road involving a vehicle with an engine, the death being the result of the crash. In the U.S., therefore, if a driver has a non-fatal heart attack that leads to a road-traffic crash that causes death, that is a road-traffic fatality. However, if the heart attack causes death prior to the crash, then that is not a road-traffic fatality.

The definition of a road accident fatality can change with time in the same country. For example, fatality is defined in France as a person who dies in the 6 days (pre 2005) after the accident and was subsequently changed to the 30 days (post 2005) after the accident.

Statistics in the European Union

Country	Surface (thousands of km^2)	Population (millions)	Density (inhabitants/km^2)	Vehicles in circulation (thousands)	Length of the road network (kilometers)	Circulation (millions of vehicles x km)	Nb of the vehic. for 100 inhabitants	Killed for million of inhabitants	Killed for billion of km travelled
Germany	357	82.5	231.1	54,520	626,981	684,283	66.1	64.8	7.8
Austria	84	8.2	97.7	5,279	107,143	82,221	64.5	93.8	9.3
Belgium	33	10.4	320.3	6,159	151,372	94,677	59.1	104.5	11.5
Denmark	43	5.4	126	2,570	72,074	47,940	47.3	61	6.9
Spain	505	43.4	86	27,657	666,204	ND	63.7	103.1	ND
Finland	338	5.2	15.5	2,871	79,150	51,675	54.7	72.2	7.3
France	551	60.5	109.7	37,168	1,002 486	552,800	61.4	87.9	9.6
Greece	132	11.1	84	6,641	40,164	81,635	59.9	149.1	20.3
Hungary	93	10.1	108.5	3,370	180,994	ND	33.4	126.6	ND
Republic of Ireland	71	4.1	58.6	1,937	95,752	37,840	46.7	96.2	10.5

Italy	301	58.1	192.8	43,141	305,388	654,197	74.3	94	8.3
Luxembourg	3	0.5	179.8	358	2,876	2,875	77	98.9	16.0
Netherlands	42	16.3	392.5	8,627	117,430	133,800	52.9	46	5.6
Poland	323	38.5	119.4	16,815	381,462	377,289	43.6	141.3	14.4
Portugal	93	10.5	113.3	5,481	81,739	ND	52.2	118.8	ND
United Kingdom	244	60.2	246.7	33,717	413,120	499,396	56	55.9	6.7
Slovakia	49	5.4	110.1	1,834	17,755	13,402	34	112.6	45.4
Slovenia	20	2	97	1,150	20,196	15,519	58.5	69*	16.6
Sweden	450	9	20.1	5,131	214,000	75,196	56.8	48.7	5.9
Czech Republic	79	10.2	129.6	4,732	55,495	50,262	46.3	125.8	27.2
Partial Total Eu (20 countries)	**3809**	**451.1**	**118.4**	**269,158**	**4,631,781**	**3,451,938**	**59.7**	**88.5**	**11.6**
Iceland	103	0.3	2.9	236	91,916	2,006	80.3	64.6	9.5
Norway	324	4.6	14.3	2,938	92,511	36,550	63.6	48.5	6.1
Switzerland	41	7.4	179.6	5,043	71,027	62,685	68	55.2	6.5

- 2010

History

The world's first road traffic death involving a motor vehicle is alleged to have occurred on 31 August 1869. An Irish scientist Mary Ward died when she fell out of her cousins' steam car and was run over by it.

German-English composer George Frideric Handel was seriously injured in a carriage crash in 1752.

The British road engineer J. J. Leeming, compared the statistics for fatality rates in Great Britain, for transport-related incidents both before and after the introduction of the motor vehicle, for journeys, including those once by water that now are undertaken by motor vehicle: For the period 1863–1870 there were: 470 fatalities per million of population (76 on railways, 143 on roads, 251 on water); for the period 1891–1900 the corresponding figures were: 348 (63, 107, 178); for the period 1931–1938: 403 (22, 311, 70) and for the year 1963: 325 (10, 278, 37). Leeming concluded that the data showed that "*travel accidents may even have been more frequent a century ago than they are now, at least for men*".

In 1969 a British road engineer compared the circumstances around road deaths as reported in various American states before the widespread introduction of 55 mph (89 km/h) speed limits and drunk-driving laws.

'They took into account thirty factors which it was thought might affect the death rate. Among these were included the annual consumption of wine, of spirits and of malt beverages — taken individually — the amount spent on road maintenance, the minimum temperature, certain of the legal measures such as the amount spent on police, the number of police per 100,000 inhabitants, the follow-up programme on dangerous drivers, the quality of driver testing, and so on. The thirty factors were finally reduced to six on elimination of those which were found to have small or negligible effect. The final six were:

- (a) The percentage of the total state highway mileage that is rural.
- (b) The percent increase in motor vehicle registration.
- (c) The extent of motor vehicle inspection.
- (d) The percentage of state-administered highway that is surfaced.
- (e) The average yearly minimum temperature.
- (f) The income per capita.

'These are placed in descending order of importance. These six accounted for 70% of the variations in the rate.'

Society and culture

Economic costs

The global economic cost of MVCs was estimated at $518 billion per year in 2003 with $100 billion of that occurring in developing countries. The Center for Disease Control and Prevention estimated the U.S. cost in 2000 at $230 billion.

Legal consequences

In the United States, individuals involved in motor vehicle accidents can be held financially liable for the consequences of an accident, including property damage, injuries to passengers and drivers, and fatalities. Because these costs can easily exceed the annual income of the average driver, most US states require drivers to carry liability insurance to cover these potential costs. However, in the event of severe injuries or fatalities, victims may seek damages in civil court, often for well in excess of the value of insurance.

Additionally, drivers who are involved in a collision frequently receive one or more traffic citations, usually directly addressing any material violations such as speeding, failure to obey a traffic control device, or driving under the influence of drugs or alcohol. In the event of a fatality, a charge of vehicular homicide is occasionally prosecuted, especially in cases involving alcohol.

Convictions for traffic violations are usually penalized with fines, and for more severe offenses, the suspension or revocation of driving privileges. Convictions for alcohol offenses generally result in the revocation or long term suspension of the driver's license, and sometimes jail time and/or mandatory alcohol rehabilitation.

Due to increase in availability of cable news and Internet news, exposure to such legal actions has increased in recent years, specifically with coverage of cases and class action suits concerning SUV rollovers and recent incidents of sudden acceleration crashes highlighted by the 2010 Toyota Recall. Increased exposure has led to larger class action suits, and automobile owners' ability to link their collision causes and issues to ones in other regions has spread knowledge of external causes.

Additional images

Emergency responders at an accident in Colorado Springs, Colorado

Police and rescue services at a traffic collision in Boston

A Honda Accord after colliding with a building

Toyota Yaris in collision with a tree in Uetersen, Germany

A Honda Fit and Toyota Echo (Platz) side collision in Tokyo

An overturned cement mixer

A collision involving two cars and a bus at an intersection in San Francisco

A traffic accident along the Kansas Turnpike in Butler County, Kansas, which was initiated by power lines being blown across the Turnpike due to severe winds.

Chapter- 2

Road Traffic Safety

Sidewalks, curbs and traffic signals in Maryland, United States

Speed limits in different areas, unusually with only a "recommended" limit (130km) for the Autobahn

The term **road traffic safety** is an indication of how safe individual users are on some particular road, or on the roads belonging to some region. The main danger to road users is the likelihood of a traffic collision. Such dangers can be reduced by individual road users operating cautiously and defensively, by building roads in alignment with competent traffic engineering practices, by the application of rational traffic control methods, and by designing road vehicles so they are more able to avoid and survive collisions.

Background

Guardrails save a vehicle from a long fall c. 1920

Road traffic crashes are one of the world's largest public health and injury prevention problems. The problem is all the more acute because the victims are overwhelmingly healthy prior to their crashes. According to the World Health Organization (WHO), more than a million people are killed on the world's roads each year. A report published by the WHO in 2004 estimated that some 1.2m people were killed and 50m injured in traffic collisions on the roads around the world each year and was the leading cause of death among children 10 – 19 years of age. The report also noted that the problem was most severe in developing countries and that simple prevention measures could halve the number of deaths.

The standard measures used in assessing road safety interventions are fatalities and Killed or Seriously Injured (KSI) rates, usually per billion (10^9) passenger kilometres. In the United States, crashes per million vehicle miles is typically used for road safety.

Speed is a key goal of modern road design, but impact speed affects the severity of injury to both occupants and pedestrians. For occupants, Joksch (1993) found the probability of death for drivers in multi-vehicle accidents increased as the fourth power of impact speed (often referred to by the mathematical term δv ("delta V"), meaning change in velocity). Injuries are caused by sudden, severe acceleration (or deceleration), this is difficult to measure. However, crash reconstruction techniques can be used to estimate vehicle speeds before a crash. Therefore, the change in speed is used as a surrogate for acceleration.

Interventions take many forms. Contributing factors to highway crashes may be related to the driver (such as driver error, illness or fatigue), the vehicle (brake, steering, or throttle failures) or

the road itself (lack of sight distance, poor roadside clear zones, etc.). Interventions may seek to reduce or compensate for these factors, or reduce the severity of crashes that do occur. A comprehensive outline of interventions areas can be seen in Management systems for road safety.

Infrastructure design

For road traffic safety purposes it can be helpful to classify roads into ones in built-up area, non built-up areas and then major highways (Motorways/Freeways etc.)

Most casualties generally occur in on roads in built-up areas and major highways are the safest. Reported Road Casualties Great Britain for 2008 show that most fatalities occur on non built-up roads but that the vast majority of serious injuries and injuries occur in built-up areas:

Road Type	Killed	Serious injury	Slight injury	total injury	Note
Non Built-up (excludes motorways)	1,323	8,342	48,810	58,475	52% of the total killed, 32% of total seriously injured, 25% of total with slight injuries
Built-up	1,057	16,823	143,079	160,959	42% of the total killed, 65% of total seriously injured, 70% of total with slight injuries
Motorway	158	869	10,444	11,471	6% of the total killed, 3% of total seriously injured, 5% of total with slight injuries. Fatalities on motorways have decreased by 9 per cent since 1994-98 in a period with traffic levels increased by 28%"
All casualties	**2,538**	**26,034**	**202,333**	**230,905**	

Built-up areas

Pedestrian crossing, line markings and street furniture

A curb extension at a mid-block crosswalk

Utrecht has specially-painted bicycle-only lanes

On neighborhood roads where many vulnerable road users, such as pedestrians and bicyclists can be found, traffic calming can be a tool for road safety. Shared space schemes, which rely on human instincts and interactions, such as eye contact, for their effectiveness, and are characterised by the removal of traditional traffic signals and signs, and even by the removal of the distinction between carriageway (roadway) and footway (sidewalk), are also becoming increasingly popular. Both approaches can be shown to be effective.

Modern safety barriers are designed to absorb impact energy and minimize the risk to the occupants of cars, and bystanders. For example, most side rails are now anchored to the ground, so that they cannot skewer a passenger compartment, and most light poles are designed to break at the base rather than violently stop a car that hits them. Some road fixtures such as road signs and fire hydrants are designed to collapse on impact. Highway authorities have also removed trees in the vicinity of roads; while the idea of "dangerous trees" has attracted a certain amount of skepticism, unforgiving objects such as trees can cause severe damage and injury to any errant road users.

Most roads are cambered (crowned), that is, made so that they have rounded surfaces, to reduce standing water and ice, primarily to prevent frost damage but also increasing traction in poor

weather. Some sections of road are now surfaced with porous bitumen to enhance drainage; this is particularly done on bends. These are just a few elements of highway engineering. As well as that, there are often grooves cut into the surface of cement highways to channel water away, and rumble strips at the edges of highways to rouse inattentive drivers with the loud noise they make when driven over. In some cases, there are raised markers between lanes to reinforce the lane boundaries; these are often reflective. In pedestrian areas, speed bumps are often placed to slow cars, preventing them from going too fast near pedestrians.

Poor road surfaces can lead to safety problems. If too much asphalt or bitumenous binder is used in asphalt concrete, the binder can 'bleed' or flush' to the surface, leaving a very smooth surface that provides little traction when wet. Certain kinds of stone aggregate become very smooth or polished under the constant wearing action of vehicle tyres, again leading to poor wet-weather traction. Either of these problems can increase wet-weather crashes by increasing braking distances or contributing to loss of control. If the pavement is insufficiently sloped or poorly drained, standing water on the surface can also lead to wet-weather crashes due to hydroplaning.

Lane markers in some countries and states are marked with Cat's eyes or Botts dots, bright reflectors that do not fade like paint. Botts dots are not used where it is icy in the winter, because frost and snowplows can break the glue that holds them to the road, although they can be embedded in short, shallow trenches carved in the roadway, as is done in the mountainous regions of California.

Road hazards and intersections in some areas are now usually marked several times, roughly five, twenty and sixty seconds in advance so that drivers are less likely to attempt violent manoeuvres.

Most road signs and pavement marking materials are retro-reflective, incorporating small glass spheres or prisms to more efficiently reflect light from vehicle headlights back to the driver's eyes.

Designing for pedestrians and cyclists

Pedestrians and Cyclists are among the most vulnerable road users, and in some countries constitute over half of all road deaths. Interventions aimed at improving safety of non-motorised users:

- Sidewalks of suitable width for the expected pedestrian traffic
- pedestrian crossings close to the desire line which allow pedestrians to cross roads safely
- segregated pedestrian routes and cycle lanes away from the main highway
- Overbridges (tend to be unpopular with pedestrians and cyclists due to additional distance and effort)
- Underpasses (these can pose heightened risk from crime is not designed well, can work for cyclists in some cases)
- traffic calming and speed humps
- low speed limits that are rigorous enforced, possibly by speed cameras
- shared space schemes giving ownership of the road space and equal priority to all road users, regardless of mode of use

- pedestrian barriers to prevent pedestrians crossing dangerous locations

Pedestrians' advocates question the equitability of schemes if they impose extra time and effort on the pedestrian to remain safe from vehicles, for example overbridges with long slopes or steps up and down, underpasses with steps and addition possible risk of crime and at-grade crossings off the desire line. The Make Roads Safe was criticised in 2007 for proposing such features. Successful pedestrian schemes tend to avoid over-bridges and underpasses and instead use at-grade crossings (such as pedestrian crossings) close the intended route. Successful cycling scheme by contrast avoid frequent stops even if some additional distance is involved given that the main effort required for cyclists is starting off.

In Costa Rica 57% of road deaths are pedestrians, however a partnership between AACR, Cosevi, MOPT and iRAP has proposed the construction of 190 km of pedestrian footpaths and 170 pedestrian crossings which could save over 9000 fatal or serious injuries over 20 years.

Shared space

A shared space in Brighton (UK)

By 1947 the Pedestrians' Association was suggesting that many of the safety features being introduced (speed limits, traffic calming, road signs and road markings, traffic lights, Belisha

beacons, pedestrian crossings, cycle lanes etc.) were potentially self defeating because "every nonrestrictive safety measure, however admirable in itself, is treated by the drivers as an opportunity for more speeding, so that the net amount of danger is increased and the latter state is worse than the first."

During the 1990s a new approach, known as 'shared space' was developed which removed many of these features in some places has attracted the attention of authorities around the world. The approach was developed by Hans Monderman who believed that "if you treat drivers like idiots, they act as idiots" and proposed that trusting drivers to behave was more successful than forcing them to behave. Professor John Adams, an expert on risk compensation suggested that traditional traffic engineering measures assumed that motorists were "selfish, stupid, obedient automatons who had to be protected from their own stupidity" and non-motorists were treated as "vulnerable, stupid, obedient automatons who had to be protected from cars – and their own stupidity".

Reported results indicate that the *shared space* approach leads to significantly reduced traffic speeds, the virtual elimination of road casualties, and a reduction in congestion. Living Streets share some similarities with Shared Spaces. The woonerven also sought to reduce traffic speeds in community and housing zones by the use of lower speed limits enforced by the use of special signage and road markings, the introduction of traffic calming measures, and by giving pedestrians priority over motorists.

Non built-up areas

Major highways

Guard rail on road in Kaluga Oblast (Russia)

The Pan-American Highway with central median and no freestanding obstructions

Major highways including motorways, freeways, Autobahnen and Interstates are designed for safer high-speed operation and generally have lower levels of injury per vehicle km than other roads.

Safety features include:

- limited access from properties and local roads.
- Grade separated junctions
- Median dividers between opposite-direction traffic to reduce likelihood of head-on collisions
- Removing roadside obstacles.
- Prohibition of more vulnerable road users and slower vehicles.
- Placements of energy attenuation devices (e.g. guard rails, wide grassy areas, sand barrels).
- Eliminating road toll booths

The ends of some guard rails on high-speed highways in the United States are protected with impact attenuators, designed to gradually absorb the kinetic energy of a vehicle and slow it more gently before it can strike the end of the guard rail head on, which would be devastating at high speed. Several mechanisms are used to dissipate the kinetic energy. Fitch Barriers, a system of

sand-filled barrels, uses momentum transfer from the vehicle to the sand. Many other systems tear or deform steel members to absorb energy and gradually stop the vehicle.

In some countries major roads have "tone bands" impressed or cut into the edges of the legal roadway, so that drowsing drivers are awakened by a loud hum as they release the steering and drift off the edge of the road. Tone bands are also referred to as "rumble strips," owing to the sound they create. An alternative method is the use of "Raised Rib" markings, which consists of a continuous line marking with ribs across the line at regular intervals. They were first specially authorised for use on motorways as an edge line marking to separate the edge of the hard shoulder from the main carriageway. The objective of the marking is to achieve improved visual delineation of the carriageway edge in wet conditions at night. It also provides an audible/vibratory warning to vehicle drivers, should they stray from the carriageway, and run onto the marking.

Better motorways are banked on curves in order to reduce the need for tire-traction and increase stability for vehicles with high centers of gravity.

An example of the importance of roadside clear zones can be found on the Isle of Man TT motorcycle race course. It is much more dangerous than Silverstone because of the lack of runoff. When a rider falls off at Silverstone he slides along slowly losing energy, so minimal injuries. When he falls of in the Manx he impacts with trees and walls. Similarly, a clear zone alongside a freeway or other high speed road can prevent off-road excursions from becoming fixed-object crashes.

The U.S. has developed a prototype automated roadway, to reduce driver fatigue and increase the carrying capacity of the roadway. Roadside units participating in future Wireless vehicle safety communications networks have been studied.

Motorways are far more expensive and space-consumptive to build than ordinary roads, so are only used as principal arterial routes. In developed nations, motorways bear a significant portion of motorized travel; for example, the United Kingdom's 3533 km of motorways represented less than 1.5% of the United Kingdom's roadways in 2003, but carry 23% of road traffic.

The proportion of traffic borne by motorways is a significant safety factor. For example, even though the United Kingdom had a higher fatality rates on both motorways and non-motorways than Finland, both nations shared the same overall fatality rate in 2003. This result was due to the United Kingdom's higher proportion of motorway travel.

Similarly, the reduction of conflicts with other vehicles on motorways results in smoother traffic flow, reduced collision rates, and reduced fuel consumption compared with stop-and-go traffic on other roadways.

The improved safety and fuel economy of motorways are common justifications for building more motorways. However, the planned capacity of motorways is often exceeded in a shorter timeframe than initially planned, due to the under estimation of the extent of the suppressed

demand for road travel. In developing nations, there is significant public debate on the desirability of continued investment in motorways.

Motorways around the world are subject to a broad range of speed limits. Recent experiments with variable speed limits based on automatic measurements of traffic density have delivered both improvements in traffic flow and reduced collision rates, based on principles of turbulent flow analysis.

With effect from January 2005 and based primarily on safety grounds, the UK's Highways Agency's policy is that all new motorway schemes are to use high containment concrete step barriers in the central reserve. All existing motorways will introduce concrete barriers into the central reserve as part of ongoing upgrades and through replacement as and when these systems have reached the end of their useful life. This change of policy applies only to barriers in the central reserve of high speed roads and not to verge side barriers. Other routes will continue to use steel barriers.

30% of highway crashes that occur in the vicinity of toll collection booths in the countries that have them, these can be eliminated by switching to a system of government taxation for road use

Vehicle safety

Cars

Simulated crashes using crash test dummies can help improve automobile design

Safety can be improved by reducing the chances of a driver making an error, or by designing vehicles to reduce the severity of crashes that do occur. Most industrialized countries have comprehensive requirements and specifications for safety-related vehicle devices, systems, design, and construction. These may include:

- Passenger restraints such as seat belts — often in conjunction with laws requiring their use — and airbags
- Crash avoidance equipment such as lights and reflectors
- Driver assistance systems such as Electronic Stability Control
- Crash survivability design including fire-retardant interior materials, standards for fuel system integrity, and the use of safety glass
- *Sobriety detectors*: These interlocks prevent the ignition key from working if the driver breathes into one and it detects significant quantities of alcohol. They have been used by some

commercial transport companies, or suggested for use with persistent drunk-driving offenders on a voluntary basis

Motorbikes

Trucks

According to the European Commission Transportation Department "it has been estimated that up to 25% of accidents involving trucks can be attributable to inadequate cargo securing". Improperly secured cargo can cause severe accidents and lead to loss of cargo, loss of lives, loss of vehicles and can be a hazard for the environment. One way to stabilize, secure and protect cargo during transportation on the road is by using Dunnage Bags which are placed in the void between the cargo and are designed to prevent the load from moving during transport.

Regulation of road users

Various types of road user regulations are in force or have been tried in most jurisdictions around the world, some these are discussed by road user type below.

Motor vehicle users

Dependent on jurisdiction, driver age, road type and vehicle type, motor vehicle drivers may be required to pass a driving test (public transport and goods vehicle drivers may need additional training and licensing), conform to restrictions on driving after consuming alcohol or various drugs, comply with restrictions on use of mobile phones, be covered by compulsory insurance, wear seat belts and comply with certain speed limits. Motorcycle riders may additionally be compelled to wear a motorcycle helmet. Drivers of certain vehicle types may be subject to maximum driving hour regulations.

Some jurisdictions such as Virginia, U.S. and in Maryland, U.S. are targeting specific regulations such as the prohibiting mobile phone use and limiting passenger numbers at young and inexperienced drivers. It has been noticed that more of these types of serious collision occur at night, when the car has multiple occupants and when seat belt use is less.

Insurance companies have proposed that the following restrictions should be imposed on new drivers: a "curfew" imposed on young drivers to prevent them driving at night, an experienced supervisor to chaperone the less experienced driver, forbidding the carrying of passengers, zero alcohol tolerance, raising the standards required for driving instructors and improving the driving test, vehicle restrictions (e.g. restricting access to 'high performance' vehicles), a sign placed on the back of the vehicle (an N- or P-Plate) to notify other drivers of a novice driver and encouraging good behaviour in the post-test period.

Some countries or states have already implemented some of these ideas. Pay-as-you-drive adjusts insurance costs according to when and where the person drives.

Pedal bicycle users

Dependent on jurisdiction, road type and age, pedal cyclists may be required conform to restrictions on driving after consuming alcohol or various drugs, comply with restrictions on use of mobile phones, be covered by compulsory insurance, wear a bicycle helmet and comply with certain speed limits.

Pedestrians

Dependent on jurisdiction, jaywalking may be prohibited.

Information campaigns

Information campaigns can be used to raise awareness of initiatives designed to reduce road casualty levels. Examples include:

- traffic awareness campaigns such as the "one false move" campaign documented by Hillman et al.
- *Speeding. No one thinks big of you.* (New South Wales, Australia, 2007)
- *Road Safety is no Accident World Health Organization*
- *Designated driver campaign, (U.S., 1970s-present)*
- *Click It or Ticket*, (U.S., 1993–present)
- *Clunk Click Every Trip* (UK 1971)
- *Green Cross Code* (UK 1970–present)

Statistics

Rating roads for safety

Since 1999 the EuroRAP initiative has been assessing major roads in Europe with a road protection score. This results in a star rating for roads based on how well its design would protect car occupants from being severely injured or killed if a head-on, run-off, or intersection accident occurs, with 4 stars representing a road with the best survivability features. The scheme states it has highlighted thousands of road sections across Europe where road-users are routinely maimed and killed for want of safety features, sometimes for little more than the cost of safety fencing or the paint required to improve road markings.

There are plans to extend the measurements to rate the probability of an accident for the road. These ratings are being used to inform planning and authorities' targets. For example, in Britain two-thirds of all road deaths in Britain happen on rural roads, which score badly when compared to the high quality motorway network; single carriageways claim 80% of rural deaths and serious injuries, while 40% of rural car occupant casualties are in cars that hit roadside objects, such as trees. Improvements in driver training and safety features for rural roads are hoped to reduce this statistic.

The number of designated traffic officers in the UK fell from 15–20% of Police force strength in 1966 to seven per cent of force strength in 1998, and between 1999 and 2004 by 21%. It is an item of debate whether the reduction in traffic accidents per 100 million miles driven over this time has been due to robotic enforcement.

KSI by country

Country	Killed per 1 Billion Veh·km (Motorways in 2003)	Killed per 1 Billion Veh·km (Non-Motorways in 2003)	Motorway AADT	Road Travel by Motorway	km/h (mph) Motorway 2003 Speed Limit
Austria	5.9	13.4	30,077	23%	130 (80)
Czech Republic	9.9	34.3	25,714	11%	130 (80)
Denmark	3.0	11.9	29,454	25%	110 (70)
Finland	1.4	8.3	22,780	10%	120 (75)
France	4.0	12.8	31,979	21%	130 (80)
Germany	3.8	12.4	48,710	31%	none (130 (80) advisory)
Ireland	7.4	11.0	26,730	4%	120 (75)
Italy	13.0	Unknown	Unknown	Unknown	130 (80)
Japan	4.0	11.9	26,152	9%	100 (60)
Netherlands	2.1	11.7	66,734	41%	120 (75)
Slovenia	8.1	18.7	15,643	19%	130 (80)
Spain	62.3	Unknown	Unknown	Unknown	130 (80)
Sweden	2.5	9.9	24,183	21%	110 (70)
Switzerland	2.8	11.8	43,641	33%	120 (75)

United Kingdom	2.0	9.3	85,536	23%	110 (70)
United States	5.2	10.7	39,634	24%	120 (75)

definition: AADT - average annual daily traffic. The bi-direction traffic count representing an average 24-hour day in a year. Sometimes called "traffic density" although it ignores or assumes a constant number of travel lanes.

Advocacy groups

The Automobile Association was established in 1905 in the United Kingdom to help motorists avoid police speed traps. They became involved in other safety issues and also erected thousands of roadside warning signs.

The Pedestrians Association in the United Kingdom was formed in 1929 to press for better road safety. Other groups have been active in other countries.

Motoring advocacy groups including the Association of British Drivers (UK), Speed cameras.org (UK), National Motorists Association (USA/Canada) argue that the strict enforcement of speed limits does not necessarily result in safer driving, and may even have negative effect on road safety in general. Safe Speed is a UK group set up specifically to campaign against the use of Speed cameras. The Association of British Drivers also argues that speed humps result in increased air pollution, increased noise pollution, and even unnecessary vehicle damage.

In 1965, Ralph Nader put pressure on car manufactures in his book Unsafe at Any Speed detailing resistance by car manufacturers to the introduction of safety features, like seat belts, and their general reluctance to spend money on improving safety. The GM President James Roche was later forced to appear before a United States Senate subcommittee, and to apologize to Nader for the company's campaign of harassment and intimidation. Nader later successfully sued GM for excessive invasion of privacy.

RoadPeace was formed in 1991 in the United Kingdom to advocate for better road safety and founded World Day of Remembrance for Road Traffic Victims in 1993 which received support from the United Nations General Assembly in 2005.

There is some controversy over the way that the motor advocacy groups has been seen to dominate the road safety agenda. Some road safety activists use the term "road safety" (in quotes) to describe measures such as removal of "dangerous" trees and forced segregation of the vulnerable to the advantage of motorized traffic. Orthodox "road safety" opinion fails to address what Adams describes as the top half of the risk thermostat, the perceptions and attitudes of the road user community.

Criticisms

Some road-safety groups argue that the problem of road safety is largely being stated in the wrong terms because most road safety measures are designed to increase the safety of drivers, but many road traffic casualties are *not* drivers (in the UK only 40% of casualties are drivers), and those measures which increase driver safety may, perversely, increase the risk to these others, through risk compensation.

The core elements of the thesis are:

- that vulnerable road users are marginalised by the "road safety" establishment
- that "road safety" interventions are often centred around reducing the severity of results from dangerous behaviours, rather than reducing the dangerous behaviours themselves
- that improved "road safety" has often been achieved by making the roads so hostile that those most likely to be injured cannot use them at all
- that the increasing "safety" of cars and roads is often counteracted wholly or in part by driver responses (risk compensation).

RoadPeace and other groups have been strongly critical of what they see as moves to solve the problem of danger posed to vulnerable road users by motor traffic through increasing restrictions on vulnerable road users, an approach which they believe both blames the victim and fails to address the problem at source. This is discussed in detail by Dr Robert Davis in the book *Death on the Streets: Cars and the mythology of road safety*, and the core problem is also addressed in books by Professor John Adams, Mayer Hillman and others.

For example; the UK publishes Road Casualties Great Britain each year detailing reported road fatalities and injuries and claims to have among the best pedestrian safety in Europe with falling injury rates, as measured in pedestrian KSI per head of population. A study published by the British Medical Journal in 2006 suggested that the reduction in injury levels was due to lower levels of reporting not reducing levels of injury as such. Considerable under-reporting was confirmed by a second report prepared for the UK Department for Transport. and the UK government now acknowledges the issue of under-reporting but is not convinced that the reductions in reported injury levels do not reflect an actual decline. Another independent report investigated if the roads were actually sufficiently dangerous as to deter pedestrians from using them at all.

Chapter- 3

Automobile Safety

Automobile safety is the study and practice of vehicle design, construction, and equipment to minimize the occurrence and consequences of automobile accidents. (Road traffic safety more broadly includes roadway design. One of the first formal academic studies into improving car safety was by Cornell Aeronautical Labs of Buffalo, New York. The main conclusion of their extensive report is the crucial importance of seat belts and padded dashboards.

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

Occupational driving

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

Active and passive safety

The terms "active" and "passive" are simple but important terms in the world of automotive safety. "Active safety" is used to refer to technology assisting in the prevention of a crash and

"passive safety" to components of the vehicle (primarily airbags, seatbelts and the physical structure of the vehicle) that help to protect occupants during a crash.

Crash avoidance

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

- The vehicle's headlamps, reflectors, and other lights and signals
- The vehicle's mirrors
- The vehicle's brakes, steering, and suspension systems

Driver assistance

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

- Automatic Braking systems to prevent or reduce the severity of collision.
- Infrared night vision systems to increase seeing distance beyond headlamp range
- Adaptive highbeam which automatically and continuously adapts the headlamp range to the distance of vehicles ahead or which are oncoming
- Adaptive headlamps swivels headlamps around corners
- Reverse backup sensors, which alert drivers to difficult-to-see objects in their path when reversing
- Backup camera
- Adaptive cruise control which maintains a safe distance from the vehicle in front
- Lane departure warning systems to alert the driver of an unintended departure from the intended lane of travel
- Tire pressure monitoring systems or Deflation Detection Systems
- Traction control systems which restore traction if driven wheels begin to spin
- Electronic Stability Control, which intervenes to avert an impending loss of control
- Anti-lock braking systems
- Electronic brakeforce distribution systems
- Emergency brake assist systems
- Cornering Brake Control systems
- Precrash system
- Automated parking system

Crashworthiness

Ferrari F430 steering wheel with airbag

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

- Seatbelts limit the forward motion of an occupant, stretch to slow down the occupant's deceleration in a crash, and prevent occupants being ejected from the vehicle.
- Airbags inflate to cushion the impact of a vehicle occupant with various parts of the vehicle's interior.

- Laminated windshields remain in one piece when impacted, preventing penetration of unbelted occupants' heads and maintaining a minimal but adequate transparency for control of the car immediately following a collision. Tempered glass side and rear windows break into granules with minimally sharp edges, rather than splintering into jagged fragments as ordinary glass does.
- Crumple zones absorb and dissipate the force of a collision, displacing and diverting it away from the passenger compartment and reducing the impact force on the vehicle occupants. Vehicles will include a front, rear and maybe side crumple zones (like Volvo SIPS) too.
- Side impact protection beams.
- Collapsible universally jointed steering columns, (with the steering system mounted behind the front axle - not in the front crumple zone), reduce the risk and severity of driver impalement on the column in a frontal crash.
- Pedestrian protection systems.
- Padding of the instrument panel and other interior parts of the vehicle likely to be struck by the occupants during a crash.

Post-crash survivability

Post-crash survivability is the chance that you can survive a crash after it occurs, these devices are often miscellaneous, and are not heavily produced as it is very difficult for them to function.

Pedestrian safety

1974 Mini Clubman Experimental Safety Vehicle featuring a "pedestrian-friendly" front end

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

Conspicuity

A Swedish study found that pink cars are involved in the fewest accidents, with black cars being most often involved in crashes (Land transport NZ 2005).

In Auckland New Zealand, a study found that there was a significantly lower rate of serious injury in silver cars; with higher rates in brown, black, and green cars. (Furness *et al.*, 2003)

The Vehicle Color Study, conducted by Monash University Accident Research Centre (MUARC) and published in 2007, analysed 855,258 accidents occurring between 1987 and 2004 in the Australian states of Victoria and Western Australia that resulted in injury or in a vehicle being towed away. The study analysed risk by light condition. It found that in daylight black cars were 12% more likely than white to be involved in an accident, followed by grey cars at 11%, silver cars at 10%, and red and blue cars at 7%, with no other colors found to be significantly more or less risky than white. At dawn or dusk the risk ratio for black cars jumped to 47% more likely than white, and that for silver cars to 15%. In the hours of darkness only red and silver cars were found to be significantly more risky than white, by 10% and 8% respectively.

Daytime running lamp that have been standard on Swedish cars since the 1970s, are soon to be mandatory across the entire EU.

History

Automobile safety may have become an issue almost from the beginning of mechanised road vehicle development. The second steam-powered "Fardier" (artillery tractor), created by Nicolas-Joseph Cugnot in 1771, is reported by some to have crashed into a wall during its demonstration run. However according to Georges Ageon, the earliest mention of this occurrence dates from 1801 and it does not feature in contemporary accounts.

One of the earliest recorded automobile fatalities was Mary Ward, on August 31, 1869 in Parsonstown, Ireland.

In the 1930s, plastic surgeon Claire L. Straith and physician C. J. Strickland advocated the use of seat belts and padded dashboards. Strickland founded the Automobile Safety League of America.

In 1934, GM performed the first barrier crash test.

In 1942, Hugh DeHaven published the classic *Mechanical analysis of survival in falls from heights of fifty to one hundred and fifty feet*.

In 1949 SAAB incorporated aircraft safety thinking into automobiles making the Saab 92 the first production SAAB car with a safety cage, and the American Tucker was built with the world's first padded dashboard.

In 1956, Ford tried unsuccessfully to interest Americans in purchasing safer cars with their Lifeguard safety package. (Its attempt nevertheless earns Ford *Motor Trend*'s "Car of the Year" award for 1956.)

In 1958, the United Nations established the World Forum for Harmonization of Vehicle Regulations, an international standards body advancing auto safety. Many of the most life saving safety innovations, like seat belts and roll cage construction were brought to market under its auspices. That same year, Volvo engineer Nils Bohlin invented and patented the three-point lap and shoulder seat belt, which became standard equipment on all Volvo cars in 1959. Over the next several decades, three-point safety belts were gradually mandated in all vehicles by regulators throughout the industrialised world.

In 1966, the U.S. established the United States Department of Transportation (DOT) with automobile safety one of its purposes. The National Transportation Safety Board (NTSB) was created as an independent organization on April 1, 1967, but was reliant on the DOT for administration and funding. However, in 1975 the organization was made completely independent by the Independent Safety Board Act (in P.L. 93-633; 49 U.S.C. 1901).

Volvo developed the first rear-facing child seat in 1964 and introduced its own booster seat in 1978.

Consumer information label for a vehicle with at least one US NCAP star rating

In 1979, NHTSA began crash-testing popular cars and publishing the results, to inform consumers and encourage manufacturers to improve the safety of their vehicles. Initially, the US NCAP crash tests examined compliance with the occupant-protection provisions of FMVSS 208. Over the subsequent years, this NHTSA program was gradually expanded in scope. In 1997, the European New Car Assessment Programme (Euro NCAP) was established to test new vehicles' safety performance and publish the results for vehicle shoppers' information. The NHTSA crash tests are presently operated and published as the U.S. branch of the international NCAP programme.

In 1984, New York State passed the first US law requiring seat belt use in passenger cars. Seat belt laws have since been adopted by all 50 states, except for New Hampshire. and NHTSA estimates increased seat belt use as a result save 10,000 per year in the USA.

In 1986, the central 3rd brake light was mandated in North America. Over the next 15 years, most of the world's other jurisdictions mandated the 3rd brake lamp as well.

In 1995, the IIHS begins frontal offset crash tests.

In 1997, EuroNCAP is founded.

In 2003, the IIHS begins conducting side impact crash tests.

In 2004, NHTSA released new tests designed to test the rollover risk of new cars and SUVs. Only the Mazda RX-8 got a 5-star rating.

In 2009, Citroën become the first manufacturer to feature "Snowmotion", an Intelligent Anti Skid system developed in conjunction with Bosch, which gives drivers a level of control in extreme ice or snow conditions similar to a 4x4

Safety trends

Despite technological advances, about 40,000 people die every year in the U.S. Although the fatality rates per vehicle registered and per vehicle distance travelled have steadily decreased since the advent of significant vehicle and driver regulation, the raw number of fatalities generally increases as a function of rising population and more vehicles on the road. However, sharp rises in the price of fuel and related driver behavioural changes are reducing 2007-8 highway fatalities in the U.S. to below the 1961 fatality count. Litigation has been central in the struggle to mandate safer cars.

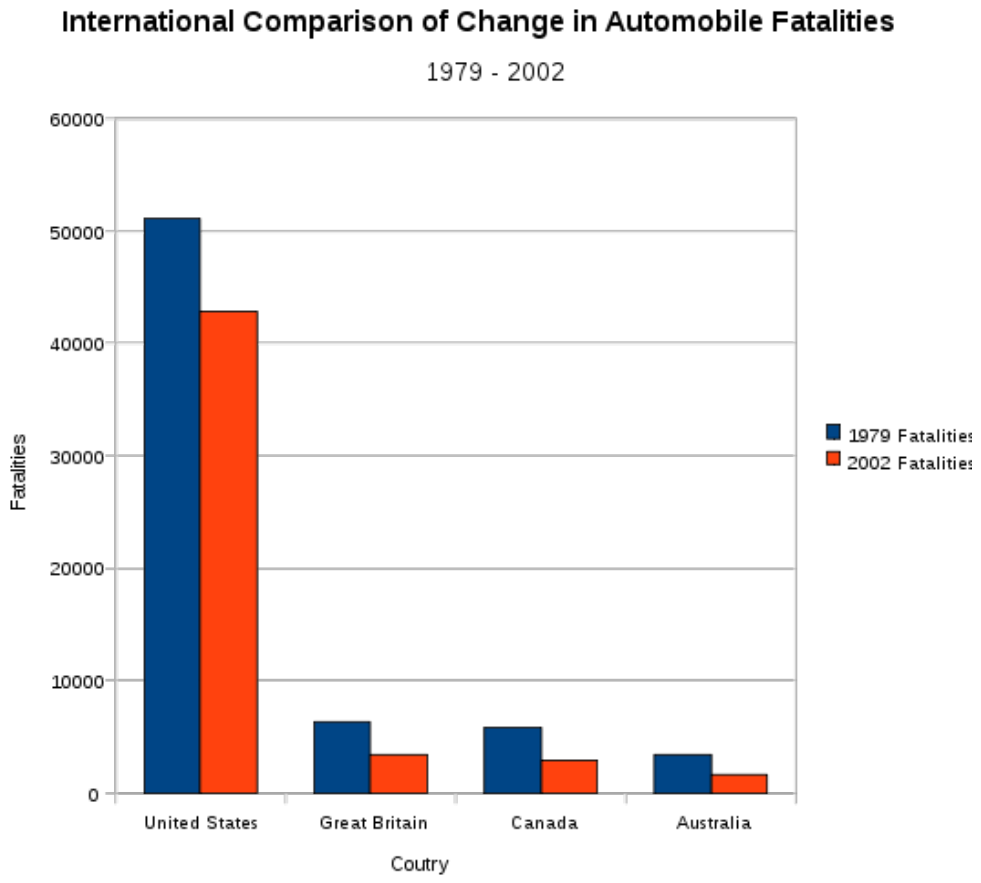
International comparison

In 1996, the U.S. had about 2 deaths per 10,000 motor vehicles, compared to 1.9 in Germany, 2.6 in France, and 1.5 in the UK. In 1998, there were 3,421 fatal accidents in the UK, the fewest since 1926.

The sizable traffic safety lead enjoyed by the USA since the 1960s had narrowed significantly by 2002, with the US improvement percentages lagging in 16th place behind those of Australia, Austria, Canada, Denmark, Finland, Germany, Great Britain, Iceland, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Sweden, and Switzerland in terms of deaths per thousand vehicles, while in terms of deaths per 100 million vehicle miles travelled, the USA had dropped from first place to tenth place.

Government-collected data, such as that from the U.S. Fatality Analysis Reporting System, show other countries achieving safety performance improvements over time greater than those achieved in the U.S.:

	1979 Fatalities	*2002 Fatalities*	*Percent Change*
United States	51,093	42,815	-16.2%
Great Britain	6,352	3,431	-46.0%
Canada	5,863	2,936	-49.9%
Australia	3,508	1,715	-51.1%



Data From Table above showing data from the U.S. Fatality Analysis Reporting System

Research on the trends in use of heavy vehicles indicate that a significant difference between the U.S. and other countries is the relatively high prevalence of pickup trucks and SUVs in the U.S. A 2003 study by the U.S. Transportation Research Board found that SUVs and pickup trucks are significantly less safe than passenger cars, that imported-brand vehicles tend to be safer than American-brand vehicles, and that the size and weight of a vehicle has a significantly smaller effect on safety than the quality of the vehicle's engineering. The level of large commercial truck traffic has substantially increased since the 1960s, while highway capacity has not kept pace with the increase in large commercial truck traffic on U.S. highways. However, other factors exert significant influence; Canada has lower roadway death and injury rates despite a vehicle mix comparable to that of the U.S. Nevertheless, the widespread use of truck-based vehicles as passenger carriers is correlated with roadway deaths and injuries not only directly by dint of vehicular safety performance *per se*, but also indirectly through the relatively low fuel costs that facilitate the use of such vehicles in North America; motor vehicle fatalities decline as fuel prices increase.

NHTSA has issued relatively few regulations since the mid 1980s; most of the vehicle-based reduction in vehicle fatality rates in the U.S. during the last third of the 20th Century were gained by the initial NHTSA safety standards issued from 1968 to 1984 and subsequent voluntary changes in vehicle design and construction by vehicle manufacturers.

Issues for particular demographic groups

Pregnant women

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

Infants and children

Children present significant challenges in engineering and producing safe vehicles, because most children are significantly smaller and lighter than most adults. Safety devices and systems designed and optimised to protect adults — particularly calibration-sensitive devices like airbags and active seat belts — can be ineffective or hazardous to children. In recognition of this, many medical professionals and jurisdictions recommend or require that children under a particular age, height, and/or weight ride in a child seat and/or in the back seat, as applicable. In Sweden, for instance, a child or an adult shorter than 140 cm is legally forbidden to ride in a place with an active airbag in front of it.

Child safety locks and driver-controlled power window lockout controls prevent children from opening doors and windows from inside the vehicle.

Infants left in cars

Very young children can perish from heat or cold if left unattended in a parked car, whether deliberately or through absentmindedness. In June 2009, a 1-year-old girl was accidentally forgotten in a car in Denmark on an extremely hot day and died from heat exhaustion.

Teenage Drivers

In the UK, a full driving licence can be had at age 17, and most areas in the United States will issue a full driver's license at the age of 16, and all within a range between 14 and 18. In addition to being relatively inexperienced, teen drivers are also cognitively immature, compared to other drivers. This combination leads to a relatively high crash rate among this demographic.

In some areas, new drivers' vehicles must bear a warning sign to alert other drivers that the vehicle is being driven by an inexperienced and learning driver, giving them opportunity to be more cautious and to encourage other drivers to give novices more leeway. In the US New Jersey has Kyleigh's Law citing that teen drivers must have a decal on their vehicle.

Some countries, such as Australia, the United States, Canada and New Zealand, have graduated levels of driver's licence, with special rules. In Italy, the maximum speed and power of vehicles driven by new drivers is restricted. In Romania, the maximum speed of vehicles driven by new drivers (less than one year in experience) is 20 km/h lower than the national standard (except villages, towns and cities).

Elderly

Insurance statistics in the United States indicate a 30% increase in the number of elderly killed, comparing 1975 to 2000. Several states require additional testing for elderly drivers. On a per-driver basis, the number of fatal and overall crashes decreases with age, with some exceptions for drivers over 75. The overall trend may be due to greater experience and avoiding driving in adverse conditions. However, on a per-miles-travelled basis, drivers younger than 25-30 and older than 65-70 have significantly higher accident rates. Survivability of crashes decreases monotonically with the age of the victim.

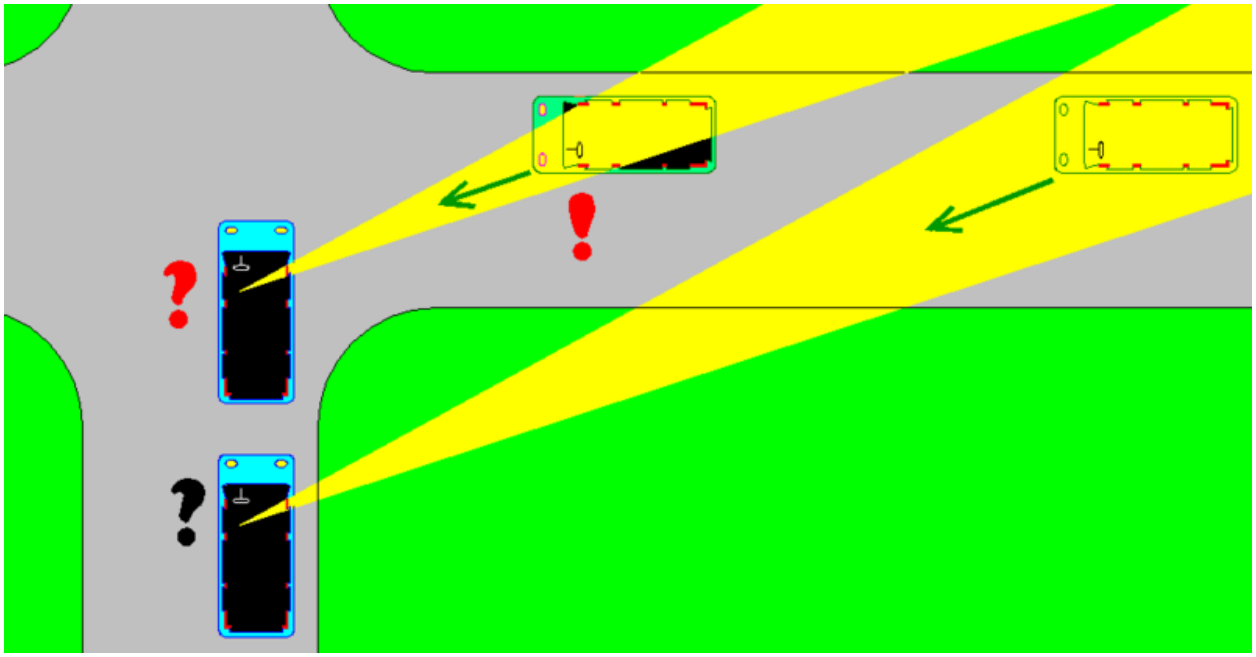
A common problem for the elderly is the question of when a medical condition or biological aging presents a serious enough problem that one should stop driving. In some cases, this means giving up some personal independence, but in urban areas often means relying more on public transportation. Many transit systems offer discounted fares to seniors, and some local governments run "senior shuttles" specifically targeted at this demographic.

Chapter- 4

Driver Visibility

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

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

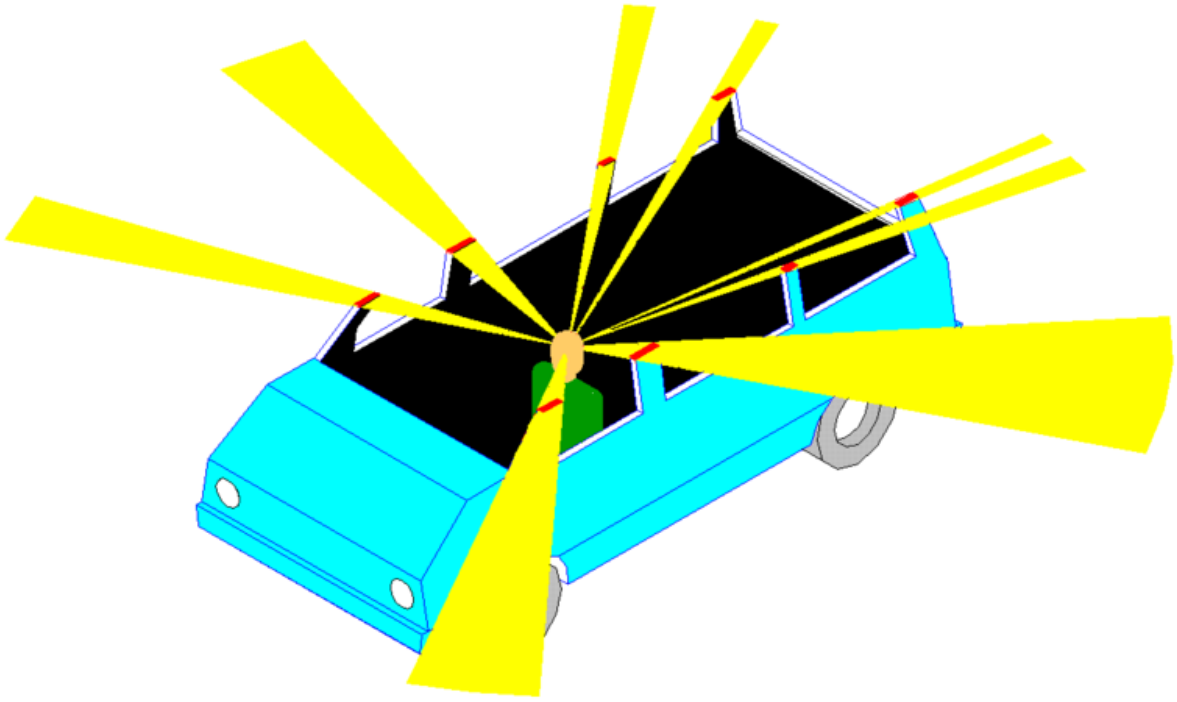


A-pillar blind spot

Forward visibility

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

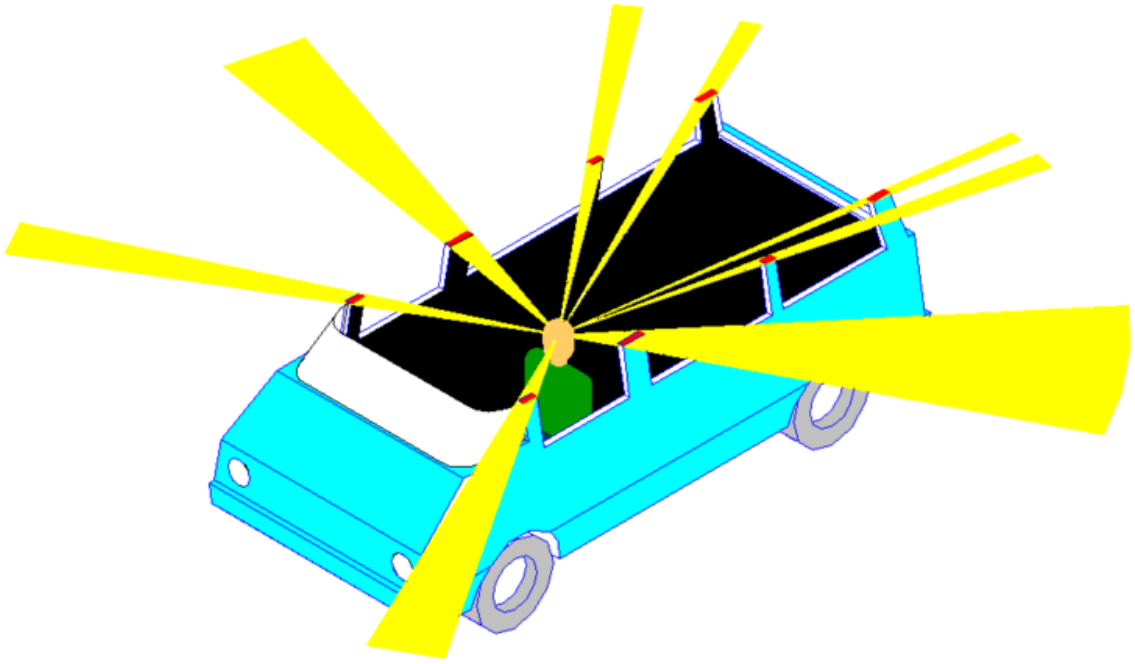
- Distance between the driver and the pillar
- Thickness of the pillar
- The angle of the pillar in a vertical plane side view
- The angle of the pillar in a vertical plane front view
- the form of the pillar straight or arc-form
- Angle of the windshield
- Height of the driver in relation to the dashboard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



40° angle A-pillar bar blind spots

Effects of A-pillar angle on visibility

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



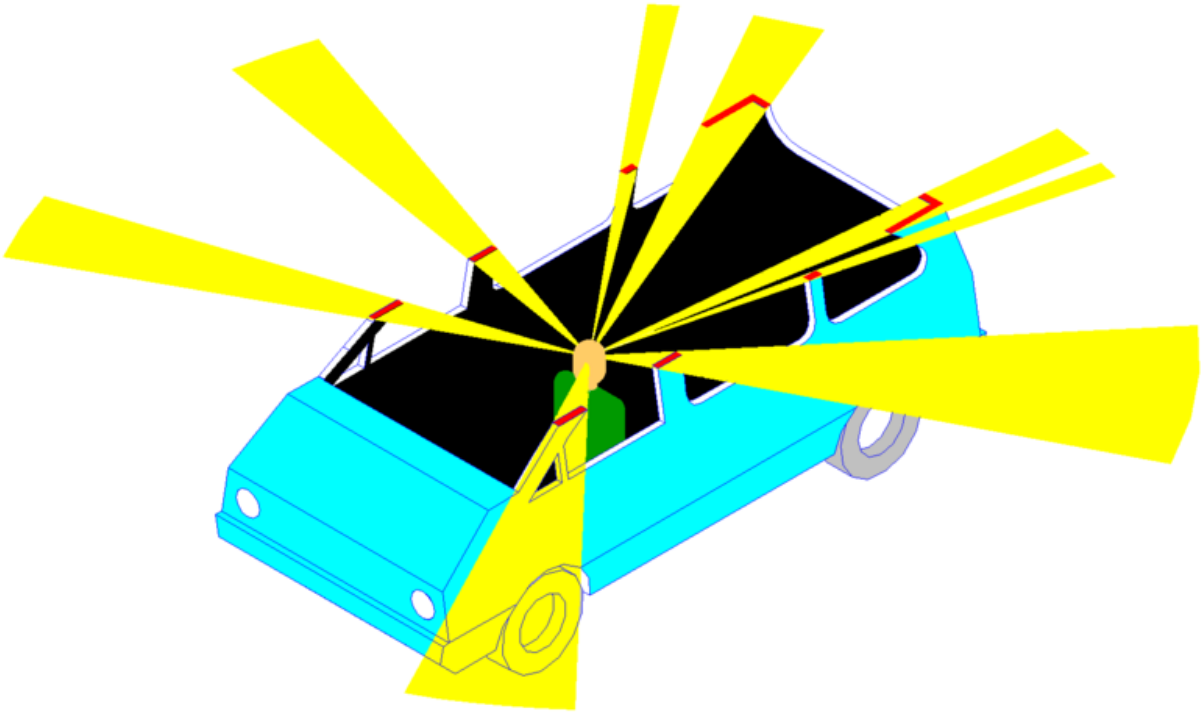
Vertical A-pillar having small blind spots

Panoramic windshield

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

Examples of cars with an almost vertical A-pillar:

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

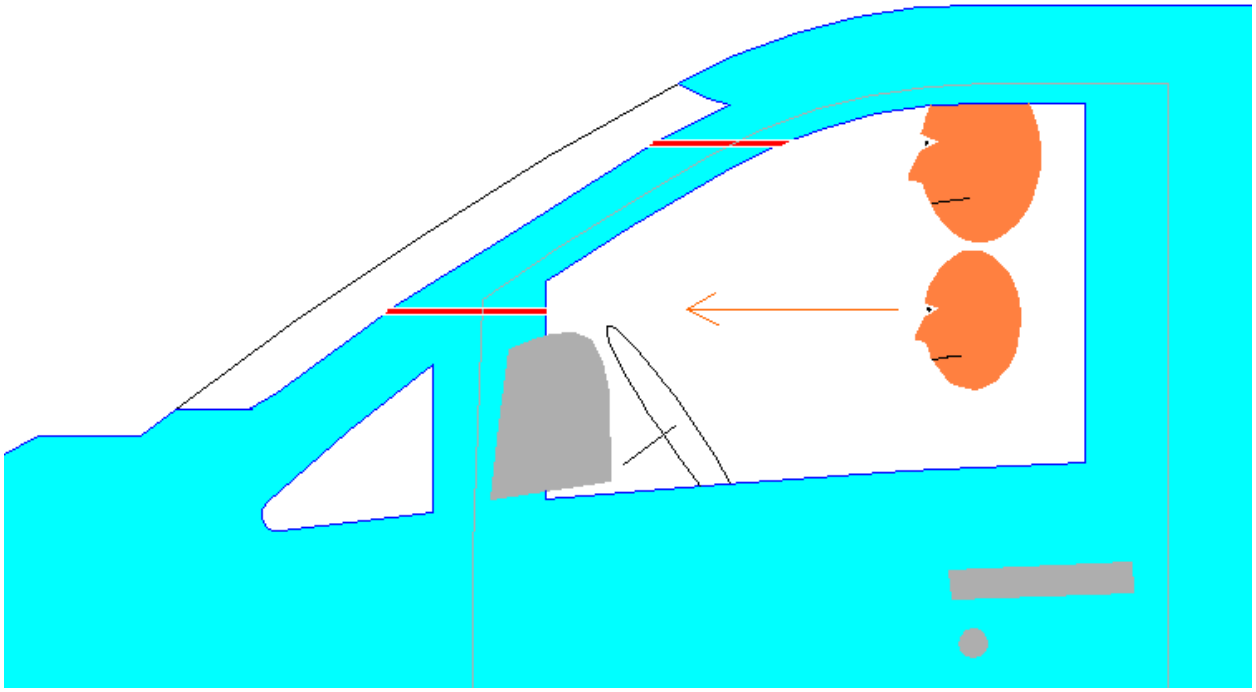


A-pillar bars reduce driver visibility

Flat windshields

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

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



Car with a "quarter glass", Visibility of short and tall drivers

Other disadvantages of a flat windshield angle

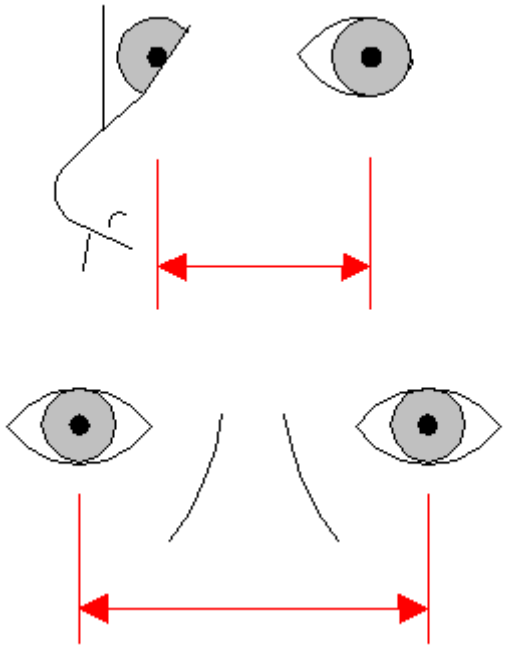
- Other traffic can not see the driver through the reflection if the driver can see them.
- The heater needs more time to heat the bigger window surface.
- The flat windshield angle does not let snow slide off easily.
- The driver cannot reach the whole flat window to clean it easily.

Height of the driver

Driver height can also affect visibility.

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

Also the B-pillar (car) can block the vision of a tall driver in small 4 door cars.



Turning your head reduces blind spot

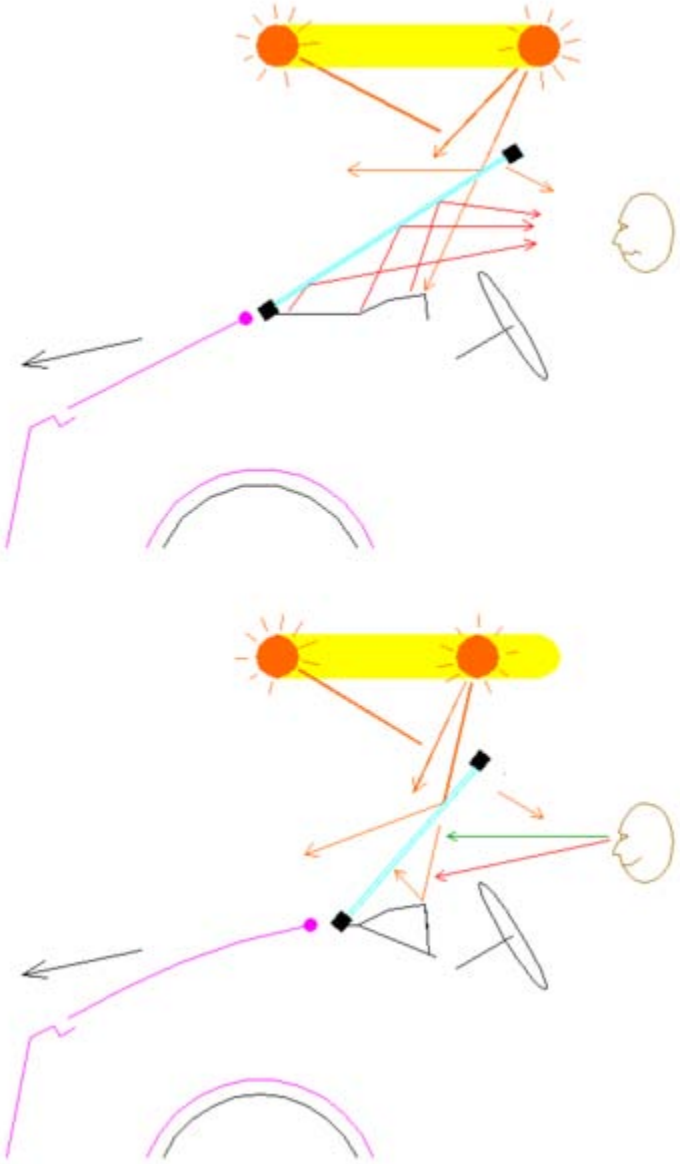
A driver may reduce the size of a blind spot or eliminate it completely by turning their head in the direction of the obstruction. This allows the driver to see better around the obstruction and allows the driver better depth perception.

Visibility in a convertible

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

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

Windshield reflections



Sunlight dashboard reflection

Dashboard reflection

It is best if the dashboard has a non-reflecting dark colored surface.

A small dashboard gives some reflection on the lower part of the windshield.

A big dashboard can give reflection on eye height.

A-pillar reflection

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

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

Light through roof reflection

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

Other automobile design factors

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

Rear-view mirror blind spots

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

Chapter- 5

Automobile Handling

Automobile handling and **vehicle handling** are descriptions of the way wheeled vehicles perform transverse to their direction of motion, particularly during cornering and swerving. It also includes their stability when moving at rest. Handling and braking are the major components of a vehicle's "active" safety. The maximum lateral acceleration is sometimes discussed separately as "road holding". (This discussion is directed at road vehicles with at least three wheels, but some of it may apply to other ground vehicles.) Automobiles driven on public roads whose engineering requirements emphasize handling over comfort and passenger space are named sports cars.

Factors that affect a car's handling

Weight distribution

Center of mass height

The center of mass height, relative to the track, determines load transfer, (related to, but not exactly weight transfer), from side to side and causes body lean. When tires of a vehicle provide a centripetal force to pull it around a turn, the momentum of the vehicle actuates load transfer in a direction going from the vehicle's current position to a point on a path tangent to the vehicle's path. This load transfer presents itself in the form of body lean.

Height of the center of mass relative to the wheelbase determines load transfer between front and rear. The car's momentum acts at its center of mass to tilt the car forward or backward, respectively during braking and acceleration. Since it is only the downward force that changes and not the location of the center of mass, the effect on over/under steer is *opposite* to that of an actual change in the center of mass. When a car is braking, the downward load on the front tires increases and that on the rear decreases, with corresponding change in their ability to take sideways load.

A lower center of mass is a principal performance advantage of sports cars, compared to sedans and (especially) SUVs. Some cars have body panels made of lightweight materials partly for this reason.

Body lean can also be controlled by the springs, anti-roll bars or the roll center heights.

Center of mass

The ideal weight distribution is "50/50" (i.e. the center of mass is mid-way between the front and rear axles). In steady-state cornering, front-heavy cars tend to understeer and rear-heavy cars to oversteer, all other things being equal. The mid-engine design seeks to achieve the ideal center of mass, though front-engine design has the advantage of permitting a more practical engine-passenger-baggage layout, and when engineered correctly can have as neutral (close to or at 50:50) weight distribution as a mid engine car. All other parameters being equal, at the hands of an expert professional driver a neutrally balanced mid-engine car can corner faster, but a FR layout car is easier to drive at the limit. Some good examples of these layouts are Ferrari F360 and Toyota MR2 for mid-engine design, and BMW M3 and Mazda MX-5 for the second.

The rearward weight bias preferred by sports and racing cars results from handling effects during the transition from straight-ahead to cornering. During corner entry the front tires, in addition to generating part of the lateral force required to accelerate the car's center of mass into the turn, also generate a torque about the car's vertical axis that starts the car rotating into the turn. However, the lateral force being generated by the rear tires is acting in the opposite torsional sense, trying to rotate the car out of the turn. For this reason, a car with "50/50" weight distribution will understeer on initial corner entry. To avoid this problem, sports and racing cars often have a more rearward weight distribution. In the case of pure racing cars, this is typically between "40/60" and "35/65". This gives the front tires an advantage in overcoming the car's moment of inertia (yaw angular inertia), thus reducing corner-entry understeer.

Using wheels and tires of different sizes (proportional to the weight carried by each end) is a lever automakers can use to fine tune the resulting over/understeer characteristics.

Roll angular inertia

This increases the time it takes to settle down and follow the steering. It depends on the (square of the) height and width, and (for a uniform mass distribution) can be approximately calculated by the equation: $I = M(height^2 + width^2) / 12$.

Greater width, then, though it counteracts center of gravity height, hurts handling by increasing angular inertia. Some high performance cars have light materials in their fenders and roofs partly for this reason.

Yaw and pitch angular inertia (polar moment)

Unless the vehicle is very short, compared to its height or width, these are about equal. Angular inertia determines the rotational inertia of an object for a given rate of rotation. The yaw angular inertia tends to keep the direction the car is pointing changing at a constant rate. This makes it slower to swerve or go into a tight curve, and it also makes it slower to turn straight again. The pitch angular inertia detracts from the ability of the suspension to keep front and back tire loadings constant on uneven surfaces and therefore contributes to bump steer. Angular inertia is

an integral over the *square* of the distance from the center of gravity, so it favors small cars even though the lever arms (wheelbase and track) also increase with scale. (Since cars have reasonable symmetrical shapes, the off-diagonal terms of the angular inertia tensor can usually be ignored.) Mass near the ends of a car can be avoided, without re-designing it to be shorter, by the use of light materials for bumpers and fenders or by deleting them entirely.

Suspension

Automobile suspensions have many variable characteristics, which are generally different in the front and rear and all of which affect handling. Some of these are: spring rate, damping, straight ahead camber angle, camber change with wheel travel, roll center height and the flexibility and vibration modes of the suspension elements. Suspension also affects unsprung weight.

Many cars have suspension that connects the wheels on the two sides, either by a sway bar and/or by a solid axle. The Citroën 2CV has interaction between the front and rear suspension.

The flexing of the frame interacts with the suspension. (See below.)

Suspension travel

The severe handling vice of the TR3 and related cars was caused by running out of suspension travel. (See below.) Other vehicles will run out of suspension travel with some combination of bumps and turns, with similarly catastrophic effect. Excessively modified cars also may encounter this problem.

Tires and wheels

In general softer rubber, higher hysteresis rubber and stiffer cord configurations increase road holding and improve handling. On most types of poor surfaces, large diameter wheels perform better than lower wider wheels. The depth of tread remaining greatly affects aquaplaning (riding over deep water without reaching the road surface). Increasing tire pressures reduces their slip angle, but lessening the contact area is detrimental in usual surface conditions and should be used with caution.

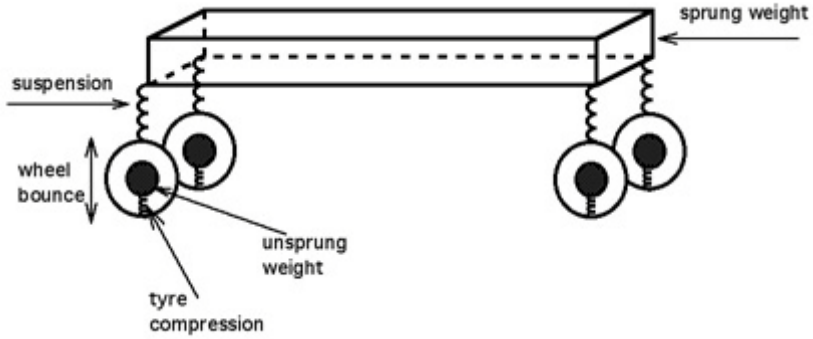
The amount a tire meets the road is an equation between the weight of the car and the type (and size) of its tire. A 1000 kg car can depress a 185/65/15 tire more than a 215/45/15 tire longitudenally thus having better linear grip and better braking distance not to mention better aquaplaning performance, while the wider tires having better (dry) cornering resistance.

The contemporary chemical make-up of tires are dependant of the ambient and road temperatures. Ideally a tire should be soft enough to conform to the road surface (thus having good grip), but be hard enough to last for enough duration (distance) to be economically feasible. It is usually a good idea having different set of summer and winter tires for climates having these temperatures.

Track and wheelbase

The axle track provides the resistance to sideways weight transfer and body lean. The wheelbase provides resistance to front/back weight transfer and to pitch angular inertia, and provides the torque lever arm to rotate the car when swerving. The wheelbase, however, is less important than angular inertia (polar moment) to the vehicle's ability to swerve quickly.

Unsprung weight



Ignoring the flexing of other components, a car can be modeled as the sprung weight, carried by the springs, carried by the unsprung weight, carried by the tires, carried by the road. Unsprung weight is more properly regarded as a mass which has its own inherent inertia separate from the rest of the vehicle. When a wheel is pushed upwards by a bump in the road, the inertia of the wheel will cause it to be carried further upward above the height of the bump. If the force of the push is sufficiently large, the inertia of the wheel will cause the tire to completely lift off the road surface resulting in a loss of traction and control. Similarly when crossing into a sudden ground depression, the inertia of the wheel slows the rate at which it descends. If the wheel inertia is large enough, the wheel may be temporarily separated from the road surface before it has descended back into contact with the road surface.

This unsprung weight is cushioned from uneven road surfaces only by the compressive resilience of the tire (and wire wheels if fitted), and which aids the wheel in remaining in contact with the road surface when the wheel inertia prevents close-following of the ground surface. However, the compressive resilience of the tire results in rolling resistance which requires additional kinetic energy to overcome, and the rolling resistance is expended in the tire as heat due to the flexing of the rubber and steel bands in the sidewalls of the tires. To reduce rolling resistance for improved fuel economy and to avoid overheating and failure of tires at high speed, tires are designed to have limited internal damping.

So the "wheel bounce" due to wheel inertia, or resonant motion of the unsprung weight moving up and down on the springiness of the tire, is only poorly damped, mainly by the dampers or shock absorbers of the suspension. For these reasons, high unsprung weight reduces road holding and increases unpredictable changes in direction on rough surfaces (as well as degrading ride comfort and increasing mechanical loads).

This unsprung weight includes the wheels and tires, usually the brakes, plus some percentage of the suspension, depending on how much of the suspension moves with the body and how much with the wheels; for instance a solid axle is completely unsprung. The main factors that improve unsprung weight are a sprung differential (as opposed to live axle) and inboard brakes. (The De Dion tube suspension operates much as a live axle does, but represents an improvement because the diff is mounted to the body, thereby reducing the unsprung weight.) Aluminum wheels also help. Magnesium alloy wheels are even lighter but corrode easily.

Since only the brakes on the driving wheels can easily be inboard, the Citroën 2CV had inertial dampers on its rear wheel hubs to damp only wheel bounce.

Aerodynamics

Aerodynamic forces are generally proportional to the square of the air speed, therefore car aerodynamics become rapidly more important as speed increases. Like darts, aeroplanes, etc., cars can be stabilised by fins and other rear aerodynamic devices. However, in addition to this cars also use downforce or "negative lift" to improve road holding. This is prominent on many types of racing cars, but is also used on most passenger cars to some degree, if only to counteract the tendency for the car to otherwise produce positive lift.

In addition to providing increased adhesion, car aerodynamics are frequently designed to compensate for the inherent increase in oversteer as cornering speed increases. When a car corners, it must rotate about its vertical axis as well as translate its center of mass in an arc. However, in a tight-radius (lower speed) corner the angular velocity of the car is high, while in a longer-radius (higher speed) corner the angular velocity is much lower. Therefore, the front tires have a more difficult time overcoming the car's moment of inertia during corner entry at low speed, and much less difficulty as the cornering speed increases. So the natural tendency of any car is to understeer on entry to low-speed corners and oversteer on entry to high-speed corners. To compensate for this unavoidable effect, car designers often bias the car's handling toward less corner-entry understeer (such as by lowering the front roll center), and add rearward bias to the aerodynamic downforce to compensate in higher-speed corners. The rearward aerodynamic bias may be achieved by an airfoil or "spoiler" mounted near the rear of the car, but a useful effect can also be achieved by careful shaping of the body as a whole, particularly the aft areas

In recent years, aerodynamics have become an area of increasing focus by racing teams as well as car manufacturers. Advanced tools such as wind tunnels and computational fluid dynamics (CFD) have allowed engineers to optimize the handling characteristics of vehicles. Advanced wind tunnels such as Wind Shear's Full Scale, Rolling Road, Automotive Wind Tunnel recently built in Concord, North Carolina have taken the simulation of on-road conditions to the ultimate level of accuracy and repeatability under very controlled conditions. CFD has similarly been used as a tool to simulate aerodynamic conditions but through the use of extremely advanced computers and software to duplicate the car's design digitally then "test" that design on the computer.

Delivery of power to the wheels and brakes

The coefficient of friction of rubber on the road limits the magnitude of the vector sum of the transverse and longitudinal force. So the driven wheels or those supplying the most braking tend to slip sideways. This phenomenon is often explained by use of the circle of forces model.

One reason that sports cars are usually rear wheel drive is that power induced oversteer is useful, to a skilled driver, for tight curves. The weight transfer under acceleration has the opposite effect and either may dominate, depending on the conditions. Inducing understeer by applying power in a front wheel drive car is useful via proper use of "Left-foot braking." In any case, this is not an important safety issue, because power is not normally used in emergency situations. Using low gears down steep hills may cause some oversteer.

The effect of braking on handling is complicated by load transfer, which is proportional to the (negative) acceleration times the ratio of the center of gravity height to the wheelbase. The difficulty is that the acceleration at the limit of adhesion depends on the road surface, so with the same ratio of front to back braking force, a car will understeer under braking on slick surfaces and oversteer under hard braking on solid surfaces. Most modern cars combat this by varying the distribution of braking in some way. This is important with a high center of gravity, but it is also done on low center of gravity cars, from which a higher level of performance is expected.

Steering

Depending on the driver, steering force and transmission of road forces back to the steering wheel and the steering ratio of turns of the steering wheel to turns of the road wheels affect control and awareness. Play — free rotation of the steering wheel before the wheels rotate — is a common problem, especially in older model and worn cars. Another is friction. Rack and pinion steering is generally considered the best type of mechanism for control effectiveness. The linkage also contributes play and friction. Caster — offset of the steering axis from the contact patch — provides some of the self-centering tendency.

Precision of the steering is particularly important on ice or hard packed snow where the slip angle at the limit of adhesion is smaller than on dry roads.

The steering effort depends on the downward force on the steering tires and on the radius of the contact patch. So for constant tire pressure, it goes like the 1.5 power of the vehicle's weight. The driver's ability to exert torque on the wheel scales similarly with his size. The wheels must be rotated farther on a longer car to turn with a given radius. Power steering reduces the required force at the expense of feel. It is useful, mostly in parking, when the weight of a front-heavy vehicle exceeds about ten or fifteen times the driver's weight, for physically impaired drivers and when there is much friction in the steering mechanism.

Four-wheel steering has begun to be used on road cars (Some WW II reconnaissance vehicles had it). It relieves the effect of angular inertia by starting the whole car moving before it rotates toward the desired direction. It can also be used, in the other direction, to reduce the turning radius. Some cars will do one or the other, depending on the speed.

Steering geometry changes due to bumps in the road may cause the front wheels to steer in different directions together or independent of each other. The steering linkage should be designed to minimize this effect.

Electronic stability control

Electronic stability control (ESC) is a computerized technology that improves the safety of a vehicle's stability by attempting to detect and prevent skids. When ESC detects loss of steering control, the system applies individual brakes to help "steer" the vehicle where the driver wants to go. Braking is automatically applied to individual wheels, such as the outer front wheel to counter oversteer, or the inner rear wheel to counter understeer.

The stability control of some cars may not be compatible with some driving techniques, such as power induced over-steer. It is therefore, at least from a sporting point of view, preferable that it can be disabled.

Static alignment of the wheels

Of course things should be the same, left and right, for road cars. Camber affects steering because a tire generates a force towards the side that the top is leaning towards. This is called camber thrust. Additional front negative camber is used to improve the cornering ability of cars with insufficient camber gain.

Rigidity of the frame

The frame may flex with load, especially twisting on bumps. Rigidity is considered to help handling. At least it simplifies the suspension engineers work. Some cars, such as the Mercedes-Benz 300SL have had high doors to allow a stiffer frame.

Driver handling the car

Handling is a property of the car, but different characteristics will work well with different drivers.

Familiarity

A person learns to control a car much as he learns to control his body, so the more he has driven a car or type of car the better it will handle for them. One needs to take extra care for the first few months after buying a car, especially if it differs in design from those they are used to. Other things that a driver must adjust to include changes in tires, tire pressures and load. That is, handling is not just good or bad; it is also the same or different.

Position and support for the driver

Having to take up "g forces" in his/her arms interferes with a driver's precise steering. In a similar manner, a lack of support for the seating position of the driver may cause them to move

around as the car undergoes rapid acceleration (through cornering, taking off or braking). This interferes with precise control inputs, making the car more difficult to control.

Being able to reach the controls easily is also an important consideration, especially if a car is being driven hard.

In some circumstances, good support may allow a driver to retain some control, even after a minor accident or after the first stage of an accident.

External conditions that affect handling

Weather

Weather affects handling by changing the amount of available traction on a surface. Different tires do best in different weather. Deep water is an exception to the rule that wider tires improve road holding.

Road condition

Cars with relatively soft suspension and with low unsprung weight are least affected by uneven surfaces, while on flat smooth surfaces the stiffer the better. Unexpected water, ice, oil, etc. are hazards.

Common handling problems

When any wheel leaves contact with the road there is a change in handling, so the suspension should keep all four (or three) wheels on the road in spite of hard cornering, swerving and bumps in the road. It is very important for handling, as well as other reasons, not to run out of suspension travel and "bottom" or "top".

It is usually most desirable to have the car adjusted for a small amount of understeer, so that it responds predictably to a turn of the steering wheel and the rear wheels have a smaller slip angle than the front wheels. However this may not be achievable for all loading, road and weather conditions, speed ranges, or while turning under acceleration or braking. Ideally, a car should carry passengers and baggage near its center of gravity and have similar tire loading, camber angle and roll stiffness in front and back to minimise the variation in handling characteristics. A driver can learn to deal with excessive oversteer or understeer, but not if it varies greatly in a short period of time.

The most important common handling failings are;

- Understeer – the front wheels tend to crawl slightly or even slip and drift towards the outside of the turn. The driver can compensate by turning a little more tightly, but road-holding is reduced, the car's behaviour is less predictable and the tires are liable to wear more quickly.
- Oversteer – the rear wheels tend to crawl or slip towards the outside of the turn more than the front. The driver must correct by steering away from the corner, otherwise the car is liable to

spin, if pushed to its limit. Oversteer is sometimes useful, to assist in steering, especially if it occurs only when the driver chooses it by applying power.

- Bump steer – the effect of irregularity of a road surface on the angle or motion of a car. It may be the result of the kinematic motion of the suspension rising or falling, causing toe-in or toe-out at the loaded wheel, ultimately affecting the yaw angle (heading) of the car. It may also be caused by defective or worn out suspension components. This will always happen under some conditions but depends on suspension, steering linkage, unsprung weight, angular inertia, differential type, frame rigidity, tires and tire pressures. If suspension travel is exhausted the wheel either bottoms or loses contact with the road. As with hard turning on flat roads, it is better if the wheel picks up by the spring reaching its neutral shape, rather than by suddenly contacting a limiting structure of the suspension.
- Body roll – the car leans towards the outside of the curve. This interferes with the driver's control, because he must wait for the car to finish leaning before he can fully judge the effect of his steering change. It also adds to the delay before the car moves in the desired direction. It also slightly changes the weight borne by the tires as described in weight transfer.
- Excessive load transfer – On any vehicle that is cornering, the outside wheels are more heavily loaded than the inside due to the CG being above the ground. Total weight transfer (sum of front and back), in steady cornering, is determined by the ratio of the height of a car's center of gravity to its axle track. When the weight transfer equals half the vehicle's loaded weight, it will start to roll over. This can be avoided by manually or automatically reducing the turn rate, but this causes further reduction in road-holding.
- Slow response – sideways acceleration does not start immediately when the steering is turned and may not stop immediately when it is returned to center. This is partly caused by body roll. Other causes include tires with high slip angle, and yaw and roll angular inertia. Roll angular inertia aggravates body roll by delaying it. Soft tires aggravate yaw angular inertia by waiting for the car to reach their slip angle before turning the car.

Compromises

Ride quality and handling have always been a compromise - technology has over time allowed automakers to combine more of both features in the same vehicle. High levels of comfort are difficult to reconcile with a low center of gravity, body roll resistance, low angular inertia, support for the driver, steering feel and other characteristics that make a car handle well.

For ordinary production cars, manufactures err towards deliberate understeer as this is safer for inexperienced or inattentive drivers than is oversteer. Other compromises involve comfort and utility, such as preference for a softer smoother ride or more seating capacity.

Inboard brakes improve both handling and comfort but take up space and are harder to cool. Large engines tend to make cars front or rear heavy. In tires, fuel economy, staying cool at high speeds, ride comfort and long wear all tend to conflict with road holding, while wet, dry, deep water and snow road holding are not exactly compatible. A-arm or wishbone front suspension tends to give better handling, because it provides the engineers more freedom to choose the geometry, and more road holding, because the camber is better suited to radial tires, than MacPherson strut, but it takes more space.

The older Live axle rear suspension technology, familiar from the Ford Model T, is still widely used in most sport utility vehicles and trucks, often for the purposes of durability (and cost). The live axle suspension is still used in some sports cars, like the Ford Mustang, and is better for drag racing, but generally has problems with grip on bumpy corners, fast corners and stability at high speeds on bumpy straights.

Aftermarket modifications and adjustments

Lowering the center of gravity will always help the handling (as well as reduce the chance of roll-over). This can be done to some extent by using plastic windows (or none) and light roof, hood (bonnet) and trunk (boot) lid materials, by reducing the ground clearance, etc. Increasing the track with "reversed" wheels will have a similar effect, but remember that the wider the car the less spare room it has on the road and the farther you may have to swerve to miss an obstacle. Stiffer springs and/or shocks, both front and rear, will generally improve handling on close to perfect surfaces, while worsening handling on less-than-perfect road conditions by "skipping" the car (and destroying grip), thus making handling the vehicle difficult. Aftermarket performance suspension kits are usually readily available.

Lighter (mostly aluminum or magnesium alloy) wheels improve handling as well as ride comfort, by lessening unsprung weight.

Moment of inertia can be reduced by using lighter bumpers and wings (fenders), or none at all.

Component	Reduce Under-steer	Reduce Over-steer
Weight distribution	center of gravity towards rear	center of gravity towards front
Front shock absorber	softer	stiffer
Rear shock absorber	stiffer	softer
Front sway bar	softer	stiffer
Rear sway bar	stiffer	softer
Front tire selection[1]	larger contact area[2]	smaller contact area
Rear tire selection	smaller contact area	larger contact area[2]
Front wheel rim width or diameter	larger[2]	smaller

Rear wheel rim width or diameter	smaller	larger[2]
Front tire pressure	lower pressure	increase pressure
Rear tire pressure	increase pressure	lower pressure
Front wheel camber	increase negative camber	reduce negative camber
Rear wheel camber	reduce negative camber	increase negative camber
Rear spoiler	smaller	larger
Front height (because these usually affect camber and roll resistance)	lower front end	raise front end
Rear height	raise rear end	lower rear end
Front toe in	decrease	increase
Rear toe in	decrease	increase

1) Tire contact area can be increased by using wider tires, or tires with fewer grooves in the tread pattern. Of course fewer grooves has the opposite effect in wet weather or other poor road conditions.

2) These also improve road holding, under most conditions.

Cars with unusual handling problems

Certain vehicles can be involved in a disproportionate share of single-vehicle accidents; their handling characteristics may play a role:

- Early Porsche 911s — suffered from treacherous lift off oversteer (where the rear of the car loses grip as the driver lifts off the accelerator); also the inside front wheel leaves the road during hard cornering on dry pavement, causing increasing understeer. The roll bar stiffness at the front is set to compensate for the rear-heaviness and gives neutral handling in ordinary driving. This compensation starts to give out when the wheel lifts. A skilled driver can use the 911's other features to his/her advantage, making the 911 an extremely capable sports car in expert hands. Later 911s have had increasingly sophisticated rear suspensions and larger rear tires, eliminating these problems.
- Triumph TR2, and TR3 — began to oversteer more suddenly when their inside rear wheel lifted.

- Volkswagen Beetle — (original Beetle) senstitivity to crosswinds, due to the lightness of the front of the rear engine car; and poor roll stability due to the swing axle suspension. People who drove them hard fitted reversed wheels and bigger rear tires and rims to ameliorate.
- Chevrolet Corvair - cited for dangerous handling in Unsafe at Any Speed caused by poor roll stability due to the swing axle rear suspension similar to that used in the Volkswagen Beetle. These problems were corrected with the redesign of the Corvair for 1965, however, it died from its negative publicity.
- The large, rear-engine Tatra (known as the 'Czech secret weapon') killed so many Nazi officers during World War II that the German Army eventually forbade its officers from driving the Tatra.
- Some 1950s American "full size" cars responded very slowly to steering changes because of their very large angular inertia, softly tuned suspension which made ride quality a priority over cornering, and comfort oriented cross bias tires. *Auto Motor und Sport* reported on one of these that they lacked the courage to test it for top speed, probably due to their familiarity with smaller European cars and their unfamiliarity with large American cars.
- Dodge Omni and Plymouth Horizon — these early American responses to the Volkswagen Rabbit were found "unacceptable" in their initial testing by Consumer Reports, due to an observed tendency to display an uncontrollable oscillating yaw from side to side under certain steering inputs. While Chrysler's denials of this behaviour were countered by a persistent trickle of independent reports of this behaviour, production of the cars was altered to equip them with both a lighter weight steering wheel and a steering damper, and no further reports of this problem were heard.
- The Suzuki Samurai — was similarly reported by Consumer Reports to exhibit a propensity to tipping over onto two wheels, to the point where Consumer Reports claimed they were afraid to continue testing the vehicle without the attachment of outrigger wheels to catch it from completely rolling over. In its first set of tests, the Samurai performed well. R. David Little, Consumers Union's technical director, drove the light SUV through several short, hard turns, designed to simulate an emergency, such as trying to avoid a child running in front of the car. An article published several years later in a Consumer Reports anniversary issue prompted Suzuki to sue. The suit was based on the perception that Consumer Reports rigged the results: "This case is about lying and cheating by Consumers Union for its own financial motives," George F. Ball, Suzuki's managing counsel, said Monday. "They were in debt [in 1988], and they needed a blockbuster story to raise and solicit funds." Entrepreneur Magazine reported that "Suzuki's case centered on a change CU made while testing the vehicle. After the Samurai and other SUVs completed the standard course without threatening to roll over, CU altered the course to make the turns more abrupt. The other vehicles didn't show a problem, but the Samurai tipped up and would have rolled over but for outriggers set up to prevent that outcome" After eight years in court the parties consented to a settlement which did not include monetary damages nor a retraction. Commenting on the settlement, Consumer Union said,"Consumers Union also says in the agreement that it "never intended to imply that the Samurai easily rolls over in routine driving conditions." CU Vice President of Technical Policy further stated: "There is no apology. "We stand fully behind our testing and rating of the Samurai." In a joint press statement Suzuki recognized "CU's stated commitment for objective and unbiased testing and reporting."

- Mercedes-Benz A-Class — a tall car with a high center of gravity; early models showed excessive body roll during sharp swerving manoeuvres and rolled over, most particularly during the Swedish moose test. This was later corrected using Electronic Stability Control and retrofitted at great expense to earlier cars.

- Ford Explorer — a dangerous tendency to blow a rear tire and flip over. Ford had constructed a vehicle with a high center of gravity - the tendency to roll over on sharp changes in direction is built in to the vehicle. Ford attempted to counteract the forces of nature by specifying lower than optimum pressures, in the tires in order to induce them to lose traction and slide under sideways forces rather than to grip and force the vehicle to roll over. For reasons that were never entirely clear, tires from one factory tended to blow out when under inflated, these vehicles then rolled over, which led to a spate of well publicized single-vehicle accidents.

  Ford and Firestone, the makers of the tires, pointed fingers at each other, with the final blame being assigned to quality control practices at a Firestone plant which was undergoing a strike. Tires from a different Firestone plant were not associated with this problem. An internal document dated 1989 states
  Engineering has recommended use of tire pressures below maximum allowable inflation levels for all UN46 tires. As described previously, the reduced tire pressures increase understeer and reduce maximum cornering capacity (both 'stabilising' influences). This practice has been used routinely in heavy duty pick-up truck and car station wagon applications to assure adequate understeer under all loading conditions. Nissan (Pathfinder), Toyota, Chevrolet, and Dodge also reduce tire pressures for selected applications. While we cannot be sure of their reasons, similarities in vehicle loading suggest that maintaining a minimal level of understeer under rear-loaded conditions may be the compelling factor.

  This contributed to build-up of heat and tire deterioration under sustained high speed use, and eventual failure of the most highly stressed tire. Of course, the possibility that slightly substandard tire construction and slightly higher than average tire stress, neither of which would be problematic in themselves, would in combination result in tire failure is quite likely. The controversy continues without unequivocal conclusions, but it also brought public attention to a generally high incidence of rollover accidents involving SUVs, which the manufacturers continue to address in various ways. A subsequent NHTSA investigation of real world accident data showed that the SUVs in question were no more likely to roll over than any other SUV, after a tread separation.

- The Jensen GT (hatchback coupe) — was introduced in attempt to broaden the sales base of the Jensen Healey, which had up to that time been a roadster or convertible. Its road test report in *Motor Magazine* and a very similar one, soon after, in *Road & Track* concluded that it was no longer fun enough to drive to be worth that much money. They blamed it on minor suspension changes. Much more likely, the change in weight distribution was at fault. The Jensen Healey was a rather low and wide fairly expensive sports car, but the specifications of its suspension were not particularly impressive, having a solid rear axle. Unlike the AC Ace, with its double transverse leaf rear suspension and aluminium body, the Jensen Healey could not stand the weight of that high up metal and glass and still earn a premium price for its handling. The changes also included a cast iron exhaust manifold replacing the aluminium one, probably to partly balance the high and far back weight of the top. The factory building was used to build multi-tub truck frames.
- The rear engined Renault Dauphine earned in Spain the sobriquet of the *"widow's car"*, due to its bad handling.

- Three-wheeled cars/vehicles have unique handling issues, especially considering whether the single wheel is at the front or back. (Motorcycles with sidecars; another matter.) Buckminster Fuller's Dymaxion car caused a sensation, but ignorance of the problems of rear-wheel-steering led to a fatal crash that destroyed its reputation.

Chapter- 6

Headlight Flashing

Headlight flashing refers to the act of either briefly switching on the headlights of a car, or of momentarily switching between a headlight's high beams and low beams. This signal can mean a multitude of things, but is most often interpreted as a warning to other drivers of road hazards. Flashing has also been used to warn of speed traps, and as a form of aggressive driving. The legality of headlight flashing varies by jurisdiction.

History

Headlight flashing first became common among drivers in the mid-1960s, when cars began to come with headlight beam selectors located on the steering column—typically activated by pulling the turn signal stalk—rather than the previous foot-operated pushbutton switches. The signal stalk configuration permitted the incorporation of momentary activation of the high beams regardless of whether the headlamp switch is turned on or off. Thus provided with the means, drivers began to attempt communication with one another by flashing their headlamps.

Uses

Headlight flashing is commonly used to warn other drivers of dangers on the road, such as crashed cars or police speed traps. It can also be used to inform drivers of problems with their car, such as headlamps left off after dark, burned out or misaimed lights, or misuse of high beam rather than low beam in traffic, or to berate a driver who is driving poorly. Headlight flashing coupled with blowing the car's horn can help clear deer from a driver's path. Drivers often flash headlights to indicate the intention to pass another driver, or to signal a driver who has just overtaken that he or she is far enough ahead to change back into the lane of the overtaken vehicle. Flashing is also commonly used to request or insist that a leading driver speed up or change lanes to get out of the way of a faster following driver. Headlight flashing may also be a part of aggressive driving, and can be used in an attempt to intimidate others into speeding or otherwise driving unsafely. Headlight flashing can let other drivers know of one's presence. It may also be an indication of yielding the right-of-way to another driver. Headlight flashing is also commonly used in attempts to warn oncoming drivers of police speed traps in the area. In situations where a driver is warned of police activity in the area, it is sometimes considered

courteous to flash one's lights in response. Headlight flashing may also indicate protest or celebration of an event or position.

Among drivers of certain expensive sports cars, headlight flashes are sometimes used as a greeting to other drivers of the same makes of cars. These flashes are generally restricted to uncommon or sportier cars, or cars that have a particular enthusiast following behind them; although the practice appears to be in decline.

Motorcycle headlamp modulators automatically blink the high beams on and off while the low beam is steadily illuminated, in an effort to make the motorcycle more conspicuous to other drivers.

The use of headlight flashing has been questioned as an effective communication tool between drivers; the ability of drivers to communicate with one another is estimated to be the same as the communication abilities among insects. Researchers say the flashing can have contradictory meaning; it may mean, for example, the driver intends to yield the right of way, or that he intends to take it.

Urban legend

Beginning in the early 1980s, a widespread rumor regarding flashing headlights was spread mainly through fax, and later on the internet. The rumor states that various gangs across the United States carry out an initiation wherein the initiate drives around at night with his headlights off. Whichever driver flashes his headlamps in response to the unlit car becomes the target; to complete the initiation, the prospective gang member must hunt down and shoot, kill, assault, or rape the target. The story was widely spread by many government organizations, including the New Mexico State Police. This rumor has been proven an urban legend.

The story originated in Montana in the early 1980s, where it was rumored that the Hells Angels bike gang was initiating recruits in this way. By 1984, the story had spread to Eugene, Oregon, where it had morphed into a story of Latino and black gangs targeting whites. In August 1993, the story once again appeared, this time spread through fax and email forwarding. Warning of a "blood initiation weekend" on September 25 and 26, the rumor this time compelled some police departments to issue actual warnings after having received the fake ones. In February 1994, Ann Sibila of Massillon, Ohio reinstated the rumor by issuing flyers which claimed that killings would take place at Westfield Belden Village. After a night of sending faxes to local businesses, Sibila was arrested for inducing panic.

The rumor once again spread in October 1998, when a new fax, this time claiming to originate with a Drug Abuse Resistance Education officer in Texas. The rumor spread further when officials in the San Diego government circulated the fax among city agencies; this version of the fax, though quickly dismissed within city government when it was found that the Sheriff's office had no real connection to it, now appeared to be a legitimate government-issued document. Also in the fall of 1998, the Sheriff's office of Nassau County, Florida sent a warning about such gang initiation to the county fire department, who subsequently spread the fax to all county agencies.

Police dispatcher Ann Johnson had thought the message urgent enough to send, but had not bothered to check its legitimacy.

The rumor provided inspiration for the 1998 film *Urban Legend*.

Legality

United States

In the United States, the legality of headlight flashing varies from state to state. Historically, law enforcement officers give citations for headlight flashing under three types of laws: (1) laws prohibiting a person from obstructing a police investigation, (2) laws prohibiting a person from having flashing lights on their vehicle, and (3) laws prohibiting shining a vehicle's high beams at oncoming traffic. The specific language of each law varies by state along with courts' holdings on whether their respective laws prohibit headlight flashing. Additionally, although not legally binding, the state driver's manual of some states suggests flashing high beams under specific scenarios (e.g. if an oncoming vehicle is using its high beams, driver's manuals suggest a motorist flash his or her high beams).

In Alaska, a State Trooper has probable cause to stop a driver who flashes a vehicle's high beams based upon a violation of 13 AAC 04.020(e)(1).

In Arizona, flashing high beams or headlights is a violation of A.R.S. Section 28-942.1 (Failure to Dim Headlights).

In California, headlight flashing is legal in some situations and illegal in others. It is legal for a driver to flash his headlights to indicate intention to pass on a road which does not allow passing on the right. However, headlight flashing on multiple-lane highways is illegal.

Florida state statute indicates that "flashing lights are prohibited on vehicles except as a means of indicating a right or left turn, to change lanes, or to indicate that the vehicle is lawfully stopped or disabled upon the highway". This has been used as a basis for issuing a moving violation with a $90 fine to drivers who flash their headlights to warn oncoming drivers of speed traps; some police and at least one journalist believes that the law applied to those who manually flash their high beams.

In Maryland, police officers ticket drivers for flashing car headlights under a law which prohibits driving in a vehicle with flashing lights and laws prohibiting "obstructing a police investigation". The American Civil Liberties Union of Maryland challenges the current interpretation of the law, contending the law refers to an adjective and not a verb; automatic flashing lights on non-emergency vehicles are illegal, but the act by a driver of flashing a vehicle's headlamps is not. Though ticketing was common in the 1990s, Maryland and Washington, D.C. police say that flashing one's headlights was not against the law in either place.

In Massachusetts, the practice of headlight flashing is technically not forbidden. A clever police officer though can ask a motorist if they were flashing their lights to warn oncoming motorists of

police. If the motorist says no, the officer can ask if the vehicle has defective lights—which is a violation of Massachusetts General Laws Chapter 90, Section 7.

In New Jersey, drivers are allowed to flash their headlights to warn approaching drivers about a speed trap ahead. In 1999, The Superior Court of New Jersey Appellate Division held that a statute limiting how far high beams may project is not violated when a motorist flashes his or her high beams to warn oncoming motorists of radar. The Court also concluded that a stop by a police officer based upon high beam flashing is also improper.

In New York, headlight flashing is not illegal. New York Vehicle and Traffic Law Section 375 requires that headlamps "shall be operated so that dazzling light does not interfere with the driver of the approaching vehicle". In 1994, New York Supreme Court, Appellate Division held that flipping or flicking high beams at approaching vehicles is insufficient to cause the "dazzling lights" prohibited under New York Vehicle and Traffic Law Section 375. In 2009, the New York Supreme Court held that the flashing of lights alone is not a violation of New York Vehicle and Traffic Law Section 375, that stopping a vehicle based upon that is illegal, and all evidence gather as a result of the illegal stop should be suppressed.

In North Dakota, when an oncoming vehicle is within 500 feet, high-beam flashing for any length of time (including momentary flashes) and for any purpose at night is illegal under N.D.C.C. Section 39-21-21.

In Ohio, courts have held that the act of flashing one's headlights so as to alert oncoming drivers of a radar trap does not constitute the offense of obstructing a police officer in the performance of his duties, where there was no proof that the warned vehicles were speeding prior to the warning. In another case, where a driver received a citation under an ordinance prohibiting flashing lights on a vehicle, a court held that the ordinance referred to the noun of flashing lights and did not prohibit the verb of flashing the headlights on a vehicle. In a difference case, a court held that a momentary flick of the high beams is not a violation of Ohio R.C. 4513.15 (which prohibits drivers from aiming glaring rays into the eyes of oncoming drivers).

In Pennsylvania, the Supreme Court of Pennsylvania has ruled that flashing one's highbeams during the day to warn of speed traps is legal.

In Tennessee, flashing headlights to warn oncoming traffic of a police car ahead is protected free speech under the First Amendment to the United States Constitution.

In Virginia, headlight flashing to warn of police activity is not illegal, even though other evasion techniques like radar detectors are outlawed.

In Washington, high beam flashing is illegal. Washington law prohibits flashing one's high beams within 400 feet of another vehicle, including using them to signal for any reason. Under section 46.37.230 of the Revised Code of Washington, flashing one's headlights illegally may result in a $124 traffic infraction.

In Wisconsin, the law allows a vehicle operator to intermittently flash a vehicle's highbeam headlamps at an oncoming vehicle whose highbeam headlamps are lit.

Jamaica

On some occasions, motorists who flashed their headlights to warn of police activity have unwittingly helped fugitives evade police. In 2008, one of Jamaica's most wanted men went around police checkpoints which had been set up on his most likely routes after a driver had flashed his headlights to warn of police ahead. Drivers were warned that flashing headlights may result in "unwittingly facilitating criminal activity".

Australia

Headlight flashing to warn drivers of traffic enforcement cameras is illegal in the Australian State of Queensland, carrying a $30 fine and one demerit point, or a $1500 fine if the fine is unsuccessfully challenged in court. Officers may either fine a driver for improper use of headlights, or may even arrest and prosecute for hindering police.

Canada

In Ontario, the Highway Traffic Act prohibits "flashing head beams". Some have brought tickets to court, claiming the law only regulates the use of alternating lights in an attempt to impersonate emergency and law enforcement vehicles, and not a driver's manually flashing his car's headlamps to communicate with other drivers.

United Kingdom

Though not all of its rules represent law, the Highway Code states "Only flash your headlights to let other road users know that you are there. Do not flash your headlights in an attempt to intimidate other road users".

Chapter- 7

Seat Belt

A 3-point seat belt

A **seat belt** or **seatbelt**, 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 any sudden deceleration, 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 a system, to reduce the force of this final impact.

Types of seatbelt

Lap

A lap ("2-point") belt in an airplane

An adjustable strap that goes over the waist. This type of belt is frequently found in older cars, and has been used, until recently, on some newer vehicles in rear or rear middle seats. These types of belt are also found on some coaches. Passenger aircraft seats also use lap seat belts to help prevent injuries while still allowing passengers to adopt a brace position.

Sash

An adjustable strap that goes over the shoulder. Used mainly in vehicles during the 1960s, however they had limited benefit because it was very easy to slip out of them in a collision.

Three-point

A 3-point seat belt

Similar to the lap and sash belts, but has one single continuous length of belt. 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 first car to feature the three point seat belt however was the 1959 Volvo 122 The three point belt was developed by Nils Bohlin who had earlier also 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 were only often fitted with lap or sash belts. Evidence of the potential of lap belts to

cause separation of the lumbar vertebrae and the sometimes associated paralysis, or "seat belt syndrome", led to a revision of passenger safety regulations in nearly all developed countries, requiring that all seats in a vehicle have to 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.

Besides regulatory changes, "seat belt syndrome" has led to tremendous liability for vehicle manufacturers. One Los Angeles case resulted in a $45 million jury verdict against the Ford Motor Company; the resulting $30 million judgment (after deductions for another defendant who settled prior to trial) was affirmed on appeal in 2006.

Belt-in-Seat (BIS)

A 5-Point harness belt-in-seat on a quad bike

The BIS is a three-point harness where the shoulder belt attachment is to the backrest, not to the b pillar. The first car using this system in the United States was the 1990 Mercedes-Benz SL. Some cars like the Renault Vel Satis use this system for the front seats. This system allegedly is safer in case of rollover, especially with 4–8 years old children, though other sources dispute this claim.

Experimental production car safety belts

- *Criss-cross* Experimental safety belt presented in the Volvo SCC. It forms a cross-brace across the chest.
- *3+2 Point Seatbelt*: Experimental safety belt from Autoliv similar to the criss-cross. The 3+2 improves protection against rollovers and side impacts.
- *Four point "belt and suspenders"*: An experimental design from Ford where the "suspenders" are attached to the backrest, not to the frame of the car.
- *Inflatable Safety Belts*: An airbag is included within the belt for the rear seat belts.

Five-point harnesses

A 6-point harness in a racing car

These restraints are safer but more restrictive than most other seat belt types. Five-point harnesses are typically found in child safety seats and in racing cars. The lap portion is connected to a belt between the legs and there are two shoulder belts, making a total of five points of attachment to the seat. (Strictly speaking, harnesses are never to be fastened to the seat—they should be fastened to the frame/sub-frame of the automobile.)

Six-point harnesses

These harnesses are similar to a five-point harness but include an extra belt between the legs, which is seen by some to be a weaker point than the other parts. These belts are used mainly in racing. In NASCAR, the six-point harness became popular after the death of Dale Earnhardt. Earnhardt was wearing a five-point harness when he suffered his fatal crash. As it was first thought that his belt had broken, some teams ordered a six-point harness in response.

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. While providing redundancy for negative-g maneuvers (which lift the pilot out of the seat), they also require the pilot to un-latch two harnesses if it is necessary to parachute from a failed aircraft.

History

Seat belts were invented by George Cayley in the early 19th century, though Edward J. Claghorn of New York, New York was granted the first patent (U.S. Patent 312,085, on February 10, 1885 for a safety belt). Claghorn was granted United States Patent #312,085 for a Safety-Belt for tourists, painters, fireman, etc. who are being raised or lowered, described in the patent as "designed to be applied to the person, and provided with hooks and other attachments for securing the person to a fixed object."

In 1911, Benjamin Foulois had the cavalry saddle shop fashion a belt for the seat of Wright Flyer Signal Corps 1. He wanted it to hold him firmly in his seat so he could better control his aircraft as he bounded along the rough field used for takeoff and landing. C-130 aircraft in South Vietnam also bounded on runways to the extent that a tight seat belt improved the pilot's ability to control the aircraft. It was not until World War II that seat belts were fully adopted in military aircraft, and even then, it was mainly for safety reasons, not improved aircraft control.

In 1946 Dr. C. Hunter Shelden had opened a neurological practice at Huntington Memorial Hospital in Pasadena, California. In the early 1950s Dr. Shelden had made a major contribution to the automotive industry with his idea of retractable seat belts. This came about greatly in part from the high number of head injuries coming through the emergency rooms. He investigated the early seat belts whose primitive designs were implicated in these injuries and deaths. His findings were published in the November 5, 1955 Journal of the American Medical Association (JAMA) in which he proposed not only the retractable seat belt, but also recessed steering wheels, reinforced roofs, roll bars, door locks and passive restraints such as the now-and-ever-popular air bag. Subsequently in 1959 Congress passed legislation requiring all automobiles to comply with certain safety standards.

American car manufacturers Nash (in 1949) and Ford (in 1955) offered seat belts as options, while Swedish Saab first introduced seat belts as standard in 1958. After the Saab GT 750 was introduced at the New York motor show in 1958 with safety belts fitted as standard, the practice became commonplace.

Glenn Sheren of Mason, Michigan submitted a patent application on March 31, 1955 for an automotive seat belt and was awarded US Patent 2,855,215 in 1958. This was a continuation of an earlier patent application that Mr. Sheren had filed on September 22, 1952.

However, the first modern three point seat belt (the so-called *CIR-Griswold restraint*) used in most consumer vehicles today was patented in 1955 (US Patent 2,710,649) by the Americans Roger W. Griswold and Hugh DeHaven, and developed to its modern form by Nils Bohlin for Swedish manufacturer Volvo—who introduced it in 1959 as standard equipment. Bohlin was granted U.S. Patent 3,043,625 for the device. Bohlin's lap-and-shoulder belt was introduced by Volvo in 1959, in Sweden.

In 1970, the state of Victoria, Australia, passed the first law worldwide making seat belt wearing compulsory for drivers and front-seat passengers.

Technologies

Seat Belt with uncovered Inertial Reel

Most seat belts are equipped with locking mechanisms (or inertia reels) that stop the reel from spinning during decelerative conditions. There are two common types of locking mechanism used: 1) a centrifugal clutch which engages as the reel spins quickly, or 2) by a weighted pendulum or ball bearing: when these are deflected by deceleration or roll-over they lock into pawls on the reel. The most recent forms of inertia reels contain both of these locking mechanisms.

Types of inertia reel type seatbelts:

NLR (no locking retractor): Commonly used in recoiling lap belts

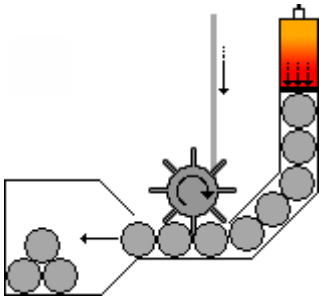
ELR V (emergency locking retractor - vehicle sensitive): Single sensitive mechanism, composed of a locking mechanism activated in an emergency by deceleration or rollover of the vehicle. Thus, the seatbelt is sensitive to the vehicle's motion.

ELR VW (emergency locking retractor - vehicle and webbing sensitive): Dual sensitive means a seatbelt retractor that, during normal driving conditions, allows freedom of movement by the wearer of the seatbelt by means of length-adjusting components that automatically adjust the strap to the wearer, with a locking mechanism that is activated by two or more of the following:

- deceleration or rollover of the vehicle,
- acceleration of the strap (webbing) from the retractor, or
- other means of activation.

A recent study by McCoy & Chou (2007) from the Ford Motor Company (Safety Test Methodology, SP-2123) demonstrated that the standard inertia reel seatbelt does not stop the head from making contact with the interior of the roof on a standard rollover test in their dynamic Rollover Component test System (ROCS). Even with modern pre-tensioning devices the head contacts the interior of the roof and the neck suffers 'visible' compression.

Pretensioners and webclamps



Pyrotechnic pretensioner diagram

Seatbelts in many newer vehicles are also equipped with "pretensioners" and/or "Webclamps".

- Pretensioners preemptively tighten the belt to prevent the occupant from jerking forward in a crash. Mercedes-Benz first introduced pretensioners on the 1981 S-Class. In the event of a crash, a pretensioner will tighten the belt almost instantaneously. This reduces the motion of the occupant in a violent crash. Like airbags, pretensioners are triggered by sensors in the car's body, and most pretensioners use explosively expanding gas to drive a piston that retracts the belt. Pretensioners also lower the risk of "submarining", which is when a passenger slides forward under a loosely worn seat belt. An alternative approach being looked at by major car companies is the CG-Lock technology whereby the occupant is held in position via the lap belt in order to prevent the passenger from coming out of position in the event of a crash.
- Webclamps clamp the webbing in the event of an accident and limit the distance the webbing can spool out (caused by the unused webbing tightening on the central drum of the mechanism) these belts also often incorporate an energy management loop ("rip stitching") which is when the lower part of the webbing is looped and stitched with a special stitching. The function of this

is to "rip" at a predetermined load, which reduces the load transmitted through the belt to the occupant, reducing injuries to the occupant.

Inflatable Seatbelts

Inflatable seatbelts have tubular inflatable bladders contained within an outer cover. When a crash occurs the bladder inflates with a gas to increase the area of the restraint contacting the occupant and also shortening the length of the restraint to tighten the belt around the occupant, improving the protection. The inflatable sections may be shoulder-only or lap and shoulder. The system supports the head during the crash better than a web only belt. It also provides side impact protection. The inflatable seatbelt was invented by Donald Lewis and tested at the Automotive Products Division of Allied Chemical Corp. Ref an early patent US 3,841,654 filed in 1972

Automatic seat belts

Automatic seat belt in a Honda Civic

Seatbelts that automatically move into position around a vehicle occupant once the adjacent door is closed and/or the engine is started were developed as a countermeasure against low usage rates of manual seat belts, particularly in the United States of America. The first car to feature

Automatic Shoulder belts as standard equipment was the 1981 Toyota Cressida, but the history of the belts go back further.

The 1972 Volkswagen ESVW1 Experimental Safety Vehicle presented passive seat belts. Volvo tried to develop a passive three point seatbelt. In 1973 Volkswagen announced they had a functional passive seat belt. The first commercial car to use automatic seat belts was the 1975 Volkswagen Rabbit.

Automatic seat belts received a boost in the United States in 1977 when Brock Adams, United States Secretary of Transportation in the Carter Administration, mandated that by 1983 every new car should have either airbags or automatic seat belts. despite strong lobbying from the auto industry. Adams was attacked by Ralph Nader, who said that the 1983 deadline was too late. Soon after, General Motors began offering automatic seat belts, first on the Chevrolet Chevette, but by early 1979 the VW Rabbit and the Chevette were the only cars to offer the safety feature, and GM was reporting disappointing sales. By early 1978, Volkswagen had reported 90,000 Rabbits sold with automatic seat belts. A study released in 1978 by the United States Department of Transportation claimed that cars with automatic seat belts had a fatality rate of .78 per 100 million miles, compared with 2.34 for cars with regular, manual belts. In 1981, Drew Lewis, the first Transportation Secretary of the Reagan Administration, influenced by studies done by the auto industry, "killed" the previous administration's mandate; the decision was overruled in a federal appeals court the following year, and then by the Supreme Court. In 1984, the Reagan Administration reversed its course, though in the meantime the original deadline had been extended; Elizabeth Dole, then Transportation Secretary, proposed that the two passive safety restraints be phased into vehicles gradually, from vehicle model year 1987 to vehicle model year 1990, when all vehicles would be required to have either automatic seat belts or driver side air bags. Though more awkward for vehicle occupants, most manufacturers opted to use less expensive automatic belts rather than airbags during this time period.

When driver side airbags became mandatory on all passenger vehicles in model year 1994, most manufacturers stopped equipping cars with automatic seat belts. Exceptions include the 1995-1996 Ford Escort/Mercury Tracer and the Eagle Summit Wagon which had automatic safety belts along with dual airbags.

Automatic belt systems

- **Manual lap belt with automatic motorized shoulder belt** — When the door is opened, the shoulder belt moves from a fixed point near the seat back on a track mounted in the door frame of the car to a point at the other end of the track near the windshield. Once the door is closed and the car is started, the belt moves rearward along the track to its original position, thus securing the passenger. The lap belt must be fastened manually.

- **Manual lap belt with automatic non-motorized shoulder belt** — This system was used in American-market vehicles such as the Hyundai Excel and Volkswagen Jetta. The shoulder belt is fixed to the aft upper corner of the vehicle door, and is not motorized. The lap belt must be fastened manually.

- **Automatic shoulder and lap belts** — This system was mainly used in General Motors vehicles, though it was also used on some Honda Civic hatchbacks and Nissan Sentra coupés. When the door is opened, the belts go from a fixed point in the middle of the car by the floor to retractors on the door. Passengers must slide into the car under the belts. When the door closes, the seat belt retracts into the door. The belts have normal release buttons that are supposed to be used only in an emergency, but in practice are routinely used in the same manner as manual seat belt clasps.

Disadvantages

Automatic belt systems generally offer inferior occupant crash protection. In systems with belts attached to the door rather than a sturdier fixed portion of the vehicle body, a crash that causes the vehicle door to open leaves the occupant without belt protection. He or she will in that case be thrown from the vehicle and suffer greater injury or death. Because many automatic belt system designs compliant with the US passive-restraint mandate did not meet the safety performance requirements of Canada—which were not weakened to accommodate automatic belts—vehicle models which had been eligible for easy importation in either direction across the US-Canada border when equipped with manual belts became ineligible for importation in either direction once the US variants got automatic belts and the Canadian versions retained manual belts. Two such models were the Dodge Spirit and Plymouth Acclaim.

Automatic belt systems also present several operational disadvantages. Motorists who would normally wear seat belts must still fasten the manual lap belt, thus rendering redundant the automation of the shoulder belt. Those who do not fasten the lap belt wind up inadequately protected by only the shoulder belt; in a crash without a lap belt such a vehicle occupant is likely to "submarine" (be thrown forward under the shoulder belt) and be seriously injured. Motorized or door-affixed shoulder belts hinder access to the vehicle, making it difficult to enter and exit—particularly if the occupant is carrying items such as a box or a purse. Vehicle owners tend to disconnect the motorized or door-affixed shoulder belt to alleviate the nuisance of entering and exiting the vehicle, leaving only a lap belt for crash protection. Also, many automatic seat belt systems are incompatible with child safety seats, or compatible only with special modifications.

Use of seat belts by child occupants

As with adult drivers and passengers, the advent of seat belts was accompanied by calls for their use by child occupants, including legislation requiring such use. Generally children using adult seat belts suffer significantly lower injury risk when compared to non-buckled children.

The UK extended compulsory seatbelt wearing to child passengers under the age of 14 in 1989. It was observed that this measure was accompanied by a 10% *increase* in fatalities and a 12% *increase* in injuries among the target population. In crashes, small children who wear adult seatbelts can suffer "seat-belt syndrome" injuries including severed intestines, ruptured diaphragms and spinal damage. There is also research suggesting that children in inappropriate restraints are at significantly increased risk of head injury, one of the authors of this research has been quoted as claiming that "The early graduation of kids into adult lap and shoulder belts is a leading cause of child-occupant injuries and deaths." As a result of such findings, many

jurisdictions now advocate or require child passengers to use specially designed child restraints. Such systems include separate child-sized seats with their own restraints and booster cushions for children using adult restraints. In some jurisdictions children below a certain size are forbidden to travel in front car seats."

In rear seats

In 1955 (as a 1956 package) Ford offered lap only seat belts in the rear seats as an option within the *Lifeguard* safety package. In 1967 Volvo started to install lap belts in the rear seats. In 1972 Volvo upgraded the rear seat belts to a three point belt.

In crashes, unbelted rear passengers increase the risk of belted front seat occupants' death by nearly five times.

Reminder chime and light

Examples of warning lights on a car dashboard

In North America, cars sold since the early 1970s have included an audiovisual reminder system consisting of a light on the dashboard and a buzzer or chime reminding the driver and passengers to fasten their belts. Originally, these lights were accompanied by a warning buzzer whenever the transmission was in any position except park if either the driver was not buckled up or, as determined by a pressure sensor in the passenger's seat, if there was a passenger there not buckled up. However, this was considered by many to be a major annoyance, as the light would be on and the buzzer would sound continuously if front-seat passengers were not buckled up. Therefore, people who did not wish to buckle up would defeat this system by fastening the seatbelts with the seat empty and leaving them that way.

By the mid-1970s, auto manufacturers modified the system so that a warning buzzer would sound for several seconds before turning off (with the warning light), regardless of whether the car was started. However, if the driver was buckled up, the light would appear, but with no buzzer. New cars sold in the United States in 1974 and the first part of the 1975 model year were sold with a special "ignition interlock", whereby the driver could not start the car until the seat belt was fastened; however, this system was short-lived.

Today, the belt warning light may stay on for several minutes after the car is started if the driver's seat belt is not fastened.

In Europe and some other parts of the world, most modern cars include a seat-belt reminder light for the driver and some also include a reminder for the passenger, when present, activated by a pressure sensor under the passenger seat. Some cars will intermittently flash the reminder light

and sound the chime until the driver (and sometimes the front passenger, if present) fasten their seatbelts.

Legislation

Observational studies of car crash morbidity and mortality, experiments using both crash test dummies and human cadavers indicate that wearing seat belts greatly reduces the risk of death and injury in the majority of car crashes.

This has led many countries to adopt mandatory seat belt wearing laws. It is generally accepted that, in comparing like-for-like accidents, a vehicle occupant not wearing a properly fitted seat belt has a significantly and substantially higher chance of death and serious injury. One large observation studying using US data showed that the odds ratio of crash death is 0.46 with a three-point belt, when compared with no belt. In another study that examined injuries presenting to the ER pre- and post-seat belt law introduction, it was found that 40% more escaped injury and 35% more escaped mild and moderate injuries.

The effects of seat belt laws are disputed by those who observe that their passage did not reduce road fatalities. There was also concern that instead of legislating for a general protection standard for vehicle occupants, laws that required a particular technical approach would rapidly become dated as motor manufacturers would tool up for a particular standard which could not easily be changed. For example, in 1969 there were competing designs for lap and 3-point seat belts, rapidly-tilting seats, and air bags being developed. But as countries started to mandate seat belt restraints the global auto industry invested in the tooling and standardized exclusively on seat belts, and ignored other restraint designs such as air bags for several decades

Risk compensation

Some have proposed that the number of deaths was influenced by the development of risk compensation, which says that drivers adjust their behavior in response to the increased sense of personal safety wearing a seat belt provides.

In one trial subjects were asked to drive go-karts around a track under various conditions. It was found that subjects who started driving unbelted drove consistently faster when subsequently belted. Similarly, a study of habitual non-seatbelt wearers driving in freeway conditions found evidence that they had adapted to seatbelt use by adopting higher driving speeds and closer following distances. Similar responses have been shown in respect of anti-lock braking system, airbags, and, more recently, the electronic stability control system.

A 2001 analysis of US crash data aimed to establish the effects of seatbelt legislation on driving fatalities and found that previous estimates of seatbelts effectiveness had been significantly overstated. According to the analysis used, seatbelts were claimed to have decreased fatalities by 1.35% for each 10% increase in seatbelt use. The study controlled for endogenous motivations of seat belt use, which it is claimed creates an artificial correlation between seat belt use and fatalities, leading to the conclusion that seatbelts cause fatalities. For example, drivers in high risk areas are more likely to use seat belts, and are more likely to be in accidents, creating a non-

causal correlation between seatbelt use and mortality. After accounting for the endogeneity of seatbelt usage, Cohen and Einav found no evidence that the risk compensation effect makes seatbelt wearing drivers more dangerous, a finding at variance with other research.

Increased traffic

Other statistical analyses have included adjustments for factors such as increased traffic, and other factors such as age, and based on these adjustments, a reduction of morbidity and mortality due to seat belt use has been claimed. However, Smeed's law predicts a fall in accident rate with increasing car ownership and has been demonstrated independently of seat belt legislation.

Chapter- 8

Anti-lock Braking System

An **anti-lock braking system** (**ABS**, from German: ***Antiblockiersystem***) is a safety system that allows the wheels on a motor vehicle to continue interacting tractively with the road surface as directed by driver steering inputs while braking, preventing the wheels from locking up (that is, ceasing rotation) and therefore avoiding skidding.

An ABS generally offers improved vehicle control and decreases stopping distances on dry and slippery surfaces for many drivers; however, on loose surfaces like gravel or snow-covered pavement, an ABS can significantly increase braking distance, although still improving vehicle control.

Since initial widespread use in production cars, anti-lock braking systems have evolved considerably. Recent versions not only prevent wheel lock under braking, but also electronically control the front-to-rear brake bias. This function, depending on its specific capabilities and implementation, is known as electronic brakeforce distribution (EBD), traction control system, emergency brake assist, or electronic stability control (ESC).

History

Early systems

The ABS was first developed for aircraft use in 1929 by the French automobile and aircraft pioneer. These systems use a flywheel and valve attached to a hydraulic line that feeds the brake cylinders. The flywheel is attached to a drum that runs at the same speed as the wheel. In normal braking, the drum and flywheel should spin at the same speed. However, if a wheel were to slow down, then the drum would do the same, leaving the flywheel spinning at a faster rate. This causes the valve to open, allowing a small amount of brake fluid to bypass the master cylinder into a local reservoir, lowering the pressure on the cylinder and releasing the brakes. The use of the drum and flywheel meant the valve only opened when the wheel was turning. In testing, a 30% improvement in braking performance was noted, because the pilots immediately applied full brakes instead of slowly increasing pressure in order to find the skid point. An additional benefit was the elimination of burned or burst tires.

In 1958, a Royal Enfield Super Meteor motorcycle was used by the Road Research Laboratory to test the Maxaret anti-lock brake. The experiments demonstrated that anti-lock brakes can be of great value to motorcycles, for which skidding is involved in a high proportion of accidents. Stopping distances were reduced in most of the tests compared with locked wheel braking, particularly on slippery surfaces, in which the improvement could be as much as 30 percent. Enfield's technical director at the time, Tony Wilson-Jones, saw little future in the system, however, and it was not put into production by the company.

A fully mechanical system saw limited automobile use in the 1960s in the Ferguson P99 racing car, the Jensen FF, and the experimental all wheel drive Ford Zodiac, but saw no further use; the system proved expensive and unreliable in automobile use.

Modern systems

Chrysler, together with the Bendix Corporation, introduced a computerized, three-channel, four-sensor all-wheel ABS called "Sure Brake" for its 1971 Imperial. It was available for several years thereafter, functioned as intended, and proved reliable. In 1971, General Motors introduced the "Trackmaster" rear-wheel only ABS as an option on their Rear-wheel drive Cadillac models. In the same year, Nissan offered an EAL (Electro Anti-lock System) as an option on the Nissan President, which became Japan's first electronic ABS.

ABS brakes on a BMW motorcycle

In 1988, BMW introduced the first motorcycle with an electronic-hydraulic ABS: the BMW K100. Honda followed suit in 1992 with the launch of its first motorcycle ABS on the ST1100 Pan European. In 2007, Suzuki launched its GSF1200SA (Bandit) with an ABS. In 2005, Harley-Davidson began offering ABS as an option for police bikes. In 2008, ABS became a factory-installed option on all Harley-Davidson Touring motorcycles and standard equipment on select models.

Operation

The anti-lock brake controller is also known as the CAB (Controller Anti-lock Brake).

A typical ABS includes a central electronic control unit (ECU), four wheel speed sensors, and at least two hydraulic valves within the brake hydraulics. The ECU constantly monitors the rotational speed of each wheel; if it detects a wheel rotating significantly slower than the others, a condition indicative of impending wheel lock, it actuates the valves to reduce hydraulic pressure to the brake at the affected wheel, thus reducing the braking force on that wheel; the wheel then turns faster. Conversely, if the ECU detects a wheel turning significantly faster than the others, brake hydraulic pressure to the wheel is increased so the braking force is reapplied, slowing down the wheel. This process is repeated continuously and can be detected by the driver via brake pedal pulsation. Some anti-lock system can apply or release braking pressure 16 times per second.

The ECU is programmed to disregard differences in wheel rotative speed below a critical threshold, because when the car is turning, the two wheels towards the center of the curve turn slower than the outer two. For this same reason, a differential is used in virtually all roadgoing vehicles.

If a fault develops in any part of the ABS, a warning light will usually be illuminated on the vehicle instrument panel, and the ABS will be disabled until the fault is rectified.

The modern ABS applies individual brake pressure to all four wheels through a control system of hub-mounted sensors and a dedicated micro-controller. ABS is offered or comes standard on most road vehicles produced today and is the foundation for ESC systems, which are rapidly increasing in popularity due to the vast reduction in price of vehicle electronics over the years.

Modern electronic stability control (ESC or ESP) systems are an evolution of the ABS concept. Here, a minimum of two additional sensors are added to help the system work: these are a steering wheel angle sensor, and a gyroscopic sensor. The theory of operation is simple: when the gyroscopic sensor detects that the direction taken by the car does not coincide with what the steering wheel sensor reports, the ESC software will brake the necessary individual wheel(s) (up to three with the most sophisticated systems), so that the vehicle goes the way the driver intends. The steering wheel sensor also helps in the operation of Cornering Brake Control (CBC), since this will tell the ABS that wheels on the inside of the curve should brake more than wheels on the outside, and by how much.

The ABS equipment may also be used to implement a traction control system(TCS) on acceleration of the vehicle. If, when accelerating, the tire loses traction, the ABS controller can detect the situation and take suitable action so that traction is regained. More sophisticated versions of this can also control throttle levels and brakes simultaneously.

Components

There are four main components to an ABS: speed sensors, valves, a pump, and a controller.

Speed sensors

The anti-lock braking system needs some way of knowing when a wheel is about to lock up. The speed sensors, which are located at each wheel, or in some cases in the differential, provide this information.

Valves

There is a valve in the brake line of each brake controlled by the ABS. On some systems, the valve has three positions:

- In position one, the valve is open; pressure from the master cylinder is passed right through to the brake.
- In position two, the valve blocks the line, isolating that brake from the master cylinder. This prevents the pressure from rising further should the driver push the brake pedal harder.
- In position three, the valve releases some of the pressure from the brake.

Pump

Since the valve is able to release pressure from the brakes, there has to be some way to put that pressure back. That is what the pump does; when a valve reduces the pressure in a line, the pump is there to get the pressure back up.

Controller

The controller is an ECU type unit in the car which receives information from each individual wheel speed sensor, in turn if a wheel loses traction the signal is sent to the controller, the controller will then limit the brakeforce (EBD) and activate the ABS modulator which actuates the braking valves on and off.

Use

There are many different variations and control algorithms for use in an ABS. One of the simpler systems works as follows:

1. The controller monitors the speed sensors at all times. It is looking for decelerations in the wheel that are out of the ordinary. Right before a wheel locks up, it will experience a rapid deceleration. If left unchecked, the wheel would stop much more quickly than any car could. It might take a car five seconds to stop from 60 mph (96.6 km/h) under ideal conditions, but a wheel that locks up could stop spinning in less than a second.
2. The ABS controller knows that such a rapid deceleration is impossible, so it reduces the pressure to that brake until it sees an acceleration, then it increases the pressure until it sees the deceleration again. It can do this very quickly, before the tire can actually significantly change speed. The result is that the tire slows down at the same rate as the car, with the brakes keeping

the tires very near the point at which they will start to lock up. This gives the system maximum braking power.

3. When the ABS system is in operation the driver will feel a pulsing in the brake pedal; this comes from the rapid opening and closing of the valves. This pulsing also tells the driver that the ABS has been triggered. Some ABS systems can cycle up to 16 times per second.

Brake types

Anti-lock braking systems use different schemes depending on the type of brakes in use. They can be differentiated by the number of channels: that is, how many valves that are individually controlled—and the number of speed sensors.

Four-channel, four-sensor ABS

This is the best scheme. There is a speed sensor on all four wheels and a separate valve for all four wheels. With this setup, the controller monitors each wheel individually to make sure it is achieving maximum braking force.

Three-channel, three-sensor ABS

This scheme, commonly found on pickup trucks with four-wheel ABS, has a speed sensor and a valve for each of the front wheels, with one valve and one sensor for both rear wheels. The speed sensor for the rear wheels is located in the rear axle. This system provides individual control of the front wheels, so they can both achieve maximum braking force. The rear wheels, however, are monitored together; they both have to start to lock up before the ABS will activate on the rear. With this system, it is possible that one of the rear wheels will lock during a stop, reducing brake effectiveness.

One-channel, one-sensor ABS

This system is commonly found on pickup trucks with rear-wheel ABS. It has one valve, which controls both rear wheels, and one speed sensor, located in the rear axle. This system operates the same as the rear end of a three-channel system. The rear wheels are monitored together and they both have to start to lock up before the ABS kicks in. In this system it is also possible that one of the rear wheels will lock, reducing brake effectiveness. This system is easy to identify. Usually there will be one brake line going through a T-fitting to both rear wheels.

Effectiveness

A 2003 Australian study by Monash University Accident Research Centre found that ABS:

- Reduced the risk of multiple vehicle crashes by 18 percent,
- Reduced the risk of run-off-road crashes by 35 percent.

On high-traction surfaces such as bitumen, or concrete, many (though not all) ABS-equipped cars are able to attain braking distances better (i.e. shorter) than those that would be easily possible without the benefit of ABS. In real world conditions even an alert, skilled driver without ABS would find it difficult, even through the use of techniques like threshold braking, to match or improve on the performance of a typical driver with a modern ABS-equipped vehicle. ABS reduces chances of crashing, and/or the severity of impact. The recommended technique for non-expert drivers in an ABS-equipped car, in a typical full-braking emergency, is to press the brake pedal as firmly as possible and, where appropriate, to steer around obstructions. In such situations, ABS will significantly reduce the chances of a skid and subsequent loss of control.

In gravel, sand and deep snow, ABS tends to increase braking distances. On these surfaces, locked wheels dig in and stop the vehicle more quickly. ABS prevents this from occurring. Some ABS calibrations reduce this problem by slowing the cycling time, thus letting the wheels repeatedly briefly lock and unlock. Some vehicle manufacturers provide an "off-road" button to turn ABS function off. The primary benefit of ABS on such surfaces is to increase the ability of the driver to maintain control of the car rather than go into a skid, though loss of control remains more likely on soft surfaces like gravel or slippery surfaces like snow or ice. On a very slippery surface such as sheet ice or gravel, it is possible to lock multiple wheels at once, and this can defeat ABS (which relies on comparing all four wheels, and detecting individual wheels skidding). Availability of ABS relieves most drivers from learning threshold braking.

A June 1999 National Highway Traffic Safety Administration (NHTSA) study found that ABS increased stopping distances on loose gravel by an average of 22 percent.

According to the NHTSA,

"ABS works with your regular braking system by automatically pumping them. In vehicles not equipped with ABS, the driver has to manually pump the brakes to prevent wheel lockup. In vehicles equipped with ABS, your foot should remain firmly planted on the brake pedal, while ABS pumps the brakes for you so you can concentrate on steering to safety."

When activated, some earlier ABS systems caused the brake pedal to pulse noticeably. As most drivers rarely or never brake hard enough to cause brake lock-up, and a significant number rarely bother to read the car's manual, this may not be discovered until an emergency. When drivers do encounter an emergency that causes them to brake hard, and thus encounter this pulsing for the first time, many are believed to reduce pedal pressure, and thus lengthen braking distances, contributing to a higher level of accidents than the superior emergency stopping capabilities of ABS would otherwise promise. Some manufacturers have therefore implemented a brake assist system that determines that the driver is attempting a "panic stop" (by detecting that the brake pedal was depressed very fast, unlike a normal stop where the pedal pressure would usually be gradually increased, Some systems additionally monitor the rate at the accelerator was released) and the system automatically increases braking force where not enough pressure is applied. Hard or panic braking on bumpy surfaces, because of the bumps causing the speed of the wheel(s) to become erratic may also trigger the ABS. Nevertheless, ABS significantly improves safety and control for drivers in most on-road situations.

Anti-lock brakes are the subject of some experiments centred around risk compensation theory, which asserts that drivers adapt to the safety benefit of ABS by driving more aggressively. In a Munich study, half a fleet of taxicabs was equipped with anti-lock brakes, while the other half had conventional brake systems. The crash rate was substantially the same for both types of cab, and Wilde concludes this was due to drivers of ABS-equipped cabs taking more risks, assuming that ABS would take care of them, while the non-ABS drivers drove more carefully since ABS would not be there to help in case of a dangerous situation. A similar study was carried out in Oslo, with similar results.