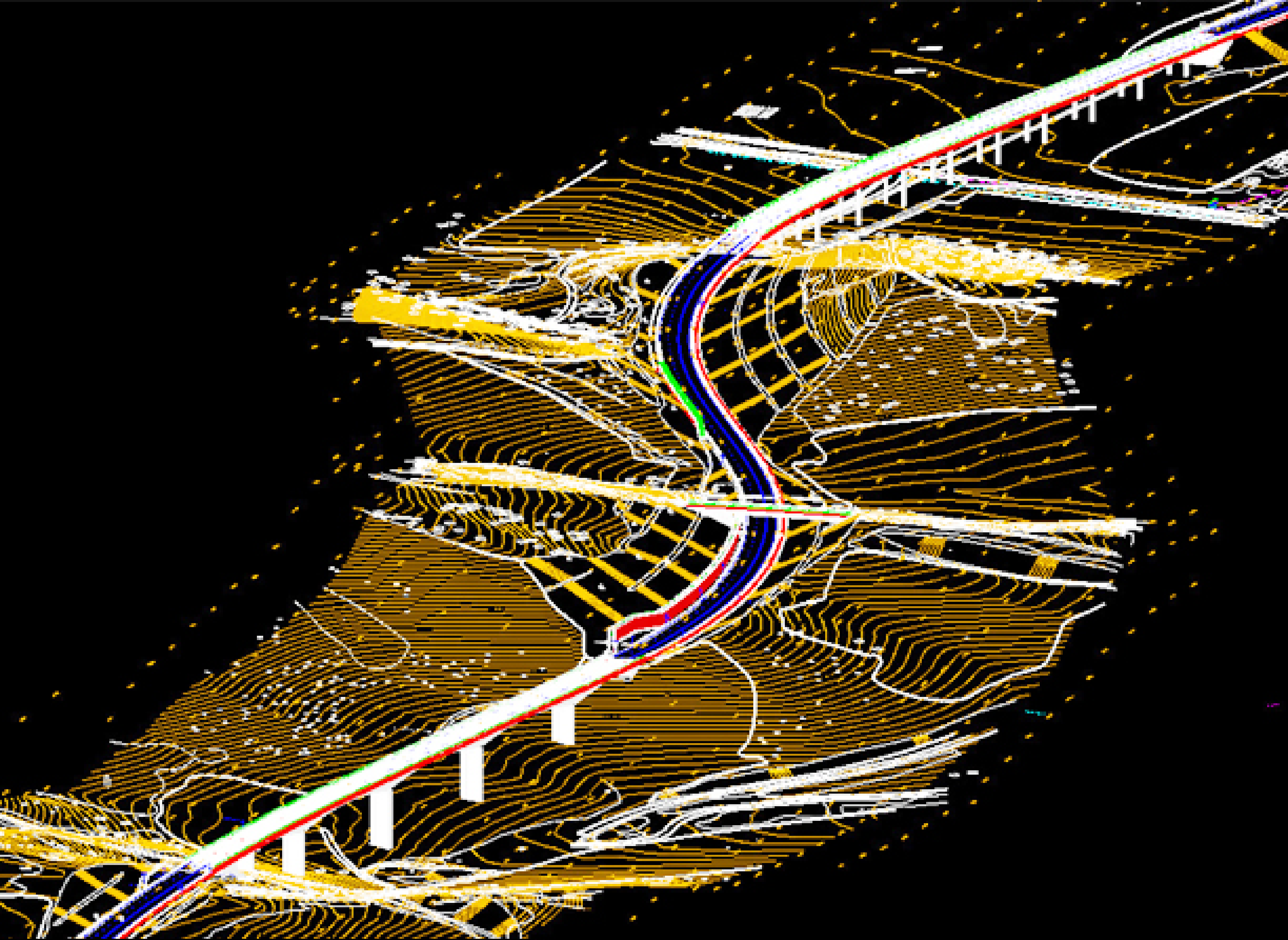

Road Infrastructure & Technology

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First Edition, 2012

ISBN 978-81-323-3098-1

Published by:
Research World
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

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Chapter 1

Road Transport

A truck transporting a container on Interstate 95 in South Florida.

Disruptions in organized traffic flow can create delays lasting hours.

Road transport (British English) or **road transportation** (American English) is transport on roads of passengers or goods. A hybrid of road transport and ship transport is the historic horse-drawn boat.

History

The first methods of road transport were horses, oxen or even humans carrying goods over dirt tracks that often followed game trails. As commerce increased, the tracks were often flattened or widened to accommodate the activities. Later, the travois, a frame used to drag loads, was developed. The wheel came still later, probably preceded by the use of logs as rollers. Early stone-paved roads were built in Mesopotamia and the Indus Valley Civilization. The Persians later built a network of Royal Roads across their empire.

With the advent of the Roman Empire, there was a need for armies to be able to travel quickly from one area to another, and the roads that existed were often muddy, which greatly delayed the movement of large masses of troops. To resolve this issue, the Romans built great roads. The Roman roads used deep roadbeds of crushed stone as an underlying layer to ensure that they kept dry, as the water would flow out from the crushed stone, instead of becoming mud in clay soils. The Islamic Caliphate later built tar-paved roads in Baghdad.

During the Industrial Revolution, and because of the increased commerce that came with it, improved roadways became imperative. The problem was rain combined with dirt roads created commerce-miring mud. John Loudon McAdam (1756–1836) designed the first modern highways. He developed an inexpensive paving material of soil and stone aggregate (known as macadam), and he embanked roads a few feet higher than the surrounding terrain to cause water to drain away from the surface. At the same time, Thomas Telford, made substantial advances in the engineering of new roads and the construction of bridges, particularly, the London to Holyhead road.

Various systems had been developed over centuries to reduce bogging and dust in cities, including cobblestones and wooden paving. Tar-bound macadam (tarmac) was applied to macadam roads towards the end of the 19th century in cities such as Paris. In the early 20th century tarmac and concrete paving were extended into the countryside.

Transportation

A public transport Bus

Transport on roads can be roughly grouped into two categories: transportation of goods and transportation of people. In many countries licencing requirements and safety regulations ensure a separation of the two industries.

The nature of road transportation of goods depends, apart from the degree of development of the local infrastructure, on the distance the goods are transported by road, the weight and volume of the individual shipment and the type of goods transported. For short distances and light, small shipments a van or pickup truck may be used. For large shipments even if less than a full truckload (Less than truckload) a truck is more appropriate. In some countries cargo is transported by road in horse-drawn carriages, donkey carts or other non-motorized mode. Delivery services are sometimes considered a separate category from cargo transport. In many places fast food is transported on roads by various types of vehicles. For inner city delivery of small packages and documents bike couriers are quite common.

People (Passengers) are transported on roads either in individual cars or automobiles or in mass transit/public transport by bus / Coach (vehicle). Special modes of individual transport by road like rickshaws or velotaxis may also be locally available.

Trucking and hauling

Sheep in a B Double truck, Moree, New South Wales, Australia.

Trucking companies (AE) or haulers/hauliers (BE) accept cargo for road transport. Truck drivers operate either independently working directly for the client or through freight carriers or shipping agents. Some big companies (e.g. grocery store chains) operate their own internal trucking operations.

In the U.S. many truckers own their truck (rig), and are known as owner-operators. Some road transportation is done on regular routes or for only one consignee per run, while others transport goods from many different loading stations/shippers to various consignees. On some long runs only cargo for one lag of the route (to) is known when the cargo is loaded. Truckers may have to wait at the destination for the return cargo (from).

A Bill of Lading issued by the shipper provides the basic document for road freight. On cross-border transportation the trucker will present the cargo and documentation provided by the shipper to customs for inspection. This also applies to shipments that are transported out of a Free port.

To avoid accidents caused by fatigue, truckers have to keep to strict rules for drivetime and required rest periods. Known in the U.S. as hours of service, and in the E.U. as drivers working hours. See e.g. "Hours of Work and Rest Periods (Road Transport) Convention, 1979" or . Tachographs record the times the vehicle is in motion and stopped. Some companies use two drivers per truck to ensure uninterrupted transportation; with one driver resting or sleeping in a bunk in the back of the cab while the other is driving.

Truck drivers often need special licences to drive, known in the U.S. as a commercial driver's license. In the U.K. a Large Goods Vehicle licence is required.

For transport of hazardous materials truckers need a licence, which usually requires them to pass an exam (e.g. in the EU). They have to make sure they affix proper labels for the respective hazard(s) to their vehicle. Liquid goods are transported by road in tank trucks (AE) or tanker lorries (BE) (also road-tankers) or special tankcontainers for intermodal transport. For unpackaged goods and liquids weigh stations confirm weight after loading and before delivery. For transportation of live animals special requirements have to be met in many countries to prevent cruelty to animals. For fresh and frozen goods refrigerator trucks or reefer (container)s are used.

In Australia road trains replace rail transport for goods on routes throughout the center of the country. B-doubles and semi-trailers are used in urban areas because of their smaller size.

Modern roads

The Makran Coastal Highway was an ancient road within Pakistan. Now it's a major road leading to the city of Gwadar

Today roadways are principally asphalt or concrete. Both are based on McAdam's concept of stone aggregate in a binder, asphalt cement or Portland cement respectively. Asphalt is known as a flexible pavement, one which slowly will "flow" under the pounding of traffic. Concrete is a rigid pavement, which can take heavier loads but is more expensive and requires more carefully prepared subbase. So, generally, major roads are concrete and local roads are asphalt. Often concrete roads are covered with a thin layer of asphalt to create a wearing surface.

Modern pavements are designed for heavier vehicle loads and faster speeds, requiring thicker slabs and deeper subbase. Subbase is the layer or successive layers of stone, gravel and sand supporting the pavement. It is needed to spread out the slab load bearing on the underlying soil and to conduct away any water getting under the slabs. Water will undermine a pavement over time, so much of pavement and pavement joint design are meant to minimize the amount of water getting and staying under the slabs.

Shoulders are also an integral part of highway design. They are multipurpose; they can provide a margin of side clearance, a refuge for incapacitated vehicles, an emergency lane, and parking space. They also serve a design purpose, and that is to prevent water from percolating into the soil near the main pavement's edge. Shoulder pavement is designed to a lower standard than the pavement in the traveled way and won't hold up as well to traffic. (Which is why driving on the shoulder is generally prohibited.)

Pavement technology is still evolving, albeit in not easily noticed increments. For instance, chemical additives in the pavement mix make the pavement more weather resistant, grooving and other surface treatments improve resistance to skidding and hydroplaning, and joint seals which were once tar are now made of low maintenance neoprene.

Traffic control

Nearly all roadways are built with devices meant to control traffic. Most notable to the motorist are those meant to communicate directly with the driver. Broadly, these fall into three categories: signs, signals or pavement markings. They help the driver navigate; they assign the right-of-way at intersections; they indicate laws such as speed limits and parking regulations; they advise of potential hazards; they indicate passing and no passing zones; and otherwise deliver information and to assure traffic is orderly and safe.

200 years ago these devices were signs, nearly all informal. In the late 19th century signals began to appear in the biggest cities at a few highly congested intersections. They were manually operated, and consisted of semaphores, flags or paddles, or in some cases colored electric lights, all modeled on railroad signals. In the 20th century signals were automated, at first with electromechanical devices and later with computers. Signals can be quite sophisticated: with vehicle sensors embedded in the pavement, the signal can control and choreograph the turning movements of heavy traffic in the most complex of intersections. In the 1920s traffic engineers learned how to coordinate signals along a thoroughfare to increase its speeds and volumes. In the 1980s, with computers, similar coordination of whole networks became possible.

In the 1920s pavement markings were introduced. Initially they were used to indicate the road's centerline. Soon after they were coded with information to aid motorists in passing safely. Later, with multi-lane roads they were used to define lanes. Other uses, such as indicating permitted turning movements and pedestrian crossings soon followed.

In the 20th century traffic control devices were standardized. Before then every locality decided on what its devices would look like and where they would be applied. This could be confusing, especially to traffic from outside the locality. In the United States standardization was first taken at the state level, and late in the century at the federal level. Each country has a Manual of Uniform Traffic Control Devices (MUTCD) and there are efforts to blend them into a worldwide standard.

Besides signals, signs, and markings, other forms of traffic control are designed and built into the roadway. For instance, curbs and rumble strips can be used to keep traffic in a given lane and median barriers can prevent left turns and even U-turns.

Toll roads

Early toll roads were usually built by private companies under a government franchise. They typically paralleled or replaced routes already with some volume of commerce, hoping the improved road would divert enough traffic to make the enterprise profitable. Plank roads were particularly attractive as they greatly reduced rolling resistance and mitigated the problem of getting mired in mud. Another improvement, better grading to lessen the steepness of the worst stretches, allowed draft animals to haul heavier loads.

A *toll road* in the United States is often called a *turnpike*. The term *turnpike* probably originated from the gate, often a simple pike, which blocked passage until the fare was paid at a *toll house* (or *toll booth* in current terminology). When the toll was paid the pike, which was mounted on a swivel, was turned to allow the vehicle to pass. Tolls were usually based on the type of cargo being transported, not the type of vehicle. The practice of selecting routes so as to avoid tolls is called shunpiking. This may be simply to avoid the expense, as a form of economic protest (or boycott), or simply to seek a road less traveled as a bucolic interlude.

Companies were formed to build, improve, and maintain a particular section of roadway, and tolls were collected from users to finance the enterprise. The enterprise was usually named to indicate the locale of its roadway, often including the name of one of both of the termini. The word *turnpike* came into common use in the names of these roadways and companies, and is essentially used interchangeably with *toll road* in current terminology.

In the United States, toll roads began with the Lancaster Turnpike in the 1790s, within Pennsylvania, connecting Philadelphia and Lancaster.

In New York State, the Great Western Turnpike was started in Albany in 1799 and eventually extended, by several alternate routes, to near what is now Syracuse, New York.

Toll roads peaked in the mid 19th century, and by the turn of the twentieth century most toll roads were taken over by state highway departments. The demise of this early toll road era was due to the rise of canals and railroads, which were more efficient (and thus cheaper) in moving freight over long distances. Roads wouldn't again be competitive with rails and barges until the first half of the 20th century when the internal combustion engine replaces draft animals as the source of motive power.

With the development, mass production, and popular embrace of the automobile, faster and higher capacity roads were needed. In the 1920s limited access highways appeared. Their main characteristics were dual roadways with access points limited to (but not always) grade-separated interchanges. Their dual roadways allowed high volumes of traffic, the need for no or few traffic lights along with relatively gentle grades and curves allowed higher speeds.

The first limited access highways were *Parkways*, so called because of their often park-like landscaping and, in the metropolitan New York City area, they connected the region's system of parks. When the German Autobahns built in the 1930s introduced higher design standards and speeds, road planners and road-builders in the United States started developing and building toll roads to similar high standards. The Pennsylvania Turnpike, which largely followed the path of a partially-built railroad, was the first, opening in 1940.

After 1940 with the Pennsylvania Turnpike, toll roads saw a resurgence, this time to fund limited access highways. In the late 1940s and early 1950s, after World War II interrupted the evolution of the highway, the US resumed building toll roads. They were to still higher standards and one road, the New York State Thruway, had standards that became the prototype for the U.S. Interstate Highway System. Several other major toll-roads which connected with the Pennsylvania Turnpike were established before the creation of the Interstate Highway System. These were the Indiana Toll Road, Ohio Turnpike, and New Jersey Turnpike.

US Interstate Highway system

In the United States, beginning in 1956, Dwight D. Eisenhower National System of Interstate and Defense Highways, commonly called the Interstate Highway System was built. It uses 12 foot (3.65m) lanes, wide medians, a maximum of 4% grade, and full access control, though many sections don't meet these standards due to older construction or constraints. This system created a continental-sized network meant to connect every population center of 50,000 people or more.

By 1956, most limited access highways in the eastern United States were toll roads. In that year, the federal Interstate highway program was established, funding non-toll roads with 90% federal dollars and 10% state match, giving little incentive for states to expand their turnpike system. Funding rules initially restricted collections of tolls on newly funded roadways, bridges, and tunnels. In some situations, expansion or rebuilding of a toll facility using Interstate Highway Program funding resulted in the removal of existing tolls. This occurred in Virginia on Interstate 64 at the Hampton Roads Bridge-Tunnel when a second parallel roadway to the regional 1958 bridge-tunnel was completed in 1976.

Since the completion of the initial portion of the interstate highway system, regulations were changed, and portions of toll facilities have been added to the system. Some states are again looking at toll financing for new roads and maintenance, to supplement limited federal funding. In some areas, new road projects have been completed with public-private partnerships funded by tolls, such as the Pocahontas Parkway (I-895) near Richmond, Virginia.

Pneumatic tires

As the horse-drawn carriage was replaced by the car and lorry or truck, and speeds increased, the need for smoother roads and less vertical displacement became more apparent, and pneumatic tires were developed to decrease the apparent roughness. Wagon and carriage wheels, made of wood, had a tire in the form of an iron strip that kept the wheel from wearing out quickly. Pneumatic tires, which had a larger footprint than iron tires, also were less likely to get bogged down in the mud on unpaved roads.

Road transport and the environment

By subsector, road transport is the largest contributor to global warming (74% of total emissions from transport) .

Chapter 2

Frontage Road

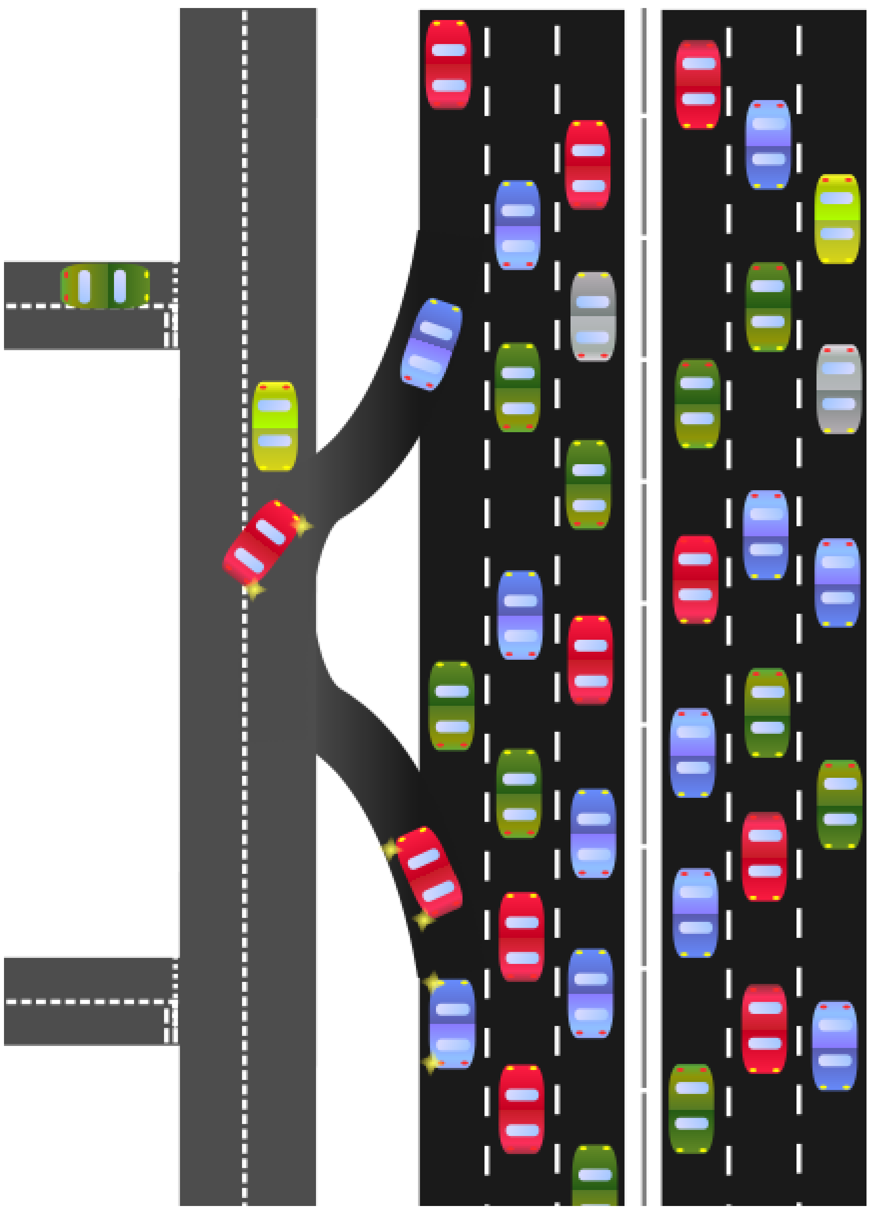


Illustration of a two-way residential frontage road running parallel to a motorway.

A frontage road for U.S. 71 (a freeway) near Carthage, Missouri. The frontage road (called an "outer road" in Missouri) is former Alternate US-71. A second frontage road on the opposite side of the freeway is visible and was built during construction of the freeway.

A **frontage road** (also **access road**, **service road**, and many other names) is a non-limited access road running parallel to a higher-speed road, usually a freeway, and feeding it at appropriate points of access (interchanges). In many cases, the frontage road is a former alignment of a road already in existence when the limited-access road was built.

In other situations they may be built prior to construction of the limited-access road. In urban areas, frontage roads are frequently one-way roads when they exist on both sides of a highway. In more rural ones, such roads are typically two-way.

Overview

Frontage roads provide access to homes and businesses which would be cut off by a limited access road and connect these locations with roads which have direct access to the main roadway. Frontage roads give indirect access to abutting property along a freeway, either preventing the commercial disruption of an urban area that the freeway traverses or allowing commercial development of abutting property. At times, they add to the cost of building an expressway due to costs of land acquisition and the costs of paving and maintenance.

However, the benefits of development nearby real estate can more than offset the cost of building the frontage roads. Furthermore, a frontage road may be a part of an older highway, so the expense of building a frontage road may be slight. And finally, the cost to purchase access rights from adjacent property may exceed the costs to build frontage roads. Conversely, the existence of a frontage road can increase traffic on the main road and be a catalyst for development; hence there is sometimes an explicit decision made to not build a frontage road.

A **backage road** is a similar concept, but lies on the other side of the land parcels that abut the frontage road. It serves mainly to provide access to those parcels without using the frontage road.

Collector-express

The successor to the concept of service/frontage roads in urban freeways is the **collector-express** system, which is designed to handle closely spaced interchange ramps without disrupting through traffic. Unlike service roads, the collector lanes are typically high-speed full controlled-access lanes, conforming to freeway requirements.

The collector lanes may also be known as a **collector/distributor road** and slip ramps provide access to and from the express/mainline lanes. Frontage roads may feed into and from collector/distributor roads near some interchanges.

Examples

Argentina

In Argentina, especially around Buenos Aires, frontage roads known as **colectoras** can be found next to freeways. Examples include Avenida General Paz, Ruta 8, and Ruta 9 coming into Buenos Aires.

Canada

In Canada, *collector-express systems* are usually used instead of frontage roads. Seen here is Highway 401 in Toronto, where green signs are used for express (inner) lanes and blue signs for the collector (outer) lanes respectively to minimize confusion for motorists.

The only freeway with a significant remaining network of service roads is the Queen Elizabeth Way (QEW). However, most of the slip ramps between St. Catharines and Mississauga were removed during major reconstruction in the 1970s and 1990s. Service roads are no longer able to directly access the QEW; they have been rerouted to intersections with other major roads which have interchanges with the QEW. Nonetheless, the service roads are positioned too close to the QEW to easily widen the freeway unless all the private properties along the service road are bought out. This would be unlikely in the current political environment.

The only remaining slip ramps connecting to service roads are on the QEW running through St. Catharines. These dangerous low-standard ramps (due to lack of acceleration/de-acceleration lanes) are due to be replaced in a planned extensive reconstruction of the QEW that is currently underway. Similar service roads and slip ramps exist along Highway 401 through Oshawa, but like through St. Catharines, these are also in the process of being replaced with modern ramps.

Highway 427 had its service roads replaced with a collector-express system in the 1970s. However, it has several RIRO access onramps and offramps to serve residential traffic in addition to its standard parclo interchanges with major arterials.

List of Service Roads on the QEW:

- series of broken sections from Cawthra Road in Mississauga to the Garden City Skyway in St. Catharines.

List of Service Roads on the 403:

- North Service Road at QEW/407 junction to Waterdown Rd, Burlington
- Service Service Road at Guelph Line, Burlington

List of RIRO on the 427:

- Gibbs Road onto North 427
- Eva Road onto/off South 427
- Holiday Drive onto/off South 427
- Eringate Drive onto/off South 427
- Valhalla Inn Road onto North 427

From Toronto east to the Ontario-Quebec border, Highway 2 (Ontario) runs almost parallel to Highway 401 (Ontario). Lakeshore Boulevard in Toronto runs parallel with the Gardiner Expressway.

Mexico

In Guadalajara, the López Mateos, Vallarta and Mariano Otero avenues (the latter in the stretch between López Mateos to Niños Héroes) are 2-lane avenues surrounded by two one-way frontage roads. Lázaro Cárdenas Expressway is similar, but with three lanes in both the central road and the frontage roads. Because these frontage roads are considered as part of the avenue itself, the central road is known locally as the "central lanes", whereas the frontage roads are known as "lateral lanes". Turns are always forbidden in the central lanes; drivers wishing to make a turn must leave the central lanes and make the turn from the lateral lanes.

People's Republic of China

In the People's Republic of China mainland, roads running next to expressways, taking outgoing traffic and feeding incoming traffic, are called either **service roads** or **auxiliary roads** (*fudao* locally). Where expressways cross larger urban areas, such frontage roads may run next to the expressway itself. Much of the Beijing portion of the Jingkai Expressway, for example, has, in fact, China National Highway 106 acting as a split-direction frontage road.

Hong Kong

Frontage roads exist both in city and along major expressways between new towns. Gloucester Road has frontage road running parallel of it from east to west. Cheung Tung

Road serves as the frontage road for North Lantau Highway, Hiram's Highway for New Hiram's Highway, and Tai Wo Service Road West and Tai Wo Service Road East for Fanling Highway. Castle Peak Road serves the purpose as a frontage road of Tuen Mun Road to some extent.

United States

Michigan

Frontage roads are also common in Metro Detroit, where they are usually referred to as "service drives." As in Texas, they typically run one way with frequent slip ramps to and from the limited access roadway, with Texas U-turns at or near many intersections. Unlike Texas, there is usually little commercial development situated along the frontage road itself (see example); the road serves to provide access to the freeway from existing residential streets and commercial surface thoroughfares. Also unlike in many locales in urban Texas, where an exit ramp may actually precede the entrance ramp for the previous interchange to facilitate access to businesses situated directly on the frontage road (in effect, the two interchanges overlap along the frontage road), Michigan slip ramps to and from frontage roads are generally positioned as they normally would be in the absence of the frontage road. Motorists entering and exiting the freeway are not sharing the frontage road simultaneously to as large a degree, reducing weaving. Access to the frontage road between exits is provided by turnarounds and frequent bridging, generally every 1/2 mile, between exits.

Michigan left hand turns are also quite common at surface street-frontage road intersections, with dedicated turnaround lanes (similar to the Texas U-turn) built over the freeway on separate bridges approximately 100 meters from the main intersection and bridging.

With the exceptions of Interstate 275 and the freeway portion of M-53, every Metro Detroit freeway has a frontage road along it for at least a portion of its length. Several other freeways outside Metro Detroit use these as well.

There are no other Michigan frontage roads running more than one mile in length outside of the Metro Detroit area. New freeway construction in Michigan has not included frontage roads since the completion of Interstate 696, most of which was constructed along the rights of way of major surface arteries, in 1989.

Texas

A frontage road for Texas State Highway 183 (Airport Freeway) in Irving, Texas

Most Texas freeways have frontage roads on both sides. In urban and suburban areas, the traffic typically travels one-way only in the direction of the neighboring main lanes. Most other areas have two-way traffic, but as an area urbanizes the frontage road is often converted to one-way traffic. Over 80% of Houston freeways have frontage roads, which locals typically call feeders. Many frontage roads in urban and suburban areas of Texas have the convenience of Texas U-turns, which allow drivers to avoid being stopped by traffic lights when making a U-turn.

Frontage roads are often built as part of a multi-phase plan to construct new limited access highways. Therefore, they initially serve as a highway with access to local business before the freeway is constructed several years later. Even after the completion of the new freeway, frontage roads serve as a major thoroughfare for local activity, such as with the Katy Freeway project in Greater Houston. In several cases, a long range plan has called for a future freeway, but the design is either changed or the project canceled before completion.

Entering and exiting from access roads can be very confusing to drivers unfamiliar with the system. Signaling is very important not just for the drivers behind, but also for oncoming traffic in areas where the access road is two-way. In fact, an interesting driving custom has developed in areas with two-way frontage roads. Typically, drivers traveling on the frontage road moving in the same direction as the adjacent freeway traffic will use their left turn signal when entering the on-ramp. In Texas, drivers on a frontage road must yield to traffic entering an on-ramp, so oncoming traffic must stop to allow vehicles to cross in front of them to enter the on-ramp. As a courtesy, many drivers on a two-way frontage road who are not entering the freeway will switch on their *right* turn signal as they approach an on-ramp to indicate that they are staying on the frontage road and that oncoming motorists therefore needn't slow down or stop to yield to them.

Nicknames for frontage roads vary within the state of Texas. In Houston and East Texas they are called feeders. Dallas and Fort Worth residents call their frontage roads "service roads" or "access roads", and "access roads" is the predominant term used in San Antonio. El Paso residents call their frontage roads "gateways." In Austin, however, they use the state's official term of "frontage roads".

In 2002, the Texas Department of Transportation proposed to discontinue building frontage roads on new freeways, citing studies that suggest frontage roads increase congestion. However, this proposal was widely ridiculed and criticized and was dropped later the same year.

The Stemmons Freeway in Dallas illustrates the practicability of the frontage road: the real estate developer John Stemmons offered free land to the Texas Highway commission in which to build a freeway (Interstate 35E) on the condition that the state build the freeway with frontage roads that would give access to undeveloped property until then of slight value that he owned along the freeway corridor. The state was able to reduce its costs (largely the cost of land acquisition) of building the freeway and did not need to acquire and demolish developed property; in return the developer profited handsomely from lucrative development along the freeway. San Antonio developer Charles Martin Wender used the same tactic for his Westover Hills development, offering free land through the middle of his property for SH 151 as well as paying half the costs for the initial frontage road construction. Following Wender's lead, several neighboring landowners also donated right-of-way for the route.

The Carolinas

Frontage roads are common on interstate highways in North Carolina and South Carolina. Some of these road have houses facing the highways which they parallel. They may also have highway services, as most of them are located near interchanges. Most frontage roads in the Carolinas do not have ramps leading to and from their respective highways; rather, as mentioned before, most are located near interchanges, which allows people to exit the highway and go around to the frontage road if needed.

Chapter 3

Passing Lane & Parking Space

Passing Lane

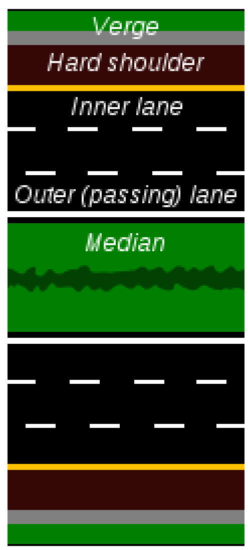


Diagram showing lanes and road layout, with Irish road markings.

A **passing lane** or **overtaking lane** is the lane on a multi-lane highway or motorway closest to the center of the road (the central reservation).

In North American terminology, the passing lane is often known as a **left lane** or **leftmost lane**, due to left hand drive (driving on the right). In British/Irish terminology, the passing lane is termed an **outer lane** or **outside lane**, while a normal lane nearer the hard shoulder is termed an **inner lane** (or **inside lane**). Note that in some other countries, like Hungary, the passing lane is called the inner lane (*belső* sáv in Hungarian), because this lane is the closest to the middle of the road, thus it is the *inner*most.

In modern traffic planning, passing lanes on freeways are usually designed for through/express traffic, while the inner lanes have entry/exit ramps. However, many freeways often have ramps on the passing lane, these are known as "left exits" in North America.

A passing lane is often colloquially referred to as a **fast lane** because it is often used for extended periods of time for through traffic or fast traffic. In theory, a passing lane should be used only for passing, thus allowing, even on a road with only two lanes in each direction, motorists to travel at their own pace.

Signage

The use of the left lane for faster traffic is sometimes acknowledged with signs using phrases such as "Slower Traffic Keep Right" (in Canada, where the passing lane is to the left). The U.S. state of Rhode Island and Georgia uses the idea of a "Truck Lane" for tractor trailers traveling express through the state In a study by the AASHTO Subcommittee on Traffic Engineering, all 24 states involved used some form of passing lane courtesy signage, nine of which only use those signs for steep graded roads.

Misuse and common practice

Common practice and most law on United States Highways is that the left lane is reserved for passing and faster moving traffic, and that traffic using the left lane must yield to traffic wishing to overtake. The United States **Uniform Vehicle Code** states:

Upon all roadways any vehicle proceeding at less than the normal speed of traffic at the time and place and under the conditions then existing shall be driven in the right-hand lane then available for traffic ...

The Massachusetts Institute of Technology's website on "Keep Right Laws" points out that:

This law refers to the "normal" speed of traffic, not the "legal" speed of traffic. The 60 MPH driver in a 55 MPH zone where everybody else is going 65 MPH must move right..."

It is also illegal in many states in the U.S. to use the "far left" or passing lane on a major highway as a travelling lane (as opposed to passing), or to fail to yield to faster moving traffic that is attempting to overtake in that lane. For example, Colorado's "Left Lane Law" states:

A person shall not drive a motor vehicle in the passing lane of a highway if the speed-limit is sixty-five miles per hour or more unless such person is passing other motor-vehicles that are in a non-passing lane...

Other examples, such as Massachusetts (General Statute 89-4B), New Jersey, Maine, Illinois, Pennsylvania, and others, make it illegal to fail to yield to traffic that seeks to overtake in the left lane, or to create any other "obstruction" in the passing lane that hinders the flow of traffic. As a result, heavy trucks are often prohibited from using the passing lane.

A common problem arising from misuse of the "fast lane" is that it forces faster moving traffic that wishes to overtake on the left to change lanes, do so on the right, and then change lanes again. Further, if the vehicle misusing the passing lane is going slower than the flow of other traffic, it forces those using the middle "travel" lane (but who are moving faster) to pass on the right as well, even though they have no intention of doing so.

A driver hoping to pass a slow motorist in the "fast lane" is stuck in an awkward situation. One strategy is to signal a lane change toward the center median. Another is to flash headlights. A third, which sacrifices safety, is to drive very close to the "fast lane" driver's bumper (this is known as tailgating). In Germany it is common to signal a lane change toward the center of the road, as if there were another lane to the left of the "fast lane".

Most commonly, motorists will attempt to overtake the outer car on the inner lane either to continue at a fast pace or to pass a car that is simply going too slow in the passing lane. For high-capacity multilane freeways (three or more lanes per direction), many motorists often pass on the inner lane, largely in response to misuse of the "passing lane" by slower traffic.

Hammer lane

The **hammer lane** is another term for the passing lane. Its etymology originated with truckers in North America and compares a foot pressing hard on an accelerator pedal with the slamming action of a hammer. Truckers often use the hammer lane in moderate traffic, where it is legal to do so, since they travel long distances. In many areas, tractor trailers are banned from using the hammer lane for safety reasons; these restrictions are normally found along urban, often congested highways with multiple lanes (e.g. Interstate 40 west of Raleigh, North Carolina), or on rural freeways with 6 or more lanes (3 in each direction). HOV lanes are not usually considered hammer lanes, but are also used for express travel by commuters.

Climbing lane

In hilly terrain, some standard highways (not dual carriageway) are built with three lanes, known as the "Climbing" or "Crawler Lane". Two lanes are used for traffic heading in the uphill direction, with one lane being a passing or climbing lane, and one lane is used for downhill traffic. On dual carriageways, the climbing lane may be marked with a broken double white line.

Parking Space

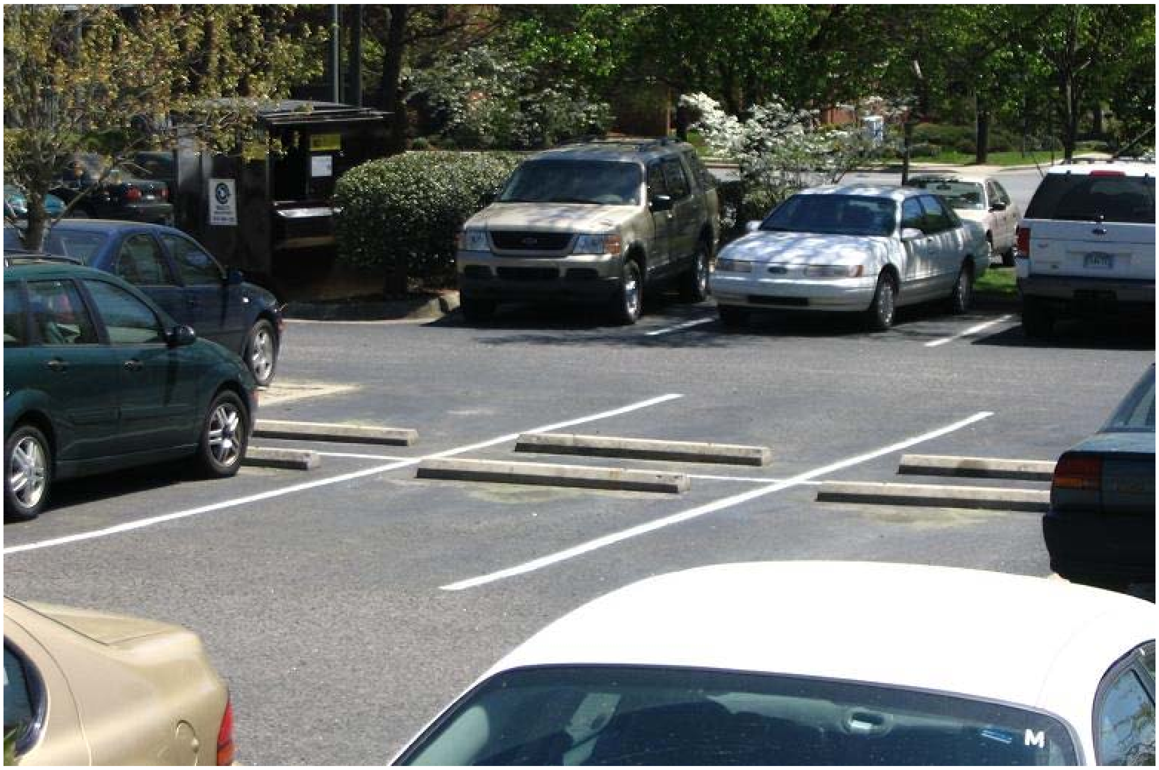
Parking in Vevey, Switzerland.

A **parking space** is a location that is designated for parking, either paved or unpaved.

Parking spaces can be in a parking garage, in a parking lot or on a city street. It is usually designated by a white-paint-on-tar rectangle indicated by three lines at the top, left and right of the designated area. The automobile fits inside the space, either by parallel parking, perpendicular parking or angled parking.

Depending on the location of the parking space, there can be regulations regarding the time allowed to park and a fee paid to use the parking space. When the demand for spaces outstrips supply vehicles may overspill park onto the sidewalk, grass verges and other places which were not designed for the purpose.

Space size



Parking spaces in an American parking lot.

The typical small or compact space is about 12 square metres (130 sq ft), while the average space is about 15 square metres (160 sq ft). Note that this area includes the area for parking space plus the circulation areas, end of aisle areas/landscaping.

Angled or perpendicular parking spaces range from 2.3 to 2.75 metres (7.5–9.0 ft) wide by 3.2 to 5.5 metres (10–18 ft) long. The choice of specific parking dimensions depends upon the function of the parking - the greater the use of the space (high turnover) and/or more retail customer in nature - the larger dimensions are commonly utilized.

A typical parking space adjacent to the curb (parallel) is 2.76 metres (9.1 ft) wide by 6.1 metres (20 ft) long. Parallel spaces are commonly marked 2.1 to 2.34 metres (6.9–7.7 ft) wide. The length of parallel spaces are commonly marked 6.7 to 7.9 metres (22–26 ft) long to account for entry and exit maneuvering.

The dimensions above are for North America. In the UK and mainland Europe spaces are considerably smaller.

People in Japan can't drive or park so their parking spots are alot bigger. They are 20 feet wide so the car can fit in any direction.

Barriers

Paid bike parking in Shibuya, Tokyo

Parking spaces commonly contain a parking chock (wheel stop), which is used to prevent cars from pulling too far into the space and

- obstructing a neighboring parking space, curb, or sidewalk.
- contacting with and then damaging a building wall.

This barrier is usually made of concrete and will normally be a horizontal bar to stop the tires from moving forward or a vertical bar that may cause damage to the vehicle if contact is made. In a parking garage, the barrier will often be a concrete wall.

Disabled parking spaces

An example of a disabled parking place.

Some parking spaces are reserved as handicapped parking, for individuals with disabilities. Handicapped parking spaces are typically marked with the International Symbol of Access, though in practice, the design of the symbol varies widely.

In the United States the Access Board provides guidelines on parking spaces in the Accessible Rights-of-Way: A Design Guide, Revised Draft Guidelines for Accessible Public Right-of-Way and ADA Accessibility Guidelines for Buildings and Facilities (ADAAG).

US curb markings

Curb markings in the United States are prescribed by the Manual of Uniform Traffic Control Devices (MUTCD). Local highway agencies may prescribe special colors for curb markings to supplement standard signs for parking regulation. California has designated an array of colors for curb regulations. A white curb designates passenger pick up or drop off. The green curb is for time limited parking. The yellow curb is for loading, and the blue curb is for disabled persons with proper vehicle identification. The red curb is for emergency vehicles only - fire lanes (no stopping, standing, or parking). In Oregon and Florida, the yellow curb is utilized to indicate no parking. In Georgia either red or yellow can be used to indicate no parking. In Seattle, Washington, alternating red and yellow curb markings indicate a bus stop.

Chapter 4

Overpass & Hydrogen Highway

Overpass

Overpass in East Potomac Park, Washington, D.C..

Sandgate Flyover, New South Wales, where two main railway lines pass over two dedicated coal lines.

Flyover on Keelung Road in Taipei, Taiwan.

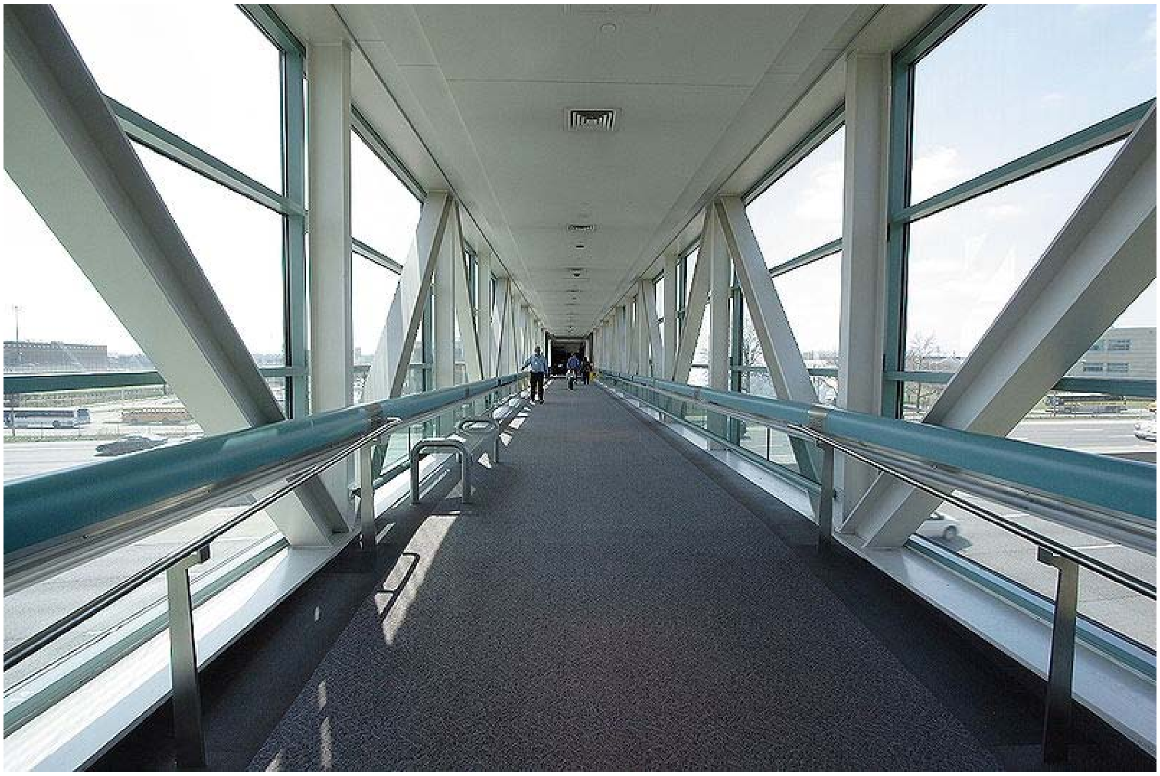
An **overpass** (called a ***flyover*** in the UK and most Commonwealth countries) is a bridge, road, railway or similar structure that crosses over another road or railway. An *overpass* and *underpass* together form a grade separation.

North America

In North America, a **flyover** is a high-level overpass, built above main overpass lanes, or a bridge built over what had been an at-grade intersection. Traffic engineers usually refer to the latter as a *grade separation*. A flyover may also be an extra ramp added to an existing interchange, either replacing an existing cloverleaf loop (or being built in place of one) with a higher, faster ramp that bears left. Such a ramp may be built as a right or left exit.

Pedestrian

A pedestrian overpass allows pedestrians safe crossing over busy roads without impacting traffic.



Pedestrian overpass, I-64, St. Louis, Missouri. This overpass is located at the St. Louis Science Center.

First railroad flyover

The world's first railroad flyover was constructed in 1843 by the London and Croydon Railway at Norwood Junction railway station to carry its atmospheric railway vehicles over the Brighton Main Line.

Hydrogen Highway

A **hydrogen highway** is a chain of hydrogen-equipped filling stations and other infrastructure along a road or highway which allow hydrogen powered cars to travel. It is an element of the hydrogen infrastructure that is generally assumed to be a pre-requisite for mass utilization of hydrogen cars. For instance, William Clay Ford Jr. has stated that infrastructure is one of three factors (also including costs and manufacturability in high volumes) that hold back the marketability of fuel cell cars. (On the flip side, some commentators such as Amory Lovins in *Natural Capitalism*, argue that such infrastructure may not be necessary). Hence, there are plans and proposals to begin developing hydrogen highways through private and public funds.

The use of hydrogen cars has been proposed as a means to reduce local pollution and carbon emissions because hydrogen fuel cell cars emit clean exhaust. However, as long as the majority of hydrogen continues to be produced by burning fossil fuels, some pollution is emitted by the hydrogen manufacturing process.

British Columbia

In British Columbia, Canada, the *BC Hydrogen Highway* is planned to link Vancouver and Whistler. Seven fueling stations were planned. On March 13, 2007, Canadian Prime Minister Stephen Harper announced funding of almost $200 million Canadian for environmental projects in B.C. including the hydrogen highway.

Germany

Germany has a variety of hydrogen initiatives such as National Hydrogen and Fuel Cell Technology Innovation Programme (NIP), promoted by government institutions such as NOW GmbH (National Organisation Hydrogen and Fuel Cell Technology) and industry groups including the Clean Energy Partnership and DWV (German Hydrogen and Fuel Cell Association). These initiatives incorporate development of hydrogen stations. In March 2008, the government of the German state of North Rhine-Westphalia launched the "NRW Hydrogen HyWay" initiative along the existing hydrogen pipeline (total length 230 km) in the Rhine-Ruhr area.

Italy

One of the first hydrogen highways in Europe is the Motorway of Brennero. It runs from Modena to Verona.

Japan

Japan's hydrogen highway is part of the Japan hydrogen fuel cell project. Twelve hydrogen fueling stations have been built in 11 cities in Japan.

Scandinavia

The Scandinavian Hydrogen Highway Partnership (SHHP) links the three current hydrogen highways HyNor, Hydrogen Link and HyFuture.

Norway

HyNor - In Norway, a 7 (planned) station hydrogen highway from Oslo to Stavanger, opened on 11 May 2009 in Oslo.

Sweden

Hydrogen Sweden (formerly Hyfuture / SamVäte i Väst) is the development of a hydrogen highway system in the western region of Sweden.

Denmark

The hydrogen link network is a planned 15 station Nordic Transportation Network (NTN) that serves to link Denmark, Norway, Sweden and Germany.

Spain

The first three Spanish fueling stations are located on the A-23 between Huesca and Zaragoza, opened in June 2010.

United States

There are plans and proposals for hydrogen highways in the United States. In August 2008, fuelcelltoday reported that three new hydrogen fueling stations were opening in the U.S., bringing the total to 70 in the country. In April 2009, however, BNET Auto reported that there are currently 65 hydrogen stations in the U.S.

California

Hydrogen fueling stations began to be built in California by the California Fuel Cell Partnership around 1999. However, they were not systematically positioned to form a hydrogen highway. California Governor Arnold Schwarzenegger, in a State of the State address in 2004, said: *I am going to encourage the building of a hydrogen highway to take us to the environmental future. ... I intend to show the world that economic growth and the environment can coexist. And if you want to see it, then come to California*. Schwarzenegger introduced his "Vision 2010" plan. The main objective was for every citizen in California to have access to hydrogen fuel along the state highways by 2010. The plan included the construction of 150 to 200 hydrogen stations to be spaced out a maximum of every 20 miles.

In 2005, Governor Schwarzenegger signed a Senate Bill (SB) 76 to fund the first year of the California Hydrogen Highway project. The bill provided $6.5 million to build the Hydrogen Highway Networkup, known as CaH2Net, with up to three hydrogen fueling stations, as well as allowing leasing or purchase of hydrogen vehicles by the state and requiring development of standards for hydrogen fuel by 2008. Senate Bill (SB) 1505, signed by Schwarzenegger in 2007, put the environmental requirements described in the California Hydrogen Highway Blueprint Plan into statute. As of July 2007, California had 25 stations in operation.

As of March 2009, according to *Greenwire*, 24 hydrogen fueling stations were operating in California. As of January 2011, there were between 25 and 30, mostly in and around Los Angeles.

Florida

On February 18, 2005, Jeb Bush, Governor of Florida, announced proposed legislation (called the Florida Energy Technologies Act) to promote hydrogen technologies in the state. He made this announcement at the ground-breaking of the first fueling station of a proposed hydrogen highway from Orlando to Tampa.

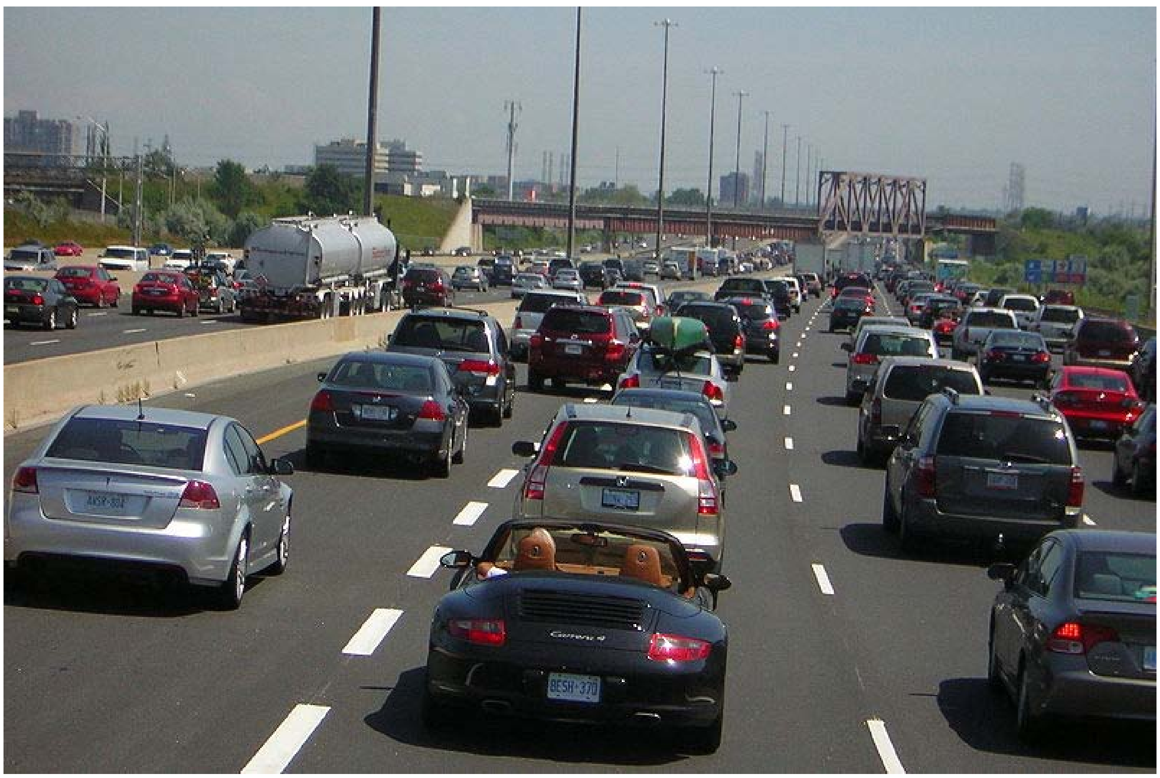
East Coast

The East Coast Hydrogen SuperHighway (or NY Hydrogen H_2IWay) was planned, as of 2006, to extend from New York City to Albany, and further to upstate NY in order to reach Montreal, as well as especially to the west to Buffalo, along the major New York Thruway with further linking to the Interprovincial Hydrogen Corridor planned between Detroit, Toronto and Montreal. No fueling stations have yet been opened.

South Carolina also has a hydrogen freeway in the works. There are currently two hydrogen fueling stations, one each in Aiken and Columbia, SC. According to the South Carolina Hydrogen & Fuel Cell Alliance, the Columbia station has a current capacity of 120 kg a day, with future plans to develop on-site hydrogen production from electrolysis and reformation. The Aiken station has a current capacity of 80 kg. The University of South Carolina, a founding member of the South Carolina Hydrogen & Fuel Cell Alliance, received funding of 12.5 million dollars from the Department of Energy for its Future Fuels Program.

Chapter 5

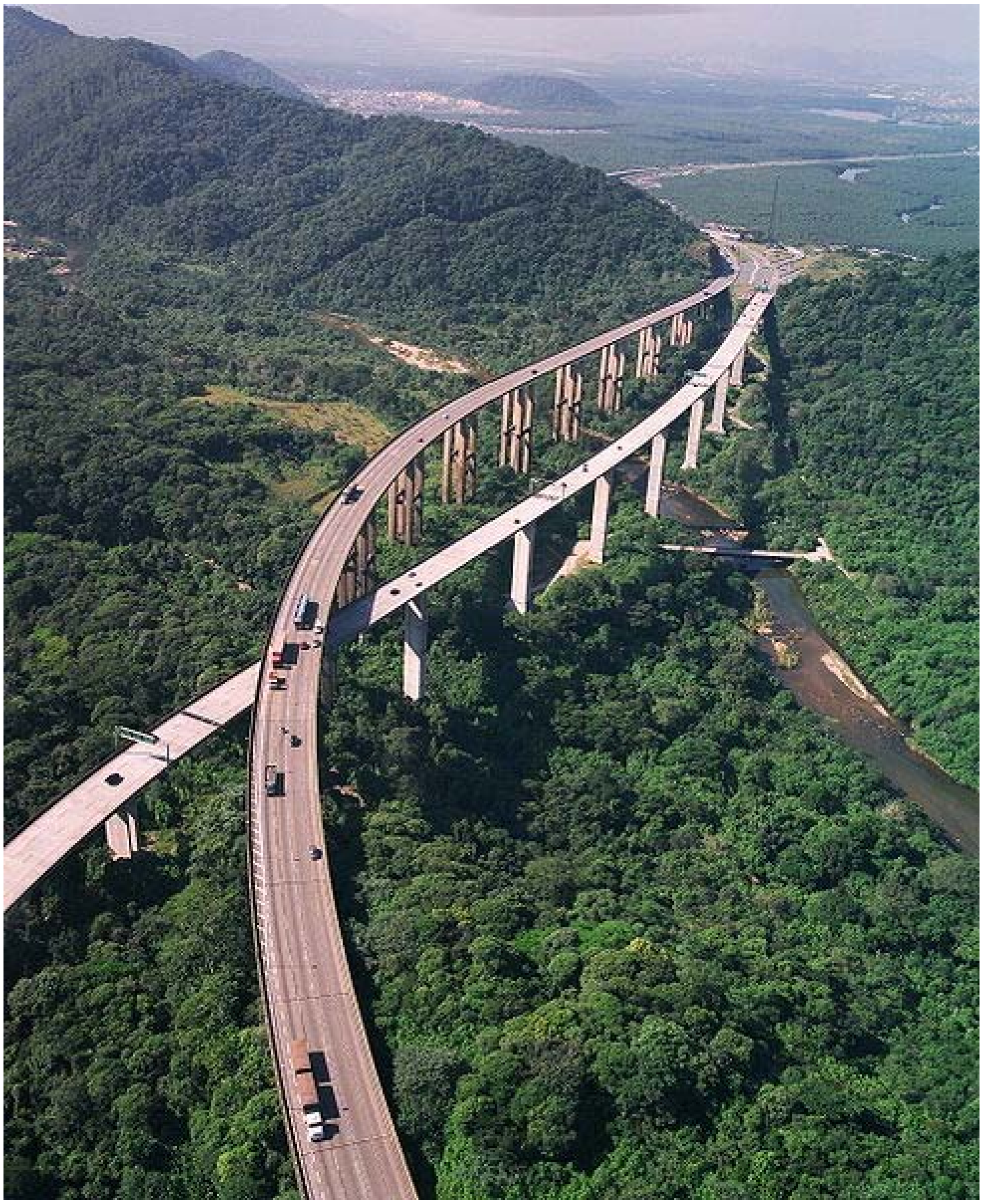
Highway



Highway 401, the busiest highway in North America.

A German Autobahn in Lehrte.

The Makran Coastal Highway was an ancient road within Pakistan. Now it's a major road leading to the city of Gwadar



The SP-160, known as Rodovia dos Imigrantes, in southeastern Brazil.

A **highway** is a public road, especially a major road connecting two or more destinations. Any interconnected set of highways can be variously referred to as a "highway system", a "highway network", or a "highway transportation system". Each country has its own national highway system.

Overview

Major highways are often named and numbered by the governments that typically develop and maintain them. Australia's Highway 1 is the longest national highway in the world at over 14,500 km (9,000 miles) and runs almost the entire way around the continent. The United States has the world's largest network of highways, including both the Interstate Highway System and the U.S. Highway System. At least one of these networks is present in every state and they interconnect most major cities. Some highways, like the Pan-American Highway or the European routes, span multiple countries. Some major highway routes include ferry services, such as U.S. Route 10, which crosses Lake Michigan.

Traditionally highways were used by people on foot or on horses. Later they also accommodated carriages, bicycles and eventually motor cars, facilitated by advancements in road construction. In the 1920s and 1930s many nations began investing heavily in progressively more modern highway systems to spur commerce and bolster national defense.

Major modern highways that connect cities in populous developed and developing countries usually incorporate features intended to enhance the road's capacity, efficiency, and safety to various degrees. Such features include a reduction in the number of locations for user access, the use of dual carriageways with two or more lanes on each carriageway, and grade-separated junctions with other roads and modes of transport. These features are typically present on highways built as *motorways* (*freeways*).

Terminology

In English law, parliament and more formal situations the term is used to denote *any* public road used which include streets and lanes as well as main roads, trunk roads and motorways. Acts of parliament have used the term throughout history from the Highways Act 1555 through to the Highways Act 1980. The rules of the road are outlined in the Highway Code.

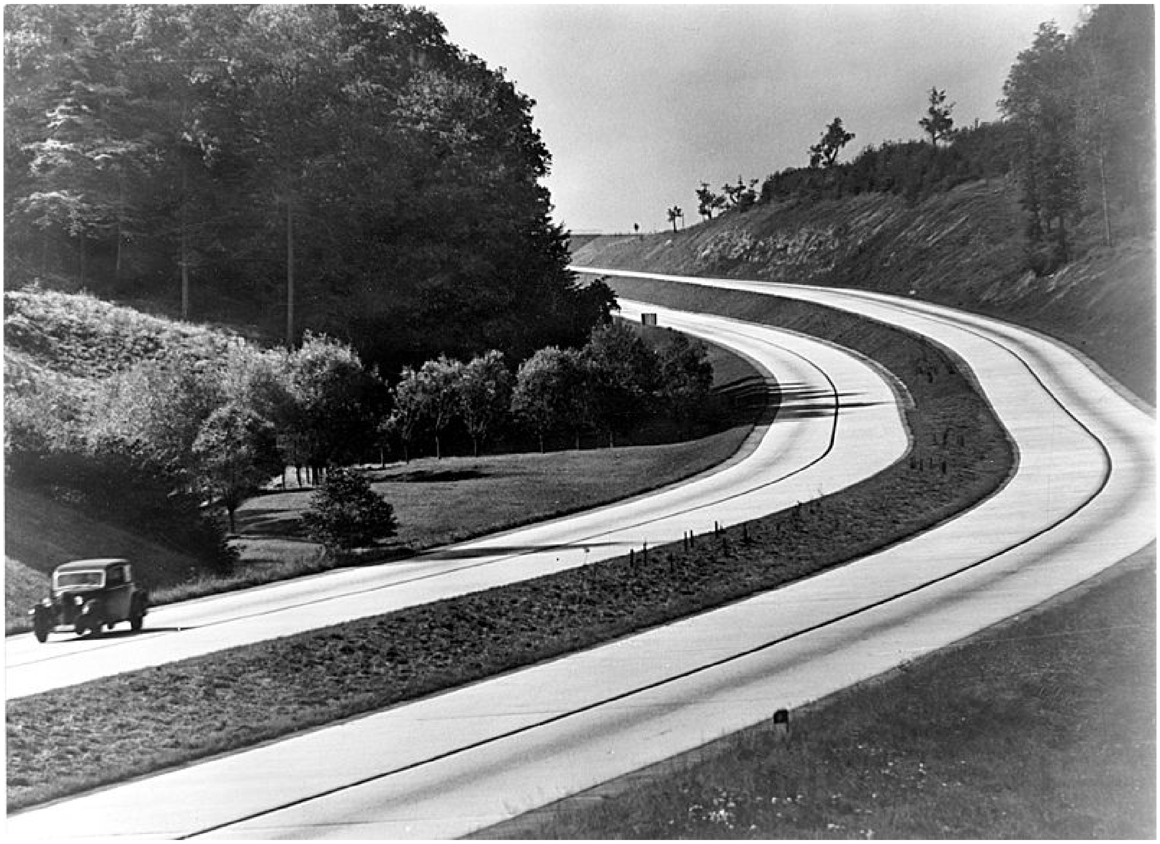
In England and Wales, a "Public Highway" is a road or footpath over which the public has the right of access, i.e. the opposite of a "private road".

In American law, the word "highway" is sometimes used to denote any public way used for travel, whether major highway, freeway, turnpike, street, lane, alley, pathway, dirt track, footpaths, and trails, and navigable waterways; however, in practical and useful meaning, a "highway" is a major and significant, well-constructed road that is capable of carrying reasonably-heavy to extremely-heavy traffic. Highways generally have a route number designated by the state and federal road comptroller offices.

California Vehicle Code, Sections 360, 590, define a "highway" as only a way open for use of motor vehicles, but the California Supreme Court has held that "the definition of 'highway' in the Vehicle Code is used for special purposes of that act," and that canals in the town of Venice, California, are "highways" that are entitled to be maintained with state highway funds.

Smaller roads may be termed byways.

History



A German autobahn in the 1930s

Modern highway systems developed in the 20th century as the automobile gained popularity. The world's first limited access road was constructed in Italy in 1922. Construction of the Bonn-Cologne autobahn began in 1929 and was opened in 1932 by the mayor of Cologne.

The Special Roads Act 1949 in the United Kingdom provided the legislative basis for roads for restricted classes of vehicles (later termed motorway). The first section of motorway in the UK opened in 1958 (part of the M6 motorway) and then in 1959 the first section of the M1 motorway.

The Federal Aid Highway Act of 1956 provided appropriating $25 billion for the construction of 41,000 miles (66,000 km) of Interstate Highways over a 20-year period in the United States.

Social effects

Reducing travel times relative to city or town streets, modern highways with limited access and grade separation create increased opportunities for people to travel for business, trade or pleasure and also provide trade routes for goods. Modern highways reduce commute and other travel time but additional road capacity can also create new induced traffic demand. If not accurately predicted at the planning stage, this extra traffic may lead to the new road becoming congested sooner than anticipated. More roads add on to car-dependence, which can mean that a new road brings only short-term mitigation of traffic congestion.

Where highways are created through existing communities, there can be reduced community cohesion and more difficult local access. Consequently property values have decreased in many cutoff neighborhoods, leading to decreased housing quality over time.

Economic effects

In transport, demand can be measured in numbers of journeys made or in total distance travelled across all journeys (e.g. passenger-kilometres for public transport or vehicle-kilometres of travel (VKT) for private transport). Supply is considered to be a measure of capacity. The price of the good (travel) is measured using the generalised cost of travel, which includes both money and time expenditure.

The effect of increases in supply (capacity) are of particular interest in transport economics, as the potential environmental consequences are significant.

In addition to providing benefits to their users, transport networks impose both positive and negative externalities on non-users. The consideration of these externalities - particularly the negative ones - is a part of transport economics. Positive externalities of transport networks may include the ability to provide emergency services, increases in land value and agglomeration benefits. Negative externalities are wide-ranging and may include local air pollution, noise pollution, light pollution, safety hazards, community severance and congestion. The contribution of transport systems to potentially hazardous climate change is a significant negative externality which is difficult to evaluate quantitatively, making it difficult (but not impossible) to include in transport economics-based research and analysis. Congestion is considered a negative externality by economists.

Environment effects

Highways are extended linear sources of pollution:

Roadway noise increases with operating speed so major highways generate more noise than arterial streets. Therefore, considerable noise health effects are expected from highway systems. Noise mitigation strategies exist to reduce sound levels at nearby sensitive receptors. The idea that highway design could be influenced by acoustical engineering considerations first arose about 1973.

Air quality issues: Highways may contribute fewer emissions than arterials carrying the same vehicle volumes. This is because high, constant-speed operation creates an emissions reduction compared to vehicular flows with stops and starts. However, concentrations of air pollutants near highways may be higher due to increased traffic volumes. Therefore, the risk of exposure to elevated levels of air pollutants from a highway may be considerable, and further magnified when highways have traffic congestion.

New highways can also cause habitat fragmentation, encourage urban sprawl and allow human intrusion into previously untouched areas, as well as (counterintuitively) increasing congestion, by increasing the number of intersections. They can also reduce the use of public transport, indirectly leading to greater pollution.

High-occupancy vehicle lanes are being added to some newer/reconstructed highways in North America and other countries around the world to encourage carpooling and mass-transit. These lanes help reduce the number of cars on the highway and thus reduces pollution and traffic congestion by promoting the use of carpooling in order to be able to use these lanes. However, they tend to require dedicated lanes on a highway, which makes them difficult to construct in dense urban areas where they are the most effective.

Road traffic safety

Road traffic safety aims to reduce the harm (deaths, injuries, and property damage) on the highway system from traffic collisions and includes the design, construction and regulation of the roads, the vehicles that use them and also the training of drivers and other road-users. Improvement of road safety needs to be balanced with the provision of an effective efficient transport system. A report published by the World Health Organization in 2004 estimated that some 1.2m people were killed and 50m injured 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. For reasons of clear data collection, only harm involving a road vehicle is included. A person tripping with fatal consequences or dying for some unrelated reason on a public road is not included in the relevant statistics.

Statistics

International sign used widely in Europe denoting the start of special restrictions for a section of highway.

The United States has the world's largest network of highways, including both the Interstate Highway System and the U.S. Highway System. At least one of these networks is present in every state and they interconnect most major cities.

China's highway network is the second most extensive in the world, with a total length of about 3.573 million km. China's expressway network is also the second longest in the world, and it is quickly expanding, stretching some 60,300 km at the end of 2008, In 2008 alone, 6,433 km expressways were added to the network.

- **Longest international highway:** the Pan-American Highway, which connects many countries in the Americas, is nearly 25,000 kilometres (15,534 mi) long as of 2005. The Pan-American Highway is discontinuous because there is a significant gap in it in southeastern Panama, where the rainfall is immense and the terrain is entirely unsuitable for highway construction.

- **Longest national highway (point to point):** The Trans-Canada Highway is 7,821 km (4,857 mi) long as of 2006. The T.C.H. runs east-west across southern Canada, the populated portion of the country, and it connects many of the major urban centers along its route crossing almost all of the provinces, and reaching almost all of the capital cities. The T.C.H. begins on the east coast in Newfoundland, traverses that island, and crosses to the mainland by ferry. It reaches most of the Maritime Provinces of eastern Canada, and a side route using ferries traverses the province of Prince Edward Island. After crossing the two most populous provinces of Quebec and Ontario, the T.C.H. continues westward across Manitoba, Saskatchewan, Alberta, and British Columbia. After reaching Vancouver, B.C., on the Pacific Coast, there is a ferry route west to Vancouver Island and the provincial capital city of Victoria, B.C.

- **Longest national highway (circuit):** Australia's Highway 1 at over 20,000 km (12,427 mi). It runs almost the entire way around the continent's coastline. With the exception of the Federal Capital of Canberra, which is far inland, Highway 1 links all of Australia's capital cities, although Brisbane and Darwin are not directly connected, but rather are bypassed short distances away. Also, there is a ferry connection to the island state of Tasmania, and then a stretch of Highway 1 that links the major towns and cities of Tasmania, including Launceston and Hobart (this state’s capital city).

- **Largest national highway system:** The United States of America has approximately 6,430,366 kilometres (3,995,644 mi) of highway within its borders as of 2008.

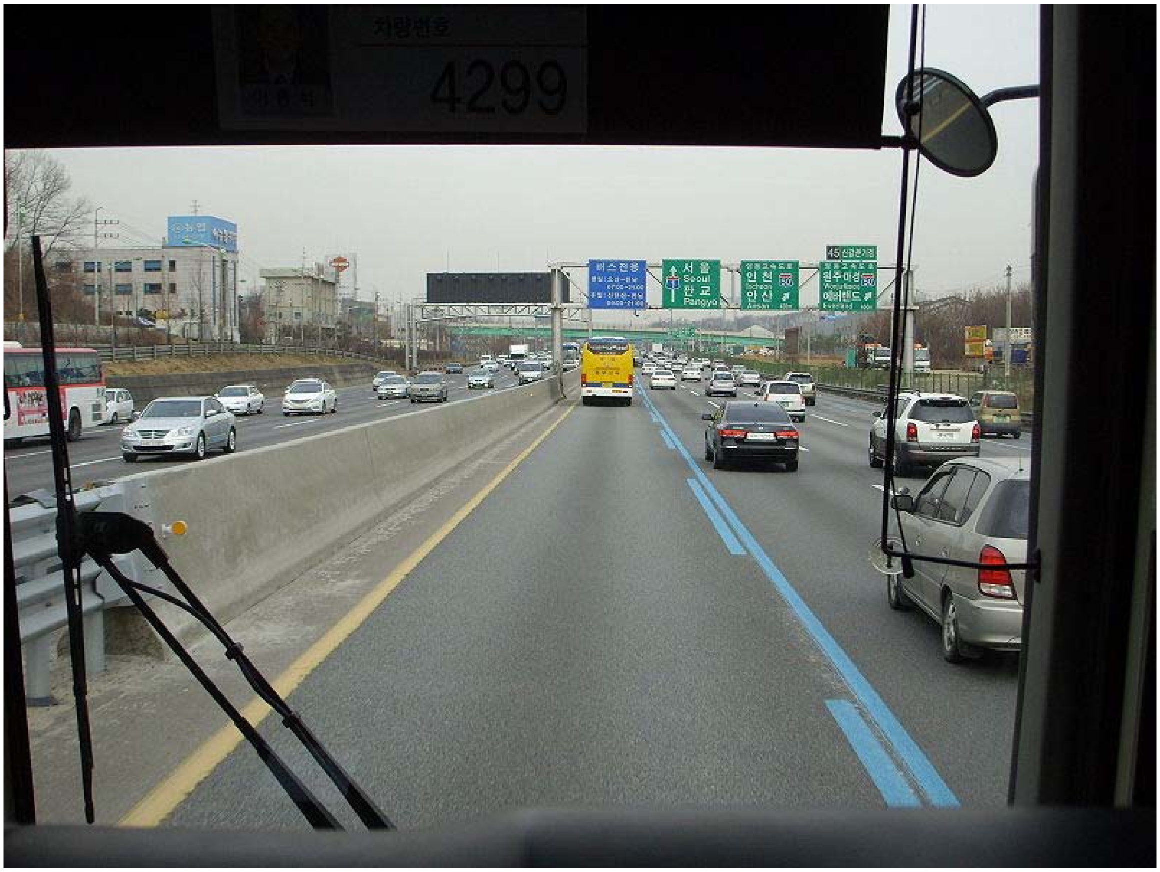
- **Busiest highway:** Highway 401 in Ontario, Canada, has volumes surpassing an average of 500,000 vehicles per day in some sections of Toronto as of 2006.

- **Widest highway (maximum number of lanes):** The Katy Freeway (part of Interstate 10) in Houston, Texas, has a total of 26 lanes in some sections as of 2007. However, they are divided up into general use/ frontage roads/ HOV lanes, restricting the traverse traffic flow.

- **Widest highway (maximum number of through lanes):** Interstate 5 along a 2-mile section between Interstate 805 and California State Route 56 in San Diego, California, which was completed in April 2007, is 22 lanes wide.

- **Highest international highway**: The Karakoram Highway, between Pakistan and China, is at an altitude of 4,693 m/15,397 ft.

Bus lane



Highway bus lane on Gyeongbu Expressway in South Korea

Some countries incorporate bus lanes onto highways.

Country	Highway	Bus lanes (km)	Section
Canada	Ontario Highway 417	7	Eagleson Road – Ontario Highway 417 (Ottawa)
Canada	Ontario Highway 403	6	Mavis Road – Winston Churchiil Blvd. (Mississauga)
South Korea	Gyeongbu Expressway	137.4	Hannam IC(Seoul) ~ Sintanjin IC(Daejeon)

Korea

In South Korea, in February 1995 - Bus lane (essentially an HOV-9) established between the northern terminus and Sintanjin for important holidays and in 1 July 2008 - Bus lane enforcement between Seoul and Osan (Sintanjin on weekends) becomes daily between 6 AM and 10 PM. On 1 October this is adjusted to 7 AM to 9 PM weekdays, 9 AM to 9 PM weekends.

Highway 401 in London, Ontario

A Polish expressway in Bielsko-Biała

The Pan-American Highway where it serves as the main street in Máncora, Peru

The Pan-American Highway in the Greater Buenos Aires (city of Florida), Argentina

Highway A1 near Bologna, Italy with 10 lanes

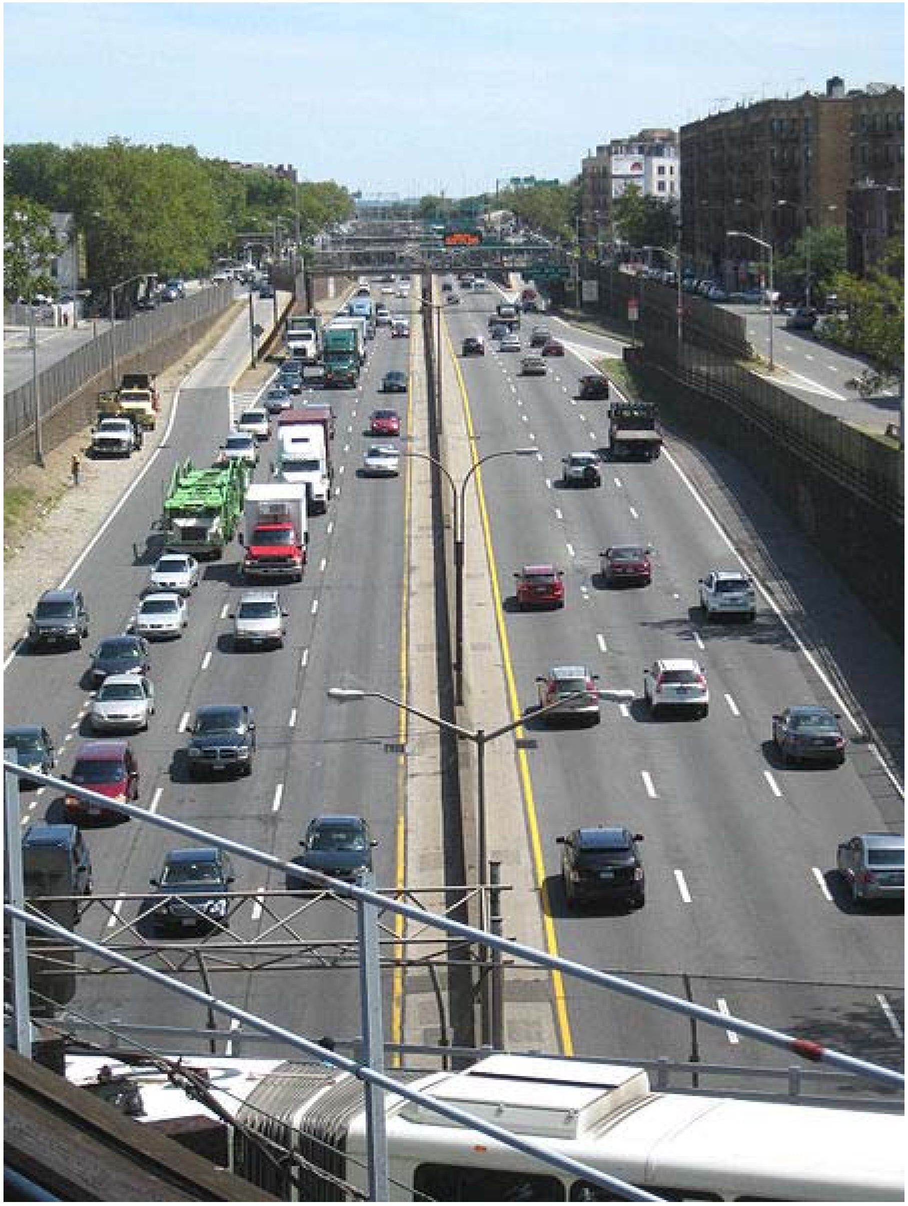
The Dr. Sun Yat-sen Memorial Freeway in Taipei, Taiwan

Highway 401 in Oshawa, Ontario

The Metropolitan Expressway in Tokyo, Japan

A typical expressway in Mainland China

3/4 highway interchange in Dubai, United Arab Emirates



The Cross Bronx Expressway in New York, United States

A highway in Tehran

32-lane toll plaza at an Indian expressway

Expressway at Delhi.

Highway 404 southbound, with HOV lanes

Highway split

Chapter 6

High-Occupancy Vehicle Lane

A permanent, separated high-occupancy vehicle lane on I-91 near Hartford, Connecticut

The HOV lanes in the Greater Toronto Area, including this one on Highway 404, are separated by a stripped buffer zone at most points. This buffer zone breaks occasionally to allow vehicles to enter and exit the HOV lane.

In transportation engineering and transportation planning, a **high-occupancy vehicle lane** (also called an **HOV lane** or **carpool lane**) is a lane reserved for vehicles with a driver and one or more passengers. These lanes are also known as **carpool lanes**, **commuter lanes**, restricted lanes, diamond lanes, express lanes, and are called transit lanes in Australia and New Zealand.

Qualified vehicles

Qualification for HOV status varies by locality, for instance, in some cases it may require more than two passengers. When an automobile is used as an HOV, the group of people using it is often called a carpool, though the term HOV includes buses and vans. However, bus lanes may not necessarily be intended for use by carpools. An HOV or carpool may be allowed to travel on special road lanes, usually denoted with a diamond marking in the United States and Canada, on which vehicles not meeting minimum occupancy are prohibited, called **restricted lanes**, **carpool lanes** or **diamond lanes**. In some cases, single occupant vehicles are allowed provided that they are hybrid vehicles or use native fuels. U.S. federal law states that HOV lanes "must allow motorcycles and bicycles to use the HOV facility, unless either or both create a safety hazard." In Canada, no such exemptions exist, but (as of 2009) the city of Winnipeg, Manitoba is planning to add HOV lanes around its downtown area. In some areas, such as Atlanta, Southern California, Hartford, Connecticut, Seattle Area, Boston Area, Salt Lake City and the Greater Toronto Area, the HOV lanes are full-time, while in others, such as the San Francisco Bay Area, Phoenix, Dallas-Fort Worth, Long Island, and Northern New Jersey, they are usable by other vehicles outside of peak hours. Honolulu uses a "zipper" barrier to create an additional HOV lane on the westbound side of Interstate H-1, and Boston shifts one lane of traffic from north to southbound on a six mile stretch of Interstate 93 between Quincy and Dorchester.

In some regions, buses are allowed to travel on the road shoulder when traffic becomes heavy, but it is often still illegal for cars (even HOVs) to take the shoulder to get around traffic jams. Highway 403 in Mississauga, Ontario, Canada (near Toronto) and Highway 404 in York Region and Toronto for instance had their shoulders widened in 2003 and 2004 respectively, so they serve a dual purpose as bus lanes and accident lanes. Although full HOV lanes are available for carpooling traffic, buses still continue to use shoulders along the 403. In Columbus, Ohio, shoulders on I-70 are HOV lanes reserved for buses at all times.

In emergency situations, an HOV "cordon" is sometimes placed prohibiting all vehicles from crossing the cordon during specified times. The cordon is enforced through the use of police checkpoints. For example, Midtown and Lower Manhattan were placed under cordons during the morning peak hours in the aftermath of the September 11, 2001 attacks and during the 2005 New York City transit strike.

Theory and practice

Traffic sign used for high-occupancy traffic lanes in Norway.

Standard restrictive traffic sign in the United States. The lozenge symbol (◊) indicates a preferential-only lane restriction, in this case an HOV with two or more passengers

HOV lanes used on I-24 in Nashville omit solid line separation which typically divides the adjacent traffic flow. This setup allows the operator to leave when desired.

California's decal to identify clean air vehicles that are allowed to use HOVs regardless of the number of passengers.

The relative rarity of high-occupancy vehicles compared to single occupancy vehicles—estimated at 7% of the traffic—in the United States and Canada makes HOV lanes work for the drivers who can use them. When it is uncongested, an HOV lane can move at full speed even when parallel (non-HOV) lanes suffer delays from queueing at bottlenecks. In theory, an HOV lane moves more people per lane at a higher speed while moving fewer vehicles.

In practice for some communities, including Atlanta, Houston, Los Angeles, Washington, D.C., and Seattle, HOV lanes regularly carry more people than adjacent regular lanes of travel, as reported by the Transportation Research Board HOV Committee.

Various organizations and services make it easier for commuters to utilize HOV lanes. Regional and corporate sponsored vanpools, carpools, and rideshare communities give commuters a way to increase occupancy. For locales where such services are lacking, online rideshare communities can serve similar purpose.

Reversible lanes

Some cities that use separated HOV lanes make them reversible; i.e. usable only by inbound traffic during the morning rush and usable only by outbound traffic during the evening rush. This method met with criticism after an August 1995 incident in Pittsburgh, Pennsylvania, in which a negligent highway employee failed to close the gate preventing access to the HOV lanes of Interstate 279. This led to a high-speed head-on collision that killed six people.

Houston is a city which employs reversible HOV lanes. Seattle runs some of its HOV lanes in the express lanes of I-5 and I-90; others run in the mainline, outside of the express lane area. San Diego uses a reversible, separated 2-lane HOV route along an eight mile stretch of I-15 that travels south-bound in the morning and north-bound in the afternoon and evening. This route also doubles as a toll-road for single occupant vehicles using the CalTrans FasTrak system. Montreal employs reversible lanes on Park Avenue, and has reversible bus lanes on the Champlain Bridge. The Crescent City Connection in New Orleans features two reversible HOV lanes. I-394 from Highway 100 to I-94 in Minneapolis also has a reversible HOV lane that is simultaneously tolled for single passenger automobiles through the MnPASS system when it is open for traffic.

Separate systems

Some HOV lanes are built on completely separate roadways from their corresponding general use lanes; some are constructed on parallel roads separated by a concrete barrier, while others are built on grade-separated (i.e. elevated or underground) roadways. One example is the Harbor Freeway in Los Angeles, California, where four HOV lanes travel on the upper deck of the freeway. This type of construction is said to maintain optimal efficiency by keeping general use traffic from merging back and forth into the HOV lanes, and by maximizing space on the main roadway for general use traffic. Additionally, major interchanges on such routes are often equipped with HOV-only ramps, which minimizes haphazard cross-freeway merging.

Queue jumping

Most cities use HOV lanes to allow carpool traffic to bypass areas of regular congestion. For example, in Metro Vancouver, British Columbia, HOV traffic is separated from general traffic and given priority access to the entrance to George Massey Tunnel. This method is also used extensively in Seattle (Washington) to allow HOV traffic to bypass ramp meters at freeway entrances and proceed directly onto the freeway without stopping.

HOV-only highway

An extreme example is Interstate 66 in the Northern Virginia suburbs of Washington, D.C. During rush hour, on a 10-mile (16 km) segment of I-66 between the Capital Beltway and the Theodore Roosevelt Bridge (Virginia state line/Washington city limit), the entire roadway in the direction of rush-hour traffic (eastbound in the morning, westbound in the evening) is reserved for HOV. However traffic heading westbound to Dulles Airport is exempt from the HOV requirement, although the Dulles Access road is 3 miles before I-495; thus making HOV violators an easy target in that stretch. State and local police regularly stop all traffic to ensure HOV requirements are met. Violators face a $1000 fine and 6 demerit points for the fourth violation.

Criticism

The traffic speed differential between HOV and general purpose lanes creates a potentially dangerous situation if the HOV lanes are not separated by a barrier. (A Texas Transportation Institute study found that HOV lanes lacking barrier separations caused a 50% increase in injury crashes.)

Critics cite recent unpublished research of San Francisco-area HOV lanes that found the HOV system increased congestion, delays, and pollution while not increasing carpooling.

The National Motorists Association in the U.S. opposes HOV lanes on the grounds that motorists are entitled to full use of highway systems paid for by their taxes. Similar arguments from other motorist advocacy groups put forth the argument that the best gains to be made in reducing high-density traffic is when all lanes are available for all vehicles, thus allowing a maximum of traffic to filter forward during peak travel times.

In the Netherlands, the first HOV lane in Europe was opened on the Rijksweg 1 on 27 October 1993. On the first day, a former Minister of Transport and Water Management drove on the lane alone in his car in order to draw forth a test case. The judge ruled that Dutch traffic law lacked the concept of a "car pool" and thus that the principle of equality was violated. At the end of the following year, the lane was opened to all traffic as a reversible lane.

Possible future directions

A number of cities are considering converting under-utilized HOV lanes to high-occupancy toll (HOT) lanes, and others intend to build new highway infrastructure. This would permit single-occupant vehicles to buy the right to use the HOV lanes for a toll, but total flow would be regulated (with automatically determined variable pricing based on demand), to ensure total speeds on the HOV lane do not drop noticeably.

In August 2010, the Utah Department of Transportation implemented such a program for traffic along Interstate 15 from Layton in the north to Lehi in the south. The system uses RFID transmitters to monitor entry and exiting of the lane and charges drivers between 25 cents to one dollar, depending on demand. The transmitters can be turned off in the event that the driver has two or more occupants in their vehicle.

User phenomena

One symptom of HOV lanes that challenges the contention that HOV lanes are not effective has been the slugging phenomenon in the Northern Virginia suburbs of Washington, D.C. *Slugging* is the term used to describe a unique form of commuting where drivers go to pre-arranged "slug lines" and pick up commuters who need a ride.

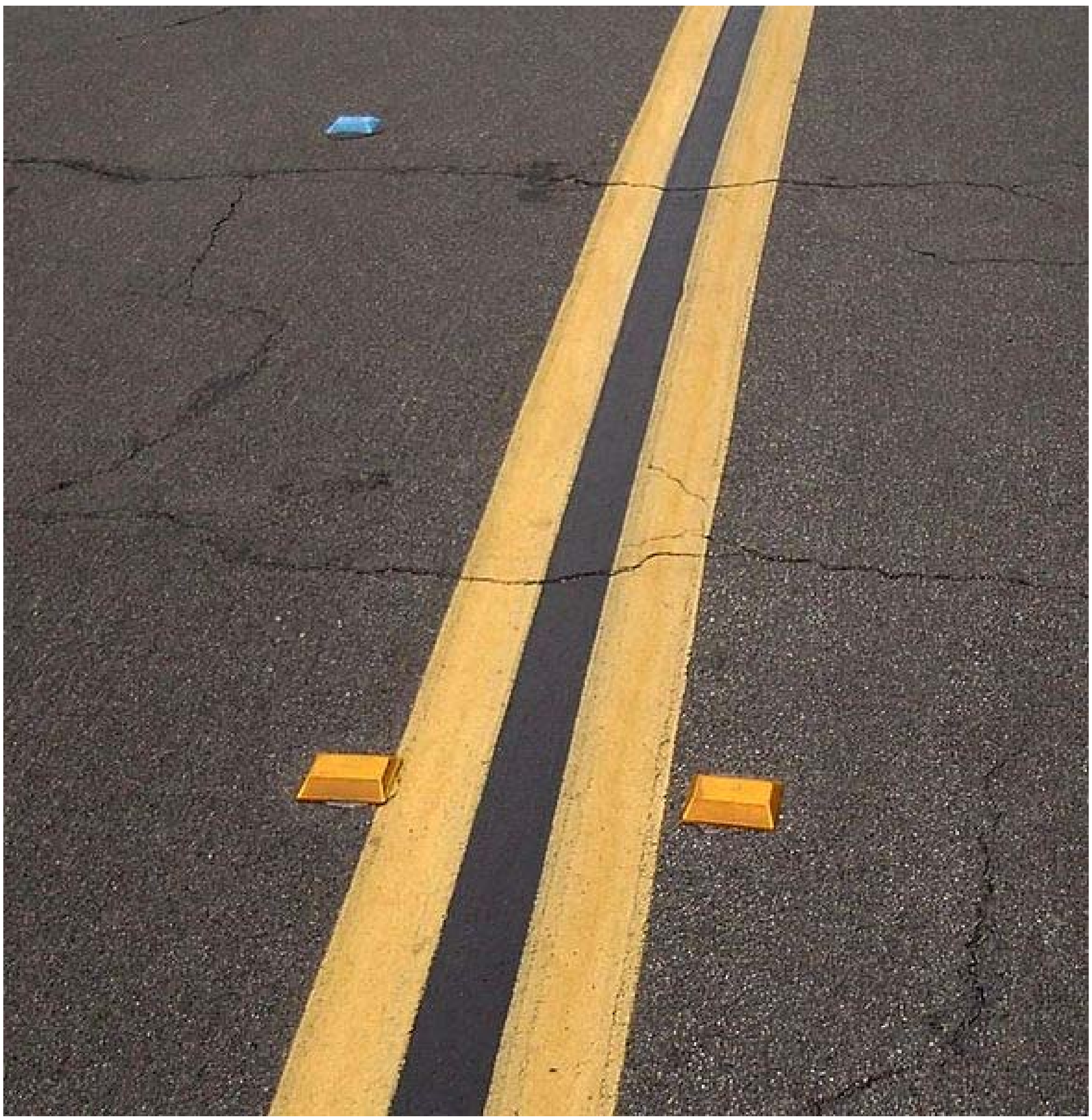
The driver shouts out his destination, and people in the line going to that destination enter the car on a first-come-first-served basis. There is very specific etiquette to the system to ensure a fair, consistent, and agreeable commute for all. Slugging benefits drivers by enabling them to use the HOV lane, benefits "sluggers" by getting them free rides, and benefits the community by decreasing the number of cars on the road.

In San Francisco and surrounding communities, designated casual carpool sites allow drivers to pick up passengers to the same destination.

When HOV lanes were first introduced in California in the 1970s, some drivers placed an inflatable person in the passenger seat in an attempt to fool regulators. This was soon outlawed, but the practice persists. In the UK in 2005, a camera that was claimed to distinguish mannequins or dolls from humans was being tested on the Forth Road Bridge in an effort to thwart cheaters.

Chapter 7

Raised Pavement Marker



The amber markers separate opposing traffic lanes. The blue marker denotes a fire hydrant on the left sidewalk.

A **raised road marker** or **raised pavement marker** is a safety device used on roads. These devices are usually made with plastic, ceramic, or occasionally metal, and come in a variety of shapes and colors. Many varieties include a lens or sheeting that enhance their visibility by reflecting automotive headlights. Some other names for specific types of raised pavement markers include Botts' dots, delineators, cat's eyes, road studs, or road turtles. Sometimes they are simply referred to as reflectors.

Reflective raised pavement markers

In the United States, Canada, as well as Australia, these plastic devices commonly have two angled edges facing drivers and containing one or more corner reflector strips. In areas where snowplowing is frequent, conventional markers are placed in a shallow groove cut in the pavement, or specially designed markers are used which include a protective metal casting that is embedded in recesses in the pavement, allowing the marker to protrude slightly above the pavement surface for increased visibility, much like a cat's eye. In areas with little snowfall, reflective raised pavement markers are applied directly to the road surface rather than being embedded into the surface.

Snowplowable reflective marker

The device's reflective surface enables the device to be clearly visible at long distances at night and in rainy weather. The devices come in multiple colors which vary in usage depending on local traffic marking standards.

Usage of color in Europe

In almost all European countries, such markers will include reflective lenses of some kind. Most appear white or gray during daylight; the colors discussed here are the color of light they reflect. Because of their inconspicuousness during the day, they are always used in conjunction with painted retro-reflective lines, they are never seen on their own.

- White markers — for lane markings. When used on dual-carriageways, motorways or one-way roads they may illuminate red on the reverse, to indicate drivers are traveling the wrong way.
- Yellow or amber markers — These are found next to the central reservation (U.S.: median) on motorways and dual carriageways.
- Red markers — These are found by the hard shoulder on motorways and at the edge of the running surface on other roads. They are also occasionally used to indicate a no-entry road.

- Green markers — These are used where slip-roads (U.S.: off ramp) leave and join the main carriageway.
- Blue markers — Are used to indicate the entrance to police reserved slip-roads (these do not lead anywhere, they are to allow police to park and monitor motorway traffic).

The exception to the above rules are:

- Fluorescent yellow markers — These are used to indicate temporary lanes during roadworks on major roads and are glued to the road surface, they are never embedded in it. Any painted markings will be removed from the road surface if they contradict the markers. They are fluorescent yellow in color, so they stand out in the day, but reflect white light at night. Where used they are much more numerous and dense than standards markers, as they are not used in conjunction with painted lines.

Usage of color in North America

A white reflective raised pavement marker (Stimsonite design)

A blue raised pavement marker (for marking the location of fire hydrants)

- White markers — for lane markings or to mark the right pavement edge.
- Yellow or amber markers — These separate traffic moving in opposite directions, or mark the left pavement edge on one-way roadways.
- Blue markers — Usually used to mark the location of fire hydrants.
- Green markers — Usually used to indicate that emergency vehicles can open gates to enter a gated community.

Colors can also be combined, with a different color facing each direction:

- White and red or yellow and red — white or yellow for normal use in one direction, and red to indicate "do not enter" in the other direction
- White and black — white for marking lane restrictions (such as an HOV diamond) in one direction on a roadway that has "reversible" traffic flow, and black in the other direction when the markings don't apply

The current trend for lane markings is to intersperse retroreflective paint lines with reflectors as seen on the majority of American highways.

Usage of color in Australia

A red raised pavement marker

A yellow raised pavement marker used to mark a stop valve.

While Australian designs generally follow those in the U.S., the colors generally follow European usage. Differences from European usage include:

- Blue — Usually used to mark the location of fire hydrants, as in North America
- Yellow — In addition to marking the median of freeways, single yellow reflectors are used with broken yellow lines to denote tram tracks on which motorized traffic can drive, and double yellow reflectors are used with solid yellow lines to denote tram tracks on which motorized traffic may not drive other than to cross.

History

Cat's eyes were the earliest form of reflective pavement markers, and are in use in the United Kingdom and other parts of the world. They were invented in the United Kingdom in 1933 by Percy Shaw and patented in 1934 (UK patents 436,290 and 457,536), and the United States in 1939 (U.S. patent 2,146,359). On March 15, 1935, Shaw founded Reflecting Roadstuds Ltd, which became the first manufacturer of raised pavement markers.

The designs now used widely throughout the United States didn't appear until more than a decade later. They are based on the invention of engineer Sidney A. Heenan in the course of his employment with the Stimsonite Corporation in Niles, Illinois. Heenan filed an application for a patent on October 23, 1964. Patent No. 3,332,327 was subsequently granted on July 25, 1967.

Stimsonite went on to become the leading manufacturer of raised pavement markers in the United States and was acquired in the mid-1990s by Avery Dennison Corporation. For about a decade, Avery sold Stimsonite's line under its Sun Country brand. In 2006, Avery sold its raised pavement marker division to Ennis Paint, one of the largest manufacturers worldwide of paint for pavement markings (particularly lane markings). Ennis Paint (based in Ennis, Texas) now markets the Stimsonite product line (and descendants) under the Stimsonite brand. Other manufacturers of reflective raised pavement markers sold in the United States under various designs include 3M, Apex Universal, and Ray-O-Lite.

Cat's eyes

Cat's eyes, in their original form, consist of two pairs of reflective glass spheres set into a white rubber dome, mounted in a cast iron housing. They are generally more durable than Botts' dots (they are snowplough safe) or other forms of markers and also come in a variety of colors. They have enjoyed widespread usage in the British Isles and elsewhere around the world.

Botts' dots

A round, white Botts' dot

Nonreflective raised pavement markers (also known as Botts' dots) are usually round, are white or yellow, and are frequently used on highways and interstates in lieu of painted lines. They are glued to the road surface with an epoxy and as such are not suitable in areas where snow plowing is conducted. They are usually made out of plastic or ceramic materials.

Pedestrian crossing studs

A Toucan crossing with markers visible. In this case thermoplastic paint has been used.

In the UK, the area in which pedestrians should cross at pelican crossings is marked out by a series of markers. Occasionally these are painted as squares on the road but more often a metal stud is used. These are usually square and made from unpainted steel or aluminum.

Delineator

Delineators are tall pylons (similar to traffic cones or bollards) mounted on the road surface, or along the edge of a road, and are used to channelize traffic. These are a form of raised pavement marker but unlike most such markers, delineators are not supposed to be hit except by out-of-control or drifting vehicles. Unlike their smaller cousins, delineators are tall enough to impact not only a vehicle's tires but the vehicle body itself. They usually contain one or more reflective strips. They can be round and open in the center or curved (45 degree sections) of plastic with a reflective strip. They are also used in low reflective markers in a "T" shape. They can also be used to indicate lane closures as in cases where the number of lanes is reduced.

The name delineator is also used for reflective devices attached to other objects which are technically not pavement markers.

Chapter 8

Reversible Lane

The Lions Gate Bridge from the south end in Stanley Park, Vancouver.

A **reversible lane** (called a **counterflow lane** or **contraflow lane** in transport engineering nomenclature) is a lane in which traffic may travel in either direction, depending on certain conditions. Typically, it is meant to improve traffic flow during rush hours, by having overhead traffic lights and lighted street signs notify drivers which lanes are open or closed to driving or turning.

Reversible lanes are also commonly found in tunnels and on bridges, and on the surrounding roadways — even where the lanes aren't regularly reversed to handle normal changes in traffic flow. The presence of lane controls allows authorities to close or reverse lanes when unusual circumstances (such as construction or a traffic mishap) require use of fewer or more lanes to maintain orderly flow of traffic.

Signals and markings

In the United States and Canada, reversible lane markings are typically a dashed or broken double yellow line on both sides. Most often done on three-lane roads, the reversible lane is typically used for traffic in one direction at morning rush hour, the opposite direction in the afternoon or evening, and as a turning lane at most other times. There is also a transition period (typically 30–60 min) between reversals during which traffic is prohibited to prevent collisions.

Sometimes, lane control signals are placed over the roadway at regular intervals (within sight of each other) indicating which lanes are allocated to which travel direction; a red X indicates the lane is closed or reserved for the opposite direction; a green arrow indicates a permitted travel lane. The center lane is marked with either one of those (depending on time of day), and often a flashing yellow X at other times to indicate an imminent closure of a lane, becoming solid yellow before turning red. Other setups had double-turn-lane signs backlit with white fluorescent lighting instead of the flashing yellow X.

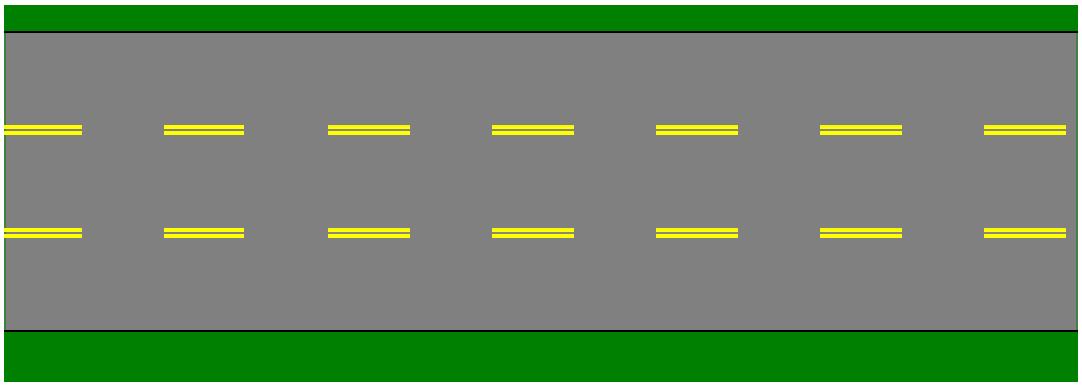
Other streets with reversible lanes (including several in Washington, D.C.) simply have signs posted indicating what lanes are open to which direction when.

Separation of flows

Some more recent implementations of reversible lanes use a movable barrier to establish a physical separation between allowed and disallowed lanes of travel. In some systems, a concrete barrier is moved during low-traffic periods to switch a central lane from one side of the road to another; some examples are the Coronado Bridge in San Diego, California, the seven lane Tappan Zee Bridge on the Hudson River in New York and the 8 lane Auckland Harbour Bridge across the Waitemata Harbour in Auckland, New Zealand. Other systems use retractable cones or bollards which are built into the road, or retractable fences which can divert traffic from a reversible ramp. The two center lanes of the six-lane Golden Gate Bridge are reversible; they are southbound during morning rush hour and northbound at evening rush hour, and are demarcated by vertical yellow markers placed manually in sockets in the roadway.

Many urban freeways have entirely separate carriageways (and connecting ramps) to hold reversible lanes (the reversible lanes in such a configuration are often referred to as "express lanes"). Generally, traffic flows in one direction or another in such a configuration (or not at all); the carriageways are not "split" into two-lane roadways during non-rush periods. Typically, this sort of express lane will have fewer interchanges than the primary lanes, and many such roadways only provide onramps for inbound traffic, and offramps for outbound traffic.

Passing lanes



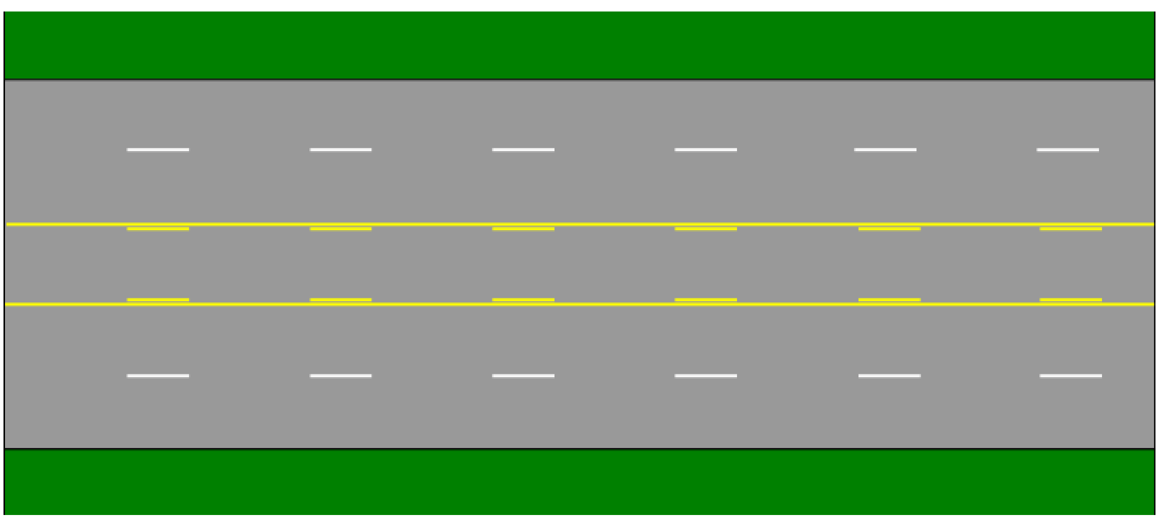
Typical striping on an old-style suicide lane setup in the United States

Historically, a **suicide lane** has also referred to a lane in the center of a highway meant for passing in both directions. Neither direction has the right-of-way, and both directions are permitted to use the lane for passing. In a similar layout, three lanes are striped with two in one direction and one in the other, but traffic in the direction with one lane is allowed to cross the centerline to pass.

2+1 roads have replaced some of these in Europe and North America.

Turn lanes / flush median

A turn lane (called a 'flush median' in New Zealand parlance), with a raised median in the forefront.



This is a typical 5-lane arterial equipped with a center-turn lane. These are often found in cities, towns and developed areas near cities. In the United States, the sequence line is located on the inside of the lane. In Canada it is the same for all provinces with the exception of Ontario where the sequence line is located on the outside.

Another type of center two-way lane is a **center left-turn lane** (for countries which drive on the right), *center turn lane* or *median turn lane*, a single lane in the center of the road into which traffic from both directions pulls to make a left turn. While this is sometimes also called a "suicide lane", it is actually far safer, as traffic collisions occur at far lower speeds.

These roads are very common in suburban areas and less common in rural areas, though developed areas near Interstate Highway bypasses of a small city often have them. Many were divided highways before the median was demolished or otherwise filled with the turn lane. Many four-lane streets with a double-yellow line are being phased out in favor of five-lane streets with center turn lanes, because the center lane allows for less disruption of traffic flow. For routes with moderate traffic, other movements involve downgrading four-lane undivided streets to three-lane streets with a turn-only center lane.

This center lane can be used by emergency vehicles like police cars, ambulance, and fire trucks to avoid traffic traveling in either direction. Drivers are not allowed to use the center lane of such a highway for passing slow-moving vehicles, except when funding or space constraints dictate use of it as a rush hour "travel lane" when traffic is largely asymmetric between a central business district and its suburbs.

Bus transit

In bus transit, a contraflow lane is a lane reserved for buses in which the direction of bus traffic is opposite the flow of traffic on the other lanes.

Examples

No (or minimal) lane controls

- Connecticut Avenue in Washington, D.C.
- Chain Bridge in Washington, D.C.
- Bailey Bridge, in Coquitlam, B.C..

Lane controls and no (or minimal) physical separation

Trans-national

- The Peace Bridge between the U.S. and Canada, connecting Fort Erie, Ontario to Buffalo, New York. Three lanes total, all marked reversible, 1 reversed in the direction of rush hour flow with the possibility of all lanes flowing in the same direction based on traffic needs.
- The Lewiston-Queenston Bridge connecting Niagara-on-the-Lake, Ontario to Lewiston, New York. Five lanes total, all marked as reversible, 1 to 4 lanes

marked daily in the same direction depending on traffic needs. In addition to the directional signals, special signals are also fitted to specify what type of vehicle may use the lane.

Australia

- The Sydney Harbour Bridge in Sydney, New South Wales (8 lanes total, 3 (formerly 4) potentially reversible, 3 reversed daily. AM peak 6 South 2 North. PM peak 3 South 5 North. Other times, 4 South 4 North),
- The Spit Bridge, Sydney, New South Wales (4 lanes total. AM peak 3 South, 1 North. PM peak 3 North, 1 South. All other times 2 North, 2 South).
- The Alfords Point Bridge in the south-western suburbs of Sydney, New South Wales. 3 lanes total, with the centre lane reversible using manual placement of plastic bollards. Originally this bridge was built with two lanes, and was to be part of twin spans, but only the foundations and excavations for approach works were built for the Eastern span, and the bridge was opened with one lane used in each direction. New approach works commenced in January 2007 for the second span, at a cost of 45 million AUD, eliminating the need for a reversible lane. However, a 300-metre reversible centre lane will still remain on Alfords Point Road over Henry Lawson Drive, approximately 500 meters north of this proposed bridge.
- General Holmes Drive generally has 4 north lanes and 4 south lanes, but during morning peak hour one southbound lane is divided from the others with a plastic island with signes placed along the top. The island is shifted across by the RTA with a specialized veichle. This lane is used as a northbound lane for local traffic to get to Botany and Mascot from the St George area.
- Flagstaff Road in the southern suburbs of Adelaide, South Australia. 3 lanes total, with the centre lane reversible.
- Johnston Street, Melbourne, Victoria. 5 lanes total, with the centre lane reversible.
- Queens Road, Melbourne, Victoria. 5 lanes total, with the centre lane reversible.
- Tasman Bridge, Hobart, Tasmania. 5 lanes total, with center lane reversible

Canada

- The Lions' Gate Bridge in Vancouver (3 lanes total, 1 reversible)
- The Angus L. Macdonald Bridge, Chebucto Road and the Herring Cove Road in Halifax, Nova Scotia (3 lanes total, 1 reversible)
- Jarvis Street in downtown Toronto (5 lanes total, centre lane reversed daily for AM/PM rush hours) - now converted to 2 lanes each direction + bicycle lane
- The Champlain Bridge in Ottawa (3 lanes total; 1 reversible)
- Sherman Access and Sherman Cut in Hamilton, Ontario (2 lanes, both reversible)
- The George Massey Tunnel in Delta and Richmond, B.C. (4 lanes total, 2 reversible, with access controlled by gates)
- Connors Road in Edmonton (4 lanes, 3 reversible)
- 170th Street from north of 137th Avenue to Levasseur Road in Edmonton (3 lanes total, 1 reversible)

- 97th Street from 118th Avenue to 127th Avenue in Edmonton (7 lanes total, 3 reversible)
- Centre Street from 20th Avenue N to 6th Avenue S in Calgary (4 lanes total, 2 reversible; standard configuration is 2 out, 2 in; morning rush is 1 out, 3 in; and evening rush is 3 out, 1 in)
- 10th Street NW / 9th Street SW from 5th Avenue NW to 4th Avenue SW in Calgary (4 lanes total, 2 reversible; standard configuration is 2 out, 2 in; morning rush is 1 out, 3 in; and evening rush is 3 out, 1 in)
- Park Avenue in Montreal, five lanes total, centremost lane is reversible, sidemost lanes are reserved for public transport during rush hour; morning rush is 2 in, one out (not including bus lanes), evening rush is reversed
- Champlain Bridge in Montreal, rush hour bus lanes
- Jacques Cartier Bridge in Montreal, five lanes total, two for both directions, one rush hour central reversible lane
- During the 2010 Winter Olympics, British Columbia Highway 99 was subject to lane control in three-lane sections of the highway, via signs on the side of the road that were changed manually.

Croatia

- State Route 102 near Kraljevica leading southbound to the Krk Bridge used to have a three-lane passing lane combination, blind curves, and a steep grade. It was later changed to a passing lane combination that makes the northbound traffic dominant.

Turkey

- Reversible lanes are frequently used in hilly sections of highways with heavy truck traffic. Most of them were built during the 1980s and 1990s.

United Kingdom

- The A38 road across the Tamar Bridge and through the Saltash Tunnel in Saltash, England. The middle lane is reversible, allowing for control of traffic flows in holiday periods and during rush hour.
- The A61 Queens Road in Sheffield, England, although it is a very short section (4 lanes total, 1 reversible: allowing for either 3 out, 1 in, or 2 out, 2 in).
- The A470 North Road in Cardiff, Wales, A section of around 1 mile long between the Maindy Road Junction and College Avenue where the road drops from a dual two-lane to a three-lane section. One lane is always dedicated to Northbound (out of town) traffic, and one lane to Southbound (city centre bound traffic) with the centre lane reversing depending on the time of day - i.e. in the morning 2 lanes into the city, 1 lane out, in the evening 2 lanes out of the city, 1 lane in.
- The A15 in Lincoln (Canwick Road) has a short three-lane section of tidal flow.

United States

Alabama

- In Montgomery, Norman Bridge Road through the Garden District and Old Cloverdale has a center lane with reversible markings and traffic flow lights between Burton Street and Legrand Place.

Arizona

- In Phoenix on 7th Avenue between McDowell Road and Northern Avenue, and 7th Street between McDowell Road and Cave Creek Road/Dunlap Avenue. On both roads, the lane configuration is 2 southbound and 3 northbound, with the center lane open for southbound traffic between 6-9am and open to northbound traffic between 3-6pm. No left turns are permitted during these hours for either direction.

California

- The Golden Gate Bridge (6 lanes total, 2 reversible, vertical median markers provide minimal physical separation) connecting San Francisco with suburban Marin County
- Doyle Drive (U.S. Route 101) in San Francisco
- Lafayette Street in Santa Clara - the center lane is used for northbound traffic on weekday mornings, southbound traffic for weekday afternoons, and as a center turning lane at other times.
- The Barry-Baker Tunnel, one of only two means of access to the Marin Headlands from U.S. Route 101 in Marin County, is not wide enough to accommodate bidirectional traffic. It consists of a single reversible lane for automobiles and two bicycle lanes. The direction of automobile traffic alternates every five minutes, controlled by a traffic light at each end of the tunnel. The bicycle lanes, one for each direction, are located on either side of the reversible lane; buttons on either side of the tunnel trigger flashing signs alerting drivers entering the tunnel to the presence of cyclists.

Connecticut

- Asylum Avenue in Hartford

Florida

- Bay Street in Jacksonville

Georgia

- Northside Drive in Atlanta: the center lane of three is reversed using overhead lane-use control signals.
- Vineville Avenue in Macon: the center lane of three is reversed using overhead lane-use control signals.

Kentucky

- The Clay Wade Bailey Bridge in Covington (3 lanes total, 1 reversible)
- Nicholasville Road (U.S. Highway 27) in Lexington, has reversible lanes (lane signals, no physical separation) starting at its intersection with Rose Street at the University of Kentucky campus and ending at New Circle Road, the city's inner beltway. During morning rush hour, southbound traffic (away from the UK campus and downtown) is restricted to one lane between campus and Southland Drive, and two lanes from Southland to New Circle. Northbound traffic faces the same restrictions in the evening rush hour. During off-peak hours, an equal number of lanes are dedicated to traffic in each direction.
- Baxter Avenue and Bardstown Road (U.S. Highway 31E) in Louisville have reversible lanes (lane signals without any physical separation) for 2½ miles starting at their intersection with Lexington Road and ending at Douglass Boulevard. Southbound traffic leaving downtown Louisville is restricted to one lane during the morning rush hour, with northbound traffic having the same restriction during the evening rush hour. Electronic signs over the roadway alert motorists to the traffic flow dedication of each lane.

Indiana

- In Indianapolis, Fall Creek Parkway North Drive between Central Avenue and Evanston Avenue has 5 lanes (7 in some sections) with 1 lane marked as reversible. Configuration is typically designed to allow for 3 in 2 out during morning rush hours, and 2 in/3 out during afternoon rush hours. Due to Fall Creek Parkway's proximity to the Indiana State Fairgrounds, lane configurations change periodically to facilitate traffic flow during events at the fairgrounds.

Maryland

- The Chesapeake Bay Bridge near Annapolis (5 lanes total, all marked reversible, 1 usually reversed for normal peak traffic). However, due to its dual spans, when there are 2 eastbound lanes and 3 westbound the opposing sides are completely divided, this is the usual configuration.
- The Hanover Street Bridge in Baltimore has 5 lanes total marked reversible, with 1 usually reversed for normal peak traffic).
- Georgia Avenue in Silver Spring has 7 lanes. During most hours, the center lane is marked with a yellow lit *X* as a left turn lane for both directions. During morning and evening rush hours, the lane is marked with a down facing green arrow – southbound in the morning, northbound in the evening – or a red *X* –

northbound in the morning, southbound in the evening – and left turns are prohibited.

- Colesville Road in Silver Spring has 6 lanes. During off-rush hours, three lanes go in each direction. During morning rush hours, four lanes (marked with green arrows) go southbound, while northbound (marked with Xs in those lanes) is relegated to two lanes. During afternoon rush, the process is reversed.

Michigan

- The Mackinac Bridge near St. Ignace treats the passing lane of the southbound side as a temporary northbound lane during the Labor Day bridge walk, at which timee the northbound side is used for pedestrians.

Nebraska

- Dodge Street between Turner Boulevard and 68th Street in Omaha: no physical separation; lanes marked with overhead lane-use control signals.

New York

- Delancey Street in New York City has two lanes on the eastbound side adjacent to the median used for westbound traffic in the morning rush hour between the Williamsburg Bridge and Allen Street. All traffic in these lanes must continue to and then turn left onto Allen, during these times left turns are prohibited from the regular westbound roadway onto Allen Street.
- Manhattan Bridge (New York City) lower level has three lanes, which can have all lanes used in one direction or reversible with two lanes one way and the other for the opposite direction.
- The upper level of the Queensboro Bridge in New York City has 4 lanes and can have all flowing outbound (PM peak), or two lanes each direction in normal configuration.

North Carolina

- 7th Street in Charlotte
- Tyvola Road in Charlotte
    - Since the closure (2005) and implosion (2007) of the former Charlotte Coliseum (II), this road is no longer reversible; all lights have been removed and lane signs are permanent. It was designed this way for Coliseum traffic from NBA games and concerts.
- U.S. Route 29 in Charlotte
    - This road is the access road to Charlotte Motor Speedway from the city, and links to Interstate 485. It is used for any events at the Speedway.
- High Point Road in Greensboro
- Edwards Mill Road in Raleigh

Ohio

- At least one road in Sandusky has reversible lanes, for the purpose of allowing quick departure of Cedar Point guests.

Pennsylvania

- The Liberty Bridge near the southern terminus of I-579 in Pittsburgh has 4 lanes, all of which are potentially reversible, and 2 of which are reversed based on rush-hour times.
- The West End Bridge in Pittsburgh has 4 lanes, which are all potentially reversible.
- West General Robinson Street near Heinz Field in Pittsburgh has 4 lanes, and 2 are reversible.

Texas

- West Alabama Street and North Main Street in Houston – both are three-lane streets, which operate in a 2 in, 1 out configuration during the morning rush, a 1 in, 2 out configuration during the evening rush, and a 1 each way + two-way left turn lane at other times.
- Interstate highway 10 and highway 290 in Houston have contraflow HOV lanes intended to help ease rush hour traffic.

Lane controls and physical separation

- The A38(M) motorway (also known as the Aston Expressway) in Birmingham, England. The road connects the city centre with Spaghetti Junction on the M6. It is a 2-mile, 7-lane section of motorway with no central reservation, and a lower than usual speed limit of 50 mph. Constructed in 1971, it was the United Kingdom's first contraflow road. Overhead lane control signals allow for 4 lanes in and 2 out in the morning rush hour, reversed in the evening, and 3 lanes each way at all other times. One dividing lane is closed to traffic at all times, and motorcycles are permanently prohibited from using the central, red-surfaced lane (with a fixed sign) owing to its use as an off-camber drain. The lane control signals can be set to allow travel in either direction for any lane in exceptional circumstances, which has been used for single-lane, reduced-speed running in each direction (or 2+1 with no divider) during road work, allowing the expressway to remain largely open even during major repairs. However, the 7-lane section splits at both ends to fully divided sets of 4x2 lane slip roads, with the central red lane ending in a barrier, so full use of this flexibility is uncommon and occasional overnight closure is required.
- The U.S. Route 78 portion in Snellville, GA, United States, has 6 lanes in total. This occurs from the limited access portion through Stone Mountain Park to G.A. State Route 124 (Scenic Highway) for several miles. The middle two lanes are reversible (usually occurring during rush hour) with a varying lane always

reserved a center turn lane while the 3 lanes are used for one side and 2 for the other. Example of an intersection on U.S. 78. However, due to rising traffic volumes during peak hours that made traffic flows equivalent, the reversible lane system was removed in 2009.
- The Caldecott Tunnel between Oakland, California and Contra Costa County, California has three separate bores, with the middle bore switching direction twice daily for rush hour traffic.

Lane controls and physical separation by movable barrier

- Benjamin Franklin Bridge, Walt Whitman Bridge, Commodore Barry Bridge, and Betsy Ross Bridge in Philadelphia, PA
- Tappan Zee Bridge in New York
- Theodore Roosevelt Bridge in Washington, D.C.
- Auckland Harbour Bridge in Auckland, New Zealand
- Coronado Bridge in San Diego, California
- Southeast Expressway in and near Boston, Massachusetts
- A contraflow line, also called a zipper lane, is in used on eastbound Interstate H-1 for traffic heading from leeward Oahu to Pearl Harbor. It is open from 5:30 to 8:30 a.m.

Third (reversible) carriageways on freeways

- Bundesautobahn 7, New Elbe Tunnel, Hamburg, Germany (actually two reversible carriageways, plus two fixed)
- Warringah Expressway in Sydney, Australia
- Interstate 5 in Seattle, Washington, and Interstate 90 between Seattle and Bellevue, Washington
- Interstate 15 in northern San Diego, California
- Interstate 25 and US-36 in Denver, Colorado
- Interstate 394 through Minneapolis, Minnesota and its western suburbs
- Interstate 90/Interstate 94 (Kennedy Expressway portion) in Chicago, Illinois
- Interstate 70 through St. Louis, Missouri
- Lee Roy Selmon Crosstown Expressway from Brandon to Tampa, Florida
- Interstate 64 in Norfolk, Virginia (center carriageway reserved for HOV traffic during rush hour)
- Interstate 395 and Interstate 95 through Washington, D.C. and its Virginia suburbs (center carriageway reserved for HOV traffic during rush hour)
- Lincoln Tunnel between Weehawken, New Jersey and New York, New York has three tubes with two lanes each. The center tube carries two lanes in peak direction weekdays (with a reserved inbound bus lane during the AM rush period) and a single lane each direction off-peak (nights, weekends, holidays).
- Interstate 93 through Boston, Massachusetts
- Caldecott Tunnel (on California State Route 24), soon to be gone (additional tunnel bore being added to remove need for reversible lanes).

Entire roadway routinely reversed

South and Marion Roads in Adelaide, provide access to the Southern Expressway at its northern end. Here, southbound access to the expressway from South Road is restricted.

- The Anchieta/Imigrantes highway system in Brazil contains the world's longest fully reversible road (The Imigrantes variant at a length of 58.5 km). It comprises a total of 10 lanes distributed over 4 separate roadways (3+3+2+2), each of which can be reversed. Traffic flow is unidirectional on up to three roadways at a time, in different combinations, depending on demand. Since this highway system is the only quick route from São Paulo to the beach, the majority of the traffic on Fridays and Sundays are cars on weekend trips, creating highly asymmetrical demand.
- The Southern Expressway in Adelaide, South Australia is the world's longest exclusively one-way reversible road, spanning 21 km though the city's southern suburbs. It changes direction to carry peak hour traffic to the city centre in the morning and away from the city in the evening. On weekends the directions are reversed.
- In Washington, D.C., the Rock Creek and Potomac Parkway between the Lincoln Memorial and Calvert St. is converted from two lanes in each direction to one-way southbound in the morning and one-way northbound in the evening rush hour Monday through Friday, excluding federal holidays. The P Street exit, usually unavailable northbound, is an allowed left exit in the evening. South of Virginia

Avenue, two lanes are closed during rush hours to facilitate the merge to or from Virginia Avenue. There are no overhead markings, but police barricades block wrong-way entrances to the roadway.

- In Washington, D.C., parts of 15th Street NW and 17th Street NW are one-way during certain hours. There are no overhead markings on either road.
- Canal Road in Washington, D.C. (between Foxhall Road and Arizona Avenue)
- Sherman Access in Hamilton, Ontario. 2 lanes total, both marked as reversible, with both lanes flowing in the same direction during rush hour each weekday.
- Assembly Street and Bluff Road (both part of South Carolina 48), along with Shop Road and George Rogers Blvd, in Columbia, South Carolina, are one-way during gridiron football matches at Williams-Brice Stadium/
- The lower deck of the Centre Street Bridge in Calgary, Alberta is fully reversible. It normally allows for two way traffic, but both lanes flow in the same direction during rush hour each day.
- Victoria Bridge, in Montreal, Quebec, normally allows for two-way traffic. But during rush hours, it only allows one-way traffic, northbound in the morning, and southbound in the afternoon.
- Farnam Street in Omaha is a normally two-way, two-lane street that during rush hour becomes one-way eastbound in the morning and westbound in the evening.
- Sierichstraße in Hamburg, Germany, a fully-reversible, two-lane city street.
- The 4th Street Bridge in Los Angeles, a fully reversible street controlled by overhead signals. It switches direction every rush hour and on weekends. In case of emergencies, the bridge can be one-way to or from Los Angeles.

Chapter 9

Rail Trail

A "rail with trail" in the United States; train at right

A **rail trail** is the conversion of a disused railway easement into a multi-use path, typically for walking, cycling and sometimes horse riding. The characteristics of former tracks—flat, long, frequently running through historical areas—are appealing for various development. The term sometimes also covers trails running alongside working railways; these are called "rails with trails". Some shared trails are segregated, with the segregation achieved with or without separation. Many rail trails are long distance trails.

A rail to trail may still include rails, such as light rail or streetcar. By virtue of their characteristic shape (long and flat), some shorter rails to trails are known as greenways and linear parks.

History

United States

In North America, the decades-long consolidation of the rail industry led to the closure of a number of uneconomical branch lines in the 1960s. Some were maintained as short line railways, but many others were abandoned.

Beginning with a few lines in the Midwestern United States, these disused industrial relics were turned into ecological areas functioning as linear parks or community space, but mainly as non-motorized transportation or recreation corridors for walking, hiking, bicycling, horse riding, birdwatching, etc.

By the 1970s, even main lines were being sold or abandoned. This was especially true when regional rail lines merged and streamlined their operations. As both the supply of potential trails increased and awareness of the possibilities rose, state governments, municipalities, conservation authorities and private organizations bought the rail corridors to create, expand or link greenspaces. The first abandoned rail corridor in the United States converted into a recreational trail was the Elroy-Sparta State Trail in Wisconsin, which opened in 1965. The following year the Illinois Prairie Path opened. The longest developed rail trail is currently the 225-mile Katy Trail in Missouri; when complete, the Cowboy Trail in Nebraska will extend for 321 miles.

The conversion of rails to trails hastened with the federal government passing legislation promoting the use of railbanking for abandoned railroad corridors. This process would preserve rail corridors for possible future rail use with interim use as a trail.

A "rail to trail" in Germany

A former railway tunnel, near Houyet, Belgium, now converted to pedestrian and bicycle use

Australia

The development of rail trails in southeastern Australia can be traced to the gold rushes of the second half of the 19th century. Dozens of rail lines sprang up, aided by the overly enthusiastic "Octopus Act", but soon became unprofitable as the gold ran out, leading to a decreased demand for timber in turn. Decades later, these easements found a new use as tourist drawcards, once converted to rail trails. Dozens exist in some form, but only a few — such as the 95 kilometre Murray to the Mountains Rail Trail — have been fully developed. Progress is frequently hampered by trestle bridges in unsafe condition, easements that have been sold off to farmers, and lack of funds. Funding is typically contributed in roughly equal parts from federal, state and local governments, with voluntary labour and in kind donations contributed by local groups.

New Zealand

A number of rail trails have been established through New Zealand, the most well known are the Otago Central Rail Trail and the Little River Rail Trail. The New Zealand Cycle Trail project, which is a Government-led initiative, will greatly accelerate the establishment of new trails. The first seven projects (not all of them rail trails, though) were announced in July 2009 and will receive $9 million in funding of the total project budget of $50 million.

Other countries

There are tens of thousands of miles and thousands of rail trails in the United States, Canada, United Kingdom, Australia and many other countries. The main factor restricting the potential scope of the movement is the lack of abandoned or surplus rail lines in continental Europe, though abandoned canal towpaths are readily available and used for similar purposes.

Conversion issues

Cyclists and joggers on the Arkansas River Trail in Little Rock, Arkansas

Rail trail conversions can be complex for legal, social and economic reasons. Railroads in North America were often built with a mix of purchased land, government land grants, and easements. The land deeds can be over a hundred years old, land grants might be conditional upon continuous operation of the line and easements may have expired, all expensive and difficult issues to determine at law.

Railroad property rights have often been poorly defined and sporadically enforced, with neighboring property owners intentionally or accidentally using land they do not own. Such encroachers often later oppose a rail to trail conversion. Even residents who are not encroaching on railway lands may oppose conversion on the grounds of increased traffic in the area and the possibility of a decline in personal security.

Because linear corridors of land are only valuable if they are intact, special laws regulate the abandonment of a railroad corridor. In the United States, the Surface Transportation Board regulates railroads, and can allow a corridor to be "rail banked" or placed on hold for possible conversion back to active status when or if future need demands.

While many rail trails have been built, many more potential trails have been squashed by community opposition. The stature of the conversion organization, the quality of involvement of the local community, and government willingness are all keys factor in the successful acceptance of a trail.

Typical features

Bicyclist on the Conotton Creek Trail in Ohio

Most original rail lines were surveyed for ease of transport and gentle (often less than 2%) grades. Therefore, the rail trails that succeeded them are often fairly straight and ideally suited to overcome steep or awkward terrain such as hills, escarpments, rivers, swamps, etc. Rail trails often share space with linear utilities such as pipelines, electrical transmission wires and telephone lines.

Hiker on the Pine Creek Rail Trail in Pennsylvania

The Katy Trail crosses a creek on a preserved rail bridge in Missouri.

Most purchase of railway land is dictated by the free market value of the land, so that land in urban and industrial cores is often impractical to purchase and convert. Therefore, rail trails may end on the fringes of urban areas or near industrial areas and resume later, as discontinuous portions of the same rail line, separated by unaffordable or inappropriate land.

A railroad right-of-way (easement) width varies based on the terrain, with 30 m or 100 ft being amply wide enough where little surface grading is required. The initial 705 mile or 1135 km stretch of the Illinois Central Railroad is the most liberal in the world with a width of 200 ft or 60m along the whole length of the line. Rail trails are often graded and covered in gravel or crushed stone, although some are paved with asphalt and others are left as dirt. Where rail bridges are incorporated into the trail, the only alterations (if any) tend to be adding solid walking areas on top of ties or trestles. If paved, they are especially suitable for people in wheelchairs.

Where applicable, the same trails used in the summer for walking, jogging and inline skating can be used in the winter for Nordic skiing, snowshoeing and sometimes snowmobiling.

Railbanking

Railbanking is preserving railroad rights-of-way for possible future use. Railbanking leaves the tracks, bridges, and other infrastructure intact, relieving the railroad operating company from responsibility of maintenance and taxation. Often the tracks are put in custody of a state transportation agency, who then seeks a new operator for possible rehab or reactivation. This helps ensure the possibility of future restored rail service when new economic conditions may warrant resuming operation.

In places with many environmental laws and other governmental regulations as the United States, it is very difficult to restore an abandoned line, but it is easier with a railbanked line than one that has undergone a "total abandonment", as the Federal government guarantees the railroad the full rights to reactivate it. A railbanked line can be reopened within a year's time while an abandoned corridor could take years to be reactivated, if it was even possible. In railbanking, the government helps fund the line's rebuild. 14,184 route miles (22,694 route km) of railroad have been abandoned in the 25 year time period from 1983 to 2008. Of that, 8056.5 miles (12,890 km), representing 56.8% of the lines abandoned in the past 25 years, were originally negotiated for railbanking agreements.

21% of those railbanking agreements failed; that is they were ultimately abandoned. Thus 5079 miles (8126 km) of those originally negotiated 8,056.5 miles (12,890 km) actually reached a railbanking agreement, representing 35.8% of the lines abandoned during the 25-year time period. The remaining 43.2% of the lines not yet mentioned, representing 6,127.5 miles (9804 km) were lines that railroads never even considered trying to have railbanked, and were totally abandoned. In total, 9,105 miles (14,568 km) of the 14,184 miles abandoned during the 25-year time period were not railbanked, or about 64.2%. Some bold railroads even refused to railbank lines, and would instead sell the land in parcels to the surrounding landowners.

Since railbanking began in 1983, nine railbanked corridors have been approved for reactivation by the STB. Some of these reactivated corridors had only short sections reactivated, while others had the entire corridor reactivated. Two of these approved have not yet been reopened, though both are in the process, as of March 2010. Railbanked corridors are usually turned into multi-use recreational trails for cyclists, walkers, joggers, snowmobiling, cross country skiing, and in some cases, even horseback riding. These trails not only better preserve the rail corridors, but also provide a great way for people to do physical activity as well as enjoy the nature and the outdoors. If a railroad decides to rebuild a railbanked line, they (with the help of the government) will help compensate whatever it cost to build the trail so that they may rebuild the trail alongside the right-of-way, or build a new trail elsewhere.

The land over which railways pass may have many owners — private, rail operator or governmental — and, depending on the terms under which it was originally acquired, the type of operating rights may also vary. Without Rail Banking, on closure, some parts of a railway's route might otherwise revert to the former owner. The owner could reuse them for whatever purpose he chose (for example, for building) or modify the ground conditions (remove embankments or fill-in cuttings), potentially prejudicing the line's future reuse if required. However, the landowner(s) must agree to keep the infrastructure such as bridges and tunnels intact.

Approximately 85 percent of the railroad rights-of-way in the United States, were acquired by easement from the then abutting property owners. Normally when the use for an easement is abandoned, the easement is extinguished and the land is not burdened by this adverse use. In 1983, Congress passed what is now known as the federal Rails-To-Trails law codified as 16 U.S.C. 1247(d). The federal rails to trails law in effect took the property rights of thousands of property owners throughout the United States for rail trails. Several property owners sued the federal government as the law took property without compensation. In 1990, the United States Supreme Court ruled that the property owners were entitled to compensation for the land taken for these rail trail. In 1996, Mr. Preseault was awarded $1.5 million as compensation for the land taken for a trail through his property.

In some cases, the infrastructure is removed regardless. Laws have been passed to remove infrastructure, in some case. For example, in the Commonwealth of Pennsylvania, a law was made to remove all unused railroad overpasses. Another example is a natural disaster. If a flood washes away a railbanked railroad bridge, that is beyond the owner's control. The local, state, and Federal governments, could give some financial help for the railroad to rebuild any infrastructure that may have been damaged or destroyed during the time that it was unused.

This causeway once carried the Rutland Railroad over portions of Vermont's largest lake, Lake Champlain

A single section of a route changed in this way could have serious consequences for the viability of a restoration of a service, with the costs of repurchasing the land or right-of-way or of restoring the site to its former condition outweighting the economic benefit. Over the full length of a railway's route with many different owners the reopening costs could be considerable.

By designating the route as a Rail Bank, these complications are avoided and the cost of maintaining a right-of-way are removed from the railway operator. In the United States land transferred to Rail Banks is held by the state or federal governments and many Rail Banks have been reused as Rail Trails.

In the United Kingdom, thousands of miles of railway were closed under the Beeching Axe cuts in the 1960s and whilst a few of these routes have subsequently been reopened, none were formally treated as Land Banks in the US manner. The Beeching closures were driven by the government's desire to reduce expenditure on railways, and so most lines were offered for sale to the highest bidder, a process which frequently led to great fragmentation in the ownership of former UK railway lines.

Chapter 10

Road Surface

A road in the process of being resurfaced

Road surface (British English) or **pavement** (American English) is the durable surface material laid down on an area intended to sustain vehicular or foot traffic, such as a road or walkway. In the past cobblestones and granite setts were extensively used, but these surfaces have mostly been replaced by asphalt or concrete. Such surfaces are frequently marked to guide traffic. Today, permeable paving methods are beginning to be used for low-impact roadways and walkways.

Metalling

The term *road metal* refers to the broken stone or cinders used in the construction or repair of roads or railways, and is derived from the Latin *metallum*, which means both "mine" and "quarry". Metalling is known to have been used extensively in the construction of roads by soldiers of the Roman Empire but a limestone-surfaced road, thought to date back to the Bronze Age, has been found in Britain. Metalling has had two distinct usages in road surfacing. The term originally referred to the process of creating a gravel roadway. The route of the roadway would first be dug down several feet and, depending on local conditions, French drains may or may not have been added. Next, large stones were placed and compacted, followed by successive layers of smaller stones, until the road surface was composed of small stones compacted into a hard, durable surface. "Road metal" later became the name of stone chippings mixed with tar to form the road surfacing material tarmac. A road of such material is called a "metalled road" in Britain, a "paved road" in the USA, or a "sealed road" in Australia.

Asphalt

Closeup of asphalt on a driveway

Asphalt (specifically, asphalt concrete) has been widely used since 1920–1930. The viscous nature of the bitumen binder allows asphalt concrete to sustain significant plastic deformation, although fatigue from repeated loading over time is the most common failure mechanism. Most asphalt surfaces are built on a gravel base, which is generally at least as thick as the asphalt layer, although some 'full depth' asphalt surfaces are built directly on the native subgrade. In areas with very soft or expansive subgrades such as clay or peat, thick gravel bases or stabilization of the subgrade with Portland cement or lime may be required. Polypropylene and polyester materials have also been used for this purpose and in some northern countries, a layer of polystyrene boards have been used to delay and minimize frost penetration into the subgrade.

Depending on the temperature at which it is applied, asphalt is categorized as hot mix asphalt (HMA), warm mix asphalt, or cold mix asphalt. Hot mix asphalt is applied at temperatures over 300 F with a free floating screed. Warm mix asphalt is applied at temperatures of 200 to 250 degrees F, resulting in reduced energy usage and emissions of volatile organic compounds. Cold mix asphalt is often used on lower volume rural roads, where hot mix asphalt would cool too much on the long trip from the asphalt plant to the construction site.

An asphalt concrete surface will generally be constructed for high volume primary highways having an Average Annual Daily Traffic load higher than 1200 vehicles per day. Advantages of asphalt roadways include relatively low noise, relatively low cost compared with other paving methods, and perceived ease of repair. Disadvantages include less durability than other paving methods, less tensile strength than concrete, the tendency to become slick and soft in hot weather and a certain amount of hydrocarbon pollution to soil and groundwater or waterways.

In the 1960s, rubberized asphalt was used for the first time, mixing crumb rubber from used tires with asphalt. In addition to using tires that would otherwise fill landfills and present a fire hazard, rubberized asphalt is more durable and provides a 7–12 decibel noise reduction over conventional asphalt. However, application of rubberized asphalt is more temperature-sensitive, and in many locations can only be applied at certain times of the year.

Concrete

Concrete surfaces (specifically, Portland cement concrete) are created using a concrete mix of Portland cement, gravel, sand and water. The material is applied in a freshly-mixed slurry, and worked mechanically to compact the interior and force some of the thinner cement slurry to the surface to produce a smoother, denser surface free from honeycombing. The water allows the mix to combine molecularly in a chemical action called hydration.

Concrete surfaces have been refined into three common types: jointed plain (JPCP), jointed reinforced (JRCP) and continuously reinforced (CRCP). The one item that distinguishes each type is the jointing system used to control crack development.

Jointed Plain Concrete Pavements (JPCP) contain enough joints to control the location of all the expected natural cracks. The concrete cracks at the joints and not elsewhere in the slabs. Jointed plain pavements do not contain any steel reinforcement. However, there may be smooth steel bars at transverse joints and deformed steel bars at longitudinal joints. The spacing between transverse joints is typically about 15 feet for slabs 7–12 inches thick. Today, a majority of the U.S. state agencies build jointed plain pavements.

Jointed Reinforced Concrete Pavements (JRCP) contain steel mesh reinforcement (sometimes called distributed steel). In jointed reinforced concrete pavements, designers increase the joint spacing purposely, and include reinforcing steel to hold together intermediate cracks in each slab. The spacing between transverse joints is typically 30 feet or more. In the past, some agencies used a spacing as great as 100 feet. During construction of the interstate system, most agencies in the Eastern and Midwestern U.S. built jointed-reinforced pavement. Today only a handful of agencies employ this design, and its use is generally not recommended as JPCP and CRCP offer better performance and are easier to repair.

Continuously Reinforced Concrete Pavements (CRCP) do not require any transverse contraction joints. Transverse cracks are expected in the slab, usually at intervals of 3–5 ft. CRCP pavements are designed with enough steel, 0.6–0.7% by cross-sectional area, so that cracks are held together tightly. Determining an appropriate spacing between the cracks is part of the design process for this type of pavement.

Continuously reinforced designs generally cost more than jointed reinforced or jointed plain designs initially due to increased quantities of steel. However, they can demonstrate superior long-term performance and cost-effectiveness. A number of agencies choose to use CRCP designs in their heavy urban traffic corridors.

One advantage of cement concrete roadways is that they are typically stronger and more durable than asphalt roadways. They also can easily be grooved to provide a durable skid-resistant surface. Disadvantages are that they typically have a higher initial cost and are perceived to be more difficult to repair.

The first street in the United States to be paved with concrete was Court Avenue in Bellefontaine, Ohio. The mayor of Bellefontaine at the time, Mr. Reid Simon, was given the honors of being the first individual to drive on the new concrete road. His vehicle was a 1954 Dodge Royal. The record for first mile of concrete pavement to be laid in the United States is claimed by Michigan.

Composite surfaces

Composite surfaces combine Portland cement concrete and asphalt. They are usually used to rehabilitate existing roadways rather than in new construction.

Asphalt overlays are sometimes laid over distressed concrete to restore a smooth wearing surface. A disadvantage of this method is that the joints between the underlying concrete slabs usually cause cracks, called *reflective cracks* in the asphalt.

Whitetopping uses Portland cement concrete to resurface a distressed asphalt road.

In-place recycling

Distressed road materials can be reused when rehabilitating a roadway. The existing pavement is ground or broken up into small pieces, then compacted to form the base or subbase for new pavement. Some methods used include:

- Rubblizing of concrete pavement. Existing concrete pavement is broken into gravel-sized particles, compacted, then overlaid with asphalt pavement.
- Cold in-place recycling. Bituminous pavement is ground or milled into small particles, compacted, and overlaid with asphalt pavement. The asphalt millings are blended with a small amount of asphalt emulsion, paved and compacted, allowed to cure for seven to ten days, then overlaid with asphalt.
- Hot in-place recycling. Bituminous pavement is heated to 250 to 300°F (120 to 150°C), milled, combined with a rejuvenating agent or virgin asphalt binder, and compacted. It may then be overlaid with a new asphalt overlay. This process only recycles the top two inches (50 mm) or less, so it can be used to correct rutting, polishing or other surface defects. It is not a good procedure for roads with structural failures. It also generates high heat and vapor emissions, and may not be a good candidate for built-up areas.
- Full depth reclamation is a process which pulverizes the full thickness of the asphalt pavement and some of the underlying material to provide a uniform blend of material. A binding agent may be mixed in to form a base course for the new pavement, or it may be left unbound to form a subbase course. Common binding agents include asphalt emulsion, fly ash, Portland cement or calcium chloride. It can also be mixed with aggregate, recycled asphalt millings, or crushed Portland cement to improve the gradation of the material.

Bituminous Surface Treatment (BST)

Concrete pavers

Bituminous Surface Treatment (BST) is used mainly on low-traffic roads, but also as a sealing coat to rejuvenate an asphalt concrete pavement. It generally consists of aggregate spread over a sprayed-on asphalt emulsion or cut-back asphalt cement. The aggregate is then embedded into the asphalt by rolling it, typically with a rubber-tired roller. BSTs of this type are described by a wide variety of regional terms including "chip seal", "tar and chip", "oil and stone", "seal coat", "sprayed seal" or "surface dressing".

BST is used on hundreds of miles of the Alaska Highway and other similar roadways in Alaska, the Yukon Territory, and northern British Columbia. The ease of application of BST is one reason for its popularity, but another is its flexibility, which is important when roadways are laid down over unstable terrain that thaws and softens in the spring.

Other types of BSTs include micropaving, slurry seals and Novachip. These are laid down using specialized and proprietary equipment. They are most often used in urban areas where the roughness and loose stone associated with chip seals is considered undesirable.

Thin membrane surface

A thin membrane surface (TMS) is an oil treated aggregate which is laid down upon a gravel road bed producing a dust free road. A TMS road reduces mud problems and provides stone free roads for local residents where loaded truck traffic is negligible. The TMS layer adds no significant structural strength, and so is used on secondary highways with low traffic volume and minimal weight loading. Construction involves minimal subgrade preparation, following by covering with a 50 to 100 millimetres (2.0–3.9 in) cold mix asphalt aggregate. The Operation Division of the Ministry of Highways and Infrastructure in Saskatchewan has the responsibility of maintaining 6,102 kilometers (3,792 mi) of thin membrane surface (TMS) highways.

Granular

A granular surface can be used with a traffic volume where the average annual daily traffic is 1,200 vehicles per day or less. There is some structural strength as the road surface combines a sub base, base and is topped with a double graded seal aggregate with emulsion. Besides the 4,929 kilometers (3,063 mi) of granular pavements maintained in Saskatchewan, over 90% of New Zealand roads are unbound granular pavement structures.

Otta seal

Otta seal is a low-cost road surface using a 16–30-millimetre (0.63–1.2 in) thick mixture of bitumen and crushed rock.

A brick main street in Lebanon, Illinois

Other surfaces

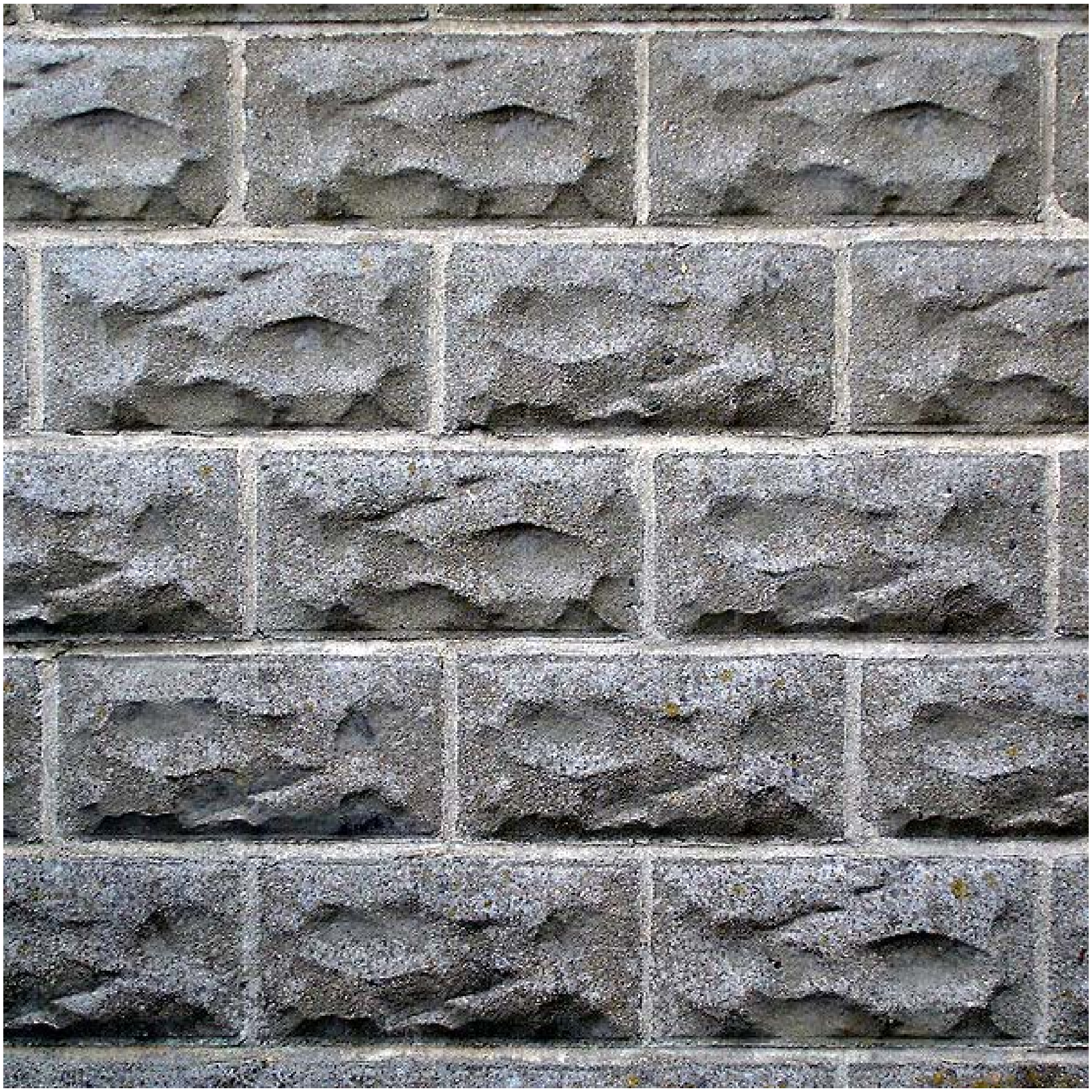
Pavers (or **paviours**), generally in the form of pre-cast concrete blocks, are often used for aesthetic purposes, or sometimes at port facilities that see long-duration pavement loading. Pavers are rarely used in areas that see high-speed vehicle traffic.

Brick, cobblestone, sett, and wood plank pavements were once common in urban areas throughout the world, but fell out of fashion in most countries, due to the high cost of labor required to lay and maintain them, and are typically only kept for historical or aesthetic reasons. In some countries, however, they are still common in local streets. Likewise, macadam and tarmac pavements can still sometimes be found buried underneath asphalt concrete or Portland cement concrete pavements, but are rarely constructed today.

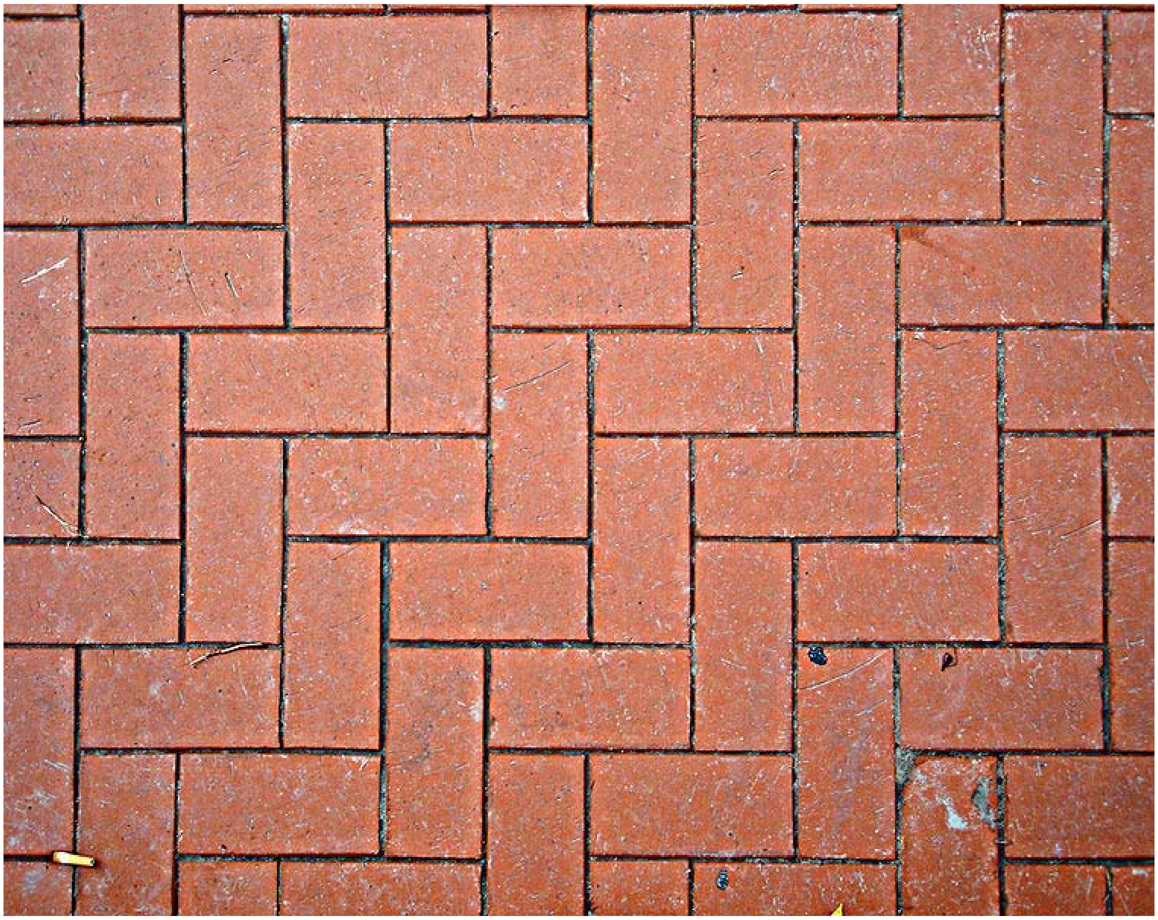
Acoustical implications

Roadway surfacing choices are known to affect the intensity and spectrum of sound emanating from the tire/surface interaction. Initial applications of this knowledge occurred in the early 1970s. Roadway surface types contribute differential noise effects of up to four dB, with chip seal type and grooved roads being the loudest and concrete surfaces without spacers being the quietest. Asphaltic surfaces perform intermediately relative to concrete and chip seal. These phenomena are, of course, highly influenced by vehicle speed. Rubberized asphalt has been shown to give a very significant 7–12 decibel reduction in road noise when compared to conventional asphalt applications.

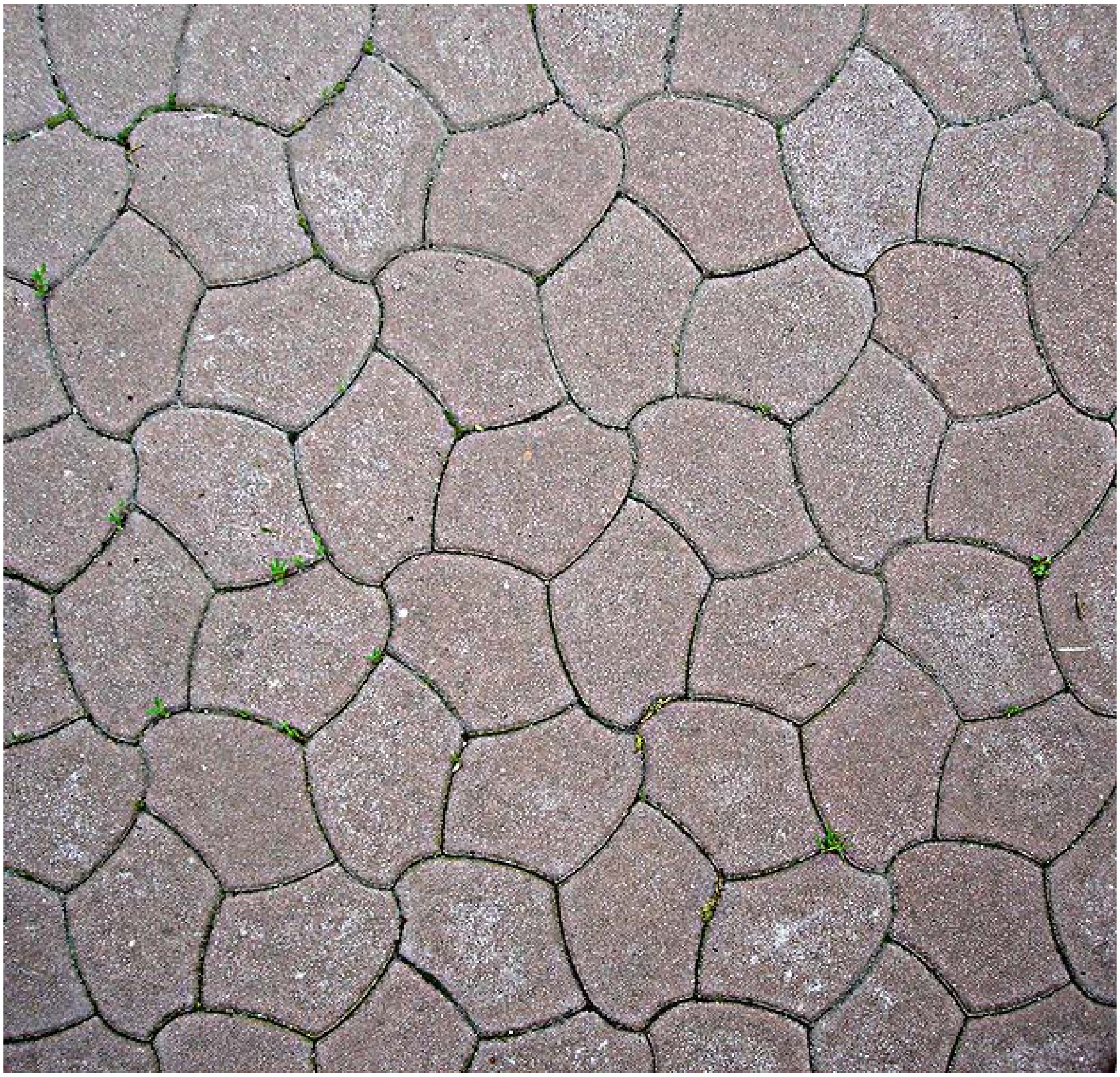
Cobbles



Rectangles



Bricks



More bricks

Deteriorating asphalt

Surface deterioration

As pavement systems primarily fail due to fatigue (in a manner similar to metals), the damage done to pavement increases with the fourth power of the axle load of the vehicles traveling on it. Civil Engineers consider truck axle load, current and projected truck traffic volume, supporting soil properties (can be measured using the CBR) and sub-grade drainage in design. Passenger cars are considered to have no practical effect on a pavement's service life, from a fatigue perspective.

Other failure modes include aging and surface abrasion. As years go by, the binder in a bituminous wearing course gets stiffer and less flexible. When it gets "old" enough, the surface will start losing aggregates, and macrotexture depth increases dramatically. If no maintenance action is done quickly on the wearing course potholing will take place. If the road is still structurally sound, a bituminous surface treatment, such as a chipseal or surface dressing can prolong the life of the road at low cost. In areas with cold climate, studded tires may be allowed on passenger cars. In Sweden and Finland, studded passenger car tires account for a very large share of pavement rutting.

Several design methods have been developed to determine the thickness and composition of road surfaces required to carry predicted traffic loads for a given period of time. Pavement design methods are continuously evolving. Among these are the Shell Pavement design method, and the American Association of State Highway and Transportation Officials (AASHTO) 1993 "Guide for Design of Pavement Structures". A new mechanistic-empirical design guide has been under development by NCHRP (Called Superpave Technology) since 1998. A new design guide called Mechanistic Empirical Pavement Design Guide (MEPDG) was developed and is about to be adopted by AASHTO.

According to the AASHO Road Test, heavily loaded trucks can do more than 10,000 times the damage done by a normal passenger car. Tax rates for trucks are higher than those for cars in most countries for this reason, though they are not levied in proportion to the damage done.

The physical properties of a stretch of pavement can be tested using a falling weight deflectometer.

Further research by University College London into pavements has led to the development of an indoor, 80-sq-metre artificial pavement at a research centre called Pedestrian Accessibility and Movement Environment Laboratory (PAMELA). It is used to simulate everyday scenarios, from different pavement users to varying pavement conditions. There also exists a research facility near Auburn University, the NCAT Pavement Test Track, that is used to test experimental asphalt pavements for durability.

Chapter 11

Level Crossing

A level crossing at Chertsey, England, as the barriers rise

A manually operated level crossing in India

A **level crossing** (also called a **railway crossing**, **railroad crossing**, **road through railroad**, **train crossing** or **grade crossing**) is a crossing on one level ("at-grade intersection") — without recourse to a bridge or tunnel — of a railway line by a road or path. The term also applies when a light rail line with separate right-of-way (or a reserved track tramway) crosses a road.

Overview

Europe uses a St Andrew's Cross to warn road users

Early level crossings had a flagman in a nearby booth who would, on the approach of a train, wave a red flag or lantern to stop all traffic and clear the tracks. Manual or electrical closable gates that barricaded the roadway were later introduced. The gates were intended to be a complete barrier against intrusion of any road traffic onto the railway. In the early days of the railways much road traffic was horsedrawn or included livestock. It was thus necessary to provide a real barrier. Thus, crossing gates, when closed to road traffic, crossed the entire width of the road. When opened to allow road users to cross the line, the gates were swung across the width of the railway, preventing any pedestrians or animals getting onto the line. The first U.S. patent for such crossing gates was awarded on 27 August 1867, to J. Nason and J. F. Wilson, both of Boston.

With the appearance of motor vehicles, this barrier became less effective and the need for a barrier to livestock diminished dramatically. Many countries therefore substituted the gated crossings with weaker but more highly visible barriers and relied upon road users following the associated warning signals to stop.

In many countries, level crossings on less important roads and railway lines are often "open" or "uncontrolled", sometimes with warning lights or bells to warn of approaching trains. Ungated crossings represent a safety concern; many accidents have occurred due to failure to notice or obey the warning. Railways in the United States are adding reflectors to the side of each train car to help prevent accidents at level crossings. In some countries, such as Ireland, instead of an open crossing there may be manually operated gates, which the motorist must open and close. These too have significant risks, as they are unsafe to use without possessing a knowledge of the train timetable: motorists may be instructed to telephone the railway signaller, but may not always do so.

The director of rail safety at the UK HM Railway Inspectorate commented in 2004 that "the use of level crossings contributes the greatest potential for catastrophic risk on the railways." Eighteen people were killed in the UK on level crossings in 2003-4. Bridges and tunnels are now favoured, but this can be impractical in flat countryside where there is insufficient space to build a roadway embankment or tunnel (because of nearby buildings).

At railway stations, a pedestrian level crossing is sometimes provided to allow passengers to reach other platforms in the absence of an underpass or bridge.

Where third rail systems have level crossings, there is a gap in the third rail over the level crossing, but the power supply is not interrupted since trains have current collectors on multiple cars.

An innovation yet to be proved practical is to transmit level crossing warning signals by radio into the cabin of the road vehicle. This would be particularly useful at passive crossings not yet fitted with flashing lights.

Major accidents

1999 Bourbonnais, Illinois train accident attributed to a truck driver's failure to yield at the grade crossing. The truck driver was subsequently jailed.

Level crossings present a significant risk of collisions between trains and other vehicles. They are also used for suicides. This list is not a definitive list of the world's worst accidents and the events listed are limited to those where a separate article describes the event in question.

Accident	Deaths	Country	Year
Langenweddingen level crossing disaster	94	Germany	1967
Nagpur level crossing disaster	55	India	2005
Polgahawela level crossing accident	35	Sri Lanka	2005
Xirivella level crossing accident	27	Valencia, Spain	1980
Dorion level crossing accident	19	Canada	1996
2009 Slovak coach and train collision	12	Slovakia	2009
Bourbonnais train accident	11	United States	1999
Hixon rail crash	11	United Kingdom	1968
Glendale train crash	11	United States	2005
Kerang rail accident	11	Australia	2007
Lockington rail crash	9	United Kingdom	1986
Gerogery level crossing accident	5	Australia	2001
Fox River Grove level crossing accident	7	United States	1995
Ufton Nervet rail crash	7	United Kingdom	2004

Crossings around the world

Asia

A level crossing on China National Highway 109 in Beijing, China

Level crossings in China, Thailand, and Malaysia are still largely manually-operated, where the barriers are lowered using a manual switch when trains approach. A significant number of crossings are without barriers. Railway electrification in Malaysia has gradually eliminated level crossings in Peninsular Malaysia, replacing those along nearly all upgraded lines with large overhead viaducts or deep underground tunnels, and simply cutting off non-essential crossings outright.

Taiwan

As most railways in Taiwan were built during Japanese administration, railway level crossings remain very common, though many urban crossings have been eliminated when the railroads have been moved underground, e.g., segments of the Western Line in Taipei City, or abolished, e.g. the former Danshui TRA Line that is now the Danshui Line of the Taipei Metro with no level crossings.

The Act Governing the Punishment of Violation of Road traffic Regulations (zh:道路交通管理處罰條例) defines three types of railway level crossing violations:

1. Not obeying a direction of a flagman or insisting to cross when the gate starts lowering or when the bell rings or the lights flash is a violation for drivers of motorized and non-motorized vehicles and pedestrians.
2. Directly crossing a railway level crossing not guarded by any flagman, gate, bell, or flashing light equipment without stopping as required when a warning sign is present is also a violation for drivers of motorized and non-motorized vehicles and pedestrians.
3. Overtaking, making a U-turn, backing up, stopping or parking on a railway level crossing is a violation for drivers of motorized and non-motorized vehicles but not pedestrians.

The same Act provides different penalties against different types of railway level crossing violators as follows, with very heavy penalties against drivers of motorized vehicles and much lighter penalties against drivers of non-motorized vehicles and pedestrians:

- Article 54: A driver of a motor vehicle shall be administratively fined 6000 to 12000 new Taiwan dollars for a railway level crossing violation. Should an accident occur, the driver license shall also be revoked permanently according to Article 67. This lifetime revocation used to be absolute, but the amendment of the law proclaimed on 28 December 2005 and effective on 1 July 2006 has allowed a possible waiver after serving at least 6 years of the revocation.

- Article 75: A driver of a non-motorized vehicle (e.g., a bicycle) shall be administratively fined 1200 to 2400 New Taiwan dollars for a railway level crossing violation.

- Article 80: A pedestrian shall be administratively fined 1200 New Taiwan dollars for a railway level crossing violation.

Accidents at railway level crossings remain a very serious concern. The Taiwan Railway Administration alone has hundreds of level crossings along its routes of slightly more than 1100 km. In average, there is a level crossing in less than 2 km.

Red emergency buttons have been installed to allow the public to report an emergency at a level crossing, such as stalled vehicles or any obstacles that would be very dangerous should any train approach. However, willfully misusing the emergency button is a *criminal offence*. In an emergency, the public is asked to:

1. First, press the button and be sure of its activation with a flashing light.
2. Second, try to clear any obstacles, including any vehicles.
3. Third, if unable to clear the obstacles and the warning bell rings, **leave quickly**. "A train is coming and please quickly leave the level crossing" will be announced in Mandarin, Taiwanese and Hakka.

Europe

Belgium

Belgian level crossing sign

At a level crossing, any overhead electric power cables must also cross. This led to a conflict where a mainline railway that crossed one of the country's once extensive interurban tramlines (*vicinal* or *buurtspoorweg*) was electrified. In at least one location, this led to the tram overhead being dismantled.

Automatic Level crossings in Belgium have two red lights, an amber light and sometimes barriers. However, the amber flashes for a second every certain number of seconds just to inform drivers and pedestrians that they do not need to check if a train is coming, if the amber light is absent you proceed at your own risk.

Italy

The cable-hauled section of the tramway up the hill from Trieste to Opicina has an interesting level crossing with a minor road at midpoint. As well as the rails, people crossing have to step or drive over two haulage cables, separated by wooden planking.

Sweden

In Sweden there are 8,500 level crossings, according to Trafikverket, the Swedish Transport Administration (former Banverket, Swedish Rail Administration). On public roads they have light signals with or without gates. On private roads there are level crossings without signals. Most accidents occur on crossings without gates. For many years there have been activities to reduce the number of accidents, usually by adding gates, or adding light signals if there were none. On the main lines many bridges have been built, and also anywhere a new road or new railway has been built. Still there are some level crossings left on the main lines. A train speed of 200 km/h is allowed in Sweden over level crossings, if there are gates and an obstacle detection unit. This unit detects cars on the track and prevents the gates from closing fully and stops the train. According to Trafikverket in 15 years there has only been one serious collision between a car and a train on such a level crossing, when a car ran through the gates just in front of the train.

Finland

Finnish level crossings contains light units each with a daytime running light in addition to the red lights. In Finland the tracks at level crossings of all kinds of other warning agencies not only in appearance throughout the boom institutions in Finland are used only for pedestrian and bicycle lanes, the reason why Finland is not used for the entire boom car plants you have it that the whole boom in institutions of higher risk to be stuck with a car between the booms. Finnish level crossings are the safest in the seventh level crossings in Europe. Finnish has a state track a total of 3376 level crossings.

Finnish level crossing in Eura, Finland.

United Kingdom

A level crossing sign on the Romney, Hythe and Dymchurch Railway (a 15" narrow gauge heritage railway) at St Mary's Bay railway station, England

Britain's first automatically operated level crossing came into operation at Spath near Uttoxeter in Staffordshire in May 1961.

There were 8,200 level crossings in the UK in 2005, of which, 1,600 were road crossings. This number is gradually being reduced as the risk of accident at level crossings is considered high. The director of the UK Railway Inspectorate commented in 2004 that "the use of level crossings contributes the greatest potential for catastrophic risk on the railways." Bridges and tunnels are now favoured, and there is a commitment on the part of UK rail authorities not to build new level crossings, and to reduce the number of existing level crossings. The cost of making significant reductions, other than by simply closing the crossings, is substantial; some commentators argue that the money could be better spent. Some 6500 crossings are user-worked crossings or footpaths with very low usage. The removal of crossings can also improve train performance as some crossings have low rail speed limits enforced on them to protect road users. In fact, between 1845 and 1933, a 4 mph speed limit was notionally in force over level crossings.

Situation

In the United Kingdom, major crossings were normally situated within easy viewing distance of a signal box, and usually directly adjacent to the signal box. This ensured that the signalman could verify that the road was clear before allowing a train onto the crossing. The traditional form of road crossing on British railways from the mid 19th century consisted of four wooden gates (two on each side of the railway). These prevented road traffic from crossing when closed and when open lay across the railway to prevent horses and livestock inadvertently escaping from the road to the railway. Many gated crossings have been replaced by lifting barriers, which are easier to mechanise. "Full barriers" consist of barriers each side of the track, which block the full width of the road and "half barriers" consist of a single arm each side of the road, which block only oncoming traffic. Half barriers were considered to have an advantage as motorists are less likely to be stranded on the crossing and unable to exit, but cases where impatient motorists have driven around the barriers have raised safety concerns. Video cameras are now often used at crossings to allow the human operator to be some distance from the crossing. On lightly used railways many crossings are sited next to station stops or other stopping points and are crew operated. The guard pushes a plunger to operate the crossing. On completion of the crossing sequence, an indicator light permits the train to proceed if the crossing is observed by the train driver to be clear. After the train has cleared the crossing, it re-opens to road traffic.

To ensure that the barriers are noticed and to draw attention, public road crossings may be fitted with a ringing warning bell or siren and with lights. Some crossings also have telephones which connect to the relevant signal box, so that in case of an emergency, or a large slow moving vehicle wanting to use the crossing, the signalman's attention can be drawn promptly to the hazard and action can be taken. Some "automatic open crossings", with warning lights and bells but no barriers, were introduced, but their expansion was largely halted after the Lockington rail crash. Some smaller crossings, particularly pedestrian crossings on low-speed lines consist of nothing but a warning sign and raised pathway across the track itself.

In November 2004 there were two major accidents on UK level crossings: one involved a car driver committing suicide, who caused the death of seven people (Ufton Nervet rail crash); another involving a train carrying 50 school children resulted in no fatalities but a number of injuries. These incidents have increased efforts to review the placing of level crossings and to eliminate them where this is practicable. In the UK it has also been suggested that cameras similar to the type used to detect drivers who run traffic lights be deployed at level crossings, and that penalties for ignoring signals should be much more severe. British Transport Police typically prosecute motorists who jump the barriers with either trespass or failing to conform with a traffic signal. A particular problem has been that the responsibility for the road safety at crossings is entirely outside the control of the railways. In 2006 legislative activities are in progress to permit Network Rail to be involved in the road side safety of crossings. This will allow the introduction of anti-slip surfaces and also barriers to prevent motorists driving around crossing arms and, it is hoped, reduce the number of crossing related deaths.

Pedestrian crossings

The use of pedestrian crossings at stations is now rare, although historically it was common that passengers walked across the line between platforms on branch lines. At Settle, for example, before the footbridge was installed in the 1990s, the time taken while passengers from Leeds walked across the line was happily used to top up the driver's kettle with hot water. With a few exceptions, such as at Carmarthen, the remaining examples occur only on heritage railways or as a means for passengers who cannot climb stairs to move between platforms where the only other route is a footbridge.

For the episode of British motoring television programme *Top Gear* on 25 February 2007, Network Rail staged an incident in which a locomotive was driven into a Renault Espace at around 80 mph to graphically illustrate the dangers of "running the risk".

The idea of 'modular' level crossing barriers were a consideration by Network Rail when they introduced a new modular building system in 2008. The term 'modular' meaning they can be assembled and erected into place in a mere matter of hours.

North America

Canada

Grade crossing protection practices in Canada are virtually identical to those in the United States (see below) using the same alternating flashing red lights and gate arms. The only significant differences are the crossbucks, which have no wording but are white with a red outline, and the advance-warning sign, which is a yellow diamond shape with a diagram of a track crossing a straight segment of road (similar to a crossroads sign, except that the horizontal road is replaced by a track). Before changes in regulations mandated bilingual (English and French) or no-wording signs, crossbucks were nearly identical to those in the States, except that they read "Railway Crossing" instead of "Railroad Crossing." The red lights also flash a little faster than in the United States.

United States

In North America, the words "Railroad Crossing" normally appear on the warning sign in the US, while in Canada, the sign is white with red trim. The road appears to make a turn so that it crosses the railroad at an angle closer to 90 degrees.

This circular sign is used in the US as an advance warning of the crossing; the crossbuck is at the crossing proper. This is one of the few road signs in the US with a circular shape.

In the United States and in countries following United States practices, a locomotive must have a bright headlight and ditch lights (two lights located below the headlight), a working bell, and a whistle or horn that must be sounded four times (long-long-short-long), similar to the signal for the International Morse Code letter "Q", as the train approaches the crossing.

Some American cities, in the interest of noise abatement, have passed laws prohibiting the sounding of bells and whistles; however, their ability to enforce such rules is debatable. In December 2003, the U.S. Federal Railroad Administration published regulations that would create areas where train horns could be silenced, provided that certain safety measures were put in place, such as concrete barriers preventing drivers from circumventing the gates or automatic whistles (also called *wayside horns*) mounted at the crossing (which reduce noise pollution to nearby neighborhoods). Implementation of the new "Quiet Zone" Final Rule was delayed repeatedly but was finally implemented in the summer of 2005. Rail "Quiet Zone" crossings still require bells as part of the automatic warning devices (AWDs) in addition to the wayside horns. The wayside horns usually are sets of speakers that are directed at the crossing mounted right up on a pole.

Every crossing, whether above grade, below grade, or at grade, is required to be assigned a unique identifier which is a six-digit number and a trailing letter used as a checksum. This identifier is called a Grade Crossing Number, and is usually posted with a sign or sticker on the sign or equipment. This allows a particular crossing anywhere in the United States to be precisely identified as to its exact location in the event of an incident involving that crossing.

All public crossings in the United States are required to be marked by at least a crossbuck; most crossings intersecting rural roads have this setup. If the crossing has more than one railroad track, the crossbuck will usually have a small sign beneath it denoting the number of tracks. As traffic on the road crossing or the rail crossing increases, safety features are increased accordingly. More heavily trafficked crossings have AWDs, with alternately flashing red lights to warn automobile drivers and a bell to warn pedestrians. Additional safety is attained through crossing gates that block automobiles' approach to the tracks when activated. Increasingly, crossings are being fitted with four-quadrant gates to prevent circumventing the gates.

Operation of a typical AWD-equipped railroad crossing in the United States is as follows:

- Approximately 30 seconds before arriving at the crossing, the train trips a track circuit near the crossing, triggering the crossing signals. The lights begin to flash alternately, and a bell mounted at the crossing begins ringing. After several seconds of flashing lights and ringing bells, the crossing gates (if equipped) begin to lower, which usually takes 5–10 seconds. Some AWDs will silence the bell once the gates are fully lowered (typically seen on most Norfolk Southern and CSX crossings) ; most continue ringing the bells throughout. The lights continue to flash throughout regardless.
- Approximately 15 to 20 seconds before arriving at the crossing, the train begins ringing its bell and sounding its horn in accordance with NORAC rule 14L or GCOR rule 5.8.2(7): two longs, one short, and one long. These are prolonged or repeated until the engine occupies the crossing. If the AWD is equipped with a horn in accordance with FRA Quiet Zone rules, the AWD may provide the whistle signal instead of the train; however, the train is required to ring its bell regardless.
- After the train has cleared the crossing, the gates (if equipped) begin to rise, and the bells (if silenced) may begin ringing again. Once the gates have completely risen back to their fully raised position, all warning signals, including the lights and bells, are deactivated.

Some AWD track circuits are equipped with motion detectors that will deactivate the crossing signal if the train stops or slows significantly before arriving at the crossing.

As indicated above, the pattern of the bells at each individual crossing can be different. (These bells should not be confused with the bells that are mounted on the trains.) Generally, the bells follow one of these patterns:

- The bell begins ringing when the lights begin flashing and stops when the gates have completely lowered.
- The bell begins ringing when the lights begin flashing and stops when the gates begin to go up following the passing of the train.
- The bell begins ringing when the lights begin flashing and stops when the gates have completely lowered, and then resums ringing when the gates begin to go up, until the gates have returned to their original position.
- The final, and most common, practice is for the bells to begin ringing when the lights begin flashing and continue till the gates have gone up after the train passes.

Some level crossings that are located too close to intersections with traffic lights will program the signals so when the approaching train trips the track circuit, it not only activates the crossing signals, but also changes the traffic lights facing the crossing from green to red, with no yellow phase. Some track circuits disable the traffic lights the entire time the AWDs are active, making them flash yellow in one direction and red in the other.

In prior years, when Railroads would share the right of way with vehicular traffic, a simple railroad preemption would cause an all red flash in traffic lights

A few level crossings still use wigwag signals, which were developed in the early 1900s by the Pacific Electric Railway interurban system in the Los Angeles region to protect its many level crossings. Though now considered to be antique, around 100 such signals are still in use, almost all on branch lines. By law, these signals must be replaced by the now-standard alternating red lights when they are retired.

U.S. Federal Railroad Administration regulations restrict trains to a maximum speed of 110 mph (177 km/h) at standard grade crossings. Crossings are permitted up to 125 mph (201 km/h) only if an "impenetrable barrier" is in place to block traffic when a train approaches. Crossings are prohibited at speeds in excess of 125 mph (201 km/h).

A track that will run high-speed trains in excess of 120 mph (193 km/h) is being tested in Illinois between Chicago and St. Louis, Missouri. Here, due to the high speed of the trains, gates that totally prevent road traffic from reaching the tracks are mandatory on all level crossings. Steel mesh nets were tested on some crossings to further prevent collisions, but these were removed because of maintenance issues in 2001.

A new device called "StopGate" has been installed at four locations, one in Madison, Wisconsin; another in Monroe, Wisconsin and two in Santa Clara, California (on a light rail system). This system resembles a fortified version of a standard crossing gate, with two larger arms blocking the entire width of the roadway and locking into a securing device on the side of the road opposite the gate pivot mechanism. The gate arms are reinforced with high-strength steel cable, which helps the gate absorb the impact of a vehicle attempting to crash through the gate. The manufacturer claims that the StopGate can arrest a 2,000 kg (4,400 lb) truck within 13 feet (four meters). Already the system has been tested at the Madison crossing, when the system stopped a truck while a Wisconsin and Southern Railroad train was in the crossing.

Another new type of barrier is being tested in Michigan that is hoped will reduce the number of times drivers attempt to drive around lowered crossing gates. The new devices are called "delineators" consisting of a series of flexible bollards that raise vertically out of vertical tubes in the pavement when the crossing signal is activated. The delineators are designed so that they will not be broken and will not damage vehicles if they are hit, allowing vehicles to exit the level crossing if they are already within it when the gates are activated. The test period for the new barrier began on 5 December 2007, and will run for a period of 17 months.

Oceania

Australia

A level crossing in New South Wales.

Australian railways generally follow United States practices, and they have increasingly been employing American-made crossing warning equipment, such as grade crossing predictors, which are able to provide a consistent amount of warning time for trains of widely varying speeds.

One recent innovation in Australia is to provide crossbucks with a pair of flashing yellow lights at a distance of say 200m from the level crossing itself, particularly where there are curves and visibility problems on the road. These are called Advance Active Warning Signals.

In Melbourne, Australia, there are several level crossings where electrified train tracks cross roads with electrified tram tracks. These crossings are fitted with equipment to change the voltage supplied to the overhead wiring depending on the vehicle using the crossing at that point in time. Trains are severely speed-limited across these intersections.

Although all cases where a train line crosses a road are level crossings whether or not they are signed, a tram track in its own right of way crossing a road can also be a level crossing if it is signed with a crossbuck which can read either "TRAM WAY CROSSING" or "RAIL WAY CROSSING". Otherwise, it is a regular intersection and usually has either traffic lights or a give way sign facing the road (see Gallery).

New Zealand

There are 1400 public road level crossings in New Zealand. Half of the crossings are equipped with flashing red lights and bells, with the most major and all multi-track crossings having half-arm barriers. The remainder are controlled by stop and give way signs. Level crossings are the responsibility of rail infrastructure owner ONTRACK, the New Zealand Transport Agency, and if the crossing is on a local road, the local city or district council.

On the Taieri Gorge line and the Hokitika Branch, in rural South Island, New Zealand, roads and railways share the same bridge when crossing a river, with the rail line in the road. Motorists, as well as giving way to oncoming traffic if required (the bridges have one lane) must ensure that the bridge is clear of a train, end to end, before starting to cross the bridge. For safety, trains are limited to 10 km/h (6 mph) while crossing the bridges.

A unique level crossing exist near Gisborne, in which the Palmerston North - Gisborne Line crosses one of Gisborne Airport's runways. Aircraft landing on sealed 1310-metre runway 14L/32R are signalled with two red flashing lights on either side of the runway and a horizontal bar of flashing red lights to indicate the runway south of the railway line is closed, and may only land on the 866 m section of the runway north of the railway line. When the full length of the runway is open, a vertical bar of green lights signal to the aircraft, with regular rail signals on either side of the runway indicating trains to stop.

Level crossing safety in New Zealand is relatively poor, with 85 level crossing deaths in the past five years. One of the most notable level crossing accidents occurred in August 1993, when a southbound Southerner passenger train hit a cement mixer at a level crossing at Rolleston, near Christchurch. The accident resulted in three deaths, including Louise Cairns, sister of New Zealand international cricketer Chris Cairns.

Unusual crossings

Bishton level crossing in Wales is unusual in that it is partly replaced by an underpass for low clearance cars, leaving the level crossing for high clearance trucks. There are many similar crossings on the line between London Liverpool Street and King's Lynn (built by the Great Eastern Railway Company), including at Ely and Great Chesterford, and also near Cambridge Science Park on the former line to St Ives. The level crossing at Manningtree station in Essex also features this set-up.

A new Finnish warning sign at Loimaa. It is inexpensive and intended for low-traffic roads.

AAWS, the advance active warning signal, is used in Australia and positioned around 200 metres before the level crossing.

British Rail sign at Manor Road railway station in Hoylake, Wirral, United Kingdom, indicating dangers of misusing crossing.

A railroad crossing in Belton, Missouri, with only the crossbuck, flashing lights, and warning bell

An electronic crossing bell made by General Signals Inc.

A traditional mechanical crossing bell. Newer crossings have electronic bells that produce a clearer warning sound.