

MOBILITY INDUSTRY INSIGHTS

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In *Mobility Industry Insights* we will investigate and debate the issues that affect how people and goods are transported, how governments attempt to enable and restrict transport, how consumers decide which transport options they will use, and the methods being used to make mobility safer, more convenient, and more affordable for all. We will discuss and debate the issues, presenting multiple perspectives, and will solicit views from a variety of sources.

A Discourse on Merging Into the Flow of Traffic

“Never take more than your share – whether of the road in driving your car, of chairs on a boat, or seats on a train, or food at the table.”

Emily Post¹

ABRIDGEMENT

WHEN I’M DRIVING, I often wish it were possible to talk to the other drivers around me. “You are following too closely.” “You left your blinker (turn signal) on.” “Please let me into your lane.” I think it would be especially useful on two lane undivided country roads with tight curves and hilly terrain where it is impossible to know if a car up ahead has decided to pass and is waiting for me in my lane at the next bend or just over the approaching knoll.

Driverless cars, like those from Waymo plying the roads in Arizona, California, and Texas, have been avoiding the trickiest driving situations, the ones requiring merging, when cars need to blend together from two lanes into one, or when cars must find a spot in the flow of highway traffic to sneak into from a joining ramp. Then there is the roundabout merging exercise where cars are expected to curtsy but where rudeness often rules. These situations are the ones which would benefit the most from vehicles being able to communicate with each other, but that possibility does not currently exist. Anyone who has driven anywhere outside of their own home patch knows that merging is both a local art and an imperfect science. Merging requires equal doses of empathy and *chutzpah*, two characteristics absent from the bag of tricks that today’s robots can pull out and perform.

If driverless cars are going to join the traffic mainstream, they are going to have to make the implicit explicit. They are going to have to talk to each other in plain robotspeak. “R2-D2-2-C-3P0: UGO 1st; IGO 2nd. What is it going to take to make this happen? Transportation authorities could start by stopping the practice of building lane reductions, start posting clear signs on how merging should occur (preferably the zipper method), making the merging rules for acceleration lanes specific and then enforcing the rules. Beyond that, the main steps that have to be taken are to put communications into all cars, allocate the appropriate amount of bandwidth for communications in all jurisdictions, and standardize the message sets that will be needed for all vehicles of all types and with all levels of priority (i.e., police, ambulance, rescue, etc.) to talk to each other. Driverless vehicle software developers and vehicle manufacturers need to focus on incorporating the correct driving behaviors into their vehicles. It wouldn’t hurt if all driver’s license tests required a trip onto a motorway, a pass through a highway construction site, and a swing through a roundabout.



¹ Emily Post was an American author and socialite, best known for her influential writings on etiquette and manners. Her book, *Etiquette in Society, in Business in Politics, and at Home* (1922), referred to as the *Blue Book on Etiquette*, became a best seller, and her syndicated column on etiquette, called *Good Taste*, appeared daily in over 200 newspapers.

“Whenever two people come together and their behavior affects one another, you have etiquette.”

Emily Post

Everything I needed to know about merging into a stream of traffic I learned in kindergarten.

MERGING INTO A stream of traffic is often listed under the "etiquette" category in country and state road transport regulations. Etiquette is the “conduct or procedure required by good breeding or prescribed by authority to be observed in social or official life.”² It builds on the human trait of ‘reciprocal altruism’, which is behavior that gives benefits conditionally upon receiving a returned benefit. I bring back the rabbit for dinner and you make the fire. The practice of sharing food among members of a group helped all humans to survive so that they would eventually have the means to become more mobile, including inventing vehicles, the roads on which we drive them, and then merging lanes.

Six of the sixteen reciprocal altruism lessons American author and Unitarian Universalist minister Robert Fulgham wrote in his 1986 book, All I Really Need to Know I Learned in Kindergarten are directly related to driving in general and merging in particular:

- Share
- Play fair
- Don’t hit people
- Don’t take things that aren’t yours
- When you go out into the world, watch out for traffic
- Hold hands and stick together

Being a good driver is not all that different from being a good person, especially when you interact with other people. If we had the road all to ourselves, we would never have to think about sharing it by staying in our lane so that we don’t hit other people, and we would not have to watch out for traffic or look out for the other guy’s back. But we rarely drive alone.

One of the several definitions of merging is ‘to blend or come together without abrupt change, in the sense of merging traffic’.³ In other words, merging was invented to minimize the need to stop along roads and at junctions and intersections with the purpose of keeping the stream of traffic moving. A ‘junction’ is a general term referring to a point when two or more things meet or join, such as roads, sewer lines, train track beds. An intersection is a specific type of junction when two or more things meet or cross at the same level (i.e., at grade). An intersection is the most common type of road-related junction and includes four-way intersections, T-intersections, Y-intersections, circular intersections (roundabouts), and the most recent type of intersection, the interchange with merging lanes.

² The French word *étiquette* means “ticket”; its direct French ancestor also referred to a label attached to something for description or identification. Spaniards of the 16th-century adopted the French word (altering it to *etiqueta*) and used it to refer to the written protocols describing the behavior demanded of those who appeared at court. Eventually, *etiqueta* came to be applied to the court ceremonies themselves as well as to the documents which outlined their requirements. Word of this linguistic development got back to the French, who then expanded their word’s meaning to include “proper court behavior” along with its “label” sense. By the middle of the 18th century English speakers had taken on *etiquette* as their own, applying it to the rules that indicate the proper and polite way to behave, whether in the presence or royalty or not.

³ Merriam-Webster

We could jump right in and start discussing the problems and possible solutions to merging, to make those special types of meetings between vehicles safer and more determinable, but we would miss the opportunity to understand why the concept of merging was developed in the first place and what expectations there were for improving traffic flow by employing the merge.

Road etiquette is nothing new

When two people meet along a narrow path, there is a negotiation that takes place to determine who will give way (yield) to allow the other to pass. If one of the persons is bigger and stronger than the other, he may feel that the other person should give way and simply push ahead without stopping. If one of the persons is obviously a part of the ruling class in the region, and the other is a peasant, the person with the greater amount of power may expect the person with less to stand aside. (Of course, there would have to be some way of distinguishing rank, and I suppose that is one reason clothes were invented or bars and stars on uniforms.) If the meeting parties were equals, they would be expected to follow a set of rules which they had been taught (i.e., etiquette). Widen the path to accommodate two persons passing each other, and the problem is solved, unless one of the persons is driving a wagon pulled by an ox or two that fills up the entire width of the road. A wagon is not so easily moved off the side of a road so that another wagon may pass. So, widen the road to allow two wagons to pass each other, and you have invented the concept of a dedicated lane for moving in a specific direction. *Hmmm, let's see, on which side of the road am I supposed to be driving?*

Road etiquette evolved as transport evolved, and the Romans made major contributions to the rules of the road because they made so many significant advancements in road building. The Romans did not invent the concept of paved roads, nor did they invent the concept of wheeled transport. The first roads constructed by humans have been found in the Indus Valley dating from around 4000 B.C. The first carts are dated to around 3000 B.C. and existed in Mesopotamia. In 2000 BC, the Minoans built a paved road that was about fifty kilometers long. It had side drains, a sandstone base and a covering of basaltic flagstones. Other cultures also built roads, but it was the Romans who built many, many more of them, and they stretched from the capital to the farthest reaches of the empire, the furthest point being 4000 kilometers away along the Red Sea in what has become Saudi Arabia. Anyone who has their roots within that empire has ancestors who lived on or near to one of the *viae*. My maternal roots are along the Via Flaminia in Umbria, and my fraternal ones are along the Via Appia in Campagna.



The Roman empire in the time of Hadrian (ruled 117–138), showing the network of main Roman roads

The Laws of the Twelve Tables

The year 450 B.C. was a big one for both the political history of the world and for transportation. It was during the period of the Roman Republic when the plebians, members of the lowest social class, demanded that their legal rights be made clear and not

A Roman bas relief of a *raeda* carriage



Raised sidewalk called *samita* ('footpath') with stone curbs beside a *Viae vicinales* in Pompeii, Italy

subject to the whims of patricians who made judgments according to unwritten custom. It is claimed to be the earliest written legislation of Roman law. Within the Twelve Tables is a definition of 'public road' (*Via*). It was to be 8 Roman feet (approximately 2.37 meters) wide when straight, and twice that width when curved. This requirement was known as the *latitudo legitima*. The Tables make the building of roads a government requirement and provide the right of travelers to pass over private land wherever the road is unable to be traversed. This is what led the Romans to build roads that were durable and to keep them maintained, so the plebs would not be traipsing across the fields of the wealthy. The right to use a road was known as *servitus*, or 'liability'. The right of driving a wagon was called *ius agandi*.

A Roman chariot was around 1.4 meters wide, which is the distance between the outside hind quarters of two horses harnessed together side-by-side in front of a chariot.⁴ The prescribed 8 Roman feet was later increased to 12 so that two chariots could pass each other on a *via* without hindering the passage of walkers (who would eventually be called 'pedestrians' and be given their own paths alongside the paved roads, as in Pompeii). Roman law forbade the use of vehicles in urban areas, with exceptions (usually for carrying wealthy or important people or their possessions). Government officials could ride, for example. The *Lex Julia Municipalis* (Julian Law of Municipalities), developed in 49 B.C. during the time of Julius Caesar and intended to establish laws for all municipalities, not just a particular one, prohibited commercial vehicles from being used within the walls or in the proximity of a city from dawn to dusk.

There were three types or categories of Roman roads. These categories are with us to this day, and they form the basis for merging rules.

- *Viae publicae, consulares, praetoriae or militares* – Public main roads constructed and maintained at public expense with the ownership of the roadbed invested in the state. They were placed under the jurisdiction of commissioners (*curatores*) and repaired by contractors (*redemptores*). Adjacent landowners were taxed to contribute to the payment of building and maintenance of these roads. They were named after the magistrate (*censor*) who ordered their construction.
- *Viae privatae, rusticae, glareae or agrariae* – Private or country roads constructed and maintained by private individuals and at their private expense. They led from the *Viae publicae* to villages or private estates. A sub-category of these roads were the 'dirt roads', *viae terrenae*.
- *Viae vicinales* – Roads in and around villages. These roads ran into the other two categories of roads or into other *viae vicinales*. They were built and maintained with either private or public funds, and the maintainers were local governing authorities. Neighboring landholders contributed money and/or labor.

⁴ This width has carried on through the ages, establishing the standard for railroad track widths and lane widths.



Roads were not free to use. Toll collectors were everywhere, especially at those places where you could not sneak around them, like at bridges. The city gate was the favorite collection spot. On top of the road use taxes there were tariffs on the goods being transported. (Yes, the more things change the more they stay the same.) I have found no mentions of directing traffic in the Roman era or controlling the meeting of vehicles at intersections.

The beginnings of road etiquette

What happened when two legions met on a road? If the road was not wide enough for the legions to pass each other, one of them had to give way. As you might expect, the legion being led by the officer with the highest rank had the right of way. Rank was trumped by mission purpose. The legion which had the more critical mission, like responding to an emergency or transporting supplies that were vital for a battle, had the right to go first. If they met at the edge of a city, generally the legion leaving would have precedence over the one entering, presumably so that all those waving off the leaving legion would be able to get on with their lives.



A recently discovered Roman milestone in Cilicia, Turkey

There was not much of a need for road regulations in the form of signage until road vehicles moved faster than 2-3 times the average speed of a walk, which is about 2.5-3 mph (3.6-4.8 km/hr.). The Romans erected stone markers called *miliarium* (milestones), which is derived from the words *mille* for ‘thousand’ and *passus* for ‘step’ or ‘pace’. A Roman mile is 1000 paces, which translates to about 5000 feet in today’s measurements, not far from the 5280 feet in an English mile. The stone obelisks contained the full title of the emperor at the time the road was built or modified, the distance to Rome or the most important town along the road, the name of the person or group responsible for the building or maintenance of that particular stretch of road, and the latest work that had been performed. There have been no discoveries of signs to regulate how the road should be used or how travelers should behave (e.g., yield or share). That would come over a millennium-and-a-half later when surface structure⁵ would begin to be laid over the road infrastructure.



A 1911 milestone in the City of Westminster, London, showing the distance from Kensington Road to Hounslow and Hyde Park Corner. (Photo by Christine Matthews in Wikipedia)

It was in 1686 that the first-known Traffic Regulation Act in Europe was established by King Peter II of Portugal. This act stated which traffic should back up to give way in the streets of Lisbon. One of these signs still exists at Salvador street, in the neighborhood of Alfama. It reads: *His Majesty commands all coaches, carriages and litters coming from Salvador's entrance to back up to the same part.* Imagine the king being the first traffic cop.



⁵ Surface structure is a combination of traffic control systems and signs, regulations that are written into the country’s or city’s transport laws, and traditions and cultural practices that people who drive long enough in an area learn. (Sena, M., Kornhauser, A. *The Real Case for Driverless Mobility*. Elsevier (2024). Page .



Photo taken in 1916 with a Penny Farthing mingling with cars and safety bicycles. (Credit: Getty Image)

From royal beginnings, road signs became a common occurrence when a new form of mobility was invented: the modern bicycle. This was around the late 1880s.⁶ Their riders thought they were marvelous; those who were not riding them thought of them as killing machines. They were silent and travelled at high speeds, which made them a danger to anyone in their paths. The pro-cyclists formed cycling organizations, like the Dutch ANWB, which was founded in 1883 as the *Nederlandsche Vélocipèdisten-Bond* for bicyclists and only later became a motor car association. These organizations took the initiative with signage. Their signs warned of steep hills and dangerous curves. They should also have been issuing warnings to pedestrians and horse riders for the Penny Farthings that were coming at them, unable to stop without the rider falling over.

Bicycles were the first real test of humans exhibiting reciprocal altruism with regard to controlling their behavior with a new form of mobility, and they did not do well. Accounts of what happened at the time are similar to what has happened during the past five-or-so years with the introduction of electric scooters and electrified bicycles. It took some time for the city authorities in both Europe and North America to come to grips with the problems and begin to regulate where cyclists could ride and how fast they could travel. At the turn of the 19th into the 20th century, authorities began to mandate lights on bicycles after dark and made reckless riding (e.g., no hands on the handlebars) a traffic violation. This was all before the first cars began to ply the streets.

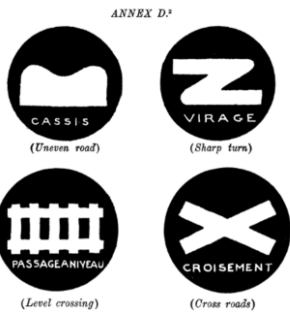
The first prescription for safe motor vehicle travel

The undersigned plenipotentiaries⁷ of the governments hereinafter specified, assembled in conference at Paris from the 5th to the 11th October 1909, with a view of facilitating, as far as possible, the international circulation of motor vehicles.

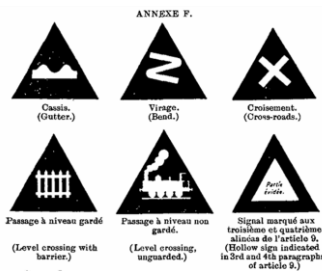
This was the preamble to the *Convention With Respect to the International Circulation of Motor Vehicles - Paris 1909*. In the first article, it defined the conditions “to be fulfilled by motor-cars in order to be allowed to be driven on the highway”. The vehicle had to be “trusted to work efficiently” (i.e., not subject to fire or explosion, not so noisy so as to frighten animals, and not emitting too much smoke or vapor). It had to be equipped with a steering apparatus; it had to have two brakes, one to stop the vehicle and the other to keep it stopped; it had to be reversible; all the driving and steering apparatus had to be designed so that they did not hamper the driver’s view of the road; and all motor-cars (sic) had to be fitted with signs showing the name of the vehicle’s manufacturer, the

⁶ Earlier bicycles, like the one invented by Karl von Drais, had no pedals. The velocipede, that appeared in the 1860s, had pedals on the front wheel. The penny farthing had a big front wheel over which the rider was placed. It just looked like just getting up to the seat was life-threatening. The safety bicycle came at the end of the 1880s and had equal-sized wheels, a chain driver, and served as the prototype for the modern bicycle. (<https://world-of-bicycles.com/when-was-the-bicycle-invented-a-journey-through-its-history-and-impact/>.)

⁷ A person and especially a diplomatic agent invested with full power to transact business. (Merriam-Webster).



Appendix D in the 1909 Paris Convention indicating dangerous places



Appendix F in the 1926 Paris International Convention relative to Motor Traffic

POLICE NOTICE.

STREET CROSSING SIGNALS.
BRIDGE STREET, NEW PALACE YARD.

CAUTION. **STOP.**

The Semaphore Arms lowered, and the Signal with a Green Light.

The Semaphore Arms elevated, and the Signal with a Red Light.

By the Signal "CAUTION", all persons in charge of Vehicles and Horses are warned to pass over the Crossing with care and due regard to the safety of Foot Passengers.

The Signal "STOP", will only be displayed when it is necessary that Vehicles and Horses shall be actually stopped on each side of the Crossing, to allow the passage of Persons on Foot; notice being thus given to all persons in charge of Vehicles and Horses to stop clear of the Crossing.

RICHARD MAYNE,
Department of Public Works.

vehicle’s manufacturing number, the horsepower of the engine, the number and bore of its cylinders, and the weight of the car unladen.

Article 2 of the *Paris 1909 Convention* addressed drivers. They had to have reached the age of 18 and have been judged competent to drive a motor-car by the competency-judging authority in the country where they intended to drive. Article 5 specified that motor-cars had to have warning mechanisms in the form of a horn that emitted a “deep note” to give warning, and two lamps in front and a light behind. The use of “dazzling lights” was not permitted.

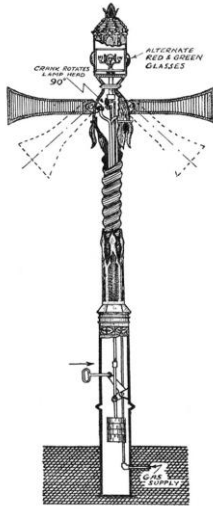
In Article 8, the *1909 Convention* makes the first attempt to standardize “notices directing attention to dangerous places”. These are shown in the sidebar and include uneven road surface, sharp turn, guarded/gated level crossing with a railroad, and crossroads/intersections. In the text of Article 8, it makes mention of an additional sign to order a ‘halt’ of the vehicle and to signs indicating the direction to a toll house or custom house. As yet, there were no mentions of yielding or merging, either to other cars or to pedestrians. In the next version of the *Convention*, finalized in Paris on the 24th of April 1926. The round signs have been replaced by triangles, and an unguarded level crossing between a road and train tracks has been added.

As roads got better, cars went faster – and were more dangerous

A Ford Model T had a 20-horsepower 4-cylinder engine with a three-speed transmission. Its top speed was 42 mph (68 km/h). The 1912 Chevrolet Series C Classic 6 was Chevy’s first car. It had a 40-horsepower 6-cylinder engine that could attain a speed of 65 mph. When these cars started being sold, few drove them at their top speeds, either because the roads didn’t allow it, because the likelihood was high that the engines or other parts would give out, or because there were plenty of other vehicles pulled by horses that were moving at a much slower pace.⁸ A stagecoach pulled by four or six horses would average about 15 mph on a flat-surfaced road for about 20 minutes, but then the horses would need a rest. A carriage trip might average around 10 mph. As the speed of the vehicles increased, the need to design roads that could accommodate those speeds increased as well. On top of this, there were all the people still on foot or riding on, or being pulled by, horses.

As with the introduction of bicycles, there were conflicting objectives between those who drove the cars and those who didn’t. The former group wanted to move as fast as possible, unhindered, to their goal. They did not want to slow down or give way or stop. The latter wanted to be able to move wherever they had moved before, unthreatened by a force that was moving at a pace twenty times faster than it could travel, and weighed, on average, over ten times more than it did. Even before the introduction of cars,

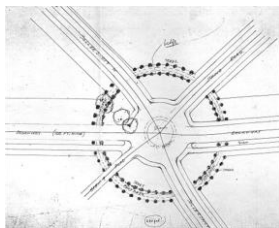
⁸ The top speed of a 1961 VW Beetle is listed as 68 mph. I blew out two engines in my ‘61 Bug pushing it at that speed across the state of Pennsylvania on the PA Turnpike, up and down its hills.



Purportedly, the first traffic light



In some countries, like Sweden, there is the concept of a 'priority road', and it is marked with a yellow diamond. Cars entering a Priority Road must give way, whether they are turning right or left and whether or not there is a yield sign on the entering road. In other words, the right-hand rule does not apply. On the intersection shown above, if there were no Priority Road sign, a vehicle entering from the right would have the right-of-way.



1908 Parker and Unwin plan of the suggested layout of 'Sollershott & Broadway Circus' in Letchworth Garden city as the UK's first roundabout. It was built in 1909.

heavily trafficked roads made crossing them by pedestrians a problem. In 1868, the first pedestrian crossing was installed in the Borough of Westminster in London, on Bridge Street. It was railway engineer John Peake Knight's bright idea, and it would be carried into the 20th century with stop lights and walk lights.

In 1913, there were approximately 1.3 million cars in the United States and 2 million drivers. There were 4,200 motorcar-related deaths in that year. By 1930, the number of deaths had reached 32,900 and the number of cars was 26 million.⁹ Twenty times the number of cars and eight times the number of deaths. People knew they had to start doing something about the toll cars were taking on their populations. Stop signs and pedestrian controls could be applied within urban areas, both to control the meeting of cars with each other and the meeting of cars with pedestrians, but what could be done with the actual design of the roads to reduce the potential for accidents? This is where we first see the concept of merging applied, combined with the etiquette of yielding.

Round and round and round we go

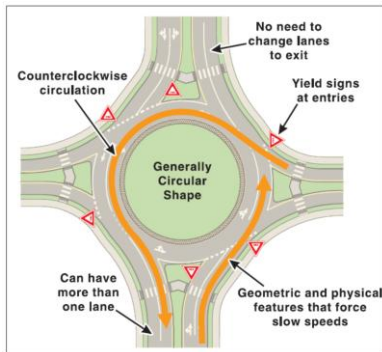
The circular junction, traffic circle, rotary, or roundabout was invented in the late 19th and early 20th century, both to keep traffic flowing and to reduce crash-related injuries and deaths. The circular junction combines the concept of yield and merge. Yielding to the right had been proposed first in France in 1896 by Charles-Marie Gariel, a professor of physics at the School of Highways and Bridges. He suggested a rule for when two cyclists arrived at an intersection at the same time, that the cyclist on the right would proceed, and the cyclist on the left would slow down and give way.¹⁰ Paris adopted it in 1910 for all vehicles on its roads. It is applied to this day in most countries where traffic drives on the right side of the road (and reversed in those countries where they drive on the left) and where there are no other regulations or signs for an intersection.¹¹ Although it was not specifically referred to in the 1926 *Convention*, Article 8 states that "the driver of a motor vehicle travelling in a country is bound to conform to the laws and regulations regarding traffic which are in force in that country", so, as the right-hand rule was extended, it became general practice and it was extended into roundabouts.

There were many "inventors" of the traffic circle. The early ones, like the one around the *Arc de Triomphe* in Paris (*Place de l'Étoile*) or *Columbus Circle* in Manhattan, seem to be more about creating focal points for orientation purposes (i.e., points in space in architectonic-speak) rather than improving traffic flow. Anyone who has joined the hoard of drivers around *Place de l'Étoile* understands

⁹ <https://injuryfacts.nsc.org/motor-vehicle/historical-fatality-trends/deaths-and-rates/>

¹⁰ Gariel, Charles Marie. "De la Règle à adopter en cas de Rencontre sur deux Routes qui se croisent" *Revue Mensuelle du Touring-club de France* July 1896 pp. 246-247 (Reported by Stephen Rees in <https://stephenrees.blog/2008/08/26/the-yield-to-the-right-concept/>)

¹¹ Yield to the right is a regulation in most U.S. states, but it is not emphasized to the same extent as in European countries. This is my person experience having driven extensively in both regions. In the U.S. and most European countries, bicycles must follow the same rules as motorized vehicles, and this also includes yielding to the right.



This is an illustration from a November 2009 pamphlet produced by the U.S. Department of Transportation Federal Highway Administration: *Roundabouts: A Proven Solution that Reduces the Number and Severity of Intersection Crashes*.

quickly that it is the survival of the fittest that applies. As traffic improvements, early traffic circles were considered a failure. Unfortunately, yielding to the right in roundabouts – which was the practice – even when there was a moderate level of traffic, resulted in roundabouts becoming jammed with cars, blocking the entry of cars entering the roundabouts and freezing the cars already inside the circle. In 1966, the UK adopted a rule at all circular junctions that required entering traffic to give way to circulating traffic already in the rotary.¹² In the U.S., modern rotaries began to be installed in the 1970s. Studies have shown that roundabouts, with the new yield rule, are safer than traditional stop sign or signal-controlled intersections. Roundabouts reduced injury crashes by 75 percent at intersections where stop signs or signals were previously used for traffic control, according to a study by the Insurance Institute for Highway Safety (IIHS).

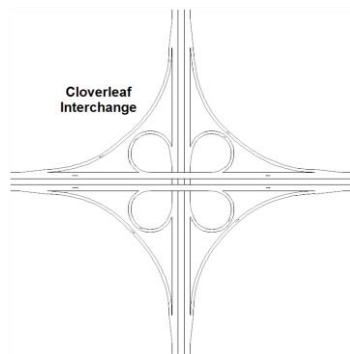
The case for roundabouts soon became compelling. They cut out unnecessary delays and so were less congested than junctions with traffic lights, and they eliminated one of the most dangerous turning movements: right or left into oncoming traffic, with the potential for lethal side-on impacts. The roundabout with offside priority became one of Britain's most successful international exports – at one point in the 1990s, France was building them at a rate of about a thousand a year.¹³

Time for a change, an interchange

Inside urban areas, the road infrastructure that had evolved over hundreds of years was being adapted to motorized vehicles with yields and stop signs, pedestrian crossings, and traffic circles. Outside of urban areas, highways were being built that could apply completely new design ideas. The main one was the cloverleaf interchange, attributed to and patented in 1916 by a civil engineer in Maryland by the name of Arthur Hale.¹⁴

“In the field of road transport, an ‘interchange’ (in American English) or a ‘grade-separated junction’ (in British English) is a road junction that uses grade separations to allow for the movement of traffic between two or more roadways or highways, using a system of interconnecting roadways to permit traffic on at least one of the routes to pass through the junction without interruption from crossing traffic streams. It differs from a standard intersection, where roads cross at grade. Interchanges are almost always used when at least one road is a controlled-access highway (freeway) or a limited-access highway (expressway), though they are sometimes used at junctions between surface streets.”¹⁵

There were many variations on the interchange theme, but the cloverleaf was the simplest. Clover plants usually have three leaves.



¹² <https://en.wikipedia.org/wiki/Roundabout#HeroSection>

¹³ Defining Moment: The British invent the modern roundabout, 1966. The Financial Times (October 11, 2009). (<https://www.ft.com/content/3c75e10e-b799-11de-9812-00144feab49a>)

¹⁴ https://en.wikipedia.org/wiki/Cloverleaf_interchange

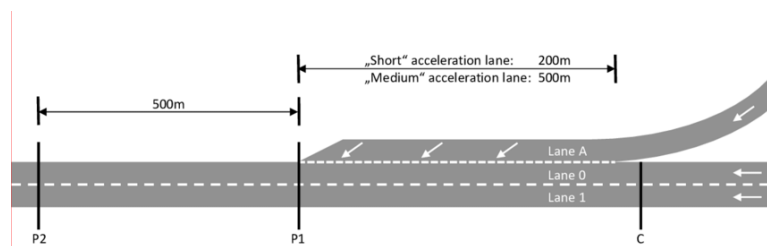
¹⁵ This is the definition provided in the Wikipedia post on “Interchange (road)”. It is not attributed to any source. It is complete and clear, so I assume that it has been created by the contributor(s) to this Wiki page. ([https://en.wikipedia.org/wiki/Interchange_\(road\)](https://en.wikipedia.org/wiki/Interchange_(road)))



This is an illustration of a simple slip road at an intersection.

The four-leaf clover is a rare mutation of the three-leaf clover. These were highway engineers, not botanists, who gave the interchange a name, but since clovers can have different numbers of leaves, just calling it a ‘cloverleaf’ was perfectly acceptable. It was in Woodbridge, NJ on the 15th of December 1929 that the first cloverleaf interchange opened for traffic, connecting Routes 25/4 (now 1/9) to Route 35.

The cloverleaf interchange applied four new concepts: the grade-separated crossing; the slip road; the acceleration lane; and the merge. A slip lane is a road at an intersection that allows cars turning to the right (left in left-hand drive countries) to ease onto the intersecting road without entering the intersection. In the illustration in the sidebar, vehicle 2 is on a slip road that connects to the intersecting road, and, given that it is a red light for cars on the road on which vehicle 2 was driving, vehicle 2 must yield to vehicle 1. Slip roads are also useful for enabling large trucks and buses to make turns. With the cloverleaf interchange, the slip lane was extended into an acceleration lane to allow the car entering the higher-speed road to reach the speed of vehicles already on the road and provide an opportunity for the entering car to merge into the flow of traffic.



Merging is both challenging and stressful

Merging from an acceleration lane onto an expressway and merging from a lane that is closed into the adjacent lane which continues (called ‘lane reduction’¹⁶), are two of the three most challenging and stressful driving tasks. The third, which also involves merging, is entering, driving in, and exiting a roundabout. Merging is difficult for two reasons. First, it requires cooperation among all the drivers in the vicinity of the merge, not just the two vehicles in the immediate vicinity of the lane change. All drivers must adapt their driving speeds and heighten their awareness to maintain the general flow of traffic while allowing the vehicles attempting to enter that flow the maximum opportunity to do so. Second, the rules which should be defined by the responsible traffic authorities and followed by motorists to facilitate merging are either not well-defined, are unclear, are not followed by drivers, or there is neither police enforcement of whatever laws that do exist nor is there signage reinforcement to encourage drivers to do the right thing.

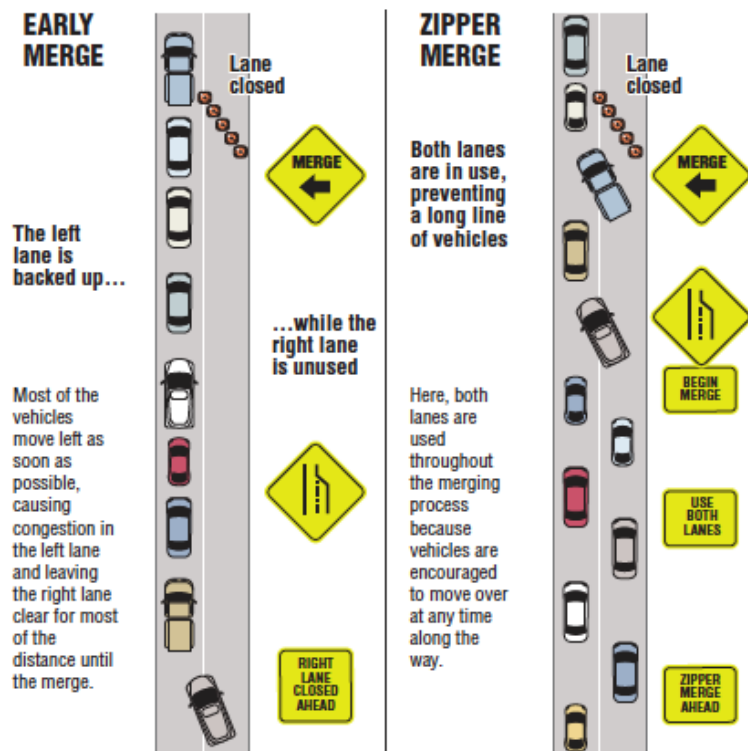
Here is what the Swedish law states concerning motorway slip roads and acceleration lanes: “If there is an acceleration lane, neither

¹⁶ Federal Highway Administration, Evaluation of Lane Reduction and Late Merge Signing (Washington, DC: 2023) <https://doi.org/10.21949.1521375>

Lane reduction causes a traffic 'choke points'. Choke points occur when roads narrow, either by design (converting a three-lane road to a two-lane one—called an 'own goal' in soccer), as a result of a mishap, as a result of construction or repair (e.g., at an overpass or bridge), or when an entrance at an interchange fills with cars attempting to merge from the acceleration lane into the inner lane of through traffic.

those in the acceleration lane nor those already on the motorway have priority. Mutual consideration and adaptation apply. If there is no acceleration lane, those entering have an obligation to give way to traffic already on the motorway. Leave the entry slip road as soon as you can. Remember to check your blind spot."

With lane reduction, in addition to the problem of merging there is also the problem of lane utilization, which affects the level of traffic congestion on the roadway at the rear of the lane closure. According to the FHWA paper referenced above, "when approaching a lane reduction, drivers typically attempt to merge into the appropriate lane as soon as possible, even in congested conditions. Some transportation agencies have considered or used methods to encourage a late merge at lane reduction, sometimes referred to as a 'zipper merge', in which drivers are encouraged to remain in their lane until the merge point and then alternate merging into one lane." Research conducted by FHWA on the effects of late merging found that there are "potential benefits, particularly during times of congestion" with the late/zipper merge, but the level of benefits is directly related to the types and locations of signs used to direct drivers on when to merge.



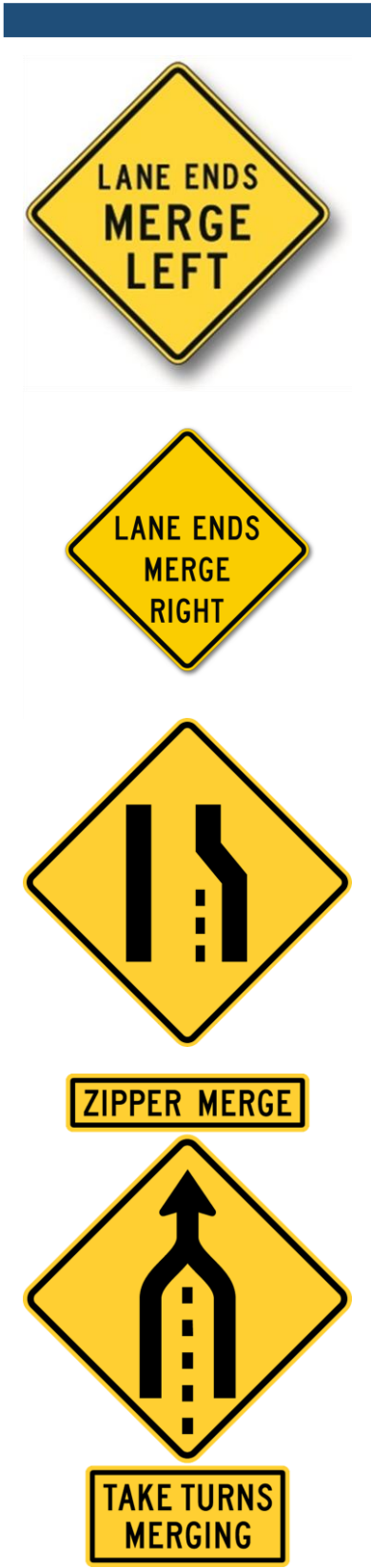
SOURCE: Arkansas Highway and Transportation Department

Arkansas Democrat-Gazette/KIRK MONTGOMERY

Ramp meter on ramp from Miller Park Way to Interstate 94 east in Milwaukee, Wisconsin, USA



One bright idea for improving traffic flow at interchanges was to add what is euphemistically called 'ramp metering'. This turns the whole idea of slip lanes and acceleration lanes on its ear and returns the interchange to an intersection with a stop light. It was first introduced in the U.S. in 1963 on the Eisenhower Expressway in Chicago and they are now everywhere in the world. Ramp meters are traffic lights that operate according to the flow of traffic on the main through road and manage the rate of vehicles entering



the through road. They are usually programmed to operate only at peak times and show either a steady green or flashing yellow at non-peak times. Some give free passes to high-occupancy vehicles (HOVs), carpoolers, buses, and other VIP vehicles, allowing them to skip line and drive directly onto the through road.

Merging requires exactly what robots do not have

Automated vehicles are at a potential disadvantage when merging into traffic with human-driven vehicles because AVs may not take the chances humans take to push into a tightly spaced lane of traffic (call it *chutzpah*¹⁷), and may reach the end of an acceleration lane, or the end of the closed lane, without having what the AV operations programs have judged to be a “safe opportunity” to merge. The vehicle has signaled its intention to merge with its turn signal, and it should be obvious to vehicles on the through lane that the vehicle is attempting to merge, but no driver slows down and indicates (e.g., by blinking its high beams) that the vehicle should merge into the through lane. In other words, the human drivers have shown no empathy and exhibited not a grain of reciprocal altruism, perhaps because they do not expect reciprocal altruism from a robot.

After a certain period of time passes without merging, the vehicle is in what is called a “stranded state”. It has not merged and it has stopped attempting to merge. This is a dangerous situation for the AV vehicle’s passengers, who may be tempted to exit the vehicle and attempt to stop traffic in order to create an opening in the flow for their vehicle. Avoiding this situation is the principal reason for developing communications between vehicles so that altruism can be programmed into interaction of vehicles, both human-driven and driverless.

What do we do in the meantime, as AVs begin to attempt to extend their operational design domains beyond local streets and at-grade intersections? For the sake of the passengers in the driverless vehicle and the occupants of the human-driven vehicles, it is imperative that merging is not left to the programmatic interpretation of sensor data of whatever kind. A driverless vehicle cannot infer the intention of a human driver. Until there is a method that guarantees that each vehicle knows exactly what the other car is going to do, merging of AVs at interchanges and lane reduction locations should be restricted. I see two options:

- Use only interchanges that are ramp metered – This is the safest way for AVs to begin to expand their range from local streets to expressways. It will require less direct routing of the driverless vehicles, but it is the best way to guarantee that AVs will not become stranded even in the most heavily congested times of travel.

¹⁷ Chutzpah (less commonly chutzpa or hutzpah or hutzpa): supreme self-confidence : nerve, gall (Merriam-Webster). The word derives from the Hebrew חִטְּפָה (chutzpah), meaning "insolence", "cheek" or "audacity". Thus, the original Yiddish word has a strongly negative connotation, but the form which entered English as a Yiddishism in American English has taken on a broader meaning, having been popularized through vernacular use in film, literature, and television. “In American English the word is sometimes interpreted—particularly in business parlance—as meaning the amount of courage, mettle or ardor that an individual has.” Collins American English Dictionary.



- Use only interchanges that are either ramp metered or where zipper merging is clearly marked and enforced – This offers a slightly larger degree of flexibility for AVs, but at the increased risk that vehicles in the through lanes do not obey the rules and there is insufficient enforcement of these rules.

Even though we may believe it is a hopeless task to convince transport regulators and traffic engineers to begin to adapt their regulations and practices to a time when vehicles will be driverless and vehicles will communicate with each other, what I have written here should show us that it is not hopeless. Regulators and engineers have been adapting regulations and practices on all things related to roads for a few thousand years, and they are ready to continue to do it. They just need to know what they should be doing.

The moral of what I have written here is that if you make things easier and better for humans, it will be easier to make things easier and better for robots.

Ontogeny recapitulates phylogeny

Driverless vehicle development is still in its embryonic stage, but developers and investors are fantasizing that it was born as a fully functioning adult ready to take on the role of the human-plus-vehicle that it will replace, like Mary Shelley’s Frankenstein. But, like Frankenstein, it will never succeed in becoming like-human unless it passes through all the steps we humans have passed through. Communication is one of our most important traits, and indicating our intentions, verbally, non-verbally, in writing and with signs, were the evolutionary steps that distinguished us from rest of fauna. I will not go so far as to claim that empathy cannot be programmed into a robot, but it is not there now and if it appears at some point in the future, it will have to evolve in steps, just as it has with us, first in the incubator and then out in the real world.

The Biogenetic Law, proposed by Ernst Haeckel in the late 19th century, states that “ontogeny recapitulates phylogeny,” meaning the development of an individual organism retraces its species’ evolutionary history. The evolutionary history of a species is the cause of its embryonic development, therefore, during embryonic development an organism passes through the stages of its evolution.

Barnes, M. Elizabeth, "Ernst Haeckel's Biogenetic Law (1866)". Embryo Project Encyclopedia (2014-05-03).
ISSN: 1940-5030 <https://hdl.handle.net/10776/7825>



About Michael L. Sena

Through my writing, speaking and client work, I have attempted to bring clarity to an often-opaque world of highly automated and connected vehicles. I have not just studied the technologies and analyzed the services. I have developed and implemented them and have worked to shape visions and followed through to delivering them. What drives me – why do what I do – is my desire to move the industry forward: to see accident statistics fall because of safety improvements related to advanced driver assistance systems; to see congestion on all roads reduced because of better traffic information and improved route selection; to see global emissions from transport eliminated because of designing the most fuel-efficient vehicles; and to see everyone who needs a ride get one.

I try to put vehicles into their context. It is not just roads; it is communities, large and small. Vehicles are tools, and people use these tools to make their lives and the lives of their family members easier, more enjoyable, and safer. Businesses and services use these tools to deliver what people need. Transport is intertwined with the environment in which it operates, and the two must be developed in concert.



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