

Intelligent Transportation Systems

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Chapter-1

Intelligent Transportation System

The term *intelligent transport system* (ITS) refers to efforts to add information and communications technology to transport infrastructure and vehicles in an effort to manage factors that typically are at odds with each other, such as vehicles, loads, and routes to improve safety and reduce vehicle wear, transportation times, and fuel consumption.

Background

Interest in ITS comes from the problems caused by traffic congestion and a synergy of new information technology for simulation, real-time control, and communications networks. Traffic congestion has been increasing worldwide as a result of increased motorization, urbanization, population growth, and changes in population density. Congestion reduces efficiency of transportation infrastructure and increases travel time, air pollution, and fuel consumption.

The United States, for example, saw large increases in both motorization and urbanization starting in the 1920s that led to migration of the population from the sparsely populated rural areas and the densely packed urban areas into suburbs. The industrial economy replaced the agricultural economy, leading the population to move from rural locations into urban centers. At the same time, motorization was causing cities to expand because motorized transportation could not support the population density that the existing mass transit systems could. Suburbs provided a reasonable compromise between population density and access to a wide variety of employment, goods, and services that were available in the more densely populated urban centers. Further, suburban infrastructure could be built quickly, supporting a rapid transition from a rural/agricultural economy to an industrial/urban economy.

Recent governmental activity in the area of ITS – specifically in the United States – is further motivated by the perceived need for homeland security. Many of the proposed ITS systems also involve surveillance of the roadways, which is a priority of homeland

security. Funding of many systems comes either directly through homeland security organizations or with their approval. Further, ITS can play a role in the rapid mass evacuation of people in urban centers after large casualty events such as a result of a natural disaster or threat. Much of the infrastructure and planning involved with ITS parallels the need for homeland security systems.

In the developing world, the migration of people from rural to urbanized habitats has progressed differently. Many areas of the developing world have urbanized without significant motorization and the formation of suburbs. In areas like Santiago, Chile, a high population density is supported by a multimodal system of walking, bicycle transportation, motorcycles, buses, and trains. A small portion of the population can afford automobiles, but the automobiles greatly increase the congestion in these multimodal transportation systems. They also produce a considerable amount of air pollution, pose a significant safety risk, and exacerbate feelings of inequities in the society.

Other parts of the developing world, such as China, remain largely rural but are rapidly urbanizing and industrializing. In these areas a motorized infrastructure is being developed alongside motorization of the population. Great disparity of wealth means that only a fraction of the population can motorize, and therefore the highly dense multimodal transportation system for the poor is cross-cut by the highly motorized transportation system for the rich. The urban infrastructure is being rapidly developed, providing an opportunity to build new systems that incorporate ITS at early stages.

Intelligent transport technologies

Intelligent transport systems vary in technologies applied, from basic management systems such as car navigation; traffic signal control systems; container management systems; variable message signs; automatic number plate recognition or speed cameras to monitor applications, such as security CCTV systems; and to more advanced applications that integrate live data and feedback from a number of other sources, such as parking guidance and information systems; weather information; bridge deicing systems; and the like. Additionally, predictive techniques are being developed to allow advanced modeling and comparison with historical baseline data. Some of the constituent technologies typically implemented in ITS are described in the following sections.

Wireless communications

Various forms of wireless communications technologies have been proposed for intelligent transportation systems.

Radio modem communication on UHF and VHF frequencies are widely used for short and long range communication within ITS.

Short-range communications (less than 500 yards) can be accomplished using IEEE 802.11 protocols, specifically WAVE or the Dedicated Short Range Communications

standard being promoted by the Intelligent Transportation Society of America and the United States Department of Transportation. Theoretically, the range of these protocols can be extended using Mobile ad-hoc networks or Mesh networking.

Longer range communications have been proposed using infrastructure networks such as WiMAX (IEEE 802.16), Global System for Mobile Communications (GSM), or 3G. Long-range communications using these methods are well established, but, unlike the short-range protocols, these methods require extensive and very expensive infrastructure deployment. There is lack of consensus as to what business model should support this infrastructure.

Computational technologies

Recent advances in vehicle electronics have led to a move toward fewer, more capable computer processors on a vehicle. A typical vehicle in the early 2000s would have between 20 and 100 individual networked microcontroller/Programmable logic controller modules with non-real-time operating systems. The current trend is toward fewer, more costly microprocessor modules with hardware memory management and Real-Time Operating Systems. The new embedded system platforms allow for more sophisticated software applications to be implemented, including model-based process control, artificial intelligence, and ubiquitous computing. Perhaps the most important of these for Intelligent Transportation Systems is artificial intelligence.

Floating car data/floating cellular data

"Floating car" or "probe" data collection is a set of relatively low-cost methods for obtaining travel time and speed data for vehicles traveling along streets, highways, freeways, and other transportation routes. Broadly speaking, three methods have been used to obtain the raw data:

- **Triangulation Method.** In developed countries a high proportion of cars contain one or more mobile phones. The phones periodically transmit their presence information to the mobile phone network, even when no voice connection is established. In the mid 2000s, attempts were made to use mobile phones as anonymous traffic probes. As a car moves, so does the signal of any mobile phones that are inside the vehicle. By measuring and analyzing network data using triangulation, pattern matching or cell-sector statistics (in an anonymous format), the data was converted into traffic flow information. With more congestion, there are more cars, more phones, and thus, more probes. In metropolitan areas, the distance between antennas is shorter and in theory accuracy increases. An advantage of this method is that no infrastructure needs to be built along the road; only the mobile phone network is leveraged. But in practice the triangulation method can be complicated, especially in areas where the same mobile phone towers serve two or more parallel routes (such as a freeway with a frontage road, a freeway and a commuter rail line, two or more

parallel streets, or a street that is also a bus line). By the early 2010s, the popularity of the triangulation method was declining.

- **Vehicle Re-Identification.** Vehicle re-identification methods require sets of detectors mounted along the road. In this technique, a unique serial number for a device in the vehicle is detected at one location and then detected again (re-identified) further down the road. Travel times and speed are calculated by comparing the time at which a specific device is detected by pairs of sensors. This can be done using the MAC (Machine Access Control) addresses from Bluetooth devices, or using the RFID serial numbers from Electronic Toll Collection (ETC) transponders (also called "toll tags").
- **GPS Based Methods.** An increasing number of vehicles are equipped with in-vehicle GPS (satellite navigation) systems that have two-way communication with a traffic data provider. Position readings from these vehicles are used to compute vehicle speeds.

Floating car data technology provides advantages over other methods of traffic measurement:

- Less expensive than sensors or cameras
- More coverage (potentially including all locations and streets)
- Faster to set up and less maintenance
- Works in all weather conditions, including heavy rain

Sensing technologies

Technological advances in telecommunications and information technology, coupled with state-of-the-art microchip, RFID (Radio Frequency Identification), and inexpensive intelligent beacon sensing technologies, have enhanced the technical capabilities that will facilitate motorist safety benefits for intelligent transportation systems globally. Sensing systems for ITS are vehicle- and infrastructure-based networked systems, i.e., Intelligent vehicle technologies. Infrastructure sensors are indestructible (such as in-road reflectors) devices that are installed or embedded in the road or surrounding the road (e.g., on buildings, posts, and signs), as required, and may be manually disseminated during preventive road construction maintenance or by sensor injection machinery for rapid deployment. Vehicle-sensing systems include deployment of infrastructure-to-vehicle and vehicle-to-infrastructure electronic beacons for identification communications and may also employ video automatic number plate recognition or vehicle magnetic signature detection technologies at desired intervals to increase sustained monitoring of vehicles operating in critical zones.

Inductive loop detection

Inductive loops can be placed in a roadbed to detect vehicles as they pass through the loop's magnetic field. The simplest detectors simply count the number of vehicles during

a unit of time (typically 60 seconds in the United States) that pass over the loop, while more sophisticated sensors estimate the speed, length, and weight of vehicles and the distance between them. Loops can be placed in a single lane or across multiple lanes, and they work with very slow or stopped vehicles as well as vehicles moving at high-speed.

Video vehicle detection

Traffic flow measurement and automatic incident detection using video cameras is another form of vehicle detection. Since video detection systems such as those used in automatic number plate recognition do not involve installing any components directly into the road surface or roadbed, this type of system is known as a "non-intrusive" method of traffic detection. Video from black-and-white or color cameras is fed into processors that analyze the changing characteristics of the video image as vehicles pass. The cameras are typically mounted on poles or structures above or adjacent to the roadway. Most video detection systems require some initial configuration to "teach" the processor the baseline background image. This usually involves inputting known measurements such as the distance between lane lines or the height of the camera above the roadway. A single video detection processor can detect traffic simultaneously from one to eight cameras, depending on the brand and model. The typical output from a video detection system is lane-by-lane vehicle speeds, counts, and lane occupancy readings. Some systems provide additional outputs including gap, headway, stopped-vehicle detection, and wrong-way vehicle alarms.

Intelligent transport applications

Emergency vehicle notification systems

The in-vehicle eCall is an emergency call generated either manually by the vehicle occupants or automatically via activation of in-vehicle sensors after an accident. When activated, the in-vehicle eCall device will establish an emergency call carrying both voice and data directly to the nearest emergency point (normally the nearest E1-1-2 Public-safety answering point, PSAP). The voice call enables the vehicle occupant to communicate with the trained eCall operator. At the same time, a minimum set of data will be sent to the eCall operator receiving the voice call.

The minimum set of data contains information about the incident, including time, precise location, the direction the vehicle was traveling, and vehicle identification. The pan-European eCall aims to be operative for all new type-approved vehicles as a standard option. Depending on the manufacturer of the eCall system, it could be mobile phone based (Bluetooth connection to an in-vehicle interface), an integrated eCall device, or a functionality of a broader system like navigation, Telematics device, or tolling device. eCall is expected to be offered, at earliest, by the end of 2010, pending standardization by the European Telecommunications Standards Institute and commitment from large EU member states such as France and the United Kingdom.



Congestion pricing gantry at North Bridge Road, Singapore.

Automatic road enforcement



Automatic speed enforcement gantry or "*Lombada Eletrônica*" with ground sensors at Brasilia, D.F.

A traffic enforcement camera system, consisting of a camera and a vehicle-monitoring device, is used to detect and identify vehicles disobeying a speed limit or some other road legal requirement and automatically ticket offenders based on the license plate number. Traffic tickets are sent by mail. Applications include:

- Speed cameras that identify vehicles traveling over the legal speed limit. Many such devices use radar to detect a vehicle's speed or electromagnetic loops buried in each lane of the road.
- Red light cameras that detect vehicles that cross a stop line or designated stopping place while a red traffic light is showing.
- Bus lane cameras that identify vehicles traveling in lanes reserved for buses. In some jurisdictions, bus lanes can also be used by taxis or vehicles engaged in car pooling.
- Level crossing cameras that identify vehicles crossing railways at grade illegally.
- Double white line cameras that identify vehicles crossing these lines.
- High-occupancy vehicle lane cameras for that identify vehicles violating HOV requirements.
- Turn cameras at intersections where specific turns are prohibited on red. This type of camera is mostly used in cities or heavy populated areas.

Variable speed limits



Example variable speed limit sign in the United States.

Recently some jurisdictions have begun experimenting with variable speed limits that change with road congestion and other factors. Typically such speed limits only change to decline during poor conditions, rather than being improved in good ones. One example is on Britain's M25 motorway, which circumnavigates London. On the most heavily-traveled 14-mile (23 km) section (junction 10 to 16) of the M25 variable speed limits combined with automated enforcement have been in force since 1995. Initial results indicated savings in journey times, smoother-flowing traffic, and a fall in the number of accidents, so the implementation was made permanent in 1997. Further trials on the M25 have been thus far proved inconclusive.

Collision avoidance systems

Japan has installed sensors on its highways to notify motorists that a car is stalled ahead.

Dynamic Traffic Light Sequence

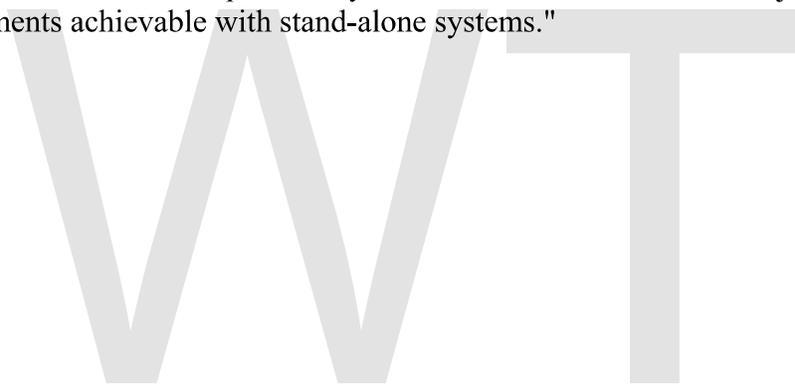
Intelligent RFID traffic control has been developed for dynamic traffic light sequence. It circumvents or avoids problems that usually arise with systems that use image processing and beam interruption techniques. RFID technology with appropriate algorithm and database were applied to a multi vehicle, multi lane and multi road junction area to provide an efficient time management scheme. A dynamic time schedule was worked out for the passage of each column. The simulation has shown that, the dynamic sequence algorithm has the ability to intelligently adjust itself even with the presence of some extreme cases. The real time operation of the system able to emulate the judgment of a

traffic policeman on duty, by considering the number of vehicles in each column and the routing proprieties.

Cooperative systems on the road

Communication cooperation on the road includes car-to-car, car-to-infrastructure, and vice versa. Data available from vehicles is acquired and transmitted to a server for central fusion and processing. This data can be used to detect events such as rain (wiper activity) and congestion (frequent braking activities). The server processes a driving recommendation dedicated to a single or a specific group of drivers and transmits it wirelessly to vehicles. The goal of cooperative systems is to use and plan communication and sensor infrastructure to increase road safety. The definition of cooperative systems in road traffic is according to the European Commission:

"Road operators, infrastructure, vehicles, their drivers and other road users will cooperate to deliver the most efficient, safe, secure and comfortable journey. The vehicle-vehicle and vehicle-infrastructure co-operative systems will contribute to these objectives beyond the improvements achievable with stand-alone systems."



Chapter-2

Traffic Enforcement Camera



Gatso speed camera

A **traffic enforcement camera** (also **road safety camera**, **road rule camera**, **photo radar**, **speed camera**, **Gatso**) is an automated ticketing machine. It may include a camera which may be mounted beside or over a highway or installed in an enforcement vehicle to detect traffic regulation violations, including speeding, vehicles going through a red traffic light, unauthorized use of a bus lane, for recording vehicles inside a congestion charge area and others.

The latest automatic number plate recognition systems can be used for the detection of average speeds and raise concerns over loss of privacy and the potential for governments to establish mass surveillance of vehicle movements and therefore by association also the movement of the vehicle's owner. Vehicles owners are often required by law to identify the driver of the vehicle and a case was taken to the European Court of Human Rights who found that the Human Rights Act 1998 was not being breached. Some groups, such as the National Motorists Association in the USA, claim that systems "encourage ... revenue-driven enforcement" rather than the declared objectives.

Types



Automatic speed enforcement gantry or "*Lombada Eletrônica*" with ground sensors at Brasília, D.F.



Gatso Mobile Speed Camera, used in Victoria, Australia. The camera is mounted on the passenger side dash, whilst the black box on the front is the radar unit.

Bus lane enforcement

Some bus lane enforcement cameras use a sensor in the road which triggers a number plate recognition camera which compares the vehicle registration plate with a list of approved vehicles and records images of other vehicles. Other systems use a camera mounted on the bus, for example in London where they monitor Red routes on which stopping is not allowed for any purpose (other than taxis and disabled parking permit holders).

On Monday, February 23, 2009, New York City announced testing camera enforcement of bus lanes on 34th Street in Midtown Manhattan where a New York City taxi illegally using the bus lanes would face a fine of \$150 adjudicated by the New York City Taxi and Limousine Commission.

Red light enforcement



Red light camera in Springfield, Ohio, USA.



A red-light camera in use in Beaverton, Oregon, USA

A red light camera is a traffic camera that takes an image of a vehicle that goes through an intersection where the light is red. The system continuously monitors the traffic signal and the camera is triggered by any vehicle entering the intersection above a preset minimum speed and following a specified time after the signal has turned red.

Speed limit enforcement

Speed enforcement cameras are used to monitor compliance with speed limits which may use Doppler, LIDAR or Automatic number plate recognition. Other speed enforcement systems are also used which are not camera based.

Fixed or mobile speed camera systems that measure the time taken by a vehicle to travel between two or more fairly distant sites (from several hundred metres to several hundred kilometres apart) are called automatic number plate recognition (ANPR) cameras. These cameras time vehicles over a known fixed distance, then calculate the vehicle's average speed for the journey. The name derives from the fact that the technology uses infrared cameras linked to a computer to "read" a vehicle's registration number and identify it in real-time.

Number plate recognition systems

Automatic number plate recognition can be used for purposes unrelated to enforcement of traffic rules. In principle any agency or person with access to data either from traffic cameras or cameras installed for other purposes can track the movement of vehicles for any purpose.

In Australia's SAFE-T-CAM system, ANPR technology is used to monitor long distance truck drivers to detect avoidance of legally prescribed driver rest periods.

The United Kingdom's police ANPR system logs all the vehicles passing particular points in the national road network, allowing authorities to track the movement of vehicles and individuals across the country.

In the UK an 80-year-old pensioner John Catt and his daughter Linda (with no criminal record between them) were stopped by City of London Police while driving in London, UK in 2005, had their vehicle searched under section 44 of the Terrorism Act 2000 and were threatened with arrest if they refused to answer questions. After they complained formally, it was discovered they were stopped when their car was picked up by roadside ANPR CCTV cameras; it had been flagged in the Police National Computer database when they were seen near EDO MBM demonstrations in Brighton. Critics point out that the Catts had been suspected of no crime, however the UK's mass surveillance infrastructure allowed them to be targeted due to their association.

Other

- Congestion charge cameras to detect vehicles inside the chargeable area which have not paid the appropriate fee
- High-occupancy vehicle lane cameras to identify vehicles violating occupancy requirements.
- Level crossing cameras to identifying vehicles crossing railways at grade
- Noise pollution cameras that record evidence of heavy vehicles that break noise regulations by using engine braking
- Parking cameras which issue citations to vehicles which are illegally parked or which were not moved from a street at posted times.
- Toll-booth cameras to identify vehicles proceeding through a toll booth without paying the toll
- Turn cameras at intersections where specific turns are prohibited on red. This type of camera is mostly used in cities or heavy populated areas.
- Automatic number plate recognition systems can be used for multiple purposes, including identifying untaxed and uninsured vehicles, stolen cars and potentially mass surveillance of motorists .

Fixed camera systems can be mounted in boxes or on poles beside the road or attached to gantries over the road, or to overpasses or bridges. Cameras can be concealed, for example in garbage bins.

Mobile speed cameras may be hand-held, tripod mounted, or vehicle-mounted. In vehicle-mounted systems, detection equipment and cameras can be mounted to the vehicle itself, or simply tripod mounted inside the vehicle and deployed out a window or door. If the camera is fixed to the vehicle, the enforcement vehicle does not necessarily have to be stationary, and can be moved either with or against the flow of traffic. In the latter case, depending on the direction of travel, the target vehicle's relative speed is either added or subtracted from the enforcement vehicle's own speed to obtain its actual speed. The speedometer of the camera vehicle needs to be accurately calibrated.

Some number plate recognition systems can be used from vehicles.

Controversy

Legal issues

There are a number of legal issues which arise as a result depending on local laws and the procedures used by the enforcing bodies. Various legal issues arise from such cameras and the laws involved in how cameras can be placed and what evidence is necessary to prosecute a driver varies considerably in different legal systems.

One issue is the potential conflict of interest when private contractors are paid a commission based on the number of tickets they are able to issue. Pictures from the San Diego red light camera systems were ruled inadmissible as court evidence in September

2001. The judge said that the "total lack of oversight" and "method of compensation" made evidence from the cameras "so untrustworthy and unreliable that it should not be admitted".

Some U.S. states and provinces of Canada such as Alberta operate "owner liability" where it is the registered owner of the vehicle who must pay all such fines regardless of whether he was driving at the time of the offense, although they do release the owner from liability if he signs a form identifying the actual driver and that individual pays the fine. These states do not issue demerit points for camera infractions which has been criticized by some as giving a "license to speed" to those who can more easily afford speeding fines.

In Albuquerque, New Mexico, the city government attempted to bypass the legal issue of a defendant's right to cross-examine his accuser, as well as the issue of verifying the driver's identity. Automated red-light and speeding offenses are classed as public nuisances and fined to the vehicle's registered owner as civil violations, not as criminal offenses.

In April 2000 two motorists who were caught speeding in the United Kingdom challenged the Road Traffic Act 1988 which required the keeper of a driver to identify the driver at a particular time as being in contradiction to the Human Rights Act 1998 on the grounds that it amounted to a 'compulsory confession', also that since the camera partnerships included the police, local authorities, Magistrates Courts Service (MCS) and Crown Prosecution Service (CPS) which had a financial interest in the fine revenue that they would not get a fair trial. Their plea was initially granted by a judge then overturned but was the heard by the European Court of Human Rights (ECtHR), and the European Court of Justice (ECJ). In 2007 the European Court of Human Rights found there was no breach of article 6 in requiring the keepers of cars caught speeding on camera to provide the name of the driver.



A red-light and speed camera in Darwin, Northern Territory, Australia

Surveillance

- Police and government have been accused of "Big Brother tactics" in over-monitoring of public roads, and of "revenue raising" in applying cameras in deceptive ways to increase government revenue rather than improve road safety.

Revenue not safety

- In 2010 a campaign was set up against a speed camera on a dual carriageway in Poole, Dorset in a 30 mph area in the United Kingdom. which had generated £1.3m of fines every year since 1999. The initial Freedom of information request

was refused and the information was only released after an appeal to the Information Commissioner.

- In May 2010 the new Coalition government said that the 'Labour's 13-year war on the motorist is over' and that the new government 'pledged to scrap public funding for speed cameras' In July Mike Penning, the Road safety minister reduced the Road Safety Grant for the current year to Local Authorities from £95 million to £57 million saying that local authorities had relied too heavily on safety cameras for far too long and that he was pleased that some councils were now focusing on other road safety measures. It is estimated that the as a result the Treasury is now distributing £40 million less in Road Safety Grant than is raised from fines in the year. Dorset and Essex announced plans to review camera provision with a view to possibly ending the scheme in their counties, however Dorset strongly affirmed its support for the scheme, albeit reducing financial contributions in line with the reduction in government grant. Seven counties also announced plans to turn off some or all of their cameras, amidst warnings from the country's most senior traffic policeman that this would result in an increase in deaths and injuries. Gloucestershire cancelled plans to update cameras and has reduced or cancelled maintenance contracts.

Unpopularity

Use of cameras is opposed by some motorists and motoring organisations. They have also be rejected in some places by referendum.

- The first speed camera systems in the USA was in Friendswood, Texas in 1986 and La Marque, Texas in 1987. Neither program lasted more than a few months before public pressure forced them to be dropped.
- In 1991 cameras have been rejected by voters in referenda in Peoria, Arizona voters were the first to reject cameras by a 2-1 margin. Speed cameras have since been installed on the highways in the Phoenix area since 2007.
- In 1992 cameras have been rejected by voters in referenda in Batavia, Illinois.
- Anchorage, Alaska rejected cameras in a 1997 referendum
- In 2002 the state of Hawaii experimented with speed limit enforcement vans but they were withdrawn months later due to public outcry.
- In 2005, the Virginia legislature declined to reauthorize its red light camera enforcement law after a study questioned their effectiveness, only to reverse itself in 2007 and allow cameras to return to any city with a population greater than 10,000.
- Steubenville, Ohio rejected cameras in a 2006 referendum.
- In 2009, a petition was started in the town of College Station, Texas which requested that all red light cameras be dismantled and removed from all of the town's intersections. Enough signatures were captured to put the measure on the November 2009 general election ballot. After an extensive battle between the College Station city council and the opposing sides, both for and against red light cameras, the voters voted to eliminate the red light cameras throughout the entire

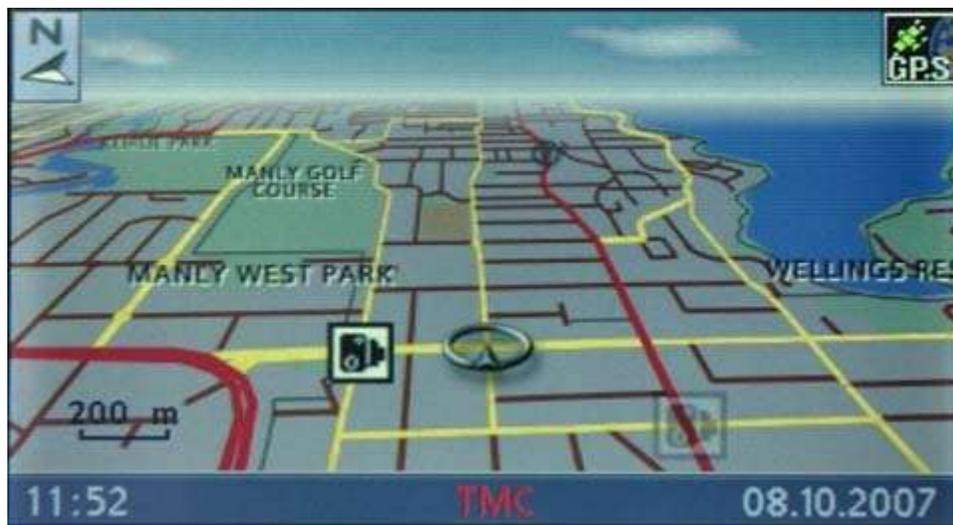
city. By the end of November the red light cameras were taken down. However, all citations issued are still valid and must be paid by the offenders.

- On May 4, 2010 an ordinance authorizing the use of speed cameras in the town of Sykesville, Maryland was put to a referendum, in which 321 out of 529 voters (60.4%) voted against the cameras. The turnout for this vote was greater than the number of voters in the previous local Sykesville election for mayor where 523 residents voted.
- Arizona decided to not renew their contract with Redflex in 2011 following a study of their statewide 76 photo enforcement cameras. Reasons given included less than expected revenue due to improved compliance, mixed public acceptance and mixed accident data.

Effectiveness

- The town of Swindon abandoned the use of fixed cameras in 2009, questioning their cost effectiveness with the cameras being replaced by vehicle activated warning signs and enforcement by police using mobile speed cameras: in the nine months following the switch-off there was a small reduction in accident rates which had changed slightly in similar periods before and after the switch off (Before: 1 fatal, 1 serious and 13 slight accidents. Afterwards: no fatalities, 2 serious and 12 slight accidents). The journalist George Monbiot claimed that the results were not statistically significant highlighting earlier findings across the whole of Wiltshire that there had been a 33% reduction in the number of people killed and seriously injured generally and a 68% reduction at camera sites during the previous 3 years.
- In January 2011 Edmonton, Alberta cancelled all 100,000 "Speed On Green" tickets issued in the previous 14 months due to concerns about camera reliability.

Avoidance/evasion



A GPS map showing speed camera POI information overlaid onto it

To avoid detection or prosecution drivers may:

- Brake just before a camera in order to travel past its sensor below the speed limit. This is however a cause of collisions.
- Use GPS navigation devices which contain databases of known camera locations to alert them in advance. These databases may in some cases be update in near-realtime. The use of GPS devices to locate speed cameras is illegal in some jurisdictions.
- Install passive laser detectors or radar detectors that detect when the vehicle's speed is being monitored and warn the driver. Use of these devices may be illegal in some jurisdictions.
- Install active laser jammer or radar jammer devices which actively transmit signals that interfere with the measuring device. These devices are illegal in many jurisdictions.
- Remove, falsify, obscure or modify vehicle license plate. Tampering with number plates is illegal in many jurisdictions.

In August 2010 a fast driving Swedish driver reportedly avoided several older model speed cameras, but was detected by a new model, as traveling at 186 mph (300 km/h), resulting in the world's largest speeding fine to date.

- In the past it was possible to avoid detection by changing lanes when SPECS average speed cameras were in use as they measured a vehicle's speed over distance in one lane only. As of 2011 the cameras are type approved to cover multiple lanes.

History



Older traffic enforcement camera in Ludwigsburg, Germany



Dazzle camouflaged speed camera in Loipersdorf, Austria

The concept of the speed camera can be dated back to at least 1905; Popular Mechanics reports on a patent for a "Time Recording Camera for Trapping Motorists" that enabled the operator to take time-stamped images of a vehicle moving across the start and endpoints of a measured section of road. The timestamps enabled the speed to be calculated, and the photo enabled identification of the driver.

The Dutch company *Gatsometer BV*, which was founded in 1958 by rally driver Maurice Gatsonides, produced the 'Gatsometer'. Gatsonides wished to better monitor his average speed on a race track and invented the device in order to improve his lap times. The company later started supplying these devices as police speed enforcement tools. The first systems introduced in the late 1960s used film cameras to take their pictures.

Gatsometer introduced the first red light camera in 1965, the first radar for use with road traffic in 1971 and the first mobile speed traffic camera in 1982;

From the late 1990s, digital cameras began to be introduced. Digital cameras can be fitted with a network connection to transfer images to a central processing location automatically, so they have advantages over film cameras in speed of issuing fines, maintenance and operational monitoring. However, film-based systems may provide superior image quality in the variety of lighting conditions encountered on roads, and are required by courts in some jurisdictions. New film-based systems are still being sold, but digital pictures are providing greater versatility and lower maintenance and are now more popular with law enforcement agencies.

WWT

Chapter-3

Intelligent Speed Adaptation

Intelligent Speed Adaptation (ISA), also known as Intelligent Speed Assistance, is any system that constantly monitors vehicle speed and the local speed limit on a road and implements an action when the vehicle is detected to be exceeding the speed limit. This can be done through an advisory system, where the driver is warned, or through an intervention system where the driving systems of the vehicle are controlled automatically to reduce the vehicle's speed.

Intelligent speed adaptation uses information about the road on which the vehicle travels to make decisions about what the correct speed should be. This information can be obtained through use of a digital maps incorporating roadway coordinates as well as data on the speed zoning for that roadway at that location, through general speed zoning information for a defined geographical area (e.g., an urban area which has a single defined speed limit), or through feature recognition technology that detects and interprets speed limit signage. ISA systems are designed to detect and alert a driver when a vehicle has entered a new speed zone, when variable speed zones are in force (e.g., variable speed limits in school zones that apply at certain times of the day and only on certain days), and when temporary speed zones are imposed (such as speed limit changes in adverse weather or during traffic congestion, at accident scenes, or near roadworks). Many ISA systems will also provide information about locations where hazards may occur (e.g., in high pedestrian movement areas, railway level crossings or railroad grade crossings, schools, hospitals, etc.) or where enforcement actions is indicated (e.g., speed camera and red light camera locations). The purpose of ISA is to assist the driver in keeping to the lawful speed limit at all times, particularly as they pass through different speed 'zones'. This is particularly useful when drivers are in unfamiliar areas or when they pass through areas where variable speed limits are used.

Most motorists do not appreciate the extra risks involved in travelling just a few km/h over the speed limit. Most think that the risk of a casualty crash is doubled if you are travelling at least 25 km/h over the speed limit. Research has found that that, in urban areas, the risk of a casualty crash is doubled for each 5 km/h over the limit. So travelling at 70 km/h in a 60 km/h zone quadruples the risk of a crash in which someone is

hospitalised. As a result, it is estimated that about 10% of casualties could be prevented if the large group of motorists who routinely travel at up to 10 km/h over the limit were encouraged to obey the speed limits. About 20% of casualties could be prevented if all vehicles complied with the speed limits. Savings in fatal crashes would be larger.

"Minor" speeding therefore makes up a large proportion of preventable road trauma. It is difficult for enforcement methods alone to have an effect on this minor speeding. An added problem is that even motorists who want to obey the speed limits (to keep their life, licence or livelihood) have difficulty doing so in modern cars on city roads. This is where an ISA system comes into its own.

Types of ISA (Active/ Passive)

The two types of ISA systems, passive and active, differ in that passive systems simply warn the driver of the vehicle travelling at a speed in excess of the speed limit, while active systems intervene and automatically correct the vehicle's speed to conform with the speed limit. Passive systems are generally driver advisory systems: They alert the driver to the fact that they are speeding, provide information as to the speed limit, and allow the driver to make a choice on what action should be taken. These systems usually display visual or auditory cues, such as auditory and visual warnings and may include tactile cues such as a vibration of the accelerator pedal. Some passive ISA technology trials have used vehicle modified to provide haptic feedback, wherein the accelerator pedal becomes more resistant to movement (i.e., harder to push down) when the vehicle travels over the speed limit. Active ISA systems actually reduce or limit the vehicle's speed automatically by manipulating the engine and/or braking systems. Most active ISA systems provide an override system so that the driver can disable the ISA, if necessary, on a temporary basis.

An often unrecognised feature of both active and passive ISA systems is that they can serve as on-board vehicle data recorders, retaining information about vehicle location and performance for later checking and fleet management purposes.

Speed and location determining/ verification technology

There are four types of technology currently available for determining local speed limits on a road and determining the speed of the vehicle. These are:

- GPS
- Radio Beacons
- Optical recognition
- Dead Reckoning

Global Positioning System (GPS) Receiver based systems

GPS is based on a network of satellites that constantly transmit radio signals. GPS receivers pick up these transmissions and compare the signals from several satellites in

order to pinpoint the receiver's location to within a few meters. This is done by comparing the time at which the signal was sent from the satellite to when it was picked up by the receiver. Because the orbital paths of the satellites are known very accurately, the receiver can perform a calculation based on its distance to several of the orbiting satellites and therefore obtain its position. There are currently 24 satellites making up the GPS network, and their orbits are configured so that a minimum of five satellites are available at any one time for terrestrial users. Four satellites is the minimum number of satellites required to determine a precise three-dimensional position.

The popularity of GPS in current ISA and in car navigation systems may give the impression that GPS is flawless, but this is not the case. GPS is subject to a number of fundamental problems. Many of these problems relate to the accuracy of the determined position. The receiver still gets the signal from the satellites, but due to satellites' ephemeris uncertainties, propagation errors, timing errors, multiple signal propagation path, and receiver noises, the position given can be inaccurate. Usually these inaccuracies are small and range from five to ten meters for most systems, but they can be up to hundreds of meters. In most situations this may not matter, but these inaccuracies can be important in circumstances where a high speed road is located immediately adjacent to roads with much lower speed limits (e.g., residential streets). Furthermore, because GPS relies upon a signal transmitted from a satellite in orbit, it does not function when the receiver is underground or in a tunnel, and the signal can become weak if tall buildings, trees, or heavy clouds come between the receiver and the satellites. Current improvements being made to the GPS satellite network will help to increase GPS reliability and accuracy in the future but will not completely overcome the fundamental shortcomings of GPS. In order to be used for ISA systems, GPS must be linked to a detailed digital map containing information such as local speed limits and the location of known variable speed zones, e.g., schools. Advanced digital maps have the capacity for real-time updating to include information on areas where speed limits should be reduced due to adverse weather conditions or around accident scenes and roadworks.

Radio beacons

Roadside radio beacons, or bollards, work by transmitting data to a receiver in the car. The beacons constantly transmit data that the car-mounted receiver picks up as it passes each beacon. This data could include local speed limits, school zones, variable speed limits, or traffic warnings. If sufficient numbers of beacons were used and were placed at regular intervals, they could calculate vehicle speed based on how many beacons the vehicle passed per second. Beacons could be placed in/on speed signs, telegraph poles, other roadside fixtures, or in the road itself. Mobile beacons could be deployed in order to override fixed beacons for use around accident scenes, during poor weather, or during special events. Beacons could be linked to a main computer so that quick changes could be made.

The use of radio beacons is common when ISA systems are used to control vehicle speeds in off road situations, such as factory sites, logistics and storage centres, etc.,

where occupational health and safety requirements mean that very low vehicle speeds are required in the vicinity of workers and in situations of limited or obscured visibility.

Optical recognition systems

So far, this technology has been focused solely on recognizing speed signs. However, other roadside objects, such as the reflective "cats eyes" that divide lanes could possibly be used. This system requires the vehicle to pass a speed sign or similar indicator and for data about the sign or indicator to be registered by a scanner or a camera system. As the system recognizes a sign, the speed limit data is obtained and compared to the vehicle's speed. The system would use the speed limit from the last sign passed until it detects and recognizes a speed sign with a different limit. If speed signs are not present, the system does not function. This is a particular problem when exiting a side road onto a main road, as the vehicle may not pass a speed sign for some distance.

Dead reckoning

Dead reckoning (DR) uses a mechanical system linked to the vehicle's driving assembly in order to predict the path taken by the vehicle. By measuring the rotation of the road wheels over time, a fairly precise estimation of the vehicle's speed and distance traveled can be made. Dead reckoning requires the vehicle to begin at a known, fixed point. Then, by combining speed and distance data with factors such as the angle of the steering wheel and feedback from specialized sensors (e.g., accelerometers, flux gate compass, gyroscope) it can plot the path taken by the vehicle. By overlaying this path onto a digital map, the DR system knows approximately where the vehicle is, what the local speed limit is, and the speed at which the vehicle is traveling. The system can then use information provided by the digital map to warn of upcoming hazards or points of interest and to provide warnings if the speed limit is exceeded. Some top-end GPS-based navigation systems currently on the market use dead reckoning as a backup system in case the GPS signal is lost. Dead reckoning is prone to cumulative measurement errors such as variations between the assumed circumference of the tyres compared to the actual dimension (which is used to calculate vehicle speed and distance traveled). These variations in the tyre circumference can be due to wear or variations in tyre pressure due to variations in speed, payload, or ambient temperature. Other measurement errors are accumulated when the vehicle navigates gradual curves that inertial sensors (e.g., gyroscopes and/or accelerometers) are not sensitive enough to detect or due to electromagnetic influences on magnetic flux compasses (e.g., from passing under power lines or when travelling across a steel bridge) and through underpasses and road tunnels.

Limitations

An initial reaction to the concept of ISA is that there could be negative outcomes, such as driving at the speed limit rather than to the conditions, but numerous ISA trials around the World have shown these concerns are unsubstantiated.

A particular issue is that most ISA systems use a speed database based purely on information regarding the posted maximum speed limit for a roadway or roadway segment. Obviously, many roads have features such as curves and gradients where the appropriate speed for a road segment with these features is less than the posted maximum speed limit. Increasingly, road authorities indicate the appropriate speed for such segments through the use of advisory speed signage to alert drivers on approach that there are features which require a reduction in travelling speed. It is recognised that the speed limit databases used in ISA systems should ideally take account of posted advisory speeds as well as posted maximum speed limits. The New South Wales ISA trial, underway in the Illwarra region south of Sydney currently, is the only trial that is using posted advisory speeds as well as posted maximum speed limits.

Some car manufacturers have expressed concern that some types of speed limiters "take control away from the driver". This is also unsubstantiated, firstly because ISA systems do have provision for over-ride by the driver in the event that the set speed is inappropriate and secondly, the claim is somewhat hypocritical given that cruise control has been in use on vehicles for many years and forces the vehicle to travel at a minimum speed unless there is driver intervention.

For some traffic safety practitioners, active intelligent speed adaptation is thought to be an example of 'hard automation', an approach to automation that has been largely discredited by the Human Factors community. An inviolable characteristic of human users is that they will adapt to these systems, often in unpredictable ways. Some studies have shown that drivers 'drive up to the limits' of the system and drive at the set speed, compared to when they are in manual control, where they have been shown to slow down. Conversely, the experience of some drivers with driving under an active ISA system has been that they find they can pay more attention to the roadway and road environment as they no longer need to monitor the speedometer and adjust their speeds on a continuing basis.

There is also concern that drivers driving under speed control might accept more risky headways between themselves and vehicles in front and accept much narrower gaps to join traffic (this fact drawing particular criticism from motorcycling groups).

Wider criticism also comes from the insistent focus on speed and that road safety outcomes could be better achieved by focusing on driving technique, situational awareness, and automation that 'assists' drivers rather than 'forces' them to behave in particular ways. Intelligent speed adaptation has also been held as an example of a technology which, like speed cameras, can often alienate the driving public and represents a significant barrier to its widespread adoption.

Some studies which pre-date the development of ISA systems indicated that drivers make relatively little use of the speedometer and instead use auditory cues (such as engine and road noise) to successfully regulate their speed. These studies, however, remain unverified. There is an argument in the literature that suggests that as cars have become quieter and more refined speed control has become more difficult for drivers to perform.

Thus an alternative 'soft-automation' approach is simply to re-introduce some of those cues that drivers naturally use to regulate speed (rather than incur the expense and unexpected behavioral adaptations of ISA).

Benefits

Real and perceived benefits of ISA are a reduction of accident risks and reductions of noise and exhaust emissions.

Commercial use

Strategic thinking in traffic safety acknowledges that Intelligent Transportation Systems (ITS), and in-vehicle technologies in particular, hold promise as safety measures to counter the risk of road crashes and the trauma arising from crashes. However, road safety practitioners have been hesitant in embarking on vigorous pursuit of emerging technologies in crash avoidance and occupant protection. This is perhaps best described as a combination of appropriate caution, bureaucratic reluctance, tinged perhaps with historical bias and lack of knowledge. It is recognized that it is difficult indeed to identify just which of a number of future or proposed technologies will prove to be viable, and to identify those future or proposed technologies that will not, as time progresses, result in significant commercial implementation. Perhaps it is because of such concerns that the development of ISA systems under research and development programs funded by governments has remained at the prototype or trial stages, despite positive experiences and strong endorsement of ISA technologies for more than a decade.

It is thus not surprising that the commercialisation of ISA systems occurred outside of the mainstream traffic safety community and with only very limited governmental support.

In Australia in 2007 two ISA products emerged in the marketplace and have since established commercial success. Some road safety researchers are surprised that Australia is leading the world with this technology.

SpeedAlert is a passive ISA product marketed by Smart Car Technologies, based in Sydney NSW. It offers full national speed zoning information embedded within a GPS-based navigation system, providing drivers with information on speed limits and vehicle speed, as well as related information on locations such as schools, railway level crossings, speed camera sites, etc.. The software is easily affordable for both fleet and private drivers, typically selling for about A\$200.

SpeedShield is an active ISA product marketed by Automotion Control Systems, based in Melbourne, Vic. It offers speed zoning information embedded within a GPS-based navigation system, providing drivers with information on speed limits and vehicle speed and is combined with technology that intervenes and controls the vehicle speed to no faster than the posted speed limit for that section of roadway. The technology is generally transferrable across vehicle manufacturers and models, but must be configured for an individual make and model. As the cost is variable (estimated to be A\$1–3,000

depending on vehicle type and number of vehicles to be fitted), its commercial use has tended to be into vehicle fleet operations rather than private owners.

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Chapter-4

Vehicle Infrastructure Integration



Automated control would enhance road safety and traffic flow

Vehicle Infrastructure Integration (VII) is an initiative fostering research and applications development for a series of technologies directly linking road vehicles to their physical surroundings, first and foremost in order to improve road safety. The technology draws on several disciplines, including transport engineering, electrical

engineering, automotive engineering, and computer science. VII specifically covers road transport although similar technologies are in place or under development for other modes of transport. Planes, for example, use ground-based beacons for automated guidance, allowing the autopilot to fly the plane without human intervention. In highway engineering, improving the safety of a roadway can enhance overall efficiency. VII targets improvements in both safety and efficiency.

Vehicle infrastructure integration is that branch of engineering, which deals with the study and application of a series of techniques directly linking road vehicles to their physical surroundings in order to improve road safety.

Goals

The goal of VII is to provide a communications link between vehicles on the road (via On-Board Equipment, OBE), and between vehicles and the roadside infrastructure (via Roadside Equipment, RSE), in order to increase the safety, efficiency, and convenience of the transportation system. It is based on widespread deployment of a dedicated short-range communications (DSRC) link, incorporating IEEE 802.11p. VII's development relies on a business model supporting the interests of all parties concerned: industry, transportation authorities and professional organisations. The initiative has three priorities:

- evaluation of the business model (including deployment scheduling) and acceptance by the stakeholders;
- validation of the technology (in particular the communications systems) in the light of deployment costs; and
- development of legal structures and policies (particularly in regard to privacy) to enhance the system's potential for success over the longer term.

Safety

Current active safety technology relies on vehicle-based radar and vision systems. For example, this technology can reduce rear-end collisions by tracking obstructions in front or behind the vehicle, automatically applying brakes when needed. This technology is somewhat limited in that it senses only the distance and speed of vehicles within the direct line of sight. It is almost completely ineffective for angled and left-turn collisions. It may even cause a motorist to lose control of the vehicle in the event of an impending head-on collision. The rear-end collisions covered by today's technology are typically less severe than angle, left-turn, or head-on collisions. Existing technology is therefore inadequate for the overall needs of the roadway system.

VII would provide a direct link between a vehicle on the road and all vehicles within a defined vicinity. The vehicles would be able to communicate with each other, exchanging data on speed, orientation, perhaps even on driver awareness and intent. This could increase safety for nearby vehicles, while enhancing the overall sensitivity of the VII system, for example, by performing an automated emergency maneuver (steering,

decelerating, braking) more effectively. In addition, the system is designed to communicate with the roadway infrastructure, allowing for complete, real-time traffic information for the entire network, as well as better queue management and feedback to vehicles. It would ultimately close the feedback loops on what is now an open-loop transportation system.

Through VII, roadway markings and road signs could become obsolete. Existing VII applications use sensors within vehicles which can identify markings on the roadway or signing along the side of the road, automatically adjusting vehicle parameters as necessary. Ultimately, VII aims to treat such signs and markings as little more than stored data within the system. This could be in the form of data acquired via beacons along a roadway or stored at a centralised database and distributed to all VII-equipped vehicles.

Efficiency

All the above factors are largely in response to safety but VII could lead to noticeable gains in the operational efficiency of a transportation network. As vehicles will be linked together with a resulting decrease in reaction times, the headway between vehicles could be reduced so that there is less empty space on the road. Available capacity for traffic would therefore be increased. More capacity per lane will in turn mean fewer lanes in general, possibly satisfying the community's concerns about the impact of roadway widening. VII will enable precise traffic-signal coordination by tracking vehicle platoons and will benefit from accurate timing by drawing on real-time traffic data covering volume, density and turning movements.

Real-time traffic data can also be used in the design of new roadways or modification of existing systems as the data could be used to provide accurate origin-destination studies and turning-movement counts for uses in transportation forecasting and traffic operations. Such technology would also lead to improvements for transport engineers to address problems whilst reducing the cost of obtaining and compiling data. Tolling is another prospect for VII technology as it could enable roadways to be automatically tolled. Data could be collectively transmitted to road users for in-vehicle display, outlining the lowest cost, shortest distance, and/or fastest route to a destination on the basis of real-time conditions.

Existing applications

To some extent, results along these lines have been achieved in trials performed in around the globe, making use of GPS, mobile phone signals, and vehicle registration plates. GPS is becoming standard in many new high-end vehicles and is an option on most new low- and mid-range vehicles. In addition, many users also have mobile phones which transmit trackable signals (and may also be GPS-enabled). Mobile phones can already be traced for purposes of emergency response. GPS and mobile phone tracking, however, do not provide fully reliable data. Furthermore, integrating mobile phones in vehicles may be prohibitively difficult. Data from mobile phones, though useful, might even increase risks to motorists as they tend to look at their phones rather than

concentrate on their driving. Automatic registration plate recognition can provide high levels of data, but continuously tracking a vehicle through a corridor is a difficult task with existing technology. Today's equipment is designed for data acquisition and functions such as enforcement and tolling, not for returning data to vehicles or motorists for response. GPS will nevertheless be one of the key components in VII systems.

Limitations

There are numerous limitations to the development of VII. A common misconception is that the biggest challenge to VII technology is the computing power that can be fitted inside a vehicle. While this is indeed a challenge, the technology for computers has been advancing rapidly and is not a particular concern for VII researchers. Given the fact that technologies already exist for the most basic of forms of VII, perhaps the greatest hurdle to the deployment of VII technology is public acceptance.

Privacy

The most common myth about VII is that it includes tracking technology; however, this is not the case. The architecture is designed to prevent identification of individual vehicles, with all data exchange between the vehicle and the system occurring anonymously. Exchanges between the vehicles and third parties such as OEMs and toll collectors will occur, but the network traffic will be sent via encrypted tunnels and will therefore not be decipherable by the VII system.

Although the system will be able to detect signal and speed violations, it will not have the capability to identify the violator and report them. The detection is for the purpose of alerting the violator and/or approaching vehicles, to prevent collisions.

Other public concerns

Other public acceptance concerns come from advocates of recreational driving as well as from critics of tolling. The former argue that VII will increase the automation of the vehicle, reducing the driver's enjoyment. Recreational driving concerns are particularly prevalent among owners of sports cars. They could be attenuated by compensating for the presence of vehicles without VII or perhaps by maintaining roadways where vehicles without VII are permitted to travel.

Those opposed to tolling believe it will make driving prohibitively expensive for motorists in the lower-income bracket, conflicting with the general wish to provide equal services for all. In response, public transit discounts or road use discounts can be considered for qualifying individuals and/or families. Such provisions currently exist for numerous tolled roadways and could be applicable to roadways that are tolled via VII. However, as VII could allow for the tolling of *every* VII-enabled roadway, the provisions may be ineffective in view of the increased need to provide user-efficient transit services to every area.

Technical issues

Coordination

A major issue facing the deployment of VII is the problem of how to stand up the system initially. The costs associated with installing the technology in vehicles and providing communications and power at every intersection are significant. Building out the infrastructure along the roadside without the auto manufacturers' cooperation would be disastrous, as would the reverse situation; therefore, the two parties will need to work together to make the VII concept work.

There are proof of concept tests being performed in Michigan and California that will be evaluated by the US DOT and the auto manufacturers, and a decision will be made, jointly, about whether or not to move forward with implementation of the system at that time.

Maintenance

Another factor for consideration in regard to the technology's distribution is how to update and maintain the units. Traffic systems are highly dynamic, with new traffic controls implemented every day and roadways constructed or repaired every year. The vehicle-based option could be updated via the internet (preferably wireless), but may subsequently require all users to have access to internet technology. Many local government agencies have been testing deployment of internet facilities in cities and along roadways, for example at rest-stops. These systems could be used for VII updating.

An additional option is to provide updates whenever a vehicle is brought in for inspection or servicing. A major limitation here is that updating would be in the hands of the user. Some vehicle owners maintain their vehicles themselves, and periodic inspections or servicing are considered too infrequent for updating VII. Motorists might also be reluctant to stop at rest-stops for an update if they do not have the possibility of driving in an internet-enabled city.

Alternatively, if receivers were placed in all vehicles and the VII system was primarily located along the roadside, information could be stored in a centralised database. This would allow the agency responsible to issue updates at any time. These would then be disseminated to the roadside units for passing motorists. Operationally, this method is currently considered to provide the greatest effectiveness but at a high cost to the authorities.

Security

Security of the units is another concern, especially in the light of the public acceptance issue. Criminals could tamper with VII units, or remove and/or destroy them regardless of whether they are installed inside vehicles or along the roadside. If they are placed inside vehicles, laws similar to those for tampering with an odometer could be enacted;

and the units could be examined during inspections or services for signs of tampering. This method has many of the limitations mentioned in relation to the frequency of inspection and motorists who perform their own servicing. It also raises concerns regarding the honesty of vehicle technicians performing the inspections. The ability of technicians to identify signs of tampering would be dependent on their knowledge of the VII systems themselves.

Magnets, electric shocks, and malicious software (viruses, hacking, or jamming) could be used to damage VII systems - regardless of whether units are located inside vehicle or along the roadside. Extensive training and certification would be required for technicians to inspect VII units within a vehicle. Along the roadside, a high degree of security would be required to ensure that the equipment is not damaged and to increase its durability. However, as roadside units could well be placed on the public right-of-way - which is often close to the edge of the roadway - there could be concerns about vehicles hitting them (whether on purpose or by accident). The units would either have to be built so that they do not provide a threat to motorists: perhaps in the form of a low-profile and/or low-mass object designed to be run over or to break apart (which would entail a relatively inexpensive unit); or the unit would have to be shielded by a device such as a guardrail, raising safety concerns of its own.

Data input

Yet another limitation is in digitizing the inputs for the VII system. VII systems will probably continue to sense existing signs and roadway markings but one of the goals is to eliminate such signs and markings altogether. This would require converting the locations and messages of each item into the VII system's format. Responsibility for this work would probably fall on the highway agencies which nearly all face difficulties in funding, manpower, and available time. Implementing and maintaining VII systems may therefore require support at the national level.

Communications and authorization

While VII is largely being developed as a joint research enterprise involving numerous transport agencies, it is likely initial products will be tailored to individual applications. As a result, compatibility and formatting issues could well arise as systems expand. Overcoming these difficulties could require complicated translation programs between different systems or possibly a complete overhaul of existing VII systems in order to develop a more comprehensive approach. In either case, the costs and potential for bugs in the software will likely be high.

Legislation will be required to set in place access to the VII data and communications between applicable agencies. In the USA, for example, an Interstate is a Federal roadway that is often maintained by the State, but the local county or municipal authorities may be involved too. The legislation would need to set the levels of authority of each agency. In Pennsylvania, for example, municipalities tend to have greater authority than counties and sometimes even the State whereas neighboring Maryland has more authority at the

county level than at municipal level; and State roads are almost exclusively controlled by the State. It would also have to be determined which other agencies can use the data (i.e. law enforcement, Census, etc.) and to what degree it is permissible to use the information. Law enforcement would be needed to minimise data misuse. The various levels of authority could also increase incompatibility.

Recent developments

Much of the current research and experimentation is conducted in the United States where coordination is ensured through the Vehicle Infrastructure Integration Consortium, consisting of automobile manufacturers (Ford, General Motors, DaimlerChrysler, Toyota, Nissan, Honda, Volkswagen, BMW), IT suppliers, U.S. Federal and state transportation departments, and professional associations. Trialling is taking place in Michigan and California.

The specific applications now being developed under the U.S. initiative are:

- Warning drivers of unsafe conditions or imminent collisions.
- Warning drivers if they are about to run off the road or speed around a curve too fast.
- Informing system operators of real-time congestion, weather conditions and incidents.
- Providing operators with information on corridor capacity for real-time management, planning and provision of corridor-wide advisories to drivers.

In mid-2007, a VII environment covering some 20 square miles (52 km²) near Detroit will be used to test 20 prototype VII applications. Several automobile manufacturers are also conducting their own VII research and trialling.

Chapter-5

Traffic Signal Preemption

Traffic signal preemption is a type of system that allows the normal operation of traffic lights to be preempted, often to assist emergency vehicles. The most common use of these systems is to manipulate traffic signals in the path of an emergency vehicle, stopping conflicting traffic and allowing the emergency vehicle right-of-way, to help reduce response times and enhance traffic safety. Sometimes, signal preemption is also used at railroad grade crossings to prevent collisions, and by light-rail and bus rapid transit systems to allow public transportation priority access through intersections to ensure they remain on schedule and improve commute times.

Implementation

Traffic preemption devices are implemented in a variety of ways. They can be installed on road vehicles, integrated with train transportation network management systems, or operated by remote control from a fixed location, such as a fire station, or by a 9-1-1 dispatcher at an emergency call center. Traffic lights must be equipped to receive an activation signal to be controlled by any system intended for use in that area. A traffic signal not equipped to receive a traffic preemption signal will not recognize an activation, and will continue to operate in its normal cycle.

Vehicular devices can be switched on or off as needed, but in the case of emergency vehicles they are frequently integrated with the vehicle's emergency warning lights. When activated, the traffic preemption device will cause properly-equipped traffic lights in the path of the vehicle to cycle immediately, to grant right-of-way in the desired direction, after allowing for normal programmed time delays for signal changes and pedestrian crosswalks to clear.

Traffic signal preemption systems integrated with train transportation networks typically extend their control of traffic from the typical crossarms and warning lights to one or more nearby traffic intersections, to prevent excessive road traffic from approaching the

crossing, while also obtaining the right-of-way for road traffic that may be in the way to quickly clear the crossing.

Fixed-location systems can vary widely, but a typical implementation is for a single traffic signal in front of or near a fire station to stop traffic and allow emergency vehicles to exit the station unimpeded. Alternatively, an entire corridor of traffic signals along a street may be operated from a fixed location, such as to allow fire apparatus to quickly respond through a crowded downtown area, or to allow an ambulance faster access when transporting a critical patient to a hospital in an area with dense traffic.

Traffic signal preemption systems sometimes include a method for communicating to the operator of the vehicle that requested the preemption (as well as other drivers) that a traffic signal is under control of a preemption device, by means of a **notifier**. This device is almost always an additional light located near the traffic signals. It may be a single light bulb visible to all, which flashes or stays on, or there may be a light aimed towards each direction that traffic approaches the intersection from. In the case of multiple notifier lights at a controllable intersection, they will either flash or stay on depending on the local configuration, to communicate to all drivers from which direction a preempting signal is being received. This informs regular drivers which direction may need to be cleared, and informs activating vehicle drivers if they have control of the light (especially important when more than one activating vehicle approaches the same intersection). A typical installation would provide a flashing notifier to indicate that an activating vehicle is approaching from ahead or behind, while a solid notifier would indicate the emergency vehicle is approaching laterally. There are variations of notification methods in use, which may include one or more colored lights in varying configurations.

Events leading up to an activation and notification are not experienced by drivers on a daily basis, and driver education and awareness of these systems can play a role in how effective the systems are in speeding response times. Unusual circumstances can also occur which can confuse operators of vehicles with traffic preemption equipment who lack proper training. For example, on January 2, 2005, a fire engine successfully preempted a traffic light at an intersection which included a light rail train (LRT) crossing in Hillsboro, Oregon, yet the fire engine was hit by an LRT at the crossing. A subsequent inquiry determined that the LRT operator was at fault. The LRT operator had become desensitized to the preemption signals, as the LRT was itself granted right-of-way virtually all of the time, but the system was programmed to grant higher priority to fire apparatus over an LRT. The fire engine, granted the green light before it arrived at the intersection, proceeded through while the LRT operator, failing to notice the unexpected signal to stop, ran into the fire engine and destroyed it.

Vehicular Device Types

Line-of-Sight

A vehicle that utilizes a line-of-sight traffic signal preemption system is equipped with an **emitter** which typically sends a narrowly-directed signal forward, towards traffic lights

in front of the vehicle, to attempt to obtain right-of-way through controllable intersections before arriving at the intersection. These line-of-sight systems generally utilize an invisible infrared signal, or a visible strobe light which serves a dual purpose as an additional warning light. The emitter transmits visible flashes of light or invisible infrared pulses at a specified frequency. Traffic lights must be equipped with a compatible traffic signal preemption **receiver** to respond. Once the vehicle with the active emitter has passed the intersection, the receiving device no longer senses the emitter's signal, and normal operation resumes. Some systems can be implemented with varying frequencies assigned to specific types of uses, which would then allow an intersection's preemption equipment to differentiate between a fire engine and a bus sending a signal simultaneously, and then grant priority access first to the fire engine.



A notifier and receiver mounted between traffic lights.

Drawbacks of line-of-sight systems include obstructions, lighting and atmospheric conditions, and undesired activations. Obstructions may be buildings on a curving road that block visual contact with a traffic signal until very close, or perhaps a large freight truck in front of a police car blocking the traffic signal from receiving the emitter's signal from the police car. Modifying the position of the receiver or even locating it separate from the traffic signal equipment can sometimes correct this problem. Direct sunlight into a receiver may prevent it from detecting an emitter, and severe atmospheric conditions, such as heavy rain or snow, may reduce the distance at which a line-of-sight system will function. Undesired activations may occur if an emitter's signal is picked up by many traffic lights along a stretch of road, all directed to change to green in that direction, prior

to the activating vehicle turning off the road, or being parked without its emitter being deactivated.

Global Positioning System

With the advent of widespread Global Positioning System (GPS) applications came the introduction of a GPS-based traffic preemption system. These systems require software and a communications platform to determine where the activating vehicle is located, in which direction it is headed, which traffic lights should be preempted, and the ability for the central application to activate the desired traffic lights promptly.

Drawbacks of GPS systems include obstructions, single point of failure exposure, atmospheric conditions, and GPS satellite availability. In dense cities with tall buildings, GPS receivers may have difficulty obtaining at least three GPS satellite signals, required for triangulation to determine location. If the primary application is not installed with redundant hardware, a single failure on the primary system controller can disable all traffic preemption functions within the entire traffic network covered by the GPS-based system. Extremely heavy cloud cover or severe weather can also adversely impact the ability of the GPS receiver from obtaining the three required satellites. Additionally, recent concerns about the health of the GPS satellite network raise the possibility that the reliability of the GPS satellite system may degrade in the future.

Localized Radio Signal

Radio-based traffic-preemption systems using a local, short-range radio signal in the 900MHz band, can usually avoid the weaknesses of line-of-sight systems as well as GPS systems. A radio-based system still utilizes a directional signal transmitted from an emitter, but being radio-based, its signal is not blocked by visual obstructions, lighting or weather conditions.

Radio-based systems can offer some additional benefits: Adjustable range and collision avoidance. The operating range can be adjusted by varying the radio signal strength so that traffic lights are activated only nearby, or at greater distances. The hardware utilized by radio-based systems and installed on a vehicle is also capable of interacting with other equipped vehicles, primarily for the purpose of providing collision avoidance warnings when two or more vehicles approach each other while operating their preemption systems.

Compared to GPS systems, the cost difference may or may not be significant, as the single expense of the GPS primary application hardware and software comprises the bulk of the expense, which decreases per vehicle as more vehicles are added to the system.

Acoustic

Some systems use an acoustic sensor linked to the preemption system. This can be used by itself or in conjunction with other systems. Systems of this type override the traffic

signal when a specific pattern of tweets or wails from the siren of an emergency vehicle is picked up. Advantages of a system like this are that they are fairly inexpensive to integrate into existing traffic signals and the ability to use siren equipment already installed in emergency vehicles - thus dispensing with the need for special equipment. One disadvantage is that the acoustic sensors can sometimes be sensitive enough to activate the preemption in response to a siren from some distance away.

Railroad preemption

Another type of preemption is railroad preemption. Traffic-signal-controlled intersections next to railroad crossings on one of the roads usually have this feature. Approaching trains activate a routine where, before the train signals and gates are activated, all traffic signal phases go to red, except for the signal immediately after the train crossing, which turns green (or flashing yellow) to allow traffic on the tracks to clear (in some cases, there are auxiliary traffic signals prior to the railroad crossing which will turn red, keeping new traffic from crossing the tracks. This is in addition to the flashing lights on the crossing gates themselves). After enough time to clear the crossing, the signal will turn. The crossing lights may begin flashing and the gates lower immediately, or this might be delayed until after the traffic light turns red.

The operation of a traffic signal while a train is present may differ from municipality to municipality. In some areas, all directions will flash red, turning the intersection into an all-way stop. In other areas, the traffic parallel to the railroad track will have a green light for the duration of the train while the other directions face a red light for the duration of the train. Examples include the following:

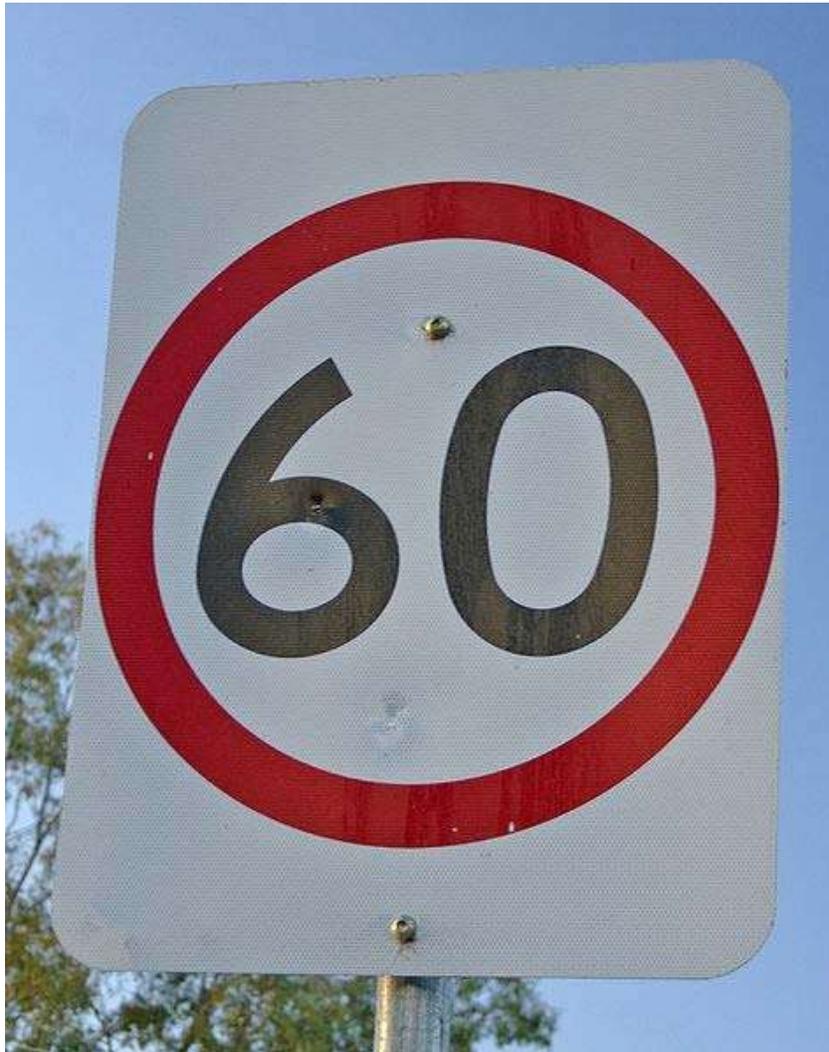
- The Chicago Drive/Ivanrest Avenue intersection in Grandville, Michigan, gives Chicago Drive traffic (parallel to the tracks) a flashing yellow with fiber-optic lit signs indicating "no right turn" or "no left turn" over the tracks, and Ivanrest traffic faces a solid red light. Similar fiber-optic or LED "no left turn" lights are used along 12th Avenue in Salem, Oregon.
- The same thing is done to three traffic intersections on Telegraph Rd. between the Ohio state line and Monroe, Michigan. Two of these also include Right turn signals which are solid red when the Telegraph lights are blinking yellow.
- In Goshen, Indiana, the signals at the intersections on Lincolnway will run normally, with the exception that oncoming traffic (across from the railroad crossing) will face "doghouse" signals with left and right arrows lit: all traffic is required to turn left or right if a train is present, to keep traffic moving.
- At the intersection of Allen Rd. and Northline Rd. on the border of Southgate and Taylor, Michigan, a railroad track runs diagonally through the intersection from the northeast corner to the southwest. When the lights come on and the arm goes down, all lights turn red and two fiber-optic "no turn on red" signs illuminate facing Northline, since their right turners cross the tracks. A similar situation is found at the intersection of Oregon Route 10 (Farmington Road) and Lombard Street in Beaverton, Oregon.

- The Middle Tennessee Blvd./ Church St. intersection in Murfreesboro, Tennessee, gives Church Street (parallel to the tracks) a green with fiber-optic lit signs indicating "no right turn" or "no left turn" over the tracks, and Middle Tennessee Blvd. traffic faces a solid red light.

WWT

Chapter-6

Speed Limit



A typical 60 km/h speed limit sign used in Australia



A typical speed limit sign in the United States showing a 50 mph restriction.

Road **speed limits** are used in most countries to regulate the speed of road vehicles. Speed limits may define maximum (which may be variable), minimum or no speed limit and are normally indicated using a traffic sign. Speed limits are commonly set by the legislative bodies of nations or provincial governments and enforced by national or regional police and / or judicial bodies.

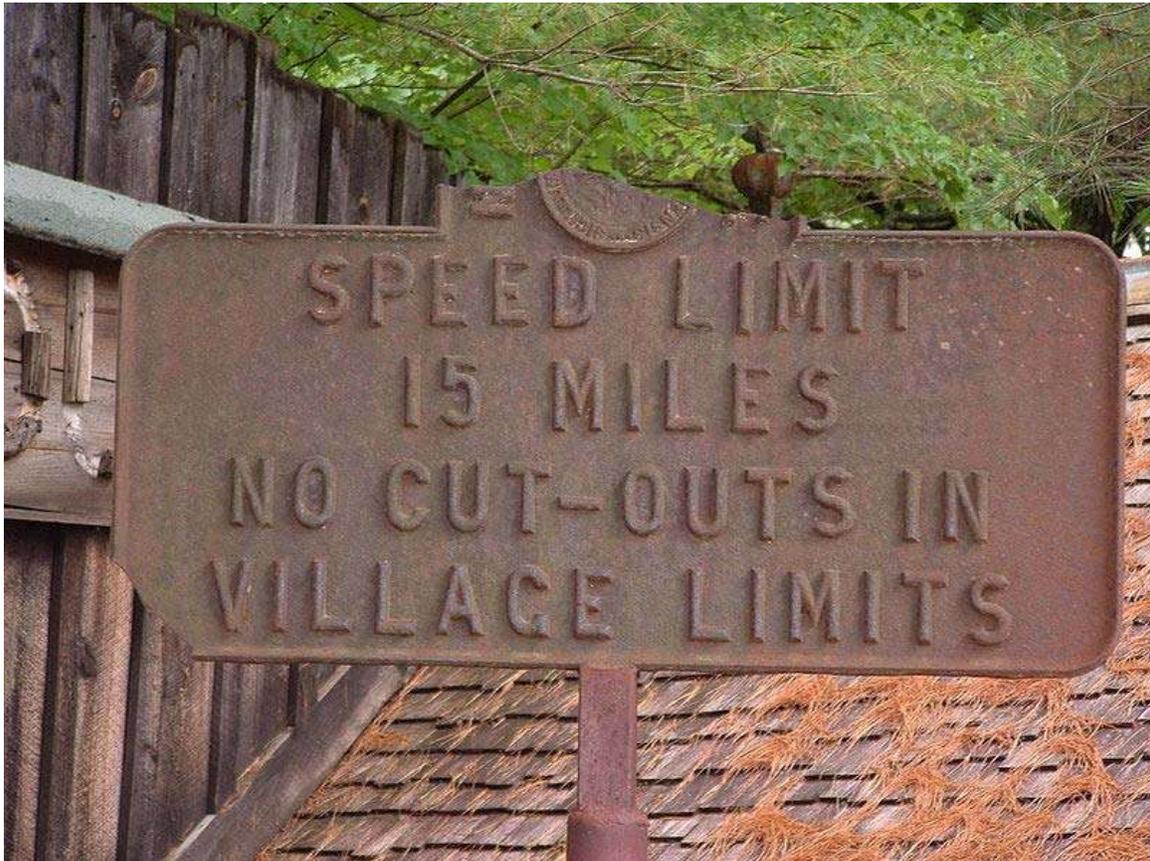
The first maximum speed limit was the 10 mph (16 km/h) limit introduced in the United Kingdom in 1861. From 2005 to 2010, the highest posted speed limit was 160 km (99 mi) in Abu Dhabi , although this was reduced to 140 km (87 mi) in 2011. However, some roads have no speed limit for certain classes of vehicles. Best known are Germany's less congested Autobahns where automobile drivers have no mandated maximum speed. Measurements from the German State of Brandenburg in 2006 show average speeds of 137 km/h (85 mph) on 4-lane sections, and 142 km/h (88 mph) on 6-lane sections, without mandatory speed limits. Rural areas on the Isle of Man, the Indian states of Andhra Pradesh and Maharashtra also lack speed limits, but speeds are lower when measured on those lower design roads.

Speed limits are usually set to attempt to cap road traffic speed; there are several reasons for wanting to do this. It is often done with an intention to improve road traffic safety and reduce the number of road traffic casualties from traffic collisions. In their *World report on road traffic injury prevention* report, the World Health Organization (WHO) identify speed control as one of various interventions likely to contribute to a reduction in road casualties. (The WHO estimated that some 1.2 million people were killed and 50 million injured on the roads around the world in 2004.) Speed limits may also be set in an attempt to reduce the environmental impact of road traffic (vehicle noise, vibration, emissions), to reduce fuel use and to satisfy local community wishes.

Speed limits are used to reduce the differences in vehicle speeds by drivers using the same road at the same time which increases safety. In situations where the natural road speed is considered too high, notably on urban areas where speed limits below 50 km/h (31 mph) are used then traffic calming is often also used. For some classes of vehicle speed limiters may be mandated to enforce compliance.

Since they have been introduced, speed limits have been opposed from various sources; including motoring advocacy groups, anti-motoring groups and others who either consider them to be irrelevant, set too low or set too high.

History



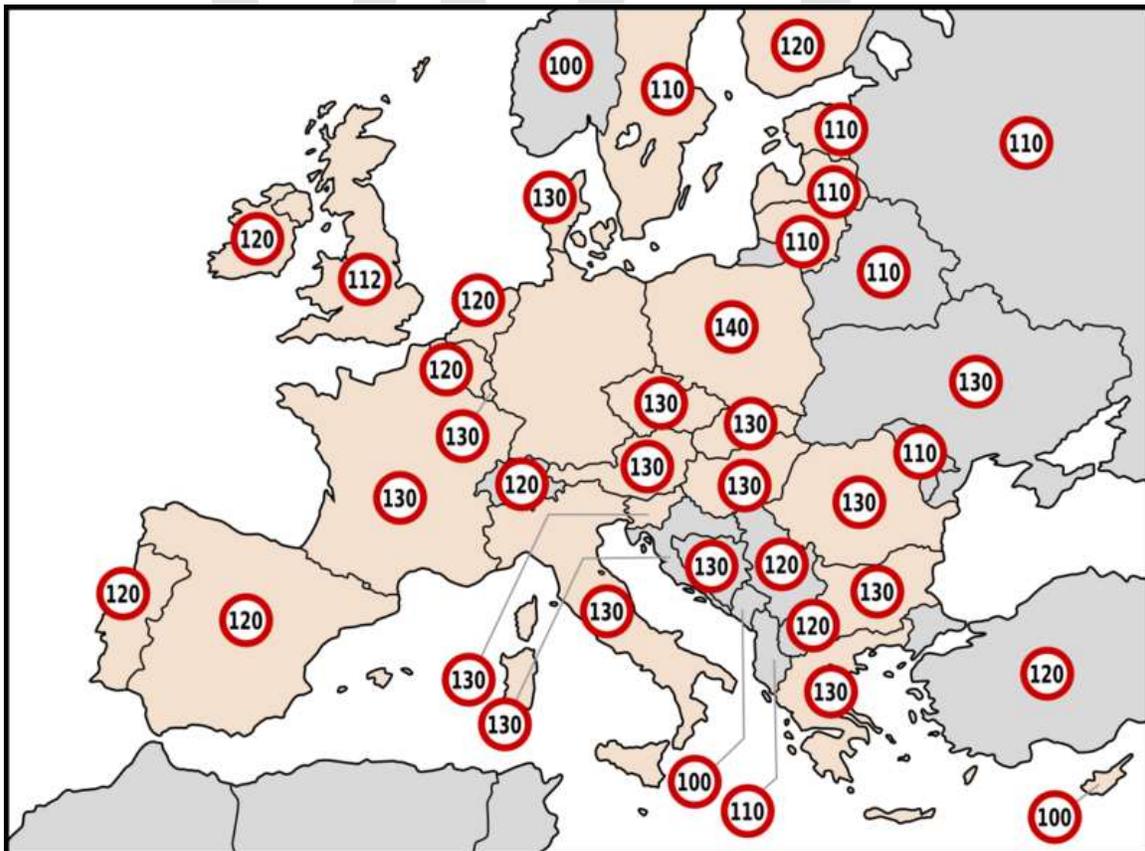
Antique New Hampshire speed limit sign.

The first speed limit legislation was created in the United Kingdom with the Locomotive Acts (automobiles were in those days termed “light locomotives”). The 1861 Act introduced a UK speed limit of 10 mph (16 km/h) which was then reduced to 4 mph (6 km/h) in the country and 2 mph (3 km/h) in towns by the 1865 Act (the 'red flag act'). The first person to be convicted of speeding is believed to be Walter Arnold of East Peckham, Kent, who on 28 January 1896 was fined for speeding at 8 mph (13 km/h). He was fined 1 shilling plus costs. Passage of the Locomotives on Highways Act 1896, which raised the speed limit to a "furious" pace of 14 mph is celebrated to this day by the annual London to Brighton Veteran Car Run.

Regulations



Speed limit sign common to much of Europe, showing a 60 km/h restriction. Similar signs in the UK are in mph.



Automobile speed limits on European freeways in km/h.

All countries use metric units (kilometres per hour), except for the United States and the United Kingdom, where speed limits are given in miles per hour.

Basic rule: reasonable speed

Drivers are required to drive at a safe speed for conditions. In the United States this requirement is referred to as the **basic rule**, but more generally in Britain and elsewhere in common law as the reasonable man requirement. Lower speed may be required due to fog, heavy rain, and pavement conditions such as freezing or gravel, or where they are not able to stop in the line of sight. California Vehicle Code section 22350 is typical; it states that "No person shall drive a vehicle upon a highway at a speed greater than is reasonable... and in no event at a speed which endangers the safety of persons or property".

Maximum speed limits

Most public roads in most countries have a legally assigned numerical maximum speed limit which applies on all roads unless otherwise stated; lower speed limits are often shown on a sign at the start of the restricted section although the presence of streetlights, or the physical arrangement of the road may sometimes also be used instead. A posted speed limit may only apply to that road or to all roads beyond the sign that defines them depending on local laws. In the European Union, large signposts showing the national (default) speed limits of the respective country are usually erected immediately after border crossings, with a repeater sign some 200 to 500 m (660 to 1,600 ft) after the first sign. Some places provide an additional "speed zone ahead" ahead of the restriction and speed limit reminder signs may appear at regular intervals which may be painted on the road surface.

Signs are normally placed on both sides of the road and in some places there are small (less than 1/4 the size of the sign) rectangular orange reflector flags attached to both upper right corners of both signs. The speed limit sign marking the new speed zone may also have the orange flags.

Signage in many countries, especially in Europe conforms to the Vienna Convention on Road Signs and Signals using black text with a red circle on a white background. In the U.S., the signs are usually rectangular with the words "SPEED LIMIT" (in Canada, "MAXIMUM") and the values in black on a white background. The U.S. Federal Highway Administration's Manual on Uniform Traffic Control Devices provides guidelines for the appearance of speed limit signs. Australian signs are rectangular but have a red circle like the conventional signs.

Posted maximum speeds are normally based on ideal driving conditions.

Minimum speed limits

Some roads also have "minimum speed limits", where slow speeds can impede traffic flow or be dangerous and on motorways slower vehicles such as horse drawn vehicles, bicycles and mopeds can be banned, e.g. in the United Kingdom.

Signs often use blue circles based on the obligatory signs of the Vienna Convention on Road Signs and Signals. A Japanese minimum speed sign has the same design as a maximum speed sign but with a horizontal line below the number. In the United States of America, they are also identical to their respective maximum speed limit signs with the exception of the text "MINIMUM SPEED".

Variable speed limits



Example variable speed limit sign in the United States.

In 1965, the first known experiments with variable speed limit signs took place on a 30 km stretch of German motorway A8 between Munich and the border city of Salzburg, Austria. Mechanically variable message signs could display speeds of 60, 80 and 100 km/h, "danger zone" or "accident". Personnel monitored traffic using video technology, and manually controlled the signage. Beginning in the 1970s, more and more advanced traffic control systems were put into service. Modern motorway control systems can work without human intervention using various types of sensors to measure traffic flow and weather conditions. In 2009, 1,300 km (810 mi) of German motorways were equipped with such systems.

In the late 1960s, heavily traveled portions of the New Jersey Turnpike began using variable speed limit signs, in combination with variable message signs. Officials can adjust the speed limit according to weather, traffic conditions, and construction. More

typically, variable speed limits are used on remote stretches of highway in the United States in areas with extreme changes driving conditions. For example, variable limits were introduced in Oct 2010 on a 52-mile stretch of Interstate 80 in Wyoming, replacing the winter season speed reduction from 75 to 65-mph that had been in place since 2008. . Similarly, Interstate 90 at Snoqualmie Pass and other mountain passes in Washington State variable speed limits are used to slow traffic in severe winter weather. A response to fog-induced chain-reaction collisions involving 99 vehicles in 1990, a variable speed limit system covering 19 miles (31 km) of Interstate 75 in Tennessee was implemented in fog-prone areas around the Hiwassee River.

A variable speed limit was introduced on part of Britain's M25 motorway in 1995 (on the busiest 14-mile (23 km) section from junction 10 to 16. Initial results suggested savings in journey times, smoother-flowing traffic, as well as a fall in the number of crashes and the scheme was made permanent in 1997. However a 2004 National Audit Organization report noted that the business case was unproved; conditions at the site of the Variable Speed Limits trial were not stable before or during the trial, and the study was deemed neither properly controlled nor reliable. From December 2008 the upgraded section of the M1 between the M25 and Luton will have the facility for variable speed limits. In January 2010 temporary variable speed cameras on the M1 between J25 and J28 were made permanent.

New Zealand introduced variable speed limits in February 2001. The first installation was on the Ngauranga Gorge section of dual carriageway on State Highway 1 with steep terrain, numerous bends, high traffic volumes, and higher than average accident rate. The speed limit is normally 80 km/h.

In 2006, Austria undertook a short term experiment with a variable limit configuration that could increase statutory limits under the most favorable conditions, as well as reduce them. In June, a stretch of motorway was configured with variable speed limits could increase the general Austrian motorway limit of 130 kilometres per hour (81 mph) up to 160 kilometres per hour (99 mph). Then Austrian Transport Minister Hubert Gorbach called the experiment "a milestone in European transport policy-despite all predictions to the contrary"; however, the experiment was discontinued.

Roads without speed limits



German border crossing sign showing 50 km/h (31 mph) limit in built-up areas, 100 km/h (62 mph) in rural areas, but only an **advisory 130 km/h (81 mph) limit** for the Autobahn

Many roads without a maximum limit became permanently limited following the 1973 oil crisis. For example, Switzerland had no maximum restriction prior to 1973 on motorways and rural roads, but imposed a temporary 100 km/h (62 mph) maximum limit in quick response to higher fuel prices; the limit on motorways was increased to 130 km/h (81 mph) later in 1974.

Montana and Nevada were the last remaining U.S. states relying exclusively on the basic rule, without a specific, numeric rural speed limit prior to the National Maximum Speed Law of 1974 . After repeal of Federal speed mandates in 1996, Montana was the only

state to revert to rural daytime speed limit, beyond the Basic Rule. After the Montana Supreme Court decided that the Basic Rule was too vague and therefore violated the due process requirement of the Montana Constitution, Montana's legislature imposed a 75 mph (121 km/h) limit on rural freeways in 1999, although the same wording in the basic rule remains.

Australia's Northern Territory had no blanket speed limits outside major towns until January 2007 when rural speed limits of 110 km/h (68 mph) or 130 km/h (81 mph) were introduced. Prior to the speed limit fatalities were 55 (in 2005) and 44 (in 2006). In 2007 they rose to 57 and then again to 75 (in 2008) before falling to 31 in 2009. The per-capita fatality rate in 2006 was the highest in the OECD and twice the Australian average.

The Isle of Man has no speed limit on many rural roads; a 2004 proposal to introduce a general speed limits 60 mph and of 70 mph on Mountain Road for safety reasons were not progressed following consultation. Measured travel speeds on the island are relatively low.

As of 2008, 52% of the German autobahns have only advisory limits (Richtgeschwindigkeit), 15% have temporary speed limits due to weather or traffic conditions and 33% have permanent speed limits. The length of speed-unrestricted autobahns slowly expanded after the opening of the East German borders in November 1989. Prior to German reunification in 1990, accident reduction programs in eastern German states were primarily focused on restrictive traffic regulation. Within two years after the opening, availability of high-powered vehicles and a 54% increase in motorized traffic led to a doubling of annual traffic deaths, despite "interim arrangements [which] involved the continuation of the speed limit of 100 km/h (62 mph) on autobahns and of 80 km/h (50 mph) outside cities. An extensive program of the four *Es* (enforcement, education, engineering, and emergency response) brought the number of traffic deaths back to pre-unification levels after ten years while traffic regulations were raised to western standards (e.g., 130 km/h (81 mph) freeway advisory limit, 100 km/h (62 mph) on other rural roads, and 0.5 milligrams BAC) .

Enforcement



Gatso speed camera

Speed limit enforcement is the action taken by appropriately empowered authorities to check that road vehicles are complying with the speed limit. Methods used include roadside speed traps set up and operated by the police and automated roadside speed camera systems which may incorporate the use of an automatic number plate recognition system.

Effectiveness

The *Synthesis of Safety Research Related to Speed and Speed Limits* report sponsored by the Federal Highway Administration published in 1998 found that changing speed limits on low and moderate speed roads appeared to have no significant effect on traffic speed or the number of crashes, whilst on high-speed roads such as freeways, increased speed limits generally resulted in higher traffic speeds and more crashes. It is also stated that there is limited evidence to suggest that speed limits have a positive effect on a system wide basis.

The speed limit is commonly set at or below the '85th percentile speed' (which is the speed at which 85% of the traffic is travelling) and in the USA is typically set 8 to 12 mph (13 to 19 km/h) below that speed.

A 2003 review of speed limits for British Columbia (Canada) identified a number of places where speed limits had been increased and decreased in various countries and the observed changes in speeding, fatalities, injuries and property damage which followed these changes:

Results from lowering speed limits.

Country	Speed limit reduction	Reported change
Australia	110 km/h to 100 km/h	Injury crashes declined by 19%
Australia	5–20 km/h decreases	No significant change
Denmark	60 km/h to 50 km/h	Fatal crashes declined by 24% Injury crashes declined by 9%
Germany	60 km/h to 50 km/h	Crashes declined by 20%
Sweden	110 km/h to 90 km/h	Speeds declined by 14 km/h Fatal crashes declined by 21%
Switzerland	130 km/h to 120 km/h	Speeds declined by 5 km/h Fatal crashes declined by 12%
UK	100 km/h to 80 km/h	Speeds declined by 4 km/h Crashes declined by 14%
USA (22 states)	8–32 km/h decreases	No significant changes

Results from increasing speed limits:

Country	Speed limit increase	Reported change
Australia	100 km/h to 110 km/h	Injury crashes increased by 25%
Australia (Victoria)	5–20 km/h increases	Crashes increased overall by 8%, 35% decline in zones raised from 60 km/h to

		80 km/h
USA	89 km/h to 105 km/h	Fatal crashes increased by 21%
USA	89 km/h to 105 km/h	Fatal crashes increased by 22% Speeding increased by 48%
USA (40 states)	89 km/h to 105 km/h	Fatalities increased by 15% Decrease or no effect in 12 States
USA (Iowa)	89 km/h to 105 km/h	Fatal crashes increased by 36%
USA (Michigan)	89 km/h to 105 km/h	Fatal and injury crashes increased significantly on rural freeways
USA (Michigan)	Various	No significant changes
USA (Ohio)	89 km/h to 105 km/h	Injury and property damage increased but not fatal crashes.
USA (40 states)	89 km/h to 105 km/h	Statewide fatality rates decreased 3-5% (Significant in 14 of 40 states)
USA (22 states)	8 km/h to 24 km/h increase	No significant changes

By contrast to the above a survey of speeds on South Dakota Interstate roads in 2008 showed that 47% of drivers were driving over the 75 mph (120 km/h) speed limit, which is below observed 85th percentile speeds of 79-81 mph".

The *Synthesis of Safety Research Related to Speed and Speed Limits* report sponsored by the Federal Highway Administration published in 1998 found that increasing speed limits on freeways and high-speed roads increased speed and crashes.

Research in 1998 showed that the reduction of some 30 mph (48 km/h) United Kingdom speed limits to 20 mph (32 km/h) had achieved only a 1 mph drop in speeds and no discernible reduction in accidents; '20 mph speed limit zones' which use self enforcing traffic calming achieved average speed reductions of 10 mph, child pedestrian accidents were reduced by 70% and child cyclist accidents by 48%.

Studies undertaken in conjunction with Australia's move from 60 km/h (37 mph) speed limits to 50 km/h (31 mph) in built-up areas and found that the measure was effective in reducing both speed and the frequency and severity of crashes.

A study of the impact of the replacement of 60 km/h (37 mph) with 50 km/h (31 mph) speed limits in New South Wales, Australia showed only a 0.5 km/h drop in urban areas and a 0.7 km/h drop in rural areas. The report noted that widespread community compliance would require a combination of strategies including traffic calming treatments.

Information campaigns are also used by authorities to support speed limits, for example the Speeding. No one thinks big of you. campaign in Australia 2007.

Justification

Speed limits are set primarily to balance road traffic safety concerns with the effect on travel time and mobility. Speed limits are also sometimes used to reduce consumption of fuel or in response to environmental concerns.

Road traffic safety



The Pan-American Highway with central median and no freestanding obstructions increasing level of safety at high speed



Traffic calming can be effective on lower speed roads

According to a 2004 report from the World Health Organisation a total of 22% of all 'injury mortality' worldwide were from road traffic injuries in 2002 and without 'increased efforts and new initiatives' casualty rates would increase by 65% between 2000 and 2020. The report identified that the speed of vehicles was 'at the core of the problem and said that speed limits should be set appropriately for the road function and design along with physical measures related to the road and the vehicle and effective enforcement by the police. Road incidents are said to be the leading cause of deaths among children 10 – 19 years of age (260,000 children die a year, 10 million are injured). They are also occasionally set to reduce vehicle emissions or fuel use.

Maximum speed limits place an upper limit on speed choice and if obeyed can reduce the differences in vehicle speeds by drivers using the same road at the same time. Traffic engineers observe that the likelihood of a crash happening is significantly higher if vehicles are traveling at speeds faster or slower than the mean speed of traffic; when severity is taken into account the risk is lowest for those traveling at or below the median speed and "increases exponentially for motorists driving faster".

It is desirable to attempt to reduce the speed of road vehicles in some circumstances because the kinetic energy involved in a motor vehicle collision is proportional to the square of the speed at impact. The probability of a fatality is, for typical collision speeds, empirically correlated to the fourth power of the speed *difference* (depending on the type of collision, not necessarily the same as *travel* speed) at impact, rising much faster than kinetic energy.

The 2009 technical report *An Analysis of Speeding-Related Crashes: Definitions and the Effects of Road Environments* by the National Highway Traffic Safety Administration showed that ca 55 percent of all speeding-related crashes in fatal crashes were due to “exceeding posted speed limits” and 45 percent were due to “driving too fast for conditions”.

The speed limit will also take note of the speed at which the road was designed to be driven (the design speed) which is defined in the USA as "a selected speed used to determine the various geometric design features of the roadway". However traffic engineers recognize that "operating speeds and even posted speed limits can be higher than design speeds without necessarily compromising safety".

Vision Zero, which envision reducing road fatalities and serious injuries to zero by 2020, suggests the following "possible long term maximum travel speeds related to the infrastructure, given best practice in vehicle design and 100% restraint use":

Possible Maximum Travel Speeds

Type of infrastructure and traffic	Possible travel speed (km/h)
Locations with possible conflicts between pedestrians and cars	30 km/h (19 mph)
Intersections with possible side impacts between cars	50 km/h (31 mph)
Roads with possible frontal impacts between cars, including rural roads	70 km/h (43 mph)
Roads with no possibility of a side impact or frontal impact (only impact with the infrastructure)	100 km/h (62 mph)+

"Roads with no possibility of a side impact or frontal impact" are sometimes designated as Type 1 (motorways/freeways/Autobahns), Type 2 ("2+2 roads") or Type 3 ("2+1 roads"). These roadways have crash barriers separating opposing traffic, limited access, grade separation and prohibitions on slower and more vulnerable road users. Undivided rural roads can be quite dangerous even with speed limits that appear low by comparison. For example, in 2008, Germany's 100 km/h (62 mph)-limited rural roads had a fatality rate of 9.5 deaths per billion travel-km, over four times higher than the autobahn rate of 2.2 deaths. Autobahns accounted for 33% of German road travel in 2008, but just 11% (495 of 4,477) of traffic deaths.

Fuel efficiency

Fuel efficiency sometimes affects speed limit selection. The United States instituted a National Maximum Speed Law of 55 mph (89 km/h) as part of the Emergency Highway Energy Conservation Act in response to the 1973 oil crisis to reduce fuel consumption. According to a report published in 1986 by The Heritage Foundation, a Conservative advocacy group, the law was widely disregarded by motorists and hardly reduced consumption at all. In 2009 The American Trucking Associations called for a 65 mph speed limit and also national fuel economy standards claiming that the lower speed limit was not effective at saving fuel.

Environmental considerations

Speed limits can also be used to improve local air quality issues or other factors affecting environmental quality for example the "environmental speed limits" in the United States including one in an area of Texas.

The European Union is also increasingly using Speed Limits as in response to environmental concerns.

Advocacy

Speed limits, and especially some of the methods used to attempt to enforce them, have always been controversial. There are a variety of notable organisations and individuals who, for a variety of often passionately held views, oppose or support the use of speed limits or the way they are enforced.

Opposition

Speed limits, and their enforcement have been opposed by various groups and for various reasons since their inception. Historically, the AA was formed in 1905, initially to warn members about speed traps.

In more recent times some advocacy groups seek to have certain speed limits as well as other measures removed. For example, automated camera enforcement has been criticised by motoring advocacy groups the Association of British Drivers, the North American National Motorists Association, and the German Auto Club.

Arguments used by those advocating a relaxation of speed limits or their removal include:

- A 1994 peer-reviewed paper by Charles A. Lave et al. titled 'Did the 65 mph Speed Limit Save Lives?' stated that evidence that a higher speed limit may be positive on a system wide in the United States by shifting more traffic to these safer roads.

- A 1998 report in the Wall Street Journal title 'Highways are safe at any speed' stated that when speed limits are set artificially low, tailgating, weaving and speed variance (the problem of some cars traveling significantly faster than others) make roads less safe.
- In 2010 German Auto Club (a major motoring organisation) concluded an autobahn speed limit was unnecessary because numerous countries with a general highway speed limit had worse safety records than Germany, for example Denmark, Belgium, Austria, and the United States.
- Safe Speed, a UK advocacy organisation campaigns for higher speed limits and to scrap speed cameras on the basis that the benefits were exaggerated and that they may actually increase casualty levels; their ePetition to the UK government in 2007 calling for speed cameras to be scrapped received over 25,000 signatures.

Support

Various other advocacy groups press for stricter limits and better enforcement. Historically, the Pedestrians' Association and the Automobile Association were described as "bitterly opposed" in the early years of United Kingdom motoring legislation. The Pedestrians Association was formed in the United Kingdom in 1929 to protect the interests of the pedestrian. Their president published a critique of motoring legislation and the influence of motoring groups in 1947 title 'Murder most foul' which laid out in an emotional but detailed way the situation as they saw it and called for tighter speed limits. More recently RoadPeace was founded in 1991 with an aim to stop road victims being "treated by the economy as acceptable, by the judicial system as trivial and by society as accidents" and called for a default 20 mph speed limit in residential areas.

Vision Zero is "a philosophy of road safety that eventually no one will be killed or seriously injured within the road transport system."

Chapter-7

National Transportation Communications for Intelligent Transportation System Protocol

The **National Transportation Communications for Intelligent Transportation System Protocol (NTCIP)** is a family of standards designed to achieve interoperability and interchangeability between computers and electronic traffic control equipment from different manufacturers.

The protocol is the product of a joint standardization project guided by the Joint Committee on the NTCIP, which is composed of six representatives each from the National Electrical Manufacturers Association (NEMA), the American Association of State Highway and Transportation Officials (AASHTO), and the Institute of Transportation Engineers (ITE). The Joint Committee has in turn formed 14 technical working groups to develop and maintain the standards, and has initiated or produced over 50 standards and information reports.

The project receives funding under a contract with the United States Department of Transportation (USDOT) and is part of a wider effort to develop a comprehensive family of Intelligent Transportation System (ITS) standards.

History of the NTCIP Development

NEMA initiated the development of the NTCIP in 1992. In early 1993, the US Federal Highway Administration (FHWA) brought together transportation industry representatives to discuss obstacles to installing field equipment for new Intelligent Transportation Systems (ITS). The representatives said that the number one priority was the need for an industry-wide standard data communications protocol. Since the NEMA Transportation Section members had already started work on a new industry standard, they offered to expedite and expand the scope of their activities.

The key objectives of the new NTCIP protocol were the interchangeability of similar roadside devices, and the interoperability of different types of devices on the same communications channel.

In 1996, the FHWA suggested a partnership of standards developing organizations to expand both user and industry involvement. AASHTO and ITE signed an agreement with NEMA to establish the Joint Committee on the NTCIP, and to work together on developing and maintaining the NTCIP standards.

NTCIP Benefits

NTCIP standards offer increased flexibility and choices for agencies operating transportation management systems. NTCIP standards usage removes barriers to interagency coordination and allows equipment of different types and different manufacturers to be mixed on the same communications line. For these reasons, operating agencies benefit from specifying that NTCIP be included in all future acquisitions and upgrades, even if NTCIP is not initially used.

According to the NTCIP Guide, use and application of the NTCIP provides the following benefits to Intelligent Transportation System (ITS) deployers:

- **Avoiding Early Obsolescence** — While retrofitting legacy equipment and systems with NTCIP support is not practical in most situations, most manufacturers offer NTCIP support in their ITS devices. It is possible to migrate a system gradually, since it is possible to operate a mixture of NTCIP and non-NTCIP devices in the same system, though not on the same communications line. Equipment may also continue to use a current protocol even though the device may also support NTCIP as a second protocol. Integrating legacy equipment and systems with NTCIP-conformant upgrades in this manner ensures that an operating agency's systems and equipment remain useful and compatible long into the future.
- **Providing a Choice of Vendor** — Since a computer system that supports NTCIP can communicate with any device from other vendors that are NTCIP-conformant, the number of vendors and systems, field devices, or software that can be considered for procurement increases greatly. While vendor-specific features may only be available to other software and ITS devices from the same vendor, the basic functionality described in an NTCIP standard is available regardless of vendor. This requires that agency specifications (procurement documents) adequately specify the mandatory and optional conformance requirements that support the agency's functional requirements. However, NTCIP makes it easier for an agency to gradually change its software, controllers and other field devices from one vendor to supporting multiple vendors for the entire system.
- **Phased Procurement and Deployment** — Specifying NTCIP allows agencies to procure devices and center systems in phases, over several financial cycles. For example, many agencies procure a few signs one year, then a few more the next

year, and so on. Sometimes devices are procured from one vendor, and sometimes from multiple vendors. Specifying NTCIP standards means that multiple deployment phases, over multiple years, can be integrated, with little difficulty. The initial deployment establishes an ITS communications infrastructure that can be leveraged by future deployment phases resulting in improved cost/benefit for ITS projects.

- **Enabling Interagency Coordination** — NTCIP allows agencies to exchange information and (with authorization) basic commands that enable any agency to monitor conditions in other agencies' systems, and to implement coordinated responses to incidents and other changes in field conditions when needed. Such data exchange and coordinated response can be implemented either manually or automatically. One agency can monitor, and issue basic commands, if authorized, to field devices operated by another agency, even though those devices may be from a different vendor than those used by the monitoring agency. Potential applications of interagency coordination include:
 - (a) Coordinating timed transfers at a shared transit center,
 - (b) Coordinating traffic signals across jurisdictional boundaries,
 - (c) Providing traffic signal priority for selected, e.g., behind schedule, transit vehicles,
 - (d) Providing real-time information to a shared traveler information center,
 - (e) Monitoring traffic volumes on another agency's roadway,
 - (f) Coordinating the operation of a freeway ramp meter with an adjacent traffic signal, or
 - (g) Posting a warning message on another agency's dynamic message sign.
- **Use One Communications Network for All Purposes** — NTCIP allows a management system to communicate with a mixture of device types on the same communications channel. For example, with the addition of appropriate application software in the system computer, a dynamic message sign could be installed near a signalized intersection, and the computer could communicate with the sign controller using the communications line or channel already in place for the traffic signal controller, if certain aspects of the communications protocols, that is, the Data Link and Physical layer protocols are the same. Similarly, a wide area network interface installed for communications with a system operated by another agency can be used for communications with any number of other systems, of any type, if NTCIP and the C2C Data Dictionaries and Message Sets of other efforts, such as the Traffic Management Data Dictionary (TMDD), are used. The communications network is usually one of the components of a transportation management system that requires the most resource investment. NTCIP ensures flexibility in the future use of that component.

NTCIP Communications Standards

Center to Field Device Communications

NTCIP has enabled the center to field communication and command/control of equipment from different manufacturers to be specified, procured, deployed, and tested. NTCIP communications standards for field devices are listed below: (the corresponding NTCIP document number is shown in parentheses):

- Traffic signals (NTCIP 1202)
- Dynamic message signs (NTCIP 1203)
- Environmental sensor stations (NTCIP 1204)
- Closed circuit television cameras (NTCIP 1205)
- Vehicle count stations (NTCIP 1206)
- Freeway ramp meters (NTCIP 1207)
- Video switches (NTCIP 1208)
- Transportation sensor systems (NTCIP 1209)
- Field master stations for traffic signals (NTCIP 1210)
- Transit priority at traffic signals (NTCIP 1211)
- Street lights (NTCIP 1213)

Center to Center Communications

Center to center (C2C) communication involves peer-to-peer communications between computers involved in information exchange in real-time transportation management in a many-to-many network. This type of communication is similar to the Internet, in that any center can request information from, or provide information to, any number of other centers.

An example of center to center communications is two traffic management centers that exchange real-time information about the inventory and status of traffic control devices. This allows each center system to know what timing plan, for example, the other center system is running to allow traffic signal coordination across center geographic boundaries. Other examples of this type of communication include:

- Two or more traffic signal systems exchanging information (including second-by-second status changes) to achieve coordinated operation of traffic signals managed by the different systems and to enable personnel at one center to monitor the status of signals operated from another center;
- A transit system reporting schedule adherence exceptions to a transit customer information system and to a regional traveler information system, while also asking a traffic signal management system to instruct its signals to give priority to a behind-schedule transit vehicle;
- An emergency management system reporting an incident to a freeway management system, to a traffic signal management system, to two transit management systems and to a traveler information system;

- A freeway management system informing an emergency management system of a warning message just posted on a dynamic message sign on the freeway in response to its notification of an incident; and
- A weather monitoring system (environmental sensors) informing a freeway management system of ice forming on the roadway so that the freeway management system is able to post warning messages on dynamic message signs as appropriate.

NTCIP communications standards for center to center communications are listed below: (the corresponding NTCIP document number is shown in parentheses):

- Data Exchange - DATEX-ASN (NTCIP 2304)
- Web Services - XML (NTCIP 2306)

The NTCIP has coordinated with other information level standards development organizations during development of the center-to-center application profiles and supports the: ITE Traffic Management Data Dictionary (ITE TMDD), IEEE 1512 Incident Management (IEEE 1512), APTA Transit Communications Interface Profiles (APTA TCIP), and SAE J2354 Advanced Traveler Information Systems standards.

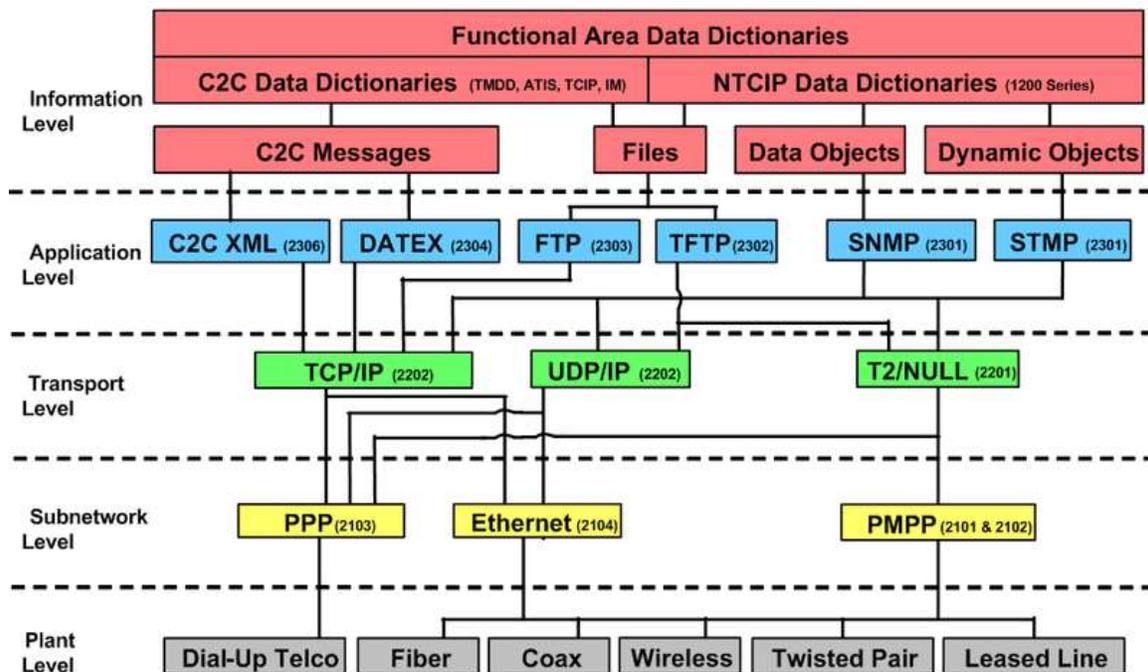
NTCIP Standards Framework

The NTCIP Framework is based primarily on the open standards of the Internet Engineering Task Force (IETF), World Wide Web Consortium (W3C), and ISO, plus NTCIP data dictionary standards specific for the task of ITS device communications. A layered, or modular, approach to communications standards, is used to represent data communications between two computers or other electronic devices.

NTCIP refers to “levels” in NTCIP, rather than “layers” to distinguish the hierarchical architecture applied from those defined by the Open System Interconnection Reference Model (OSI Model) of ISO and the Internet Engineering Task Force (IETF). The five NTCIP levels are: information level, application level, transport level, subnetwork level, and plant level.

The figure below (used with permission) shows how the NTCIP Information, Application, Transport, Subnetwork, and Plant Levels.

NTCIP Framework



NTCIP Framework.

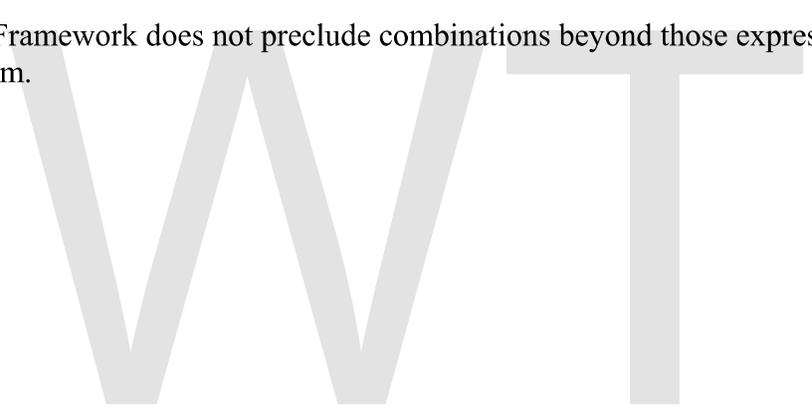
To ensure a working system, deployers should select and specify at least one NTCIP protocol or profile at each level. A discussion of each level, and NTCIP standards that apply at that level, follows:

- **NTCIP Information Level** — Information standards define the meaning of data and messages and generally deal with ITS information (rather than information about the communications network). This is similar to defining a dictionary and phrase list within a language. These standards are above the traditional ISO seven-layer OSI model. Information level standards represent the functionality of the system to be implemented.
- **NTCIP Application Level** — Application standards define the rules and procedures for exchanging information data. The rules may include definitions of proper grammar and syntax of a single statement, as well as the sequence of allowed statements. This is similar to combining words and phrases to form a sentence, or a complete thought, and defining the rules for greeting each other and exchanging information. These standards are roughly equivalent to the Session, Presentation and Application Layers of the OSI model.
- **NTCIP Transport Level** — Transport standards define the rules and procedures for exchanging the Application data between point 'A' and point 'X' on a network, including any necessary routing, message disassembly/re-assembly and network management functions. This is similar to the rules and procedures used by the telephone company to connect two remotely located telephones. Transportation

level standards are roughly equivalent to the Transport and Network Layers of the OSI model.

- **NTCIP Subnetwork Level** — Subnetwork standards define the rules and procedures for exchanging data between two 'adjacent' devices over some communications media. This is equivalent to the rules used by the telephone company to exchange data over a cellular link versus the rules used to exchange data over a twisted pair copper wire. These standards are roughly equivalent to the Data Link and Physical Layers of the OSI model.
- **NTCIP Plant Level** — The Plant Level is shown in the NTCIP Framework only as a means of providing a point of reference to those learning about NTCIP. The Plant Level includes the communications infrastructure over which NTCIP communications standards are to be used and has a direct impact on the selection of an appropriate Subnetwork Level for use over the selected communications infrastructure. The NTCIP standards do not prescribe any one media type over another. In most cases, communications media selections are made early in the design phase.

The NTCIP Framework does not preclude combinations beyond those expressly indicated on the diagram.



Chapter-8

Active Traffic Management and Traffic Camera

Active traffic management



The gantries over the M42 show the variable speed limit in operation

Active traffic management (ATM), also known as **managed lanes** or **smart lanes**, is a scheme for improving traffic flow and reducing congestion on motorways. It has been implemented in several countries, including Germany, the United Kingdom, and the United States. It makes use of automatic systems and human intervention to manage traffic flow and ensure the safety of road users.

In the United Kingdom

It is currently in operation on the M42 motorway south-east of Birmingham and in Warwickshire. The scheme has been criticised by some due to possible safety and environmental concerns, however it has now been expanded onto other roads following the initial trial on the M42. It is seen as a less expensive alternative to widening a road.

Technology

The section of road subject to ATM is monitored by MIDAS sensor loops placed in the road every 100 metres (328 ft) (which is closer than normal) to observe traffic flows. A computerised system monitors the traffic flows and can set the best speed limit for the current flow of traffic and switch on speed limit signs mounted on gantries up to 2 kilometres (1.24 mi) before an incident. Operators can also monitor 150 CCTV cameras along the route and can control both the speed limits and information signs. Overhead variable message signs can direct drivers to use the hard shoulder during busy periods.

When the speed limit has been lowered to 50 miles per hour (80 km/h) or below the hard shoulder can be opened as an additional lane. To facilitate this and still maintain safety a series of refuge areas have been created around every 500 metres (1,640 ft) along that stretch of the road. These take the form of lay bys to the side of the hard shoulder and contain the SOS phones within them. In the event of a vehicle breaking down on the hard shoulder, operators can close it or they can close a lane to allow emergency services access to an accident. The hard shoulder is never opened on the sections under a junction between the off and on slip roads. Close to junctions use of the hard shoulder as a lane is restricted to traffic exiting or entering at that junction.

ATM involves converting the hard shoulder into a normal lane during periods of high traffic flow to expand the capacity of the road and may reduce the need to widen motorways. Similar schemes have already been implemented in Europe.

The system makes use of Automatic Number Plate Recognition cameras which to monitor traffic flows and tailor the system. Digital enforcement cameras are also mounted on the gantries and are operated by the West Midlands Police to enforce the mandatory variable speed limits.

Future Implementation

- Vehicular Ad-Hoc Network
- Intelligent Traffic-light Management

In the United States

A number of highways in the United States have variable message signs and variable speed limits. The New Jersey Turnpike has been using active signage since the 1960s, though systems have evolved over time as they have been deployed in other areas of the country. A modern implementation of active traffic management was activated in 2010 using IRIS on Interstate 35W in Minneapolis, Minnesota and its southern suburbs as part of the Urban Partnership Agreement. Active lane management on I-35W is being combined with high-occupancy toll lanes and will be joined by a bus rapid transitway. An ATM scheme was deployed on 10 August 2010 in Washington.

Traffic camera



Traffic camera mounted on a traffic light pole at a intersection on the Sturt Highway in Wagga Wagga.

A **traffic camera** is a video camera which observes vehicular traffic on a road. Typically, these are put along major roads such as highways, freeways, motorways, autoroutes and expressways, as well as arterial roads, and are connected with optical fibers buried alongside or even under the road. A monitoring center receives the live video in real time, and serves as a dispatcher if there is an traffic collision or some other disruptive incident or road safety issue. Internet users can often view individual frames posted to a website every few minutes, and can then determine whether an alternate route should be taken.

Traffic cameras are a major part of most intelligent transportation systems. They are especially valuable in tunnels, where safety equipment can be activated remotely based upon information provided by the cameras and other sensors. On surface roads, they are typically mounted on high poles or masts, sometimes along with street lights. On arterial roads, they are often mounted on traffic light poles at intersections, where problems are most likely to occur.



A set of traffic cameras in Dongguan, China.



Traffic camera at Arekere junction on Bannerghatta Road. Camera footage can be viewed on the website of Bangalore Transport Information System

Traffic cameras are distinct from road safety cameras, which are put in specific places to enforce rules of the road. Those cameras take still photos in a much higher image resolution upon a trigger, whereas traffic cameras are simply for observation and constantly take lower-resolution full-motion video.

Online Traffic Cameras are cameras linked to online websites that enable the public to view real time traffic conditions online. These webcams usually refresh every minute and can be viewed from official websites.

Chapter-9

STREAMS Integrated Intelligent Transport System and Urban Traffic Management and Control

STREAMS Integrated Intelligent Transport System

STREAMS Integrated Intelligent Transport System is an enterprise traffic management system designed to operate in the Microsoft Windows environment. Like most traffic management systems, STREAMS is an array of institutional, human, hardware, and software components designed to monitor, control, and manage traffic on streets and highways. Advanced traffic management systems come under the banner of ITS (intelligent transport systems). ITS is an umbrella term referring to the application of information and communications technology to transport operations in order to reduce operating costs, improve safety and maximise the capacity of existing infrastructure. STREAMS provides traffic signal management, incident management, motorway management, vehicle priority, traveller information and parking guidance within a single integrated system. STREAMS is developed by Transmax.

History

In 1969, the Department of Main Roads (Queensland) installed the first Intelligent Transport System in Australia (located at Surfers Paradise). This included 30 signalised intersections featuring centralised control and traffic responsive capabilities.

In 1985, a second generation traffic management system was installed in Cairns, Australia. This was known as the TRAC System, or Traffic Responsive Adaptive Control System. Progressive installation of the TRAC system followed at several more sites around Queensland including the capital city, Brisbane.

In 1988, a traffic management system was installed for the South East Freeway in Brisbane, Australia. The features included were ramp metering and graphical displays of traffic conditions. It also provided automatic incident detection.

In 1992, a new integrated intelligent transport system development was commenced. The objectives were to lower ongoing costs while providing increased performance and opportunity for future ITS applications. The resultant system was STREAMS.

In 2002, the division of Department of Main Roads (Queensland) responsible for continuing development of STREAMS was privatised to form Transmax. The company remains 100% owned by the Department of Main Roads.

In April 2007, Transmax implemented a coordinated ramp metering trial for VicRoads on a 15 km section of the Monash Freeway. Later that year, in December, VicRoads installed STREAMS to manage another six ramps..

These developments were part of a much larger M1 Upgrade Project that continued over the next three years, eventually winning the 2010 National ITS Australia Award. The project to upgrade the 75-kilometre M1 Freeway, linking the Monash Freeway, the CityLink Tollway and the West Gate Freeway made use of STREAMS as its Integrated Control System..

Currently, STREAMS is at version 2010.2. The next major release, STREAMS 2011, is scheduled for early 2011.

The name STREAMS was derived via the association of managing multiple modes or "streams" of traffic (e.g. public transport, private cars, pedestrians, bicycles, and commercial vehicles) as well as the concept of "streams" of data which are inherent in any distributed computing system.

Software Architecture

STREAMS employs a distributed computing software architecture. Field hardware such as intersection controllers, video cameras and speed detectors are connected via field processors back to a central application server. Users connect to the application server via the workstation software. Field communications are via Optical Fibre, DSL, Wireless or P2P connections.

The software is built in distinct modules for each distinct area of traffic / transport control and monitoring. The workstation software communicates to the application server software via a publisher / subscriber model (i.e. workstations subscribe to specifically requested streams of data which are published by the application server).

The software architecture model is designed to support the software's claim of being an "integrated" Advanced Traffic Management System. This breaks away from the inter-

operability model, which is multiple ITS systems working in parallel, each performing a discrete function.

The workstation software is built around a central user interface called "STREAMS Explorer". Other specification / reporting applications can all be launched from STREAMS Explorer.

The transport network data is set up via a GIS (Geographic Information System). The GIS allows for a graphical user interface displaying transport network data overlaid on street maps and updating in real-time.

The application server uses a Microsoft SQL Server database running on Microsoft Windows Server. Linux is employed as the operating system for all field processors. The workstation software is designed to run on Microsoft Windows.

For security reasons, STREAMS employs 128-bit SSL encryption across all data and communication links. As well, firewalls, intrusion detection systems, and authorisation mechanisms are utilised.

Criticism

STREAMS has been criticised by competing systems such as SCATS for the lack of true adaptive traffic capabilities. SCATS employs a method of automatically modifying traffic plans in real-time to optimise traffic flow. STREAMS does not generate its own traffic plans, but instead allows for dynamic operation in which the system can choose the optimal traffic plan from a selection of plans created by users.

Urban Traffic Management and Control

The **Urban Traffic Management Control** or **UTMC programme** is the main initiative of the UK Department for Transport (**DfT**) for the development of a more open approach to Intelligent Transport Systems or ITS in urban areas.

UTMC systems are designed to allow the different applications used within modern traffic management systems to communicate and share information with each other. This allows previously disparate data from multiple sources such as ANPR cameras, Variable-message sign (VMS), car parks, traffic signals, air quality monitoring stations and meteorological data, to be amalgamated into a central console or database. The idea behind UTMC is to maximise road network potential to create a more robust and intelligent system that can be used to meet current and future management requirements.

Background and history

The UTMC was launched in 1997; during the first three years, a number of research projects were undertaken to establish and validate an approach based on modular systems and open standards. These have contributed to the UTMC Technical Specifications, which define UTMC standards.

- To assist local authorities in gaining the most from ITS and to achieve their transport objectives, the DfT initiated the six-year, £6M UTMC programme in 1997. The first half of the UTMC programme (1997–2000) concentrated on specific applied research tasks, on both technical and operational issues.
- In January 2001, the programme embarked on a demonstrator phase to consolidate the results of the earlier research. Full scale demonstrator projects taking a pragmatic UTMC approach were run in Preston by Mott MacDonald, Reading and Stratford-upon-Avon by Siemens and York by Envitia (formerly Tenet Technology).
- Early in 2003, the UTMC Development Group or UDG of stakeholders, consisting of local authorities and suppliers was set up, with the support of the DfT, to oversee the future development of UTMC.

UTMC has helped local authorities achieve their goals by adopting an appropriate, but not over constraining, set of standards to allow users, suppliers and integrators of UTMC systems to plan and supply systems cost-effectively in an open market. These standards are essential in breaking boundaries and local authority borders to allow network interoperability.

UTMC Activities

Specifications and Standards

The UTMC Specifications and Standards Group (S&SG) is responsible for ensuring that the UTMC technical framework continues to meet local authorities needs, currently and in the future. The S&SG oversees the maintenance and upkeep of the UTMC Technical Specifications. Its members are drawn from both local authorities and the supplier community, but it is always led by local authorities.

The S&SG works closely with the full range of UTMC suppliers to ensure its requirements are technically achievable. It operates a transparent consultation regime on all technical changes. From time to time it may commission and fund technical research and standards development activities, though it operates principally through coordinating the input freely provided by suppliers and users.

Outreach and marketing

As well as undertaking technical work to develop national specifications, there are a number of activities that help "market" the initiative to the traffic management community.

There is an annual conference, papers and articles are published in key industry journals and regular workshops are held focusing on key (technical or operational) themes.

In 2006, the UTMC community ran a number of special sessions at the ITS World Congress held in London, as well as running a village of suppliers demonstrating UTMC-compatible products.

The UTMC Products Register

The UTMC Products Directory is a catalogue of UTMC Compliant Products which Local Authorities may use in finding Products for their Traffic Management Systems. The Products Register outlines the process for submitting a Product to the Register and subsequently to the Directory.

Examples of UTMC in action

Local authorities with UTMC have more control over their road network. Some examples of what they can do are:

Advise

By monitoring how long it takes a vehicle to pass two ANPR cameras and then dividing the time by the distance between the cameras, an average speed can be measured and used to inform motorists via VMS how long it will take them to reach a destination, or to set diversions. Example by Envitia: VMS in Aberdeen . Example by IDT: Car park counting in Aberdeen

Warn

Wind detectors attached to a bridge give drivers of high sided vehicles warnings before they cross. The warning messages are displayed on VMS signs activated when wind speed thresholds are exceeded. Example by Siemens: Bridge VMSs offer wind warnings .

Guide

By linking parking guidance systems to a common database traffic control room operators can inform motorists via strategic VMS about the current state of car parks; especially useful for special events like carnivals when normal use is exceeded. Example by Motts MacDonald: Car Park Guidance in Edinburgh

Previously these systems would have been impracticable due to the sheer volumes of data processing and the operator time needed to apply constant manual updates.

The UTMC Objects Registry

The Objects Registry TS004 provides format standards for shared data (i.e. data communicated between applications of a UTMC system, or between a UTMC system and an external system) through:

- holding definitions of current UTMC Objects, and making them available to users;
- receiving submissions for potential new UTMC Objects, and coordinating consultation as necessary;
- facilitating contact between Object developers;
- advising on changes needed to potential new UTMC Objects;
- registering new UTMC Objects.

The current issue as of May 2009 is TS004.004:2008. A revision is anticipated in Autumn 2009.

Joint Chairs' Group (JCG)

The JCG brings together the UDG with three other key ITS community organisations, namely the Travel Information Highway, the Real Time Information Group and Intelligent Transport Systems Society for the United Kingdom. Meeting at chair's level, the JCG aims to ensure that the strategic direction of the four groups is aligned.

The JCG meets approximately quarterly. It is a consultative rather than an executive forum: it is up to individual chairs and the groups they lead to take any action as a result of JCG discussions.

Chapter-10

Congestion Pricing



Typical traffic congestion in an urban freeway. Shown here I-80 Eastshore Freeway, Berkeley, United States.



London Heathrow Airport, one of the world's most congested airports.

Congestion pricing or **congestion charges** is a system of surcharging users of a transport network in periods of peak demand to reduce traffic congestion. Examples include some toll-like road pricing fees, and higher peak charges for utilities, public transport and slots in canals and airports. This variable pricing strategy regulates demand, making it possible to manage congestion without increasing supply. Market economics theory, which encompasses the congestion pricing concept, postulates that users will be forced to pay for the negative externalities they create, making them conscious of the costs they impose upon each other when consuming during the peak demand, and more aware of their impact on the environment.

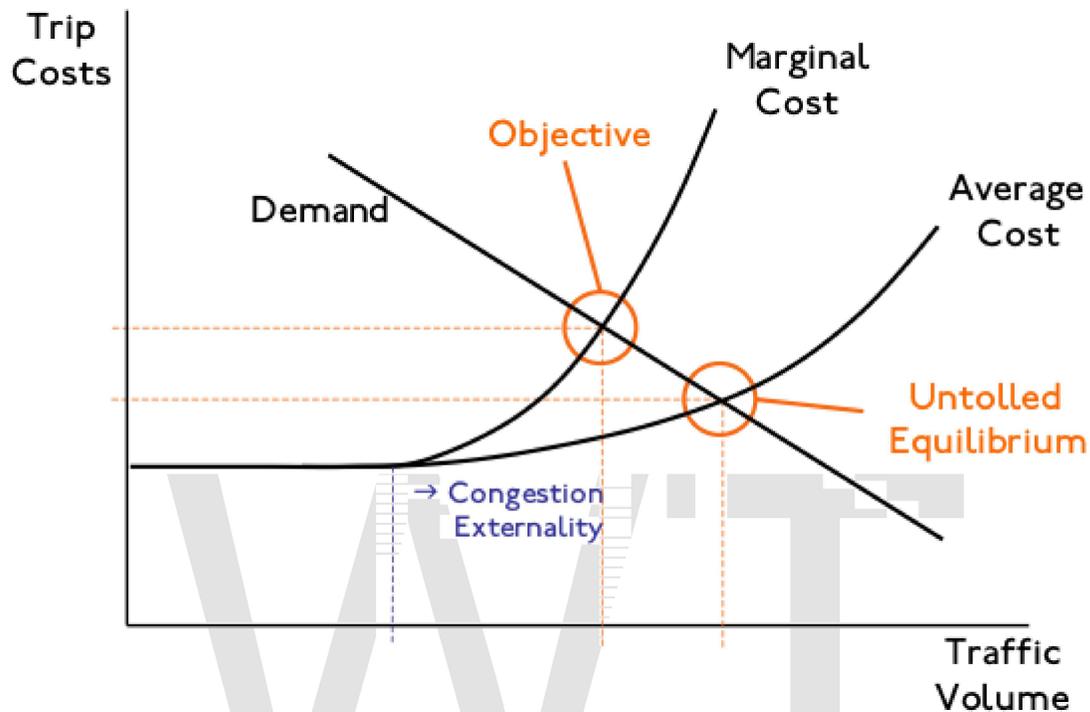
The application on urban roads is limited to a small number of cities, including London, Stockholm, Singapore, and Milan, as well as a few smaller towns. Four general types of systems are in use; a cordon area around a city center, with charges for passing the cordon line; area wide congestion pricing, which charges for being inside an area; a city center toll ring, with toll collection surrounding the city; and corridor or single facility congestion pricing, where access to a lane or a facility is priced.

Implementation of congestion pricing has reduced congestion in urban areas, but has also sparked criticism and public discontent. Critics maintain that congestion pricing is not equitable, places an economic burden on neighboring communities, has a negative effect on retail businesses and on economic activity in general, and is just another tax.

A survey of economic literature on the subject, however, finds that most economists agree that some form of road pricing to reduce congestion is economically viable, although there is disagreement on what form road pricing should take. They primarily argue that recent advances in technology have significantly reduced the previously high transaction costs of toll collection. Fuel taxes are not effective in reducing highway congestion, and tolls are the direct method. Also, concerns regarding fossil fuel supply and urban transport high emissions of greenhouse gases in the context of climate change

have renewed interest in congestion pricing, as it is considered one of the demand-side mechanisms that may reduce oil consumption.

Description



Economic rationale for moving from untolled equilibrium to congestion pricing equilibrium.

Congestion pricing is a concept from market economics regarding the use of pricing mechanisms to charge the users of public goods for the negative externalities generated by the peak demand in excess of available supply. Its economic rationale is that, at a price of zero, demand exceeds supply, causing a shortage, and that the shortage should be corrected by charging the equilibrium price rather than shifting it down by increasing the supply. Usually this means increasing prices during certain periods of time or at the places where congestion occurs; or introducing a new usage tax or charge when peak demand exceeds available supply in the case of a tax-funded public good provided free at the point of usage.

According to the economic theory behind congestion pricing, the objective of this policy is the use of the price mechanism to make users more aware of the costs that they impose upon one another when consuming during the peak demand, and that they should pay for the additional congestion they create, thus encouraging the redistribution of the demand in space or in time, or shifting it to the consumption of a substitute public good; for example, switching from private transport to public transport.

This pricing mechanism has been used in several public utilities and public services for setting higher prices during congested periods, as a means to better manage the demand for the service, and whether to avoid expensive new investments just to satisfy peak demand, or because it is not economically or financially feasible to provide additional capacity to the service. Congestion pricing has been widely used by telephone and electric utilities, metros, railways and autobus services, and has been proposed for charging internet access. It also has been extensively studied and advocated by mainstream transport economists for ports, waterways, airports and road pricing, though actual implementation is rather limited due to the controversial issues subject to debate regarding this policy, particularly for urban roads, such as undesirable distribution effects, the disposition of the revenues raised, and the social and political acceptability of the congestion charge.

Congestion pricing is one of a number of alternative demand side (as opposed to supply side) strategies offered by economists to address traffic congestion. Congestion is considered a negative externality by economists. An externality occurs when a transaction causes costs or benefits to a third party, often, although not necessarily, from the use of a public good. For example, if manufacturing or transportation cause air pollution imposing costs on others when making use of public air. Congestion pricing is an efficiency pricing strategy that requires the users to pay more for that public good, thus increasing the welfare gain or net benefit for society.

Nobel-laureate William Vickrey is considered by some to be the father of congestion pricing, as he first proposed it for the New York City Subway system in 1952. In the road transportation arena these theories were extended by Maurice Allais, Gabriel Roth who was instrumental in the first designs and upon whose World Bank recommendation the first system was put in place in Singapore, and Reuben Smeed, the deputy director of the Transport and Road Research Laboratory whose ideas presented in his report to the British government were rejected by successive governments since the 1960s.

The transport economics rationale for implementing congestion pricing on roads, described as "one policy response to the problem of congestion", was summarized in a testimony to the United States Congress Joint Economic Committee in 2003: "congestion is considered to arise from the mispricing of a good; namely, highway capacity at a specific place and time. The quantity supplied (measured in lane-miles) is less than the quantity demanded at what is essentially a price of zero. If a good or service is provided free of charge, people tend to demand more of it - and use it more wastefully - than they would if they had to pay a price that reflected its cost. Hence, congestion pricing is premised on a basic economic concept: charge a price in order to allocate a scarce resource to its most valuable use, as evidenced by users' willingness to pay for the resource".

Urban roads

Practical implementations of road congestion pricing are found almost exclusively in urban areas, because traffic congestion is common in and around city centers. Autoroute

A1 in Northern France is one of the few cases of congestion pricing implemented outside of urban areas. This is an expressway connecting Paris to Lille, and since 1992 congestion prices have been applied during weekends with the objective of spreading demand on the trip back to Paris on Sunday afternoons and evenings. As congestion pricing has been increasing worldwide, the schemes implemented have been classified into four different types: cordon area around a city center; area wide congestion pricing; city center toll ring; and corridor or single facility congestion pricing.



Electronic Road Pricing Gantry at North Bridge Road, Singapore



At Old Street, street markings and a sign (inset) with the white-on-red C alert drivers to the congestion charge, London..



The control point at Liljeholmen, Stockholm.

Cordon area and area wide

Cordon area congestion pricing is a fee or tax paid by users to enter a restricted area, usually within a city center, as part of a demand management strategy to relieve traffic congestion within that area. The economic rationale for this pricing scheme is based on the externalities or social costs of road transport, such as air pollution, noise, traffic accidents, environmental and urban deterioration, and the extra costs and delays imposed by traffic congestion upon other drivers when additional users enter a congested road.

The first implementation of such a scheme was Singapore Area Licensing Scheme in 1975, together with a comprehensive package of road pricing measures, stringent car ownership rules and improvements in mass transit. Thanks to technological advances in electronic toll collection, electronic detection, and video surveillance technology, collecting congestion fees has become easier. Singapore upgraded its system in 1998, and similar pricing schemes were implemented in Rome in 2001, London in 2003 with extensions in 2007; Stockholm in 2006, as seven month trial, and then on a permanent basis. In January 2008 Milan began a one-year trial program called Ecopass, charging low emission standard vehicles and exempting alternative fuel vehicles and vehicles using conventional fuels but compliant with the Euro IV emission standard. The Ecopass program was extended until December 31, 2009, and a public consultation will be conducted to decide if the charge becomes permanent.

Although there has not yet been a comprehensive study, initial reports from the cities that have implemented congestion pricing schemes show traffic volume reductions from 10% to 30%, as well as reduced air pollution. Also, all cities report public controversy before and after implementation, making political feasibility a critical issue.

Singapore and Stockholm charge a congestion fee every time a user crosses the cordon area, while London charges a daily fee for any vehicle driving in a public road within the congestion charge zone, regardless of how many times the user crosses the cordon. Stockholm has put a cap on the maximum daily tax, while in Singapore the charge is based on a pay-as-you-use principle, and rates are set based on traffic conditions at the pricing points, and reviewed on a quarterly basis. Through this policy, the Land Transport Authority (LTA) reports that the electronic road pricing "has been effective in maintaining an optimal speed range of 45 to 65 km/h for expressways and 20 to 30 km/h for arterial roads".

Developments

Singapore

In an effort to improve the pricing mechanism, and, to introduce real-time variable pricing, Singapore's LTA together with IBM, ran a pilot from December 2006 to April 2007, with a traffic estimation and prediction tool (TrEPS), which uses historical traffic data and real-time feeds with flow conditions from several sources, in order to predict the levels of congestion up to an hour in advance. By accurately estimating prevailing and

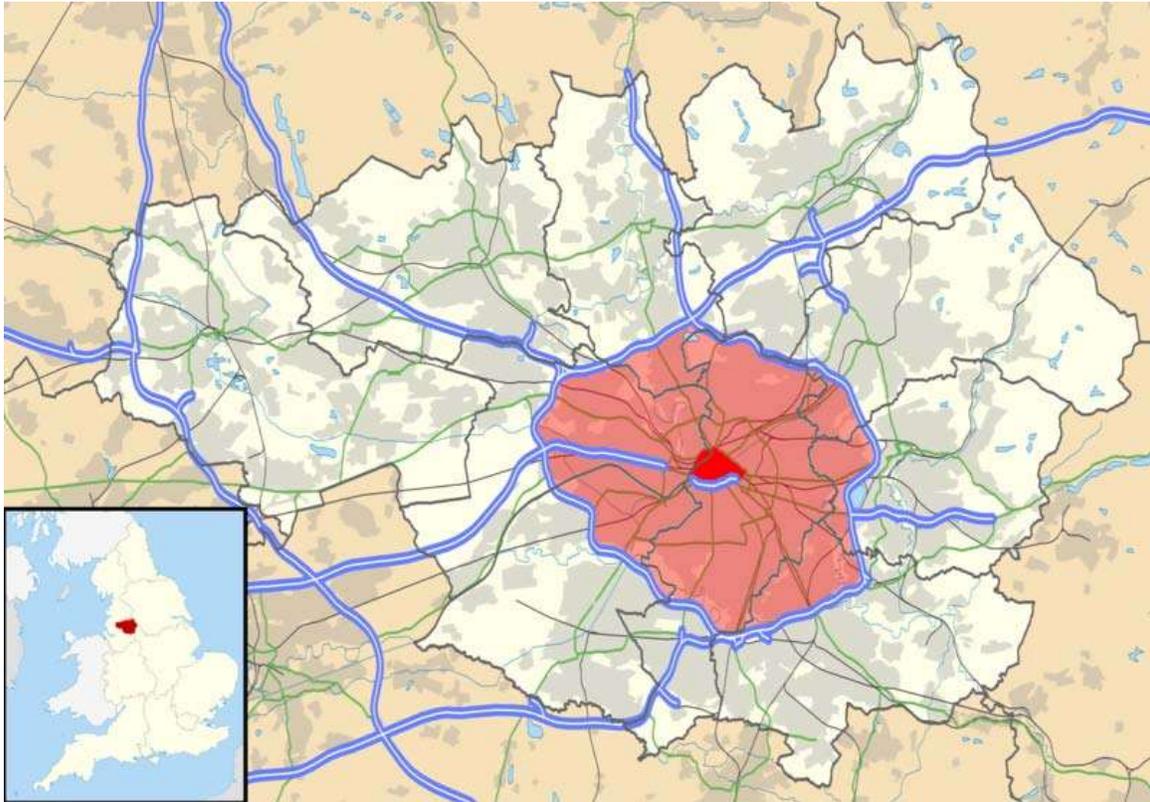
emerging traffic conditions, this technology is expected to allow variable pricing, together with improved overall traffic management, including the provision of information in advance to alert drivers about conditions ahead, and the prices being charged at that moment.

London

A proposal by former Mayor of London Ken Livingstone would have resulted in a new pricing structure based on potential CO₂ emission rates by October 2008. The goal was that vehicles with the very lowest CO₂ emission rates would be exempted, and those with higher emission rates would pay a new higher charge of GB£25, with the rest paying the same charge they pay today. However, the current Mayor of London, Boris Johnson, announced at the beginning of his administration that he would reform the congestion charge.

Johnson announced on July 2008 that the new CO₂ charging structure will no longer be implemented. Among other reasons, he said the environmental charge would encourage travel by thousands of smaller vehicles free of charge, resulting in increase congestion and pollution. He also discarded plans for extending the charge zone to the suburbs, and announced he will review the western extension implemented in 2007, based on a public consultation planned for September 2008. Having held a five-week public consultation with residents in the autumn of 2008, Johnson decided to remove the 2007 Western Extension from the congestion charging zone beginning on January 4, 2011, to increase the basic charge to GB£10, and also to introduce an automated payment system called Congestion Charging Auto Pay (CC Auto Pay), which will charge vehicles based on the number of charging days a vehicle travels within the charging zone each month, and the drivers of these vehicles will pay a reduced GB£9 daily charge.

"Old town" centres



A map of Greater Manchester highlighting area of the rejected congestion charging scheme

Around Europe several small cities, such as Durham, England; Znojmo, Czech Republic; Riga, Latvia; and Valletta, Malta, have implemented congestion pricing to reduce traffic crowding, parking problems and pollution, particularly during the peak tourism season.

Durham introduced charges in October 2002, reducing vehicle traffic by 85% after a year; prior to this 3,000 daily vehicles had shared the streets with 17,000 pedestrians.

Valletta has reduced daily vehicles entering the city from 10,000 to 7,900; making 400 readily available parking places in the center. There has been a 60% drop in car stays by non-residents of more than eight hours, but there has been a marked increase of 34% in non-residential cars visiting the city for an hour or less.

Rejected proposals

Hong Kong conducted a pilot test on an electronic congestion pricing system between 1983 and 1985 with positive results. However, public opposition against this policy stalled its permanent implementation.

In 2002 Edinburgh, United Kingdom, initiated a implementation process; a referendum was conducted in 2005, with a majority of 74.4% rejecting the proposal.

Councils from across the West Midlands in the United Kingdom, including Birmingham and Coventry, rejected the idea of imposing congestion pricing schemes on the area in 2008, despite promises from central government of transport project funding in exchange for the implementation of a road pricing pilot scheme.

In 2007, New York City in the United States shelved a proposal for a three-year pilot program for implementation in Manhattan, and a new proposition was denied in 2008, with a potential federal grants of USD 354 million being reallocated to other cities.

Greater Manchester, United Kingdom, was considering a scheme with two cordons, one covering the main urban core of the Greater Manchester Urban Area and another covering the Manchester city centre. The measure was supported by the government, but three local authorities rejected it (Bury, Trafford and Stockport); the support of two-thirds of Manchester's 10 local councils was needed for it to be implemented. A comprehensive transport investment package for Manchester, which included the congestion pricing element, was released for further public consultation and was to be subject of a referendum in December 2008. On 12 December 2008 the scheme was overwhelmingly rejected by 10 out of 10 councils by a public referendum.

Current proposals

In August 2007, the United States Department of Transportation selected five metropolitan areas to initiate congestion pricing demonstration projects under the Urban Partnerships Congestion Initiative, for US\$ 1 billion of federal funding. The five projects under this initiative are; Golden Gate Bridge in San Francisco, State Route 520 serving downtown Seattle and communities to its east, Interstate 95 between Miami and Ft. Lauderdale, Interstate 35W serving downtown Minneapolis, and a variable rate parking meter system in Chicago, which replaced New York City after it left the program in 2008.

San Francisco transport authorities began a feasibility study in 2006 to evaluate the introduction of congestion pricing. The charge would be combined with other traffic reduction implementations, allowing money to be raised for public transit improvements and bike and pedestrian enhancements. The initial pricing scenarios were presented in public meetings conducted in December 2008, and the final study results were announced in November 2010, proposing modified alternatives based on the public's feedbacks, and the updated proposal calls for implementing a six-month to one-year trial by 2015.

Urban corridors and toll rings



"Costanera Norte" Freeway, crossing downtown with 100% free flow, Santiago, Chile

Congestion pricing has also been implemented in urban freeways. Between 2004 and 2005, Santiago de Chile implemented the first 100% non-stop urban toll for concessioned freeways passing through a downtown area, charging by the distance traveled. Congestion pricing is used since 2007 during rush hours in order to maintain reasonable speeds within the city's core with the aim of keeping a minimum level of service for their customers.

Norway pioneered with implementation of electronic urban tolling in the main corridors of Norway's three major cities: Bergen (1986), Oslo (1990), and Trondheim (1991). Though initially intended only to raised revenues to finance road infrastructure, the urban toll ring at Oslo created an unintended congestion pricing effect, as traffic decreased around 5%. Also the Trondheim Toll Scheme has congestion pricing effects, as charges vary by time of the day. Norwegian authorities have been considering the use of congestion charges, as the legal basis were approved by Parliament in 2001. As of February 2008 the regulations on road pricing have however not come into force.

Single facilities



FasTrak HOT lanes at 91 Express Lanes, at Orange County, California.

Other recent application of congestion pricing policies in the urban transportation context is to adopt an innovative tolling for a particular limited purpose. The first of this kind of specific schemes allowed users of low or single-occupancy vehicles to use a high-occupancy vehicle lanes (HOV) if they pay a toll. This scheme is known as high-occupancy toll (HOT) lanes, and it has been introduced mainly in the United States and Canada. The first practical implementations was California's private toll 91 Express Lanes, in Orange County in 1995, followed in 1996 by Interstate 15 in San Diego. There has been controversy over this concept, and HOT schemes have been called "Lexus" lanes, as critics see this new pricing scheme as a perk to the rich.

Congestion pricing in the form of variable tolls by time-of-the-day have also been implemented in bridges and tunnels providing access to the central business districts of several major cities. In most cases there was a toll already in existence.



Variable tolls by time-of-the-day were implemented in the Sydney Harbour Bridge on January 2009.

In March 2001, the Port Authority of New York and New Jersey implemented a discount on regular toll fees during off-peak hours for those vehicles paying electronically with an EZ Pass. These discount toll was implemented at several tunnels and bridges connecting New York City and New Jersey, including the George Washington Bridge, Lincoln

Tunnel, and Holland Tunnel, and at some other bridges administrated by PANYNJ. Since March 2008, qualified low-emission automobiles with a fuel economy of at least 45 miles per gallon are eligible to receive a Port Authority Green Pass, which allows for a 50% discount during off-peak hours as compared to the regular full toll.

In January 2009, variable tolls were implemented at Sydney Harbour Bridge, two weeks after upgrading to 100% free-flow electronic toll collection. The highest fees are charged during the morning and afternoon peak periods; a toll 25% lower applies for the shoulder periods; and a toll lower than the previously existing is charged at nights, weekends, and public holidays. This is Australia's first road congestion pricing scheme.

In July 2010 congestion tolls were implemented at the San Francisco-Oakland Bay Bridge. The Bay Bridge congestion pricing scheme charges a US\$6 toll from 5 a.m. to 10 a.m. and 3 p.m. to 7 p.m., Monday through Friday. During weekends cars pay US\$5. The toll remained at the previous toll of US\$4 at all other times on weekdays. According to the Bay Area Toll Authority fewer users are driving during the peak hours and more vehicles are crossing the Bay Bridge before and after the 5-10 a.m. period in which the congestion toll goes into effect. The agency also reported that commute delays in the first six months have dropped by an average of 15 percent compared with 2009. When the congestion tolls were proposed, the agency expected the scheme to produce a 20 to 30 percent drop in commute traffic.

Concerns and criticisms

Both in the academic literature and in practice, the implementation of congestion pricing for urban road travel has raised several concerns, and has been subject of debate and controversy.

Measurement of effects

In a road network congestion can be considered a specific measure of the time delay in a journey or time lost through traffic jams. Delays can be caused by some combination of traffic density, road capacity, and the delaying effects of other road users and traffic management schemes such as traffic lights, junctions, and street works. This can be measured as the extra journey time needed to traverse a congested route when compared to the same route with no such interference. However, this technical definition of congestion as a measurement of delay can get confused and used interchangeably with traffic density in the public mind.

Thus some congestion charging schemes have been claimed a "success" because they have achieved a significant reduction in traffic volumes, even though there was little effect on actual journey times.

To measure the true effects of any traffic management scheme it is normally necessary to establish a baseline, or "do nothing" case, which estimates the effects on the network without any changes other than normal trends and expected local changes. Notably this

was not done for the London Congestion Charging Scheme, which has led to claims that it is not possible to determine the extent of the actual influence of the scheme. Regardless of the scheme's impact, in a retrospective analysis Transport for London estimated there would have already been a significant reduction in traffic as a consequence of parking policies and increased congestion due to traffic management and other interventions that had the effect of reducing highway capacity. In 2006, the last year before the zone was expanded, TfL observed that traffic flows were lower than in any recent year, while network traffic speeds were also lower than in any recent year. Others have noted that changes in fuel pricing and taxation may also have an effect on measurements of any congestion pricing scheme.

Academic debate and concerns

Even the transport economists who advocate congestion pricing have anticipated several practical limitations, concerns and controversial issues regarding the actual implementation of this policy. As summarized by Cervero:

"True social-cost pricing of metropolitan travel has proven to be a theoretical ideal that so far has eluded real-world implementation. The primary obstacle is that except for professors of transportation economics and a cadre of vocal environmentalists, few people are in favor of considerably higher charges for peak-period travel. Middle-class motorists often complain they already pay too much in gasoline taxes and registration fees to drive their cars, and that to pay more during congested periods would add insult to injury. In the United States, few politicians are willing to champion the cause of congestion pricing for fear of reprisal from their constituents. Critics also argue that charging more to drive is elitist policy, pricing the poor off of roads so that the wealthy can move about unencumbered. It is for all these reasons that peak-period pricing remains a pipe dream in the minds of many."

Both Button and Small et al., have identified the following issues:

- The real-world demand functions for urban road travel are more complex than the theoretical functions used in transport economics analysis. Congestion pricing was developed as a first-best solution, based on the assumption that the optimal price of road space equals the marginal cost price if all other goods in the economy are also marginal cost priced. In the real world this is not true, thus, actual implementation of congestion pricing is just a proxy or second-best solution. Based on the economic principles behind congestion pricing, the optimal congestion charge should make up for the difference between the average cost paid by the driver and the marginal cost imposed on other drivers (such as extra delay) and on society as a whole (such as air pollution). The practical challenge of setting optimal link-based tolls is daunting given that neither the demand functions nor the link-specific speed-flow curves can be known precisely. Therefore, transport economists recognize that in practice setting the right price for the congestion charge becomes a trial and error experience.

- Inequality issue: A main concern is the possibility of undesirable distribution repercussions because of the diversity of road users. The use of the tolled road depends on the user's level of income. Where some cannot afford to pay the congestion charge, then this policy is likely to privilege the middle-class and rich. *The users who shift to some less-preferred alternative are also worst off. The less wealthy are the more likely to switch to public transit. Road space rationing, is another strategy generally viewed as more equitable than congestion pricing. However, high-income users can always avoid the travel restrictions by owning a second car and users with relatively inelastic demand (such as a worker who needs to transport tools to a job site) are relatively more impacted.*
- There are difficulties in deciding how to allocate the revenues raised. This is a controversial issue among scholars. The revenues can be used to improve public transport (as is the case in London), or to invest in new road infrastructure (as in Oslo). Some academics make the case that revenues should be disposed as a direct transfer payments to former road users. Congestion pricing is not intended to increase public revenues or to become just another tax, however this is precisely one of the main concerns of road users and taxpayers.

One alternative, aimed at avoiding inequality and revenue allocation issues, is to implement a rationing of peak period travel through mobility rights or revenue-neutral credit-based congestion pricing. This system would be similar to the existing emissions trading of carbon credit. Metropolitan area or city residents, or the taxpayers, would be issued mobility rights or congestion credits, and would have the option of using these for themselves, or trading or selling them to anyone willing to continue traveling by automobile beyond their personal quota. This trading system would allow direct benefits to be accrued by those users shifting to public transportation or by those reducing their peak-hour travel rather than the government.

Public controversy

Experience from the few cities where congestion pricing has been implemented shows that social and political acceptability is key. Public discontent with congestion pricing, or rejection of congestion pricing proposals, is due mainly to the inequality issues, the economic burden on neighboring communities, the effect on retail businesses and the economic activity in general, and the fears that the revenues will become just another tax.

Congestion pricing remains highly controversial with the public both before and after implementation. This has in part been resolved through referendums, such as after the seven-month trial period in Stockholm; however this creates a debate as to where the border line for the referendum should go, since it often is the people living outside the urban area who have to pay the tax, while the external benefit is granted those who live within the area. In Stockholm there was a majority in the referendum within the city border (where the votes counted), but not outside.

Some concerns have also been expressed regarding the effects of cordon area congestion pricing on economic activity and land use, as the benefits are usually evaluated from the

urban transportation perspective only. However, congestion pricing schemes have been used with the main objective of improving urban quality and to preserve historical heritage in the small cities.

The effects of a charge on business have been disputed; reports have shops and businesses being heavily impacted by the cost of the charge, both in terms of lost sales and increased delivery costs in London, while others show that businesses were then supporting the charge six months after implementation. Reports show business activity within the charge zone had been higher in both productivity and profitability and that the charge had a "broadly neutral impact" on the London wide economy, while others claim an average drop in business of 25% following the 2007 extension.

Other criticism has been raised concerning the environmental effects on neighborhoods bordering the congestion zone, with critics claiming that congestion pricing would create "parking lots" and add more traffic and pollution to those neighborhoods, and the imposition of a regressive tax on some commuters. Stockholm's trial of congestion pricing, however, showed a reduction in traffic in areas outside the congestion zone. Other opponents argue that the pricing could become a tax on middle- and lower-class residents, since those citizens would be affected the most financially. The installation of cameras for tracking purposes may also raise civil liberties concerns.

Waterways

Panama Canal Transit Booking System and Transit Slot Auction

The Panama Canal has a limited capacity determined by operational times and cycles of the existing locks and further constrained by the current trend towards larger (close to Panamax-sized) vessels transiting the canal which take more transit time within the locks and navigational channels, and the need for permanent periodical maintenance works due to the aging canal, which forces periodical shutdowns of this waterway. On the other hand, demand is growing due to the rapid growth of international trade. Also many users require a guarantee of certain level of service. Despite the gains which have been made in efficiency, the Panama Canal Authority (ACP) estimates that the canal will reach its maximum sustainable capacity between 2009 and 2012. The long-term solution for the congestion problems is the expansion of the canal through a third set of locks. Work started in 2007 and will finish by 2014. The third set of locks will allow transit of larger, Post-Panamax ships, which have a greater cargo capacity than the current locks are capable of handling.



A Panamax ship in transit through the Miraflores locks, Panama Canal

Considering the high operational costs of the vessels (containerships have daily operational costs of approximately US\$40,000), the long queues that occur during the high season (sometimes up to a seven-day delay), and the high value of some of the cargo transported through the canal, the ACP implemented a congestion pricing scheme to allow a better management of the scarce capacity available and to increase the level of service offered to the shipping companies. The scheme gives users two choices: (1) transit by order of arrival on a first-come first-served basis, as the canal historically has operated; or (2) booked service for a fee—a congestion charge.

The booked service allows two options of fees. The Transit Booking System, available online, allowing customers who do not want to wait in queue to pay an additional 15% over the regular tolls, guaranteeing a specific day for transit and crossing the canal in 18 hours or less. ACP sells 24 of these daily slots up to 365 days in advance. The second choice is high priority transit. Since 2006, ACP has available a 25th slot, sold through the Transit Slot Auction to the highest bidder. The main customers of the Transit Booking System are cruise ships, containerships, vehicle carriers, and non-containerized cargo vessels.

The highest toll for high priority passage paid through the Transit Slot Auction was US\$220,300 charged on a tanker, bypassing a 90-ship queue awaiting for the end of maintenance works on the Gatun locks, thus avoiding a 7-day delay. The normal fee would have been just US\$13,430. The average regular toll is around US\$54,000.

Airports



New York's John F. Kennedy International Airport, one the world's busiest

Many airports are facing extreme congestion, runway capacity being the scarcest resource. Congestion pricing schemes have been proposed to mitigate this problem, including slot auctions, such as with the Panama Canal, but implementation has been piecemeal. The first scheme was started in 1968 when higher landing fees for peak-hour use by aircraft with 25 seats or less at Newark, Kennedy, and LaGuardia airports in New York City. As a result of the higher charges, general aviation activity during peak periods decreased by 30%. These fees were applied until deregulation of the industry, but higher fees for general aviation were kept to discourage this type of operations at New York's busiest airports. In 1988 a higher landing fee for smaller aircraft at Boston's Logan Airport was adopted; with much of the general aviation abandoned Logan for secondary airports. In both US cases the pricing scheme was challenged in court. In the case of Boston, the judge ruled in favor of general aviation users due to lack of alternative airports. In the case of New York, the judge dismissed the case because "the fee was a justified means of relieving congestion".

Congestion pricing has also been implemented for scheduled airline services. The British Airports Authority (BAA) has been a pioneer in implementing congestion pricing for all types of commercial aviation. In 1972 implemented the first peak pricing policy, with surcharges varying depending on the season and time of the day, and by 1976 raised these peak charges. London-Heathrow had seven pricing structures between 1976 and 1984. In

this case it was the US carriers that went to international arbitration in 1988 and won their case.

In 1991, the Athens Airport charged a 25% higher landing fee for those aircraft arriving between 11:00 and 17:00 during the high tourism season during summer. Hong Kong charges an additional flat fee to the basic weight charge. In 1991–92 peak pricing at London's main airports Heathrow, Gatwick and Stansted was implemented; airlines were charged different landing fees for peak and off-peak operations depending on the weight of aircraft. For example, in the case of a Boeing 757, the peak landing fee was about 2.5 times higher than the off-peak fee in all three airports. For a Boeing 747 the differential was even higher, as the old 747 carries a higher noise charge. Though related to runway congestion, the main objective of these peak charges at the major British airports was to raise revenue for investment.

WWT

Chapter-11

Electronic Toll Collection

Electronic toll collection (ETC), an adaptation of military "identification friend or foe" technology, aims to eliminate the delay on toll roads by collecting tolls electronically. It is thus a technological implementation of a road pricing concept. It determines whether the cars passing are enrolled in the program, alerts enforcers for those that are not, and electronically debits the accounts of registered car owners without requiring them to stop.

In 1959, Nobel Economics Prize winner William Vickrey was the first to propose a system of electronic tolling for the Washington metropolitan area. He proposed that each car would be equipped with a transponder. "The transponder's personalised signal would be picked up when the car passed through an intersection, and then relayed to a central computer which would calculate the charge according to the intersection and the time of day and add it to the car's bill"

In the 1960s and 1970's, free flow tolling was tested with fixed transponders at the undersides of the vehicles and readers, which were located under the surface of the highway.

Norway has been the world's pioneer in the widespread implementation of this technology. ETC was first introduced in Bergen, in 1986, operating together with traditional tollbooths. In 1991, Trondheim introduced the world's first use of completely unaided full-speed electronic tolling. Norway now has 25 toll roads operating with electronic fee collection (EFC), as the Norwegian technology is called. In 1995, Portugal became the first country to apply a single, universal system to all tolls in the country, the Via Verde, which can also be used in parking lots and gas stations. The United States is another country with widespread use of ETC in several states, though many U.S. toll roads maintain the option of manual collection.



Many ETC systems use transponders like this one to electronically debit the accounts of registered cars without their stopping



Transponder used in some Chilean expressways

Overview

In some urban settings, automated gates are in use in electronic-toll lanes, with 5 mph (8 km/h) legal limits on speed (and 2 to 3 times that as practical limits even with practice and extreme concentration); in other settings, 20 mph (35 km/h) legal limits are not uncommon. However, in other areas such as the Garden State Parkway in New Jersey, and at various locations in Florida and Texas, cars can travel through electronic lanes at full speed. Illinois' Open Road Tolling program features 274 contiguous miles of barrier-free roadways, where I-PASS or E-ZPass users continue to travel at highway speeds through toll plazas, while cash payers pull off the main roadway to pay at tollbooths. Currently over 80% of Illinois' 1.4 million daily drivers use an I-PASS.

Enforcement is accomplished by a combination of a camera which takes a picture of the car and a radio frequency keyed computer which searches for a drivers window/bumper mounted transponder to verify and collect payment. The system sends a notice and fine to cars that pass through without having an active account or paying a toll.

Factors hindering full-speed electronic collection include significant non-participation, entailing lines in manual lanes and disorderly traffic patterns as the electronic- and manual- collection cars "sort themselves out" into their respective lanes; problems with pursuing toll evaders; need, in at least some current (barrier) systems, to confine vehicles in lanes, while interacting with the collection devices, and the dangers of high-speed collisions with the confinement structures; vehicle hazards to toll employees present in some electronic-collection areas; the fact that in some areas at some times, long lines form even to pass through the electronic-collection lanes; and costs and other issues raised when retrofitting existing toll collection facilities. Unionized toll collectors can also be problematic.

Even if line lengths are the same in electronic lanes as in manual ones, electronic tolls save registered cars time: eliminating the stop at a window or toll machine, between successive cars passing the collection machine, means a fixed-length stretch of their journey past it is traveled at a higher average speed, and in a lower time. This is at least a psychological improvement, even if the length of the lines in automated lanes is sufficient to make the no-stop-to-pay savings insignificant compared to time still lost due waiting in line to pass the toll gate. Toll plazas are typically wider than the rest of the highway; reducing the need for them makes it possible to fit toll roads into tight corridors.

Despite these limitations, however, it is important to recognize that throughput increases if delay at the toll gate is reduced (*i.e.*, if the tollbooth can serve more vehicles per hour). The greater the throughput of any toll lane, the fewer lanes required, so expensive construction can be deferred. Specifically, the toll-collecting authorities have incentives to resist pressure to limit the fraction of electronic lanes in order to limit the length of manual-lane lines. In the short term, the greater the fraction of automated lanes, the lower the cost of operation (once the capital costs of automating are amortized). In the long term, the greater the relative advantage that registering and turning one's vehicle into an electronic-toll one provides, the faster cars will be converted from manual-toll use to

electronic-toll use, and therefore the fewer manual-toll cars will drag down average speed and thus capacity.

In some countries, some toll agencies that use similar technology have set up (or are setting up) reciprocity arrangements, which permit one to drive a vehicle on another operator's tolled road with the tolls incurred charged to the driver's toll-payment account with their home operator. An example is the United States E-ZPass tag, which is accepted on toll roads, bridges and tunnels in fourteen states from Illinois to Maine.



e-TAG lane on the Second Severn Crossing, Wales

In Australia, the e-TAG device is accepted at all tolled motorways. A toll is debited to the customer's account with their tag provider. Some toll road operators – including Sydney's Sydney Harbour Tunnel, Lane Cove Tunnel, and Westlink M7, Melbourne's CityLink and Eastlink, and Brisbane's Gateway Motorway – encourage use of such tags, and apply an additional vehicle matching fee to vehicles without a tag.

A similar device in France, called Liber-T for light vehicles and TIS-PL for HGVs, is accepted on all toll roads in the country.

In Brazil, Sem Parar/Via-Fácil allows customers to pass through approximately 150 toll barriers in the states of São Paulo, Parana, Rio Grande do Sul, and Rio de Janeiro. Sem

Parar/Via-Fácil also allows users to enter and exit some pay parking lots. There is also the Auto Express that is present in the states of Rio de Janeiro, Rio Grande do Sul, Santa Catarina, Parana and Minas Gerais.

In Pakistan, the National Database and Registration Authority is implementing an electronic toll collection system on motorways using RFID.

The European Union has created the EFC-directive, which attempts to standardize European toll collection systems. Systems deployed after 1 January 2007 must support at least one of the following technologies: satellite positioning, mobile communications using the GSM-GPRS standard or 5.8 GHz microwave technology. All toll roads in Ireland must support the eToll tag standard.

Use in urban areas and for congestion pricing



ETC at "Costanera Norte" Freeway, crossing downtown 100% free flow, Santiago, Chile

The most revolutionary application of ETC is in the urban context of congested cities, allowing to charge tolls without vehicles having to slow down. This application made feasible to concession to the private sector the construction and operation of urban freeways, as well as the introduction or improvement of congestion pricing, as a policy to restrict auto travel in downtown areas.

Between 2004 and 2005, Santiago, Chile implemented the world's first 100% full speed electronic tolling with transponders crossing through the city's core (CBD) in a system of

several concessioned urban freeways (Autopista Central and Autopista Costanera Norte). The United Arab Emirates implemented in 2007 a similar road toll collection in Dubai, called Salik. Similar schemes were previously implemented but only on bypass or outer ring urban freeways in several cities around the world: Toronto in 1997 (Highway 407), several roads in Norway (AutoPASS), Melbourne in 2000 (CityLink), and Tel Aviv also in 2000 (Highway 6).

Congestion pricing or urban toll schemes were implemented to enter the downtown area using ETC technology and/or cameras and video recognition technology to get the plate numbers in several cities around the world: urban tolling in Norway's three major cities: Bergen (1986), Oslo (1990), and Trondheim (1991); Singapore in 1998, as an upgrade to the world's first successful congestion pricing scheme implemented with manual control in 1975; Rome in 2001 as an upgrade to the manual zone control system implemented in 1998; London in 2003 and extended in 2007; Stockholm, tested in 2006 and made the charge permanent in 2007; and in Valletta, the capital city of Malta, since May 2007.

In January 2008, Milan began a one-year trial program called Ecopass, a traffic charge program in which low-emission-standard vehicles pay a user fee; alternative fuel vehicles and vehicles using conventional fuels but compliant with the Euro IV emission standard are exempted. The program is in effect until December 31, 2009, and a public consultation will be conducted to decide if the charge becomes permanent.

New York City considered the implementation of a congestion pricing scheme. The proposal was approved by the New York City Council on March 31, 2008, however, on April 7, 2008 the New York State Assembly decided not to vote on the proposal, which means that the plan is stalled.

In 2006, San Francisco transport authorities began a comprehensive study to evaluate the feasibility of introducing congestion pricing. The charge would be combined with other traffic reduction implementations, allowing money to be raised for public transit improvements and bike and pedestrian enhancements. The various pricing scenarios considered were presented in public meetings in December 2008, with final study results expected in 2009.

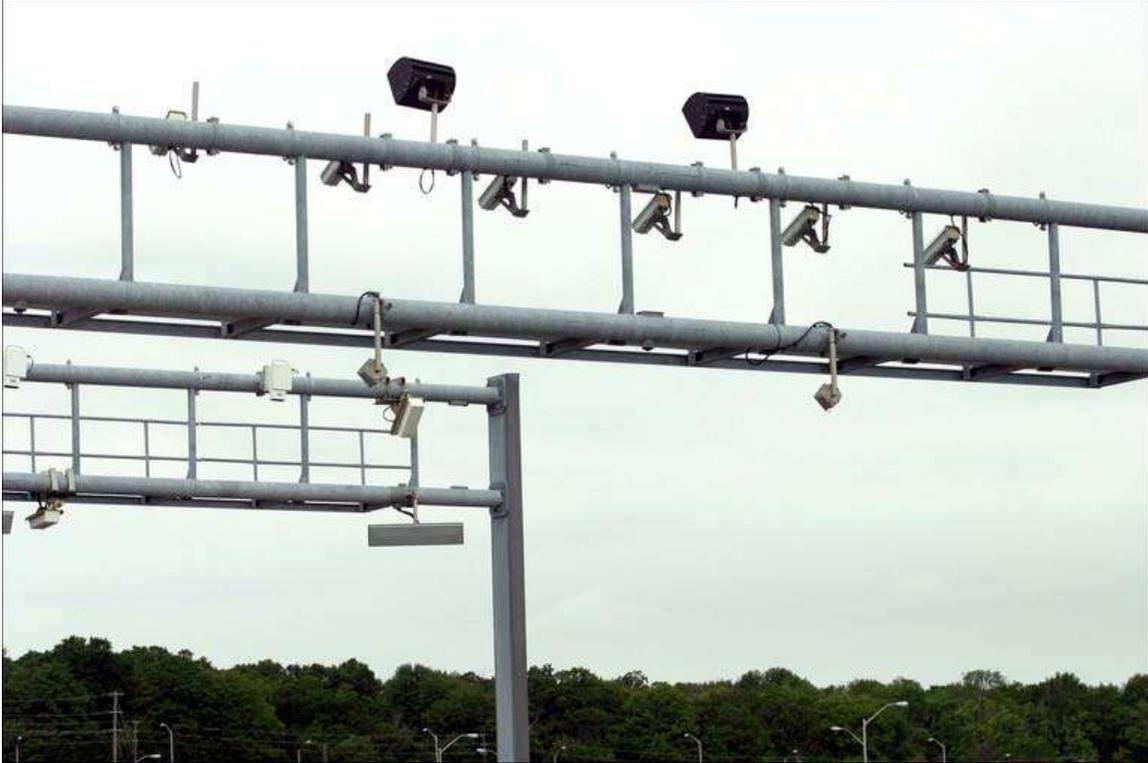
Technologies

Electronic toll collection systems rely on four major components: automated vehicle identification, automated vehicle classification, transaction processing, and violation enforcement.

The four components are somewhat independent, and, in fact, some toll agencies have contracted out functions separately. In some cases, this division of functions has resulted in difficulties. In one notable example, the New Jersey E-ZPass regional consortium's Violation Enforcement contractor did not have access to the Violation Processing contractor's database of customers. This, together with installation problems in the automated vehicle identification system, led to many customers receiving erroneous

violation notices, and a violation system whose net income, after expenses, was negative, as well as customer dissatisfaction.

Automated vehicle identification



Some highways, such as Ontario's Highway 407 use automatic number plate recognition

Automated vehicle identification (AVI) is the process of determining the identity of a vehicle subject to tolls. The majority of toll facilities record the passage of vehicles through a limited number of toll gates. At such facilities, the task is then to identify the vehicle in the gate area.

Some early AVI systems used barcodes affixed to each vehicle, to be read optically at the toll booth. Optical systems proved to have poor reading reliability, especially when faced with inclement weather and dirty vehicles.

Most current AVI systems rely on radio-frequency identification, where an antenna at the toll gate communicates with a transponder on the vehicle via Dedicated Short Range Communications (DSRC). RFID tags have proved to have excellent accuracy, and can be read at highway speeds. The major disadvantage is the cost of equipping each vehicle with a transponder, which can be a major start-up expense, if paid by the toll agency, or a strong customer deterrent, if paid by the customer.

To avoid the need for transponders, some systems, notably the 407 ETR (Electronic Toll Route) near Toronto, use automatic number plate recognition. Here, a system of cameras

captures images of vehicles passing through tolled areas, and the image of the number plate is extracted and used to identify the vehicle. This allows customers to use the facility without any advance interaction with the toll agency. The disadvantage is that fully automatic recognition has a significant error rate, leading to billing errors and the cost of transaction processing (which requires locating and corresponding with the customer) can be significant. Systems that incorporate a manual review stage have much lower error rates, but require a continuing staffing expense.

A few toll facilities cover a very wide area, making fixed toll gates impractical. The most notable of these is a truck tolling system in Germany. This system instead uses Global Positioning System location information to identify when a vehicle is located on a tolled Autobahn. Implementation of this system turned out to be far lengthier and more costly than expected.

Automated vehicle classification

Automated vehicle classification is closely related to automated vehicle identification (AVI). Most toll facilities charge different rates for different types of vehicles, making it necessary to distinguish the vehicles passing through the toll facility.

The simplest method is to store the vehicle class in the customer record, and use the AVI data to look up the vehicle class. This is low-cost, but limits user flexibility, in such cases as the automobile owner who occasionally tows a trailer.

More complex systems use a variety of sensors. Inductive sensors embedded in the road surface can determine the gaps between vehicles, to provide basic information on the presence of a vehicle. Treadles permit counting the number of axles as a vehicle passes over them and, with offset-treadle installations, also detect dual-tire vehicles. Light-curtain laser profilers record the shape of the vehicle, which can help distinguish trucks and trailers.

Transaction processing

Transaction processing deals with maintaining customer accounts, posting toll transactions and customer payments to the accounts, and handling customer inquiries. The transaction processing component of some systems is referred to as a "customer service center". In many respects, the transaction processing function resembles banking, and several toll agencies have contracted out transaction processing to a bank.

Customer accounts may be postpaid, where toll transactions are periodically billed to the customer, or prepaid, where the customer funds a balance in the account which is then depleted as toll transactions occur. The prepaid system is more common, as the small amounts of most tolls makes pursuit of uncollected debts uneconomic. Most postpaid accounts deal with this issue by requiring a security deposit, effectively rendering the account a prepaid one.

Violation enforcement

A violation enforcement system (VES) is useful in reducing unpaid tolls, as an unmanned toll gate otherwise represents a tempting target for toll evasion. Several methods can be used to deter toll violators.

Police patrols at toll gates can be highly effective, as being stopped by the police is quite memorable for the violator. In addition, in most jurisdictions, the legal framework is already in place for punishing toll evasion as a traffic infraction. However, the expense of police patrols makes their use on a continuous basis impractical, such that the probability of being stopped is likely to be low enough as to be an insufficient deterrent.

A physical barrier, such as a gate arm, ensures that all vehicles passing through the toll booth have paid a toll. Violators are identified immediately, as the barrier will not permit the violator to proceed. However, barriers also force authorized customers, which are the vast majority of vehicles passing through, to slow to a near-stop at the toll gate, negating much of the speed and capacity benefits of electronic tolling.

Automatic number plate recognition, while rarely used as the primary vehicle identification method, is more commonly used in violation enforcement. In the VES context, the number of images collected is much smaller than in the AVI context. This makes manual review, with its greater accuracy over fully automated methods, practical. However, many jurisdictions require legislative action to permit this type of enforcement, as the number plate identifies only the vehicle, not its operator, and many traffic enforcement regulations require identifying the operator in order to issue an infraction.

An example of this is the vToll system on the Illinois Tollway, which requires transponder users to enter their license plate information before using the system. If the transponder fails to read, the license plate number is matched to the transponder account, and the regular toll amount is deducted from the account rather than a violation being generated. If the license plate can't be found in the database, then it is processed as a violation. An interesting aspect of Illinois' toll violation system is a 7 day grace period, allowing tollway users to pay missed tolls online with no penalty the 7 days following the missed toll.

Privacy Issues

Electronic toll collection can be a threat to locational privacy, many implementations are implemented in a privacy-insensitive manner. Using E-Cash and other modern cryptographic methods, its possible to design systems that do not know where individuals are, but are still able to enforce fares.

Chapter-12

Electronic Road Pricing



ERP gantry at North Bridge Road

The **Electronic Road Pricing** scheme is an electronic toll collection scheme adopted in Singapore to manage traffic by road pricing, and as a usage-based taxation mechanism to complement the purchase-based Certificate of Entitlement system. The ERP was implemented by the Land Transport Authority in September 1998 to replace the

Singapore Area Licensing Scheme after successfully stress-testing the system with vehicles running at high speed. Singapore was the first city in the world to implement an electronic road toll collection system for purposes of congestion pricing.

The system

The scheme consists of ERP gantries located at all roads linking into Singapore's central business district - areas within the Central Area such as the Downtown Core. They are also located along the expressways and arterial roads with heavy traffic to discourage usage during peak hours. The gantry system is actually a system of sensors on 2 gantries, one in front of the other. Cameras are also attached to the gantries to capture the rear license plate numbers of vehicles. Currently, there are 80 ERP gantries in Singapore. New gantries are implemented where congestion is severe, like expressways and other roads.

A device known as an In-vehicle Unit (IU) is affixed on the lower right corner of the front windscreen within sight of the driver, in which a stored-value card, the CashCard, is inserted for payment of the road usage charges. The second generation IU accepts Contactless NETS CashCard and EZ-Link. The cost of an IU is S\$150. It is mandatory for all Singapore-registered vehicles to be fitted with an IU if they wish to use the priced roads.

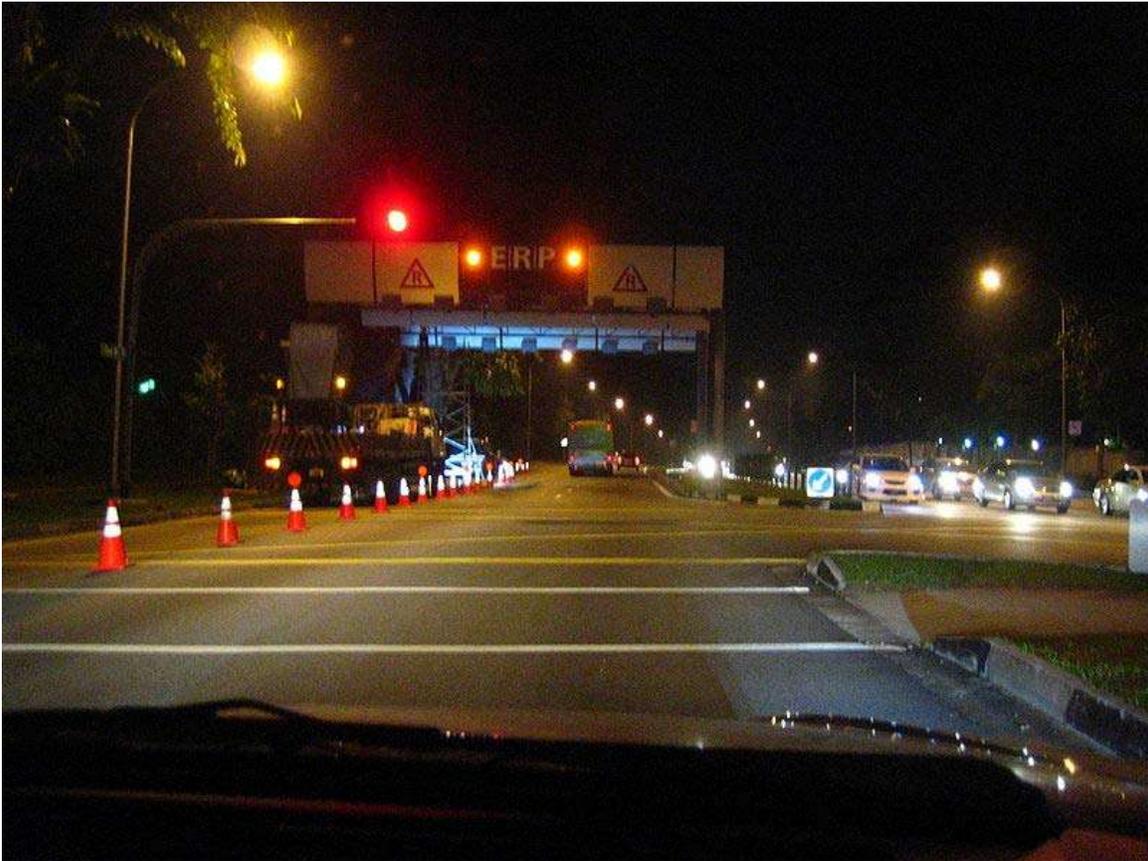
Mitsubishi Heavy Industries Ltd sold the IU technology to Singapore, and the project was spearheaded by a Consortium comprising Philips Singapore Pte Ltd, Mitsubishi Heavy Industries Ltd, Miyoshi Electronic Corporation and CEI Systems and Engineering (now known as CSE Global Ltd) in 1995 through an open tender.

When a vehicle equipped with an IU passes under an ERP gantry, a road usage charge is deducted from the CashCard in the IU. Sensors installed on the gantries communicate with the IU via a dedicated short-range communication system, and the deducted amount is displayed to the driver on an LCD screen of the IU.

The charge passing through a gantry depends on the location and time, the peak hour being the most expensive. Examples include a trip from Woodlands to Raffles Place via Yishun - CTE - CBD will cost about \$15 during peak as the driver will pass about 5 gantries whereas during lunchtime, it cost about S\$2. Foreigners driving foreign-registered cars on priced roads, during the ERP operating hours, could choose to either rent an IU or pay a daily flat fee of S\$5 when leaving Singapore.

If drivers fail to have sufficient value in their CashCard (or EZ-Link), the owner receives a fine by post within 2 weeks. He has to pay the ERP charges plus an administration fee of \$10 within 2 more weeks. On line payment is allowed, and just the vehicle Registration Number is required. Otherwise, a fixed penalty ticket of S\$70 will be issued by registered post to the vehicle owner. This may rise to a fine of \$1000 if not settled within 30 days or 1 month jail time.

Improvements and adaptations



Night works during the installation of a new ERP gantry at Hill View.



A Electronic Parking System at Yishun.

According to a paper presented in the World Roads Conference 2006, the Land Transport Authority has been testing a system based on the Global Positioning System that may eventually replace the current Electronic Road Pricing system. The proposed system overcomes the inflexibility of having physical gantries, which "are not so flexible when it comes to re-locating them".

A lightweight version of this same technology is implemented for use on parking, known as the Electronic Parking System (EPS). It has since been adopted in favour by several carpark operators, superseding the use of autopay tickets or parking coupons. These systems have also typically switched to charging by the minute.

Impact

The ERP system, although understandably unpopular among most road users, has helped to tweak road usage patterns since its implementation. The LTA reported that road traffic decreased by nearly 25,000 vehicles during peak hours, with average road speeds increasing by about 20%. Within the restricted zone itself, traffic has gone down by about 13% during ERP operational hours, with vehicle numbers dropping from 270,000 to 235,000. It has been observed that car-pooling has increased, while the hours of peak vehicular traffic has also gradually eased and spread into off-peak hours, suggesting a

more productive use of road space. In addition, it has been noted that average road speeds for expressways and major roads remained the same, despite rising traffic volumes over the years.

The system has its share of problems. Road users pointed out that the implementation of an ERP gantry along any road simply moves the traffic somewhere else, potentially causing traffic bottlenecks along smaller roads. For example, the ERP gantry along the Central Expressway (CTE) has been said to have caused traffic to increase substantially in north-south trunk roads, such as along the Thomson Road and Serangoon Road corridors. The rising traffic prompted the LTA to add a gantry along Thomson Road, while Upper Serangoon Road's capacity was increased somewhat with the building of a new viaduct. Similarly, the ERP gantry on the East Coast Parkway's west-bound carriageway was said to have led to increased traffic on Geylang Road and Nicoll Highway, where ERP gantries were also placed subsequently. This "chasing after the jam" phenomena has led the general public to question its effectiveness.

While ERP gantries on major roads and expressways have usually been implemented on the carriageway which is city-bound, major traffic congestion on the north-bound carriageway of the CTE has led to the LTA considering its implementation there, a suggestion which has been met with protests by motorists who questioned the need to pay for the time they take to go home. The LTA, sensing the displeasure, attempted to alleviate the situation by widening the road between the Pan Island Expressway (PIE) and Braddell Road in 2003, in response to public feedback which frequently attributed the jams to this congested stretch. In addition, the LTA expressed hopes that the North East MRT Line would help provide an alternative form of transport for north-eastern residents, who usually use the CTE to reach the city. The pending completion of the Kallang-Paya Lebar Expressway in 2008 has also been cited as a solution to the almost nightly jams. There were also suggestions for the CTE to be further widened, including the construction of a viaduct, which the LTA rejected citing its infeasibility. When the jams continued to persist, the LTA finally made an announcement on 30 May 2005 that a new ERP gantry would be set up on the northbound stretch between the PIE and Braddell Road from 1 August 2005.

Latest developments

In an effort to improve the pricing mechanism and to introduce real-time variable pricing, Singapore's Land Transport Authority, together with IBM, ran a pilot from December 2006 to April 2007, with a traffic estimation and prediction tool (TrEPS), which uses historical traffic data and real-time feeds with flow conditions from several sources, in order to predict the levels of congestion up to an hour in advance. By accurately estimating prevailing and emerging traffic conditions, this technology is expected to allow variable pricing, together with improved overall traffic management, including the provision of information in advanced to alert drivers about conditions ahead, and the prices being charged at that moment.

This new system integrates with the various LTA's traffic management existing systems, such as the Green Link Determining System (GLIDE), TrafficScan, Expressway Monitoring Advisory System (EMAS), Junction Electronic Eyes (J-Eyes), and the Electronic Road Pricing system. The pilot results were successful, showing overall prediction results above 85 percent of accuracy. Furthermore, when more data was available, during peak hours, average accuracy raised near or above 90 percent from 10 minutes up to 60 minutes predictions in the future.

The latest expressway in Singapore is Kallang-Paya Lebar Expressway (KPE). It has 16 ERP gantries.

Similar systems in other metropolitan areas

In Toronto, Ontario, Canada an electronic road pricing system is used on Highway 407 to collect tolls electronically and billed to the owner of the car by taking a picture of its license plate.

Despite the local public controversy, the ERP system attracted the attention of transport planners and managers in other metropolitan areas, particularly those in Europe and the United States. For example, the London Congestion Charge was introduced on 17 February 2003, after London officials visited Singapore to study the ERP system, and used it as a reference for the London system. London's charge area was expanded in 2007.

The Stockholm congestion tax is also a congestion pricing system implemented as a tax which is levied on most vehicles entering and exiting central Stockholm, Sweden. The congestion tax was implemented on a permanent basis on August 1, 2007, after a seven-month trial period was held between January 3, 2006 and July 31, 2006.

In 2007, Dubai, at the United Arab Emirates, implemented a corridor congestion pricing scheme called Salik which works on similar principles. Since January 2008, Milan introduced a traffic charge scheme as a one-year trial, called Ecopass, and exempts high emission standard vehicles and some alternate fuel vehicles.

In other cities, similar systems have failed to see the green light for various reasons. For example, Hong Kong first conducted a pilot test on its Electronic Road Pricing system between 1983 and 1985 with positive results. However, public opposition against the move stalled its implementation. New studies conducted in the 1990s and the opposition towards further reclamation of the Victoria Harbour recently has led to advocates of the ERP as a possible alternative for road management.