Lecture notes: *ZDA – 01 – History and introduction to traffic detectors*

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| version history | 1.3 (15.3.2010) added information about magnetometers  1.31 (15.3.2010) removed ILDs specification (placed into 2nd lectures concept |

# Introduction

Lecture notes for course ZDA, taken mainly from Traffic Detector handbook (FHWA, 2006) and internet resources like IEEE Xplore ([ieeexplore.ieee.org](ieeexplore.ieee.org/)), Google news (<news.google.com>), Google books ([books.google.com](http://books.google.com/)) and others. The text itself should be taken as a basic knowledge that students are required to have to get through the first lecture.

## Structure

This (first) part deals with evolution in the field of traffic sensing (it does not deal with the reasons for or the technology details). Intrusive and non intrusive detectors are briefly introduced in the historical framework.

# Evolution of traffic control (at intersections)

In the 1920s, manually operated traffic signals where being replaced by automatic signal control devices. Replacement of policemen at the intersections was not abrupt, at first they were moved to traffic towers from which they can see all traffic and operate signal lights at the intersection. In this period different traffic signals were being used, slowly standardized to green-orange-red (green-amber-red in the USA) signals as we know them now. Early automated traffic control systems were based on fixed time (pretimed) control of traffic flow; there was no data gathered at the intersection and fed to the controller.



Figure 1: Manually controlled traffic, source: Institute of Transportation Engineers

At simple crossings where fairly regular streams of traffic could be expected in each direction it was found that a fixed time could be allocated for each aspect, so that the efficiency of the intersections was as good if not better than when under the control of a police officer.

The success of the early installations and the obvious economies which resulted caused many local authorities to install traffic signals in places where traffic densities were so irregular as to make the intersection quite unsuitable for fixed-time control. To be faced with a red signal and a perfectly clear intersection is, to say the least, extremely irritating to the average motorist (Jackson, 1933), .

The possibility of a system of traffic control in which the signals were actually operated by the vehicles themselves must have suggested itself to most technically minded motorists, who, having failed to beat the signals had ample leisure in which to think about things. The first installation of this sort was put into service in America, where its superiority over fixed-time control was immediately obvious. Larger numbers of vehicles could be handled safely at higher speeds and with much less delay than occurred with other methods. In fact, the new system combined the flexibility of officer control at its best with the economic advantages of automatic signal-light systems without the disadvantages of either. System that is controlled by vehicles that are sensed by means of automatic detectors is called actuated signal control.

## Fixed (pretimed) signal control

At pre-timed traffic signals each signal phase or traffic movement is serviced in a programmed sequence that is repeated throughout the day. Main street traffic receives a fixed amount of green time followed by the amber and red clearance intervals. The same interval timing is then repeated for the minor or side street. The amount of time it takes to service all conflicting traffic movements is referred to as the cycle length. The signal timings and cycle lengths may vary by time of day to reflect changes in traffic volumes and patterns. During off peak times of day cycle lengths are reduced as traffic volumes are much lighter and therefore not as much green time is required to effectively service all movements. With pre-timed signals the pedestrian walk/don’t walk signal indications are automatically displayed in conjunction with the green signal for vehicles.

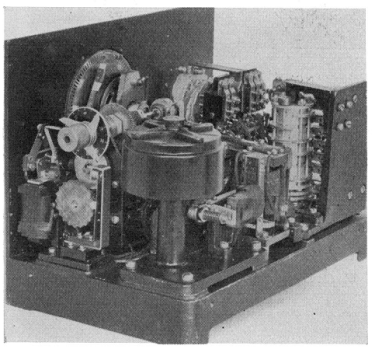
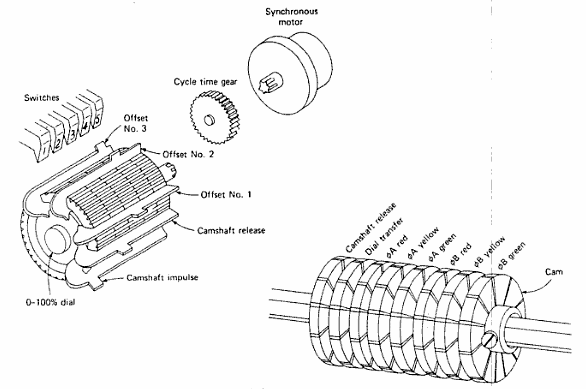


Figure 2: Pretimed controller unit, source: (TRB, 1990), Rear view of synchronous timer with removed cover, source: (Vickery & Leonard, 1932)

Pre-timed signals can provide fairly efficient operation during peak traffic periods, assuming signal timing settings reflect current conditions. However, during off-peak times, particularly at night, traffic on the major roadways are often stopping for no reason because of little or no traffic or pedestrians on the cross streets. With pre-timed signals the only method to avoid this unnecessary delay was to program the signals for flashing operation during the night time hours, generally 12:30 - 6:00 a.m.

## Actuated signal control

Actuated signal control differs from pre-timed in that it requires “actuation” by a vehicle or pedestrian in order for certain phases or traffic movements to be serviced. Actuation is achieved by vehicle detection devices and pedestrian push buttons. Actuated signals consist of two types: semi-actuated and fully-actuated.

Semi-actuated - vehicle detectors are installed on the minor street approaches and push buttons are provided for pedestrians wanting to cross the major roadway. The traffic signals remain green on the major roadway until either a cross street vehicle is detected or a pedestrian pushes the button. When this occurs a “call” is sent to the traffic signal controller and at the appropriate time in the cycle main street green will terminate and time its clearance intervals before the minor street is serviced. If the side street is servicing vehicle demand only, a minimum green of 5-7 seconds is provided which can extend up to a preset maximum provided additional vehicles are being detected. After the last vehicle passes over the detector or the preset maximum green time has been reached, the signals will return to a green state on main street.

Fully-actuated - vehicle detector and pedestrian push buttons are installed on all approaches. All signal phases including left turn arrows have preset minimum and maximum greens and will be serviced on demand only. Pedestrians must activate the push buttons in order to receive the “walk” & “flashing don’t walk” indications. Fully-actuated signals are most efficient at isolated locations where coordination with adjacent signals is not a concern and where the intersecting roadways have similar traffic volumes.

Actuated signal control provides greater efficiency compared to pre-timed signals by servicing cross street traffic and pedestrians only when required. The primary disadvantage with pre-timed signals is avoided as main street traffic is not interrupted unnecessarily. This is particularly beneficial during off peak conditions. The actuated traffic signal control was first used in 1928 (Popular Science, 1930) and is heavily used since then.

## Coordinated traffic control

In 1960’s microelectronic computers have reached level of complexity that allowed them to be used in automated traffic control. The idea of automated traffic control was not new, but at earlier times neither the available hardware nor software was adequate to handle a task of such complexity.

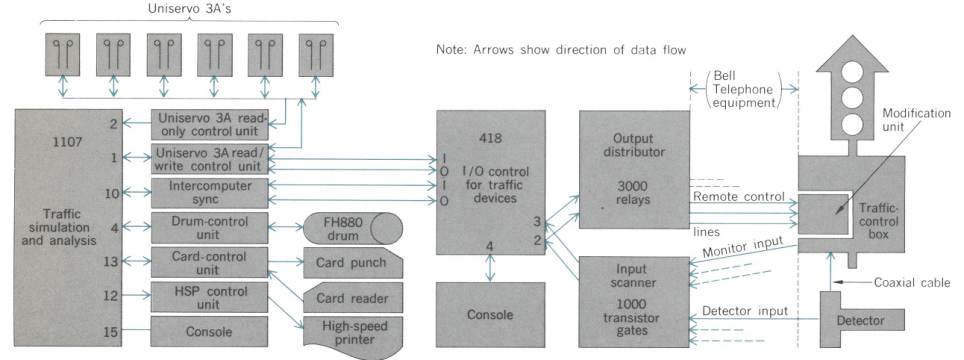


Figure 3: Diagram of the Toronto computer-controlled traffic system, source: .

According to (Friedlander, 1969) one of the first computer driven traffic control systems were successfully tested in Toronto in pilot study (1959 to 1961). In that study, nine traffic signals along 2.8 km of one of Toronto's busiest downtown streets were linked to a Univac 1107 computer. During following operation of the system 32 (59) intersections were controlled. In the metro these modes of traffic control were used.

* Fixed progression: This mode simulates operation of synchronized" or staggered time signals. It permits vehicles to proceed at normal preset speeds to experience minimum stopping in passing a series of signals.
* Volume density mode: At the beginning of a cycle, an assured green phase is provided. Proportional to the number of vehicles arriving during the previous red phase, to allow all delayed vehicles to clear the signal at the intersection. At the expiration of the assured time, the green phase is maintained only as long as the volume of vehicles approaching green is greater than the number of' vehicles stopped for red.
* Variable progression mode: The computer calculates average flow of traffic over a grid in each of two opposing directions: inbound and outbound. Signal offsets may be selected to favor inbound, outbound or average traffic flows.
* Traffic responsive type 1: This type provides local control without coordination between intersections and balances the accumulated vehicle-seconds of delay for traffic that is waiting with volume of traffic proceeding on green. When "advanced green" is provided. This mode permits a variation in advance time proportional to the length of the waiting queue in the left turn lane.
* Traffic responsive type 2: provides coordinated control of a traffic artery or grid. A common cycle length for all intersections is established, based upon maximum average traffic volume in any direction. The speed of response to cycle length change to volume change is completely variable.

# Evolution of traffic flow sensor technology

The essential component of any system of vehicle-operated traffic control is a detector. Some ingenuity has been displayed in this direction, and patents have been taken out for various types of treadle, roller and pneumatic device which operate when a vehicle passes over them.

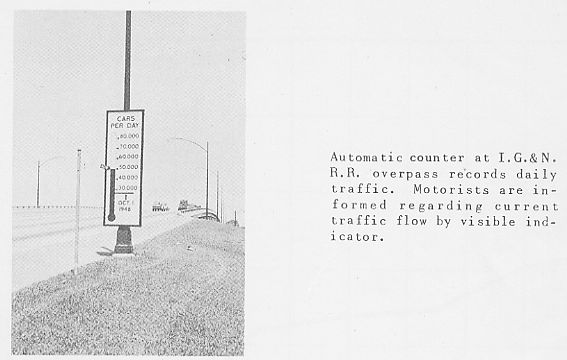


Figure 4: Manual and automatic traffic counting. From left, counting booths, traffic study tower (1945) and automatic vehicle counter (1948), source: Library of Congress

## Early history

Since the beginning of automated intersection control, there has been a pressure to increase its intelligence giving it “eyes and ears” in form of traffic flow sensors. Once such sensors had been developed they could be also used for purposes other than directing traffic. Good example is traffic counting and collection, see Figure 4.

### Sound sensors

First actuated traffic intersection control was installed in 1928 at a Baltimore intersection and utilized sound detector developed by a railway signal engineer Charles Adler, Jr., of Baltimore, MD. This device consisted of a microphone mounted in a small box on a nearby utility pole at an intersection. The driver had to stop and honk. Sonic vibrations made the mechanism shift electrical circuits and change the light. Then the driver had 10 seconds to get through the intersection. It enabled the first semi actuated signal installation to assign right-of-way by means of a vehicle sensor.

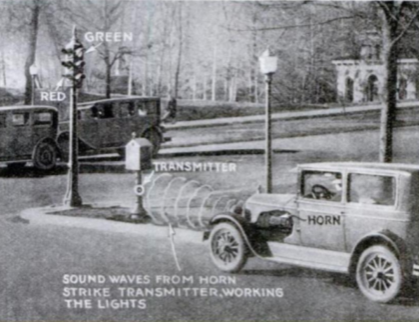


Figure 5: Charles Adler’s car horn actuated detector, source: popular mechanics, signalfan.com

Adler continued his work with sound detectors and in 1931 introduced another sound detector, which employed hollow steel boxes embedded in the intersection approach. These boxes picked up the sound of passing wheels, which was transmitted to microphones.

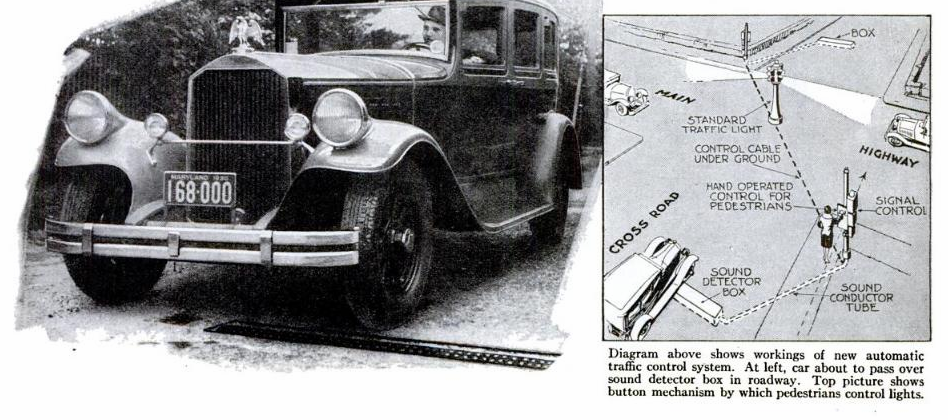


Figure 6: Charles Adler’s noise actuated detector, source: (Popular Science, 1930)

### Pressure sensors

At nearly the same time , an electrical engineer Henry A. Haugh, developed an in-roadway pressure-sensitive sensor (Haugh, 1932), utilizing two metal plates that acted as electrical contacts. The wheel pressure of passing vehicles brought the plates together, caused two metal strips to touch, which sent electrical impulses to the signal controller. The detector was installed in 1930 at a Troy intersection. This pressure-sensitive, treadle type sensor proved more popular than the horn-activated sensor. In fact, this sensor enjoyed widespread use for over 30 years as the primary means of detecting vehicles at actuated signals.

This type of vehicle detector was used in most installations in Europe. It is a contact-closing device arranged to be installed so that it lies in line with the road surface, and it is operated by the weight the vehicle passing over it. It consists of two spring-steel plates as the contacts spaced by rubber strips so that they lie parallel and about 3 mm apart. Connecting wires are soldered the plates, and the whole assembly is then molded into a complete rubber covering or envelope. The sealed contact package is placed in a shallow cast-iron bed and over it is secured a heavy, hard-wearing, rubber tread approximately 1,5 cm thick, which protects it from damage. The completed detectors are all approximately 28 cm wide and 5 cm deep, but are of various lengths .

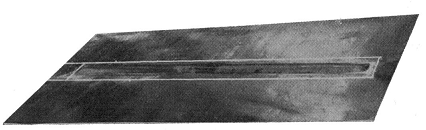


Figure 7: Pressure-sensitive, treadle type sensor embedded into pavement, source:

The construction of the pad is obvious from Figure 8, the essential point is that the passage of a vehicle forces two plates into contact with each other for a time inversely proportional to the speed of the vehicle. This type of detector had shown great advantage of being completely weatherproof in that the contact plates are inside a thick rubber bag. Furthermore, as there are no moving links, it cannot be damaged by the heaviest of vehicles.

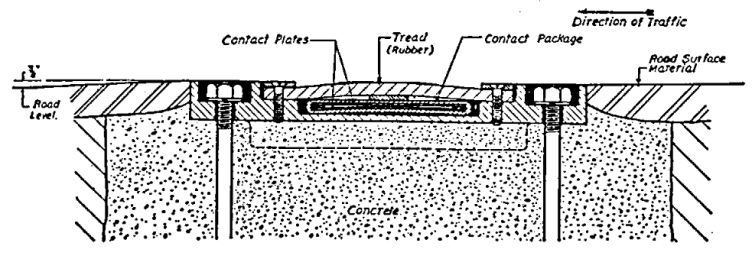


Figure 8: Diagram of a road pad, source: (Jackson, 1933)

### Pneumatic sensors

According to , mechanical problems with the contact-plate sensor led to the introduction of the electro-pneumatic sensor. Although this device found some application, it was costly to install, capable of only passage (motion) detection, and its (axle) counting accuracy was limited by the generation of air pressure waves and capsule contact bounce.

The electro-pneumatic detector consists of a rubber mat in the road through which pass two longitudinal air channels. There is no equipment which can be damaged by the traffic. A contact box is located under the pavement and is connected to the road mat by piping. The contacts can be inspected under actual service conditions without obstruction to the traffic or danger to the observer.

The top of the mat projects slightly above the road level to present a good striking face, so that it is not possible for vehicles to jump over without registering. As the channels in the mat are depressed, so miniature bellows in the contact box become inflated. There are two pairs of bellows, one associated with each channel mounted at right angles to one another so that only one can be operated at a time.

Vehicles approaching the intersection inflate the contacting bellows for periods proportional to the times o occupancy of the mat and inversely proportional to the speeds. Impulses indicating the speeds of the vehicle are thus transmitted to the controller. Vehicles leaving the intersection and passing over the mat in the wrong direction inflate the "interlocking" bellows, which prevent operation of the "contacting" bellows so that no pulse is transmitted.

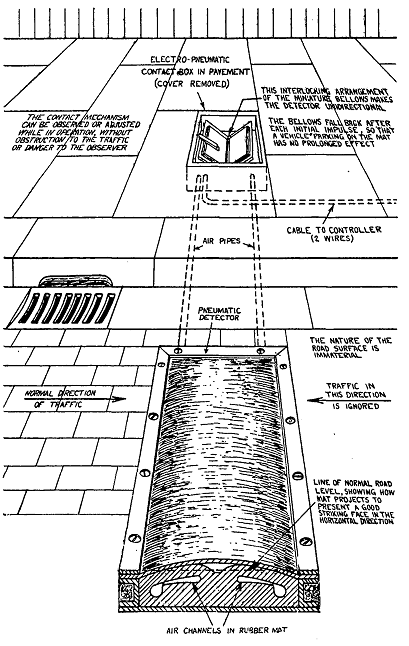


Figure 9: Explanatory diagram of electro-pneumatic detector, source:

Other pneumatic means of measuring traffic flow has been a pneumatic tube placed across the road. The tube is associated with a mechanical diaphragm and a closing electrical contact to provide an input for a counter

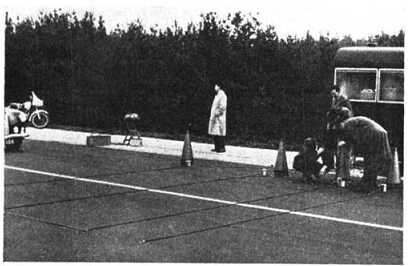


Figure 10: Pneumatic tubes for the measurement of vehicle speeds by timing over a fixed base length, source:

### Optical sensors

In the same time (1931) a photo electric detector had been tested by Westinghouse Research Laboratories. Detector was developed to obtain working information on traffic control systems and field experience on phototubes illuminated at a distance from light sources. Detectors were experimental and the equipment is not available in commercial form.

In principle a light beam is focused on a phototube across the minor street, so that when a car intercepts the beam the traffic light would be flashed green on the minor street.

Figure 11: Function of photo electric detector and its installation, source:

This system, however suffer from, the disadvantage of requiring amplification of the resulting impulse.

### Magnetic sensors

Ferrous materials in vehicles carry along with them the equivalent of a localized distortion of the earth's magnetic field. Magnetic-flux changes in sensing coils in or near the roadway provide a ready method of measuring vehicle movement past them. It utilizes a special transformer buried beneath the road surface, the disturbance of the magnetic field caused by the passage of a metal body over it, induces currents n the secondary coil. The system suffers from the same disadvantage as photo electric detector - the resulting impulse has to be amplified.

The first magnetic detectors were constructed in the late 1920s using sensing element coils and cores having 1 to 3 ft3 dimensions which operated into sensitive galvanometer contacting devices. These proved costly to manufacture and install and were subject to considerable maintenance due to the sensitive galvanometers which were required. The advent of vacuum tubes of reasonable reliability in the early 1930s opened up the use of magnetic vehicular detectors since electronic circuitry - could be substituted for the galvanometer while still maintaining the desirable feature of an inert sensing coil in or near the roadway (Barker, 1970).

Apart from sensor technology (acoustic, electric, mechanical) for road traffic detection there has been deployment of magnetic detectors in defense industry, particularly in submarine detection . This detector, called anti-submarine indicator loop, relies on the production of an induced current in a stationery loop of wire when a magnet (in this case, a submarine) moves overhead.

The loop cable was typically 5000 yards long and 200 plus 200 yards wide. The centre leg joined the top cable in a waterproof junction box. In the lower junction box, the centre leg and the two outer legs were joined to the 'tail' to shore.

The technology was developed by the British Royal Navy at HMS Osprey (Portland Naval Base) starting back in 1915. The first recorded use of indicator loops was at Scapa Flow, in the Orkney Islands at the northern tip of Scotland. Here the Royal Navy stationed its Grand Fleet and on 28th October 1918, German U-Boat UB-116 was destroyed in the controlled minefield at Hoxa Sound with the loss of 34 crew.

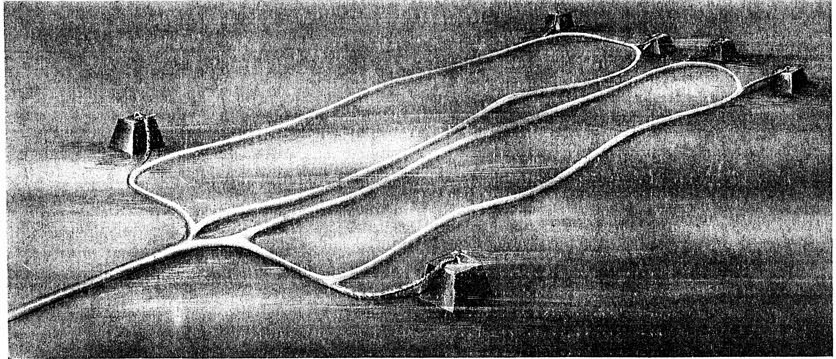


Figure 11: Multi-turn loop after installation, source:

Magnetic detectors and inductive loops were in the course of following years also introduced to road traffic control.

## Recent history

As Mace says, various other forms of vehicle detector have appeared and matured in the years following the introduction of actuated traffic control. These have been predominantly devices utilizing some form of loop of electrical cable buried in the road surface and associated with an electronic device for detecting the change in magnetic field occasioned by the passage or presence of vehicles over the loop. Ultrasonic devices have been used for detecting vehicles, as have detectors depending on infrared waves. A device has also been investigated that uses the Hall Effect in a semiconductor to detect the change in magnetic field due to the presence of a vehicle.

However the inductive loop detectors (ILD’s) were the most prominent form of vehicle-presence detectors for use in road-traffic control, in that time period (from 1960’s), as they are very reliable and their sensitive region is better defined by the loop than most devices depending on free waves or standing waves.

### Inductive loops detectors

Inductive Loop Detector technology has been in use for the detection of vehicles since the early 1960’s. The first loop detector designs were based on solid-state analog technology using discrete components including transistors, diodes, etc .

By the middle 1970’s, advances in solid-state technology made it economically possible to develop loop detectors utilizing digital design techniques. With the introduction of digital loop detectors it became possible to reliably detect small motorcycles. In addition to the detection of small motorcycles the overall reliability of vehicle detection significantly improved.

The first digital loop detectors were built using individual digital components such as gates, flip- flops, etc. The next advancement in digital loop detectors took place in the late 1970’s when MOS-LSI (metal oxide semiconductor – large scale integration) technology became economically feasible. The MOS-LSI technology made it possible to significantly reduce the component count in each detector; thus improving reliability and reducing manufacturing costs. During the 1980’s microprocessor technology advanced rapidly and loop detector designs began utilizing the available industry standard microprocessors. This technology brought, accurate gathering and processing of “inductive loop signature” information. Each vehicle having a different shape, which passes over the inductive loop embedded in the pavement, produces a different “signature”.

The digital loop detectors manufactured during the 1980’s and the first half of the 1990’s could all be considered as “hardware-based” designs. That is the detector settings (e.g. sensitivity, loop frequency, etc.) were configured using front panel mounted switches. These “hardware-based” designs had limited flexibility for programming since any function not included, as a standard feature, in the detector could not be implemented without changes to the hardware. In addition to the limitation in flexibility, which was needed for accommodating special requirements in some systems, there was no feedback information available to the user. Therefore was during the middle 1990’s introduced the “programmable software based” digital loop detector technology.

The loop detector has several operational features which make it well suited to traffic detection application. First, the detection zone is well defined by the dimension of the pavement loop, and can be made as large as required, by connecting a number of individual loops together. Second, detection is not affected by ambient light levels, heavy rain or fog, or wind and ambient noise levels. Also, these detectors can provide either a permanent presence indication, which is a continuous signal whenever any vehicle is in the detection zone, or pulse presence information, which is a signal whenever a vehicle enters the detection zone. Finally, as a factor which is important in city modernization and beautification planning, the detection element of the loop detector is concealed in the pavement. Loop detectors, as opposed to optical, sonic, radar detectors, do not require the use of either supporting poles or cross arms to mount the sensor element.

## Conclusion

In retrospect, it seems unfortunate that the treadle detector, which utilized the most obvious and most easily detected property of vehicles—their weight—could not be economically produced. Snow plows could lift the plate from the roadway, resulting in costly repairs. There was also the expense of reinstalling the detector after roadway resurfacing. These problems led to the search for traffic flow sensors based on more subtle properties such as:

* Sound (acoustic sensors).
* Opacity (optical and infrared sensors and video image processors).
* Geomagnetism (magnetic sensors, magnetometers).
* Reflection of transmitted energy (infrared laser radar, ultrasonic sensors, and microwave radar sensors).
* Electromagnetic induction (inductive-loop detectors).
* Vibration (triboelectric, seismic, and inertia-switch sensors).

Not all of these concepts have been commercially exploited. Today, the inductive-loop detector is, by far, the most widely used sensor in modern traffic control systems. Magnetometers, magnetic sensors, video image processors, microwave and laser radar sensors, ultrasonic, acoustic, and passive infrared sensors are also produced commercially and used for various traffic management applications. The optical sensor has found use for detecting priority and over height vehicles.

Use of appropriate sensor installation techniques and specification of suitable materials and products minimizes maintenance and other life-cycle costs. However, even with superior design and installation, proper and regularly scheduled sensor maintenance is critical to effective and prolonged operation of traffic signal control systems and freeway surveillance and management systems.

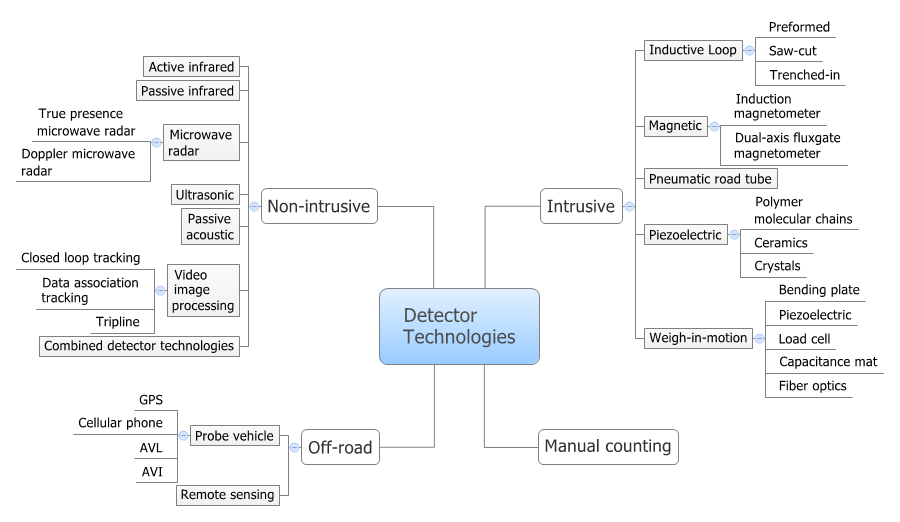


Figure 12: Classification of detector technologies, source:

# Classification of traffic flow sensor

A traffic flow sensor is a device that indicates the presence or passage of vehicles and provides data or information that supports traffic management applications such as signal control, freeway mainline and ramp control, incident detection, and gathering of vehicle volume and classification data.

* *In-roadway (aka Intrusive)* sensors are embedded in the pavement or the sub grade, or they are taped or otherwise attached to the surface of the roadway.
* *Over-roadway (aka nonintrusive)* sensors are mounted above the roadway or alongside it.

## In-roadway traffic flow sensors

One of the main types of in-roadway sensors is the inductive loop detector, which consists of loops of wire embedded into saw cuts in the road pavement. Other in-roadway sensors include magnetic detectors and magnetometers, which can be placed underneath a roadway or bridge. A magnetic detector senses changes in the Earth’s magnetic field caused by passage of a nearby vehicle that contains ferrous material. A magnetometer measures the difference in the Earth’s magnetic field caused by the passage or presence of a vehicle. Its ability to function as a presence sensor enables it to detect stopped vehicles.



Figure 13: Different designs of inductive loop, source: public domain

Although the installation and maintenance of in-roadway sensors such as inductive-loop and magnetic field sensors can disrupt traffic and pose a safety risk to the installers, a requirement for in-roadway sensors continues for several reasons. These include aesthetic considerations that dictate their use for traffic management when over-roadway sensors are excluded from consideration, axle counting and weigh-in-motion applications requiring sensors (such as pneumatic tubes, fiber-optic, bending plates, piezoelectric, pressure sensitive resistance, load cells, and capacitance mats) under or on the road surface, cost and safety issues associated with mounting over- roadway sensors where existing structures are not available, and policy that prohibits over-roadway sensors in certain locations.

Newly installed inductive-loop detectors may also provide more accurate data than over- roadway sensors when they are coupled with advanced electronics units available from several manufacturers.

## Over-roadway traffic flow sensors

The mounting location must provide an unobstructed view of vehicles for optimum performance. In general, when sensors are installed over the lane of traffic they are intended to monitor, their view and hence their data collection ability is not occluded by other vehicles that are present within the viewing area of the sensor. Over-roadway sensors that are mounted on the side of a roadway and view multiple lanes of traffic at angles perpendicular to or at an oblique angle to the flow direction may experience two types of data anomalies. The first occurs when tall vehicles block the sensor’s view of distant lanes. The occlusion may potentially cause an undercount or false average speed measurement. The second anomaly occurs when tall vehicles project their image into adjacent lanes. When a sensor is sensitive to this effect, it will over count and again may report a misleading average speed. Thus, sensor type, mounting height and location, vehicle mix, road configuration, and sensor viewing angles must be analyzed with respect to the intended application. Some over-roadway sensors may be more susceptible to these anomalies than others.



Figure 14: Video detection system, source:

Most over-roadway sensors have relay or solid state outputs that are compatible with systems that accept inductive loop data. Some also have serial outputs that directly provide multilane traffic volume, occupancy, speed, vehicle length, and classification that are not ordinarily available from inductive-loop detectors.

An emerging potential source of traffic flow data is from cellular telephone companies who monitor the transmitting status of telephones that are engaged in conversations.

# Current sensor technologies - comparison

Table 1 compares the strengths and weaknesses of current sensor technologies with respect to installation, parameters measured, and performance in inclement weather, variable lighting, and changeable traffic flow. Most over-roadway sensors are compact and mounted above or to the side of the roadway, making installation and maintenance relatively easy. Some sensor installation and maintenance applications may require the closing of the roadway to normal traffic to ensure the safety of the installer and motorist. All the sensors listed operate under day and night conditions.

Several technologies are capable of supporting multiple lane, multiple detection zone applications with one or a limited number of units. These devices may be cost effective when larger numbers of detection zones are needed to implement the traffic management strategy.

A low to moderate communication bandwidth is indicated if only data and control commands are transmitted between the sensor, controller, and traffic management center. Larger bandwidth is required if real-time video imagery is transmitted at 30 frames/second (s). The required transmission rate increases when large numbers of sensors, roadside information devices such as changeable message signs and highway advisory radio, signal timing plans, and traveler information databases are used to implement traffic management strategies.

| Tab. : Strengths and weaknesses of commercially available sensor technologies (FHWA, 2006). | | |
| --- | --- | --- |
| Technology | Strengths | Weaknesses |
| Inductive loops | * Flexible design to satisfy large variety of applications. * Mature, well understood technology. * Large experience base. * Provides basic traffic parameters (e.g., volume, presence, occupancy, speed, headway, and gap). * Insensitive to inclement weather such as rain, fog, and snow. * Provides best accuracy for count data as compared with other commonly used techniques. * Common standard for obtaining accurate occupancy measurements. * High frequency excitation models provide classification data. | * Installation requires pavement cut. * Improper installation decreases pavement life. * Installation and maintenance require lane closure. * Wire loops subject to stresses of traffic and temperature. * Multiple loops usually required to monitor a location. * Detection accuracy may decrease when design requires detection of a large variety of vehicle classes. |
| Magnetometer (two-axis fluxgate magnetometer) | * Less susceptible than loops to stresses of traffic. * Insensitive to inclement weather such as snow, rain, and fog. * Some models transmit data over wireless radio frequency (RF) link. | * Installation requires pavement cut. * Improper installation decreases pavement life. * Installation and maintenance require lane closure. * Models with small detection zones require multiple units for full lane detection. |
| Magnetic (induction or search coil magnetometer) | * Can be used where loops are not feasible (e.g., bridge decks). * Some models are installed under roadway without need for pavement cuts. However, boring under roadway is required. * Insensitive to inclement weather such as snow, rain, and fog. * Less susceptible than loops to stresses of traffic. | * Installation requires pavement cut or boring under roadway. * Cannot detect stopped vehicles unless special sensor layouts and signal processing software are used. |
| Microwave radar | * Typically insensitive to inclement weather at the relatively short ranges encountered in traffic management applications. * Direct measurement of speed. * Multiple lane operation available. | * Continuous wave (CW) Doppler sensors cannot detect stopped vehicles. |
| Active infrared (laser radar) | * Transmits multiple beams for accurate measurement of vehicle position, speed, and class. * Multiple lane operation available. | * Operation may be affected by fog when visibility is less than ≈20 feet (ft) (6 m) or blowing snow is present. * Installation and maintenance, including periodic lens cleaning, require lane closure. |
| Passive infrared | * Multizone passive sensors measure speed. | * Passive sensor may have reduced vehicle sensitivity in heavy rain, snow and dense fog. * Some models not recommended for presence detection. |
| Ultrasonic | * Multiple lane operation available. * Capable of over height vehicle detection. * Large Japanese experience base. | * Environmental conditions such as temperature change and extreme air turbulence can affect performance. * Temperature compensation is built into some models. * Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds. |
| Acoustic | * Passive detection. * Insensitive to precipitation. * Multiple lane operation available in some models. | * Cold temperatures may affect vehicle count accuracy. * Specific models are not recommended with slow-moving vehicles in stop-and-go traffic. |
| Video image processor | * Monitors multiple lanes and multiple detection zones/lane. * Easy to add and modify detection zones. * Rich array of data available. * Provides wide-area detection when information gathered at one camera location can be linked to another. | * Installation and maintenance, including periodic lens cleaning, require lane closure when camera is mounted over roadway (lane closure may not be required when camera is mounted at side of roadway) * Performance affected by inclement weather such as fog, rain, and snow; vehicle shadows; vehicle projection into adjacent lanes; occlusion; day-to-night transition; vehicle/road contrast; and water, salt grime, icicles, and cobwebs on camera lens. * Reliable nighttime signal actuation requires street lighting * Requires 30- to 50-ft (9- to 15-m) camera mounting height (in a side-mounting configuration) for optimum presence detection and speed measurement. * Some models susceptible to camera motion caused by strong winds or vibration of camera mounting structure. * Generally cost effective when many detection zones within the camera field of view or specialized data are required. |

# Summary

The text above about history of traffic detection contains just incomplete compilation of useful resources. Students are encouraged to find out more about development timeline of individual detector technologies as well as about their functionality.

## Question topics related to this lecture notes

* General history of traffic control
* Types of intersection traffic control systems, explanation, function
* Evolution of detector technology (what, by whom, where, how and when)
* Classification and comparison of traffic detector technology

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