Lecture notes: *ZDA – 03 – Over-roadway (nonintrusive) detectors*

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# Introduction

Lecture notes for course ZDA, taken mainly from Traffic Detector handbook(FHWA, 2006) and internet resources like IEEE Xplore ([ieeexplore.ieee.org](file:///Z:\PB\vyuka\ZDA\lecture_notes\01_history\ieeexplore.ieee.org\)), Google news ([news.google.com](file:///Z:\PB\vyuka\ZDA\lecture_notes\01_history\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 (third) part deals with description of intrusive detectors. For each detector type, this text shall cover architecture, construction, implementation and maintenance of the sensor as well functionality and use within traffic control systems.

# Detectors – overview

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.

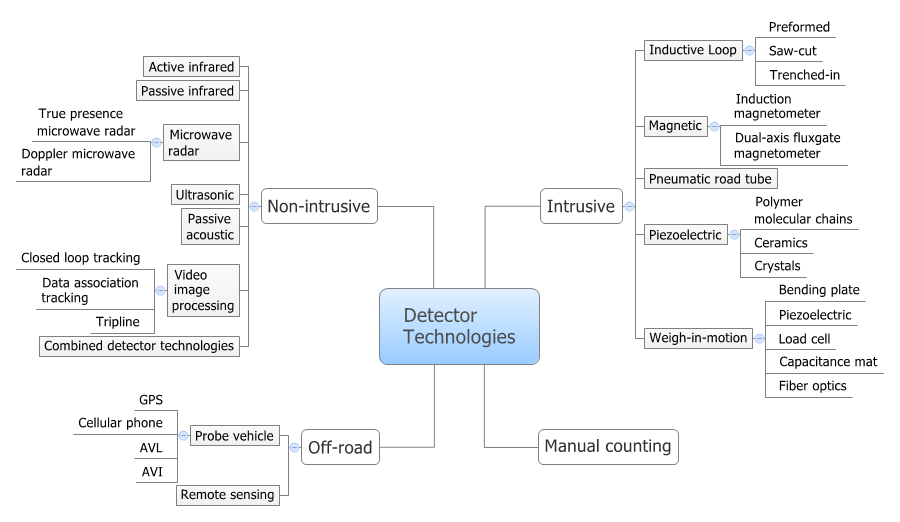


Figure 1: Classification of detector technologies, source:

Use of appropriate sensor installation techniques and specification of suitable materials and products will minimize 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.

## Over-roadway traffic flow sensors

An over-roadway sensor is one that is mounted above the surface of the roadway either

* Above the roadway itself or
* Alongside the roadway, offset from the nearest traffic lane by some distance.

Examples of over-roadway sensors are video image processors (i.e., machine vision based sensors) that utilize cameras mounted on poles adjacent to the roadway, on structures that span the roadway, or on traffic signal mast arms over the roadway; microwave radar sensors mounted adjacent to the roadway or over the lanes to be monitored; ultrasonic, passive infrared, and laser radar sensors normally mounted over the lanes to be monitored (some passive infrared models can be mounted adjacent to the roadway); and passive acoustic sensors mounted adjacent to the roadway. Some emerging applications for wide area surveillance envision over-roadway sensors mounted on tall buildings and radio towers near the roadway and on aerial platforms. Recent evaluations have shown that modern over-roadway sensors produce data that meet the requirements of many current freeway and surface street applications (Klein and Kelley, 1996; Kranig J., E. Minge, and C. Jones, 1997; MnDOT, 2002; Middleton, D. and R. Parker, 2002). Similar to in-roadway sensors, the over-roadway sensors provide vehicle count, presence, and passage. However, many also provide vehicle speed, vehicle classification, and multiple-lane, multiple-detection zone coverage. Some over-roadway sensors incorporate more than one technology. Figure 1 displays sensors that combine passive infrared with ultrasound and Doppler microwave radar. The passive infrared-ultrasound combination provides enhanced accuracy for presence and queue detection, 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.

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.

## Sensors covered in this lecture notes

Following part of these notes is divided to separate chapters to cover these sensor technologies:

* Microwave radar,
* Passive infrared,
* Active infrared (and LIDAR),
* Ultrasonic
* Passive acoustic
* Video image processing
* Combined technologies

Structure of information about each detector technology includes: short description, principle of operation, design requirements, hardware configuration and operation.

# Location of non intrusive sensors

In over roadway 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.

# Comparison, field tests

**Errors**

Field tests at the Texas Transportation Institute freeway test bed included inductive loop detectors for baseline data, Accuwave (microwave), Nestor TrafficVision (VIDS), RTMS, SmartSonic (acoustic), and PIR-1 (passive infrared). Count accuracy of the ILDs was within 1 to 2 percent of manual counts based upon repetitive review of videotapes. With the exception of the RTMS, test detectors exhibited count errors as high as 20 to 50 percent in short one-hour intervals. The worst count error observed with the RTMS was 15 percent for only one hour, with the remainder falling within 10 percent (6).

**Count and Speed Accuracy**

In a sample of 70 carefully selected individual vehicle comparisons, 53 percent of the RTMS speeds were within 0 or 1 mph of the laser speeds. Fourteen percent differed by 2 mph, while 3 percent differed by 3 mph. None were different by more than 3 mph. In this same data set, aggregating data into samples of 10 and comparing means between RTMS and a laser speed detector revealed differences that were usually less than 1 percent and never more than 2 percent.

The 3M microloop was the only one of the three test detectors unaffected by rain; it also demonstrated the best speed accuracy of the three systems being tested. The 3M microloop performed better both on the bridge and on SH 6 when two probes were used in each lane compared to one probe in each lane.

The VideoTrak and the SAS-1 demonstrated significantly worse speed performance during wet weather; the VideoTrak was more erratic, and the SAS-1 speeds increased by 10 mph compared to those measured during dry conditions.

The VideoTrak performance at night was unacceptable, due at least in part to no street lighting. The plotted histograms suggest that the 3M and the SAS-1 predict speed within 8 mph and 11 mph, respectively, 95 percent of the time.

**Ease of Setup and Calibration**

The VideoTrak was by far the most difficult system to set up and calibrate. Some public agencies will find this difficulty a serious impediment to using this detector. Both the 3M microloop/Canoga system and the SmarTek SAS-1 had reasonably user-friendly interfaces and provided the needed functionality for setup, calibration, and downloading of data (except that the SAS-1 needs a speed calibration algorithm added).

**Installation Cost**

The installation cost of the SAS-1 was significantly less than that for either of the other two systems. Its cost is attractive on a per-lane basis, since it can monitor up to five lanes.

For the two-lane SH 6 site, the 3M microloop system cost $9,900, the VideoTrak system cost $13,200, and the SAS-1 system cost $4,000.

**Other Considerations**

It is critically important that each detector be set up properly to optimize performance. The novice installer could easily think that a detector is set up properly but get poor performance due to the improper setup. This problem is common with new technologies, especially if they are complex.

In real-world operations, an agency must filter out anomalous speed data to avoid meaningless alarms being generated. All of the test detectors occasionally generated anomalous speeds, including the RTMS.

During loss of power, the VideoTrak required being physically reset for it to resume operation.

The shallow installation depth recommended by 3M is a constraint to its use in many locations unless it can be integrated into the initial construction process.

A diamond-shaped warning sign near the SAS-1 acoustic detector initially caused the detector to double-count vehicles, apparently due to sounds reflected from the sign. Repositioning the detector solved the problem.

Based on these findings related to count and speed accuracy, cost, and ease of setup and calibration, the authors believe that the 3M microloops and the SAS-1 are acceptable for monitoring traffic under low to moderate free-flow traffic.

Limited testing indicated good performance of the 3M microloops under stop-and-go traffic.

Installing the 3M microloop system at greater depths since horizontal boring at the manufacturer’s recommended depth of 21 inches (plus or minus 3 inches) could cause roadway damage.

## Questions

For all intrusive sensors:

Function of the sensor? – exact function, measured quantity, transformation, theory, function under different conditions

Installation and placement of sensor into a pavement? – exact procedure, where it is placed, difficultness, part of the roadway taken, cost

Configuration of a sensor? – according to telematic application

Parameters of a sensor? – exact proven values

Advantages and disadvantages, best practices with the use of the sensor? - examples

For all intrusive sensors make comparison? – which one suits well and where (use examples)

