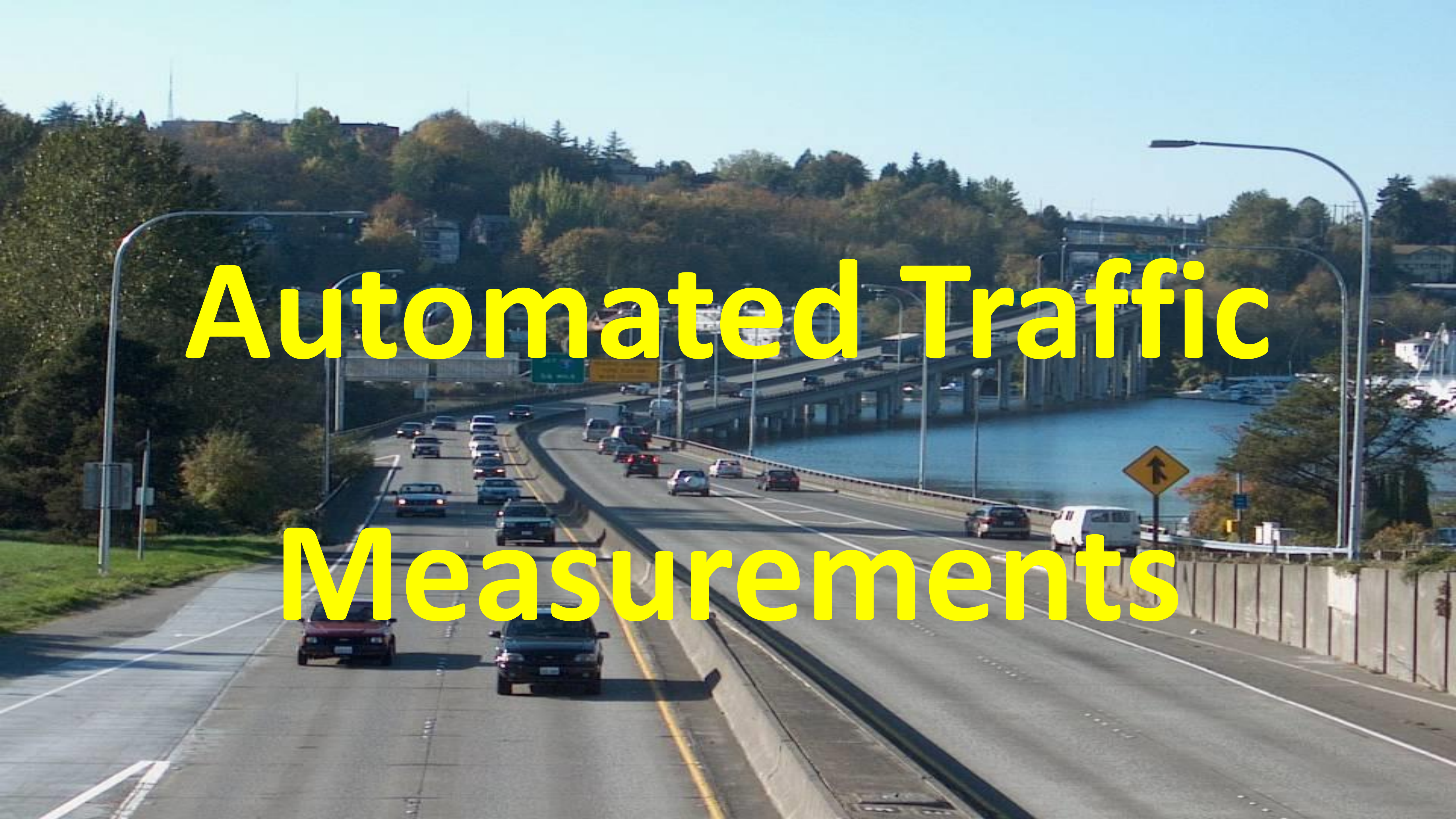
Automated Traffic Measurements



Outline

Introduction

- Volume Count
- Vehicle Classification
- Travel Time
- Occupancy
- Delay

Detector Technology

1. **In-Situ Technology**

   1.1. Intrusive

   - pneumatic tubes
   - IDL
   - Piezoelectric sensors
   - Magnetometers
   - Weigh-In-Motion

   1.2. Non-Intrusive

   - *Video image detection*
   - Infrared Sensors(P/A)
   - Passive Acoustic
   - *Microwave – Doppler*
   - *Ultrasonic*

2 **In Vehicle Technology**

- GPS-based FCD
- Cellular phones
- RFID

3 **Special Applications**

- Probe Vehicle
- Vehicle Signature

Conclusions

Introduction

1. Intelligent Transportation System (ITS) can not survive without surveillance
2. Intelligence requires information; information requires data, which is generated by surveillance.
3. What types of data does an ITS need ?

    i. Volume count
    ii. Vehicle classification
    iii. Travel time
    iv. Speed
    v. Occupancy
    vi. Delay

Volume Count

- Manual Count Method
- Automatic Count Method

Vehicle Classification Counts

- Vehicle classification counts are used in establishing structural and geometric design

Integration of Vehicle count and Classification

Vehicle Occupancy

- The measure of occupancy is a function of speed and length of individual vehicle

Travel Time

- Real-time travel time prediction as part of their advanced traveler information systems (ATIS).

- Travel time data can be obtained through license plate matching technique and probe vehicles.

Delay

- "The additional travel time experienced by a driver, passenger, or pedestrian." is known as delay

Road traffic Detector Technology

- Traffic detector information technologies divided into two main groups

In-Situ Technology

- Information collected via in-situ detectors

In-Vehicle Technology.

- Information from mobile technologies that are located within vehicles themselves

- In-vehicle technologies proved to be successful because of satellite-based technologies

2.1 In-Situ Technology

In-Situ Technologies

- In-situ traffic detector technologies divided into two categories:

1. ***Intrusive technologies***
2. ***non-intrusive technologies***

- *Intrusive* technologies that are physically mounted at, or below, the road surface.

- *non-intrusive* technologies are mounted at, or above the road surface, and their installation causes little or no disruption to traffic.

Source: IMAGINE- Collection Methods for Additional Data

Intrusive technologies

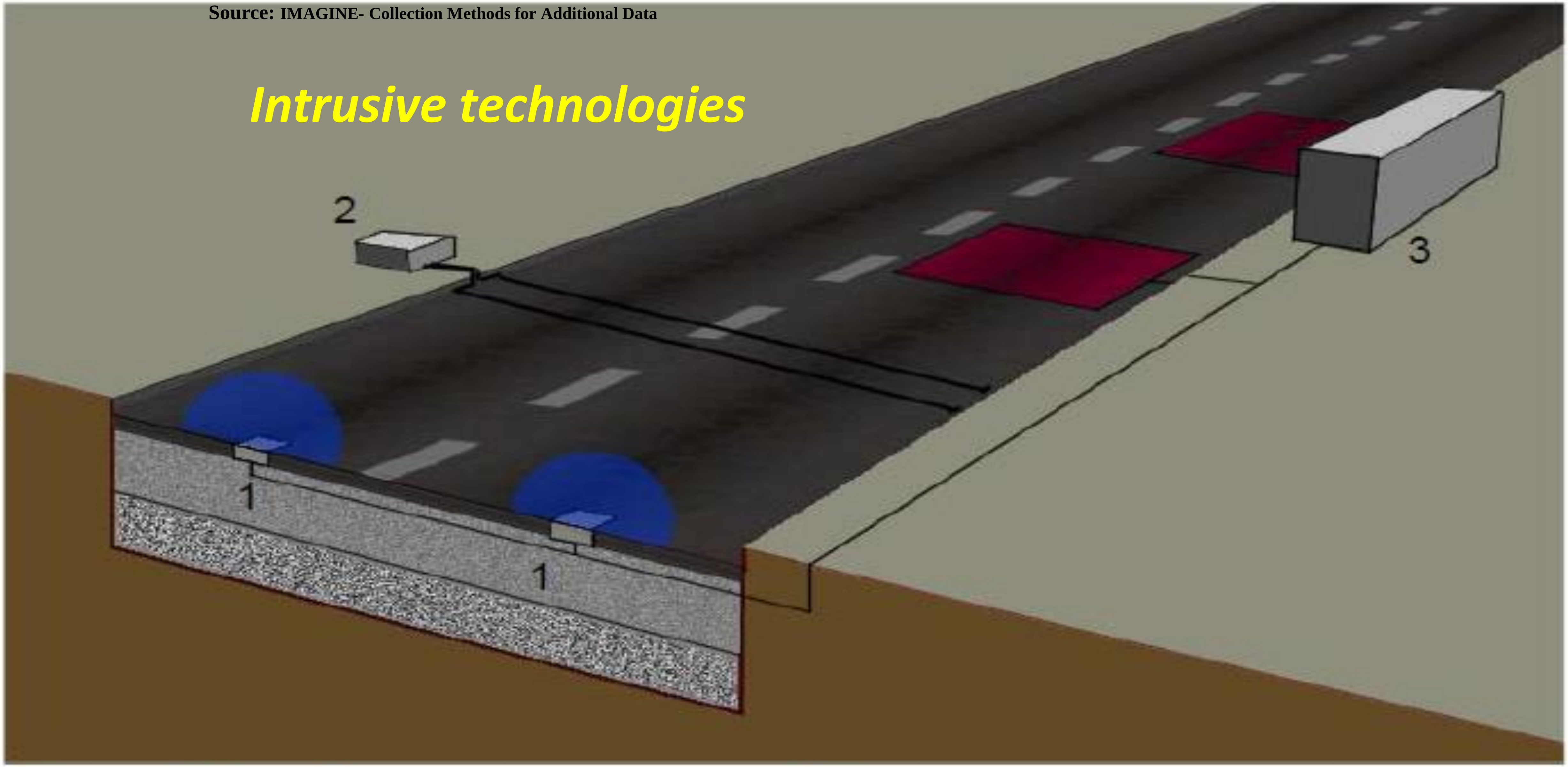


Figure 1 Typical intrusive detector configurations

1. Embedded magnetometers
2. Pneumatic tube detectors
3. Inductive detector loops (IDLs)

2.1.1.1 **Pneumatic Tube Detectors**

1. Pneumatic road tube sensors send a burst of air pressure along a rubber tube when a vehicles tire passes over the tube
2. Used for short-term traffic counting, vehicle classification by axle count and spacing.

Advantages

1. Cheap and self-contained, the easiest to deploy of all intrusive systems, recognized technology with acceptable accuracy

Disadvantages

1. Some units are not counted or classify vehicles and tube installations are not durable, the life of tubes are less than one month only
2. The tube detectors are not suitable for high flow and high speed roads.
3. Two wheelers not counted.

Source: IMAGINE- Collection Methods for Additional Data

2.1.1.2 ***Inductive Detector Loop (IDL)***

- Oscillating electrical signal is applied to the loop.

- The metal content of a moving vehicle chassis changes the electrical properties of the circuit.

- A single loop system collects flow and occupancy .

- Two-loop systems collect flow, occupancy, vehicle length, and speed

Advantages

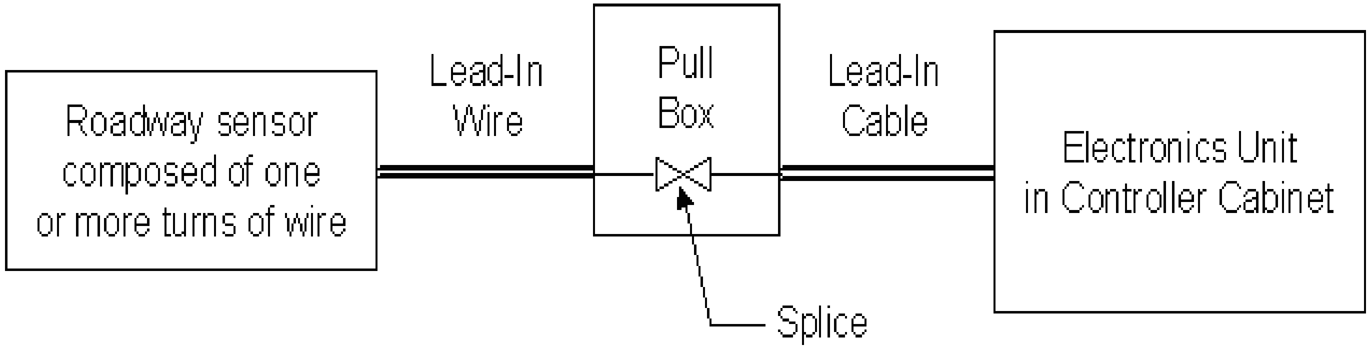
- It is very cheap technology. Almost every dynamic traffic control system in the world uses IDL data

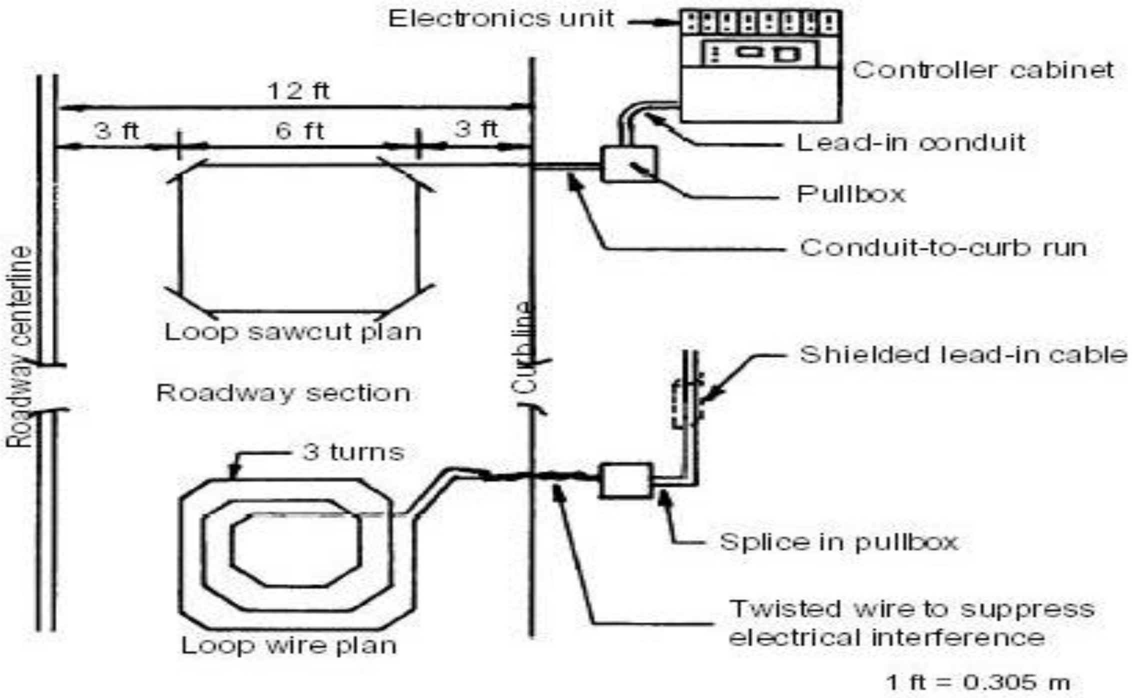
Disadvantages

- Loops may be damaged by utility and street maintenance activities or penetration of water
- IDLs with low sensitivity, fail to detect vehicles with speed below a certain threshold
- Miscount vehicles with complex or unusual chassis configurations, or vehicles with low metal content
- Not suitable for metallic bridge decks

- The primary components of an inductive loop are:

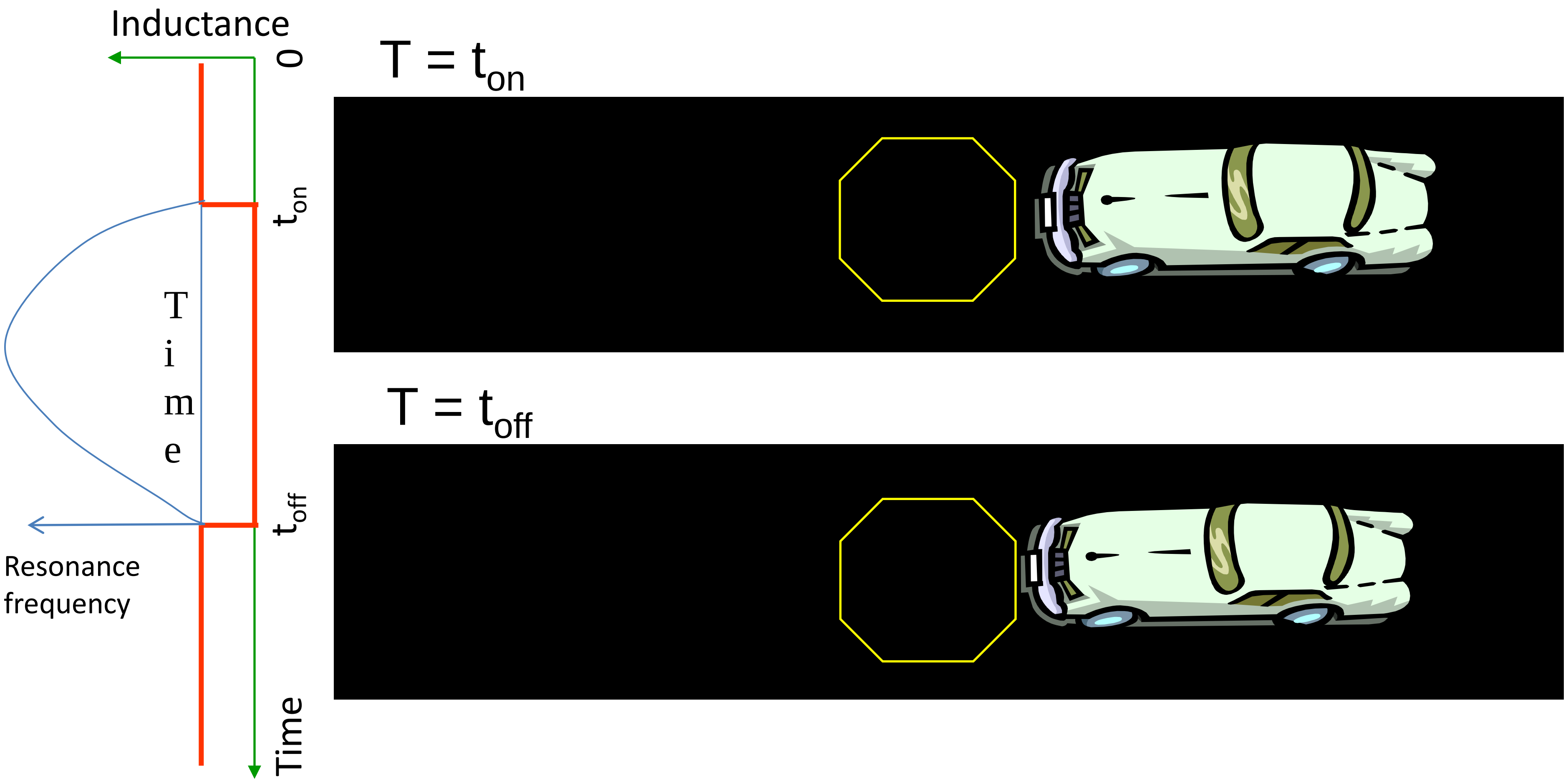
- A detector oscillator , lead-in cable and Insulated loop- (hexagon-shaped wires buried in the road)





Single Loop Detector

- Single loops measure:
  - Occupancy (O): % of time loop is occupied per interval
  - Volume (N): vehicles per interval



Dual Loop Detectors

T = t_2 T = t_1

- Dual loop measurements

$$Speed = \frac{l_{dist}}{t_2 - t_1} \qquad L_{vehicle} = \frac{Speed(ot_2 + ot_1)}{2}$$

ot_i = on-time for loop detector i

Measured vehicle lengths are used to classify vehicles into different categories, such as long and short.

Example

If the vehicle entering the freeway in loop M at time 8:32:22:00 am and leaving loop N at time 8:32:22:15 am, the distance between two loops are 3.66 m find the speed of the vehicle. Also find the length of the vehicle if time occupancy for M – loop is 0.25sec and 0.29 for N-loop.

Solution

$$Speed = \frac{l_{dist}}{t_2 - t_1} = \frac{3.66}{(8{:}33{:}22.15 - 8{:}32{:}22.00)/100} = 24.4m/\text{sec}$$

How to measure speed from a Single Loop?

- The most common method is based on the relationship between fundamental traffic variables.
- By converting of loop occupancy into density.
- The variables include inductive loop length, average vehicle length, occupancy, and traffic volume. The equation is shown below.

$$s = \frac{EVL}{t_o}$$

s = Spot speed (m/sec)

EVL = effective vehicle length (m)

t_o = occupancy time (s)

EVL ~ vehicle length + detector length

Source: Detector Technology Evaluation

Example

- The length of vehicle is 4 m and the length of loop detector zone is 1.83 m. The time occupancy in the loop is 0.3 sec, find the speed of the vehicle?

Solution

$$s = \frac{EVL}{t_o}$$

$$s = \frac{4 + 1.83}{0.3}$$

$$s = 19.4 \text{ m/sec}$$

Space mean speed measurement

$$s = \frac{N}{T \times O \times g}$$

s = Space mean speed (m/sec)

N = number of vehicles in the observation interval

T = observation interval (s)

O = Lane occupancy

g = speed correction factor
(based upon assumed vehicle length, detector configuration, and traffic conditions)

Most of the algorithms followed as
(40.9/ **6.55**) for average vehicle length **6.55m**

Source: Detector Technology Evaluation

Example

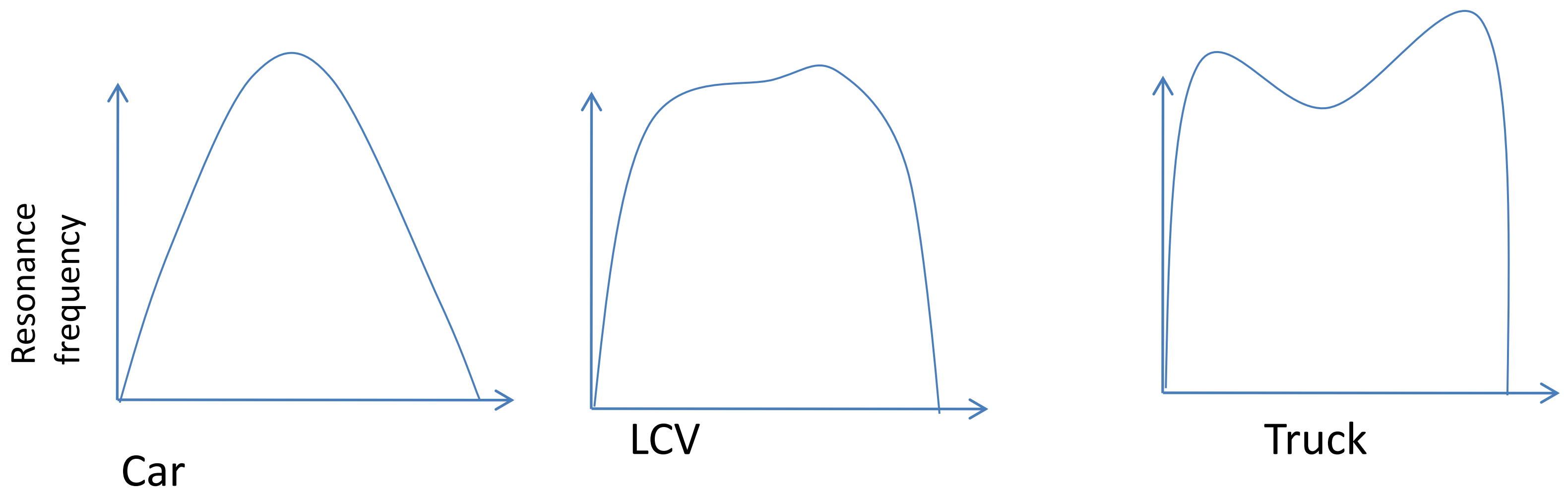
- In freeway 2500 vehicles are observed during 300 sec interval. The lane occupancy is 75 percentage and the average length of vehicle observed as 6.55 m. Find the space mean speed on the freeway section?

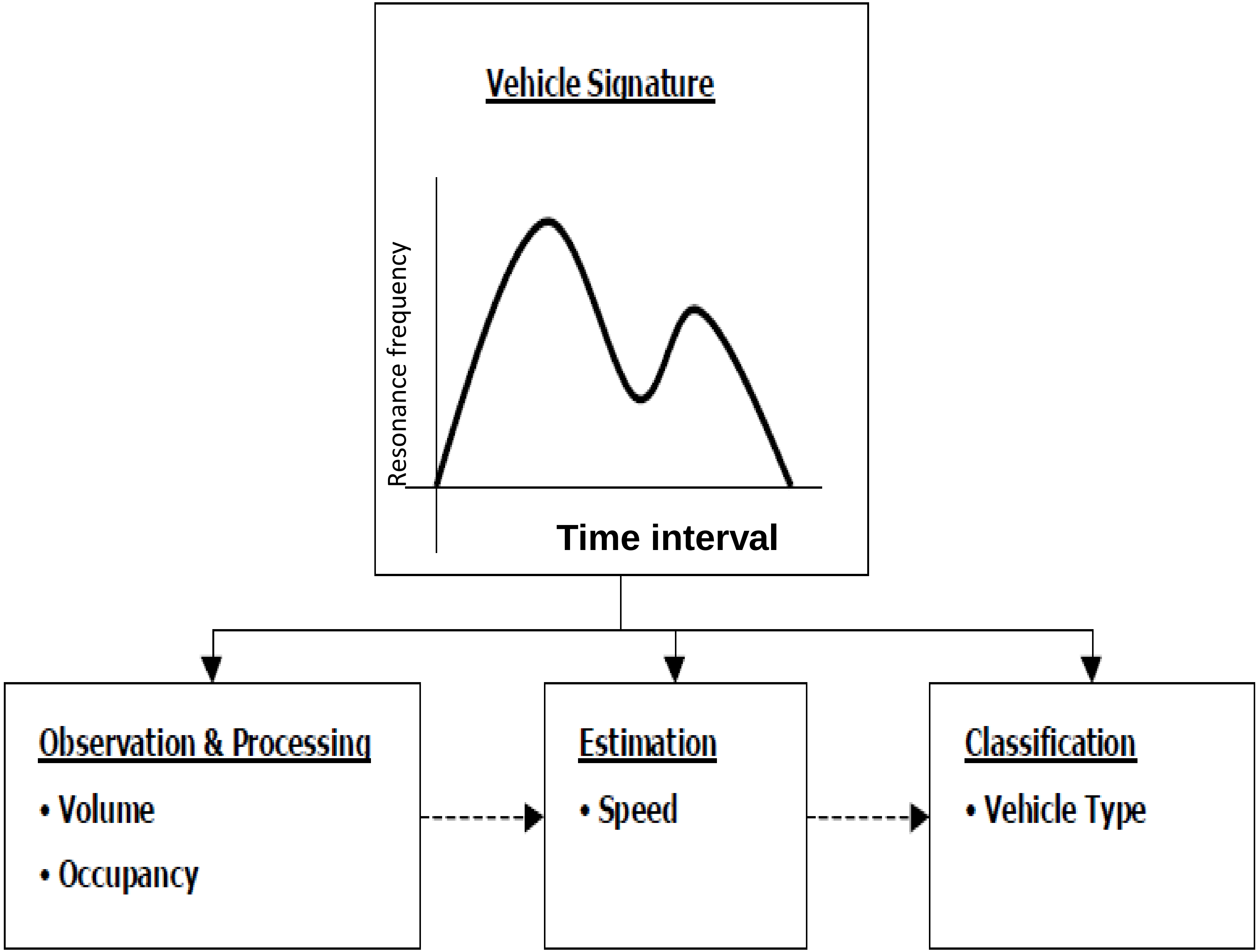
$$s = \frac{N}{T \times O \times g}$$

$$s = \frac{2500 \times 6.55}{300 \times .75 \times (40.9)} = 6.405 Kmph$$

Vehicle Signature

- Inductance changes in ILD are computed by change in frequency
- The waveform obtained by plotting the sampled inductance changes is referred to as the vehicle inductive waveform or inductance signature
- Inductance signature depends on vehicle length, speed, and metal surface of the vehicle.





Vehicle Signature
Resonance frequency
Time interval
Observation & Processing
• Volume
• Occupancy
Estimation
• Speed
Classification
• Vehicle Type

Cont…

- Volume and occupancy are directly derived from processing raw vehicle signatures

- Vehicle length is obtained based on vehicle speed

- vehicle classification is to be measured by combining vehicle length with existing vehicle signature

- A series of vehicle signature acquired by IDL located at upstream and downstream of a freeway.

Piezoelectric Sensors

- A piezoelectric is a specially processed material capable of converting kinetic energy to electrical energy.

- Polymer materials exhibit these properties, these are ideal suitable for construction of piezoelectric sensors

- Piezoelectric materials generate a voltage when subjected to mechanical impact or vibration.

- The measured voltage is proportional to the force or weight of the vehicle.

- Piezoelectric sensors are classify the vehicles by axle count and spacing and to measure **vehicle weight and speed**

- Main advantage of piezoelectric sensors is collect the information on the tire passing over the sensor, rather than on the passing of a vehicle.

- The drawbacks of this technique is disruption of traffic for installation and repair and difficult to install in poor road surfaces

Source: FHWA vehicle detection manual

Magnetometers/Passive magnetic systems

- Magnetometers monitor the fluctuations in the relative strength of the Earth’s magnetic field, when vehicles are moving.

- Two types of magnetic field sensors are available.

1. **The magnetic detector**, more properly referred to as an induction or search coil magnetometer.

- It detects the vehicle signature by measuring the change in the magnetic lines of flux caused by the change in field values produced by a moving ferrous metal vehicle.

2. **Two-axis fluxgate magnetometer**, detects changes in the vertical and horizontal components of the Earth s magnetic field produced by a ferrous metal vehicle.

Advantages

- It can be used where the loops are not possible to install
- Insensitive to whether condition

Disadvantages

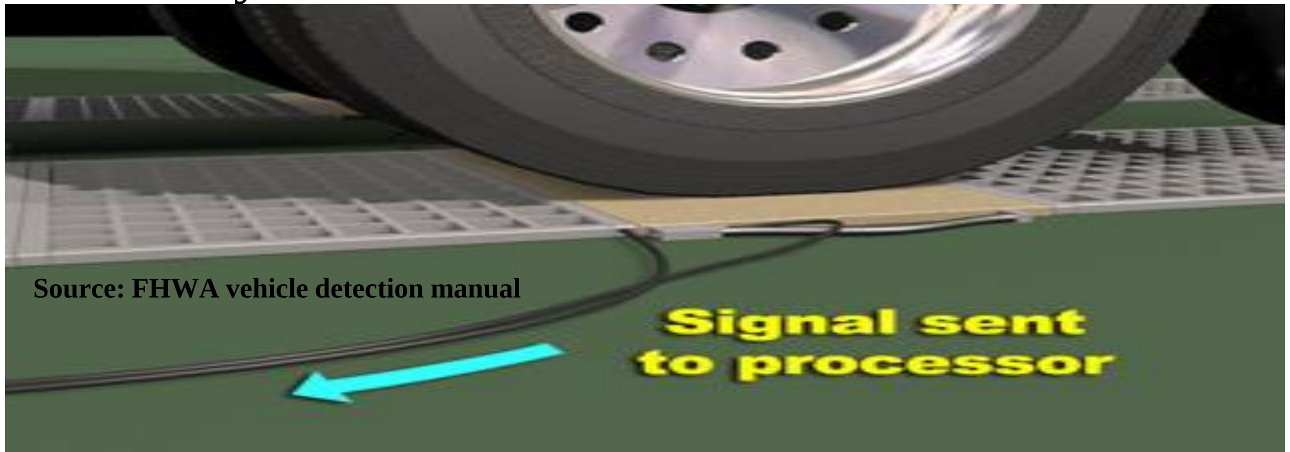
- Installation of magnetic sensors requires pavement cut or tunneling under the roadway and thus requires lane closure during installation.

- Can’t detect the stopped vehicle

Weigh-In-Motion (WIM) systems

- Two types of WIM systems are available i.e. **Bending plate and Piezoelectric**

- Bending plate WIM systems utilize plates with strain gauges bonded to the underside.
- volume, speed, lane occupancy, axle distances, and axle weights.
- As a vehicle passes over the bending plate, the system records the strain measured by the strain gauges and calculates the dynamic load.



Source: FHWA vehicle detection manual

Advantages

- WIM systems can be used for traffic data collection as well as for weight enforcement purposes.

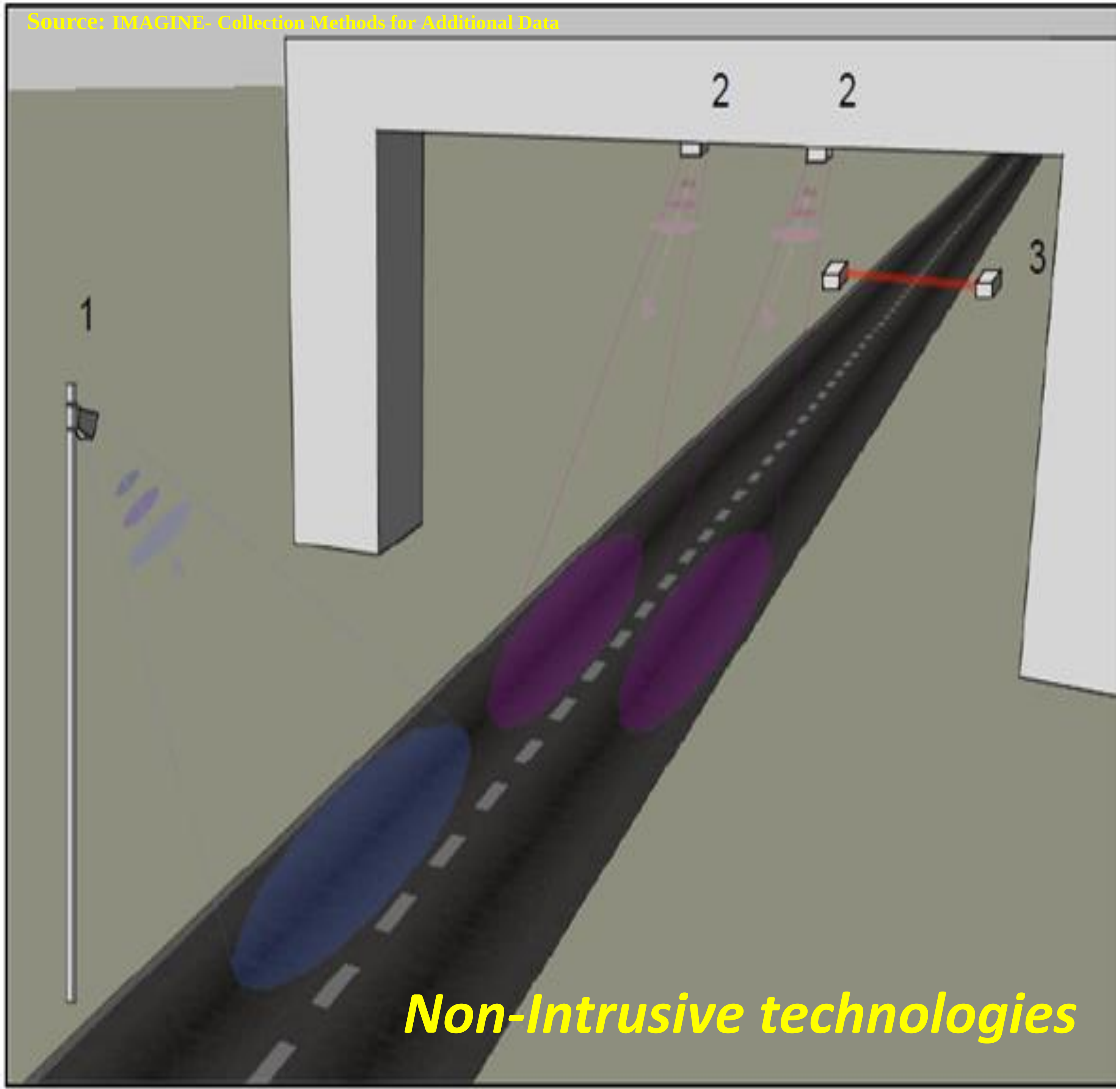
- WIM systems do not require complete replacement of the sensor.

Disadvantages

- Bending plate WIM systems are not as accurate as load cell systems and are considerably more expensive than piezoelectric systems

- Tracking of most standard passenger cars is difficult because of similar axle and weight configurations

2.2.2 Non-Intrusive Technologies


Source: IMAGINE- Collection Methods for Additional Data
1
2
2
3
Non-Intrusive technologies

Video image detection (VID)

- The traffic parameters are collected by frame-by-frame analysis of video images captured by roadside cameras.

Strengths

- Installation and repair need not interrupt traffic
- Single camera and processor can service multiple lanes
- Rich data available

Weaknesses

- Large vehicles project their image into adjacent lanes, leading to false detection
- Shadows, reflections from wet pavement, day or night transitions, headlight beams, relative color of vehicles and background, camera vibration can affect detection

Video Image Processor

- It consists of one or more cameras,
- A microprocessor computer - digitizing and processing the imagery
- Software for interpreting the images and converting them into traffic flow data.
- In image processing analyze black and white imagery, examine the variation of gray levels in groups of pixels contained in the video frames.

Cont….

- Some algorithms are designed to remove gray level variations in the image background caused by weather conditions, shadows, and daytime or nighttime

- Objects are identified as automobiles, trucks, motorcycles, and bicycles.

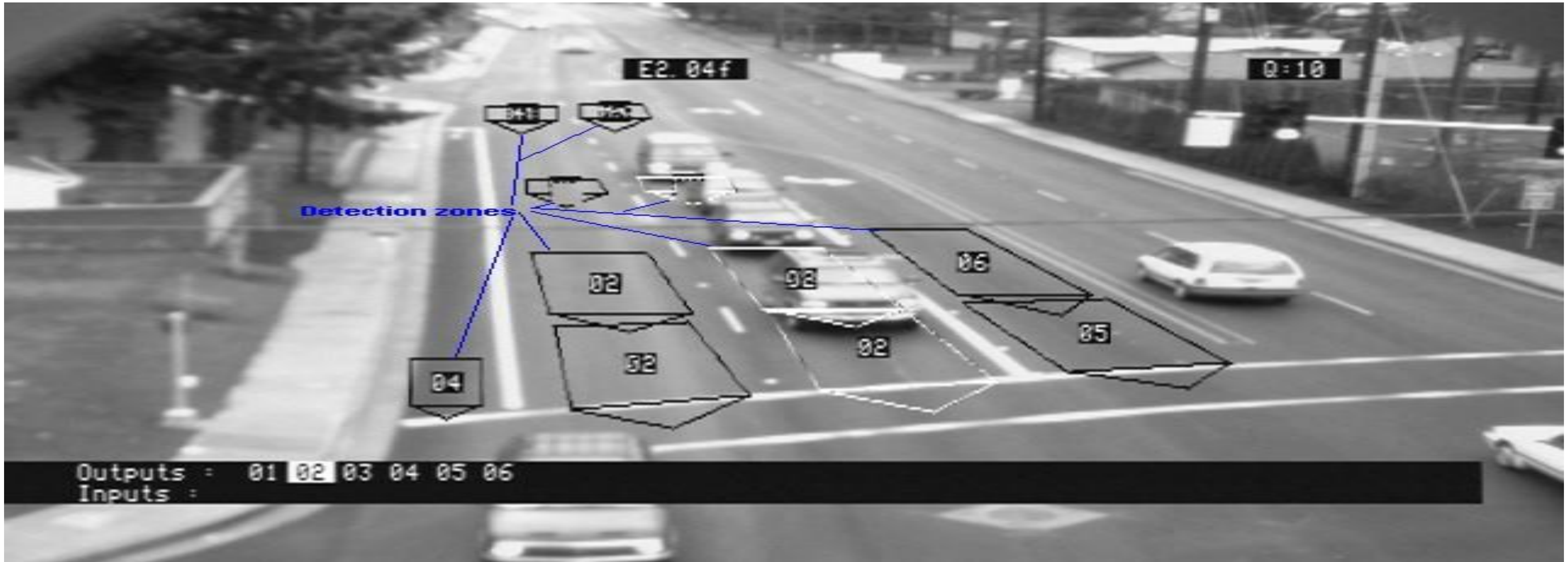
- Three different types of VIP systems are available,

1. Tripline,
2. Closed-loop tracking,
3. Data association tracking.

- In tripline system, detection zones are defined in the field of view of video camera.

- When a vehicle crosses one of these zones, it is identified by noting changes in the pixels caused by the vehicle

- Vehicle speed – Time spend in detection zone of known length of vehicle.



- Closed-loop tracking are extension of the tripline, it permits vehicle detection along larger roadway sections.

- It tracks vehicles continuously through the field of view of the camera.

- These tracking systems provide lane-to-lane vehicle movements.

- Data association tracking systems identify and track a particular vehicle by marker as gradients and morphology.

- It provide link travel time and origin-destination information

Infrared Sensors

- The sensors are mounted overhead to view approaching or departing traffic

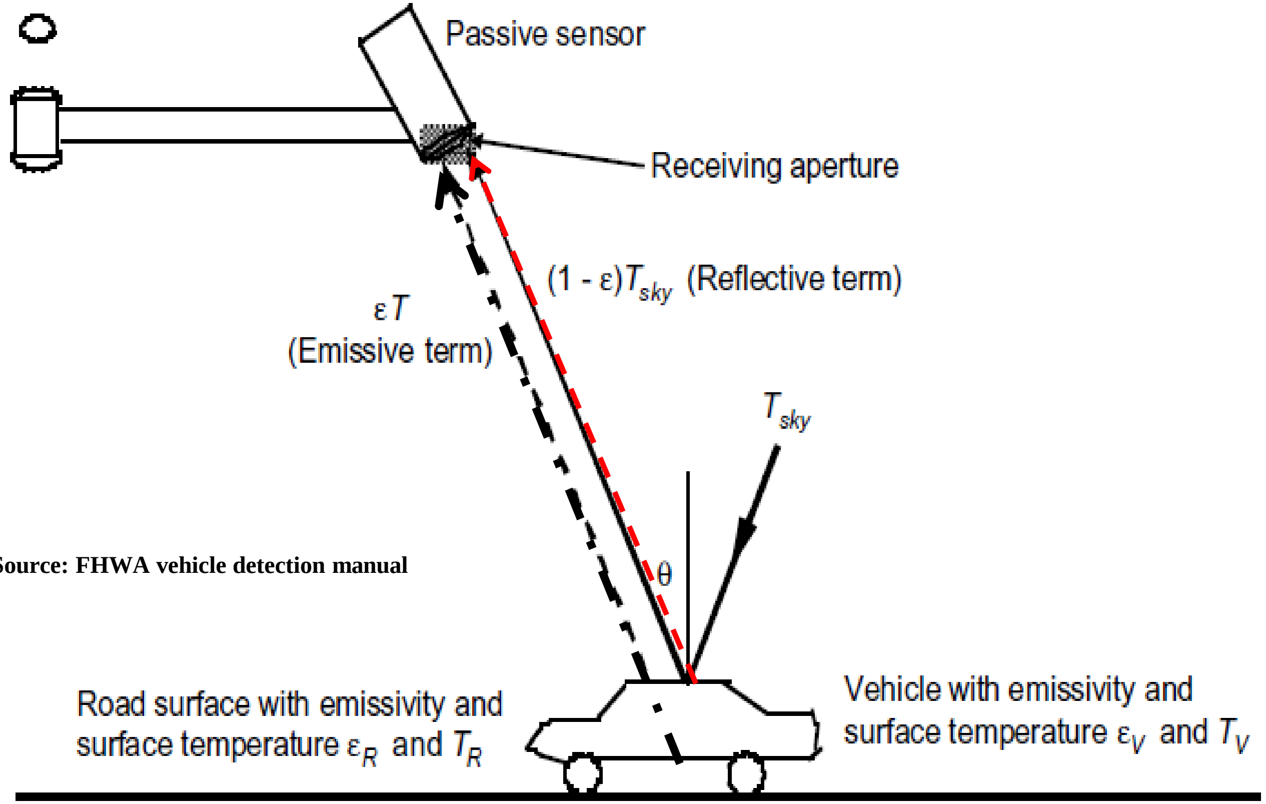
- Infrared sensors are used for signal control; volume, speed, and vehicle class measurement

- The light-sensitive element that converts the reflected or emitted energy into electrical signals

- Real-time signal processing is used to analyze the received signals for the presence of a vehicle

Passive Infrared (PIR)

- Detection of vehicle is based on emission or reflection of infrared radiation from vehicle surface
- Relatively long wavelength of light used in PIR systems makes them less susceptible to weather effects
- Accuracy of speed information may be poor with low resolution sensors



Source: FHWA vehicle detection manual

Active Infrared (AIR)/Laser

- Low power LED or laser diode fires a pulsed or continuous beam down to road surface. Time for reflection to return is measured.

- Presence of a vehicle lowers the time of reflection.

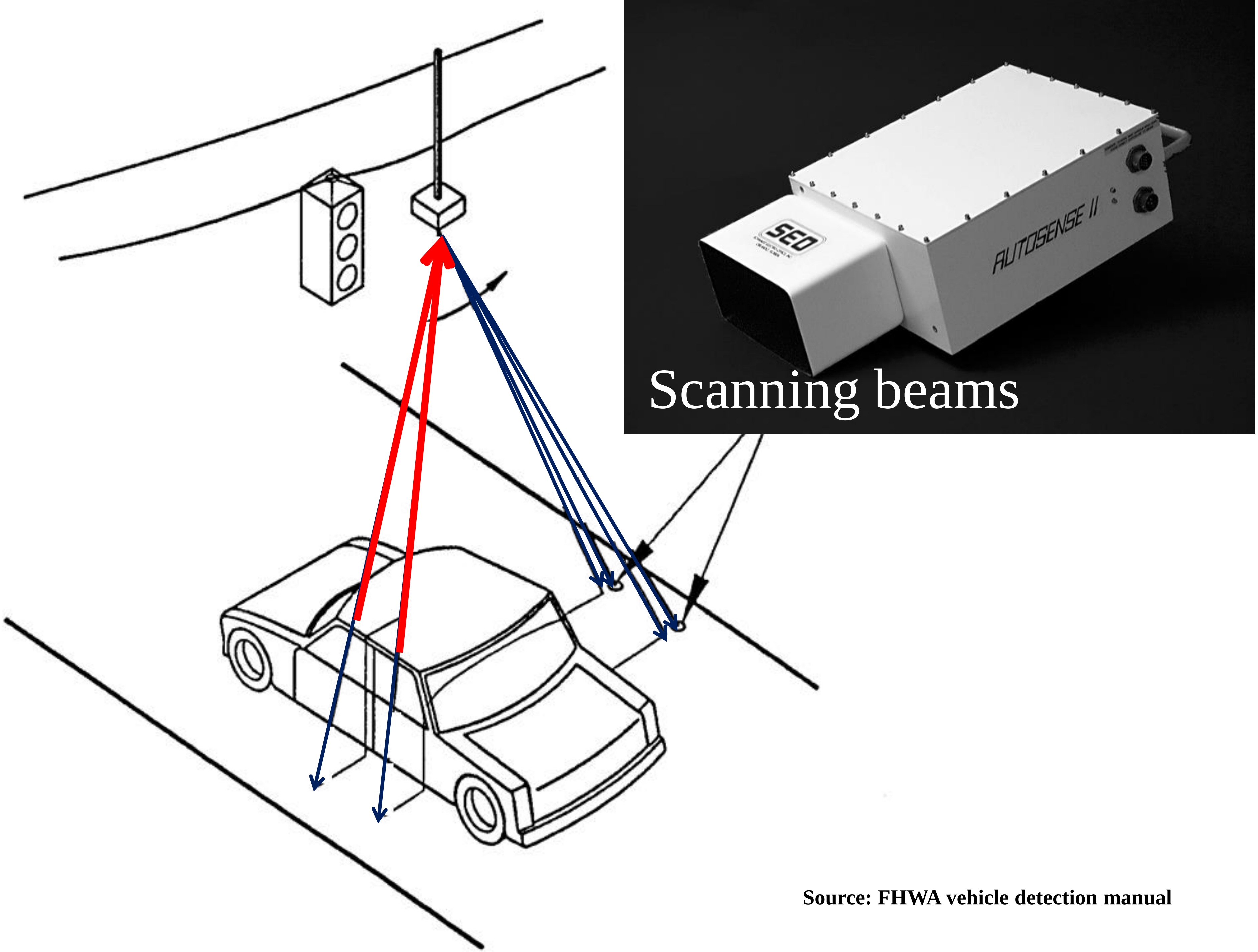
Advantages

- Very accurate flow, speed and classifications possible.
- Laser systems work in day and night conditions

Disadvantages

- Active near-IR sensors may be adversely affected by weather conditions.

- Laser systems may be impeded by haze or smoke

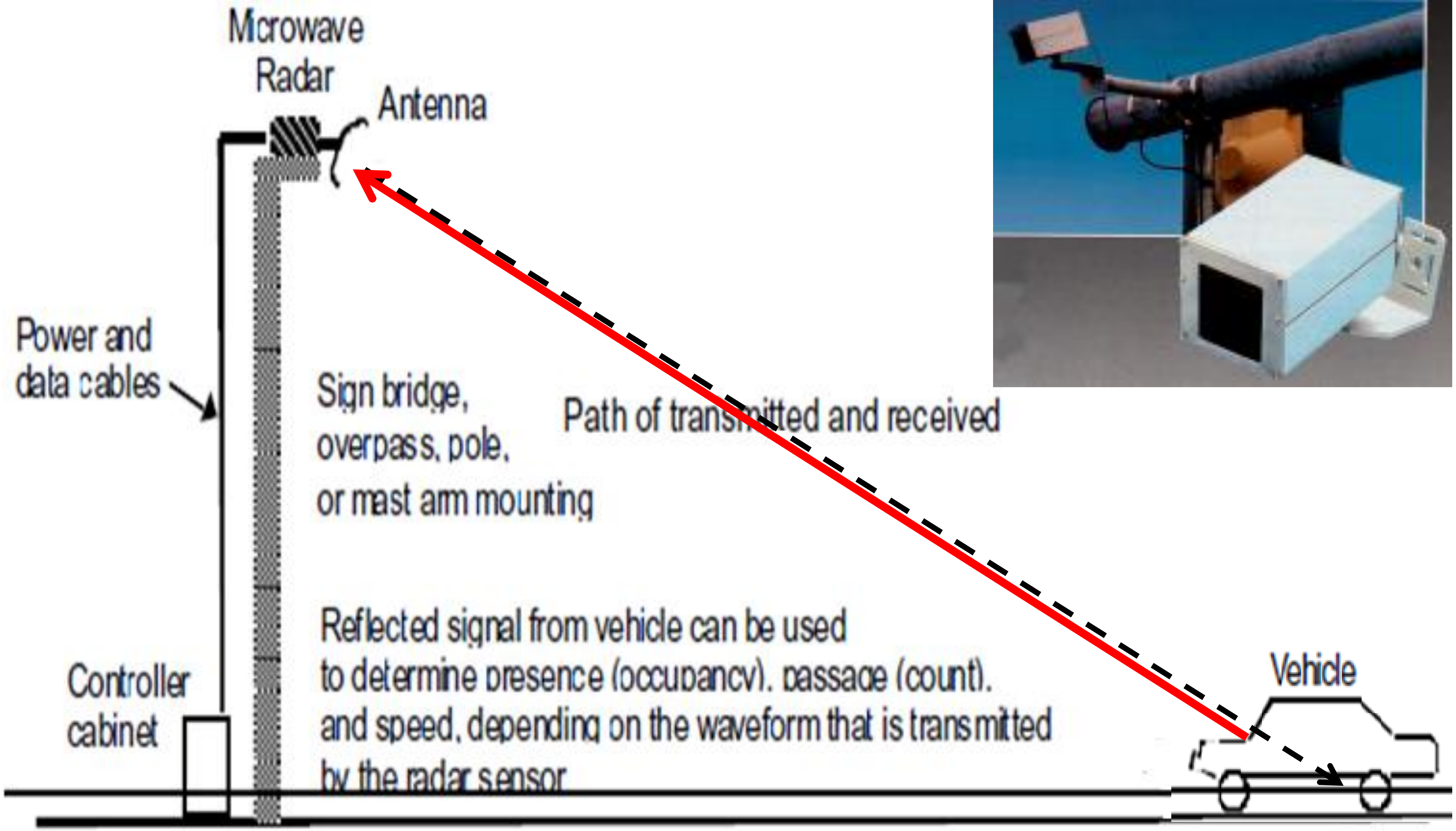


Source: FHWA vehicle detection manual

Passive Acoustic Array Sensors

- An array of microphones is used to detect the sound of an approaching vehicle above an ambient threshold level
- Time lags and signal variations between microphone positions are used to determine vehicle location relative to the array
- It collect the flow, speed, occupancy, possibly classification.
- Main advantage is multiple lane operation.
- Disadvantage is cold temperature may affect vehicle count.

Source: FHWA vehicle detection manual



Microwave - Doppler and Radar** **(RAdio Detection And Ranging)

- microwave radar transmit energy toward an area of the roadway

Cont…

Advantages

- Main advantages of microwave radar is that it is generally insensitive to inclement weather.
- Microwave radar provides a direct measurement of speed.
- Also, multiple lane operation models are available.

- **Disadvantages**

- Doppler sensors cannot detect stopped vehicles unless equipped with an auxiliary device

- Doppler microwave sensors have
- been found to perform poorly at intersection locations

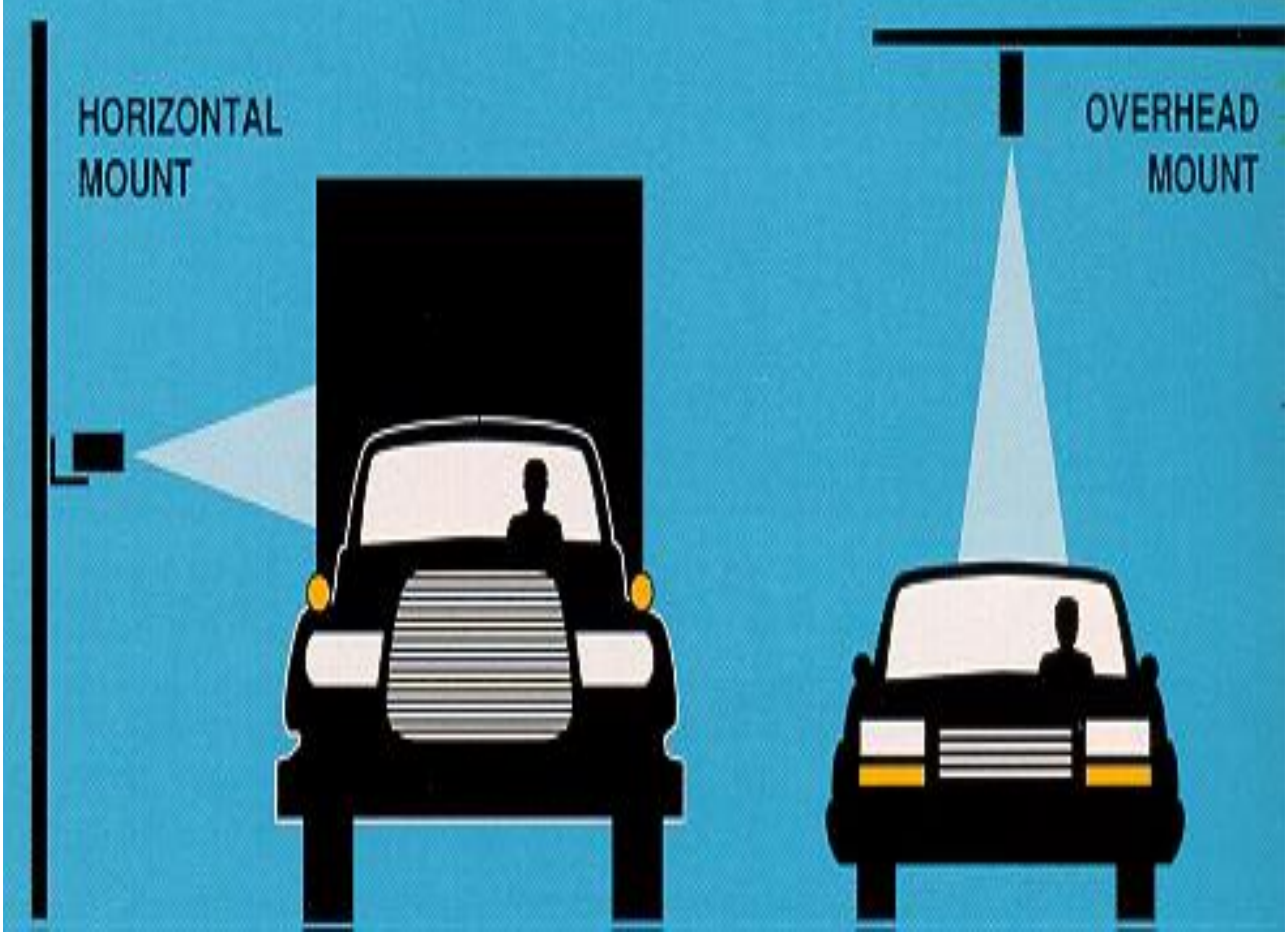
Pulsed and Active Ultrasonic

- Ultrasonic sensors transmit pressure waves of sound energy at a frequency between 25 and 50 KHz.

- Pulse waveforms measure distances to the road surface and vehicle surface by detecting the portion of the transmitted energy that is reflected towards the transmitter s beam width.

- When a distance other than that to the background road surface is measured, that measurement as the presence of a vehicle.

Source: FHWA vehicle detection manual



In-Vehicle Technologies

In-Vehicle Technologies

- Many network management applications making use of in-vehicle devices, for Automatic Vehicle Location (AVL)

- It provides positional information, whenever a suitably equipped vehicle passes a certain point in the network.

- The vehicles being equipped with transponders which transmit and receive information from roadside units.

- The advanced system uses vehicles equipped with Global Positioning System (GPS) technology.

- It improves safety, efficiency and reliability of the transportation system.

Floating Car Data (FCD)

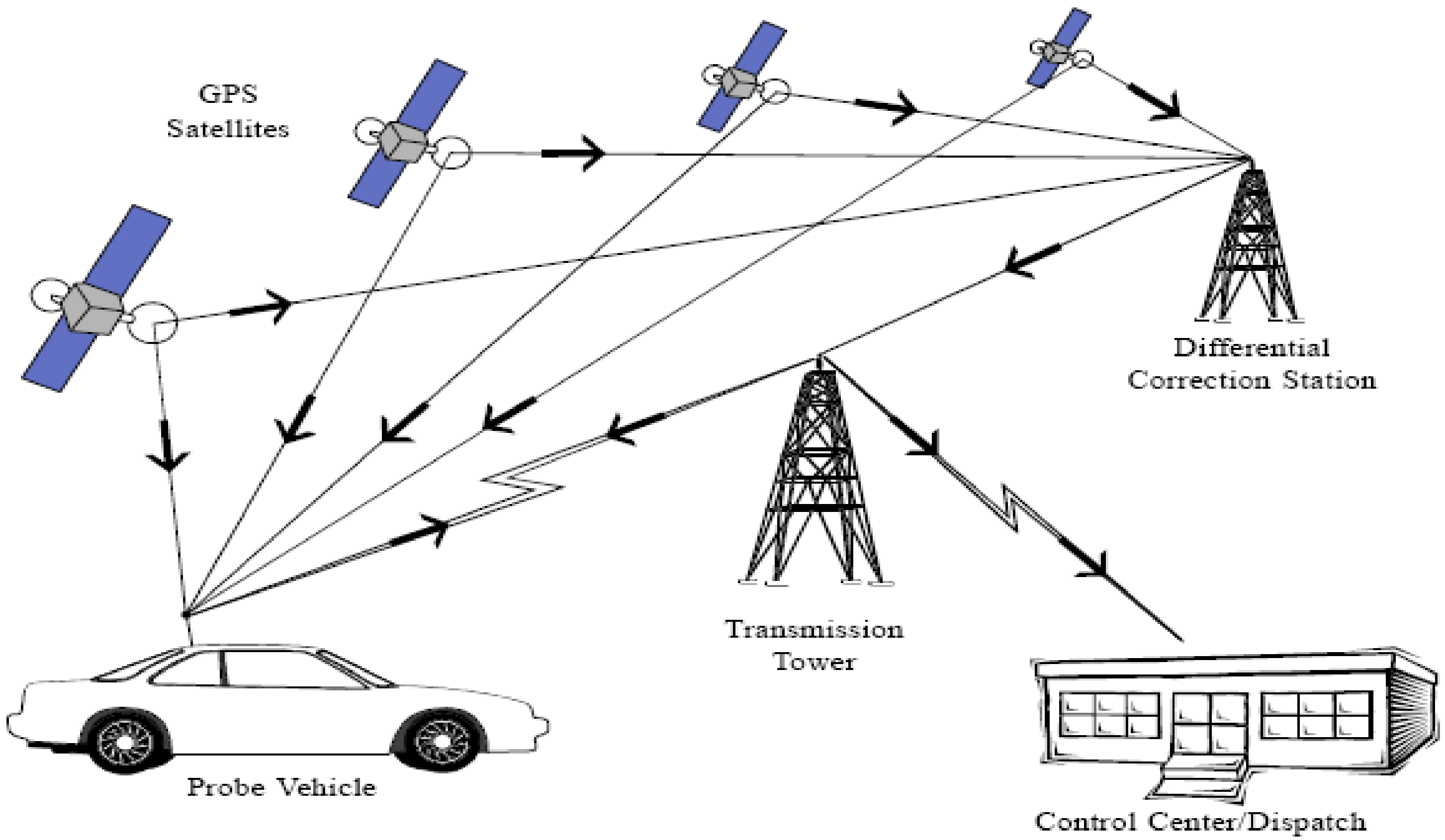
- A vehicle equipped with GPS (or) Cellular phones.

- FCD collect the real-time traffic data- journey times for congestion monitoring and incident detection

- After collected data by FCD and extracted, useful information such as status of traffic and alternative routes can be redistributed to the drivers on the road.

GPS-based FCD

- The GPS system provides time-stamped positional (vehicle location and position) information, it is transmitted via GPRS to a data management centre.



Source: Road Traffic Data: Collection Methods and Applications

Advantages

- Relatively low operating cost after initial installation.
- Provides detailed continuously data along the entire travel corridor.
- GPS direct speed measurement
- Data collection is automated.

- **Disadvantages**

- Relatively high installation cost.
- Privacy issues
- Signals can be lost in urban areas due to large buildings
- It is necessary to install two-way communication systems to send and receive signals.

GPS based data collection system

Uses

- It is very efficient and economic method to collect the real-time location of vehicles

- It is very important for automatic vehicle monitoring (AVM), an integral component of Intelligent Vehicle-Highway Systems (IVHS) technology and Integrated Traffic Management Systems (ITMS).

Travel Time and Delay Studies using GPS

- Travel time study techniques involve using probe vehicles.

- GPS receivers record location in latitude-longitude pairs.

- GPS data storage problem involves aggregating the GPS data into highway segments or links

- Some GPS data includes acceleration and deceleration patterns, control delay, and stopped delay.

Automatic Vehicle Location (AVL)

- AVL is advanced method of remote vehicle tracking and monitoring using GPS.

- Each vehicle is equipped with a module that receives signals from a series of satellites, and calculates its current geographical location and speed.

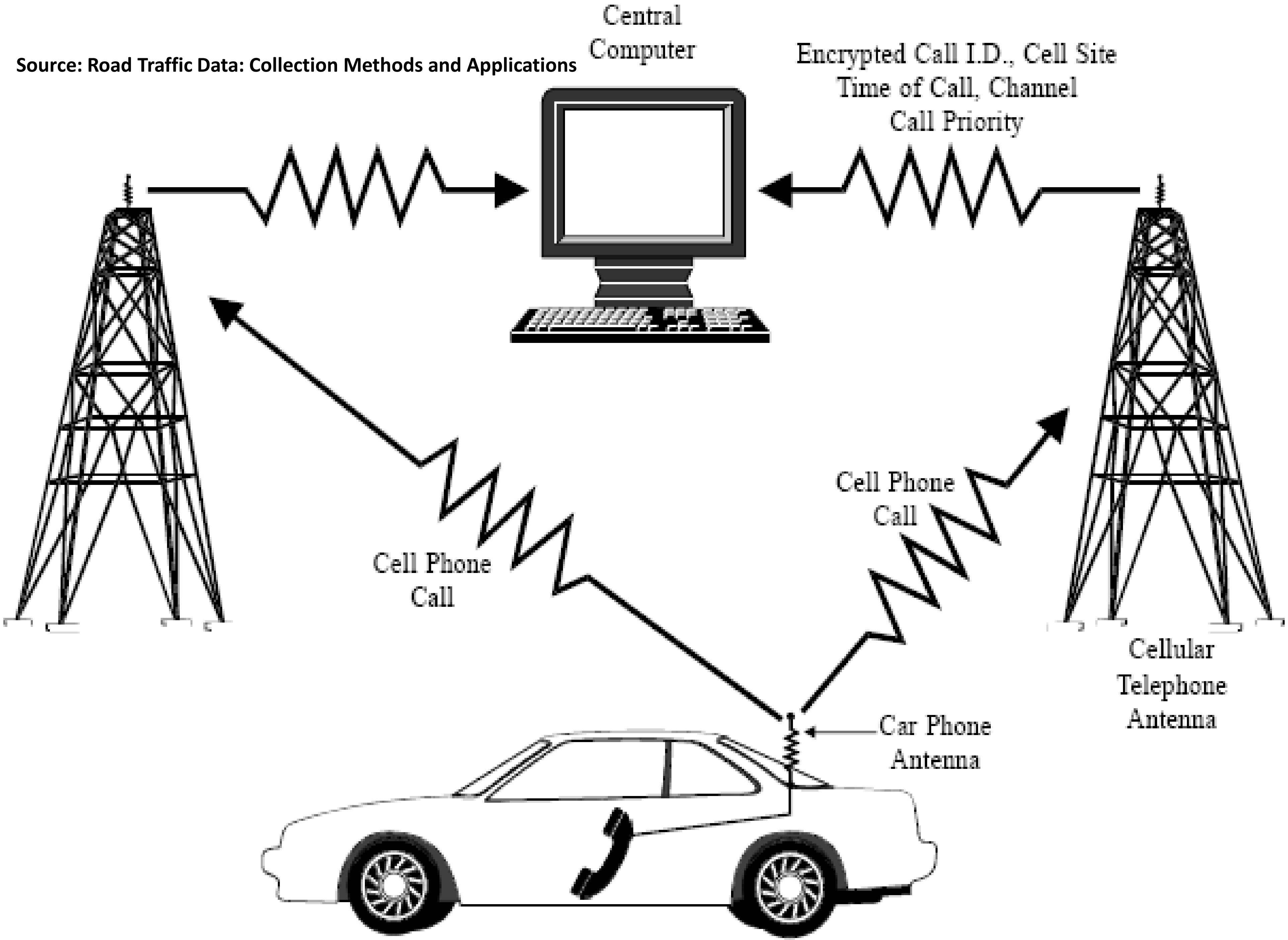
- It is very useful for the police and emergency response services.

- The central station usually diverts the vehicle nearest to the site, where the vehicles are required.

Cellular phones based FCD

- Vehicles are equipped with at least one or several mobile phones
- The mobile phone positioning is regularly transmitted to the network usually by means of triangulation
- Travel times and further data can be estimated over a series of road segments before being converted into useful information by traffic centers.
- It deliver relatively accurate information due to the lower distance between antennas
- It is less expensive than conventional detectors

Source: Road Traffic Data: Collection Methods and Applications



Advantages

- Driver recruitment not necessary
- No in-vehicle equipment to install.

Disadvantages

- Experimental in stage
- Privacy issues
- Infrastructure dependent -
- Low accuracy

Cont…

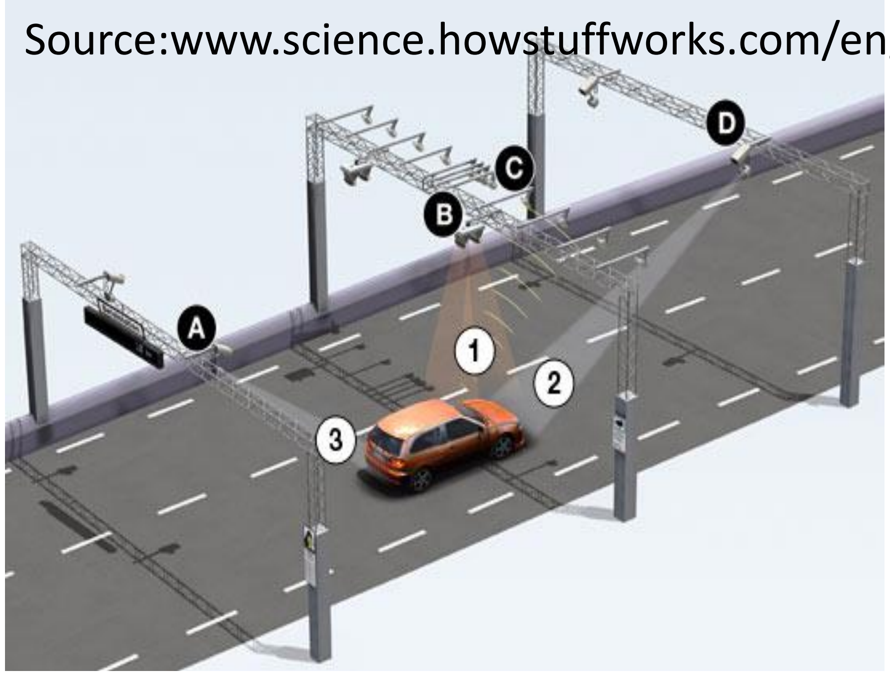
- There are different types of cellular FCD systems are using like
- Code Division Multiple Access (CDMA),
- Global System for Mobile communications (GSM),
- Universal Mobile Telecommunications System (UMTS) also called 3GSM,
- General Packet Radio Service (GPRS) also called GSM++ or GSM2+).

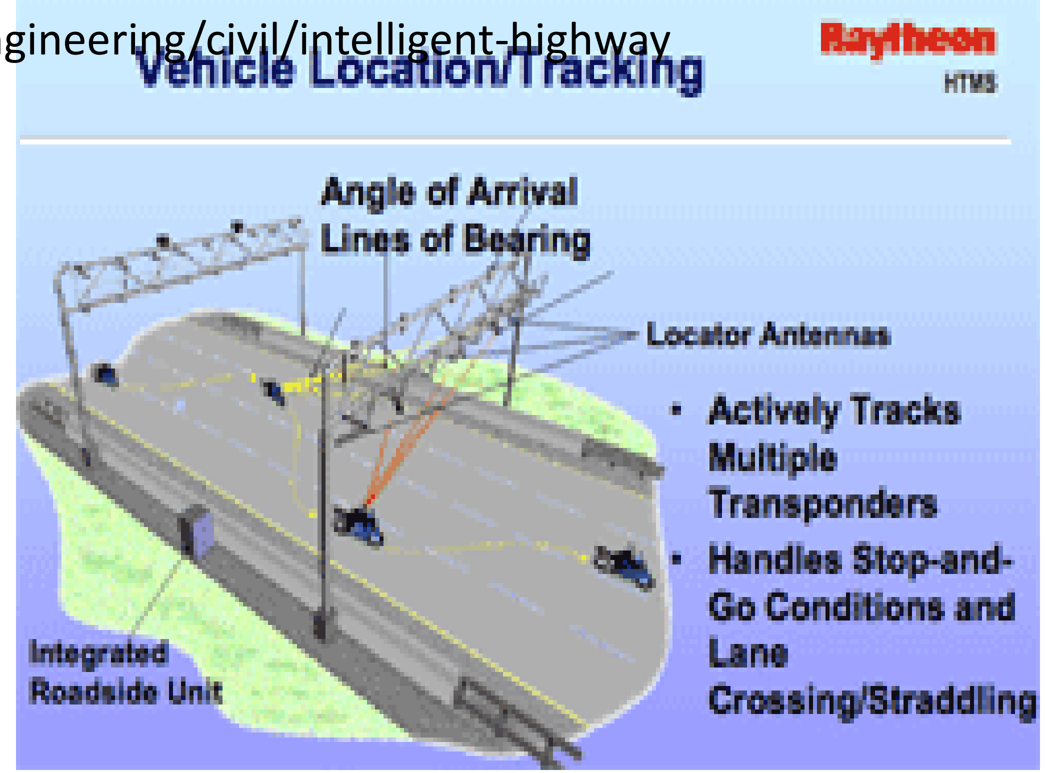
RFID or Transponder Systems

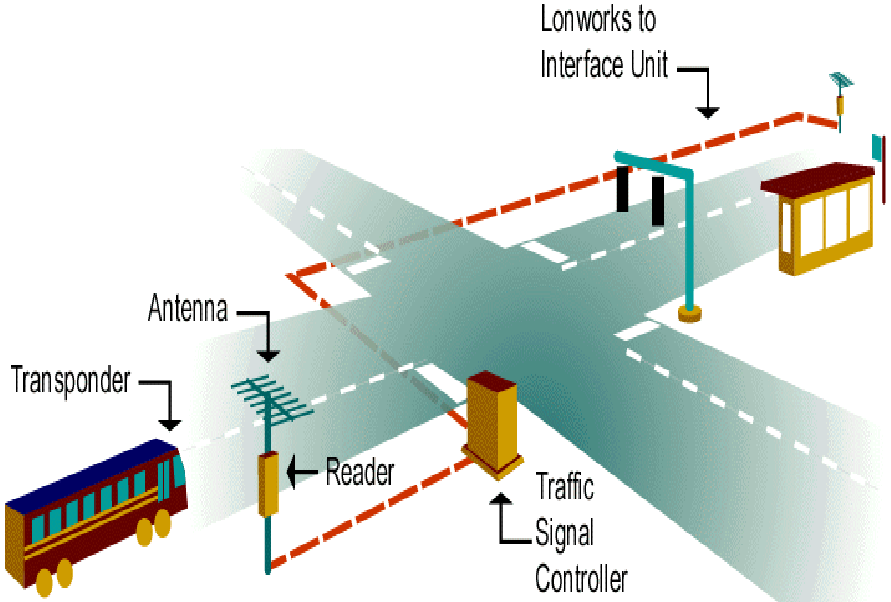
- It is very useful for public transport authorities, for obtaining vehicle tracking and passenger occupancy information along equipped routes.

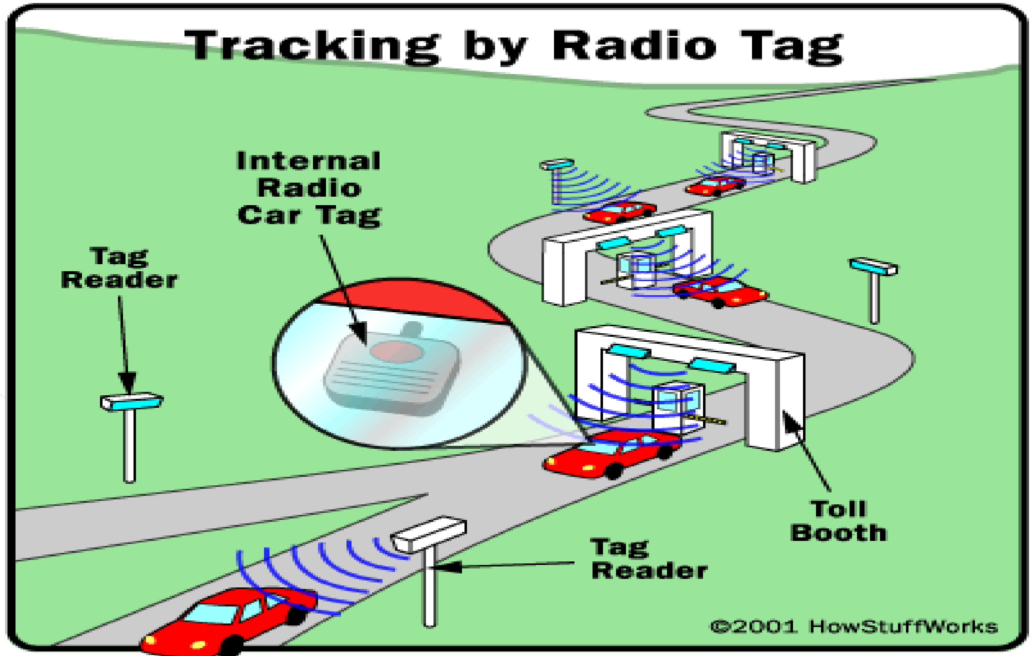
- It is also used with Selective Vehicle Detection (SVD) systems which are designed to allow priority at traffic signals.

Source:www.science.howstuffworks.com/engineering/civil/intelligent-highway





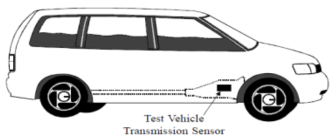




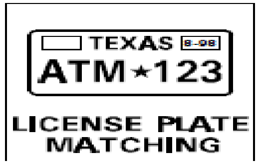
Special Applications

Travel Time Data collection Technique

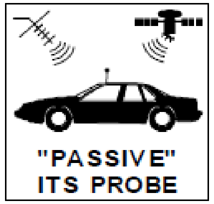
- **Test Vehicle Techniques**



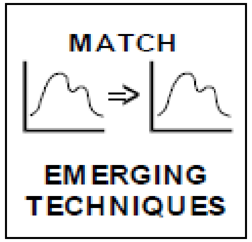
- **License Plate Matching Techniques**



- **ITS Probe Vehicle Techniques**



- **Emerging and Non-Traditional Techniques**



ITS Probe Vehicle Techniques

- **Probe vehicles-** vehicles equipped with a dynamic route guidance (DRG) device acting as roving traffic detectors

- A probe vehicle is equipped with on-board electronics, such as a location and a communication device

- These vehicles moving with road traffic and automatically reporting the time needed for traveling between two intersections.

Advantages

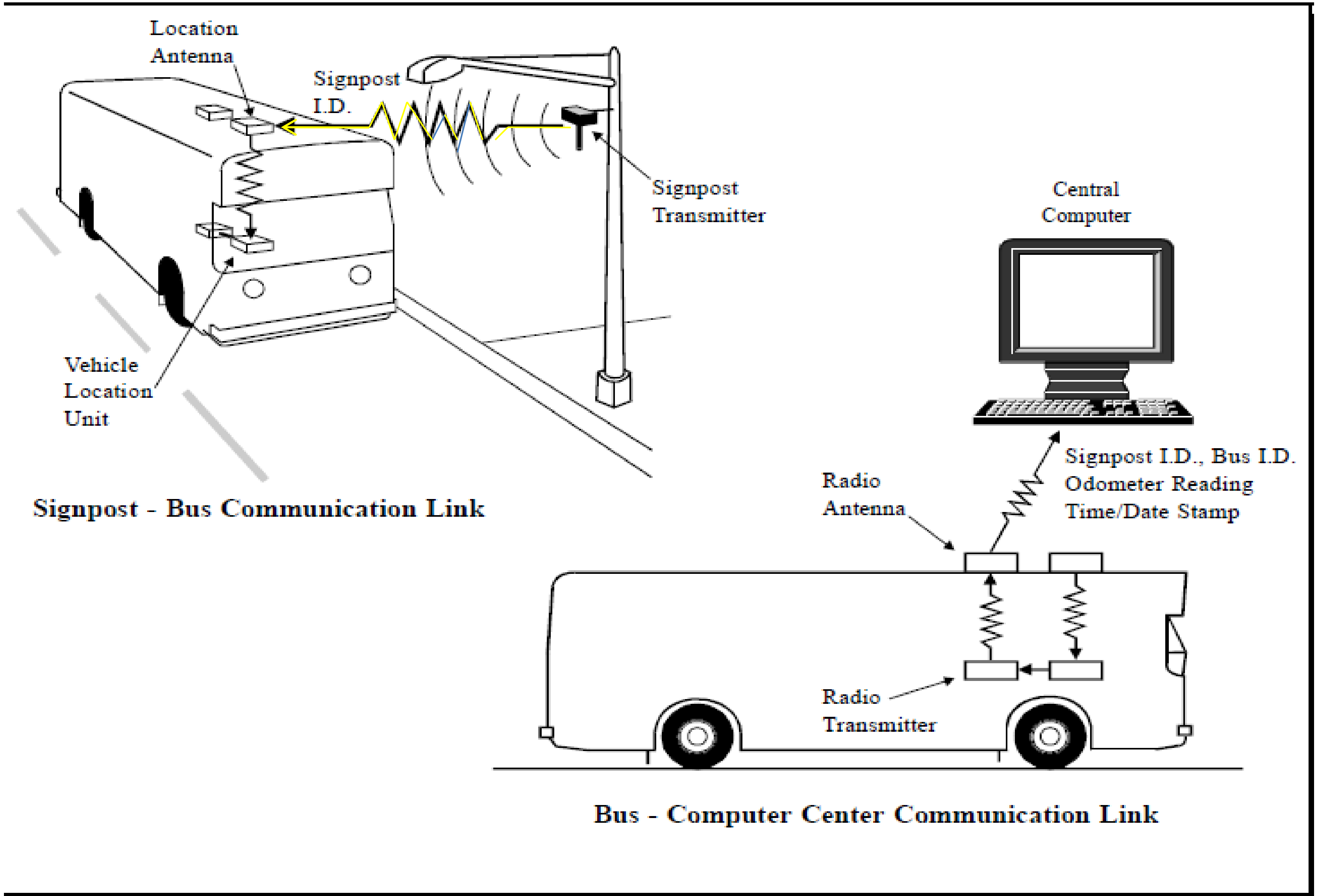
- Low cost per unit of data
- Continuous data collection
- Automated data collection
- Data are in electronic format
- No disruption of traffic

Disadvantages

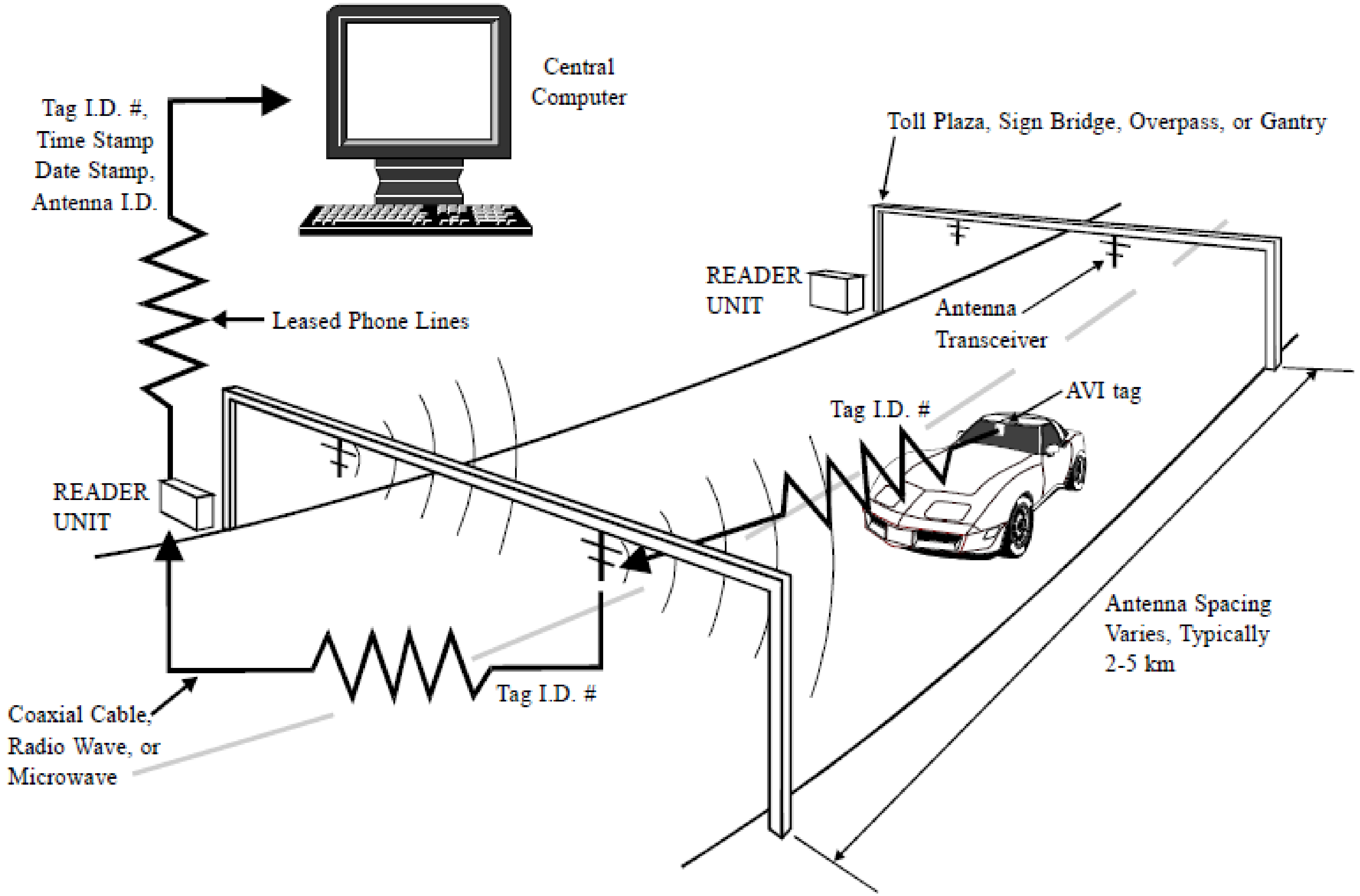
-
- High implementation cost
- Fixed infrastructure constraints - Coverage area, including locations of antenna
- Requires skilled software
- Not recommended for small scale data collection efforts

ITS probe vehicle data collection systems

- **Signpost-Based Automatic Vehicle Location (AVL)**



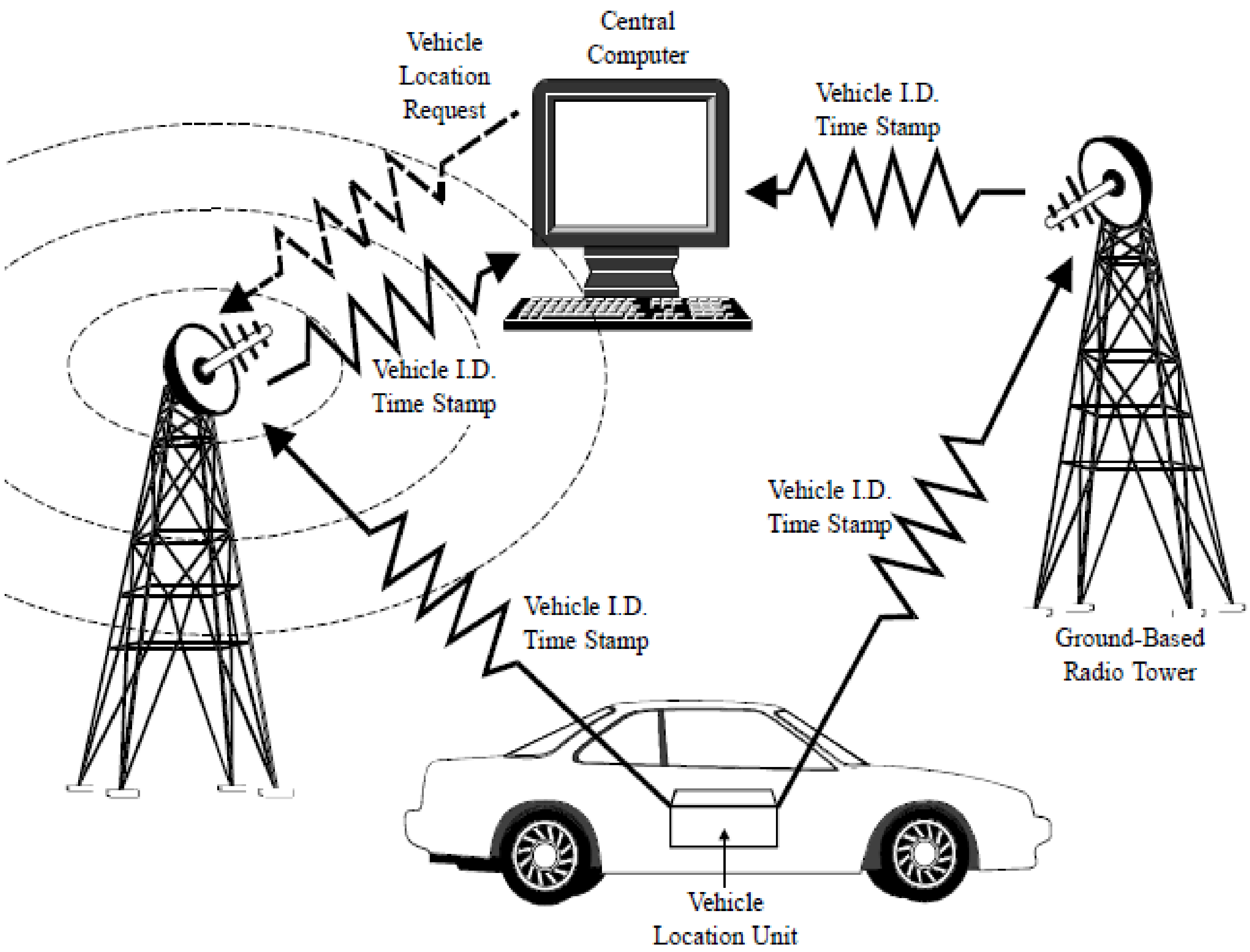
Automatic Vehicle Identification



electronic toll collection (ETC)

Ground-Based Radio Navigation

- Fleet management



Emerging and Non-Traditional Techniques

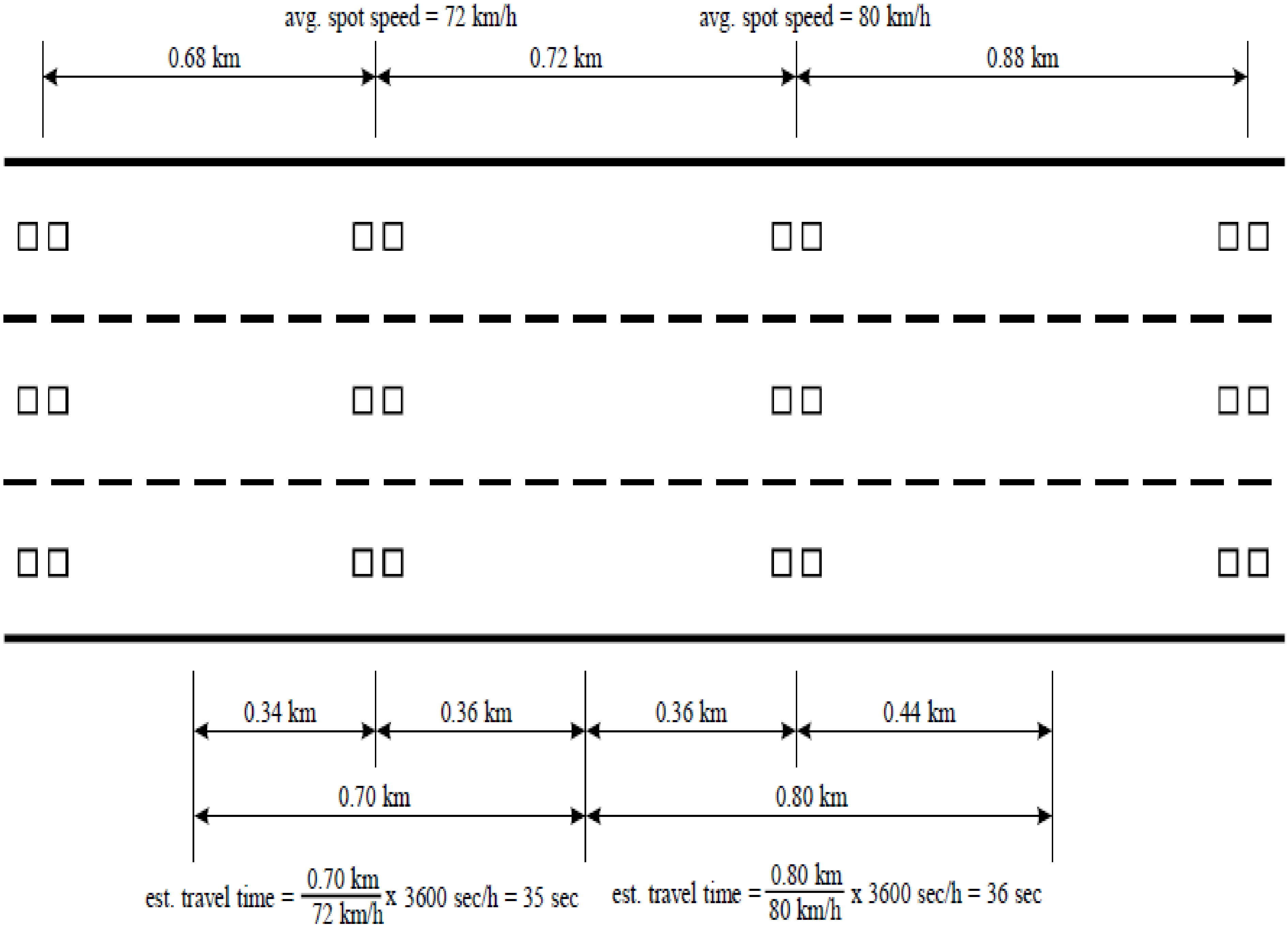
- Emerging or non-traditional techniques are based on using “point” vehicle detection equipment.

- The following are the some of the methods using in emerging techniques
- **Extrapolation Method** - Travel time by spot speeds

- **Vehicle Signature Matching** - Travel time by matching vehicle signatures

- **Platoon Matching** - Travel time by matching vehicle platoons such as the position or distribution of vehicle gaps.

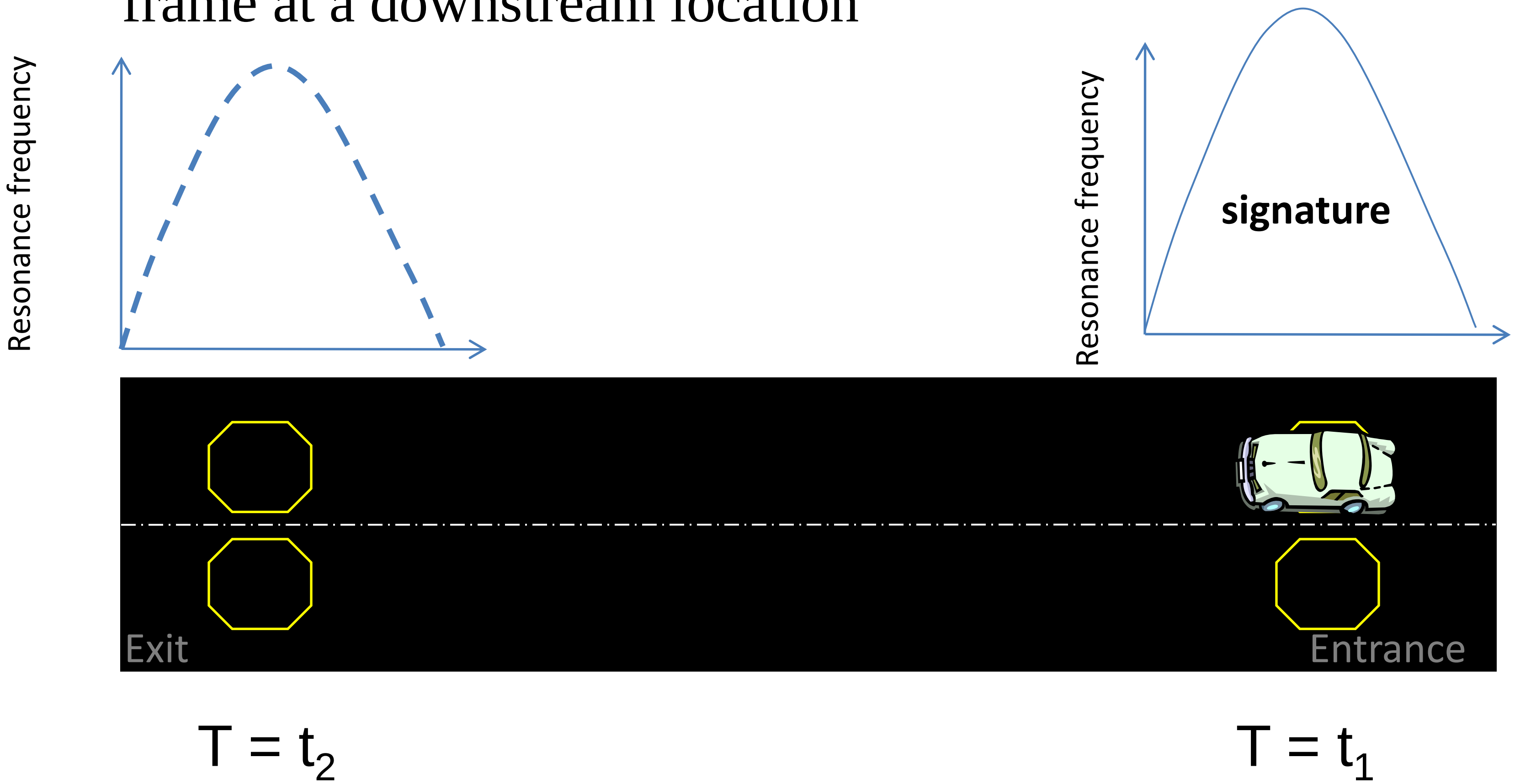
Source: Travel Time Data Collection Handbook/FHWA/Extrapolation Method/pg: 6-3



Vehicle Signature Matching

- Several algorithms are available to capture vehicle signatures from a loop detector

- Vehicle signature are then compared to signatures within a given time frame at a downstream location



Conclusions

- Each detector technology and particular device has its own limitations and individual capability.

- The successful application of detector technologies largely depends on proper device selection.

- Many factors impact detector selection,

data type,

data accuracy,

ease of installation and

calibration, cost, reliability,

maintenance, communication, power, and installation site.