3 FACTORS AFFECTING PERFORMANCES OF NON-INTRUSIVE VEHICLE DETECTORS

Numerous factors affect the performances of non-intrusive vehicle detectors, and the factors change in different local environments. When we select particular non-intrusive vehicle detectors to replace inductive loops to maintain signal actuation, we should consider whether the selected vehicle detectors can operate correctly and really maintain traffic signal actuation under the local environment. In the guideline, three main factors are considered:

- Traffic Flow Conditions
- Weather Conditions
- Construction Conditions

3.1 Traffic Flow Conditions

3.1.1 Introduction

The vehicle detections are the base of a signal controller at signalized intersections. The efficiency of vehicle detections is directly relative to phase split and intersection capacity. The high accuracy of vehicle detection at a signalized intersection can truly reflect the real volumes of each approach and reasonably allocate the green time for each phase. When choosing the type of vehicle detection device to be utilized for a signal controller, many factors need to be considered. The traffic characteristics of the intersections is the primary.

Traffic characteristics at intersections refer to the traffic flow parameters at intersections, such as the volume, speed, density, saturation flow rate, delay and traffic flow component etc. Study on traffic flow characteristics at signalized intersections is one of most effective and immediate measures to enhance the capacity of intersections and relieve the congestion. According to the research requirements of the guideline, several traffic characteristics that are most relative to the research have been selected for the study:

- Traffic volume
- Traffic speed
- Traffic flow component (such as the percentage of trucks and buses)

The guideline will discuss the effect of the three flow characteristics on performances of vehicle detections one by one in the following sections.

3.1.2 Traffic Volume

Traffic volume is defined as the number of vehicles that pass a point on a highway, or a given lane or direction of a highway, during a specified time interval. Volume data are generally

expressed in terms of flow rate. Flow rate is a temporal quantity measure defined as the number of vehicles passing a point in a given period of time, usually one hour. When the volume in a highway is heavy or light, the traffic flow is often called heavy or light traffic.

Generally, on highways traffic volume is not a constant value for every hour in a day. Traffic flow patterns vary from time to time based on the traffic demand. In the morning and afternoon when people go to or from work, the traffic volume will be much heavier than at in other times, this heavy traffic is called peak-hour traffic flow. The volume in intersection approaches has an important effect on the accuracy of vehicle detections. When a particular vehicle detector is selected to maintain the signal actuation, the detection accuracy should be satisfied in peak-hour traffic flow and other time traffic flow. That is, the detector can maintain a high accuracy in detect heavy flow and light flow in the particular intersection. In the signalized intersection control, the allowable error for measuring traffic flow is ±2.5 percent at 500 vehicles per hour per lane.

Most of the detectors give good results when used under light traffic conditions. Some vehicle detectors have high detection accuracy by virtue of their multiple outputs or detection zones. If a single traffic detector had multiple detection zones, the most favorable of the outputs was used in the results. This affords a greater opportunity for these devices to appear in a favorable light; whereas, a simple detector having a single relay output was represented solely on the basis of that single output.

But some vehicle detectors cannot satisfy the accuracy requirements in high-volume traffic conditions. Some may exhibit a tendency to undercount vehicles, and some overcount vehicles in heavy traffic flow. This may be the main problem to maintain the vehicle detection in heavy flow. When a non-intrusive detector is selected to maintain the signal actuation, the detection accuracy in peak-hour hour should be satisfied.

When traffic demand is over the capacity of a highway, traffic congestion will be induced. Especially during peak periods, congestion can even cause volumes to drop. Under this circumstance the detectors designed to detect vehicle passage should have the capability to detect slow-moving or even stopped vehicles. If the detector miscounts slow-moving vehicles, it will have difficulty accurately detecting vehicles in congested traffic conditions.

Based on the analysis above, when a particular detector is selected to maintain the traffic signal actuation, the detector should satisfy detection accuracy in detecting vehicles during peak-hour and non-peak hour traffic flow. At the same time, the detection accuracy under congestion flow should be considered.

3.1.3 Traffic Flow Speed

All the different types of vehicle detections can be divided into two kinds of detection: passage detection and presence detection. The main difference is that passage detection needs to detect moving vehicles, while presence detection needs to detect slow-moving vehicles or stopped vehicles. That means that particular detectors should detect special speeds for a particular application.

Just like traffic volume on highways discussed above, the traffic speed on highways also varies (from 0 to free flow speed). The main difference in requirements between low- and high-volume applications stems from the change in vehicle speeds. Vehicles in low-volume conditions are likely to be free flowing and unconstrained in their movements, while vehicles in high-volume conditions, where the roadway is at or near its designed capacity, will be restricted in their speed. When the traffic demand exceeds the capacity of the roadway, speeds will obviously decrease. When a particular detector is used to detect passage vehicles, the speed change should be considered. Because the detector can detect the vehicles in free flow speed, it should have the ability to detect the vehicles whose speed may fall below some fixed threshold because of congestion.

3.1.4 Traffic Flow Component

Here traffic flow component means the percentage of different types of vehicles in traffic flow. Some highways may have a high percentage of buses or bikes according to the different trip modes. While some highways, as parts of interstate highway, will have a higher percentage of trucks.

Traffic flow component is significant to select particular vehicle detectors to maintain signal actuation. The most important points are as follows.

First, the selected vehicle detectors should have the capability to detect all the component vehicles in the traffic flow. Currently, inductive loop has been the most widespread detectors at signalized intersections. And it also proves that inductive loop has the strong capability to detect different types of automobiles. If other detection technologies are used to replace the inductive loop, the selected detectors should have the capability to detect all types of automobiles efficiently in the traffic flow.

The second important point is that for non-intrusive technologies the detectors mounted over the road or roadside may cause detection occlusion, especially for video detectors. Occlusion refers to a situation where one vehicle blocks or obscures the detection of a second vehicle. Inductive loop does not have this kind of problem. When the non-intrusive technologies are used to replace the inductive loop, the problem may rise. For example, a big truck may block the detection of the vehicle following it.

Generally there are three types of occlusion: adjacent-lane occlusion, same-lane occlusion and cross-lane occlusion. Adjacent-lane occlusion occurs when the blocked and blocking vehicles are in adjacent lanes; same-lane occlusion occurs when the blocked and blocking vehicles are in same lanes; cross-lane occlusion occurs when a vehicle crosses between the detector and the intersection approach being detected. When we use non-intrusive technologies to detect vehicles, we should consider the selected detectors and the location of detectors to avoid the problem.

3.1.5 Summary

Traffic characteristics are important factors to select particular detectors to maintain signal actuation. Based on the requirement of the research, three main traffic characteristics (volume, speed and component) should be considered in selection of particular detectors to maintain signal actuation at signalized intersections. The traffic characteristics vary at different times in a day. Selected detectors should satisfy the requirement of detection accuracy in changed volume, speed and vehicle component to maintain the signal actuation correctly.

3.2 Weather Conditions

3.2.1 Introduction

A variety of weather variables may affect non-intrusive technologies. Compared with intrusive technologies, non-intrusive devices are devices that do not need to be installed in or on the pavement but can be mounted overhead, to the side, or beneath the pavement by "pushing" the device in from the shoulder. All but ultrasonic and acoustic applications utilize some form of electromagnetic energy to detect the presence of a vehicle. Because of the different theories of operation and installation locations of non-intrusive technologies with that of intrusive technologies, weather conditions affect the performances of non-intrusive technologies more than that of intrusive technologies. For example, Snow, rain and fog will reduce the visibility; and wind will make the detector vibrate. All these kinds of weather conditions may affect the performances of non-intrusive vehicle detectors.

When a vehicle detection device enters the market, the manufacturers design criteria and test data will help determine if the detectors can operated in cold, hot, fog, and wet weather environments and in electrical disturbances, such as lightning, anticipated for the field tests. When a particular detector is selected to maintain the traffic signal actuation, the local weather conditions should be considered. The performance of the detector should be satisfied in the local weather conditions according to the specification of the selected vehicle detectors.

According to some test reports and specifications of non-intrusive detectors in some State DOTs, the following part in the guideline will discuss the effects of weather conditions on non-intrusive detectors.

3.2.2 Wind

Wind is a factor in data collection if it causes a sensor to sway or vibrate excessively. Sensor movement may cause false alarms in a variety of above-ground applications.

3.2.3 Precipitation

Precipitation (snow, rain, or fog) can affect some types of non-intrusive technologies. Machine vision, infrared and ultrasonic type sensors can all be adversely affected by precipitation. Either light refraction or line of sight obstruction may be a problem depending on the technology.

Severe weather conditions such as fog, smog, or smoke (but not rain) can cause degradation of the infrared transmission. The disadvantage of the laser technology is that it has a very short operating distance, approximately one mile, needs a straight line of site for the laser transmission, and the video quality is affected by rain, fog, and snow.

A wet roadway can adversely affect sensor performance due to roadway glare, particularly for machine vision technologies, or by changing the reflective properties of the road surface for active infrared. Also, snow on the roadway can obscure lane delineation, causing vehicles to travel outside of normal travel ways.

3.2.4 Sunlight/Shadows

The amount of sunlight in a sensor's detection zone may impact its performance. The presence of shadows is likely to have the greatest impact on video sensors. Clear weather conditions and plentiful sunlight causes a strong shadow contrast.

The most significant weather impacts on video detectors were lighting conditions. The presence of vehicle shadows, stationary shadows, and the transition from day to night and vice versa were the most common conditions that were correlated with miscounting.

3.2.5 Temperature

Temperature is another important variable to consider in evaluating non-intrusive technologies. Extreme highs or lows may affect the performance of a sensor, especially when temperature changes directly affect the detection process, such as sound propagation relied on by acoustic and ultrasonic technologies.

3.2.6 General Results for Some Field Tests

In general, weather conditions have a minimal impact on the majority of the non-intrusive detection technologies. The greatest impact was snow on the roadway, which caused some vehicles to track outside of their normal driving patterns. Devices with narrow detection zones were most affected. In addition, lighting conditions were observed to affect some of the video devices, particularly in the transition from day to night. The salt spray generated by the traffic stream coated everything in the field with a layer of grime. This impacted the performance of some video devices and possibly other optic-dependent devices, such as the active infrared. Cold temperatures also caused some cables to become brittle and split open. The systemic analyses of the effects of weather conditions on non-intrusive technologies will be given in the following part in the guideline.

Overall the effect of weather on device performance was minimal. This is especially true if a device is being used to gather traffic count data for historical use. In this case the data from a day with inclement weather do not represent typical traffic levels and could be discarded. Urban traffic conditions, including heavy congestion, were found to have little affect on the device performance. But when we use the non-intrusive technologies to maintain traffic signal actuation at intersections under construction, it may be important to consider weather conditions fully

because it will cause the wrong operation in the intersections if the selected detectors cannot work correctly in the local weather conditions.

3.3 Construction Conditions

Some testing reports about non-intrusive vehicle detectors show that construction and geometric factors in signalized intersections is minimal. But in some conditions these factors can affect of the performances of non-intrusive detectors and reduce the detection accuracy. Moreover, some constructions and geometric factors at intersections can hinder the installation of particular non-intrusive detectors.

Although it is needed to analyze the effects of construction and geometric factors on particular non-intrusive detectors in the guideline, it is still difficult to divide all the constructions and geometric factors into some defined categories. Actually, every intersection has its own geometric characters, and so does every construction. The geometric category of intersections in traditional traffic engineering actually has little effect on the performances of non-intrusive detectors. Crossroad intersections and T intersections can use the same non-intrusive detectors to detect vehicles without any differences in the performances.

In the guideline, category of signalized intersections is not divided. The guideline just point out that construction and geometric factors may affect the selection of non-intrusive detectors to maintain the signal actuation at signalized intersections. Generally, the effects can be divided into two kinds: one is that the construction and geometric factors would hamper the installation of particular detectors; two is that the construction and geometric factors would affect the performances of particular detectors. When the contractors select a particular vehicle detector to maintain traffic signal, these kinds of factors should be considered.

As some references, the following points can be considered in the selection of particular detectors.

- If the construction and geometric factors constraints hamper the installation of a specific non-intrusive detector, an alternative detector system may be selected.
- If the construction project is in extremely short duration, the cost effectiveness should be considered before traffic signal maintenance is applied.
- If the construction at intersections will cause vibration of vehicle detectors and affect their performance, the installation location of vehicle detectors should be changed. Otherwise, some alternative detector insensitive to vibration should be applied.
- If acoustic noise in the audible or ultrasonic ranges in the construction could conceivably interfere with the operation of passive acoustic arrays and ultrasonic detectors, the two kinds of vehicle detectors cannot be applied.
- Electromagnetic interference has the potential to affect the operation of all types of traffic detectors, as it can enter through the aperture of the detector or through the enclosure that

protects the electronics that process the data. When construction can emit electromagnetic radio, the problem should be considered.

3.4 References for Chapter 3

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