NON-INTRUSIVE DETECTION, THE WAY FORWARD

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ABSTRACT

With an increasing demand on our transportation networks, it is important to design and implement effective detection systems, for numerous reasons it can also be advantageous if these systems can be non-intrusive.

Implementation of a detection system needs careful consideration, as there is a wide variety of technologies available on the market, each with its own characteristic strength and weakness. The strengths of a specific technology, will in most cases determine whether the detection system is suitable for the desired application.

Other factors which can easily be overlooked, during the planning of detection system installation is: life span, maintenance and operating costs of the equipment. Environmental influences are also important to bear in mind, as the specific environment into which a chosen system is to be deployed, will in many instances affect the choice of the detection system.

From the most basic detection technologies to more advanced systems. We provide a series of examples, based on tests conducted throughout South Africa and also studies conducted overseas. These examples demonstrate how these detection systems are deployed, and how they operate in a real life environment.

The intent of this paper is to present an approach to the design and implementation of a detection system, ensuring that we make use of the best detection solutions.

INTRODUCTION

In the quest to improve mobility, reduce travel times and delays in our transportation networks, we require effective detection solutions. This paper presents the advantages and disadvantages of non-intrusive detection and a comparison between intrusive and non-intrusive detection systems.

This paper also highlights infrastructure requirements, system requirements and environmental influences, which assist in determining the most suitable technology for a specific application.

COMPARISON OF DIFFERENT TECHNOLOGIES

There are two main types of detection technologies: intrusive and non-intrusive. Technologies which are commonly used for intrusive detection are: Inductive loop, Piezoelectric, Magnetic, Weigh-in-motion and Pneumatic road tube. Non-intrusive technologies are: Video, Radar, Ultrasonic, Infrared and Mobile tracking.

Inductive loop

Inductive loop detectors measure the change in the inductance of the loop, as vehicles move near or over the loop, installed in the road surface. Inductive loops are widely used for vehicle detection at signalised intersections and vehicle counting.

Advantages of Inductive loop detectors: low cost, low power consumption and high accuracy.

Disadvantages of Inductive loops: poor detection of small vehicles, damaged by road deterioration or heavy vehicles, major disruption to traffic during installation, sensitivity to temperature fluctuations, affected by metallic road construction materials and high risk of the loop and feeder cable theft.

Piezoelectric

Piezoelectric sensors generate a voltage when pressure is applied by vehicles passing over the piezoelectric material. Piezoelectric sensors are used for counting, speed measurement and vehicle classification.

Advantages of Piezoelectric sensors: low power consumption and high accuracy.

Disadvantages of Piezoelectric sensors: detection can be affected by temperature changes, damaged by road deterioration and major disruption to traffic during installation.

Magnetic sensor

A Magnetic sensor measures a disturbance in the earth's magnetic field, created by a metallic vehicle near to the sensor. Magnetic sensors are commonly used as vehicle detection at signalised intersections, vehicle counting and Inductive loop replacement.

Advantages of a Magnetic sensor: high accuracy, quick to install, low power consumption, long service life, wireless technology and low operating cost.

Disadvantages of a Magnetic sensor: high initial cost, minor disruption to traffic during installation.

Pneumatic road tube

A Pneumatic road tube measures a change in air pressure within the tube as a vehicle's wheels pass over the tube. Pneumatic road tubes are mostly used for short term counting.

Advantages of a Pneumatic road tube: low cost, quick to install and low power consumption.

Disadvantages of a Pneumatic road tube: affected by temperature variations, can be easily vandalised or broken by heavy vehicles and minor disruption to traffic during installation.

Video

Video detection systems analyse the image, looking for changes in the pixel values to determine if there is a vehicle to be detected. Video detection also includes thermal image detection systems. Video detection systems are used at intersection to detected vehicles, for data collection on highways and automated incident detection on highways and in tunnels.

Advantages of video detection: quick to install, very reliable, video monitoring, flexible setup, optional uni-directional operation and no disruption to traffic during installation.

Disadvantages of video detection: high initial cost and detection accuracy affected by occlusion.

Radar

Radar detection unit projects microwave radar waves towards the roadway, and listen if any waves are reflected back. Based on the reflections the unit receives back it is able to determine if there is a vehicle or not. Radar systems are used to count, measure speed and classify vehicles on highways and approaching intersections.

Advantages of Radar detection: performs well in all weather conditions, quick to install, accurate speed measurement, flexible setup, optional uni-directional operation and no disruption to traffic during installation.

Disadvantages of Radar detection: detection accuracy affected by occlusion, decreased counting accuracy with slow moving traffic and some radar units can only detect moving vehicles.

Ultrasonic

Ultrasonic sensors transmit high frequency sound waves and listen to how quickly the waves bounce back. The sensor is able to determine if a vehicle is present when the waves bounce back quicker than normal. Ultrasonic sensors can be used to measure vehicle speed and are also widely used in parking applications.

Advantages of Ultrasonic sensors: quick to install, very reliable, optional uni-directional operation and no disruption to traffic during installation.

Disadvantages of Ultrasonic sensors: high initial cost and detection accuracy affected by occlusion, temperature fluctuations and wind noise.

Infrared

Active Infrared detectors emit light in the infrared spectrum, and measure how much of the emitted light is reflected back to determine if a vehicle is present in the view of the sensor. Passive infrared detectors do not emit any infrared light, they only measure the levels of infrared light emitted by vehicles to determine if a vehicle is present or not. Infrared detectors are used to detect presence of vehicles at intersections, counting, speed measurement and classification.

Advantages of Infrared detection: quick to install, very reliable, optional uni-directional operation and no disruption to traffic during installation.

Disadvantages of Infrared detection: high initial cost, detection accuracy affected by occlusion and detection influenced by poor weather conditions.

Mobile tracking

Mobile tracking is a relatively new field of detection. Mobile tracking make use of mobile devices such as vehicle trackers, mobile phones and tablets. There are two ways in which a mobile tracking system works: the devices can transmit their location to a central system or receive unit are placed alongside the road to detect Bluetooth or Wi-Fi signals from the devices.

Advantages of Mobile Tracking: potential for a wide variety of applications, no disruption to traffic during installation and detailed statistics data collection available.

Disadvantages of Mobile Tracking: still requires further development, system may be vulnerable to cyber-attacks and delay in the communications infrastructure and processing may limit real time application.

APPLICATIONS OF DETECTION

In the realm of detection there are many different applications, each application has its own unique set of criteria. The choice of detection technology depends largely on the strengths and weaknesses of a particular technology.

Data collection

As data collection is often conducted on highways and arterials. Inductive loops, Piezoelectric, Radar and Video detection technologies are appropriate technologies.

Incident detection

Incident detection requires coverage of a large area, video detection is the best technology for this application, and it can also be linked to recording equipment to capture useful evidence of incident.

Queue detection

Queue detection applications depend on the flexibility of detectors, and built in intelligent features of the detectors. Video, Radar and Magnetic are good technologies to use in this application.

Stop line and Advance presence detection
At signalised intersections there is a need to consistently detect the presence of all vehicle types, without false detection. Inductive loop, Video, Radar and Magnetic detectors are suitable, video and radar are favoured as there is no disruption to traffic during installation.

Adaptive control
The nature of Adaptive control requires detection based on a standard Inductive loop. Therefore Inductive loop, Video, Magnetic and Mobile tracking have proven to work well with Adaptive control systems.

Dilemma Zone detection
For safety reasons dilemma zone detection is gaining popularity. Dilemma zone detection is used to allow approaching vehicles to safely enter or clear an intersection before the appearance of Amber and Red signals. Magnetic and Video/Radar combination technologies, with an on board dilemma zone algorithm, offer an effective solution for Dilemma zone detection

Pedestrian detection
For safety reasons it is extremely important to detect pedestrian. Conventional push buttons and capacitive sensors are good detectors. However all pedestrians must choose to interact with the detector, which is not the case in many instances. Radar, Standard video detection and Video detection using thermal imaging provide excellent detection and require no user interaction

Bicycle detection
This is a very tough form of detection, as bicycles are small objects with little or no metal. Inductive loops are not good at detecting modern bicycles. Technologies that are good at detecting bicycles are Radar, Video detection using thermal imaging.

Over speed detection
Reliable detection of vehicle traveling above a specific speed is critically important for safety on our roads. Piezoelectric, Radar and Magnetic detectors provide accurate and reliable over speed detection.

Bus priority
In order for public transport to become a success, it is necessary to be able to detect busses as the travel along the designated routes. This detection can be used to optimise signal timings and provide travel information to passengers on the bus and waiting at the bus stops. Video detection and Mobile tracking are two technologies which are useful at detecting busses.

Travel time calculation
This is an application of detection which is relatively new, and still developing. By identifying a specific vehicle at point A in the network and then measuring how long that vehicle takes to arrive at point B in the network, an approximate travel can be calculated and displayed to vehicles approaching point A. Technologies which can be used for travel time calculation are Magnetic, Video and Mobile tracking.

ACCURACY OF DETECTION

There are two distinct areas in which vehicle detection is widely used: Highways or arterials where traffic is mostly free flowing and urban intersections where traffic is often slow moving or stopped at times. Each of these areas will experience differences in detection accuracy due to a range of different factors.

To date many detection accuracy studies have been conducted worldwide on highways, where speed and volume are the key evaluation criteria. Fewer studies have been conducted at intersections, where criteria other than speed and volume accuracy should be used to determine successful operation of a detector.

The tables shown below list the overall accuracy of each detection technology based on results from local and foreign trials.

Table 1: Detection Accuracy for Highways

Detection technology	Accuracy
Inductive loop	99.3%
Pneumatic road tube	99.4%
Piezoelectric	99.9%
Video	95.6%
Magnetic	96.9%
Radar	97.8%
Infrared	95.5%

Table 2: Detection Accuracy for Intersections

Detection technology	Accuracy
Inductive loop	97.9%
Magnetic	96.4%
Video	95.5%
Radar	96.0%
Infrared	92.0%

Most of these studies conclude that intrusive technologies, such as inductive loops, provide more accurate data than non-intrusive technologies. However these are short term studies, the test duration varying from 24 hours to 1 year. Long term studies may prove that non-intrusive technologies are more accurate, as they have proven to be more reliable than intrusive technologies. A long term study should ideally be a minimum of 3 years.

BENEFIT-COST RATIO

The key benefit, of a non-intrusive detection system, is highlighted in the amount of work required during the installation. Intrusive system installations often require extensive trenching, cabling and reinstatement. The impact of this installation work is: longer installation times, disruption to traffic flows and larger installation teams. In comparison non-intrusive installations are typically completed by smaller installation teams, in half the time of an intrusive installation with no disruption to traffic.

An important advantage of non-intrusive detection is the extra features. The most important feature, which is available in most non-intrusive detectors, is the capability of a single detector unit to cover multiple lanes. When multiple lane functionality is taken into consideration in determining the detection cost per lane, non-intrusive detection becomes very affordable.

It is highly recommended that all the features of a specific detector unit are analysed and understood, before a specific detector is chosen for deployment. Many detectors have their own set of features and there are also subtle differences between the features and performance of detector units from different manufacturers. The functionality of an entry level detector unit can differ dramatically from the functionality of a mid or high level unit.

When choosing a detection system, the initial cost of the system is often the only factor which is taken into account. Most non-intrusive systems have a higher initial cost. When the life time operating cost of a system is taken into account, non-intrusive systems are on a par and sometimes even cheaper than intrusive systems.

Table 3: Benefit-Cost Ratio for intersection technologies

Inductive Loop	Magnetic	Radar	Video
0.8	1.1	1.3	1.4

The benefit cost ratio is calculated by dividing total added value of benefits: multi-lane, remote monitoring, reliability and life span; by the total capital and operating expenditure.

INFRASTRUCTURE AND SYSTEM REQUIREMENTS

During the planning of a detection system, it is important to consider what external equipment is required by the detection system, and whether or not the detection system has the ability to be linked to another system.

Questions which should always be asked are: What power supply does the detection system require? Does the installation site have a power supply available? How much power does the system consume? Are alternative energy sources, such as wind or solar power, an option? What type of communication infrastructure is available at the site: ADSL, Fibre Optic, Mobile or Wi-Fi?

Remote management of a detection system can provide extra functionality, and makes it quick to gather data from remote locations. It is important to understand whether or not the chosen detection system is able to operate as a standalone unit, or if it requires a backend server system to provide full functionality.

Most modern detection systems have the facilities to be monitored remotely. Although remote management options may be out of the scope of an initial project, they can be made available for future system enhancement.

ENVIRONMENTAL INFLUENCES

Various environmental factors influence the choice of detection technology: weather, road surface, incidents, end user, maintenance, future planning, vandalism and theft

Weather
Extreme weather conditions are an unavoidable reality; these conditions provide real challenges for all detection technologies. Extreme high and low temperatures for example affect the operation of Inductive loops, causing them to miss vehicles or generate false detections. Heavy rain can cause video detection systems to miss vehicles, when the field of view is impaired.

Road surface
If the road surface is in poor condition, or is likely to be resurfaced in the immediate future. It would not be a good decision to install an Invasive detection technology. Certain road surfaces, such as gravel, reinforced concrete or bridge may prevent the installation of intrusive technologies entirely. In these cases a non-intrusive technology would be the best choice.

Incidents
There are many sections of road in South Africa which are known high incident zones. When choosing a detection technology which will be used at these zones, the benefit of video can provide an additional layer of functionality not available in any other technology.

End user
The skill and abilities of the end user must be taken into account when choosing the appropriate detection technology. If the end user does not have the skills required to use the detection system, then extensive training will be required. In some instances there may not even be a person available to perform the role of the end user.

Maintenance
Technical support staff must be available to maintain any detection system, and must have all of the equipment and tools required to perform maintenance of the detection system. If this support is not in place then the detection system will become ineffective.

Future planning
When designing a detection system for a particular application, it is advisable to look at the future planning for the road and infrastructure in the area. For example a detection system may be designed and deployed to cover a two lane road, six months after the installation it is decided that the road should be increased to 3 lanes to cater for an increase in traffic. If future planning was taken into account the system installation could be delayed or a flexible non-intrusive system chosen.

Vandalism and Theft
Due to ever increasing rates of theft and vandalism it is necessary to take care when choosing a detection system for a specific location. For example inductive loop detectors, which are made mostly of copper wire, are very attractive to thieves due to the scrap value of copper. Inductive loops should be avoided in areas that are at risk to copper theft.

In areas at risk of vandalism, detection equipment should be installed in such a way as to minimise the risk of it being vandalised. Mounting equipment in secure cabinets or on high poles are two methods of reducing the risk of vandalism. Video detection is often a good choice in these areas, as it acts as a deterrent for potential criminal activities.

CONCLUSIONS

Whether using non-intrusive or intrusive technologies, it is important to understand all the strengths and weaknesses of each detection technology. This ensures that an informed decision is made. The strength of a specific technology can help solve critical problems and improve conditions in the transportation network.

Each detection technology has its own unique strengths; there is no single technology or product which is suitable for all applications, the correct technology must be chosen to match the application.

Speed and volume accuracy is a good measure for detectors on highways; however this accuracy does not prove that the detector will operate well at intersections.

Non-intrusive installations are much quicker, require smaller installation teams and cause no disruption to traffic.

Long term studies should be conducted as long term operation results will favour non-intrusive detection technologies as they are more reliable.

Life time cost of detection systems should be taken into account when deciding which detection system to use as the benefits of non-intrusive technologies outweigh the costs.

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