Idris goes to the tolls

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Shadow tolling, as pioneered by the UK Private Finance Initiative, provides a ready mechanism for quasi-private highway provision. Count accuracy, however, is the challenge to successful operation. A new technique to enhance loop detectors for high accuracy counting and classification, in both free-flow and stopped traffic, offers exciting possibilities for such tolling operations.

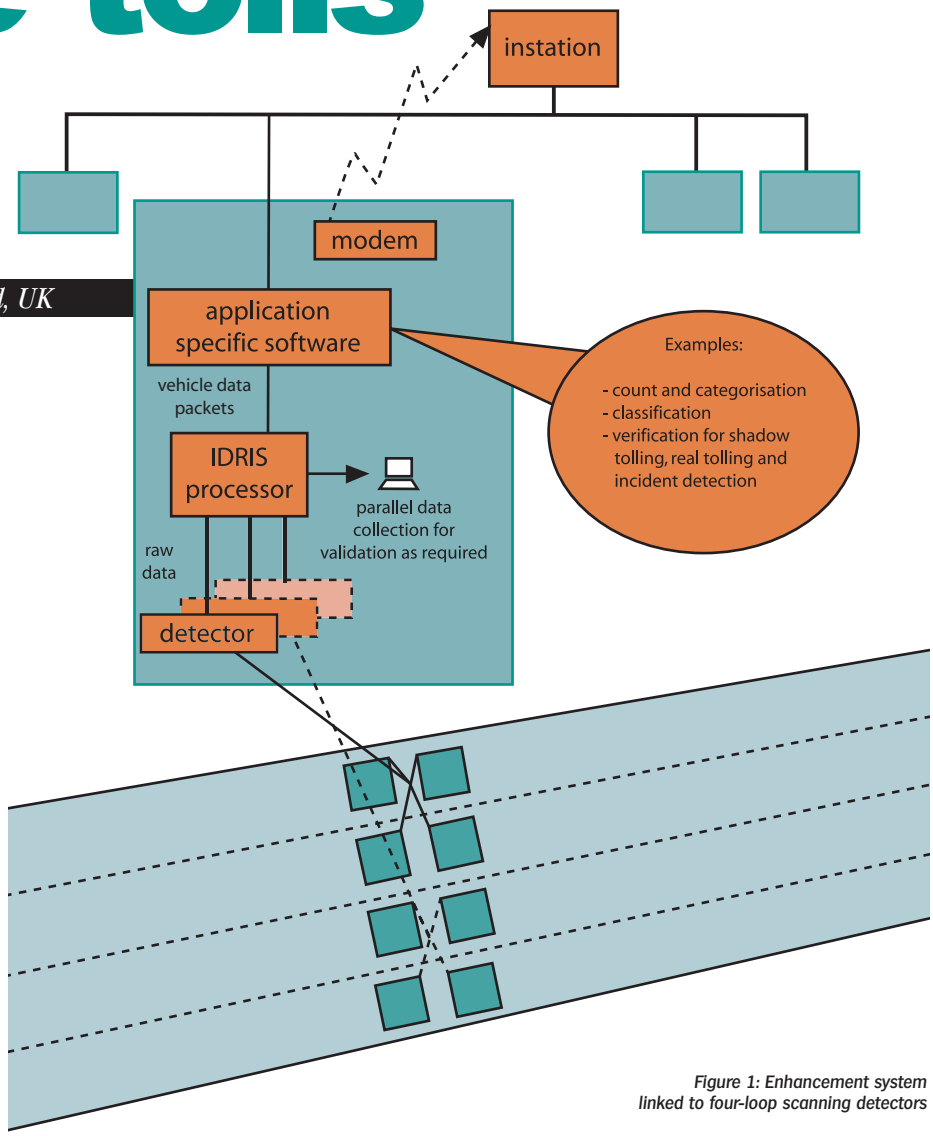

Figure 1: Enhancement system linked to four-loop scanning detectors

In the traffic world, the direct relationship between revenue and its method of collection causes closest scrutiny and generates loudest debate (at least here in the UM) when the word 'tolling' is uttered. Road users want value for money in terms of smooth and efficient journeys, good rest facilities, and consistent traffic information. Road owners and operators want value for money in terms of maximised profit and/or minimal costs.

Consequently, the importance of ensuring that every vehicle is charged correctly for its class, that no vehicles are missed, and that no error or fraud occurs at the point of detection, is heightened.

In the UK, as part of its Private Finance Initiative, the government has let contracts to private consortia for several Design, Build, Finance and Operate (DBFO) road schemes. Under these, the road operator undertakes to maintain and operate a particular stretch of trunk road, perhaps including motorway, and in return receives revenue from the Treasury dependent upon the number of vehicles in each of two categories.

This is known as shadow tolling, as the road user doesn't pay for road usage: at least, only indirectly via general taxation. Again, the need for accurate information is paramount, as only a small percentage error in vehicle count or categorisation could result in a large over or under-payment when multiplied by several thousands of vehicles over days, weeks or months.

Against this background, a breakthrough has been made in acquiring accurate vehicle data, which has enormous implications for both tolling and shadow tolling. Developed

by consultants WS Atkins and Diamond Consulting Services as part of their Idris incident detection work, techniques now exist to enhance the output of a standard vehicle detector so that it can meet all these challenges, at any point on a road equipped for tolling.

The enhancement techniques are embodied in several algorithms designed for use in roadside vehicle detection equipment, such as outstations for shadow tolling and full tolling, classifiers, census/survey apparatus, and outstations for incident detection systems - indeed, any application where high quality detailed vehicle data is required.

A patent for the Idris detector enhancement techniques is pending, and the enhancement technology has been licensed to Peek Traffic Ltd, a world leader in detection technology.

Table 1: Count accuracy

Test Site	No Lanes	Congestion		Free-Flow	
		No. of Vehicles	Error	No. of Vehicles	Errors
A55 North Wales	2	N/A	N/A	>10,000	0
A34 Winchester	2	N/A	N/A	>20,000	0
M25 West London	4	23,043	3	51,591	2

Table 2: Comparison of actual accuracy against specification

	Specification		Actual	
Congestion	1 in 500	0.2%	3 in 23,000	0.013%
Free-flow	1 in 10,000	0.01%	2 in 51,500	0.004%

TRIAL SYSTEM

Inductive loops were chosen as the technology on which to base a system incorporating the enhancement techniques, in order to test and validate them. The generic form is shown in Figure 1. This system uses two rectangular loops per lane, configured as a speed pair. They can take a value from 2m to 2.5m in the direction of travel with a gap of about 2m, and be spaced between 1.5m and 2.5m across the carriageway.

A number of standard four-loop scanning detectors with modified output are connected into the Idris processor, where one detector is required for every two lanes, and each carriageway requires one algorithm in the processor. For example, on a 10-lane highway (five in each direction), three detectors would be connected to each algorithm and there would be one algorithm for each carriageway.

Initial trials with the prototype system took place at Peek Traffic's test site on the A34, a two-lane dual carriageway of free-flowing traffic. Having proved the prototype, two outstations were prepared for thorough and exhaustive trials on a congested site - the most difficult situation from which to collect accurate vehicle data and one which other systems cannot handle.

The UK Highways Agency cooperated in traffic measurement trials conducted on one of its busiest stretches of motorway, the M25 between junctions 15 (the M4) and 16 (the M40).

The site chosen was a standard UK MIDAS loop site connected to a trial outstation, suitably modified to enable the collection of large amounts of low-level data. The site was adjacent to an overbridge, allowing simultaneous collection of video data for comparison purposes. The trial data included heavily congested but moving traffic, stop-start

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One of the key features is that accurate data is now available in congested traffic, whether slow moving, stop-start, or stationary. Even during congestion, all vehicles can be identified individually, irrespective of their position across the carriageway or relative to other vehicles.

The benefits are that when tailgating occurs across a site, the two vehicles are separated correctly, each with its own data. One mile of solid traffic is no longer translated wrongly into one ridiculously long vehicle, but each one is counted and classified.

The techniques can be applied regardless of the type of point detection sensor used, and they can handle any number of lanes. For the first time, vehicles can be classified without loss of accuracy, using a single detection technology; inductive loops can be used just as they are, without any cross-checking or duplicate detection by a second sensor.

No change is required to existing tried and tested equipment, as the techniques will work with proprietary scanning loop detectors and many existing loop installations.

Other applications of the techniques

Vehicle classification - the ability to measure vehicle length independently of vehicle position and speed, combined with the vast improvement in consistency and accuracy, enables use of narrower bands to give more detailed categorisation for tolling and census information.

Incident detection - the by improving the quality of input data to such systems at the outstation level, the benefit is seen in the reduction of false alarms at the incident detection in congestion is easier to identify.

Census and survey - the reliability and range of traffic statistics is increased, enabling more complex combinations of data using time of day, vehicle classification, and speed and lane usage to provide the complete picture of road usage for monitoring and planning purposes.

Traffic management - the range of data available has been extended so managers have more accurate information on which to base their planned maintenance activities, incident and emergency responses, and day-to-day activities.

traffic and free-flowing traffic. The trials concentrated on vehicle count and length, speed being considered a by product as far as tolling is concerned, and relatively easily produced. The following traffic manoeuvres were identified, using validation techniques described below, and subsequently confirmed by video:

- Vehicles straddling two lanes;
- Vehicles stationary over the site for up to a minute;
- Tailgating in congestion and in free-flow;
- Changing lane at 45 degrees in congestion over the loop site.

After validation, the results confirmed errors of less than the specified one in 10,000 during free flow situations and significantly less than the specified one in 500 (excluding motorcyclists) during heavily congested traffic (Tables 1 and 2). In addition, the vehicle data was validated manually against a three-hour video tape. It should be noted that to validate the tape took more than 30 hours; it was time-consuming, expensive and capable of repeated human errors, and it is unlikely to provide a long-term repeatable validation process.

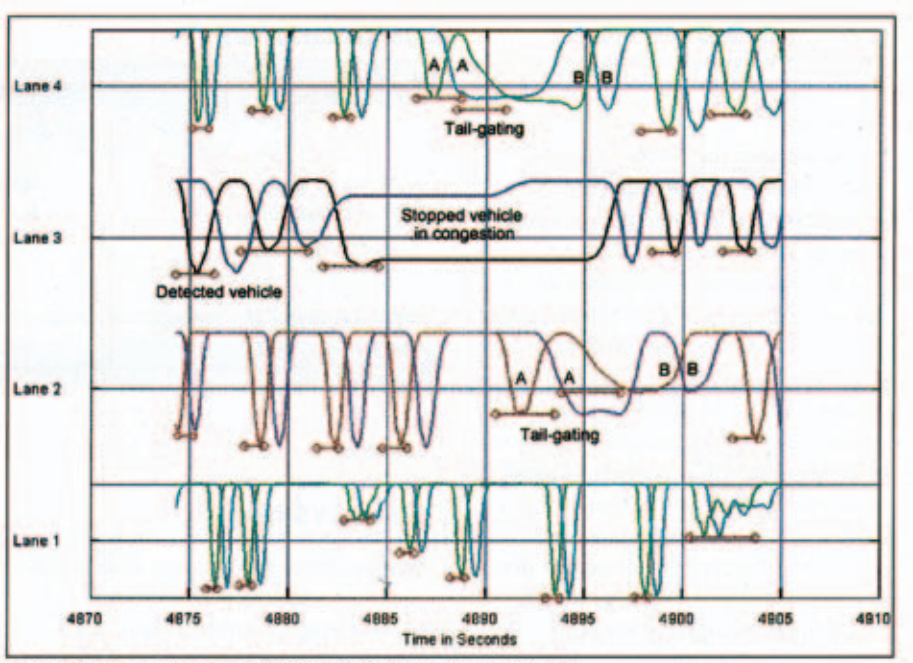

Figure 2: M25 junction 15 to 16 (site ref. 4985A) – stop-start traffic

Summary of features

- Vehicle count accuracy has only one in 25,000 error in free-flowing traffic, measured over any time period - an increase of more than two orders of magnitude from previous detector limits. In congestion, the count accuracy is one in 7,500 - simply not achievable previously, as all other known methods break down under such conditions.
- Count accuracy is improved by discrimination between signal and overspill into the adjacent lane and a real vehicle alongside. Also, two similar vehicles in adjacent lanes are different form one vehicle straddling two lanes.
- Vehicle length is measured accurately and consistency at all speeds even in congestion, and regardless of the vehicle's lateral position in relation to the sensor site.
- Vehicle speed is measured accurately and consistency for all speeds, regardless of the vehicle's lateral position in relation to the sensor site. The speed measurement accuracy is reduced when only one loop of the pair is operational , thus giving the highway authority plenty of time to plan maintenance and traffic management in the most cost-effective manner without loss of data.
- Accuracy of vehicle speed and length measurements is not restricted by previous limitations imposed by the scan rate of the detector
- Tailgating vehicles can be identified and discriminated from towing vehicle in all conditions, including congestion.

DATA ANALYSIS

During two weeks, more than 50 hours of data were collected, which included the full range of conditions from freeflowing to congested traffic on both carriageways and across all four lanes. The continuous traffic data was recorded over a period of hours from three sites for validation purposes.

The sites were a two-lane dual carriageway in North Wales, a two-lane dual carriageway section of the A34 near Winchester (south bound) and four lanes of the M25 south bound between junctions 15 and 16 (M4 & M40).

Two of the sites provided 100 per cent error-free results. Over a continuous 24 hour period, traffic data collected from the North Wales site recorded more than 10,000 vehicles without any count errors being found. Similar results were obtained from the A34 near Winchester, again, 24 hours of continuous traffic data was collected with 20,000 vehicles recorded and no errors found.

Approximately 12 hours of continuous traffic data was recorded on 10 May 1996 from 6.30am to 3.00pm for the M25 (south bound). Analysis of this data showed that until 1500 the traffic was relatively free-flowing with 51,591 vehicles recorded. Over this period there was a count error of two (two vehicles were added).

The M25 was then in and out of congestion, including stationary traffic, from 3.30pm to 7.15pm during which a total of 23,043 vehicles was recorded. There were three count errors, where one vehicle was missed and two were added. There were also four length errors, three of which were cars classed as long vehicles.

VALIDATION PROCESS

Experience has shown that using graphical presentations of analogue loop signals for count validation is superior in both speed and accuracy to examination of video data, and much superior in terms of accuracy to roadside enumeration. This is particularly evident in multi-lane congested conditions where obscuration and foreshortening become a problem. The trials were conducted by experienced people, and visual examination of a graphical presentation of the loop detector data enabled them to differentiate reliably between a straddling vehicle and two vehicles side by side, and between towing and tailgating situations.

It is also a straightforward task to count correctly vehicles passing over a site, even when some are stationary for several seconds or more over the detection site, or

when vehicles change lanes directly over the site.

Data examination for count validation purposes is particularly effective when the analogue loop signals and the processed output from the outstation are superimposed on a single graph. With this technique it is possible to see immediately when there is a discrepancy between what the outstation has detected and every change in the loop characteristics shown by the analogue loop signal.

Experience to date is that enumeration errors are virtually absent when this technique is used (Figure 2).

The M25 trials demonstrated the enhancement techniques in action, and the graph in Figure 2 is an example of the results obtained and of the validation procedure described here. The processed output is shown by the red bar, one bar for each vehicle (length of the bar is irrelevant), and the raw detector output is shown for the loop pair in each lane. Note that:

- In lane 3, a vehicle has stopped for about 15 seconds over one of the loops - its length is still measured accurately even though it is stationary;
- In lane 2, vehicle A is stationary over the front loop with vehicle B about 2m behind and stationary over the back loop - both vehicles are identified correctly and categorised as tailgating rather than towing;
- In lane 4, different vehicles are tailgating as in lane 2, but this time only 1m apart - again, both are identified and categorised correctly.

"The M25 was then in and out of congestion, including stationary traffic, from 1530 to 1915 during which a total of 23,043 vehicles was recorded. There were three count errors"

TRIAL CONCLUSIONS

The ability to count accurately and to classify vehicles by length even when traffic is stop-start and crawling has huge benefits for the tolling market as part of an integrated tolling system.

If toll booths are used, the Idris techniques can be used at an upstream site to determine the toll due, and/or at a downstream site to audit that the correct toll is paid to either the operator or the machine.

The new UK DBFO road schemes require solutions to some difficult problems in terms of performance, accuracy and reliability of shadow tolling equipment. The vehicle data collection aspects of the shadow tolling equipment are subject to a very demanding specification, which can be met now.

Peck Traffic supplies an outstation capable of meeting the full specification by combining all the known advantages of its inductive loop detector with the enhancement techniques.