TRANSPORT RESEARCH LABORATORY

TRL REPORT 217

TRAFFIC CONGESTION INCIDENT DETECTION

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Project:	**Traffic Congestion Incident Detection (UG18)**

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First Published 1996
ISSN 0968-4107

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EXECUTIVE SUMMARY

This report describes work carried out for the Driver Information Traffic Management Division of the Department of Transport. The research was completed in conjunction with European Community DRIVE 2 projects HERMES and ROMANSE. The report is in two sections and describes methods to detect traffic incidents and strategies to efficiently tackle the congestion caused by traffic incidents.

Congestion in urban areas is a regular occurrence causing delay and increasing pollution. By monitoring traffic conditions it may be possible to gain an understanding of what causes congestion. Congestion is often caused by traffic incidents. If such incidents could be quickly detected, preventive measures could be quickly taken to stop the congestion spreading further. Drivers can be warned of congestion and incidents using variable message signs (VMS). These signs can display text messages warning of incidents and congestion. The behavioural response of drivers to such messages is not widely understood. If VMS give drivers information, care must be taken to ensure that this does not make the overall traffic problem worse.

This report describes the ASTRID/INGRID system which is used to monitor traffic conditions and detect traffic incidents. The ASTRID database system was originally developed to collect data on flow, journey time, delay and congestion from the SCOOT traffic control system and store it for later retrieval and analysis. The system has now been enhanced to accept data from non-SCOOT sources and to operate on-line. It has been integrated with INGRID, which it provides with historic information on flow and congestion.

INGRID is a real-time automatic incident detection system using data from the SCOOT urban traffic control system in combination with historic data provided by ASTRID. ASTRID and INGRID have been installed in Southampton as part of the SCOPE-ROMANSE project where they have been comprehensively evaluated using data collected over a seven month period. Final results are given in this report and recommendations made as to the optimum incident detection method.

TRAFFIC CONGESTION INCIDENT DETECTION

ABSTRACT

Congestion in urban areas is often caused by traffic incidents. If such incidents could be quickly detected, preventive measures could be rapidly taken. Drivers can be warned of congestion and incidents using variable message signs. The effect of providing such messages is not widely understood.

A system called ASTRID/INGRID has been developed to monitor traffic conditions and detect traffic incidents. ASTRID is an on-line historic database which can store information collected from the SCOOT traffic control system. INGRID is a real-time automatic incident detection system using data from SCOOT and ASTRID. ASTRID and INGRID have been installed in Southampton. An evaluation of INGRID suggests that severe incidents can be detected after 5.5 minutes with a 100% detection rate and 0.5 unconfirmed incident messages per hour.

1. INTRODUCTION

Congestion in urban areas is an everyday occurrence and is very wasteful in resources. In many cases the cause of this congestion is due to traffic incidents, for example accidents, vehicle breakdowns and slow moving vehicles. If such incidents could be quickly detected then it may be possible to take preventive action to limit the spread of further congestion.

The ASTRID database system has been developed to provide a historical background of traffic conditions. This system continuously monitors and stores traffic conditions for later retrieval and analysis. This system can also act as a reference against which to compare current traffic conditions.

Under the project H5/62 'Traffic Information and Congestion' and as part of the DRIVE 1 project MONICA, various methods for the automatic detection of incidents were investigated. Adaptive UTC systems, such as SCOOT, were found to provide easily accessible information on current traffic conditions. Such systems have a network wide layout of detectors allowing a large amount of data to be obtained without large additional costs.

The work under H5/62 lead to the development of four separate incident detection algorithms. Three used historical data to provide a comparison against current traffic conditions. The fourth algorithm solely used a smoothed value of current traffic conditions. All four algorithms were tested experimentally to measure the effectiveness of the detection systems.

Under UG18 and in conjunction with the DRIVE 2 project HERMES, the INGRID automatic incident detection system has been developed from the MONICA experimental work. INGRID uses all four algorithms developed in MONICA together with new algorithms to measure the severity and confidence of any detected incident.

INGRID and ASTRID have been combined to form a traffic monitoring system. This system has been installed in Southampton in conjunction with the SCOPE-ROMANSE project and a comprehensive evaluation has been carried out.

The ASTRID system has also been installed in London in conjunction with the EC DRIVE project LLAMD-APPLE where it is being used to provide up to date journey time information for a proposed route guidance system.

2. EXPECTED IMPACTS OF URBAN AUTOMATIC INCIDENT DETECTION

Incident detection accelerates the detection of incidents. It will only realise its full benefit if this results in rapid remedial action; this might include breakdown trucks on permanent standby (as used at motorway roadworks), dissemination of incident details to motorists using radio data systems or variable message signs, or action to change traffic signal timings. Consequently, it is important to consider an automatic incident detection (AID) system as the detection part of an automatic or non-automatic traffic incident management system.

The expected benefits from AID are:-

- Improved efficiency and reduced congestion.
- Mitigating environmental impact: there is likely to be a small, second order, reduction in emissions if the system reduces congestion.
- Urban incident detection is unlikely to change accident risk. There could be an impact on safety by improving the access of emergency services.
- A greater awareness of network conditions should enable managers to operate more rationally and effectively.

3. TRAFFIC MONITORING

Automatic and continuous monitoring of traffic is performed using ASTRID. The ASTRID database system was originally designed to receive traffic information produced by SCOOT, and then process and store it for later retrieval and analysis.

3.1 ASTRID DATABASE

The ASTRID data is derived from a special format of output from SCOOT which produces compressed data every minute. This format is not a standard output from SCOOT and requires modifications by the company supplying the SCOOT system. The data is transferred from the SCOOT computer to ASTRID at regular intervals, then processed to reduce the size of data files and stored in a form suitable for access by the database programs.

Data displayed by ASTRID are either collected directly from SCOOT or calculated from stored information. The user can access and display both types of data in the same way.

The following are the basic data items *collected directly* from SCOOT messages.

Flow:	The flow in vehicles per hour arriving at a stopline, as modelled by SCOOT.
Delay:	The total delay in vehicle hours per hour.
Congestion:	The percentage of four second intervals when a detector is occupied by traffic. This value is independent of the SCOOT model.

Other SCOOT data, such as degree of saturation on a link or stage lengths can also be collected.

The following data is derived from information provide by SCOOT:

Vehicle delay:	Mean delay per vehicle estimated from SCOOT model.
Journey time:	Journey time is obtained by adding vehicle delay to the pre-measured 'cruise' time of vehicles between SCOOT detector and stopline.
Speed:	Speed is derived from link length, cruise time and vehicle delay.
Congestion index:	A congestion index is derived from vehicle delay and cruise time and indicates rising or falling levels in delay on a link.

The data is available at the level of link, node, region, area or route (a route is any predefined set of links).

ASTRID provides the following types of graph, which may also be output as tabulated data:

Profile:	Shows profiles of how the chosen data item (e.g. flow or congestion) varies throughout the day, for a particular day of the week. An example of profile data for flow on a link is given in Figure 1.
Trend:	Shows how the data item in a chosen time period has varied over a period of several months. An example of trend data for flow on a link is shown in Figure 2.

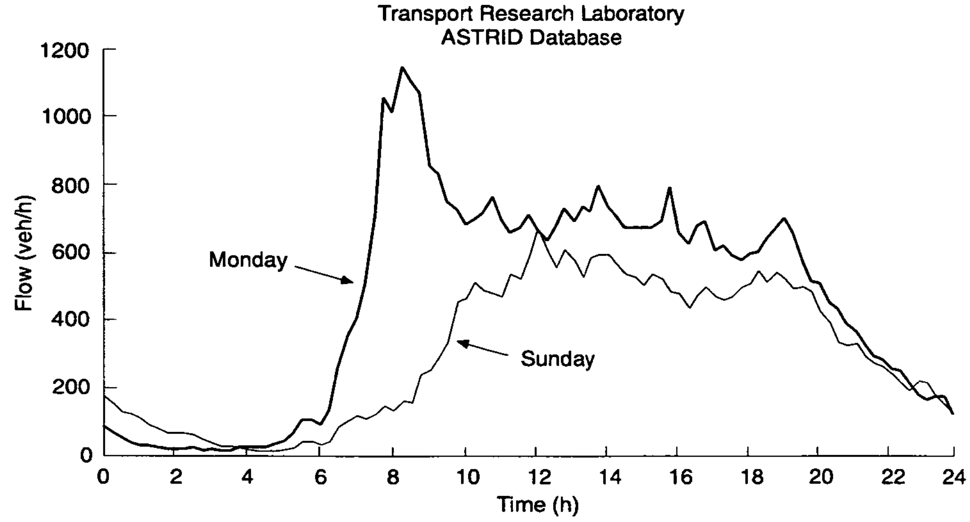

Fig.1 Shows average daily flow for a link

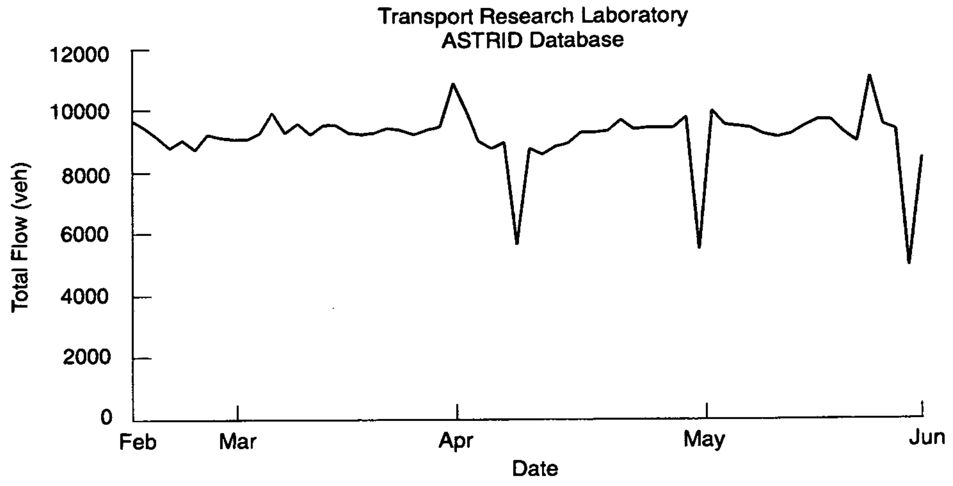

Fig.2 Shows variation of flow over a period for a link

Backup:	Shows the profile of data item for individual dates.
Max/Min:	Shows the profile for a data item for a day of the week, together with the profiles of maximum and minimum values recorded on the same day of the week.
Standard deviation:	Shows the profile together with graphs of two standard deviations above and below the profile.

3.2 ASTRID DEVELOPMENT

ASTRID has been adapted to operate on-line. This enables information on both the current state of the network and the expected state of the network based on historic data to be accessible for use by other information or incident detection systems.

4. INGRID INCIDENT DETECTION SYSTEM

4.1 BACKGROUND

Under H5/62 and as part of the DRIVE 1 project MONICA, various methods for the automatic detection of incidents were investigated. Adaptive UTC systems such as SCOOT were found to provide easily accessible information on current traffic conditions. Such systems have a network wide layout of detectors allowing a large amount of data to be obtained without large additional costs.

As part of the MONICA project, four separate incident detection algorithms were developed. Three used historical data to provide a comparison against current traffic conditions as measured by a UTC system. The fourth algorithm solely used a smoothed value of current traffic conditions. All four algorithms were tested experimentally to measure the effectiveness of the detection systems.

Under UG18 and in conjunction with the HERMES project, the INGRID automatic detection system has been developed from the MONICA experimental work. INGRID uses all four algorithms developed in MONICA together with algorithms to measure the severity and associated congestion of any detected incident. Initial work and preliminary testing of INGRID is briefly described in the following section. Full details can be found in a previous deliverable (Bretherton et al., 1993).

4.2 TOULOUSE FIELD TRIAL

During 1991, a 3 week trial was undertaken in Toulouse to provide data for the assessment of the MIDAS incident detection algorithm. The field trial took place in an area of the city were experimental testing of traffic systems was permitted. This area consisted of approximately 23 junctions with loop detectors situated at the entry to each link and also at a position 50 metres from the stopline.

An output on the status of each detector was recorded 4 times a second using a portable PC. The current stage of the traffic light cycle at each intersection was recorded by 18 on-street observers using PSION Organisers. The on-street observers also noted when, where and for what duration 'incidents' occurred e.g. parking, broken down vehicles, accidents.

The field trial was held over a total of 22 days. Observations took place each day between 14:30 and 18:00 hours. This ensured that both peak and off-peak periods were monitored. There was a break in data collection between 16:00 and 16:30 hours.

During the field trial there were 23 incidents which were classified according to:

number of links affected

degree of obstruction, congestion or exit blocking (as recorded by the on-street observers)

duration of incident

This analysis indicated that there were 15 minor incidents, 7 moderate and 1 severe incident during the field trial. It should be noted that the evaluation of the INGRID incident detection system uses a slightly different method of classifying incidents. This is because no on-street observers were available during the evaluation period.

4.3 CONCLUSION OF TOULOUSE FIELD TRIAL

An analysis of the Toulouse field trial data was completed for the MIDAS incident detection algorithm. By altering the sensitivity of the algorithm optimum settings could be found for the detection of incidents with minimal numbers of false alarms. With optimum settings MIDAS could detect the severe incident with no false alarms. By changing the sensitivity of the algorithm it could be made to also detect 6 of the 7 moderate incidents, although there was an associated increase in the number of false alarms.

4.4 SYSTEM DESIGN

Following off-line testing of INGRID the detection system was modified to accept real-time SCOOT data. For those algorithms requiring reference data, a link was made to the ASTRID traffic database. The set-up of the INGRID system is shown in Figure 3.

4.5 DESCRIPTION OF ALGORITHMS

4.5.1 'Immediate' incident detection

The 'Immediate' detection algorithm, formerly called MIDAS, (Bretherton and Bowen, 1991) is used to detect incidents immediately as they occur. This algorithm has been renamed I-Current.

The algorithm requires data on the flow and occupancy over consecutive loops to detect an incident in the road space between them. Incidents are indicated when there is a significant decrease in both flow and occupancy at the downstream detector occurring at the same time as an increase in occupancy and a decrease in flow at the upstream detector. For best results the routine requires the flow and occupancy data for each traffic signal cycle. No reference data is required for this algorithm.

4.5.2 Historical comparisons

For all SCOOT detectors in the network a daily profile of the expected cyclic flow and occupancy in each 15 minute period is stored and automatically updated in the ASTRID database. Three separate routines have been implemented which detect incidents by comparing the current traffic situation with that expected from the historic reference data in ASTRID. The algorithms use standard deviations and

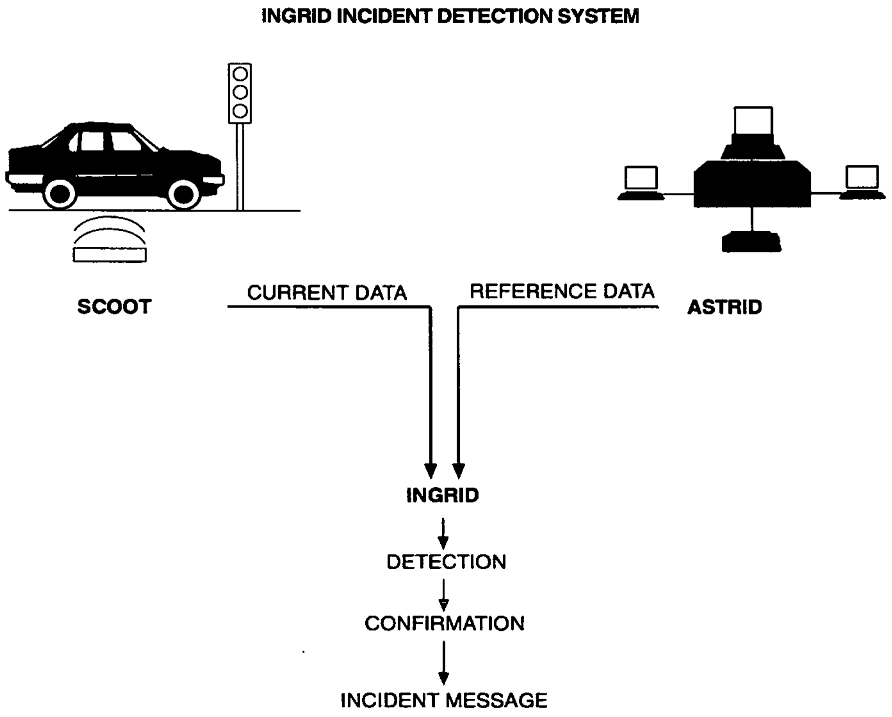

Fig.3 INGRID system set-up

mean values to determine a confidence level against which to assess the current data.

(i) The 'Slow Build Up' algorithm compares the current flow and occupancy on a detector with its corresponding historic reference data. An incident is indicated downstream of a detector when for 3 consecutive minutes there is an increase in current occupancy and a decrease in current flow outside the confidence interval of the reference data.

(ii) A variation on the Slow Build Up algorithm uses a different method of establishing the confidence interval and indicates the occurrence of an incident when the conditions are satisfied for one minute. This algorithm is named I-Reference.

(iii) The 'Regression' algorithm calculates the gradient of regression for successive cyclical occupancy counts. The current regression gradient is compared to that of the reference data and an incident is indicated when the two gradients diverge significantly.

An alternative approach would be to assess current traffic conditions against a distribution of all historic data. For example, current flow could be compared with the 85th percentile of the distribution of flows for that detector at that time. Such a method requires the ability to store a large amount data over a long period. This method is not available using current UTC technology.

4.5.3 Critical values

Each algorithm has a critical value which can be varied to alter its sensitivity. To assess which critical value provides the optimum incident detection method various investigations have been carried out. These are described later in this report. Each critical value is defined in Table 1.

TABLE 1

Algorithm	Symbol for critical value	Description
I-Current	α	Factor related to number of standard deviations away from the mean
Slow Build Up	δ	Number of standard deviations away from the mean
I-Reference	π	Number of standard deviations away from the mean
Regression	f	Factor related to divergence of occupancy gradients

4.6 SEVERITY OF A DETECTED INCIDENT

Once an incident has been detected, it is important to establish the extent to which the incident will affect traffic flow within the network, i.e. how severe is the incident. There are two main effects to be considered - the area affected by the spread of congestion due to the incident and the additional delay to vehicles travelling through the affected area.

The severity index currently deployed in INGRID considers only the first effect by indicating those detectors which are affected by an incident. The greater the severity of an incident, the larger the number of affected detectors. INGRID calculates which detectors upstream and downstream of an incident are affected. The duration of the incident is also considered.

4.6.1 Formula method

INGRID calculates the severity of an incident by utilising information on:-

- the duration of the incident
- the number of detectors affected by an incident

The minimum number of detectors to show an incident is two (one upstream and one downstream of the incident). As the duration and number of detectors involved in the incident increases, so the severity of an incident rises.

The formula used by INGRID to assess the severity, S, of an incident is,

$$S = \frac{\mathrm{Min}(d, D).\mathrm{Min}(t, T)}{D.T}.100$$

where

d = the number of detectors (upstream or downstream) affected by the incident

t = duration of incident in minutes

D = 8 detectors

T = 5 minutes

This formula gives a value between 0 and 100. Table 2 gives details of the further classification of this value.

4.6.2 Look-up table method

The severity of an incident could also be classified using a look-up table. An example is given in Table 3.

Both the formula and look-up table methods of classifying the severity of an incident have a disadvantage. Incidents

TABLE 2

Classification of incident	Minor	Moderate	Severe	Very severe
Severity, S	0-20	20-40	40-80	80+

TABLE 3

SEVERITY OF INCIDENT	Not severe	Minor	Moderate	Severe	Very severe
Duration (minutes)	0-1	2-3	4-10	10-20	20+
Number of detectors affected	2	3	3	4	5+

that occur towards the edge of the SCOOT network may have their severity under valued because part of the incident will not be near any detectors.

4.6.3 Alternative methods

Another measure of the severity of an incident would give some idea of the increase in journey time, along the link, due to an incident. Such information could be obtained by looking at the current occupancy and flow as compared with their historical counterparts. By combining this data with the time taken to traverse a link given by the ASTRID on-line database, a value could be predicted for the new journey time.

Alternatively, incidents could be displayed on a map of the network with congested links shown in one colour, lesser congested links in another colour and so on. In this way it would be easy to see how a specific incident is creating congestion over the entire network. This would be straightforward to implement as most SCOOT systems already have a congestion display mimic.

4.7 NUMBER OF DETECTORS AFFECTED

Both the algorithms for calculating the confidence and severity of a detected incident require a knowledge of the number of detectors affected. An algorithm has been developed to calculate this value.

The algorithm checks the detectors up and downstream of the incident to see if any of the four incident detection algorithms are also indicating the same incident. The algorithm uses a recursive method to examine detectors surrounding the incident until at the end of each possible route it finds a detector with normal conditions. A list of upstream and downstream detectors affected by the current incident is provided by the algorithm.

4.8 NUMBER OF ALGORITHMS SHOWING AN INCIDENT

Of the four algorithms used to detect incidents, three use significantly different methods to detect incidents. As the number of algorithms that detect an incident increases, the likelihood that a real incident is occurring rises. To calculate the confidence associated with a detected incident, INGRID requires the number of algorithms indicating an incident. An algorithm has been developed to calculate this value.

4.9 COMBINING THE INCIDENT DETECTION ALGORITHMS

All four algorithms should detect an incident and each produces a separate message. This leads to one incident having up to four different messages. The repetition of messages relating to the same incident could lead to confusion.

To overcome this problem the results of all four separate algorithms are combined by a final algorithm. This algorithm, called UNITE, also calculates the severity and confidence values associated with each incident.

When a single algorithm detects an incident, a message is added to a list of all the incidents currently occurring on the network. This message contains the following information:-

- current time and date
- the name of the detector upstream of the incident (i.e. the detector with the traffic queue over it)
- the duration, severity and confidence of the incident
- a list of affected detectors upstream of the incident
- a list of affected detectors downstream of the incident

When another incident is detected by any algorithm, a check is made to see if the incident is already listed. The check is made as follows:-

1. The new incident has associated with it a list of affected upstream and downstream detectors.
2. All these detectors are checked to see if they match detectors already present in the incident list.
3. If there is a match a new incident is not added.
4. If necessary the number of algorithms detecting the relevant incident is increased.
5. If there is no match then a new incident is added to the incident list.

For every minute the incident conditions are satisfied, the duration of the incident increases. When the incident ends, a message is given to say that the incident has cleared.

4.10 CONFIRMATION OF A DETECTED INCIDENT

Confirmation of a detected incident can be achieved in both space and time. Increased confidence that a detected incident actually exists is gained by observing the flow and occupancy on detectors surrounding the incident. On affected detectors upstream of an incident an increase in occupancy and decrease in flow is likely. On detectors downstream of an incident, a decrease in both flow and occupancy is expected.

Increased confidence that an incident has occurred is also obtained when incident conditions continue to be observed in successive time intervals. As different algorithms indicate the same incident, the confidence level associated with the incident increases.

4.11 CONFIDENCE CLASSIFICATION

A method of classifying incidents is to create a look-up table of possible incident conditions. Table 4 shows the classification method used. Immediately any one of the conditions is satisfied for a particular confidence level, the incident is set at that level. For example, an incident which is detected by 2 algorithms and affects 2 detectors would be classified as *Not Confident* for the first three minutes. Between 4 and 7 minutes it would be set as *Mildly Confident* and at 7 minutes *Confident.*

Graphically, the four classifications are represented by four regions in Figure 4.

4.12 INCIDENT DECAY TIME

In many cases an incident may fluctuate between conditions of severe congestion and free flowing traffic. This could happen in the following manner:- an incident occurs rapidly blocking the carriageway, e.g. two cars collide. Immediately, incident conditions occur and congestion builds. Traffic is still flowing freely on the opposite carriageway. The police arrive and tend to the injured. Then, to ease traffic flow, they allow alternate flow past the incident. This gives alternate conditions of congestion and free flow.

Such a scenario would give an intermittent incident message. This is because an incident is deemed to have cleared immediately incident conditions lapse. This would have consequences for the calculation of severity and confidence. In the above scenario although a severe incident would have occurred messages would indicate a series of minor/moderate incidents.

TABLE 4

Algorithms + Detectors	Time (Minutes)			
	Not Confident	Mildly Confident	Confident	Very Confident
3	1	5	10	20
4	1	4	7	13
5	1	3	5	9
6	1	2	4	6
7	1	2	3	4
8	1	2	2	3
9	1	1	2	2
10	1	1	1	1

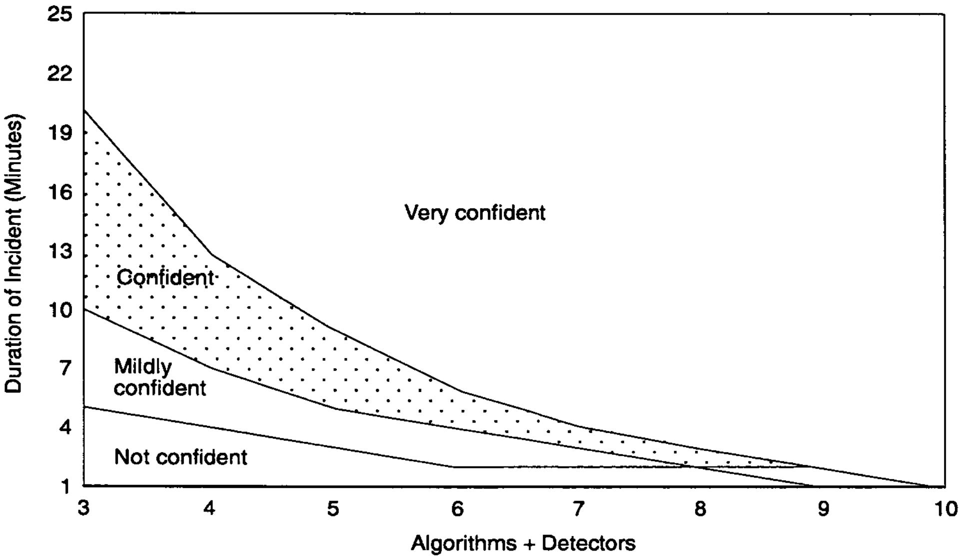

Fig.4 Regions of confidence

To overcome this problem an incident is given a decay time. Once an incident has been detected it takes 5 minutes of normal conditions before it is shown as cleared. If during this time the incident conditions resume, then the incident message continues with the previous calculated values of duration, severity and confidence. The value of 5 minutes can be altered if required.

5. APPLICATIONS

5.1 INSTALLATION OF ASTRID / INGRID IN SOUTHAMPTON

5.1.1 Background

The ASTRID/INGRID system has been installed in Southampton and integrated with the SCOOT UTC system there as part of the EC DRIVE project SCOPE-ROMANSE. The Southampton SCOOT network consists of approximately 420 detectors and 130 signalised junctions. The majority of the urban network lies bounded by the River Test and River Itchen. The main feature of the ROMANSE system is based on the provision of traffic and travel information which will enable users to make informed choices about time, mode and route for a given journey. Electronic messages, displayed both on roadside signs and through on-board vehicle systems, will alert road users to congestion and car park occupancy, and recommend alternative action. The use of the traffic network will be made more efficient by the introduction of advanced traffic signal control. Use of public transport will be encouraged by provision of passenger information and the introduction of priority measures and park-and-ride schemes. The deployment of ASTRID/INGRID within the ROMANSE traffic and traveller information system is illustrated in Figure 5.

The components within Figure 5 are:-

TTI	Traffic and travel information computer.
GIS	Geographical information system. This will display Ordnance Survey maps overlayed with traffic and travel information.
VMS	Variable message signs.
AVL/BIS	Automatic vehicle location / bus information system.
RDS/TMC	Radio data system / Traffic message channel.
SCOOT/UTC	Urban traffic control system incorporating SCOOT version 2.4. Other components with manual links (not shown in figure) may include: BBC Travel information, AA Roadwatch, closed circuit television, telephone system, British Rail travel terminal.

The function of ASTRID/INGRID within ROMANSE is to detect incidents and provide data on current traffic conditions to the travel and traffic information centre (TTIC). Having analysed this data the TTIC will then disseminate the appropriate information via a range of outlets such as Variable Message Signs, radio travel news bulletins and in-car or roadside displays. ASTRID will also provide a database of past conditions and will be used to monitor the effect of the traffic management policies being introduced. As well as data from SCOOT, ASTRID could receive data from car park occupancy detectors, UTC count detectors and the 'Trafficmaster' system. Trafficmaster is a real time traffic information system providing data on current traffic speeds to both in-car and other display units.

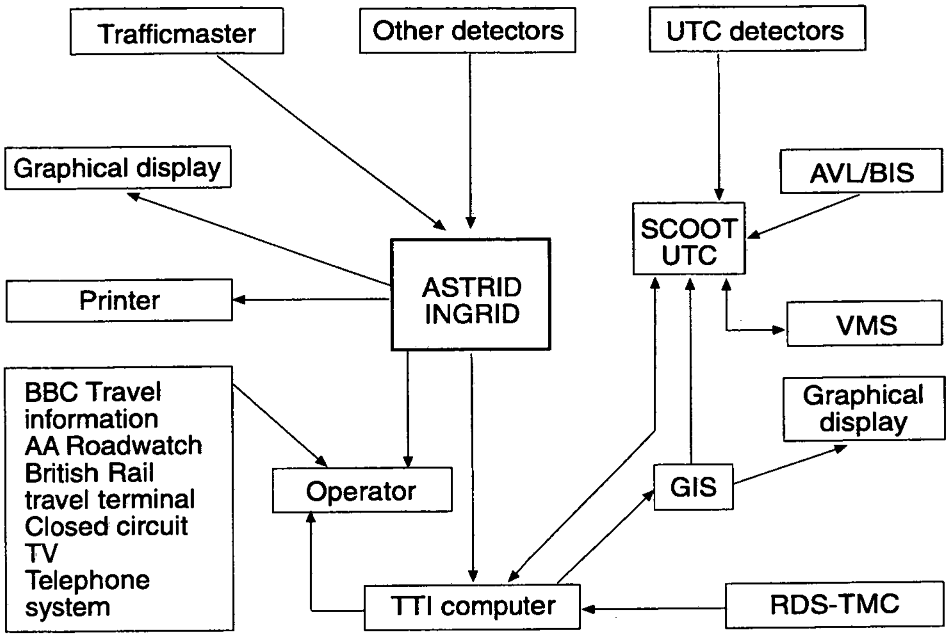

Fig.5 ROMANSE traffic and travel information system

5.2 SYSTEM ARCHITECTURE

The ASTRID/INGRID system in Southampton is based on a VAXstation 4000 VLC connected by Ethernet to the VAX 4000 SCOOT 2.4 traffic control computer. The VAXstation is a VAX VMS workstation with a colour graphics screen operating DECwindows and OSF/Motif, so the normal interface with the user is by means of a graphical user interface. The general system layout is shown in Figure 6.

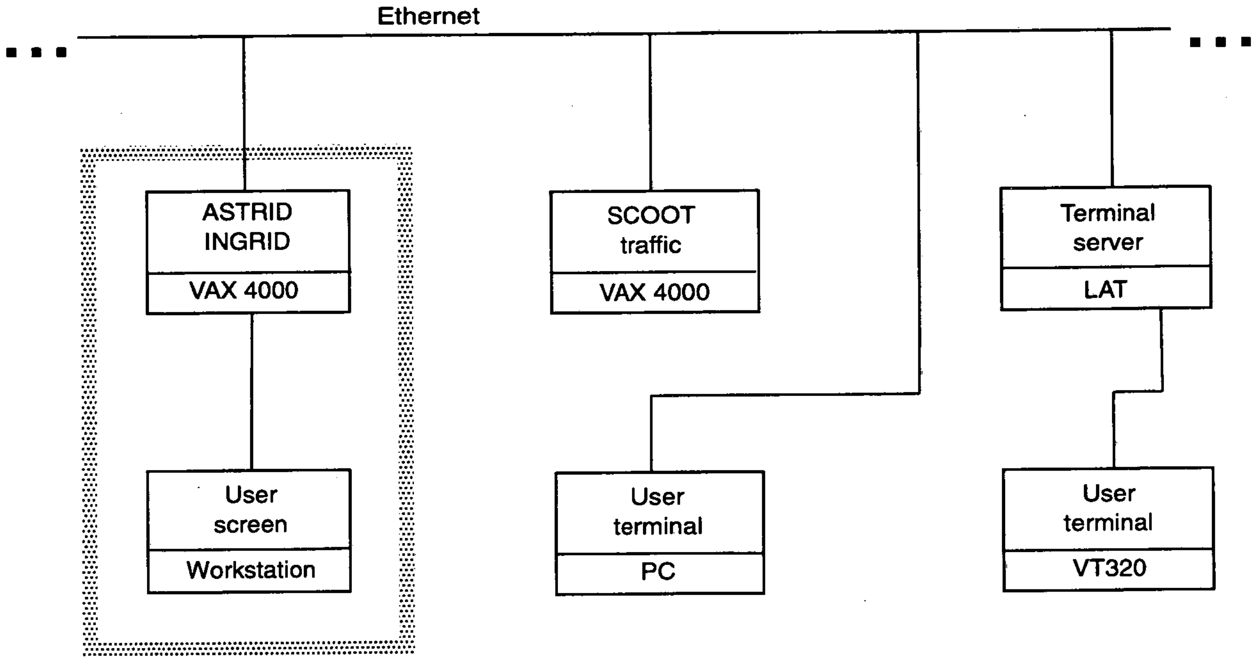

Fig. 6 General system layout

5.3 MODIFICATIONS AND ENHANCEMENTS

INGRID was installed in the Southampton Urban Traffic Control centre between January and April 1994. Links were set-up with SCOOT and ASTRID and the system was tested in real-time. The system was monitored to ensure that INGRID operated constantly without affecting other traffic control systems e.g. SCOOT, ASTRID.

5.3.1 Faulty detector data

A significant modification to INGRID was a test every cycle to see if each individual detector was faulty. As part of the preliminary testing, INGRID was evaluated off-line using data from an experiment carried out in Toulouse. The information from this experiment was automatically filtered to remove data from faulty detectors. A similar method was utilised for the real-time use of INGRID. If any detector gives either a completely blocked or completely empty reading for longer than a certain time (e.g. 5 minutes) then that detector is set as faulty. For a detector to be reset as normal, 5 consecutive minutes of non-faulty data must be received. At the start of every day INGRID automatically sets all detectors to be faulty. This methodology greatly reduces the number of unconfirmed incidents reported by INGRID.

In an incident situation it is possible that a detector could remain empty for several minutes due to a blocked road. This is not a faulty detector and INGRID accounts for this situation with extra controlling logic. If a detector is found to be faulty but an adjacent detector is indicating an incident, then the detector is reset as normal. This should ensure that INGRID can detect an incident throughout its duration and not simply at the incident's beginning. There may be a slight increase in the unconfirmed incident rate due to this extra checking mechanism.

5.3.2 Incident message output

When an incident is detected, INGRID provides a message to the *Romanse Central Processor* (RCP). This takes information from a variety of sources e.g. bus priority schemes, roadworks information and outputs them in a form suitable for travellers e.g. variable message signs, radio broadcasts. An incident message is also given on the ASTRID / INGRID machine graphical user interface. A sample message is given below.

Time	*Date*	*Detector*	*Region*
08:18:23	20051995	N07111A1	REG_SW
		Duration 15 Minutes Very confident of a severe incident	
List of affected detectors		Affected up: Affected down:	N07121J1 N07123B1

5.3.3 Geographical Information System (GIS) Interface

The location of an incident is displayed on the ROMANSE geographical information system. ASTRID also passes detailed information on traffic flows to the GIS system. Information is given on current and historic traffic flows for all links within the network. A comparison is made between these values and links with unusual flows displayed on the GIS system.

5.3.4 Demonstration mode

A demonstration has been created in association with the Southampton Urban Traffic Control Section. To give an example of the type of message INGRID provides to the TTIC, the detection system can be given a data set which mimics a traffic incident between two adjacent detectors. On receiving this information INGRID flags up an incident in the normal way. The running of this demonstration does not affect the normal monitoring that INGRID carries out.

5.4 INSTALLATION OF ASTRID SYSTEM IN LONDON

5.4.1 System architecture

ASTRID in London is based on a VAX 3400 computer connected by Ethernet to the PDP and VAX traffic control computers. At present the ASTRID machine is collecting data from SCOOT cell F. The computer is soon to be upgraded to a more powerful machine which will enable data to be collected from several of the SCOOT cells.

User terminals can be connected to the Ethernet in two ways: via a terminal server or directly to the network using Pathworks. Only PC terminals can be connected directly to the network as the Pathworks software needs to run directly on the PC. All terminals, however connected, can login to any of the computers on the network provided they have appropriate authorisation. A user can connect from any terminal to the ASTRID machine and extract data from the database in numerical form; to use the graphical interface a PC is required connected directly to the Ethernet using Pathworks.

6. INGRID EVALUATION METHODOLOGY

6.1 ASSESSMENT CRITERIA

In order to fully evaluate INGRID it is important to consider the final use of any incident information. The associated traffic management set-up, and its function as part of an incident management system, will determine the specific requirements for the automatic incident detection system. Any system to be used must also be cost effective, reliable and efficient.

In the extra-urban area, where the primary purpose of AID is safety, AID systems are judged on:-

- Detection rate
- False alarm rate (or unconfirmed incident rate)
- Time to detect

In the urban area the above factors are important but the main purpose of an AID system is likely to be to obtain improved network efficiency and reduce congestion. Important factors of AID in an urban situation which also need to be considered are:-

- about which incident does an operator of the system need to be informed
- what is the severity of the congestion caused by an incident

6.2 DEFINITION OF AN INCIDENT

In evaluating INGRID an unconfirmed incident has been defined as

> *"a traffic situation that gives rise to an incident message for which there is no corresponding police accident record"*

In many cases an incident message may refer to an incident of which the police have no knowledge. This means that it is not possible to calculate a false alarm rate as part of this evaluation. It is difficult to accurately define any other method of classifying an unconfirmed incident or false alarm. Two alternatives could be "*any incident message that is due entirely to faulty equipment or software*", or "*any incident message that does not have a serious effect on the network.*"

6.3 EVALUATION PROCESS

The INGRID detection system has been evaluated using data collected between May and November 1994.

The method of evaluation involved several stages. Firstly, SCOOT messages are stored to enable INGRID to be run repeatedly off-line. To minimise storage requirements data is only saved on weekdays between 07:30 - 09:30 and 14:00 - 18:00.

To see if any traffic incidents have been caused by accidents or roadworks during the evaluation period three sources of information can be investigated.

1. Police accident records. The record contains a location and time for the accident and the severity in terms of number of vehicles and casualties involved.
2. Local council and utility (e.g. electricity board) records detailing time and location of roadworks
3. Local knowledge from controllers at the Southampton Traffic Control Centre. They may get to know about incidents and accidents that were not reported to the police.

These records were then analysed in conjunction with the ASTRID traffic database to see if any of the accidents or roadworks had any effect on traffic conditions within the SCOOT network. The events that did alter the traffic conditions were classified as incidents. Further work was carried out to categorise the incidents as *severe*, *moderate* or *minor*.

Once the location and severity of incidents had been ascertained, INGRID could be run repeatedly in an off-line manner. By altering the threshold values within the various detection algorithms the optimum settings and combinations of the routines could be estimated.

6.4 CLASSIFICATION OF INCIDENTS

To be classified as severe, an incident must cause a significant (> 40%) drop in traffic flow over several detectors for a considerable length of time (>20 minutes). Minor incidents cause only very transient changes in traffic flow which are not significantly different from the average conditions. A moderate incident has conditions between the two extremes of severe and minor. A typical moderate

POLICE ACCIDENT RECORD

Police Ref	Date	Time	Severity	Vehicle Type	Skid	Ped	Light	Road Surface	Weather	Grid	Ref	Location
SC0172	20/05/94	08:09	SLIGHT	HGV LGV	NO	NO	LIGHT	DRY	FINE	4120	1210	B3024 WESTERN ESPLANADE JUNCTION SOUTHERN ROAD

incident would have only one or two detectors experiencing a drop in traffic flow for a short time. Table 5 shows a summary of how an incident is classified at the relevant detection locations. Figure 7 below shows how the flow dropped after an incident on the 20th May 1994.

6.5 REGRESSION ALGORITHM ANALYSIS

The method of evaluating the Regression algorithm differs slightly from the other routines using reference data. This is because the ASTRID database does not currently store Regression data for traffic flow and occupancy.

To overcome this problem a reference set of Regression data was obtained from the SCOOT data for the entire evaluation period. This was then used as a historical comparison against the Regression values obtained for current values of flow and occupancy.

6.6 UNCONFIRMED INCIDENT MESSAGES

Traffic situations that give rise to an incident message for which there is no police accident record have been described as unconfirmed incident messages for the purposes of this evaluation. In many cases an unconfirmed incident message could relate to a real incident that is happening on-street. This creates a problem of determining whether an incident message refers to a real incident or is in fact a false alarm. For this evaluation, this problem has meant that false alarm rates have not been calculated. An unconfirmed incident could also be described as an unrecorded incident although this definition could lead to confusion because although the incidents are not recorded by the police they are detected, i.e. recorded by INGRID.

TABLE 5

Time and date of accident	Detector number	Reduction in flow/ %	No. of detectors between accident and detector	Duration / minutes	Comments
20 May 08:09	N07111F1	40	0	25	Severe/Moderate
20 May 08:09	N07111H1	60	0	20	Severe
20 May 08:09	N07121E1	20	1	10	Moderate
20 May 08:09	N07121F1	40	1	30	Severe
20 May 08:09	N07351G1	-	2	-	No significant change
20 May 08:09	N07351K1	-	2	-	No significant change

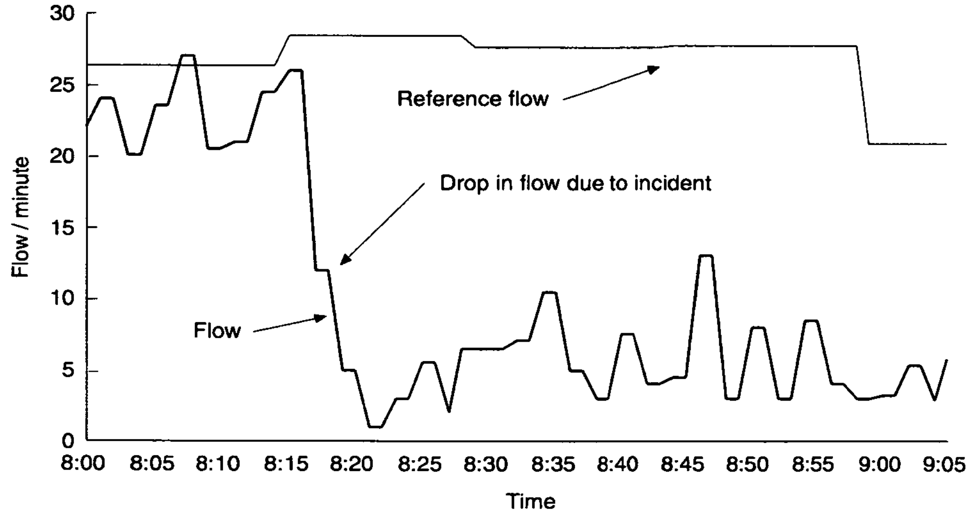

Fig.7 Changes in flow during an incident

To give an indication of the performance of the INGRID incident detection system, message frequencies were calculated as the number of unconfirmed incident messages per hour. This calculation gives a frequency that is specific to the size and complexity of the Southampton network. To give a more general value, the number of unconfirmed incident messages per junction per hour was calculated for the differing confidence levels. As there are around 130 signalised junctions in the Southampton SCOOT network, the unconfirmed incident frequency per hour is divided by 130 to obtain the unconfirmed incident frequency per junction per hour.

7. RESULTS OF INGRID ANALYSIS

7.1 SUMMARY OF DATA COLLECTION

During the evaluation period between May and November 1994 data was successfully stored on 106 weekdays. In total 540 hours of data was available for analysis. During this period police records show that 17 accidents occurred near SCOOT detectors. Analysis of the traffic data around each accident shows that of these accidents 6 were severe, none were moderate and 11 were minor. No roadworks caused significant incidents during the evaluation period.

7.2 RESULTS

7.2.1 Assumptions used

Using the data stored during the evaluation period INGRID was run off-line. Many runs were completed so that different threshold levels within each algorithm could be tested. There were several assumptions required to calculate the results:-

1) Only those incidents which were assessed to be severe were treated as incidents. This means that the detection rates that are given refer to the detection of severe incidents only. Minor incidents are not included because by their very nature they are transient and so do not require any action by the traffic controller.

2) In calculating the unconfirmed incident frequency only those incidents which directly corresponded to a police accident record were taken as true incidents. Every other incident message was taken to be an unconfirmed incident.

3) The average detection time would normally be the mean of the detection times of the severe incidents. So that extreme values do not distort the result the median detection time has been used. Full results can be found in the appendix.

7.2.2 Results of individual algorithms running in parallel

Unconfirmed incident message frequencies, detection rates of confirmed severe incidents and detection times of confirmed severe incidents were calculated. The results of this process are given in Tables 7-10. The symbols in the first column of these tables refer to the sensitivity levels used within each algorithm. Each algorithm has a critical value which can be varied to alter its sensitivity and the critical values are defined in Table 6. The contents of Table 6 are identical to Table 1 and are repeated here for convenience. More detailed results can be found in the appendix.

All four incident detection algorithms can detect severe traffic incidents. By looking at the unconfirmed incident message frequencies and detection times for each algorithm comparisons can be made between them. The success of each algorithm is briefly described below:

I-Reference:-	This is the best algorithm for the quick detection of incidents. It can detect all severe incidents. It does have a moderate unconfirmed incident frequency.
Slow Build Up:-	Detects all severe incidents but slower than I-Reference. However very small unconfirmed incident frequency means that any incidents that are detected are very likely to be true incidents.

TABLE 6

Algorithm	Symbol for critical value	Description
I-Current	α	Factor related to number of standard deviations away from the mean
Slow Build Up	δ	Number of standard deviations away from the mean
I-Reference	π	Number of standard deviations away from the mean
Regression	f	Factor related to divergence of occupancy gradients

TABLE 7

Slow Build Up

δ	Number of unconfirmed incidents per hour	Detection rate of confirmed severe incidents/%	Detection time of confirmed severe incidents/minutes
3.0	0.98	100	6
4.0	0.55	100	6.5
5.0	0.33	83	7
6.0	0.18	50	9
7.0	0.11	50	9
8.0	0.06	50	9
9.0	0.03	50	9
10.0	0.01	33	13.5

TABLE 8

I-Reference

π	Number of unconfirmed incidents per hour	Detection rate of confirmed severe incidents/%	Detection time of confirmed severe incidents/minutes
3.0	6.95	100	0.5
4.0	2.75	100	3
5.0	1.54	100	8.5
6.0	0.82	50	9
7.0	0.42	50	9
8.0	0.23	50	9
9.0	0.10	50	9
10.0	0.05	33	13.5

TABLE 9

I-Current

α	Number of unconfirmed incidents per hour	Detection rate of confirmed severe incidents/%	Detection time of confirmed severe incidents/minutes
1.0	6.56	83	0
1.1	4.53	83	0
1.2	3.06	66	0
1.3	2.00	50	0
1.4	1.34	33	4.5
1.5	0.91	33	6
1.6	0.70	33	6
1.7	0.56	16	9
1.8	0.45	16	9
1.9	0.38	16	9
2.0	0.35	16	9

TABLE 10

Regression

f	Number of unconfirmed incidents per hour	Detection rate of confirmed severe incidents/%	Detection time of confirmed severe incidents/minutes
2.0	55.21	66	6
2.1	40.19	66	18
2.2	28.57	66	37
2.3	20.00	50	55.5
2.4	13.33	33	57
2.5	8.57	33	57
2.6	5.67	16	-
2.7	2.56	16	-
2.8	1.25	16	-
2.9	0.39	0	-
3.0	0.07	0	-

I-Current:-	Detects most incidents. Moderate unconfirmed incident frequency. Moderate detection time.
Regression:-	Poor at detecting incidents. Very high unconfirmed incident frequency.

By analysing the results obtained for the four algorithms, optimum threshold levels were chosen. The values of $\delta=3.0$ and $\pi=3.0$ were chosen for the Slow Build Up and I-Reference algorithms. A value of $\alpha=1.5$ was applied to the I-Current algorithm.

The implementation of the Regression algorithm on the Southampton network indicates that it is poor at detecting incidents. There is also an unconfirmed incident frequency much higher than the other algorithms. In this situation the Regression algorithm is not recommended for use in detecting incidents. Further analysis could reveal the Regression algorithm to be more suited to other network layouts.

All algorithms operate most successfully when there is a short distance between detectors. Areas of the Southampton network with a high density of detectors are most suited to quick and reliable incident detection.

7.2.3 Results of UNITE algorithm

The individual algorithms have been combined using the UNITE algorithm. In examining how best to combine the algorithms using UNITE, the results found for each individual incident detection algorithm were used. It was found that the Regression algorithm provided no additional benefit and so it was removed.

Table 11 shows the time taken for INGRID to indicate each of the 6 severe incidents at each separate confidence level. The incident reports have been classified in terms of confidence, as described in Section 4.11. The mean time to detect is strongly influenced by the incident occurring on the 29/11. INGRID was slow to detect this incident because initially there was little traffic disruption. Table 11 also indicates the median time to detect. This is less affected by the incident on 29/11.

Table 11 also indicates a large variation in the time to detect incidents. The time taken to detect incidents is very dependent on the distance between detectors, the level of traffic and the reduction in capacity caused by the incident.

7.2.4 Results of INGRID incident detection system

The results of the evaluation of the combined algorithm are summarised in Table 12. It is recommended that INGRID only sends a message that there is an incident once the 'mildly confident' level is reached.

It should be noted that in the calculation of the unconfirmed incident message frequency, all alarms given which are not connected with the 6 severe incidents recorded by the police are included. In practice, nearly all these unconfirmed incident messages are the result of unusual traffic conditions and would be the result of traffic incidents.

To assess this effect data surrounding ten randomly chosen unconfirmed incidents was closely examined. In all cases the data corresponded to the situation to be expected during a traffic incident. None of the incidents were due to faulty equipment or software.

TABLE 11

Time since Police Record	20/5 08:09	20/5 15:58	16/9 16:00	19/10 16:12	15/11 17:15	29/11 16:45	Mean (Mins)	Median (Mins)
Not Confident	1	0	0*	0	3	21	4.17	0.5
Mildly Confident	7	1	0*	1	8	22	6.50	4.0
Confident	7	3	0	4	9	24	7.83	5.5
Very confident	9	3	0	4	13	26	9.17	6.5

* The first incident message received was at 15:59, 1 minute before the Police recorded the incident.

TABLE 12

Confidence Level	Number of unconfirmed incidents per hour	Number of unconfirmed incidents per junction per hour	Average detection time / minutes (Mean)	Average detection time / minutes (Median)	Detection rate rate of of confirmed severe incidents/ %
Not Confident	11.15	0.086	4.17	0.5	100
Mildly Confident	0.77	0.006	6.50	4.0	100
Confident	0.51	0.004	7.83	5.5	100
Very Confident	0.31	0.003	9.17	6.5	100

A preliminary examination of the distribution of unusual traffic conditions giving rise to such unconfirmed incident messages shows it to fit closely to an exponential distribution. Further details on this distribution are contained within the Appendix.

8. CONCLUSION

All four incident detection algorithms can detect severe traffic incidents with varying degrees of success. The quickest to detect incidents is the I-Reference algorithm. The most reliable algorithm is the Slow Build Up algorithm, although it is slower in detecting incidents than other algorithms. The I-Current algorithm has a success rate in between these two extremes. The Regression algorithm does not add anything significant to the results that is not already provided by the other algorithms and so the Regression algorithm should not be used as part of the INGRID incident detection system. The removal of this algorithm will help shorten the amount of processing time required to process each minute of SCOOT data. When using the three algorithms with the UNITE combination algorithm the following values are recommended:- $\alpha = 1.5$, $\delta = 3.0$, $\pi = 3.0$.

From the results of the evaluation of the combined algorithm, it is recommended that INGRID only sends a message once an incident reaches a 'mildly confident' level. This is due to the much higher unconfirmed incident message frequency of incidents reaching a 'not confident' level. Set up in this way, INGRID detects all 6 severe incidents with a median detection time of 4 minutes and a mean detection time of 6.5 minutes.

The I-Current algorithm operates in a significantly different way to the ones using reference ASTRID data. It will also operate when no ASTRID data is present. At present there are four variables which affect the sensitivity of the algorithm. For the purposes of this evaluation all four have been set to the same value. It is recommended that this practice is continued. The recommended value for this threshold is 1.5. This is different from the value of 2.0 recommended by the previous research done on the Toulouse field trial data. With the data set obtained from Southampton, if the value of 2.0 is used only 1 severe incident is detected, although there is a very low associated unconfirmed incident message frequency.

The I-Reference and Slow Build Up algorithms use a similar process of comparing current data with its reference counterpart. Both algorithms are successful in detecting all severe incidents. The Slow Build Up algorithm requires several minutes of incident conditions before it indicates an incident and this process increases the reliability of the algorithm. However, the implementation of the UNITE algorithm also separately assesses the confidence of a detected incident. As the duration of the incident increases, so the confidence associated with the incident rises. This process makes the confirmation contained within the Slow Build Up algorithm redundant. It is recommended that to simplify the setup of the INGRID system, the threshold values of I-Reference and Slow Build Up should be identical and that in future, INGRID should only use the I-Current and I-Reference incident detection algorithms.

9. FURTHER WORK

INGRID has been developed with the objective of detecting incidents automatically so that the information can be provided to the road user. Further development is needed to provide incident information to a traffic control system so that automatic signal action could be taken accurately. It will be important that INGRID is able to determine the effect of the incident on the capacity of the junctions immediately upstream and downstream of the incident. UTC strategies which could be used in response to an incident include allowing larger changes in signal timings being made than under normal SCOOT control or altering the saturation occupancy on affected links.

More incident data is required to assess the effectiveness of INGRID in detecting moderate incidents. Ideally such an evaluation would involve the presence of observers on-street so that a detailed description of an individual incident can be obtained. This is difficult in an urban area because incidents do not occur at well defined locations and times.

APPENDIX A

A.1 FULL RESULTS FOR INDIVIDUAL ALGORITHMS

A.1.1 Number of unconfirmed incidents per hour

Tables A.1 to A.4 give detailed results of the number of unconfirmed incidents per hour in each individual month of the evaluation period.

TABLE A.1

Slow Build Up

δ	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV
3	1.07	1.02	0.61	0.64	1.61	0.94	0.96
4	0.57	0.52	0.39	0.37	0.70	0.58	0.72
5	0.29	0.25	0.18	0.20	0.61	0.42	0.39
6	0.14	0.08	0.07	0.10	0.44	0.20	0.22
7	0.08	0.04	0.04	0.03	0.29	0.14	0.16
8	0.03	0.04	0.02	0.01	0.17	0.07	0.05
9	0.03	0.04	0	0	0.09	0.03	0.05
10	0.01	0	0	0	0.06	0.01	0.02

TABLE A.2

I-Reference

π	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV
3	7.08	7.05	6.40	6.21	7.76	6.91	6.67
4	2.24	3.52	2.70	2.57	2.42	2.12	3.70
5	1.53	1.25	1.26	1.26	2.15	1.58	1.73
6	0.74	0.56	0.55	0.55	1.61	0.91	0.82
7	0.31	0.29	0.22	0.18	0.99	0.48	0.50
8	0.12	0.15	0.06	0.10	0.61	0.26	0.26
9	0.07	0.06	0	0.04	0.25	0.15	0.14
10	0.03	0.02	0	0.02	0.14	0.06	0.06

TABLE A.3

I-Current

α	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV
1.0	7.22	6.81	6.18	5.26	8.94	9.51	8.12
1.1	4.90	4.22	4.29	3.47	6.42	6.19	5.41
1.2	3.33	2.77	2.51	2.25	4.35	4.19	3.35
1.3	2.19	1.63	1.44	1.31	2.71	2.70	2.24
1.4	1.36	0.79	0.90	0.85	1.74	1.77	1.48
1.5	0.82	0.50	0.57	0.52	0.95	1.00	0.91
1.6	0.54	0.44	0.42	0.23	0.68	0.61	0.63
1.7	0.40	0.31	0.24	0.16	0.46	0.36	0.41
1.8	0.22	0.21	0.15	0.09	0.27	0.19	0.26
1.9	0.10	0.13	0.04	0.04	0.19	0.14	0.13
2.0	0	0.10	0.04	0.01	0.15	0.08	0.12

TABLE A.4

Regression

f	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV
2.0	57.47	45.42	51.85	47.89	64.09	64.52	75.12
2.1	41.72	32.88	37.51	32.60	49.16	47.25	56.33
2.2	30.53	23.38	27.29	20.62	35.48	34.04	40.71
2.3	21.31	15.79	19.21	14.70	25.85	23.33	28.34
2.4	14.10	10.58	12.76	9.82	17.32	15.38	18/91
2.5	9.64	6.63	8.20	5.56	11.59	9.79	11.60
2.6	6.51	4.25	7.35	3.51	6.92	5.48	7.40
2.7	2.78	2.04	2.56	1.84	3.47	2.67	3.95
2.8	1.93	0.77	1.22	0.82	1.56	1.20	1.59
2.9	0.72	0.17	0.35	0.26	0.48	0.39	0.51
3.0	0.10	0.02	0.07	0.08	0.09	0.05	0.06

A.1.2 Time to detect confirmed severe incidents

Table A.5 to A.8 give results of the time in minutes before each individual algorithm detects each of the confirmed severe incidents with different threshold levels.

TABLE A.5

Slow Build Up

δ	08:09 20/5	15:58 20/5	16:00 16/9	16:12 19/10	17:16 15/11	16:45* 29/11
1	7	3	0	6	6	30
2	7	3	0	6	6	30
3	7	3	0	6	6	30
4	7	3	13	6	6	39
5	7	7	15	6	10	-
6	9	-	-	6	14	-
7	9	-	-	6	14	-
8	9	-	-	6	22	-
9	9	-	-	6	22	-
10	9	-	-	18	-	-

* Only at 17:00 was there actually any significant traffic disturbance.

TABLE A.6

I-Reference

π	08:09 20/5	15:58 20/5	16:00 16/9	16:12 19/10	17:16 15/11	16:45 29/11
1	1	0	0	0	2	5
2	1	0	0	0	2	5
3	1	0	0	0	2	21
4	1	2	13	2	4	24
5	7	3	15	2	10	24
6	9	-	-	3	14	-
7	9	-	-	3	14	-
8	9	-	-	6	22	-
9	9	-	-	6	22	-
10	9	-	-	18	-	-

TABLE A.7

I - Current

α	08:09 20/5	15:58 20/5	16:00 16/9	16:12 19/10	17:16 15/11	16:45 29/11
1.0	9	0	0*	0	18	-
1.1	9	0	0*	0	18	-
1.2	9	0	0*	0	-	-
1.3	9	0	0*	-	-	-
1.4	9	0	-	-	-	-
1.5	9	3	-	-	-	-
1.6	9	3	-	-	-	-
1.7	9	-	-	-	-	-
1.8	9	-	-	-	-	-
1.9	9	-	-	-	-	-
2.0	9	-	-	-	-	-

* This corresponds to an incident detected at 15:57 within the same region. The time of the accident is obtained from police records which may be inaccurate. The next incident message occurs at 16:15.

TABLE A.8

Regression

f	08:09 20/5	15:58 20/5	16:00 16/9	16:12 19/10	17:16 15/11	16:45 29/11
2.0	6	0	-	-	0*	44
2.1	6	18	-	-	0*	44
2.2	54	20	-	-	0*	54
2.3	-	57	-	-	0*	54
2.4	-	57	-	-	0*	-
2.5	-	57	-	-	0*	-
2.6	-	-	-	-	0*	-
2.7	-	-	--	-	0*	-
2.8	-	-	-	-	0*	-
2.9	-	-	-	-	-	-
3.0	-	-	-	-	-	-

* This corresponds to an incident at 17:15. The next message occurs at 17:34.

A.2 DATA SUMMARY

A.2.1 Summary of incidents

Table A.9 shows some accidents that have occurred within the SCOOT network during a period when data was successfully being collected.

A.2.2 Off-line data collection

Table A.10 gives information on the amount of data collected from the SCOOT system during the evaluation period.

TABLE A.9

Date	Time	Place	Severity
20 May 1994	08:09	Western Approach	Severe
20 May 1994	15:58	Civic centre	Severe
10 June 1994	14:50	Western Approach	Minor
15 June 1994	16:20	Bitterne	Minor
July -- No suitable accidents			
4 Aug 1994	15:55	Bitterne/West End	Minor
17 Aug 1994	07:42	Bitterne	Minor
25 Aug 1994	14:30	Civic centre	Minor
16 Sept 1994	16:00	Bassett Avenue	Severe
20 Sept 1994	17:30	Thomas Lewis Way	Minor
21 Sept 1994	17:50	Ocean Village	Minor
23 Sept 1994	15:30	University/Avenue	Minor
29 Sept 1994	14:35	Bitterne	Minor
19 Oct 1994	16:12	Bassett Avenue	Severe
26 Oct - 31 Oct Roadworks Winchester Road			
15 Nov 1994	17:16	Archers Road	Severe
18 Nov 1994	14:11	Hanover Buildings	Minor
24 Nov 1994	16:45	Portswood Road	Minor
29 Nov 1994	16:45	Bassett Avenue	Severe

TABLE A.10

Month	Number of days	Data collected Total number of hours for which data is available
MAY	13	72
JUNE	9	48
JULY	14	54.25
AUGUST	17	91
SEPTEMBER	15	79
OCTOBER	18	88.25
NOVEMBER	20	108
TOTAL	106	540.5

A.3 MONTHLY UNCONFIRMED INCIDENT MESSAGE RESULTS

Table A.11 shows the monthly unconfirmed incident message frequencies per hour for each of the confident levels.

TABLE A.11

	May	June	July	Aug	Sept	Oct	Nov	Average
Not Confident	10.78	11.13	11.08	10.35	11.54	10.95	12.24	11.15
Mildly Confident	0.81	0.77	0.53	0.58	0.95	0.84	0.91	0.77
Confident	0.53	0.60	0.33	0.32	0.62	0.58	0.62	0.51
Very Confident	0.31	0.31	0.18	0.15	0.41	0.35	0.44	0.31