Automated Detection of Expressway Incidents

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Incidents on expressways can cause congestion and impose delay and other costs to the users as well as the society. Timely detection of incidents is hence desirable and can best be achieved through automated means. Although commercial packages are available for detecting expressway incidents automatically, their performance has been unsatisfactory when implemented at a new site. For example, practically all incidents on Singapore's Central Expressway (CTE) were detected by non-automatic means such as detection by the Control Centre operators via surveillance cameras, as well as telephone calls by the public and Police. One possible reason is that most existing incident detection algorithms were developed for a specific site, and the detection logic does not work well when transferred to a new site with quite different site characteristics and driver behaviour. In addition, most of these algorithms were structured to receive traffic inputs from conventional loop-detectors which are different from the wide-area traffic data captured by the video-based detector system along CTE. This research aims to develop algorithms for the CTE which could accept wide-area traffic inputs to provide efficient detection of incidents automatically. A second objective is to develop algorithms that could achieve good detection performance when transferred to other sites.

Development of detection algorithms

A large number of CTE incidents were divided into a calibration data set for the development of automated incident detection algorithms (AIDA), and another set for validation. Several AIDA were developed to receive wide-area traffic inputs either from a single detection station, or from two detection stations (upstream and downstream). Among these, the best performing single-station algorithm is the Dual Variables (DV) algorithm, and the best dual-station algorithm is the Combined Detector Evaluation (CODE) algorithm. Both were developed using time-based, statistical approach to forecast the expected changes in incident induced-traffic disturbances. The detection performances [in terms of Detection Rates (DR) and False Alarm Rates (FAR)] between these two algorithms were not significantly different. Overall, the CODE algorithm gave slightly better performance than the DV algorithm.

Two features not found in other algorithms were incorporated in the algorithms developed. One is the use of different detection threshold values for different traffic flow and occupancy conditions immediately before the occurrence of an incident. The other is the use of speed data together with occupancy data (the latter is usually the only input used in other algorithms) in detection. These features resulted in improved detection performance.

Comparison of detection performance on CTE data

Four incident detection algorithms commonly used in North America were also calibrated on the CTE database. The performances of the California Algorithm #7 and Double Exponential algorithm were rather poor indicating that their detection logic may not be transferable. The detection logic of the Minnesota and Standard Normal Deviate algorithms were found to possess better transferability ability as well as being suitable for receiving wide-area traffic inputs. The algorithms developed in this study produced much better performance over these conventional algorithms (see Figure 1). They also met the average acceptable performance (88% DR at no more than 1.8% FAR) of several traffic management centres in the USA. From an efficiency perspective, the algorithms can detect an incident within 2.5 minutes after it had occurred, similar to that of existing detection algorithms.

Comparison of detection performance on Melbourne data

A database of incidents from the Tullamarine and South Eastern freeways in Melbourne, Australia was available for evaluating the transferability potential of the algorithms developed. The results revealed that the performance of the CTE algorithms was rather unsatisfactory when the CTE-calibrated threshold values were used with the detection logic, probably due to significant differences in site characteristics. However, when the threshold values were re-calibrated using the Melbourne data, the CTE algorithms not only produced good detection performance, but also out-performed other algorithms (California Algorithm #7, the Standard Normal Deviate algorithm and the ARRB/VicRoads Model) that were all re-calibrated with the same data (see Figure 2). They were also able to achieve similar good detection performance as the Artificial-Neural-Network-based models developed by Dia using the same Melbourne data. This suggests that the detection logic of the DV and CODE algorithms possess transferability potential and are also able to receive traffic inputs from both video-based detection system as well as conventional loop detectors.

Conclusion

This study has demonstrated the feasibility of using wide-area traffic data for the development of transferable incident detection algorithms. The DV or CODE algorithms, if implemented along the CTE, would be

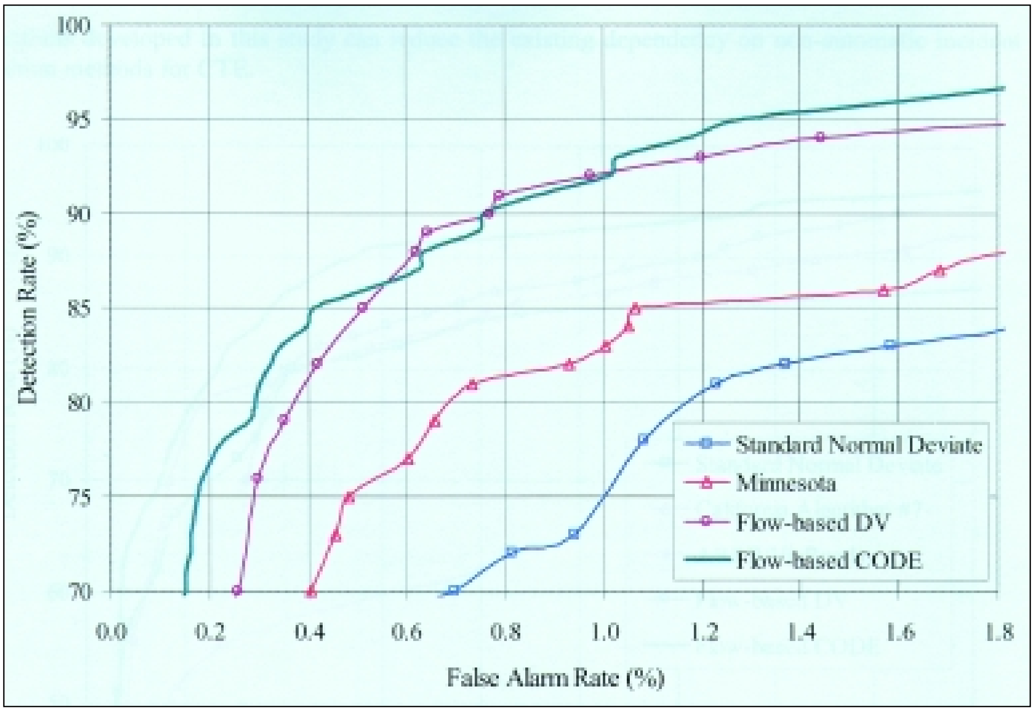

Figure 1. Comparison of detection performance on CTE data

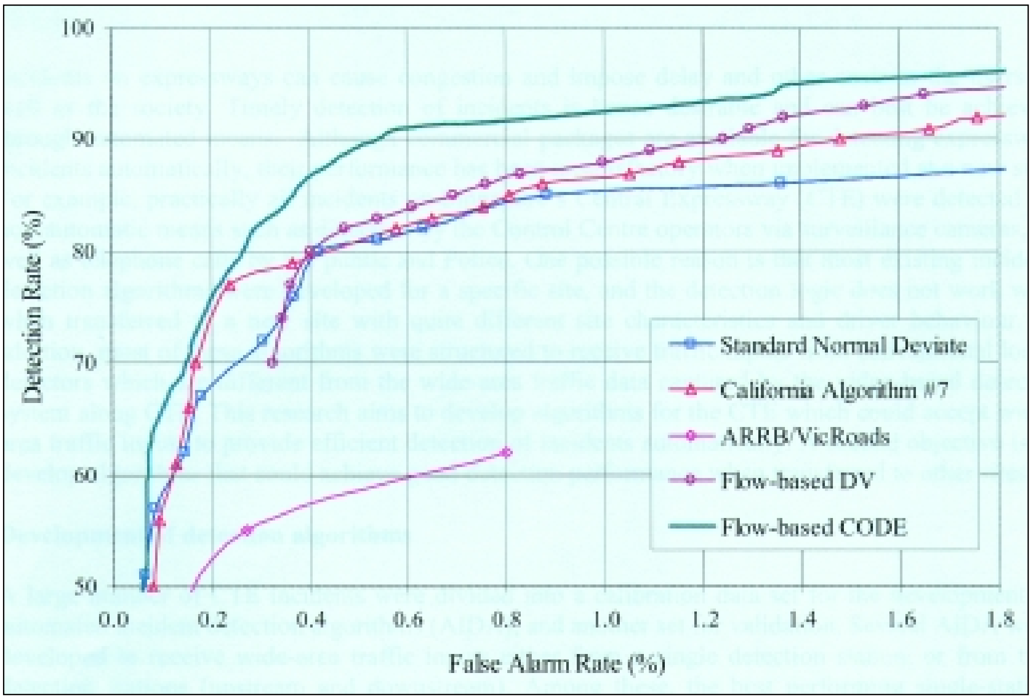

Figure 2. Comparison of detection performance of algorithms on Melbourne data

able to detect about 92% of the CTE incidents at 1% FAR, and yield an average saving of about 200 seconds in detection time per incident. The algorithms would be able to detect 56% of the incidents faster than, and another 9% of the incidents as fast as, the existing non-automatic means along the CTE. With the high DR at low FAR values, this means the algorithms developed in this study can reduce the existing dependency on non-automatic incident detection methods for CTE.

One should note that the algorithms detect an incident with a minimum time lag of 2 minutes from the actual incident occurrence time. This is because the available traffic data were captured in 1-minute intervals, and a one-interval persistence requirement was used in the detection logic to reduce false alarms. This time lag could be reduced if the detection system could produce data in shorter aggregation intervals.

Although the DV and CODE algorithms possess good transferability potential when applied to an overseas site, it would be beneficial to also verify such good capabilities locally when more incident data are available for use from other expressways in Singapore.

Stopping Propensity at Signalised Junction with Red-light Camera

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Introduction

Drivers approaching a signalised road junction must decide whether to cross or to stop upon the onset of the amber signal indication. The decisions among the drivers can be inconsistent if they are placed either in the option zone (where either proceeding straight through or braking is possible) or in the dilemma zone (where neither proceeding straight through at constant speed to clear the stop-line before red nor braking comfortably is possible). The decision to cross or to stop, especially for those positioned in the dilemma zone at the onset of amber indication, is governed by a multitude of traffic, situational, and behavioural factors. These include driver attitude and emotional state, crossing ability before red, consequence of stopping or not stopping, interactive behaviour with other drivers, approach speed and distance to the stop-line. Enforcement measures, such as the operation of red light camera (RLC), also play a significant part in influencing the stopping propensity of drivers. However, many of these factors contributing to driver decision-making have rarely been quantified objectively. In this article, a before-and-after study is described that analysed the effects of a set of factors on the stopping propensity of drivers during the signal change interval.

Data collection and logistic modelling

A special-purpose M660-type data logger from Golden Rivers working in conjunction with loop sensors was used. The M660 was deployed along an approach at Clementi Junction before and after RLC installation in order to gather traffic data such as vehicle volume, speed and distance from stop-line during the signal change interval as well as the timings and status of each signal phase (see Figure 1).

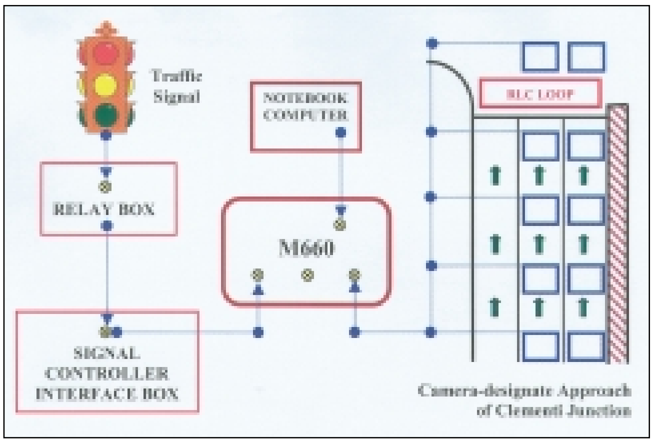

Figure 1. Layout and Connection Details of Data Collection System

The logistic modelling technique was used for analysing the stopping/crossing decisions of non-platoon vehicle drivers responding to amber signal indication. The decisions are analysed taking into account the traffic, situational and behavioural variables, including their two-order interactions such as speed interacting with distance from stop-line. The results generated by the SAS Logistic Procedure were used for selecting best-fit models based on the Pearson chi-square test, the Log-Likelihood Ratio chi-square test and a number of other regression diagnostic tests. One such logistic equation (for probability of stopping, π) based on observed data at the camera-designate approach at Clementi Junction is found to be:

$$\pi = \left[1 + e^{-(-3.8018 + 0.5502Cam\_Inst - 0.0437Day - 0.0661Time1 - 0.2995Time2 + 1.0879Lane - 0.058Vol\_Raw + 0.1803Distance - 0.545Speed + 0.028Cam\_Dist - 0.0151Spd\_Dist)}\right]^{-1}$$

where Cam_Inst = two levels: Before- (Reference level) and After-RLC situations
Day = two levels: Weekday (Reference level) and Weekend (Saturday/Sunday)
Time1 & Time2 = Three levels: 0000~0700 h (Time1), 0700~1900 h (Reference level) and 1900-2400 h (Time2)
Lane = two levels: Middle Lane (Reference level) and Median Lane
Vol_Raw = continuous: volume normalised to per 100-vehicle basis
Distance = continuous: distance measured from stop-line in metre
Speed = continuous: speed normalised to per 10-km/h basis
Cam-Dist = interaction: Cam_Inst x Distance
Spd_Dist = interaction: Speed x Distance

Findings

The logistic model permits the stopping propensity to be associated with a vector of explanatory factors from which individual and/or aggregated effects can be quantified. With reference to the calibrated equation as shown, a high propensity to stop was observed for the following situations:

- Presence of red-light camera system
- When positioned in the middle lane and at further distance before the stop-line
- At lower traffic volume and at slower vehicle speed
- During day-time and on weekdays

From the interaction terms, it is seen that the effect of distance on the stopping probability was accentuated by the presence of RLC but attenuated by faster speeds.

Modelling Driver Behaviour in Multi-storey Parking Systems

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Introduction

Multi-storey parking has become an important land use component in urban areas where there are continual pressures to utilise space more intensively due to limited land supply and high land values. The emergence of Intelligent Transport Systems has added an extra dimension to understanding parking behaviour. For instance, Parking Guidance and Information (PGI) systems that provide drivers with up-to-date information on the direction to and availability of spaces at car parks can affect the search process. This research investigates the choices and processes involved when drivers enter a multi-storey car park to search for a space. The aim is to develop a behavioural model of parking search that takes into account the availability of parking information.

Study approach

Parking search comprises a series of choices made by individual drivers at various points in time and space in a car park network under dynamic conditions in the presence of considerable uncertainty and constraints. This research uses an *interactive parking simulator* to conduct experiments in order to measure driver decisions in parking search. This innovative approach was chosen due to the difficulties in capturing real choices made by real drivers on site using conventional surveys. The advantages of the simulator are its ability to control the environment of the experiment and it offers a relatively inexpensive and safe means of collecting parking search data.

The pc-based parking simulator contains four main modules: *travel scenario, user interface, network performance* and *information provision* modules. The sampling frame comprises drivers that have parked at multi-storey car parks. Simulator experiments can be conducted in the laboratory, on-site or home environment. Experiments begin by setting the travel scenario for each test subject. Each trip involves asking subjects to 'drive' into a simulated car park to search for a parking space under scenarios that are systematically varied. The user interface module supports the creation of a realistic travel environment and collection of data on driver decisions during each simulated trip. The network performance module provides the platform to generate time-dependent traffic and parking conditions on the network. The information provision module enables the study of driver response to dynamic parking information by allowing subjects to receive information while 'driving'.

The EPSILON network performance model

The network performance of the parking simulator is anchored on a microsimulation model developed for this research known as EPSILON (**E**valuation of **P**arking **S**ystems using m**I**crosimulation on a **L**ocal r**O**ad **N**etwork). This model extends upon previous research by Young (1985) and Le (1997). The model is designed to represent road and car park networks in detail and to simulate individual *vehicle movement* as well as *parking activity* using a time-update approach. It uses as input time-dependent trip matrices and prescribed parking duration distributions to capture variations in traffic and parking demand. It has a route choice model with generalised travel cost as a random variable to represent the uncertainty in driver perception of costs through the network.

The model is able to represent car-following and lane-changing along links, moving through intersections and queuing at car park entry/exit points. The search for a parking space is simulated by assuming drivers use strategies aimed at reducing search costs. It is able to determine processes that occur after the decision to choose a space is made, namely parking and unparking manoeuvres, when to unpark and whether it is feasible to unpark.

Model application

The performance of a hypothetical two-storey car park (Figure 1) with a capacity of 114 spaces was investigated to test whether the model performed properly and produced sensible results. Building entrances were located south of the car park, while ramps for inter-floor travel were at the western end.

Traffic and parking demand were varied over a 14-hour period (09:00 to 23:00). Inspection of the computer animation of vehicles as they move to search for a parking space appears logical. Parking spaces close to building entrances had a higher level of utilisation.

Figure 2 charts the mean parking accumulation of 5

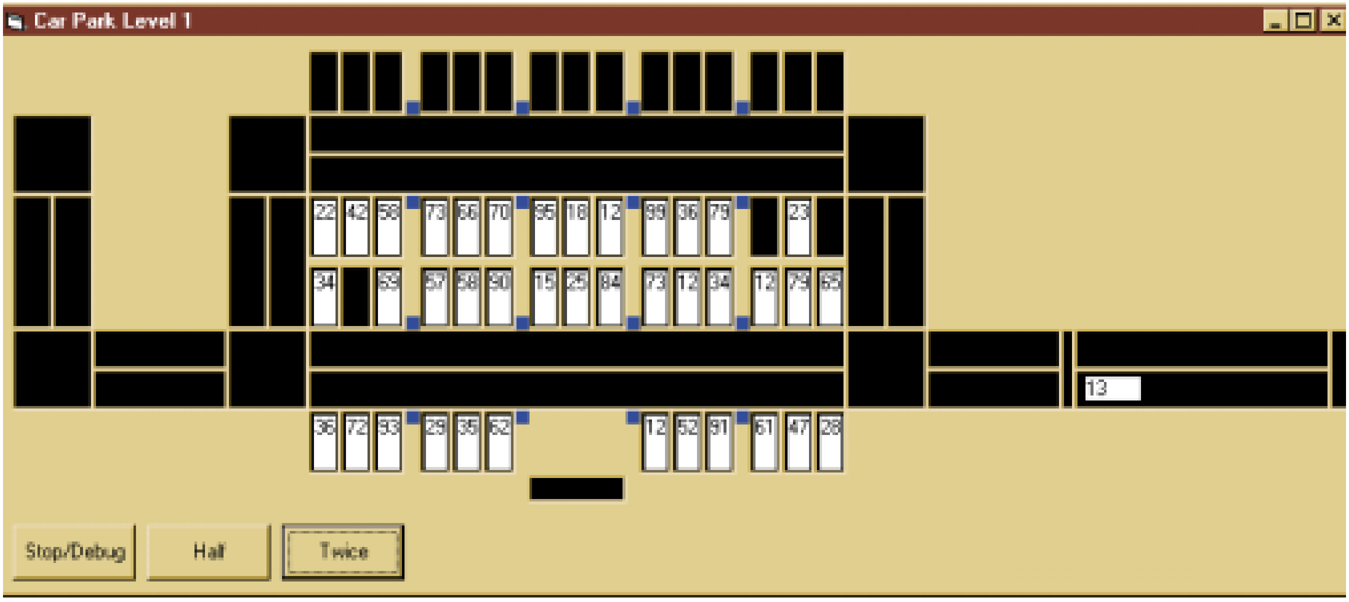

Figure 1. Snapshot of animation display at level 1 car park (interval 5, 14:00) during one simulation run

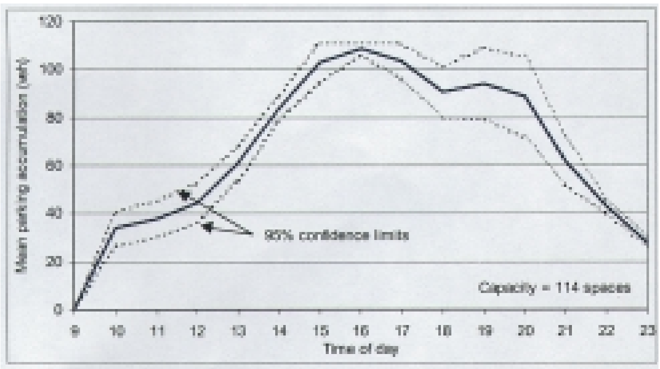

Figure 2. Mean parking accumulation by time of day

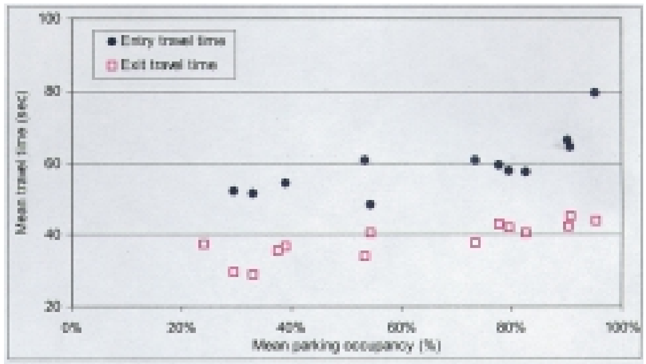

Figure 3. Entry and exit travel times by parking occupancy

runs by time of day, together with the 95% confidence intervals. Each run was treated as an independent sample with between 313 to 347 observations. The accumulation curves reflect the build up of parking demand to a mid-afternoon peak (when most shoppers have parked), followed by a smaller evening peak, before declining towards the end of the day.

Figure 3 plots the mean travel time (entering or exiting the car park) by parking occupancy. Parking search time (as reflected in entry travel time) increases with occupancy, particularly when the car park approaches capacity as drivers circulate longer to find a vacant space.

Conclusion

This research has identified microsimulation as the most feasible approach to represent the complex spatial and temporal aspects of parking activity. The parking simulator provides the means to investigate driver decisions made within a car park under controlled travel scenarios. Preliminary runs of the EPSILON model indicated that it was capable of producing stable results that were consistent with driving behaviour in multi-storey car parks. The model is being enhanced and refined using actual data from traffic surveys carried out at several sites. Further work involves the development and validation of the parking simulator, and staging of simulator experiments to construct models of the search process.

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Freight Transport in Singapore

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The efficient and safe movement of freight is vital to the economy of any country. The logistics costs, i.e. transport, warehousing and inventory costs, constitute a significant proportion of the Gross Domestic Product. However, research on the movement of goods has not attracted as much attention as the movement of people or the supply chain management. The results from two studies undertaken in recent years by the Freight Transport Research Group are described below. These studies are the modelling of freight vehicle movements and a freight survey of local logistics companies. The details have been reported in Luk et al. (2001) and Olszewski et al. (2001).

Modelling freight vehicle movements

The modelling of the movement of goods vehicles allows a better identification of the potential congested areas in a road network. These areas or routes could also be sites where road accidents and high environmental impacts occur. Two stages in freight transport modelling, trip generation and trip distribution, are described below.

The first stage of modelling involved analysing the Revised Concept Plan of the Urban Redevelopment Authority. This plan maps out the vision for Singapore's land-use attributes for various zones and Singapore's long-term development to a future year. This is defined as the time point when the population (permanent residents and citizens) reaches four millions. Currently, Singapore consists of 55 zones. The development guide for each zone gives detailed information on the present and future land-use plans.

Studies in freight movements have identified the major land-use attributes that influence goods vehicle trip generations. These land use types are: industrial, commercial, distribution or warehousing, and office or institutional. Some of the smaller zones were merged and 32 zones were used in the present study. Four external zones were also used to consider the goods trips originating from the Port of Singapore terminals, the Changi Air Cargo Terminal and the two causeway links at Woodlands and Tuas to Malaysia.

Local data on truck trip generation rates were found to be rather limited. Average rates from overseas studies were used for different land-use attributes, although it is recognised that trip generation rates could vary from cities to cities. The trips from each of the 32 zones were then determined from the zonal areas and the trip generation rates.

The second stage of modelling involved distributing the trips generated from each zone into an origin-destination (OD) matrix. Gravity models have been widely used in person-trip analysis. An appropriate modelling approach to freight transportation could be analogous to the passenger transportation model sequence. A doubly-constrained gravity model that is constrained in trips generated and attracted was selected for the distribution of freight vehicle trips.

This study used the travel time (t_{ij}) in the deterrence function, $\exp(-\beta t_{ij})$, of the gravity model. β is a parameter calibrated for local conditions. Trucks usually travel in a speed range of 30–60 km/h (the speed limit is 50 km/h). As an initial approximation, travel times between zones were found from the straight-line distance between zones by assuming a nominal speed of 40 km/h.

A limited calibration of the model was possible with the observed traffic counts of goods vehicles at some key sites in the local network. By comparing the observed and the modelled counts, the optimal value of β was found to be 0.09. This value of β for all goods vehicles agrees well with similar overseas studies - the value of β for light goods vehicles and trucks with six tyres or more (without combinations) were 0.08 and 0.10 respectively. The aggregate value of 0.09 was used in the Singapore gravity model to obtain the OD matrices of truck trips for the present and future years.

The trip lengths of the calibrated model were analysed. Most of the trips attracted to a particular destination were found to come from nearby origins. Figure 1 shows the daily trip length distribution for the present year. The average trip length is 11 min or 13.3 min if a nominal circuitry factor of 1.21 is considered. These results would depend on the assumptions on the intra-zonal travel distances (note that the results do not include vehicle trips to Malaysia).

The calibrated gravity model was also used for predicting the trip distribution for the future year. The average percentage increase in traffic for some of the selected sites was estimated to be as high as 43 %.

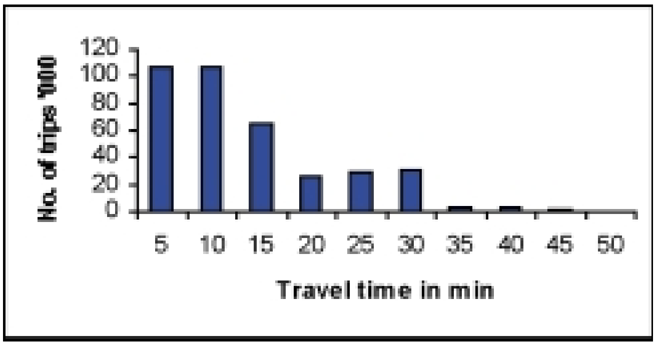

Figure 1. Daily trip length distribution

The freight survey

The survey of transport and logistics companies is a key element of developing future freight research tasks. The survey was conducted with co-operation from the Land Transport Authority, Trade Development Board and Infocomm Development Authority. The aim was to get a better understanding of the operations and needs of the local freight transport industry. The focus of the survey was on freight movements, goods vehicle fleets, transport operations and current important freight issues. The intent was also to investigate how traffic management measures and information technologies (IT) can facilitate freight transportation within Singapore.

The survey was addressed to companies which either manage their own fleet of goods vehicles, or contract other transport service providers. The survey instrument comprised 30 questions, divided into five parts: (i) general company information, (ii) goods vehicle fleet and operations, (iii) use of information technology, (iv) impact of traffic management schemes, and (v) rating of freight issues

The target sample size was 500 companies. The final mailing list comprised 474 company names and the questionnaires were mailed out in November 2000. The response was far from satisfactory and only 50 returned survey forms were useful for analysis. The fifty companies varied greatly in size – the smallest had four employees and the largest 1000. The majority of firms (60%) had less than 60 employees and can thus be classified as small and medium enterprises. Companies were classified into those that specialise only in warehousing or transport and those offering more comprehensive services. A core group of companies (66%) offers warehousing and all modes of transport or at least land transport. Smaller groups of companies specialise in warehousing only (14%) or in transport service only (16%).

Part two of the questionnaire was concerned with the details of goods vehicle fleet used by the company and their movements. It seems that the majority of companies (81%) operate only a small fleet of vehicles: less than 20.

One of the objectives of the survey was to investigate the extent of IT usage in the transport industry. The respondents were asked to indicate the status of usage (currently used, planned for introduction, not considered) of the following IT measures: radio/mobile phone communication with drivers, GPS-based system for vehicle location, computer vehicle routing and scheduling, and track-and-trace of goods.

The only widespread IT currently used is communication with drivers by means of radio or mobile phones. Very few companies have been using more advanced systems such as track-and-trace (8%), computerised vehicle routing (6%) and GPS (2%). However, almost 50% of respondents indicated that they had considered those technologies and plan to introduce them in the future. This shows that there is a wide potential market for these applications in Singapore.

The last section of the survey form was meant to capture the opinions of freight transport managers on the relative importance of transport issues from their point of view. A four-point scale of importance was suggested, ranging from 'critical' to 'least important'. The list of issues and their relative ratings are shown in Figure 2.

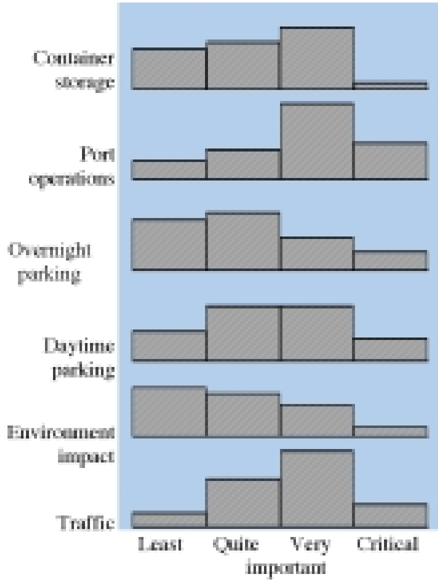

Figure 2. Rating of importance of freight issues (frequency of responses)

Two issues emerged as the most important: traffic congestion and port operations. The two issues are related. At present, the Port of Singapore is operating at high efficiency with the arrival of goods vehicles at terminal gates tightly scheduled. Terminal operations are synchronised at small time intervals – a fraction of a minute. At the same time, goods vehicles are subject to fluctuating traffic delay due to congestion. The variation of the travel time of a truck trip could be, say, ±10 min. Hence, truck operators perceive traffic congestion outside the port as an issue perhaps even more important than the port efficiency itself.

Concluding remarks

The gravity model appears useful for developing OD matrices for freight vehicle trip distribution under local conditions. There is however a need to collect local trip generation rates by land-use attributes and by vehicle types. A freight survey instrument has been developed and refined. It should be useful for future studies on national freight movements.

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