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Delays at Freeway roadworks: safety and road user cost considerations

by

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ABSTRACT: Freeway incidents are events which result in a temporary reduction in the capacity of the facility. Intelligent transport systems developments are primarily concerned with 'random' freeway incidents such as breakdowns, crashes, spilled loads etc. In contrast, relatively less attention has been given to 'planned' incidents such as maintenance activities. As part of a study aimed at predicting the delays associated with freeway incidents, this paper deals with issues associated with delays at major roadworks.

A variety of data was collected as part of a case study of a major maintenance project on Melbourne's M1 motorway. Vehicle delays were measured using a timed number plate survey. During periods of heavy delay, a number of vehicles were observed to execute illegal turns to avoid the traffic delays at the roadworks. There is evidence of a relationship between the occurrence of this behaviour and the corresponding level of delay at the roadworks. Road user delay costs were also estimated as part of the study. The potential role of an analytic delay model in maintenance planning is explored.

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INTRODUCTION

The field of incident management is attracting increased professional attention. This is especially the case on freeways where studies in the USA have indicated that about 50 to 60 per cent of the delays on US freeways are caused by incidents (Lindley, 1987). Importantly the costs associated with incidents have been recognised to be greater than just the direct costs associated with the accident. They extend to the indirect expense of waiting time, lost productivity, additional fuel consumption and environmental damage (Bovy and Muller, 1995).

To a large extent the interest in freeway incident management had arisen because of the growth in the field of intelligent transport systems (ITS). In particular the development of more reliable incident detection systems (Rose and Dia, 1995, Dia, Rose and Snell, 1996; Dia, 1996) along with developments in roadside information systems including changeable and variable message signs (CMS and VMS) presents new opportunities for traffic management around incidents. The research reported in this paper relates to an ITS project but seeks to extend the application of ITS for freeway incident management beyond the detection problem.

It is appropriate to begin by clarifying the nature of 'incidents' considered in this study. Here, incidents are defined as events which result in a temporary reduction in the capacity of the facility. We therefore distinguish between two different types of incident:

- Random

  There is little or no control over the occurrence of these incidents. They include breakdowns, crashes, spilled loads etc. which occur randomly in time and space on the freeway network. It is important to recognise that the effects of an incident are not only felt in the direction in which the incident occurred. They can also be felt in the reverse direction through 'rubber neck' effects.

- Planned

  Maintenance activity is a form of 'planned' incident since closing lanes to undertake maintenance results in a capacity reduction in the facility. While there could be times when maintenance occurs randomly, perhaps due to pavement damage inflicted by a spilled load, most of the time it is a planned activity. Another potential planned activity which may impact on capacity is enforcement activity since this can result in delays and a rubber neck effect.

To a large extent the ITS literature which deals with incident management is concerned with random incidents. The broad aim of the project, within which this research has been conducted, is to develop a model for predicting the duration and effects of freeway incidents. The 'effects' of interest are primarily the delays motorists experience as a result of the incident. As a starting point for the work, we have focused on planned incidents, specifically maintenance.

The content of this paper is as follows. The following section describes the case study which focussed on a major maintenance operation on an outer section of a radial freeway in Melbourne. The data collection undertaken in the study is then described and the results of the analysis presented. The focus is on motorists delays, road user delay costs and illegal turn behaviour. On the basis of the results from the case study implications are identified for maintenance planning and also for future research activities.

MAINTENANCE OPERATION ON MELBOURNE'S M1

Since major maintenance works on freeways are relatively rare, the scheduling of a major resealing operation on the M1 motorway in Melbourne provided an excellent opportunity for data collection. In this study, data were collected to enable delays to road users to be quantified. As will be described later, additional data collection focused on motorist's behaviour aimed at avoiding the delays produced by the roadworks.

Melbourne's M1 motorway is located to the south east of the CBD **(see Figure 1)**. It provides a major link between the city and the growing south eastern suburbs. As part of the CityLink project it is currently being extended at the city end to provide a link with other freeways to the west and north of the city.

Maintenance Details

The maintenance operation of interest focused on the inbound lanes of the freeway between Wellington Road and Fern Tree Gully Road **(see Figure 2)**. The total length of roadworks was about 2.5 kilometres and involved resealing of all three running lanes and the shoulder.

The actual works were to proceed in two stages. The first stage involved the laying of a geotextile reinforced seal designed to provide a waterproof and crack resistant layer in the pavement. This is a high speed, hot sprayed bitumen operation which starts with the spraying of a bond coat, laying of the geotextile and then application of a bitumen top coat and a stone wearing surface. This is followed, in a second stage operation, by an ultra thin asphalt overlay which provides a smooth and quite road surface. The nature of the work requires that the first stage be completed in daylight while the asphalt overlay, which by comparison is a relatively slow operation, is typically done at night.

The need for the geotextile reinforced seal to be layed in daylight required planning to minimise impacts of the operation on road users. The data collection effort reported here focused on this daylight maintenance activity. The job was scheduled for early January (14th) at a time when traffic volumes are lower than usual because of the effects of the summer school holidays.

Despite being scheduled in a relatively quite period the job was still expected to have impacts on traffic. During certain periods of the operation it is necessary to close all lanes when bitumen sprayers are in operation. This typically lasted for a few minutes. These periods of total closure along with the need to restrict traffic to one lane, rather than the usual three, were expected to produce delays.

Traffic Management

Motorists using the M1 were advised in advance of the likely delays expected from the roadworks. As can be seen from Figure 2, there was an opportunity for motorists to exit the freeway at Police Road, in advance of the roadworks. In the week prior to the maintenance works a VMS informed motorists of the upcoming works and the anticipated delays and suggested that motorists consider an alternative route.

On the day of the roadworks a combination of static signs and a mobile VMS informed motorists of the roadworks in advance of the Police Road exit. The static signs **(Figure 3)** informed motorists that roadworks lay ahead while the mobile VMS **(Figure 4)** displayed a three page message:

- Asphalt Works Today
- Well-ton Road I-Change
- Possible Delay 15 mins.

The goemetrics at this location were such that the roadworks could not be seen at this point. As can be seen in Figures 3 and 4 there is a crest vertical curve at about where the freeway crosses Jackson's Road (See Figure 1). It was generally only after motorists had passed over the top of that crest that they could see the roadworks, or at the very least the queue of traffic in advance of the roadworks. The only exception to this was that there was a period in the morning when the queue of traffic extended over the crest.

Closer to the roadworks traditional freeway traffic management was employed with static advance warning signs and weighted base safety poles used to merge traffic into a reduced number of lanes **(see Figures 5 and 6)**. Warning signs were also placed on the on-ramps at Jacksons and Wellington Roads.

Data Collection

The data collection exercise was undertaken from 8:30 AM to 4:30 PM. The actual maintenance activity began at 9 AM with the restriction of the traffic to a single lane (from the three usual running lanes).

The data collection on the day of the maintenance operation focused on three issues:
- recording the details of the traffic management (number of lanes operational, duration of complete blockages etc.),
- measurement of travel times through the roadworks, and
- recording details of motorists behaviour in the roadworks area.

The details of the traffic management in the vicinity of the roadworks were recorded by an observer who moved with the maintenance operation. Details were recorded on video along with manual notetaking.

The travel times were measured using the timed number plate method (Taylor et al, 1996). Field staff were positioned at three locations (see Figure 2). For a sample of vehicles they recorded the last three digits of the numberplate and the time the vehicle passed their station. The sampling procedure employed was to record details for all red cars and all articulated trucks. These particular sampling features were selected to ensure that data was collected relatively continuously throughout the survey period.

Details of motorists behaviour were also recorded. The particular behaviour of interest here was evasive action taken to aviod the delays imposed by the roadworks. In particular, an elevated position provided an opportunity to count the number of vehicles performing a U-turn through the freeway median. This will be discussed in more detail later.

It would have been desirable to have measured the diversion rates at Police Road. Confusion about the location of inductive loop detectors and a lack of resources on the survey day meant that these exit flows were not measured.

Data Analysis

By matching the timed number plate observations the travel time through the section could be determined. Since there was only data for a single survey day the matching operation was done by hand. While the exits at Wellington Road and Springvale Road meant that some of the vehicles observed at Station 1 may not have been matched at Station 3, the final sample never-the-less provided adequate observations throughout the day.

Of particular interest here is the travel time between Station 1 and Station 3 (Figure 2) which was simply determined by subtracting the time each vehicle was observed to pass Station 1 from the time that vehicle passed Station 3. Observations prior to the beginning of roadworks were used to determine a value for the free flow travel time through the study area. Since the study area is a long way from where the freeway terminates in the city it is not normally affected by downstream queuing. The travel time is therefore normally determined by the prevailing speed limit in the section which is sign posted as 100 kph. By subtracting the nominal 'free flow' travel time from the calculated travel time for each vehicle, an estimate could be obtained of the delay experienced by the vehicle as a result of the roadworks.

The delays experienced by vehicles travelling through the roadworks comprise two components:

- queuing delay as a result of the geometric obstruction caused by the roadworks, and
- maintenance speed limit delay which results from the lower speed limit which prevails during roadworks. Static signing imposed a maintenance speed limit through the works area of 60 kph compared to the usual speed limit of 100 kph.

It would be possible from the data to obtain insight into these two components of delay by analysing separately the data for travel times from Station 1 to Station 2 and then from Station 2 to Station 3. Since the interest here is on the total delay this more disaggregate analysis has not been undertaken.

There was a period in the morning when the queue from the roadworks extended back beyond the observer at Station 1. It is therefore recognised that the highest observed delays are in fact underestimates for a brief period in the morning.

Results from the Case Study

Delays

Using the approach described in the previous section, estimates of the delays imposed by the roadworks have been obtained throughout the survey period. **Figure 7** shows a plot of the measured delays by time of day. A five minute reporting window was used in preparing this figure. The gaps in the graph indicate that during some five minute periods there were no vehicle number plate matches. For each five minute window the minimum, average and maximum dealys are shown.

The maximum measured delays were on the order of 24 minutes at about 10 AM. As noted earlier this is an underestimate of the actual maximum delays imposed by the roadworks because the queue extended beyond Station 1 for a brief period around this time.

The peaks in the delays correspond to periods when there was a complete road closure for the bitumen spraying operation. Delays after about 1:30 PM are minimal and are primarily the result of the lower maintenance speed limit rather than any major queuing effects.

Unsafe Driver Behaviour

When confronted with traffic delays some motorists exhibit unsafe behaviour. Data were recorded on the number of vehicles which performed an illegal U-turn manoeuvres. This was observed to take place at the Jacksons Road out-bound off-ramp (Ramp OB in Figure 2). There is no central barrier in the median at this location and an emergency vehicle cross-over point also exists at this location. Some vehicles travelling towards the city performed a U-turn manoeuvre through the median to enable them to avoid the delays caused by the roadworks. Some vehicles which entered at the Jacksons Road on-ramp managed to weave through the slow moving traffic on the freeway, cross the median and take the outbound exit.

A total of 157 vehicles were observed to perform these illegal U-turn manoeuvres. Of these, 126 performed a U-turn into the outbound Jacksons Road off ramp while the remaining 31 did a U-turn to head outbound on the freeway. Five of the vehicles involved were rigid trucks with two of these being large cement mixers. It is possible that other vehicles may also have made illegal turns but were outside the view of the observer collecting this data.

The field staff regarded it as somewhat of a miracle that no serious accidents resulted from these U-turn manoeuvres. In almost all cases, the turning vehicles were beginning from a stationary start, on a gravel or grass surface with an upslope and were attempting to merge, or judge gaps, in three lanes of outbound freeway traffic which was generally travelling at or about the speed limit. In some cases the outbound traffic had to swerve to avoid a collision with the turning traffic. In some instances the turning traffic actually crossed the median on the Police Road side of the Jacksons Road off-ramp and therefore travelled against the flow of outbound traffic in order to get to the exit ramp.

Figure 8 shows the number of vehicles observed to make illegal turns through the medain as a function of time of day. This manoeuvre was most popular between 9:15 and 9:30 AM with nearly 60 vehicles involved. No vehicles were observed to perform the illegal manoeuvre after 12 NOON.

Figure 9 shows the plot of the number of illegal turns superimposed on the plot of delays by time of day. Clearly the peak of the illegal turns (9:15-9:30 AM) occurs before the peak of the delays (10-10:15 AM). Even after 11 AM a small number of vehicles were observed to perform the illegal U-turns even though the delays were moderate, typically less than about 6 minutes. Groups of vehicles tended to make the turns together. The drivers behaved somewhat like sheep so that once a driver had moved into the median to perform the manoeuvre that tended to encourage a number of others to follow.

There are a number of possible explanations for this behaviour which suggests that there was a greater intolerance of delays prior to 9:30 AM. Up to this time there could be a number of road users who are still travelling to work or to their first meetings or appointments of the day. Caplice and Mahmassani (1992) highlighted the importance of a ‘preferred arrival time’ in commuter’s travel behaviour and the extent to which commuters who have no or little lateness tolerance use traffic information in their route switching decisions. People may place a high value on not being late (or not being any later if they are already running late) in the morning and therefore get very frustrated with delays. Other overseas experience (Berthier, 1996) suggests that motorists are less tolerant of delays caused by roadworks than for accidents (random incidents).

The emphasis of this discussion has been on the illegal U-turns through the median. Other unsafe behaviour was also observed but detailed statistics were not recorded. The observer at Station 1 noted that on the order of 50 vehicles drove back down the Jacksons Road on-ramp after observing the queued traffic on the freeway.

It is likely to be the case that the behaviour observed in this case study was largely dependent on the location where this maintenance task was performed, particularly in relation to the geometric features of the freeway in advance of the roadworks. As noted earlier, motorists generally did not appreciate the extent of the traffic queues until after they travelled over the crest vertical curve above the Jacksons Road overpass. In other locations where motorists have a clearer view of the roadworks and the extent of queued traffic prior to an exit, they may be encouraged to take that exit.

Implications

This section highlights a number of issues relevant to the planning of major maintenance operations on freeways. First there is a need to consider the possible behaviour of motorists at the end of the queue. Of course, this implies that the person planning the maintenance activity has some knowledge of where the queue is likely to end. At the very least there may be a need for complementary enforcement activity to ensure that safe conditions are maintained, particularly for motorists travelling in the opposite direction.

There is also the issue of the nature of the information used to encourage diversion. While, as was noted earlier, there was advance warning signs, there are a couple of features of these signs which are noteworthy. First, while a VMS was employed, the message it displayed was static rather than dynamic. By this we mean that the VMS was simply used to display a scrolling text message and the content of that message did not change over time. The delays which were indicated on the sign (possible 15 minute delay) turned out to be an underestimate for parts of the day. A truly dynamic system would indicate the current anticipated delay in real time. While Vic Roads has installed Drive Time on the M1 (Hearn, 1995) the first Drive Time sign was located over the crest of the Jacksons Road overpass and could not be seen until after the motorists were caught in the queue.

Even if it was possible to provide dynamic information on the sign, there is still the issue of what type of information would most influence people’s diversion behaviour. The current sign provides estimates of the anticipated delays. Experience in France is that information on the queue lengths ahead is effective in influencing route choice decisions (Yim and Ygnace, 1995). It is likely that some motorists would divert if the message was indicating that the current delay was 25 minutes, while others may be more influenced by a sign which said that there was a 3 km queue of traffic ahead. The important issue is that with developments in ITS technology it should be possible to provide dynamic information on mobile VMS. Even where this information does not necessarily result in a motorist changing their route, the provision of the information reduces the uncertainty the motorist experiences and this represents an improvement in the level of service provided by the road authority.

User Delay Costs

The costs of the delays imposed by the roadworks were also calculated.

Classification Data

Just inbound from Station 3 (Figure 2) there was a permanent classification site. Although it was struck by lightening the day before the survey (Murphy's Law in operation yet again!) and was rendered inoperable for a number of days, data was available for the week prior to the survey. On an hourly basis, this site provided data of the volume of cars, rigid trucks, articulated trucks and B-Doubles. This data was used to estimate the composition of the traffic stream on the day of the survey. It has been assumed that the average figure for weekdays from the previous week is representative of the vehicle composition on the day of the roadworks. The percentage of trucks remained at about ten per cent throughout the AM period and reduced to about five per cent by the end of the afternoon. Only a very small number of B-Doubles were observed, with the remainder of the trucks split fairly evenly between rigid and articulated vehicles.

On the basis of advice received from Vic Roads staff (Davidson, 1998) it was assumed that 20 per cent of the cars were being used for business purposes.

Traffic Volume Data

Just inbound from the Wellington Road on-ramp (Figure 2) an inductive loop installation provided traffic volume data throughout the survey day. While the raw data is collected every 20 seconds this was aggregated into five minute periods to correspond with the time periods over which the delay data had been summarised. This therefore provided details of the number of vehicles which had exited downstream from the roadworks site in each five minute period.

Value of Time Data

Data were obtained on travel time unit costs from Vic Roads. The values are those provided by AUSTROADS, based on work undertaken by ARRB Transport Research, and are the values which are used by road authorities throughout Australia. For commercial vehicles, there were a number of types of vehicle within each category, for example four, five and six axle articulated trucks. In each case the lowest values of time within each category was used in the calculations.

Results

In each five minute period information was available on

- traffic volume exiting the roadworks,
- delays experienced by vehicles exiting during that time period,
- composition of the traffic stream enabling the identification of the percentage of private and business cars, rigid trucks, articulated trucks and B-Doubles (combination vehicles), and
- estimated value of travel time figures for each vehicle type.

Using this information a spreadsheet model was used to calculate the delays costs in each five minute period. The total road user delay costs were estimated to be on the order of $14,700. The cumulative road user delay costs by time of day are plotted in **Figure 10**. It is clear from this figure that most of the delay costs imposed on motorists are experienced by about 12 Noon in this case. This is largely a result of the higher traffic flows and delays (Figure 7) in the morning.

It is important to appreciate that this estimate of the road user delay costs will be an underestimate because:

- the worst delays measured in the survey are underestimates of the worst delays experienced because the queue extended beyond the first observer, and
- no allowance has been made for vehicles which exited at Police Road, or did not enter at other on-ramps, in order to avoid the roadworks. These vehicles would have experienced a delay compared to the travel time they could have expected on the freeway under non-maintenance conditions.

In this study only the travel time costs associated with the delays have been quantified. Increased vehicle operating costs and environmental impacts produced by the queued traffic are also of interest but have not been quantified here.

ISSUES FOR CONSIDERATION

This case study has provided insight into a number of issues which relate to the planning and execution of maintenance activities on freeways. It is appropriate to highlight these issues which may require greater consideration in practice.

Opportunities to Improve Maintenance Planning

A considerable amount of planning is currently done before any major freeway maintenance project. At present no modelling systems are available to support that planning process. As noted in the introduction, the broader aim of the research program from which this paper has been prepared is to develop a model capable of predicting the delays and other effects of freeway incidents. In a strategic planning context, like maintenance planning, the model would have a role in providing insight into the answers to a variety of 'What If?' questions such as:

- If the maintenance task involves closing these lanes over this time period, what will be the traffic impacts?
- How long will the queues be?
- What will be the total costs to road users of the delays imposed by the roadworks?

- How would the delays and other impacts change if the maintenance was undertaken at a different time, or split over two days?

By providing insight into questions like these it would be possible to more explicitly consider the trade-off between road user and road authority costs when planning maintenance activities on freeways.

Enforcement

As highlighted by the number of illegal U-turns observed in this study, it is critical that a variety of safety considerations be taken into account when planning maintenance activities. In the case of the maintenance project considered here, complementary enforcement activity around the back of the queue would appear to have been appropriate. The need for special enforcement will be site specific.

Role of Information to support more informed travel decisions

Developments in ITS technology should present new opportunities for displaying dynamic information on mobile VMS. In the case considered here, the mobile VMS continued to advise motorists throughout the afternoon of possible 15 minute delays when the delays were on the order of five minutes or less. There is also scope to examine how the nature of the message affects diversion behaviour with options to perhaps display queue lengths rather than travel times.

Maintenance Process Improvements

The drive to reduce costs and improve quality means that organisations are continually trying to improve maintenance processes. Technology or process improvements which result in higher speed maintenance processes will have a benefit in terms of the reductions in road user delays.

CONCLUSIONS

This paper has explored a number of impacts associated with major mainenance activity on a metropolitan freeway. The case study has provided insight into the extent of road user delays and associated costs as well as the risks of evoking unsafe driving behaviour when motorists are confronted with roadworks delays. The issues highlighted by the case study provide food for thought for those involved in the planning and execution of freeway maintenance activities.

The research program is now being focused on the development, calibration and testing of a mathematical model which will be capable of simulating the delays and associated costs experienced by road users as a result of incidents on freeways. These incidents will include maintenance activities as well as random incidents such as crashes.

REFERENCES

Berthier, J.M. (1997) Personal Communication.

Bovy, P.H.L. and Muller, T.H.J. (1995) Using incident probability models for deriving incident management measures, Second Erasmus-network conference on transportation and traffic engineering.

Caplice , C. and Mahmassani, H.S. (1992) Aspects of commuting behaviour: preferred arrival time, use of information and switching propensity. Transportation Research 26A, (5), 409-418.

Davidson, J, (1998) Personal communication, Vic Roads.

Dia, H. (1996) Artificial Neural Network Models for Automated Freeway Incident Detection, PhD Thesis, Monash University, 263pp.

Dia, H., Rose, G. and Snell, A. (1996) Comparative Performance of freeway automated incident detection algorithms. Proceedings ARRB conference, 7, 359-374.

Rose, G. and Dia, H. (1995) Freeway automatic incident detection using artificial neural networks. Proc. Of the International Conference on Application of new Technology to Transport Systems, Vol 1. Melbourne, Australia, 123-140.

Lindley, J.A. (1987) Urban freeway congestion: quantification of the problem and effectiveness of potential solutions. Institute of Transportation Engineers Journal, 4, 4-22.

Taylor, M.A.P., Young, W. and Bonsall, P.W. (1996) *Understanding Traffic Systems: Data, Analysis and Presentation*, Avebury, 441p.

Yim, Y.B. and Ygnace, J.L. (1995) Variable message signs and link flow evaluation: a case study of the Paris region, California PATH Working Paper, UCB-ITS-PWP-95-5, 38pp.

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AUTHOR BIOGRAPHIES

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Darryn Paterson is currently undertaking his PhD at Monash University in the field of Intelligent Transport Systems. His research relates specifically to the development of a model capable of predicting the duration and effects of freeway incidents. Prior to commencing postgraduate study he worked for a number of consulting firms specialising in transport planning.

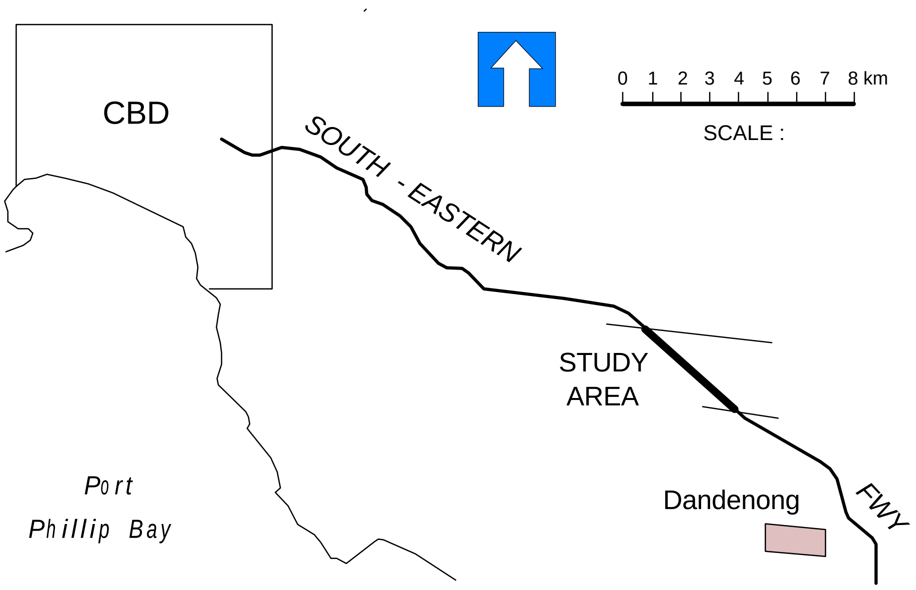

Figure 1: Location Map

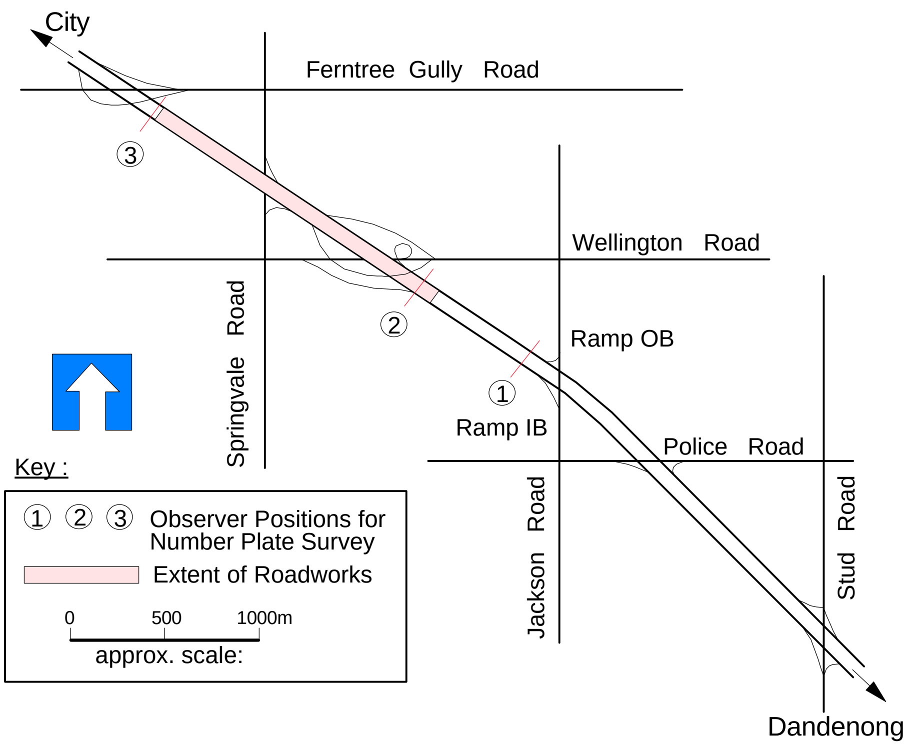

Figure 2: Site Plan

Figure 3: Advance Warning Static Signing

Figure 4: Advance Warning VMS

Figure 5: Static Signs in the Works Zone

Figure 6: Traffic Management in the Work Zone

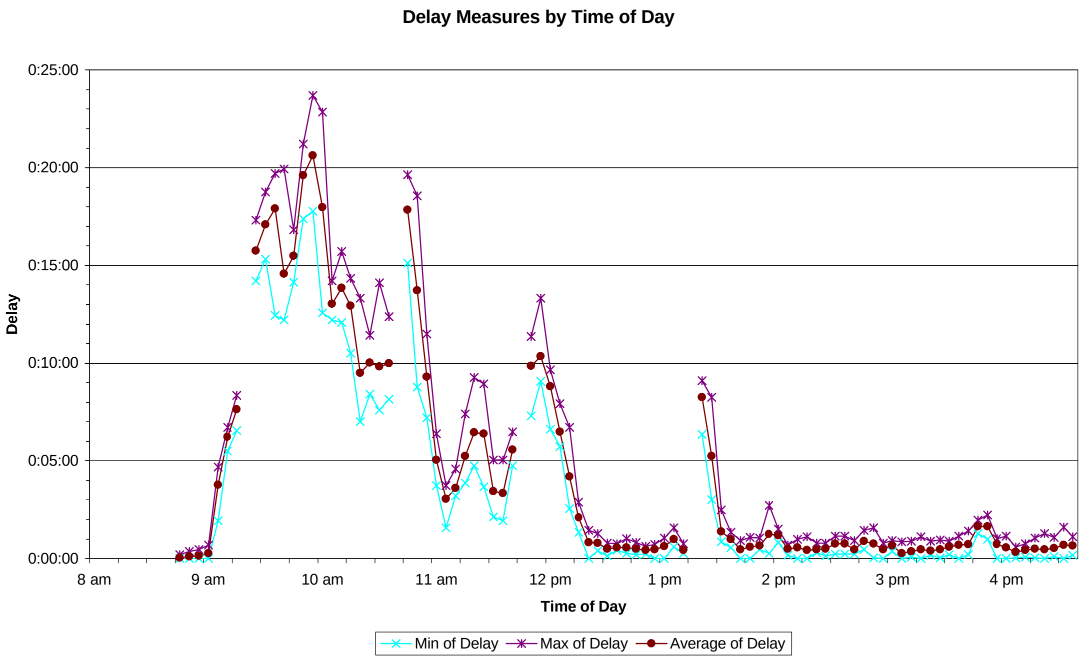

Figure 7: Delays by Time of Day

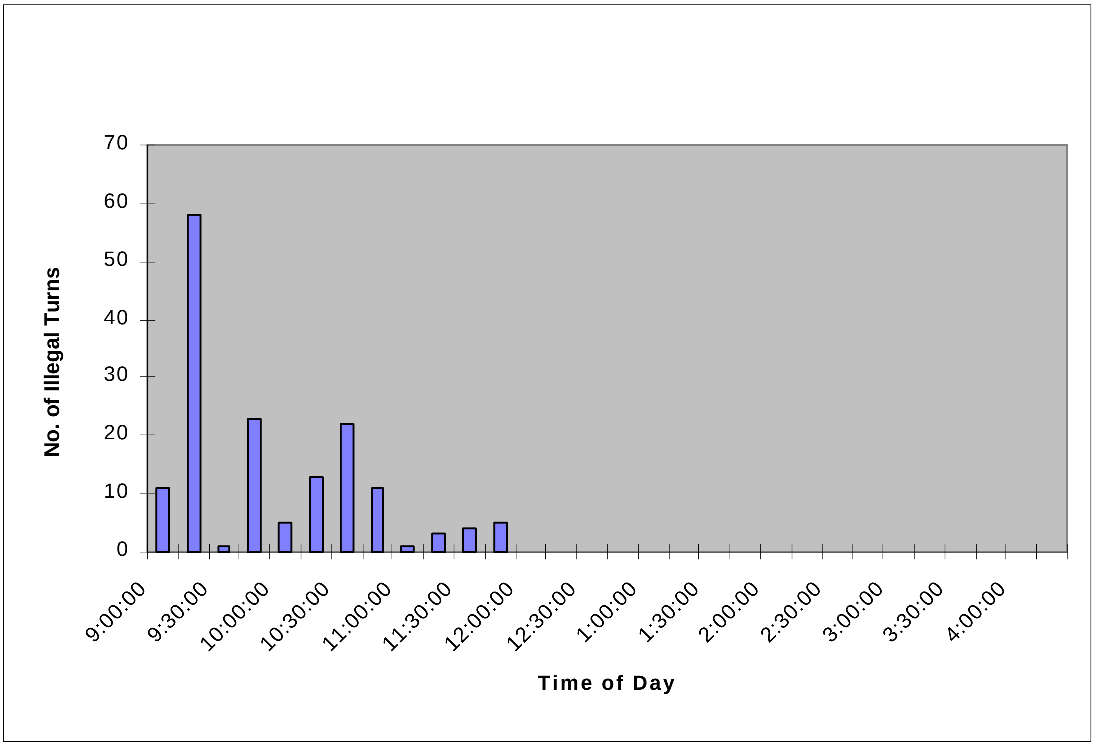

Figure 8: Illegal Turns by Time of Day

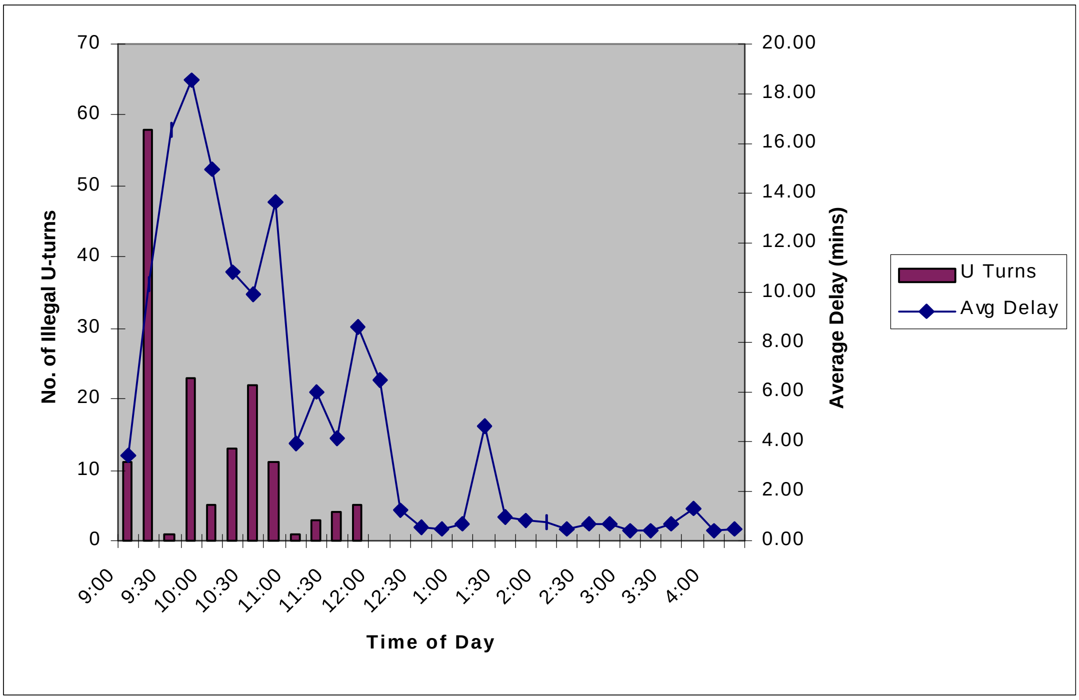

Figure 9: Illegal Turns and Delays by Time of Day

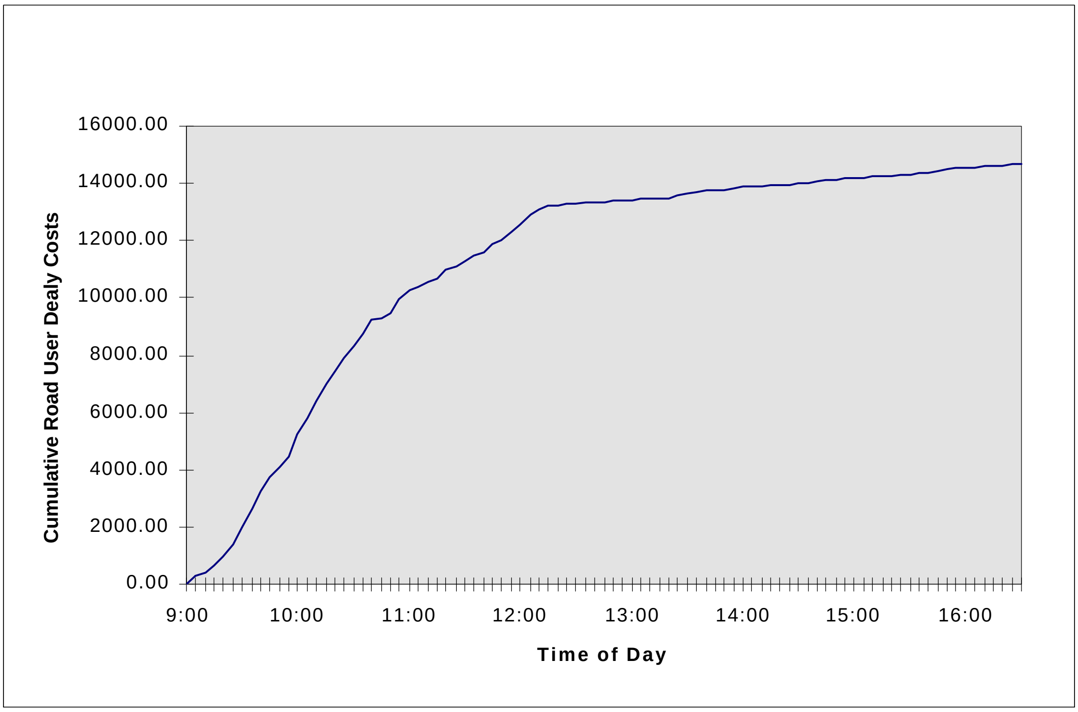

Figure 10: Cumulative Road User Costs by Time of Day