INCIDENT ANALYSIS USING PROBE DATA

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ABSTRACT

A methodology is presented for estimating the area of influence of two similar non-recurrent congestion events in two of South Africa's metros, Tshwane and Cape Town, by use of probe data. Congestion in South Africa's big cities on most of the major highways is a very common phenomenon to any regular traveller and has a substantial economic impact due to lost time while in traffic.

The proposed method utilizes historic TomTom probe data to determine the effect of a stationary truck on a major arterial during Monday morning peak hour traffic, in which some lanes are closed to traffic. The impact on the corridor and the immediate road network is presented both graphically as well as mathematically in terms of average travel time, average speed and delay. Historic probe data on the day of the incident is compared to 20 weeks' data prior to the incident.

The methodology is applicable to similar incidents in which no fatalities or serious injuries were sustained and standard incident clearance procedures were followed. A Custom Area Analysis and Custom Travel Time analysis were conducted to obtain historic data on the day of the incident and typical traffic days for comparison.

The results demonstrated this methodology's ability to represent the true state of traffic on a specified route during and after an incident, provided that there are enough probes on the route for the time sets investigated. Probe data provides reliable data that will benefit various entities to address their specific requirements, whether they be road authorities, emergency services, law enforcement, or the ordinary citizens.

1 INTRODUCTION

Congestion in South Africa's big cities on most of the major highways is a common phenomenon to any regular traveller. Large metros such as Johannesburg, Tshwane

and Cape Town experience excessive traffic delays daily, which cause frustration to drivers and has a significant economic impact due to lost time while in traffic.
A survey conducted by TomTom in 2011 revealed that one quarter of all drivers in South Africa spend 45 minutes or more in traffic daily. This amounts to a monthly cost of R1.1bn to employers, due to wasted time in traffic (SA TomTom Traffic Survey, 2011). In terms of traffic congestion, South Africa is ranked the fifth highest country in the world according to Numbeo's traffic index in 2016 (Writer, 2016), which is the world's largest database of user contributed data about cities and countries worldwide.

There are many causes for delay on major roads. Some delays are a direct result of bad weather, road works, poor visibility, faulty traffic signalling systems (Mahmud, et al., 2012) or traffic volumes that are beyond the capacity of a road (TomTom, 2009). Traffic incidents such as vehicle crashes and stationary vehicles also contribute to delay and congestion.

A better understanding of the impact of incidents on travel times and overall delay on the surrounding network is required, both from a city planning perspective as well as from a traffic management perspective (Cohn & Kools, 2014); (Anwar, et al., 2014). Information about the impact of incidents could change future road design and affect long-term policy formulation.

The aim of this research is to propose a new method to determine the effect of major incidents on busy roads and the surrounding network using ***probe data***. Major incidents in this research paper refer to the levels of congestion caused by the incident and not the severity of the incident itself. Two incidents were analysed in this research, namely stationary trucks on the N1 northbound in Pretoria and the R300 northbound in Cape Town. The two separate incidents occurred in January 2016 on consecutive Monday mornings.

2 PROBE DATA

2.1 What is Probe Data?

Any traveling vehicle fitted with sensors, which determines locational information about the vehicle, is called a *probe car*. The data that is collected by the sensors *in the vehicle* are called *probes* (Satoshi, 2011). Probe data can be sent via a Global-Positioning-System (GPS) connected device on an anonymous basis (TomTom, 2009). Probe data contains information about the device's location and time stamp (U.S. Department of Transportation, 2013).

Travel speed is derived from the travel time and the location of the signal is determined either by GPS coordinates or calculated from the nearest cell phone tower (Young, 2007). Although probes only account for about 3-5% of the total traffic volume, it is still a substantial amount given the large number of vehicles on a road during a traffic jam (Cheu, et al., 2002).

2.2 Probe Data Quality

The reliability of probe data is established by comparing it to ground truth data. Ground truth data is collected independently from other traffic data sources and is used to confirm whether the data is correct and accurate. The University of Michigan Transportation Research Institute (UMTRI) conducted an independent benchmarking study in 2013 into the accuracy of traffic jam information provided by after-market navigation systems in the U.S. Their research concluded that TomTom's iPhone Navigation App provides the most accurate real-time traffic data compared to a number of competing products, such as INRIX and Garmin (Belzowski & Ekstrom, 2014).

This study particularly makes use of TomTom historical probe data. TomTom further assures reliability of their probe data through validation by the German external independent quality institute TÜV. Each year a certificate is awarded if the traffic data is accurate and precise on highways and secondary roads (TomTom, 2009).

3 METHODOLOGY

3.1 Incidents Analysed

Stationary trucks are a common occurrence on the major roads across the country. The Traffic Management Centres in Midrand and Cape Town provided information about the time, location, duration and type of various incidents. Video footage of the incidents was viewed to gain insight into each incident.

The two incidents that were investigated in this research are:

1. **Gauteng**: Stationary truck on the N1 Northbound, Pretoria, approximately 500 m before the Garsfontein off-ramp (M30), on Monday 25 January 2016 at 04:39. The incident was cleared at 11:26, with a total duration of 6 hours 47 minutes. Two out of four lanes in the northbound direction were closed. No fatalities or serious injuries were sustained. Coordinates: -25.793891, 28.266568.

2. **Western Cape:** Stationary truck on the R300 Northbound, Cape Town, approximately 250 m before the Van Riebeeck Road off-ramp (R102), on Monday 18 January 2016 at 07:04. The incident was cleared at 08:48, with a total duration of 1 hour and 44 minutes. One out of three lanes in the

northbound direction were closed. No serious injuries or fatalities were sustained. Coordinates: -33.9204205, 18.66481399.

3.2 Probe Data Collection

3.2.1 Historical Probe Data Sets

TomTom historical probe data was used to analyse the traffic impact of the two incidents. TomTom data is obtained from the TomTom *Traffic Stats Portal*, using the tools *Custom Area Analysis* (CAA) and *Custom Travel Time (CTT)*. The aim of CAA is to determine the approximate area of influence of the incident on the surrounding network. To conduct a CAA three parameters are required, the **location**, **date** and **time sets.** Higher order roads (freeways and arterial roads) were analysed in this research.

After the CAA is conducted, a CTT analysis is performed on the route where the incident occurred. Segment-specific data is extracted from the database along the route for the approximate queue length of the incident during the CTT analysis. The approximate queue length is regarded as the length of route segment prior to the incident scene where the average speed is significantly less than that of a typical day for the same route segment (by more than 40km/h). Alternative routes around the incident scene were also analysed to demonstrate the effect of the incident on the immediate surrounding road network.

3.2.2 Study Timeframe

The data on the day of the incident is compared to a typical day at the same location for both the CAA and the CTT analysis. Typical day traffic is calculated as the average traffic condition for the period 20-weeks prior to the incident. Both incidents occurred during January, therefore the 20 week period was selected to *not* include the December-January school holiday when traffic patterns differ. The typical data set was selected from 20 July to 30 November 2015 (20 weeks). Using a long time period, such as 20 weeks, to establish typical traffic conditions reduces the impact of any one day that could have had atypical traffic due to, for example, adverse weather.

3.3 Method

The proposed methodology is summarised in the flowchart below. The CAA output is used to evaluate the network wide traffic impact of the incident and queueing length. CTT analysis provides additional detail of the impact of the incident on the traffic conditions of the corridor, as well as alternative routes.

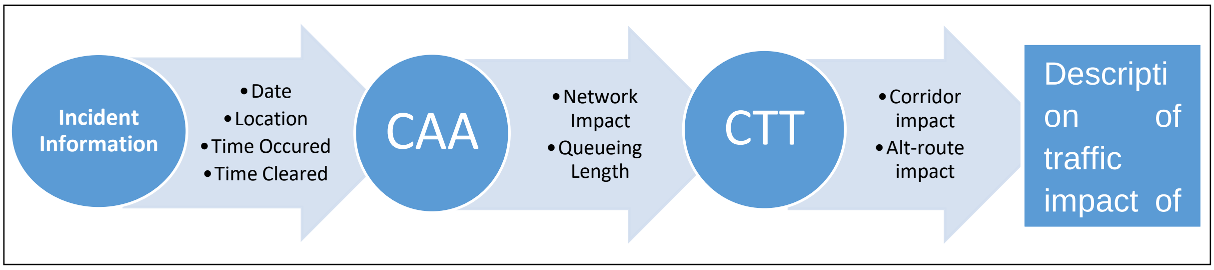


Figure 1: Methodology

4 IMPACT OF THE INCIDENT

Specific emphasis is placed on the traffic condition on the road segment directly before and after the incident's location, to illustrate the effect of the incident on the corridor. The Cape Town incident is discussed in detail in this paper to illustrate the method of incident analysis used in this research. Footage of the incident obtained from one of the numerous CCTV cameras operated as part of the Cape Town Freeway Management System is indicated in Figure 2 below. This image was taken at 7:20 AM, 16 minutes after the stationary truck blocked the left lane of the R300 northbound. The stationary truck (indicated by the yellow arrow) is in the left lane of the three northbound lanes. The resulting congestion in all three lanes behind the truck is clearly evident.

Figure 1: Stationary truck on R300 northbound and resulting congestion

4.1 Network Wide Traffic Impact

The influence of an incident on a road network can be visualised by comparing the average traffic speed on the day of the incident and typical speeds on a normal day. This can be done at different periods during the event to determine the effect of the incident as time progresses.

The average speeds between 07:00 and 07:30 on the day of the incident and a typical Monday are compared in Figure 3. The location of the incident is indicated by the star. On the day of the incident, the speed upstream of the incident site was moving at between 5 and 15 km/h, while on a Typical Monday, the speed is usually in the region of 45 to 60 km/h at the same location. Speeds upstream of the incident close to the interchange with Stellenbosch Arterial (visible in the lower part of the map) are clearly lower than normally anticipated. In the southbound direction, the road section north of the incident is more congested, compared to a usual morning peak period, probably due to “rubber-necking” drivers trying to see incident. South of the incident, the southbound lanes increase in speed and travel at faster speeds than are usually observed in this area, which seems to be quite congested on a typical Monday morning. This indicates that an incident affects not only the side of the road on which the incident occurred, but also constitutes a bottleneck in the opposite direction.

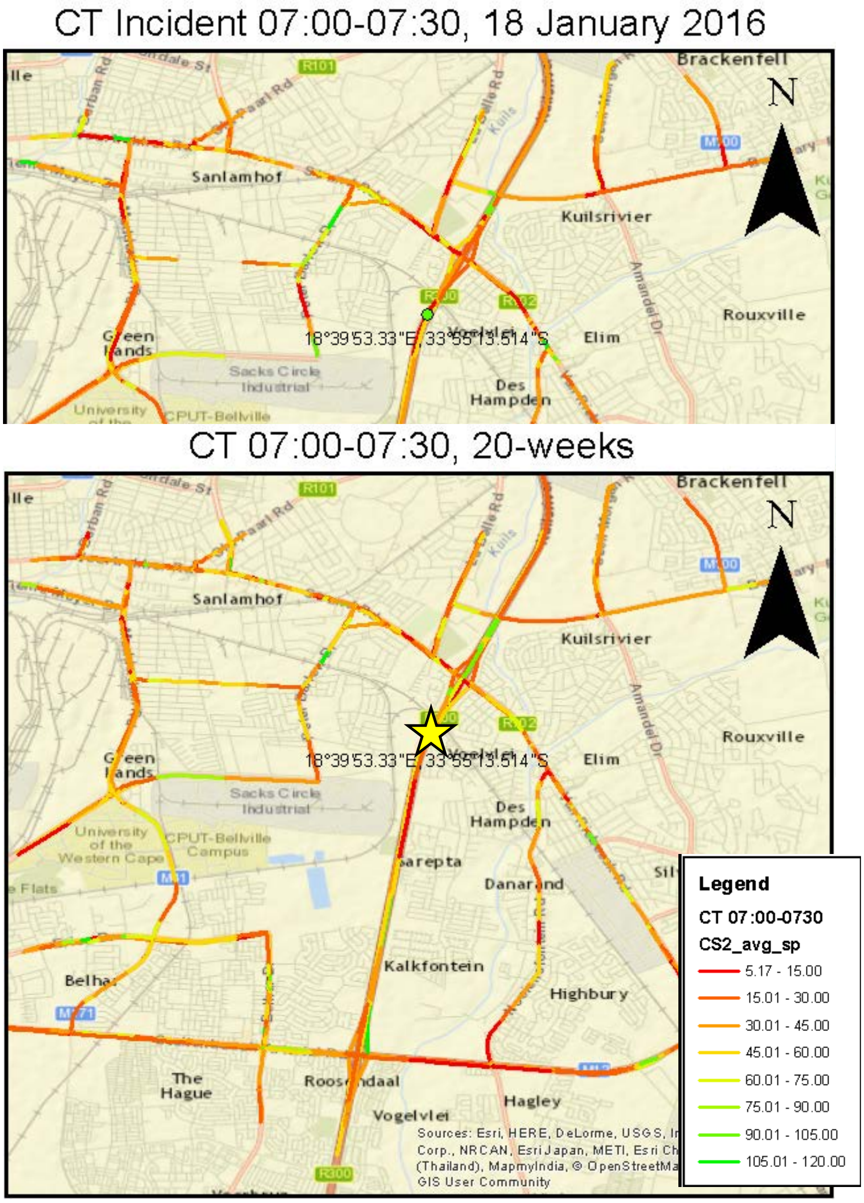


Figure 3: Average speeds 07:00 - 07:30, 18 January vs 20 weeks

The incident was cleared at 8:48 AM, after 1 hour, 44 minutes. Figure 4 indicates average speed on the day of the incident between 8:30 and 9:00 (the period that the incident was being cleared). On the day of the incident, the R300 can be observed to have speeds below 30 km/h in the vicinity of the incident. In comparison, the speeds are much higher on a typical day. It is interesting to note that there is a zone of decreased speed typically observed just south of the incident zone in the southbound direction on a normal day which corresponds to the zone of very low speeds during the peak period (see Figure 3). The reason for this is unknown and should be investigated. The merging zone after the R102 on-ramp in the southbound direction could be leading to the reduction in speed at this location.

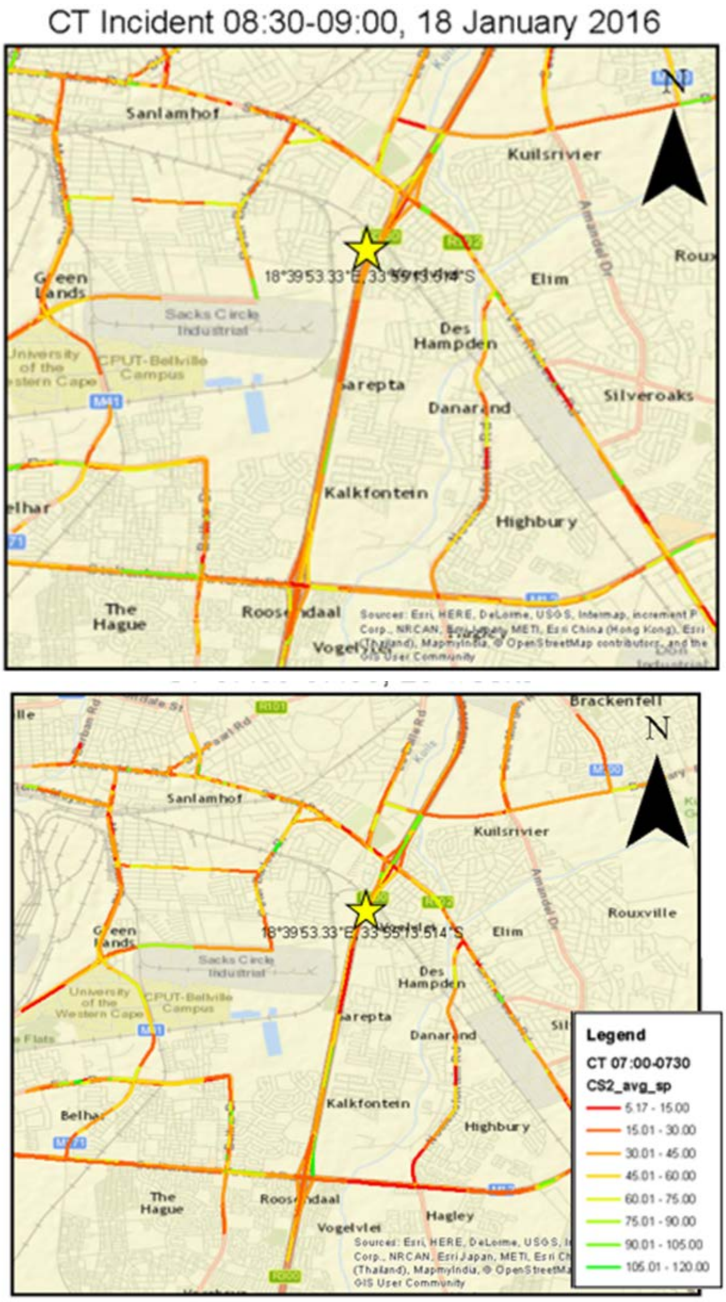
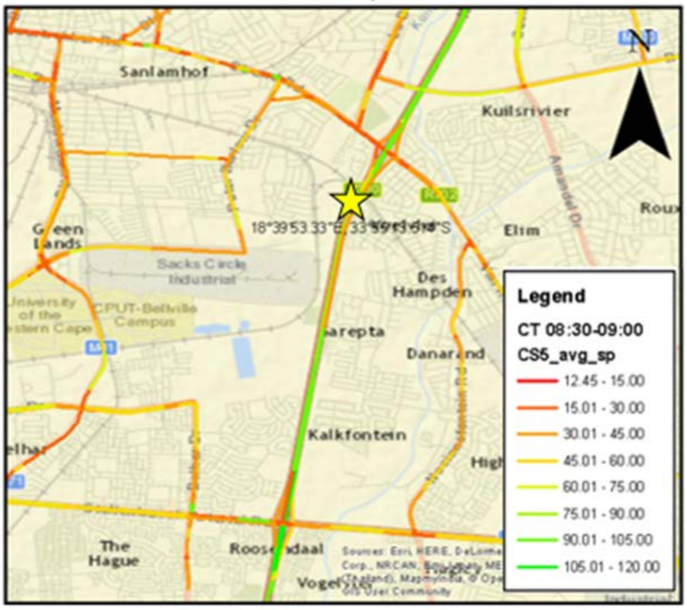


Figure 4: Average speeds 08:30 - 09:00, 18 January vs 20 weeks

4.2 Approximate Queue Length

To determine the approximate queue length that results after traffic incidents, the queue length is considered as the distance from the point where there is a sudden, significant (more than 40 km/h) decrease in average speed along the route upstream of the location of the incident scene. The average queue that formed upstream of the Cape Town incident between 8:00 and 9:00 AM is presented in Figure 5. The approximate queue resulting from the incident was assumed to be indicated by the red and dark orange line (0 to 40 km/h). It is visible that the queue extends back 3.25 km south of the incident. Traffic usually travels at about 60 km/h in this area during the peak hour. Because the incident did not block all lanes of the northbound approach, the queue will disperse albeit at a low speed, and so the queue will be shorter in periods with lower traffic volume.



CT Incident 08:30-09:00, 18 January 2016

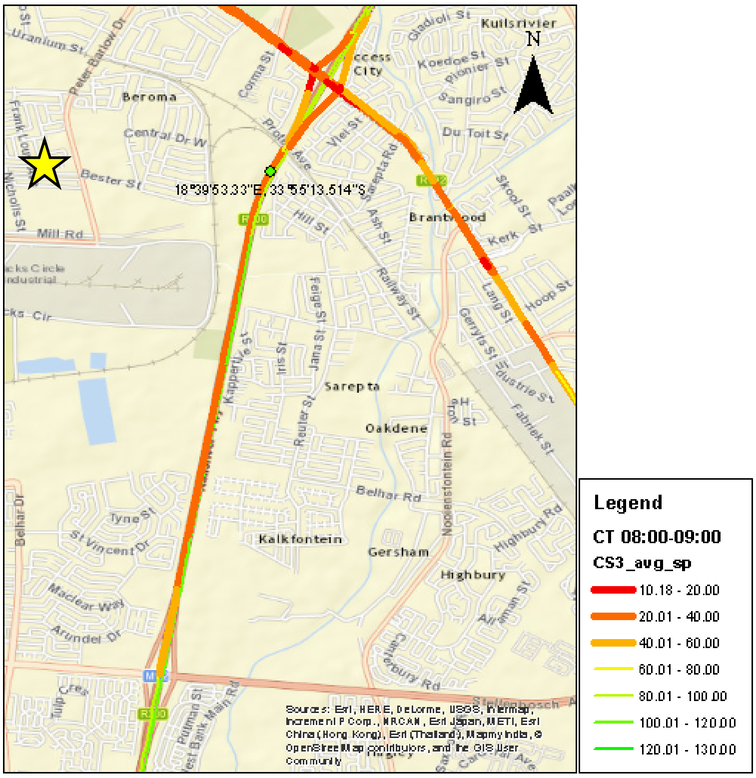


Figure 2: CT Incident approximate queueing length between 07:00 and 08:00

4.3 Corridor Impact Traffic Impact

Corridor impact in this paper considers traffic impact along the route where the incident occurred. The average speeds along the R300 in the northbound direction for different time sets during the incident are illustrated in Figure 6 (dashed lines), with average speed on a typical Monday (20 week average). Interestingly, typical speeds increase in the vicinity that the incident occurred (indicated in Figure 6 at 6800 m) on a normal day.

A comparison of the AM peak hour time (07:00-08:00) indicates a reduction in speed from about 25 km/h usually between Polkedraai and Van Riebeek Road, to about 12 km/h on the day of the incident. After the position of the incident, the average speed on the day of the incident increases to typical speeds for a Monday. It is interesting to note that downstream congestion which usually cause peak hour speeds to decrease before Old Paarl Road is absent on the day of the incident with speeds representing typical off-peak speeds (as indicated between 9:00 and 10:00 AM). This is due to the bottleneck resulting from the incident and reduced road capacity, releasing vehicles more slowly onto the remaining network.

Typical speeds between 8:00 and 9:00 AM are faster along the segment between Polkedraai and Van Riebeek Road than during the peak hour at about 50 km/h. The speeds on the day of the incident between 8:00 and 9:00 AM remain low, at about 18 km/h.

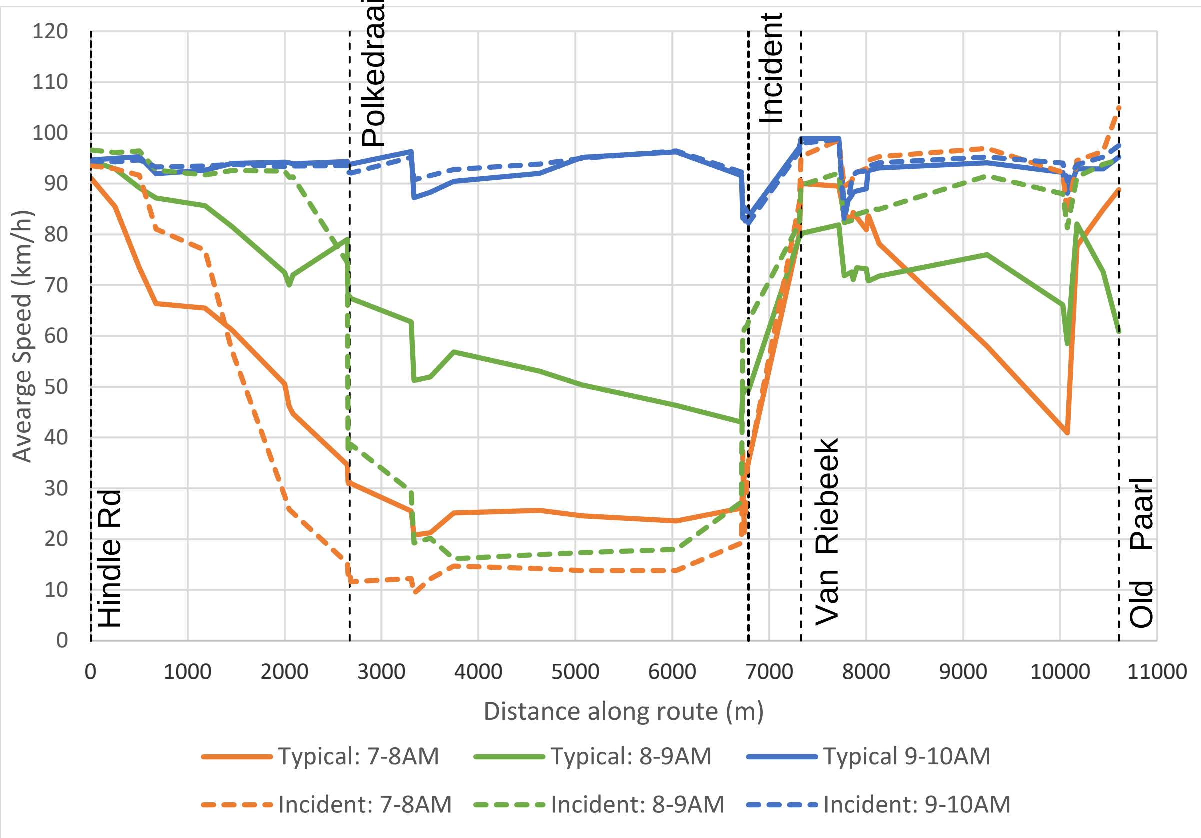


Figure 3: Comparison of Average Speeds: R300 Northbound

To further demonstrate (and verify) the impact of the incident on the R300 Northbound on 25 January 2016, the Average Travel Time along the route is illustrated in Figure 7. The base set (travel time at low flow conditions) and the period after the incident is cleared have very similar travel times. During a typical morning peak hour, 07:00-08:00, the average travel time on the day of the incident between Hindle Road and Old Paarl Road is 1000 seconds (16 minutes and 40 seconds), compared to 1470 seconds (24 minutes and 30 seconds) on the day of the incident. This implies an increase in average travel time of nearly 8 minutes or nearly a 50% increase in travel time. Between 8:00 and 9:00, travel time increases from 10 minutes to nearly 17 minutes, a 70% travel time increase.

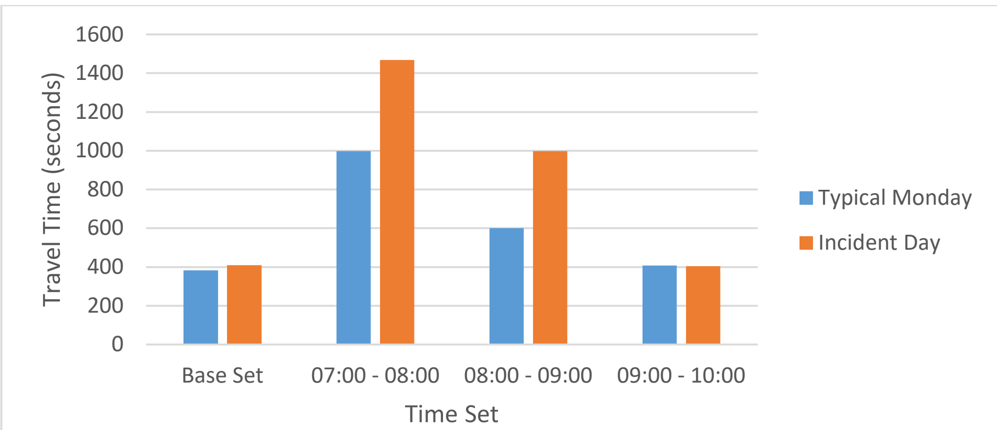


Figure 4: Average Travel Time Comparison on R300 Northbound

4.4 Alternative Route Impact

Traffic incidents can increase delay on alternative routes due to the diversion of some traffic to alternative routes to avoid congestion on the route where the incident occurred. An alternative route to avoid the incident location on the R300 could be considered along Polkedraai Road, New Nooiensfontein Drive and Van Riebeek Road, as indicated in Figure 8. The impact on travel time along the alternative route is indicated in Figure 9 below. The influence of the incident on the alternative route is clear and somewhat more dramatic than anticipated. The travel time along the route is only influenced during the peak hour (7:00 to 8:00 AM) when travel time increases from 1560 seconds (26 minutes) to 2400 seconds (40 minutes), a 14 minute increase, or an increase of 54%. This is similar to the percentage time increase for the R300 during the same time period. There is no travel time difference in the period after the peak hour, possibly because the alternative route has acceptable capacity at this time to accommodate any diverging traffic.

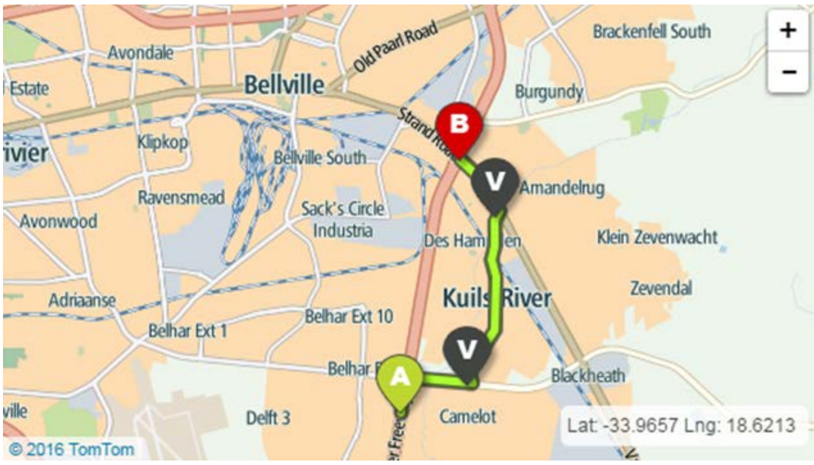


Figure 5: Alternative Route in Cape Town

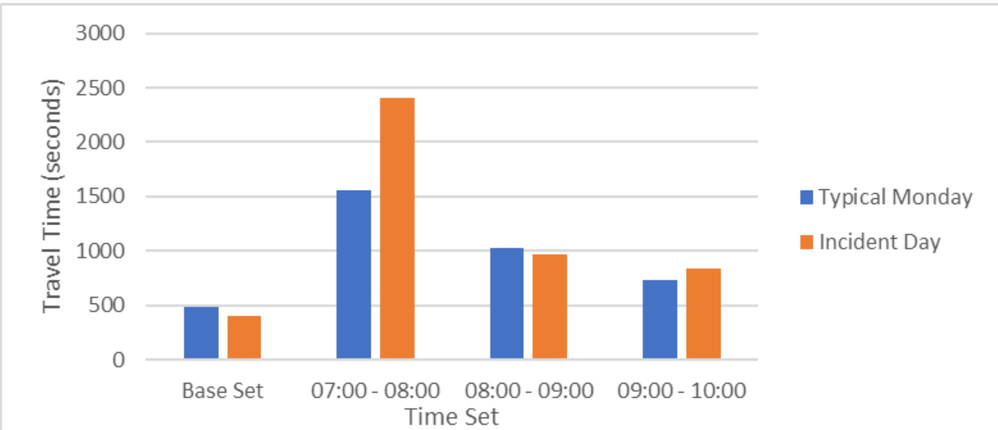


Figure 6: Average Travel Time Comparison on alternative route northbound

4.5 Summary of Pretoria Analysis

To remain concise in this paper, the traffic data of the Cape Town incident was described in detail. The full research project conducted also considered an incident in Pretoria, as described in Section 3.1. The Pretoria incident saw two of four lanes closed by a stationary truck in the northbound direction of the N1. The incident occurred at 04:39 AM on 25 January 2016. The effect of the Pretoria incident is summarised here. Typical average speeds during two 2 hour periods are presented in Figure 10. During the early morning period (05:00 – 07:00 AM), speeds decrease steadily along the N1 on the day of the incident to 20 km/h for 2 km before in the incident, while typical speeds remain relatively constant at 100 km/h during a typical Monday at this time. During the peak traffic period (07:00 – 09:00 AM), the incident reduces the average speed to 10 km/h for at least 9 km before the incident, between 60 and 70 km/h lower than usual at this time.

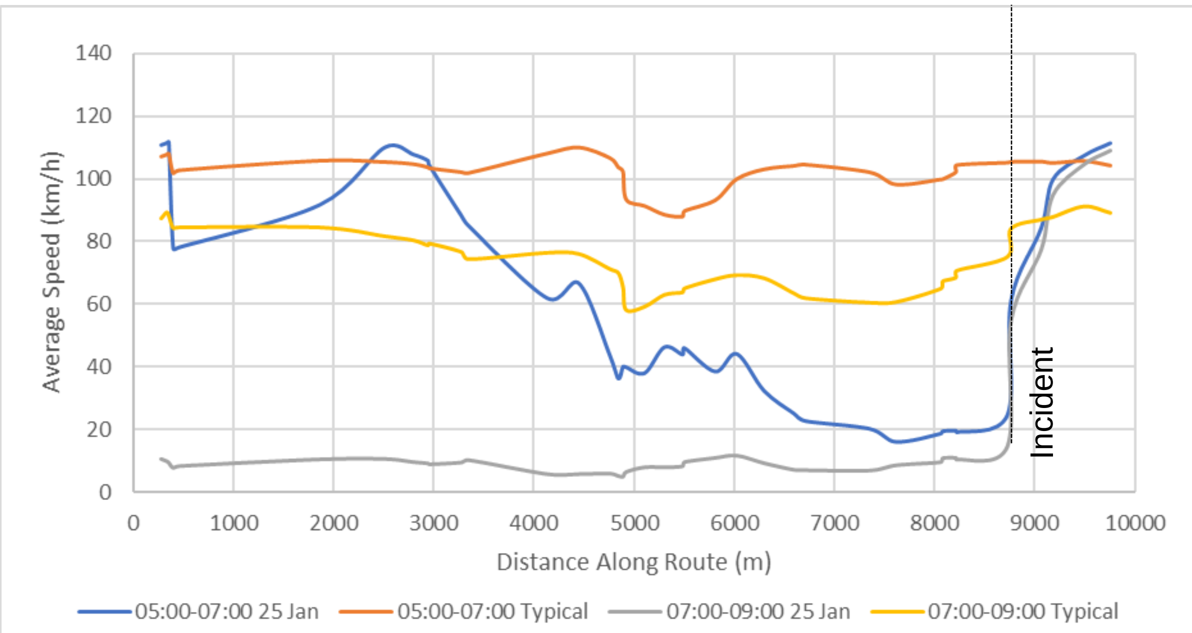


Figure 10: Comparison of Average Speeds: N1 Northbound

Figure 11 indicates the average travel time on the day of the incident and a typical Monday morning. A 9 km route was analysed (8.7 km before the incident, and 1 km after the incident). An increase in travel time of more than 813% was noted along this section on the day of the incident when compared to a typical day between 07:00 and 09:00. This amounts to an increase in travel time of more than 6 minutes per kilometre along the route. The travel time remains very high for the duration of the incident, which was cleared 11:26. Half the capacity of this route was not available during the incident, which explains the very high travel time increase and dramatic speed decrease.

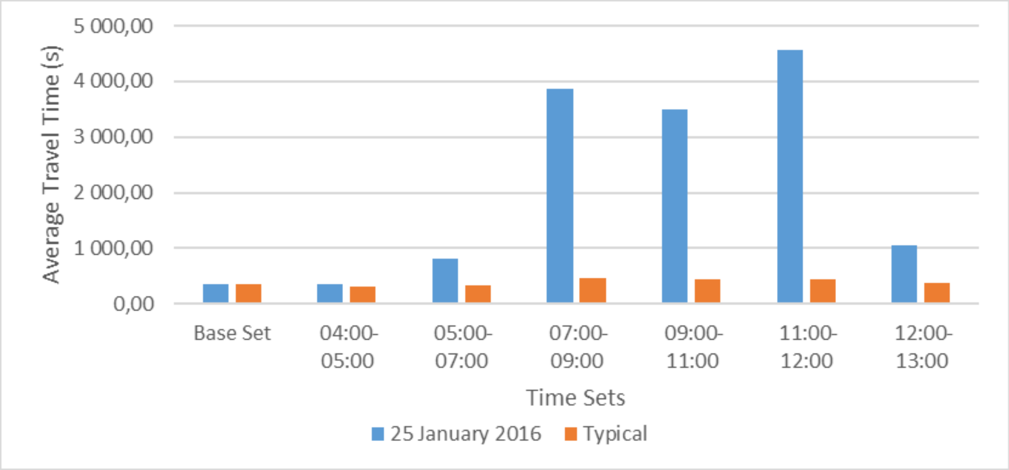


Figure 11: Average Travel Time Comparison on N1 Northbound

5 APPLICATION OF METHOD FOR INCIDENT RESPONSE

The aim of this research was to determine whether probe data could accurately represent the state of traffic during and after a non-recurrent event, such as a stationary truck, and allow comparison with typical traffic along the route and adjacent road network. This study showed that probe data can be very useful in determining the effect of an incident in terms of reduced speed, increased travel time and queue formation. The methodology used in the research can be extended to be used for further incident analysis in various other situations. Benefits include: easy to interpret results, relatively easy and quick data analysis (compared to modeling), and results that are based on actual traffic conditions, not modeling output.

This type of research could be used to evaluate various traffic situations, and can inform response planning for traffic incidents. Based on the characteristics of a future incident (number of lanes closed for example) the anticipated queue formation, reduced speeds and anticipated increased travel time could be used to manage the response to an incident.

This method would also be useful for the evaluation of incident responses, for example to determine if the process to clear the incident was successful, as well as carried out efficiently and timeously.

6 CONCLUSIONS

The methodology focussed on the analyses of the route upstream of an incident scene, as well as the immediate surrounding road network. Unlike models and mathematical algorithms used to analyse road traffic incidents, this methodology relies on probe data of the day of the incident in order to represent the impact of an incident. The methodology is simple to replicate and the results are easy to obtain and interpret.

Results clearly illustrated the impact of the incidents on the immediate road network. The results also indicated how traffic flow systematically returned to its normal conditions downstream of the incident, as well as in time sets after the incident scene was cleared. Average speed and travel time were the principal data parameters used to illustrate this effect. The approximate queueing length can also be identified. This was defined as the approximate area of influence of each incident. Analysis of the results along alternative routes confirmed that an incident will have a significant impact on the immediate road network as well.

It is recommended that the information and conclusions from this paper be further used by other interested stakeholders such as traffic management centres, road authorities, emergency services, law enforcement, or the ordinary citizens affected by the incidents.

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