

An Analysis of the KEEP CLEAR Pavement Markings Effects on Queuing Vehicles Dynamic Performance at Urban Signalised Intersections

Shuai YANG¹, Edward CHUNG², Marc Miska³, David RYAN⁴, Clinton FOOKES⁵,

Simon DENMAN⁶, Sridha SRIDHARAN⁷

^{1, 2, 3} Smart Transport Research Centre, Science and Engineering Faculty,
Queensland University of Technology

GPO Box 2434, Brisbane, QLD 4001, Australia

^{4, 5, 6, 7} Science and Engineering Faculty, Queensland University of Technology

GPO Box 2434, Brisbane, QLD 4001, Australia

Email for correspondence: ys-00@163.com (previous: shuai.yang@student.qut.edu.au)

Abstract

KEEP CLEAR pavement markings are widely used at urban signalised intersections to indicate to drivers to avoid entering blocked intersections. For example, 'Box junctions' are most widely used in the United Kingdom and other European countries. However, in Australia, KEEP CLEAR markings are mostly used to improve access from side roads onto a main road, especially when the side road is very close to a signalised intersection. This paper aims to reveal how the KEEP CLEAR markings affect the dynamic performance of the queuing vehicles on the main road, where the side road access is near a signalised intersection. Raw traffic field data was collected from an intersection at the Gold Coast, Australia, and the Kanade–Lucas–Tomasi (KLT) feature tracker approach was used to extract dynamic vehicle data from the raw video footage. The data analysis reveals that the KEEP CLEAR markings generate positive effects on the queuing vehicles in discharge on the main road. This finding refutes the traditional viewpoint that the KEEP CLEAR pavement markings will cause delay for the queuing vehicles' departure due to the enlarged queue spacing. Further studies are suggested in this paper as well.

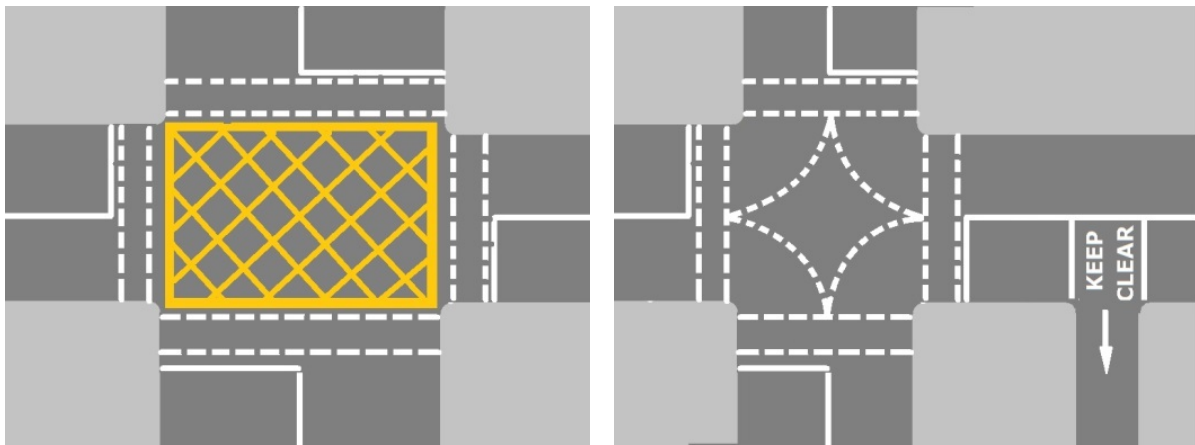
1. Introduction

The Keep Clear pavement markings are an effective method to prevent drivers from blocking intersections in urban streets. The majority of the Keep Clear road markings in use today are 'Box junctions' which are most widely implemented in the United Kingdom and some other European countries (UK, 2013). However, the Keep Clear pavement markings used in Australia follow a different approach; the most significant difference is that the pavement markings are painted on the ground, with the words 'KEEP CLEAR', and the primary function of these markings is to improve access from side roads onto a main road. This is especially important when the side road is very close to a signalised intersection (DTEI, 2010; Office of Legislative Drafting, 2009) (see Figure 1). If a 'KEEP CLEAR' road marking is positioned close to a signalised intersection, the enlarged stopping distance created by this road marking might have significant effects on those vehicles queuing behind the marking. Traditional vehicle departure theory suggests that these vehicles will be negatively affected due to the increased 'Clearance' (stopping distance) compared to a normal situation. However, contemporary research lacks any quantitative or qualitative data to demonstrate the effects of these markings on the queuing vehicles during the discharge process.

The Highway Capacity Manual 2010 indicates that the headway time or driver response time tends to decrease from the first to the fourth vehicle and then remains constant when the delayed start-up reaction has dissipated (TRB, 2010). Therefore, saturation flow is achieved and maintained after approximately 10 seconds from the onset of the green light, or after the

fourth vehicle in the queue crosses the stop-line. If the 'KEEP CLEAR' marking is positioned very close to a signalised intersection, the stopping distance of the leading vehicles in the queue will be enlarged. Akcelik (2008) stated that, "the queue discharge headway is a key parameter that determines capacity". Instinctively, the 'KEEP CLEAR' markings would lead to negative effects on the discharge headway and also would decrease the capacity as vehicles would need to cover more distance created by the keep clear markings. However, this viewpoint is based on intuition and further investigation is warranted. Previous literature has evaluated the performance of specific road markings on the traffic. For example, researchers evaluated the Spiral-marking roundabout (Wong et al., 2012) and research has been conducted for modelling the paint pavement markings performance (Mull & Sitzabee, 2012; Sitzabee et al., 2009). This highlights the necessity to conduct research to evaluate the effect of 'KEEP CLEAR' pavement markings on departure, and to characterise the dynamic performance of queuing vehicles at signalised intersections.

Figure 1: 'Box junctions' and 'KEEP CLEAR' pavement markings



2. Video Collection and Data Extraction

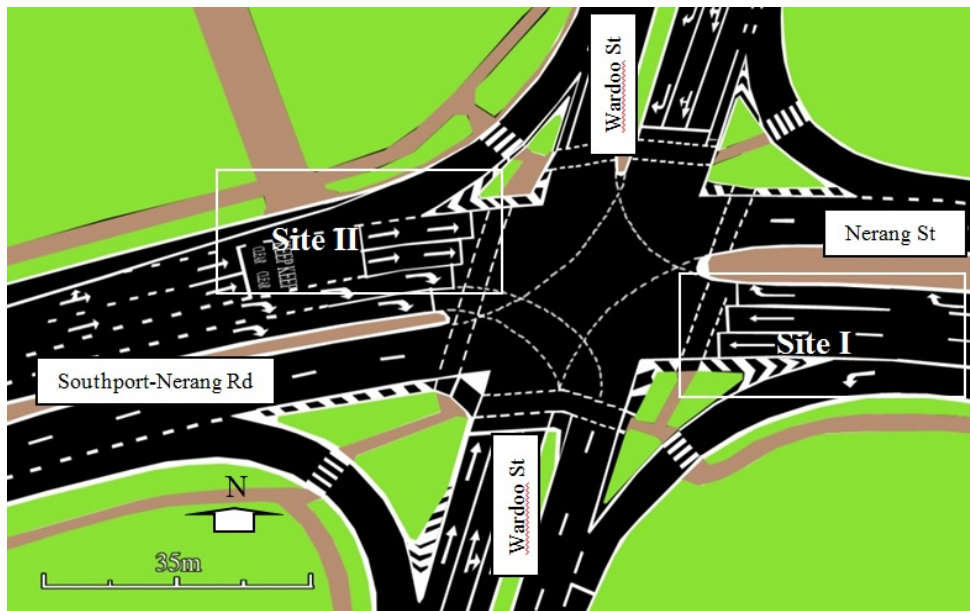
2.1 Raw Video Collection

Using video surveillance as a data collection tool is a relatively new but potentially powerful concept for performing traffic engineering research (Slinn et al., 2005). The methodology followed in this research is comprised of three steps: Raw video collection, Vehicle data extraction and Data analysis.

The study site selected for this analysis is located at the intersection of Nerang Street and Wardoo Street, Southport, Gold Coast, Queensland, Australia. An area schematic is presented in Figure 2. The study site is a four directional intersection; the eastern part of the site is Nerang Street, the western part is the Southport-Nerang Road, and the north and south sections constitute Wardoo Street. The speed limit on Nerang Street and Southport-Nerang Road is 60 kilometres per hour. This field data collection site includes two sections. The east site is labelled "Site I" which has a typical queuing discharge situation (no "KEEP CLEAR" markings); the opposite side is labelled as "Site II" and has a "KEEP CLEAR" pavement marking.

After obtaining official permission from the Department of Transport and Main Roads, raw video data was collected from the site in late 2012. The Nerang raw videos were collected using a camcorder which was mounted on a seven metre high tripod on open land on the roadside. The road at Site I has an approximately 10% slope from east to west, but the road at Site II is almost flat. Although the criteria for queuing discharge sample extraction is that queuing vehicles should completely stop and that the five leading vehicles' queue length is relatively short, the effects of the road's slope at Site I on the dynamic performance is obvious.

Figure 2: Nerang study area schematic



2.2 Vehicle Data Extraction

In 1947, Greenshields introduced the use of video and a projector to manually extract data for the purpose of conducting traffic performance research at urban signalised intersections (D.Greenshields et al., 1947). Modern advances in computer vision technology, such as object tracking, have enabled us to automate a large portion of this procedure so that vehicle data can be extracted efficiently from raw video footage. This section describes the algorithm used in this research to extract the vehicle data, including position, velocity, acceleration and headway.

The data extraction is complicated by a number of factors including severe *occlusions* between vehicles and significant *camera jitter* which occurs sporadically throughout the sequences. As shown in Figure 3, the lane closest to the camera is a turning lane, while the *lane of interest* is located behind this. The *vehicles of interest* are indicated using rectangular boxes and are labelled with a unique ID. These vehicles of interest are regularly occluded from view by those vehicles travelling in the turning lane. Similarly, vehicles in the background also produce significant motion in similar regions of the image as the vehicles of interest, complicating the data extraction process further. Camera jitter poses another problem for object tracking, because “most state-of-the-art tracking methods for fixed cameras... use background subtraction methods to detect regions of interest” (Yilmaz et al., 2006). Even small camera movements can interfere with this process, because traditional background modelling techniques model each pixel independently; for example, as a mixture of Gaussian distributions (Stauffer & Grimson, 1999; Zivkovic & Heijden, 2006).

Figure 3: Sample frames from Nerang each site video sequences



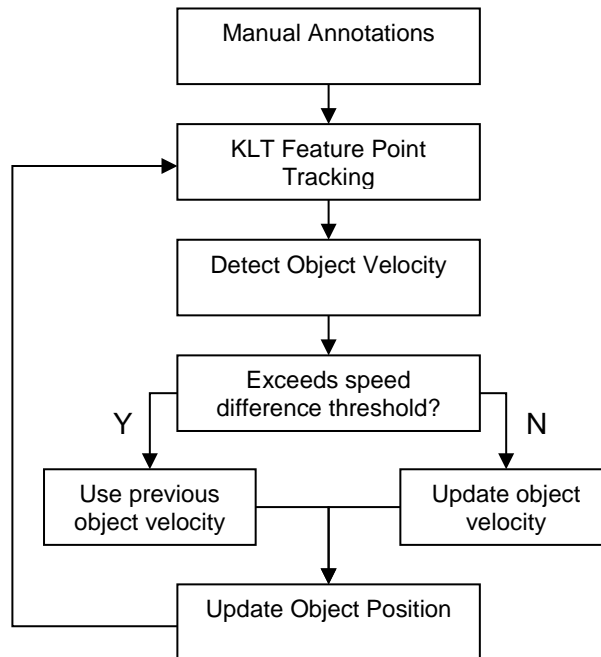
(a) Nerang Site I.



(b) Nerang Site II.

The methodology followed here is based on the KLT feature point tracking algorithm introduced by Kanade, Lucas and Tomasi (Lucas & Kanade, 1981; Shi & Tomasi, 1994; Tomasi & Kanade, 1991) and made publicly available by Birchfield (2007). The KLT algorithm tracks *feature points* in an image rather than explicit objects, and the motion of these points is used subsequently by our system to monitor vehicles. The system diagram for our approach is presented in Figure 4. Object tracking is initialised manually at the onset of the green light, by annotating each vehicle with a rectangular bounding box, and the size of this bounding box is held constant thereafter. Between each pair of video frames, KLT tracking is used to monitor the movement of feature points within each bounding box, and the *median* displacement of these feature points is taken to be the object's frame wise velocity. This velocity is used to reposition the bounding box at each successive frame.

Figure 4: Tracking system flowchart.

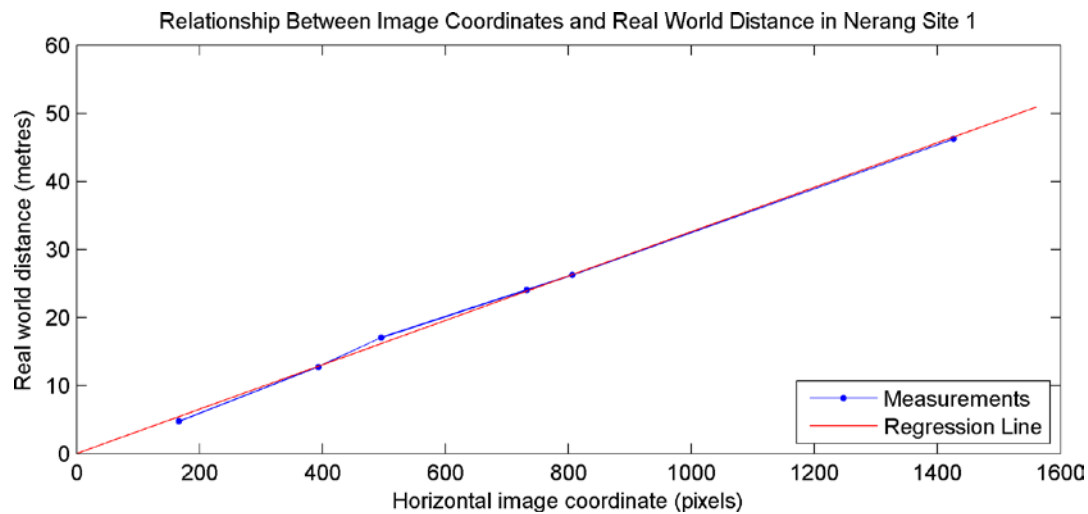


Object properties such as colour and gradients are not explicitly maintained, as in other tracking systems (Yilmaz, et al., 2006). This is because the vehicles of interest (i.e. those being tracked by the system) do not occlude one other: instead, they maintain a substantial distance apart. However, occlusion does occur with *other* vehicles in the scene, and this may interfere with the KLT tracking algorithm. Therefore, the researchers take advantage of the fact that occluding vehicles are usually travelling at different velocities (e.g. when a vehicle in the turning lane passes a stationary vehicle of interest, which is the most common form of occlusion encountered in these sequences). When occlusion occurs, the median velocity of the feature points changes rapidly, resulting in an unlikely level of acceleration. In order to suppress these unlikely levels of acceleration (and hence avoid tracking errors), a speed difference threshold is enforced between consecutive frames (Figure 4): if the change in

velocity of the bounding box exceeds this threshold then the previous value of the object's velocity is retained instead. This approach is capable of handling minor and temporary occlusions, such as those encountered in these video sequences. Furthermore, the speed difference threshold mitigates the effects of camera jitter which occurs sporadically throughout the video.

The algorithm operates at approximately 10 frames per second when processing a large 1560×320 video sequence. The video sequences were partitioned into segments corresponding to each green light transition. Vehicles were tracked both forwards and backwards in time from their stationary queuing position in order to extract their entire trajectories. Vehicle trajectories were converted to real-world distances using a quasi-calibration in which horizontal image pixels were linearly mapped to a fixed distance (in metres). Measurements were taken from unique markings along the side of the road (such as signposts and painted markings) and their corresponding image position was identified. Figure 5 shows the relationship between the horizontal image coordinate and the real world distance at Site I. The linear regression line was used to construct the quasi-calibration as shown in Figure 5. Object position was converted from image coordinates (pixels) to real-world distances (metres), while the length of each vehicle was also converted from image pixels to metres. The distance between vehicles was derived automatically from this information. Velocity and acceleration were derived from the position data, calculated as the first and second derivatives of position, respectively. Section 0 presents the analysis of this data.

Figure 5: Quasi-calibration is achieved by establishing a linear relationship between the horizontal image coordinate and real world distance.



3. Data Analysis

3.1 Raw Discharge Samples

In this data analysis discharge samples were only considered if they included five or more queuing vehicles. Results from the tracking procedure described in Section 2.2 yielded 18 discharge samples from Site I, and 31 discharge samples from Site II. The results are presented in **Error! Reference source not found.** and Figure 7 respectively. In each time-space graph, the X axis represents the time in seconds and the Y axis shows the distance to the stop line in metres. The onset of the green light occurs at $x=0$ and the stopping line is positioned at $y=0$. For example, $y=-10$ metres means the vehicle is position at 10 metres upstream of the stop line; $x=5$ seconds means 5 seconds after the green signal onset. The time space diagrams in **Error! Reference source not found.** and Figure 7 allow the determination of the space headway (y-axis), and time headway (x-axis) of consecutive vehicles.

Figure 6: Nerang Site I; 18 sets of vehicle trajectory samples.

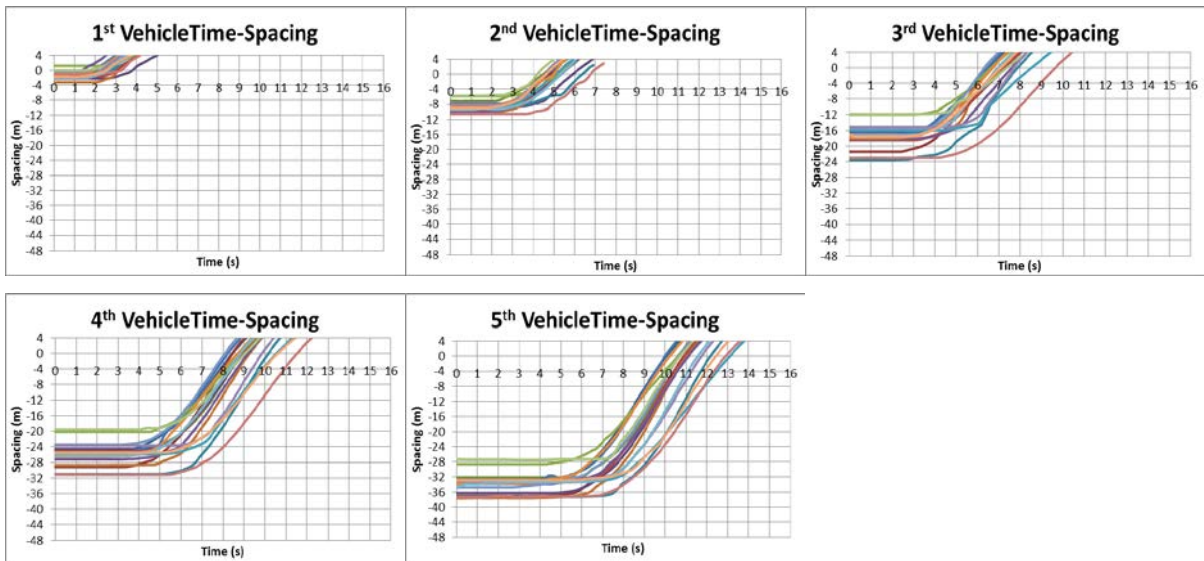
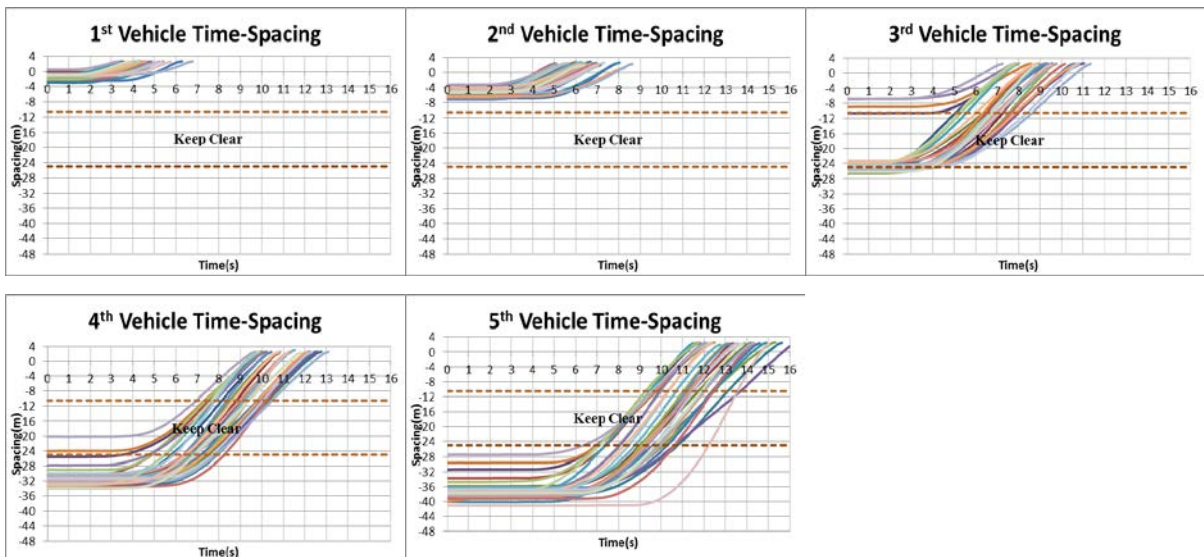


Figure 7: Nerang Site II; 31 sets of vehicle trajectory samples.



3.2 Methods and Limitations

This research used the average vehicle trajectory across all discharge samples, as depicted in **Error! Reference source not found..** Each discharge sequence is labelled with an “E number”. At Site I, the sequences E05, E09 and E14 included trucks in the queue or a vehicle pulling a trailer. At Site II, the sequences E04, E05, E07, E08, E09, E12, E14, E16, E20, E22, E25 and E30 include motor bikes, vehicles pulling a trailer, trucks or a motorhome in the queue. At Site II, there are typically two vehicles ahead of the ‘KEEP CLEAR’ road marking and three or more vehicles behind it. However, in sequences E04, E10, E20 and E26, there are three vehicles ahead of the ‘KEEP CLEAR’ road marking. This is seen in Figure 7, for the third vehicle’s trajectories: in these four sequences, the third car’s initial position is located ahead of the road marking. Consequently, these four discharge samples were excluded from the average trajectory extraction process.

One limitation of the average method is that the end part of each vehicle’s queuing position discharge trajectory appears to fluctuate (see Figure 8). The raw data samples vary widely because the amount of trajectory data suddenly drops as the time line increases. Also, because the raw video only covers the five leading vehicles’ queue stream area, only a small

part of the intersection beyond the stop line is recorded. This directly means that the data can only include a short time period after each vehicle passes through the stop line (see Figure 9). This limitation strongly suggests that future research should use more camcorders to obtain a greater coverage of the site. This would enable vehicle trajectory data to include the time since the vehicle crosses the stop line. This extended coverage would counteract the fluctuations observed in the end part of the average trajectory.

Figure 8: Nerang Site I and Site II raw average trajectories

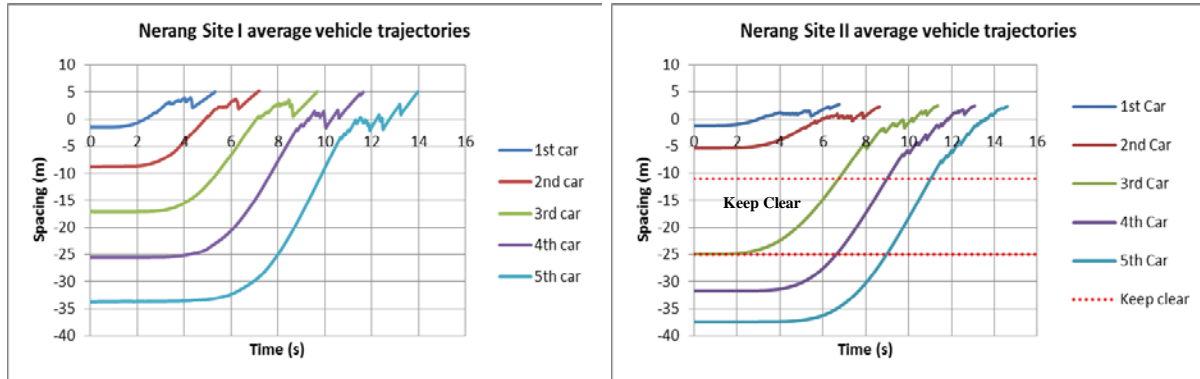
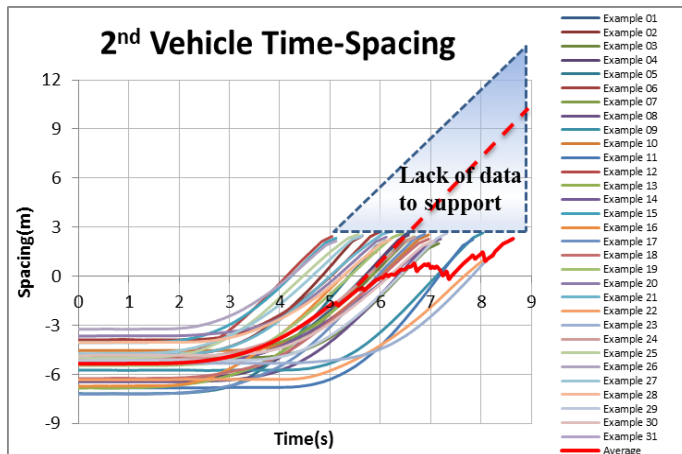


Figure 9: Limitation of the Nerang Data



3.3 Extraction of Vehicles' Dynamic Parameters

To avoid the deviation of the raw velocity and acceleration, the researchers used time difference distance formula to calculate the velocity and then extracted eight parameters items. They are queuing vehicles distance from the stop line (m), driver response time since the green signal onset (s), two successive vehicles' queue clearance (m), two successive vehicles' queue spacing (m), delay in response time (s), two successive vehicles' spacing when the follow vehicle make response to the green signal onset (m) (labelled as spacing') and the preceding vehicle's speed (m/s). And then, this step summarises the average vehicle length of the Nerang Data. For the Nerang Site I data, this step extracts five leading vehicles dynamic parameters according to vehicles' queue position. Driver response time and the corresponding queue clearance are linked together into one graph. Furthermore, two successive vehicles' spacing and the preceding car's speed, at the time when the following vehicle make response to the green signal, are joined into one graph. On the other hand, different times and locations lead to researchers using various vehicles length data in their research. For instance, Akcelik (2000) recommends allowing 6 to 7 metres per vehicle storage length for a queue of cars. However, with fuel prices increasing, more and more smaller cars are now being used on the roads. Thus, the average car length keeps changing. Therefore, the researchers calculated the average vehicle length in the applicable trajectory samples from the Nerang Data and the result is 4.15 metres. This result confirms that it is

necessary to keep this vehicle length parameter updated. It also indicates the problems that can arise when each research case uses different data.

3.4 Nerang discharge patterns

The main aim of this step is to obtain five leading vehicles' discharge patterns. Each driver's response time is extracted from the raw data, using 5 km/h as the threshold between "stopped" and "moving". As the frame rate of the video is 25 frames per second (fps), the 5 km/h threshold is equivalent to 0.0556 m per 1/25 second. This criterion is used to extract the driver response time. Consequently, each vehicle's trajectory is divided into queue waiting and acceleration phases. The vehicle discharge patterns of the five leading vehicles are generated by using the Excel Trendline Options from the average five leading vehicle trajectories which have excluded the fluctuating end parts of the trajectory curve (see Figure 10). As there is limitation of the Nerang Data, this step calibrates the obtained vehicles average discharge patterns. The average time of the vehicles crossing the stop line can be calculated by using the obtained discharge patterns and also can be directly averaged out from each discharge sample. The second method is accurate and the deviations from these two methods are used to evaluate the accuracy of the Nerang Data five leading vehicles average discharge patterns (see Table 1).

Figure 10: Nerang data raw average five leading vehicle discharge patterns

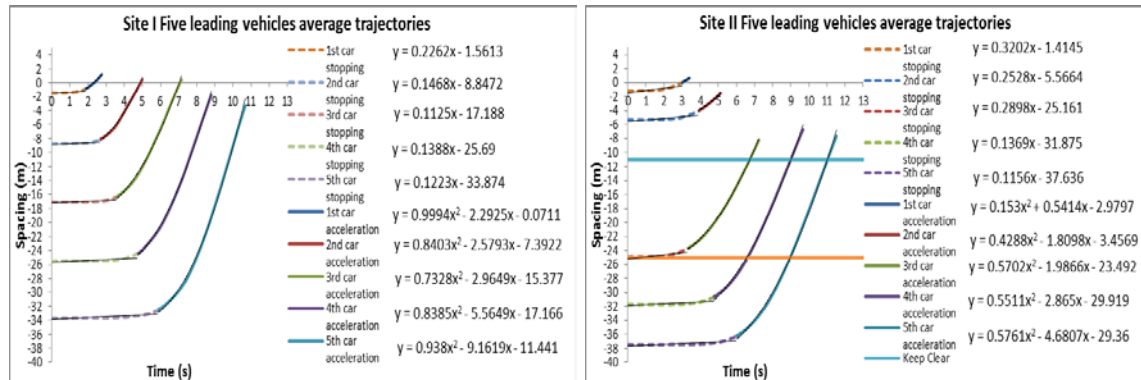


Table 1: Two methods to obtain the time of vehicles crossing the stop line

Nerang data	Time for vehicle crossing the stop line (s)					
	Queue position	1 st Car	2 nd Car	3 rd Car	4 th Car	5 th Car
Site I	Calculated by discharge patterns	2.32	4.87	7.03	8.93	10.89
	Averaged from data	2.37	4.91	7.09	9.03	11.04
	Deviation	0.05	0.04	0.06	0.1	0.15
	Calibrated discharge patterns	2.37	4.91	7.09	9.03	11.04
Site II	Calculated by discharge patterns	2.99	5.65	8.39	10.41	12.28
	Averaged from data	3.16	5.69	8.49	10.76	12.67
	Deviation	0.17	0.04	0.1	0.35	0.39
	Calibrated discharge patterns	3.16	5.69	8.49	10.76	12.67

Note: the discharge patterns are vehicle acceleration equations in Figure 10; the calibrated discharge patterns are equations in Table 2.

Furthermore, the deviations are used to manually calibrate those parameters of the obtained vehicle discharge patterns in Figure 10 to make them more accurate. Consequently, Nerang Data Site I and Site II first five leading queuing vehicle discharge patterns are accurately expressed (see Table 2). A limitation of these obtained discharge patterns is that they only accurately indicate queue dissipation up until the point where the vehicles are just over the stop line. For example, the acceleration phase of the Site I the first car discharge pattern is

$y=0.9994x^2-2.2925x-0.0711$ in the raw discharge patterns (see Figure 10) and if $y=0$, $x=2.32$. This means the first car crosses the stop line at a time of 2.32 seconds. In contrast, the average time of the first car to cross over the stop line from each of the car discharge sample is 2.37 seconds. Moreover, the above equation is manually calibrated as $f(x) = 0.9794x^2 - 2.2925x - 0.0711$, so as to make its calculation result consistent with the averaged method result. Using this method, Site I and Site II five leading vehicle discharge patterns are calibrated. The Nerang Site I data five leading vehicle discharge patterns are labelled as B1, B2, B3, B4 and B5, while the Site II patterns are labelled as C1, C2, C3, C4 and C5 in this paper.

Table 2: Nerang Site I & Site II data average five leading vehicle discharge patterns

Patterns ID	Queue position	Time x in seconds with distance to the stop line f(x) in metres. Green onset at time x=0 and stop line located at f(x) =0.	Conditions
Site I B1	1 st	$f(x) = 0.2262x - 1.5613$	$x \leq 1.9s$
		$f(x) = 0.9794x^2 - 2.2925x - 0.0711$	$x > 1.9s$
Site I B2	2 nd	$f(x) = 0.1468x - 8.8472$	$x \leq 2.7s$
		$f(x) = 0.8323x^2 - 2.5793x - 7.3922$	$x > 2.7s$
Site I B3	3 rd	$f(x) = 0.1125x - 17.188$	$x \leq 3.6s$
		$f(x) = 0.7238x^2 - 2.9649x - 15.377$	$x > 3.6s$
Site I B4	4 th	$f(x) = 0.1388x - 25.69$	$x \leq 4.8s$
		$f(x) = 0.8265x^2 - 5.5649x - 17.166$	$x > 4.8s$
Site I B5	5 th	$f(x) = 0.1223x - 33.874$	$x \leq 5.9s$
		$f(x) = 0.924x^2 - 9.1619x - 11.441$	$x > 5.9s$
Site II C1	1 st	$f(x) = 0.3202x - 1.4145$	$x \leq 3.0s$
		$f(x) = 0.127x^2 + 0.5414x - 2.9797$	$x > 3.0s$
Site II C2	2 nd	$f(x) = 0.2528x - 5.5664$	$x \leq 3.9s$
		$f(x) = 0.425x^2 - 1.8098x - 3.4569$	$x > 3.9s$
Site II C3	3 rd	$f(x) = 0.2898x - 25.161$	$x \leq 3.3s$
		$f(x) = 0.5602x^2 - 1.9866x - 23.492$	$x > 3.3s$
Site II C4	4 th	$f(x) = 0.1369x - 31.875$	$x \leq 4.8s$
		$f(x) = 0.5248x^2 - 2.865x - 29.919$	$x > 4.8s$
Site II C5	5 th	$f(x) = 0.1156x - 37.636$	$x \leq 6.0s$
		$f(x) = 0.5521x^2 - 4.6807x - 29.36$	$x > 6.0s$
Note: If speed is <5 km/h, the car is looked as 'stop', otherwise the car is 'moving'.			

4. The 'KEEP CLEAR' pavement markings effects

4.1 Effect on driver behaviour

To personally experience the 'KEEP CLEAR' road marking, the researcher drove a car many times to cross the intersection of Nerang Street and Wardoo Street on the Gold Coast. As this measure depended on the occasional opportunity to stop behind the 'KEEP CLEAR' road marking, the rate of successfully capturing the discharge process was very low. There were only a few videos that were recorded from the driver's position using a mobile phone video function. Two clips were obtained on 01 November 2010, another two (separately) on 04 November 2010 and 17 November 2010. Here are two clips that can be used to show the

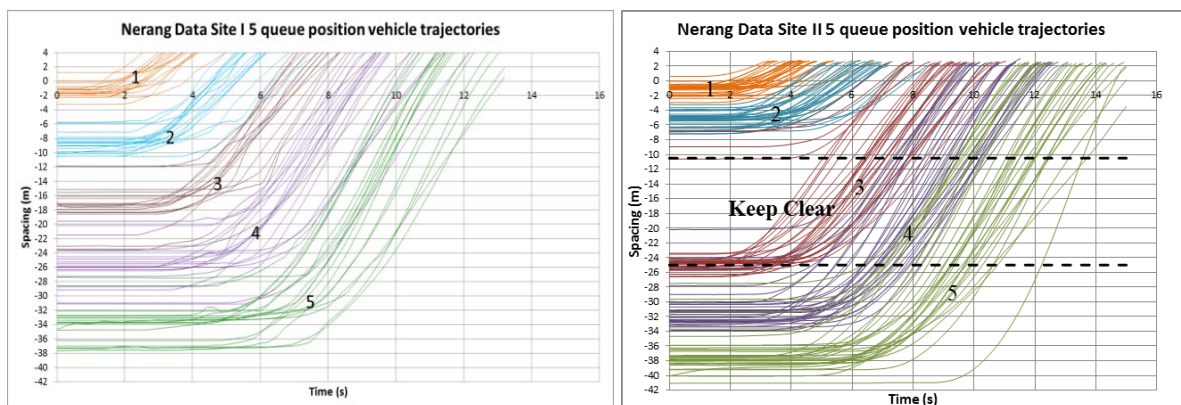
queuing vehicles discharge process. Two images from one video clip illustrate how the 'KEEP CLEAR' road marking affect the driver behaviour. The Figure 11 clips show that the third car in the left through-lane only takes 8 seconds to pass through the stop line after the signal changing to green, while on the right through-lane, the green "Mini" uses only 6 seconds.

Figure 11: Nerang Data II clips



The above visual image shows that a 'KEEP CLEAR' pavement marking does not present negative effects on the queuing vehicle discharge process. Contemporary departure models assume that queuing vehicle drivers almost always exhibit the same driving behaviour. As a result, vehicle trajectories will present as parallel curves. Hence, if a 'KEEP CLEAR' road marking causes the clearance (in metres) to be increased, the spacing (in metres) will also be enlarged. The result will be that a 'KEEP CLEAR' road marking will cause an increase in the clearance time of all the queuing vehicles. The Nerang Site II Data raw five leading vehicles discharge samples analysis results confirm that the 'KEEP CLEAR' road marking can change driver behaviour. The data show that the sequenced vehicles located behind the 'KEEP CLEAR' road marking try to keep up with the leading vehicles in the discharge process (when compared to the Site I the third vehicle trajectories and the Site II the third vehicle trajectories) until the process reverts to the typical following model (see Figure 12). This evidence vitally supports that the 'KEEP CLEAR' road marking changes driver-vehicle performance. This is contribution to the traffic management research field and this finding can be used to calibrate the traditional departure model.

Figure 12: 'KEEP CLEAR' effects on drivers' 'catching up'



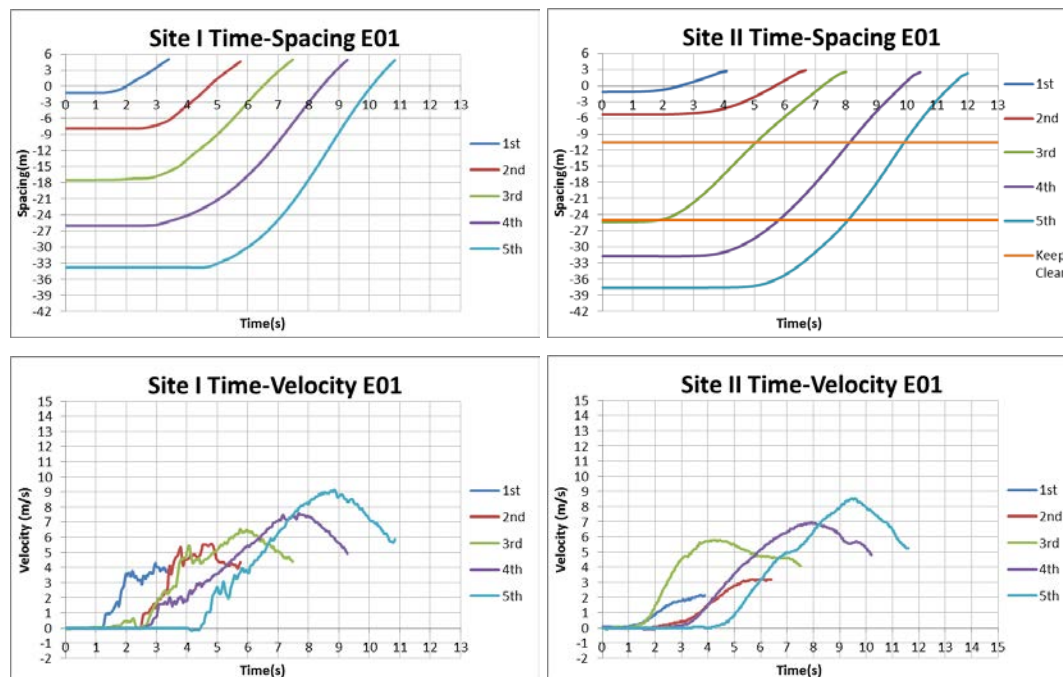
The next issue reveals that the driver's ability to comply with the road rules of the 'KEEP CLEAR' road marking. The raw videos of the Nerang Site II show that: the follow vehicle slowly approaches to the end side of the 'KEEP CLEAR' road marking and then its driver makes judgement whether they should move forward or stop behind the 'KEEP CLEAR' road marking. There are two situations that could happen: if the following driver adjusting to the front site (located in front of the 'KEEP CLEAR' road marking) can offer one more queuing position, this following vehicle will be moved forward to join the leading queuing vehicles; by

contrast, if there are no more queuing positions left, this following vehicle will completely stop behind the 'KEEP CLEAR' road marking. Additionally, few samples are detected that the following vehicle do not slow down when it approaches the 'KEEP CLEAR' road marking and the vehicle stops in the 'KEEP CLEAR' area. The Gold Coast Nerang Data analysis results show that the percentage for drivers who strictly observe the 'KEEP CLEAR' road markings. Examination of the third vehicle trajectories shows that, of the total 31 samples, there are 22 samples (71%) where the 3rd queue position drivers obey the 'KEEP CLEAR' road marking. Moreover, of the remaining 9 samples, 8 samples are just over the line by a few metres, and only one driver completely ignores the line.

4.2 Effect on velocity

Figure 13 shows the time-spacing and time-velocity plots for Sample E01 from Site I and Sample E01 from Site II, to illustrate how the 'KEEP CLEAR' road marking affects the queuing vehicles behind this road mark. The time-spacing graphs show that the third driver behind the 'KEEP CLEAR' road marking tries to keep up with the preceding vehicle, and this behaviour directly changes the traffic trajectory performance. The time-velocity graph for Site II shows that the third vehicle's velocity increases more rapidly than the preceding vehicles' speed when compared with the normal discharge (Site I). These results make an original contribution to the micro-simulation departure model research area. The conclusion of this research is also an innovative outcome for traffic management research. It can also directly benefit the calibration of other departure models. In short, the 'KEEP CLEAR' road marking can make a positive change in vehicle-driver discharge performance.

Figure 13: Comparative analysis of Nerang Data Site I and Site II



4.3 Findings within Nerang Data

As the Nerang Data are the only data available with a forced 'KEEP CLEAR' area, this data is checked first to find indications to explain the 'KEEP CLEAR' road markings' effects during discharge at an intersection. Figure 14 shows the response time of drivers depending on the stopping distance – the space between the cars from front-bumper to front-bumper. Response time is the time that it takes a driver to accelerate after the leading vehicle has started to move. Figure 14 shows data for Nerang Site I only, but instead of a stopping distance, it plots the response time which is based on the position in the queue. The plot indicates that drivers respond within normally assumed human reaction time with some

noise. Interestingly, Figure 15 of the Nerang Site II data set has a very crisp response time for queue position 3, the vehicle with the 'KEEP CLEAR' in front. This shows that the noise around the response time of the driver is related to the leading vehicle clearance distance, starting speed, or a combination of both. To investigate this further, the time a car needs from starting to move to reaching cruising speed need to be examined. Due to the limitations in the data collection behind the stop line, further data collection and research work need to be conducted in future. The majority finding shows that the third queue position driver start up loss problem is significantly improved through the 'KEEP CLEAR' road marking which enlarged vehicle queue spacing.

Figure 14: Response time of drivers in different positions in the queue at Nerang Site I - without 'KEEP CLEAR'

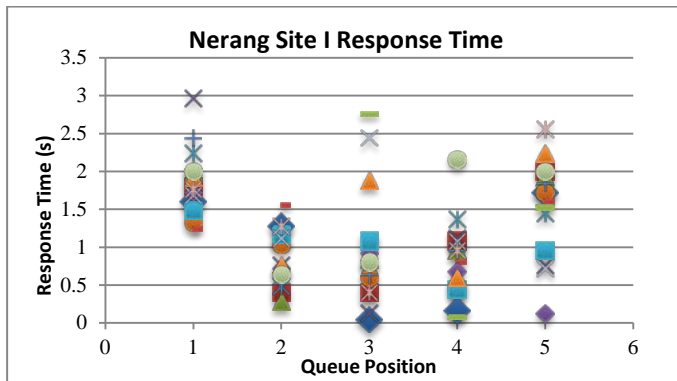
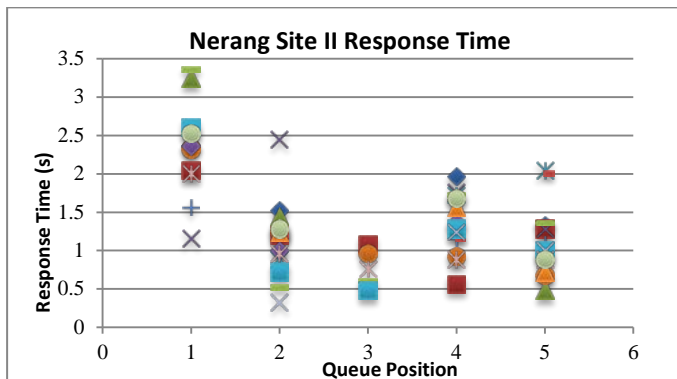


Figure 15: Response time of drivers in different queue positions at Nerang Site II - with 'KEEP CLEAR'



5. Conclusion

This research recorded raw video at the intersection of Nerang Street and Wardoo Street at the Gold Coast, Queensland, Australia. The videos separately recorded two sides of the intersection: Site I had a normal queuing situation while Site II had a 'KEEP CLEAR' pavement marking. Dynamic traffic data was extracted automatically, using a computer vision algorithm built around a KLT Tracker, from the raw videos. The data for Site II (with the 'KEEP CLEAR' pavement marking) generated 32 sets of vehicle trajectory samples while 18 sets of samples were extracted from the opposite side of the intersection (Site I). The data analyses yielded the discharge patterns of the five leading vehicles so as to better understand how the 'KEEP CLEAR' road markings affect the queuing vehicles during departure at signalised intersections.

Findings of this research include practical and theoretical aspects. From a practical viewpoint, this research offers strong evidence to refute the viewpoint that the 'KEEP CLEAR' road markings will cause delay to the queue departure as a result of the enlarged stopping distance. Civil engineers can eliminate misgivings about implementing this road

marking. From a theoretical viewpoint, the findings reveal that the 'KEEP CLEAR' pavement markings can improve the driver response time for vehicles queuing behind the marking. As a result, the contribution of this study is to identify potential solution by enlarge the stopping distance method for the traditional start-up loss time problem. This research also contributes to the field by integrating computer vision algorithms to track vehicles and extract traffic data from video footage automatically. Moreover, a new theory based on the 'enlarged stopping distance' will be explored further in future research.

6. References

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