Submission number: 104

IMPLICATIONS OF PARKING POLICY ON TRAFFIC FLOW WITHIN URBAN ENVIRONMENTS

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ABSTRACT

The provision of on-street parking within urban environments has been a heavily debated topic. Transport authorities have been under constant pressure to provide adequate parking to satisfy the commercial needs of the community in light of the argument that it may have a detrimental traffic impact on the network resulting in congestion. This study attempts to gain an understanding of the implications of on-street parking manoeuvres on traffic flow through an empirical analysis of field data. The study conducted parking surveys, collecting qualitative and quantitative data related to parking behaviour, on selected major arterial roads within Sydney, Australia. Analysis of survey data suggests that delays increase for parking zones with a greater level of parking turnover. Furthermore, the study completes a microsimulation modelling exercise to highlight the performance impacts of parking policies within Sydney. Finally, the study proposes alternative policies which could reduce the traffic flow implications of on-street parking.

Keywords: On-street parking, Congestion, Parking Policy, Microsimulation Modelling

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X	No preference		

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Hoi Shan Leung

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X	Presentation and Publication		Presentation only

Submission for HKSTS Outstanding Student Paper Award (You are a postgraduate student and the sole author of the paper): (Please put a “X” as appropriate)

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Submission for HKSTS Outstanding Dissertation Paper Award (You are PhD graduate who is citizen of an Asian country and who has completed your PhD study within three years and the first author of the paper): (Please put a “X” as appropriate)

	Yes	X	No

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The provision of on-street parking within urban environments has been a heavily debated topic. Transport authorities have been under constant pressure to provide adequate parking to satisfy the commercial needs of the community in light of the argument that it may have a detrimental traffic impact on the network resulting in congestion. This study attempts to gain an understanding of the implications of on-street parking manoeuvres on traffic flow through an empirical analysis of field data. The study conducted parking surveys, collecting qualitative and quantitative data related to parking behaviour, on selected major arterial roads within Sydney, Australia. Analysis of survey data suggests that delays increase for parking zones with a greater level of parking turnover. Furthermore, the study completes a microsimulation modelling exercise to highlight the performance impacts of parking policies within Sydney. Finally, the study proposes alternative policies which could reduce the traffic flow implications of on-street parking.

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1. INTRODUCTION

Transport authorities face a number of conflicts in managing and developing civil infrastructure to service the needs of the community. Parking policy presents a conflict between user satisfaction and maintenance of network operations. In particular, the decision to provide or restrict on-street parking on major arterial roads has presented a debate throughout the last few decades. One side of the argument suggests that on-street parking acts as a disruption to the flow of traffic which in turn significantly impacts the efficiency and capacity of a road section and ultimately the network (Sisiopiku, 2001, Marsden, 2006, Marshall *et al.*, 2008). Thus, the reduction of on-street parking can improve traffic flow characteristics and even has the potential to result in a mode shift from private to public transportation. However, there is also evidence suggesting that the economic viability of commercial districts is dependent on accessibility provided by on-street parking (De Cerreño, 2004, Marsden, 2006, Marshall *et al.*, 2008). As a result, governing authorities have been under constant pressure to provide adequate on-street parking to satisfy the commercial needs of the community in light of the argument that it may have a detrimental traffic impact on the network. This study will add to the growing body of research regarding on-street parking by further understanding the traffic flow implications of on-street parking manoeuvres. Using this understanding the study proposes alternative strategies which can resolve the conflict by providing parking but reducing the impact on traffic flow.

Field parking surveys were conducted on selected major arterial roads within the metropolitan area of Sydney, Australia in order to understand the impact of parking on the traffic conditions. The surveys involved the qualitative assessment of driving and parking behaviour of the road users as well as the measurement of the time taken to complete a parking manoeuvre. Delay and queue length data collected from these surveys were then statistically verified and used to estimate the reduction in road capacity as a result of on-street parking manoeuvres. The study was further extended by incorporating the survey data into a microsimulation modelling exercise, completed on a demonstration network. The intention of the modelling was to analyse the traffic flow implications of existing parking policies prevalent throughout Sydney, as well as investigate alternative strategies.

2. BACKGROUND

The rapid increase of automobile use since World War II has resulted in parking becoming an integral part of any transport system. Several studies conducted to assess the factors that impact transport networks highlighted parking as one of the major components that affects traffic congestion (Arnott, 2006, Shoup, 2005, Shoup, 2006). With the increase of population, parking problems were no longer confined to city suburbs and have expanded to urban areas (Sisiopiku, 2001). The management of parking has resulted in a number of policy approaches which have aimed to affect the demand for parking whilst also forcing a change in mode choice (Barter, 2014).

In Australia, and throughout a majority of countries in the world, decisions regarding parking availability have been completed by local governments or municipalities. These authorities must cater for commercial sustainability whilst maintaining the performance of arterial and collector roads within the locality. There have been three distinct types of parking policy approaches that have been developed in practice and studied throughout literature; supply-focused conventional approach, market oriented approach, and a parking management approach (Barter, 2010, Shoup, 1999, Marshall, 2014, Shoup, 2005). The conventional approach entails meeting the demand for parking through an increase in supply by providing off-street parking facilities. Sustainable transport planning encourages the reduction of car use. As a result, the parking management and market oriented approaches aim at manipulating the turnover of parking through time restrictions or pricing parking to discourage the use of private automobiles.

The parking policy approaches of a number of local government areas in Sydney were investigated and it was evident that the current policies implemented involved a mixture of the three approaches. As an example, City of Sydney's recent Neighbourhood Parking Policy aims to maintain a fair and more credible parking system. Any alterations to the parking prices are performance-based and used to encourage higher average turnovers, improved compliance and increasing the efficiency and sustainability of the transport network (City of Sydney, 2014). This element reflects the market oriented approach and the parking management approach. Minimum parking requirements for new developments in City of Sydney has also been removed. Other developments near public transportation facilities such as train stations or light rail stops in 22 council areas including North Sydney, Parramatta and Waverley may be removed. This is beneficial to the developers as this allows more flexibility in apartment design and increase cost savings (McKenny and Johnstone, 2014). This again reflects the parking management approach undertaken by the City of Sydney. This strategy aims to encourage residents residing in these developments to utilise the public transportation available within the area. A key element which has been neglected within these policies is the consideration of the impact of on-street parking on traffic flow.

In general, on-street parking can impact traffic flow in two ways. Firstly, provision of on-street parking results in the removal of kerb side lanes and thus reducing capacity. Additionally, on-street parking manoeuvres can cause stop-start traffic flow behaviour of the lanes adjacent to the parking lane, thus resulting in extensive delays of a road section. Yousif and Purnawan carried out a detailed study in 1999 to gain an understanding of the time taken to enter and leave on-street parking spaces (Yousif and Purnawan, 1999). The findings indicated that the reverse parallel parking manoeuvre is the most time consuming and is positively correlated to the size of the vehicle, thus having the most significant impact on traffic flow. Data analysis techniques have also been used to assess the impact of on-street parking on road capacity. The American Association of State Highway and Transportation Officials claim that the road capacity of four to six lane arterial roads can be increased by 50% to 80% by removing kerb side on-street parking (AASHTO, 2011). Additionally, Weant and Levinson claimed that the removal of on-street parking on a four-lane road doubles the capacity, while taking away on-street parking on a six-lane road achieves a 67% capacity gain (Levinson and Weant, 1997). This result considers the direct impact of on-street parking due to loss of traffic lanes when on-street parking is allowed but does not investigate the impact on the adjacent traffic lanes. However, a more recent study used micro-simulation modelling to show that the road capacity of the remaining lanes reduced significantly, by up to 16% due to 30 parking manoeuvres per hour (Portilla *et al.*, 2009).

This study attempts to extend the methods and approaches that have been presented within the literature to further the understanding of the impacts of on-street parking policies on the transport network. Based on the enhanced understanding, an alternative parking policy is suggested and tested using microsimulation modelling.

3. ON-STREET PARKING SURVEYS

3.1 Survey Methodology

In order to understand the driving behaviour associated with on-street parking and the impact on the flow of traffic, a rigorous parking survey was completed within Sydney, Australia. The survey methodology was consistent with previous survey based studies (Wijayaratna, 2014, Yousif and Purnawan, 1999). Four sites within Sydney metropolitan were selected to undertake the surveys to observe parking behaviour and measure disruptions to traffic flow as a result of on-street parking manoeuvres. The sites were selected based on time-restrictions at the parking zone to compare the rate of turnover of parking spaces with different time restrictions. The four sites selected to measure disruptions to through traffic flow as a result of parking manoeuvres at on-street parking areas on:

1. Victoria Road between Pittwater Road and Massey Street (**½P : ½ hour parking,**)
2. Parramatta Road between Barr Street and Larkin Street (Eastbound) (**1P: 1 hour parking**)
3. Anzac Parade between Harbourne Lane and Middle Street (Eastbound) (**2P: 2 hour parking**)
4. Parramatta Road between Barr Street and Larkin Street (Westbound) (**Unrestricted parking**)

Each site was surveyed on 4 distinct occasions during weekdays across the same 1 hour peak periods. The following data was noted prior to conducting the field surveys; observation number, site ID, date, weather, survey period, the prevailing traffic conditions and existing parking restriction. During the field survey, the manoeuvre time, queue length, delay time and the type of parking manoeuvre performed was recorded. With the information and data gathered from the field surveys, an analysis of the results was performed, as detailed in Section 3.2.

3.2 Analysis of Survey Data

Observations during the surveys conducted presented four distinct parking patterns; ***Pattern 1*** (Front-in parallel parking with a single vehicle gap), ***Pattern 2*** (Front-in parallel parking with multiple vehicle gap), ***Pattern 3*** (Reverse parallel parking with a single vehicle gap), ***Pattern 4*** (Exiting from a parking space). Each of these manoeuvre types presented different user behaviour and as such resulted in different quantitative measurements. Table 3.1 details the descriptive statistics of the collected data for each defined parking pattern. The results have been tabulated in this fashion as the impact of the level of parking restriction (time restrictions) on manoeuvre time, delay time and queueing was minimal. The time to complete the parking manoeuvres was similar amongst each time restriction data set, with mean values of manoeuvre time and delay time all within a range of 2 seconds. However, intuitively, the average turnover rate of a parking space decreases as the level of restriction is relaxed. The 1/2P restriction site had an average turnover rate of 2.14 veh/space/hr while the unrestricted parking had a much lower value of 0.50 veh/space/hr. Thus, it is evident that driving behaviour related to parking manoeuvres is not affected by the level of restriction but the number of delay occurrences increases with a more constrained time period.

Pattern 3, the reverse parallel park manoeuvre, experienced the largest variation in manoeuvre time, having a sample standard deviation of 5.5 seconds and a sample mean of 16.5 seconds. Patterns 1, 2 and 4 experienced similar results and had considerably lower manoeuvre times to Pattern 3 and overall a limited impact on the flow of traffic. The delay results mimic the results of the manoeuvre time, with a 1 to 2 second addition to manoeuvre time mean values across all patterns. From the raw survey data, it is evident that there were instances where vehicles were able to perform parking manoeuvres without obstructing the flow of traffic. This is primarily due to the presence of nearby intersection controls metering the traffic flow across all the sites, a common occurrence on arterial roads in the vicinity of commercial developments. In addition, Pattern 4, the exit manoeuvre, clearly had the least number of occurrences of queue formation. It was observed that vehicles exiting out of parking spaces tend to wait until there is a break in the flow of traffic prior to performing the manoeuvre and thus resulted in minimal delays or the development of queueing.

Table 3.1 Key results of observational parking survey characterized by parking pattern

Pattern ID	Sample Size (N)	Minimum	Maximum	Median	Mean(μ)	Standard Deviation (σ)
Manoeuvre Time (seconds)						
Pattern 1	78	5.0	9.6	7.6	7.5	1.3
Pattern 2	69	1.1	6.6	3.8	3.8	1.2
Pattern 3	145	5.0	38.4	14.5	16.5	5.5
Pattern 4	70	2.1	8.7	4.5	5.0	1.4
Delay Time (seconds)						
Pattern 1	78	5.6	15.0	9.0	8.9	1.9
Pattern 2	69	1.3	8.0	4.3	4.1	1.3
Pattern 3	145	6.2	39.1	16.1	18.2	6.2
Pattern 4	70	3.0	10.7	6.5	6.4	1.9
Queue Length (vehicles)						
Pattern 1	78	1.0	9.0	2.0	1.9	1.2
Pattern 2	69	1.0	7.0	1.0	1.8	1.2
Pattern 3	145	1.0	12.0	4.0	4.5	2.1
Pattern 4	70	1.0	3.0	1.0	1.5	0.6

Reverse parallel parking manoeuvres were observed to cause the greatest disruption to the traffic flow In addition, nearly 50% of the manoeuvres performed across all the sites were reverse parallel parking manoeuvres. Observations suggest that reverse parallel parking were often performed by users to fit within constrained spaces which do not allow for the front-in movement. The study conducted by Yousif and Purnawan in 1999 showed that reverse parallel parking manoeuvres had a mean of 21.2 seconds and a standard deviation of 12.2 seconds, which were greater delay values than what was observed throughout these surveys. Possible reasons for the differences encountered are:

- Variance in the skill level: some drivers were more skilled than others and were able to perform manoeuvres much faster.
- Width of the kerbside lane: The sites considered had locations with wider lanes allowing for more space to complete the parking manoeuvre
- Availability of new technology: Parking sensors, reverse cameras and self-parking systems within modern vehicles has reduced the time necessary for the manoeuvre since Yousif and Purnawan’s research conducted in 1999.

Front-in parking with more than one vehicle gap was observed to have the quickest manoeuvre times, resulting in considerably less impact on the transport network. The results of the survey indicate that reducing the number of reverse parallel parking manoeuvres can decrease the delays incurred by the flow of traffic. This can be achieved through a parking policy which encourages road users to perform front-in parking as an alternative.

4. PROPOSED ALTERNATIVE PARKING POLICY

Driving behaviour, in particular the parking pattern was found to have a significant impact on the efficiency of parking policies in maintaining the balance of the transport network. Based on the results of the parking surveys conducted, the study recommends authorities advocate users to perform front-in parking manoeuvres when accessing a parking space. In order to achieve this objective, it is proposed to provide line markings identifying the available spaces as well as road signage encouraging the front-in parking manoeuvre.

Field tests were conducted to gauge the length of the parking bay necessary to perform a front-in manoeuvre. The vehicle used during the field test was a Toyota Rav4 2014 model. The test was conducted on a local road in a suburban area of Sydney between 12:00PM to 1:00PM in order to have minimal disturbance to the traffic stream as well as allowing for repetitions of the manoeuvring exercise. Initially, traffic cones were set at the Australian Standard minimum requirement of six metres (Standards Australia, 1993). The driver was then required to perform a front-in parking manoeuvre, whilst the ease of manoeuvring was assessed qualitatively by the researchers. The number of adjustments necessary to park the vehicle and the time taken to park the vehicle were monitored in addition to a discussion with the driver on difficulties faced with completing the exercise. If the manoeuvre was unsuccessful, the traffic cones were then increased at a 0.2m increment until the driver was able and comfortable to perform the manoeuvre.

After conducting the surveys, it was found that the driver was able to perform front-in parking manoeuvres comfortably at a distance of 8m. Though a number of adjustments were required to align the vehicle these did not obstruct traffic in the adjacent lane. A length of 8.2m would allow the driver to park front-in without any need of adjustments. The results of the field testing suggest that the proposed parking policy to encourage front-in parking is feasible. Appropriate line marking of spaces with a minimum length of 8m is necessary with the supplement of road signage encouraging the front-in manoeuvre as shown in Figure 4.1. In addition to reducing the need to perform a reverse parallel parking manoeuvre, the line markings can reduce the phenomenon of cruising for parking spaces and users attempting parking manoeuvres that are inaccessible. To further assess the costs and benefits of the proposed policy, a microsimulation modelling exercise was conducted and presented in the following section.

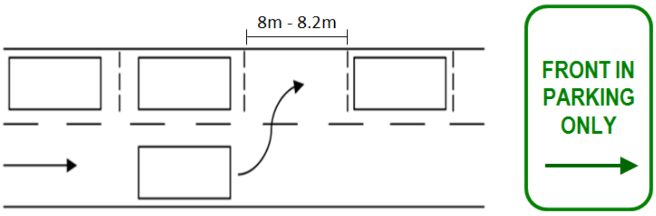

Figure 4.1 Proposed parking policy lane marking and associated road signage

5. MICROSIMULATION MODELLING EXERCISE

Microsimulation modelling provides an effective platform to identify the impact of various on-street parking policy options on the traffic flow characteristics of a major arterial road. In order to assess the potential impact of the proposed policy in Section 4 a microsimulation modelling exercise was completed using a two-intersection demonstration network presented in Figure 5.1.

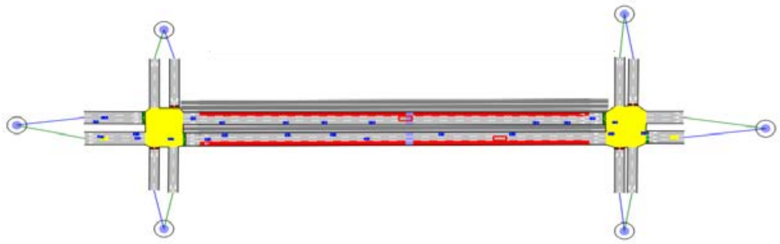

Figure 5.1 Demonstration Network

The network is indicative of an arterial road present in Sydney and consists of 30 parking spaces in each of the kerb lanes modelled. The modelling involved investigation into four separate parking policy scenarios;

- Scenario 1: “Clearways” (no parking scenario),
- Scenario 2: “Unrestricted Parking Scenario” (no parking manoeuvre scenario),
- Scenario 3: “1 hour parking time restriction”(considering reverse parking manoeuvre)
- Scenario 4: “1 hour parking time restriction, with front in parking only”

The AIMSUN microsimulation modelling software was used to model the scenarios. One hour models were used for the assessment and it was assumed that all available spaces were currently filled and during the hour period all these spaces are vacated and filled by a new vehicle, thus resulting in a worst case scenario. The provision of on-street parking was modelled through the closure of the kerb-side lane which would be occupied by parked vehicles. Parking manoeuvres were depicted using the periodic disruption feature of the software, which were applied to the 2nd lane of the arterial road section. The duration of the periodic disruptions was set to the manoeuvre time values observed within the field surveys, thus a value of 16.5 seconds was applied to the reverse parallel park manoeuvre whilst a value of 3.8 seconds was applied for the front-in manoeuvre. Furthermore, 3 different demand conditions were assessed to understand the impact of congestion. The demand conditions were identified based on the amount of input flow assigned to the arterial road section in each direction which considered; low demand: 1500 vehicles/hr, medium demand: 3000 vehicles/hr and high demand: 4500 vehicles/hr. The modelling was completed across 5 different seed values to ensure consistency amongst the results satisfying the requirements of the RMS Traffic Modelling Guidelines (RMS, 2013).

5.1 Results

The performance of each of the scenarios was assessed by considering the mean speed of vehicles, the mean travel time and the mean flow present on the arterial road sections modelled. The mean values for each of these performance metrics was obtained by considering the average result across all 5 seeds simulated. Figure 5.2 shows the change in average speed across time for all vehicles present on the arterial road section considering each simulated scenario for the medium demand setting. The graph clearly indicates that the presence of on-street parking reduces the speeds of vehicles, with blue, green and purple coloured data of the parking scenarios lying clearly below the red data of the clearway scenario.

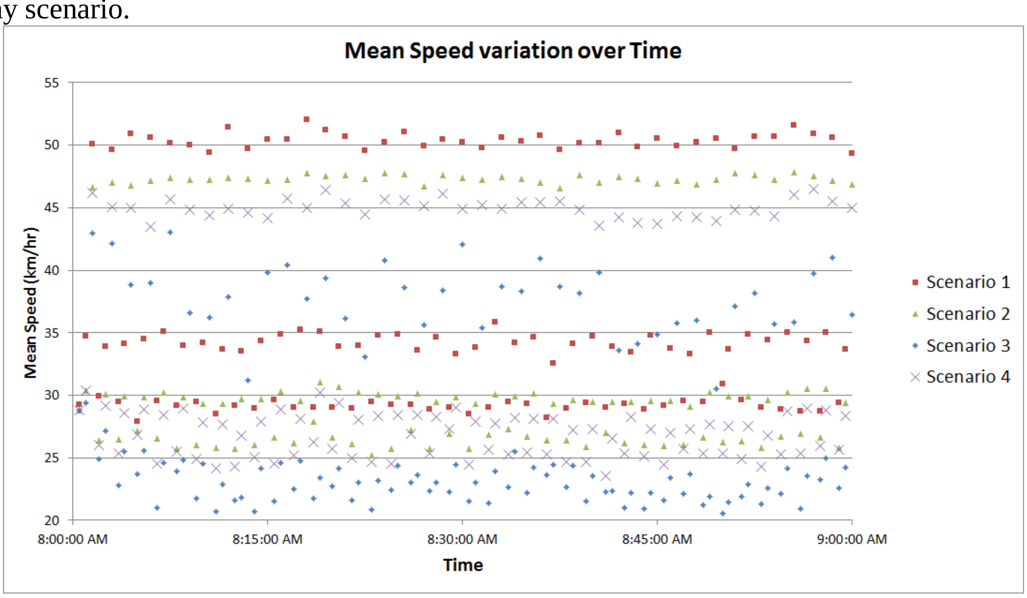

Figure 5.2 Variation of speed across time considering "Medium" demand condition

Table 5.1 presents the performance results averaged across both directions of travel within the arterial road section and further reiterates the finding that on-street parking results in added congestion. Travel time increases, throughput reduces for higher demand scenarios and average speeds reduce markedly within the parking scenarios. In addition, it is clear that when there is a greater network demand, the deteriorative impact of on-street parking is amplified. Comparing Scenario 1 and Scenario 3, the low demand condition suggests a reduction in speed of approximately 3km/hr however in the high demand condition this difference increases to almost 9km/hr highlighting the amplification. However, Scenario 2 considers unrestricted parking and shows the least impact on the traffic conditions. This is the case as unrestricted parking results in considerably lower turnover rates and as such reduces the number of parking manoeuvres.

Scenario 4 considers the application of the proposed parking policy advocating the use of the front-in parking manoeuvre. The average speed within Scenario 4 is approximately 5km/hr greater than that of Scenario 3 and travel times are lower by 16.6% within the high demand scenario. In addition, the throughput is greater suggesting that more users can utilise the network. This indicates that the implementation of the proposed policy has the potential to improve traffic flow when comparing with existing policies in Australia. Accordingly, this policy approach has the ability to reduce the impact of on-street parking on traffic flow whilst also providing users access to on-street parking, thus potentially relieving the conflict of parking policy for transport authorities.

Table 5.1 Microsimulation Modelling Results

Demand Conditions	Parking Policy Scenarios											
	Scenario 1: "Clearways"			Scenario 2: "Unrestricted Parking Scenario"			Scenario 3: "1P time restriction"			Scenario 4: "1P time restriction, with front in parking only"		
	Mean Travel Time (seconds)	Mean Flow (veh/hr)	Mean Speed (km/hr)	Mean Travel Time (seconds)	Mean Flow (veh/hr)	Mean Speed (km/hr)	Mean Travel Time (seconds)	Mean Flow (veh/hr)	Mean Speed (km/hr)	Mean Travel Time (seconds)	Mean Flow (veh/hr)	Mean Speed (km/hr)
Low	91.5	1506	42.43	93.6	1506	41.42	99.2	1506	39.09	94.4	1506	41.03
Medium	96.3	3004	40.29	104.8	2995	37.43	137.0	2827	29.35	111.6	2992	35.26
High	106.5	4530	36.88	110.3	3254	35.89	139.3	2843	28.86	116.3	3162	33.94

6. DISCUSSION

The study conducted indicates that the presence of on-street parking deteriorates the performance of an arterial road section. However, it should be emphasised that further research must be undertaken to verify these findings. The field surveys were conducted on 4 distinct sites and further surveying should be undertaken to validate the manoeuvre time, delay time and queue length statistics. Furthermore, the microsimulation modelling exercise demonstrated the impact that on-street parking can have considering the worst-case scenario of turnover, where each parking space is vacated and filled within the one hour duration of the model. Accordingly, the modelling suggests the upper-bound of the impact of parking which is a feasible outcome in heavily utilised parking zones. The authors understand that the application of the microsimulation modelling for specific cases will most likely yield more moderate results. However, the demonstration presented suggests the need to account for the impact of on-street parking on the performance of arterial roads.

7. CONCLUSION

Transport authorities are responsible for the provision of parking to satisfy the demands of a community but also must ensure that the operations of the arterial road corridors are maintained. This study provides an understanding of the implications of on-street parking manoeuvres on traffic flow through an empirical analysis of field data collected in Sydney, Australia. The reverse parallel parking manoeuvre was found to result in the greatest impedance on traffic flow out of the identifiable parking manoeuvres. The magnitude of the disruption is dependent on the turnover rate of the parking zone, with a greater turnover rate resulting in more manoeuvres and accordingly a greater impact on traffic flow. Thus, shorter time restrictions result in a greater deterioration of the traffic conditions. Based on these findings, a parking policy encouraging front-in parking manoeuvres is proposed. Furthermore, the study completes a microsimulation modelling exercise to highlight the performance impacts of various parking policies currently applied within Sydney again presenting a deterioration of the arterial road performance with the presence of on-street parking. The proposed policy was also modelled and the results suggest a lower impact and as such could provide a solution to balancing the parking needs of the community whilst maintaining adequate arterial road performance. Accordingly, the findings and extensions of this study can offer transport practitioners alternatives in decision making surrounding parking policy.

8. REFERENCES

American Association of State Highway and Transportation Officials (AASHTO) (2011), *A Policy on Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials (AASHTO), Washington D.C, 3, 3-2.

Arnott, R., & Inci, E. (2006). An integrated model of downtown parking and traffic congestion. *Journal of Urban Economics*, 60(3), pp. 418-442.

Barter, P.A. (2014), A Parking Policy Typology for Clearer Thinking on Parking Reform, *International Journal of Urban Sciences*, 19(2), pp. 136-156.

Barter, P.A. (2010), Off-Street Parking Policy without Parking Requirements: A Need for Market Fostering and Regulation, *Transport Reviews: A Transnational Transdisciplinary Journal*, 30(5), pp. 571-588.

City of Sydney (2014), *Neighbourhood Parking Policy*, City of Sydney, Sydney

De Cerreño, A. (2004). Dynamics of on-street parking in large central cities. Transportation Research Record: *Journal of the Transportation Research Board*, (1898), pp. 130-137.

Department of Transport and Main Roads (DTMR) (2010), *Cairns Transit Network-Concept Design Report*, Department of Transport and Main Roads (DTMR), Cairns.

Levinson, H. and Weant, R. (1997). *Parking and traffic congestion*. Washington, D.C.: Transportation Research Board.

Marsden, G. (2006). The evidence base for parking policies - a review. *Transport policy*, 13(6), pp. 447-457.

Marshall, W.E. (2014). On-Street Parking. *Parking Issues and Policies (Transport and Sustainability, Volume 5) Emerald Group Publishing Limited*, 5**,** pp**.** 361-380.

Marshall, W., Garrick, N., & Hansen, G. (2008). Reassessing on-street parking. *Transportation Research Record: Journal of the Transportation Research Board*, (2046), pp.45-52.

McKenny, L. and Johnstone, T. (2014). Parking requirements to be cut back under new design standards proposed for apartments. *Sydney Morning Herald*. [online] Available at: http://www.smh.com.au/nsw/parking-requirements-to-be-cut-back-under-new-design-standards-proposed-for-apartments-20140923-10kw9f.html [Accessed 8 Aug. 2015].

Portilla, A.I., Orena, B.A., Berodia, J.L.M. and Diaz, F.J.R. (2009), Using M/M/Infinite Queuing Model in On-Street Parking Manoeuvres, *Journal of Transportation Engineering*, 135, pp. 527-535.

Roads and Maritime Services (RMS) (2013), *Traffic Modelling Guidelines*, Sydney, Australia

Shoup, D.C. (2006), Cruising for Parking, *Transport Policy – Special Issue on Parking*, 13, pp. 479–486.

Shoup, D.C. (2005), *The High Cost of Free Parking*, Planners Press, Chicago.

Shoup, D.C., (1999), The Trouble with Minimum Parking Requirements, *Transportation Research Part A*, 33, pp. 549-574.

Sisiopiku, V.P. (2001), On-Street Parking on State Roads, *In:* ITE Annual Meeting Compendium, Institute of Transportation Engineers, Washington DC, USA.

Standards Australia (1993), *Australian Standard AS2890.5: Part 5 On-Street Car Parking*, Standards Australia, Sydney.

Wijayaratna, S. (2014). *The Impacts of On-Street Parking and Access to Land Uses on Road Capacity*. Undergraduate Honors Thesis. University of Technology Sydney.

Yousif, S. and Purnawan, (1999), A Study into On-Street Parking: Effects on Traffic Congestion, *Traffic Engineering and Control*, 41, pp. 30-33