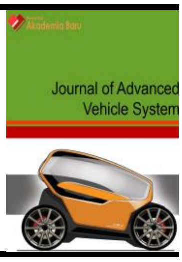
pena
Penerbit
Akademia Baru

Journal of Advanced Vehicle System

Journal homepage:
http://www.akademiabaru.com/submit/index.php/javs/index
ISSN: 2550-2212



Identification of Intersection Treatment based on International Best Practices for Bicycle Lane

Hawa Mohamed Jamil[1,*], Norfaizah Mohamad Khaidir[1], Azzuhana Roslan[2], Akmalia Shabadin[3]

[1] Road Engineering and Traffic Infrastructure Unit, Malaysian Institute of Road Safety Research, 43000 Kajang, Selangor, Malaysia
[2] Crash Data Operational & Management Unit, Malaysian Institute of Road Safety Research, 43000 Kajang, Selangor, Malaysia
[3] Data Intelligence & Traffic Exposure, Malaysian Institute of Road Safety Research, 43000 Kajang, Selangor, Malaysia

ABSTRACT

Cycling is becoming a trend lately and it reaches a "bike boom" status in Malaysia with the increase in the sales of bicycle reported to have tripled during the start of 2021. The percentages of bicyclists' fatalities at intersection are also showing an upward trend from 2010 – 2016, especially at cross and T/Y junction. In 2016 alone, there is a total of 22% of fatalities involving bicycles at these two types of intersections. Therefore, this study aims to identify intersection treatment for bicycle lane in Malaysia based on best practices overseas and determine the characteristics of Malaysian bicyclists. Apart from desk review, the study also conducts site observation; considering urban and suburban settings with 3-legged and 4-legged, signalized and unsignalized intersections. Observation of bicyclists' behavior, road geometry, site characteristics and traffic signal configurations were carried out on site. A total of 131 bicyclists were observed and the larger group was dominated by male with 86.3%. Younger people were also noticed to ride bicycle more with 61.8% as compared to older generation. Longer crossing time were observed where there is pedestrian activity while crossing with an average of 13 seconds as compared to 7 seconds when no pedestrian activity. As for best practices overseas, visibility of bicyclists is crucial when at intersection. Amongst treatment recommended to increase visibility includes the provision of advanced stop line or bike box in front of motorized vehicle and before pedestrian crossing. In addition, proper signage and road markings are also vital for safe navigation at the intersection. For complex intersection special treatment such as stage crossing or pocket lanes can be applied. However, proper studies are needed to ensure the application on Malaysian traffic and road users are compatible. Results of the study can be further enhanced with interview survey carried out to bicyclist to obtain their perception of safety, security, comfortability of bicycle lane especially pertaining to intersection design.

Keywords:
Bicycle lane; intersection; best practices; signalized; unsignalized; visibility

Received: 5 August 2021 **Revised: 13 December 2021** **Accepted: 20 January 2022** **Published: 29 January 2022**

1. Introduction

Bicycling has the ability to improve mental well- being, promotes weight loss, saves time and reduce pollution just to name a few. However, bicyclist faced more danger and will suffer higher risk of injuries than motorised vehicles since they are slower in speed and smaller in size which also put them in the vulnerable road users' category. The risk increases when bicyclists encounter an intersection due to the need of a higher level of concentration by each party involved. In 2018, 857

* *Corresponding author.*
E-mail address: hawajamil@miros.gov.my

bicyclists were reported to have been killed in motor vehicle crashes in the US which accounted to 2.3% of fatalities during the year [17]. In addition to this, twenty-nine percent of bicycle fatalities occurred at intersection, 60% at location which is not intersection while the remaining 11% occurred at other places such as sidewalk, parking, etc.

Understanding ways of making bicycling safer thus increase the usage is vital in promoting a sustainable city. At the present time, Malaysians are starting to choose cycling as their means to commute to work, for leisure and recreation purposes and also for sports. Lee in 2021 reported that the sales of bicycles increase three-fold starting 2021, especially during the conditional Movement Control Order (MCO). This is due to fact that gyms and other sporting activities were closed during the pandemic. Apart from that, the year-over-year growth in bicycle import values has increased by 11.72% in 2019 (Trend Economy, 2021). This "bicycle craze" poses major concern in Malaysia specifically in terms of safety for bicyclist. In general, the number of crashes (fatal, serious and minor crash) involving bicyclists has shown a downward trend in recent years (Figure 1). However, the same period has also observed a worrying trend of increase in percentage of bicycle fatalities. In 2016 alone, 51.0% of the total crashes involving bicycle have resulted in bicyclist fatalities (Royal Malaysia Police (RMP), 2016).

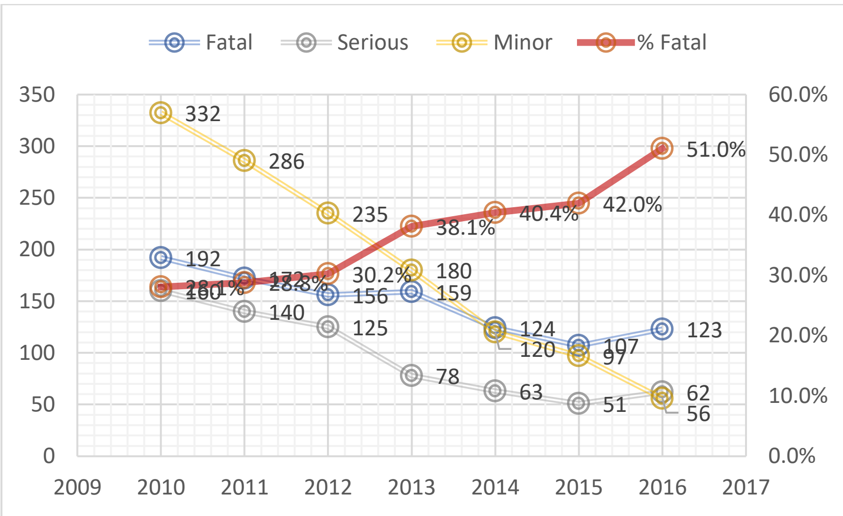


Fig. 1 Total Number of Bicycle Casualties by Type if Casualties from 2010 – 2016

Figure 2 illustrates fatal road accident involving bicycle by type of road. It can be seen that percentages of bicyclists' fatalities at intersection also displays an increasing trend from 2010 until 2016, especially at cross and T/Y junction. In year 2016, a total of 22% fatalities involving bicycles were reported at these two types of intersection (Royal Malaysia Police (RMP), 2016).

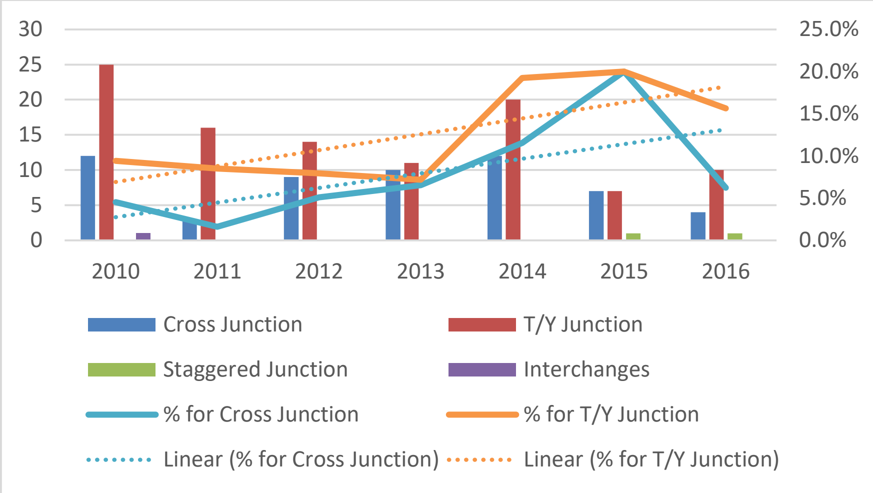


Fig.2. Fatal Road Accident involving Bicycle by Road Type

Intersection is hazardous point of contact for vehicles whereby it has many conflict points. A study carried out by Wachtel & Lewiston (1996) stated that intersection when constructed broadly, are the major point of conflict between motorcycles and motor vehicles. At intersection, bicyclists are required to make multiple task such as to decide on whether to stop or proceed through the intersection, to observed possible interaction between other motorized vehicle and at the same time to control bicycle stability from falling. A study on crash data in Palo Alto indicates that bicycle accidents at intersections accounted for 237 (64%) of 371 total bicycle accidents (Wachtel & Lewiston, 1996). On the contrary, another study on the construction of cycle tracks in Copenhagen, reported that the construction has resulted in a slight drop in the total number of crashes and injuries on the road sections between intersections but has risen significantly by 18% at intersection ((Søren & Jensen, 2007).

On the other hand, the construction of cycle lanes (on carriageway) has resulted in an increase of 5% in crashes and 15% more injuries and the increase occurred especially amongst cyclists and moped riders (Søren & Jensen, 2007). Nevertheless, for Malaysia scenario, crash data at these exact locations are scarce due to insufficient details recorded during crash incidents. However, as intersection are the major points of conflict between bicyclists and other motorists or pedestrian (Jabatan Kerja Raya Malaysia, 1986), special attention needs to be given to increase bicyclist safety at intersection. Conflicts that may arise involving bicyclists and other road users could be related to sight distance issue, lack of proper channelling, lack of dedicated space for intersection crossing, crossing time, and the provision of left turn on red.

2. Study Objective

This paper aims to identify intersection treatment for bicycle lane based on best practices overseas and characteristics of Malaysian bicyclists. Two types of data collection method were carried out; 1) on-site observation and 2) literature comparison. Four sites were chosen as the study location with the total of 4 hours per day, 3 days a week of data collection for each site. Results of the study provides insights that will help stakeholders / local authority implement the appropriate intersection treatment for bicycle lane in Malaysia.

3. Methodology
3.1. Methods

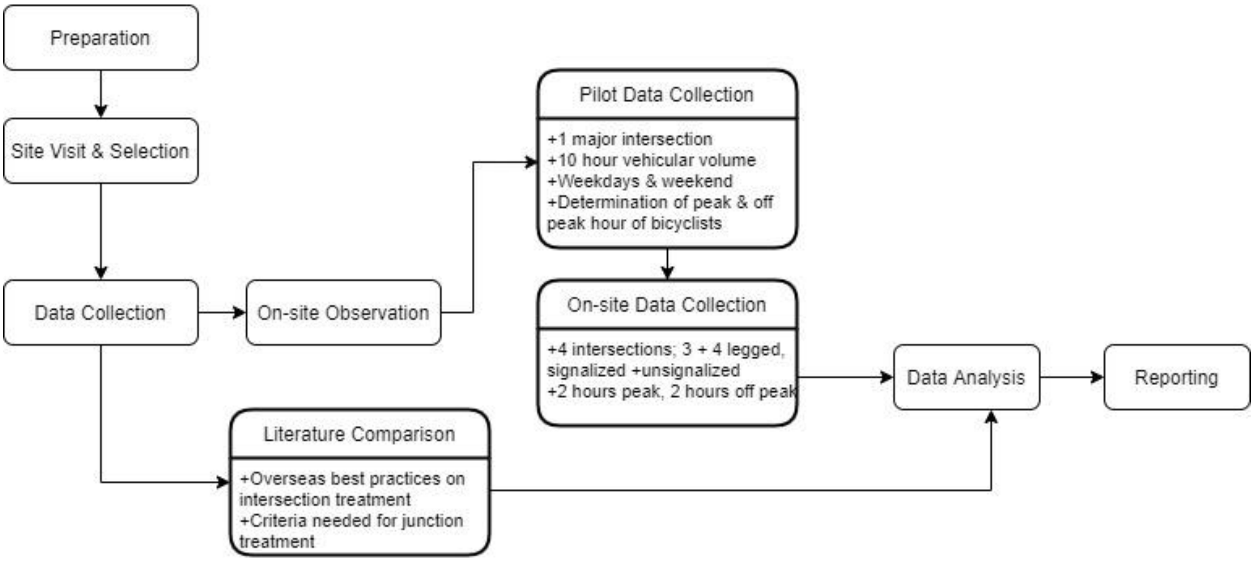


Fig. 3. Flow of the Study

Figure 2 displays the flow of the study. Data collection was divided into two phases: on-site observation and desk study. For on-site observation, the process is that pilot study was conducted first in order to establish peak and off-peak hour. The established peak and off -peak hour were then used as the time of on-site data collection. As for desk study, numerous overseas literatures were reviewed to identify criteria and best practices for junction treatment.

Criteria for selection of sites are as follows:

- 3 legged and 4 legged intersections
- Signalized and unsignalized intersections
- Must have bicycle lane (both exclusive and non-exclusive)

After considering the criteria, 4 sites were chosen in Kuala Lumpur and Selangor and they are Sg Long (unsignalized 3-legged), Sogo (signalized 3-legged), Jalan Sultan Ismail (signalized 4-legged) and Pandan Indah (unsignalized 3-legged). 4-legged unsignalized intersections were hard to find therefore we have chosen two signalized four-legged intersections instead.

3.2. Data Collection
3.2.1. Pilot Data Collection

Since cycling is a new thing for Malaysian, the peak and off-peak period of bicyclist volume may vary from usual traffic (cars, motorcycles, etc.). Therefore, a pilot data collection to determine peak hour volume for bicyclist was carried out at one major intersection for two days, considering weekday and weekend for a duration of 10 hours. As a result, peak hour for data collection was set between 7.00am and 9.00am whereas off peak hour at 10.00am – 12.00pm.

2.2.2. On-site Data Collection

In this study, data were gathered four days for each location, three days during weekdays and one-day weekend. Traffic volume count as well as road geometry, characteristics, pedestrian and bicyclist behaviour, traffic signal configurations were collected and observed on site by three or four enumerators, depending on the number of legs. Each leg was also equipped with a video camera on a tripod to gather the previously stated data.

3.2.3. Literature Comparison

Under this subtopic, guidelines, journal papers, proceedings and online website were referred to establish criteria / factor that needs to be considered for intersection safety.

4. Results and Discussion

4.1. Best Practices Overseas vs Malaysia

Intersection is where two or more roads meet and without proper traffic management, it could be a hazardous point in road network where traffic conflict most likely occur. Oregon Department of Transportation (ODOT) in 1995 reported that car-bicycle collision at intersections accounted to 45% where, 27% was due to motorists failed to yield to bicyclist and another 19% was because bicyclist failed to yield to motorists. Thus, intersection treatment is the most crucial aspect in bicycle lane design. Among criteria deemed necessary to be considered while designing safe intersection for bicyclists includes, but not limited to:

- Maintain separation through the intersection
- Visibility
- Specific cycling provisions
- Directness
- Traffic signal
- Two-stage crossing
- Minimize speed difference
- Visual guidance

For ease of understanding, the criteria above are listed in a tabulated form as per Table 1. Fourteen sources comprise of reports, guidelines and technical papers were referred. Visibility of the intersection was quoted in 10 out of 14 references (71%) reviewed in this study. This proves that visibility is an important aspect that should be considered when designing an intersection, especially if the intersection includes bicyclists. Increasing visibility offers time for motorists to react and reduces the likelihood of a collision with other road users, especially the bicyclists and pedestrians. Alta Planning + Design (2011); DiGioia et al. (2017) and Maryland State Highway Administration (2015) recommended that bike boxes installed at intersections to improve visibility of bicyclists. These bike boxes separate the bicyclists from traffic, putting them at the front of the intersection thus making them more visible to other vehicles. In addition, proper signage and road markings are also vital for safe navigation at the intersection. For complex intersection special treatment such as stage crossing or pocket lanes can be applied.

The second most highlighted criterion is the consideration for a specific provision for bicyclists. Eight out of 14 references (57%) have mentioned about this criterion. To maximize the safety of bicyclists, raised medians and refuge islands should be considered when there is cycling facilities provided on dual carriageway multi-lane road. Cambridge Cycling Campaign (2014), Alta Planning + Design (2013), Dufour (2010) and AASHTO (1999) suggested that cycle refuge, traffic and median island be provided to protect and facilitates bicyclist when crossing the intersection. These island and refuge allow bicyclists to stop temporarily in the middle of the intersection safely before proceed to finish the crossing. Additionally, raised bicycle crossings and protected intersection should be considered in increasing reaction time thus ensuring safe crossing.

Another suggested issue to be tackled at intersection is the turning treatment. Left turns (or in some countries right turn) are a bigger threat than the opposite (right turns or left in some countries) as it can be maneuvered at a wider radius which can lead to higher turning speed and also greater area of exposure for bicyclists. Wang, Liu, Guo, & Chen (2008), DiGioia et al. (2017), Systems (2014) and AASHTO (1999) have proposed a two-stage left turn crossing / two-stage turn queue boxes. This type of crossing provides a safe way to turn left for bicyclists from a right-hand side of bicycle lane or vice versa. At intersection with high volume of right turn, the application pocket lane can be considered. In the event that no other options are viable, then only, this treatment be considered as it lengthens time needed for safe pedestrian crossing and take up valuable curbside space NACTO (2014).

Five out of 14 literatures reviewed have also emphasized on visual guidance, directness and minimizing the speed difference as the criteria recommended to have at an intersection. Visual guidance can improve the attention of road user and lead them through the intersection. Maryland State Highway Administration (2015), Maryland State Highway Administration (2012) and AASHTO (1999) has suggested that road marking and proper signage be provided for safe navigation at intersections. In general, road marking and signage should be placed immediately after a major intersection. Nevertheless, precaution needs to be taken in urban areas with on-street parking where bicycle lane signs should be kept at a minimum in order to reduce signage clutter.

Directness is one of the five internationally recognized requirements for designing bicyclist's infrastructure. It can be measured by two ways; a) directness in time of travel (average speed) and b) directness in distance (trip length). Among factors that affect directness are stop or loss priority at crossings, delays at traffic, detours, sharp corners and hills. It takes a bicyclist a considerable time and effort to recover their required speed once slowed or stopped. When stopped or detoured, they will gamble their safety just to save travel time. Cambridge Cycling Campaign, (2014) stated that stop-start maneuver triggered by obstructions and narrow pavement due to shared path with pedestrian is unpreferable as people want to maintain their cycling momentum and therefore should be avoided.

Traffic calming is another measure to be considered in bicyclist intersection treatment. Reducing the speed of motorized vehicles give parties involved ample time to react and reduce the frequency and severity of collision; what more with non-motorized road users. Bicycle boulevards and raised intersections are designed to lowered the speed of motorized vehicles. DiGioia et al. (2017) and Alta Planning + Design (2011) have suggested construction of bicycle boulevard as this treatment prioritized bicycle travel over motorized traffic and promote safe , convenient travel both at midblock and intersections. In addition to that, raised crossing also meet the purpose of reducing motor vehicle speed. Raised bicycle crossing are a continuation of raised cycle track, intersection minor road without dropping the path to street level at each intersection as stated in a report published by City of Palo Alto [8].

Signalized intersections are, by nature, dangerous to bicyclists. Nonetheless, they are essential when cyclists crossing a heavily trafficked intersection. A cycle-friendly design must consider the visibility, short waiting time and easy maneuverability of bicyclists. Cambridge Cycling Campaign (2014) advised that waiting time more than 30 seconds is undesirable as it makes cycling slow and unattractive. At location where the delay of motor vehicle is of interest, hybrid beacon may be considered and a bicycle signal head be installed in addition to pedestrian signal head [2].

Table 1
Summary of Intersection Treatment for Bicycle Facilities Applied in Other Countries

Study	Location	Criteria	Treatment
Cambridge Cycling Campaign (2014)	London	Continuous separation through the intersection	
Oregon Department of Transportation (ODOT) (1995)	USA		
DiGioia, Watkins, Xu, Rodgers, & Guensler (2017)	USA, New Zealand		
Maryland State Highway Administration (2012)	USA		
Cambridge Cycling Campaign (2014)	London	Visibility	
Dufour (2010)	Netherlands		
Alta Planning + Design (2013)	USA		bike boxes
Cumming (1999)	Australia		advanced, expended, hook turn storage
Oregon Department of Transportation (ODOT) (1995)	USA		
Maryland State Highway Administration (2015)	USA		bike boxes
DiGioia, Watkins, Xu, Rodgers, & Guensler (2017)	USA, New Zealand		bike boxes
Institute of Transportation Engineers (2003)	USA		colored pavement at conflict area, bike box
Systems (2014)	North America, selected European countries, and Australia		advanced stop line, bike boxes
American Association of State Highway and Transportation Officials (AASHTO) (1999)	USA		lighting
Cambridge Cycling Campaign (2014)	London	Specific Cycling Provision	cycle refuges
Dufour (2010)	Netherlands		traffic island, cycle stocking lanes, ASL
Alta Planning + Design (2013)	USA		median island
DiGioia, Watkins, Xu, Rodgers, & Guensler (2017)	USA, New Zealand		raised bicycle crossing

Institute of Transportation Engineers (2003)	USA		transit stop striping marking when bus zone available at intersection
Systems (2014)	North America, selected European countries, and Australia		median refuges, protected intersection
Maryland State Highway Administration (2012)	USA		bicycle lane striping marking
American Association of State Highway and Transportation Officials (AASHTO) (1999)	USA		refuge island

Study	Location	Criteria	Treatment
Cambridge Cycling Campaign (2014)	London	Directness	avoid stop-start maneuvers
Dufour (2010)	Netherlands		right of way, short cycles
Oregon Department of Transportation (ODOT) (1995)	USA		
City of Palo Alto (2003)	USA		free flow travel for bicycle
American Association of State Highway and Transportation Officials (AASHTO) (1999)	USA		ramp for curb
Cambridge Cycling Campaign (2014)	London	Traffic signal	
Alta Planning + Design (2013)	USA		hybrid beacons, bicycle signals
Alta Planning & Design Bicycle Solutions (ALTA) (2011)	USA		microwave detection, that can distinguish bicycles from motor vehicles
Wang, Liu, Guo, & Chen (2008)	China	Turning treatment	two-stage left turn waiting lane
Maryland State Highway Administration (2015)	USA		Pocket lanes
DiGioia, Watkins, Xu, Rodgers, & Guensler (2017)	USA, New Zealand		two-stage turn queue box
Institute of Transportation Engineers (2003)	USA		left/right turn pocket
Systems (2014)	North America, selected European countries, and Australia		two stage left turn boxes
City of Palo Alto (2003)	USA		traffic circle
Maryland State Highway Administration (2012)	USA		pocket lane
American Association of State Highway and Transportation Officials (AASHTO) (1999)	USA		two stage crossing
Dufour (2010)	Netherlands	Minimize speed difference	
Maryland State Highway Administration (2015)	USA		tighter turning radii, traffic calming
DiGioia, Watkins, Xu, Rodgers, & Guensler (2017)	USA, New Zealand		bicycle boulevards, traffic calming
Alta Planning & Design Bicycle Solutions (ALTA) (2011)	USA		bicycle boulevards, traffic calming
City of Palo Alto (2003)	USA		raised intersection
Maryland State Highway Administration (2015)	USA	Visual guidance	for safe navigation – marking & signage
Institute of Transportation Engineers (2003)	USA		dashed markings through complex and/or confusing intersections

Systems (2014)	North America, selected European countries, and Australia		intersection crossing marking
Maryland State Highway Administration (2012)	USA		road marking & sign
American Association of State Highway and Transportation Officials (AASHTO) (1999)	USA		road marking & sign

4.2 Comparison of the Best Practices Overseas and in Malaysia

The study has carried out site observation at 4 chosen site. Table 2 summarized the treatment based on overseas best practices crosscheck with treatment available in Malaysia. Signalized intersection achieved 40% of the listed treatment whereas unsignalized intersection only 30%. Proper signage, road markings and continuity through intersection were noticed at all selected locations even though it is not provided at each leg. At signalized intersection, provision of cycle refugees / islands is spotted along with red boxes for motorcycles instead of advanced stop line/bike boxes for bicyclists.

On the other hand, no provision of raised bicycle crossing, pocket lane/two-stage crossing and traffic calming measures were discovered at all locations. Treatment at signalized intersection such as traffic signal for bicycles are also non-existent.

Table 2
Comparison of Overseas Treatment and its Availability in Malaysia

No	Recommended Overseas Treatment	In Malaysia			
		Sogo (signalized 3L*)	Jln Sultan Ismail (signalized 4L**)	Pandan Indah (unsignalized 3L)	Sg Long (unsignalized 3L)
1	Advanced Stop Line/ Bike Box	Red box for motorcycle	Red box for motorcycle	–	–
2	Proper Signage	✓	✓	✓	✓
3	Road Markings	✓	✓	✓	✓
4	Continuous through Intersection	On 2 legs only	On 2 legs only	On 1 leg only	On 1 leg only
5	Cycle Refugees / Island	✓	✓	–	–
6	Raised Bicycle Crossing	–	–	–	–
7	Right of way/ short cycles	–	–		
8	Traffic signal for bicycles	–	–		
9	Pocket lanes / two stage crossing	–	–	–	–
10	Traffic Calming Measures	–	–	–	–

* 3L indicates 3-legged
**4L indicates 4-legged

4.3 Demographics of bicyclist

Seven (7) variables have been identified to be investigated in the study as it focuses on site characteristics and bicyclist's behavior. As highlighted earlier, data were collected for four hours per day, differentiating between peak and off peak for four days per site; for four sites. A total of 281 bicyclists were observed throughout the study but only 131 bicyclists fulfilled prerequisite set for the variables of interest in the present study. Out of the 131 bicyclists, 86.3% are male. As for the age variable, 61.8% were young while 50 bicyclists were old. The determination of which age category were based on interpretation of enumerators estimation on the bicyclist's facial characteristics. Lines and wrinkles on the face shows advanced age. Lines are associated with time; the more lines naturally indicate old age [12].

Interestingly, only 24.4% of bicyclists stop in the middle of the intersection even though more than 70% encounter intersection with physical median. This suggests that bicyclists prefer to complete their crossing in "one go". In addition to that, more than half of the bicyclists crossed the intersection when there is pedestrian activity.

Demographics		N	Mean Crossing Time (sec)	P Value
No of Leg	3-legged 4-legged	79 52	7.0742 18.2433	0.000*
Gender	Male Female	113 18	9.5996 23.4867	0.000*
Age	Young Old	81 50	8.0377 17.1292	0.000*
Type of Intersection	Signalized Unsignalized	52 79	18.2433 7.0742	0.000*
Stop in the middle	Yes No	32 99	26.3794 6.7007	0.000*
Pedestrian Available	Yes No	79 52	13.9865 7.7419	0.038*
Median Available	Yes No	93 38	13.3749 6.9379	0.014*

* Independent-Samples Mann-Whitney U Test

The table also show that average crossing time were significantly different with each demographic group mentioned above. In general, the result demonstrates bicyclists crossing a 3-legged intersection (unsignalized) required an average of 7 seconds to finish crossing as compared to 4-legged intersection (signalized). Gender wise, male bicyclists required an average of 10 seconds rather than female that needs approximately 23 seconds to complete the crossing. Older bicyclists acquire 17 seconds whereas younger bicyclist takes an average of 8 seconds. Longer crossing time were also noticed when there is pedestrian activity with an average of 13 seconds as compared to 7 seconds without pedestrian activity.

5. Conclusions

Intersection is a point where conflict and delay occur and were usually being perceived as a critical part that needs to be focused on. This study aims identify intersection treatment for bicycle lane based on best practices overseas and characteristics of Malaysian bicyclists. Two types of data collection method were carried out; 1) literature comparison and 2) on-site observation. For literature comparison, guidelines, journal papers, proceedings and online website were reviewed and summarized in a tabulated form. Summarizing the best practices by looking at overseas literatures, it became apparent that visibility of the bicyclists is very important at the intersection. Amongst treatment that can be suggested to increase visibility includes the provision of advanced stop line or bike box in front of motorized vehicle and before pedestrian crossing. In addition, proper signage and road markings are also vital for safe navigation at the intersection. For complex intersection special treatment such as stage crossing or pocket lanes can be applied. Apart from that, special provision for bicyclist and turning treatment should also be put into consideration when designing an intersection. Nonetheless, proper studies are needed to ensure the application of these treatment on Malaysian traffic and road users are compatible.

The second method of data collection is on-site observation. Site considering urban and suburban settings, 3-legged and 4-legged, signalized and unsignalized were selected. Observation of bicyclists' behaviour, road geometry, characteristics, traffic signal configurations were carried out on site. A total of 131 bicyclists were observed and the larger group was dominated by male with 86.3%. Younger people were also noticed to ride bicycle more with 61.8% as compared to older generation. This could be due to nowadays trend of cycling to promote health and also recreation.

It was also observed that during the data collection, design of facilities provided at these locations have no standardization. For instance, road markings for bicycle lane provided varies between locations. It is preferable to have a full colored bicycle lane rather than a line indicating the bicycle lane. Apart from that, signages provided also varies. Standardization is important in order to ensure the targeted user understand the message it brings. That being said, crosschecking existing intersection treatment in Malaysia and overseas recommended treatment, approximately only 30% - 40% of the listed treatment were fulfilled. This is an indicator that Malaysia still have a long way to go to achieve sustainability and a bicycle-friendly environment. However, these results only represent current 4 locations of data collection. It is suggested that the study be expanded to all bicycle lanes throughout Malaysia for a thorough results.

People cycle for various reasons. These reasons may possibly involves cycling to work or for health and leisure purposes. However, there are many other factors that can motivate people to switch their mode of transport to bicycle such as proper cycling facilities, safety and comfortability, etc. Promotion of cycling such as "incentive giving" could encourage bicyclists to change their reason of cycling from recreation purposes to travelling to work. This however should be link together with proper facilities for bicyclists be it from engineering or user point of view. Results of the study can be further enhanced with interview survey carried out to bicyclist to obtain their perception of safety, security, comfortability of bicycle lane especially pertaining to intersection design.

Acknowledgements

The authors would like to express their sincerest appreciation to the Malaysian Institute of Road Safety Research (MIROS) for providing the grant in conducting this research and extending their full support in producing this paper. The authors would also like to thank all team members who have worked hard, contributed their invaluable ideas, inputs, energy and time towards the planning and execution of this research. Not forgetting research assistants for their help and contribution in completing the project.

References

[1] Alta Planning + Design. (2011). City of Palo Alto Bicycle + Pedestrian Transportation Plan.
[2] Alta Planning + Design. (2012). City of Palo Alto Bicycle + Pedestrian Transportation Plan, (July).
[3] Alta Planning + Design. (2013). Portland area comprehensive transportation system (PACTS).
[4] Amerian Association of State Highway and Transportation Officials (AASHTO). (1999). Guide for the development of bicycle facilities. AASHTO. Washington, D.C.
[5] Annual international trade statistics by country. (2021). Retrieved June 23, 2021, from https://trendeconomy.com/data/h2/Malaysia/8712
[6] C. Y. Lee. (2021). Cyclists seek clarity to keep up interest. Retrieved June 23, 2021, from https://www.thestar.com.my/metro/metro-news/2021/01/06/cyclists-seek-clarity-to-keep-up-interest

[7] Campaign, Cambridge Cycling. "Making Space for Cycling—A Guide for New Developments and Street Renewals." (2014)
[8] City of Palo Alto. (2003). Bicycle Transportation Plan. Palo Alto: City of Palo Alto.
[9] Cumming, Alistair. "A framework for bicycles at intersections." In *Fourteenth Velo-city International Conference Proceedings, Munich*. 2000.
[10] DiGioia, Jonathan, Kari Edison Watkins, Yanzhi Xu, Michael Rodgers, and Randall Guensler. "Safety impacts of bicycle infrastructure: A critical review." *Journal of safety research* 61 (2017): 105-119.
[11] Dufour, Dirk. "PRESTO Cycling policy guide. Cycling infrastructure." (2010).
[12] Ferenchak, Nicholas N. "Pedestrian age and gender in relation to crossing behavior at midblock crossings in India." *Journal of Traffic and Transportation Engineering (English Edition)* 3, no. 4 (2016): 345-351.
[13] Institute of Transportation Engineers. (2003). Innovative bicycle treatments.
[14] Jalan, Arahan Teknik. "10/86, 1986." *A Guide To The Design Of Cycle Track*.
[15] Maryland State Highway Administration. (2012). Chapter 3: Bicycle lane design. Bicycle and Pedestrian Design Guideline.
[16] Maryland State Highway Administration. (2015). Bicycle policy & design guidelines. Maryland.
National Association of City Transportation Officials (NACTO). (2014). Transit Street Design Guide. Retrieved from https://nacto.org/publication/transit-street-design-guide/intersections/intersection-design/right-turn-pocket/
[17] NHTSA. (2020). Traffic Safety Facts 2018 Data. Www-Nrd.Nhtsa.Dot.Gov, 2020(May), Volume: 2001, Issue: June, Pages: 232. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/811620.pdf%5Cnhttp://www-nrd.nhtsa.dot.gov/Pubs/809778.pdf
[18] Oregon Department of Transportation (ODOT). (1995). Oregon bicycle and pedestrian plan. Oregon.
[19] Royal Malaysia Police (RMP). (2016). Statistical report on Malaysia road accident. Bukit Aman, Kuala Lumpur, Malaysia.
[20] Jensen, Søren Underlien, Claus Rosenkilde, and Niels Jensen. "Road safety and perceived risk of cycle facilities in Copenhagen." *Presentation to AGM of European Cyclists Federation* (2007): 1-9.
[21] Systems, U. (2014). Pedestrian and Bicycle Facility Design Guidance, 86.
[22] Wachtel, A., and D. Lewiston. "Risk factors for bicycle-motor vehicle collisions at intersections." *Journal of Safety Research* 3, no. 27 (1996): 195.
[23] Wang, Shuling, Zhili Liu, Jifu Guo, and Yanyan Chen. "Research on Bicycle Safety at Intersection in Beijing." In *Logistics: The Emerging Frontiers of Transportation and Development in China*, pp. 4739-4744. 2009.