Gap Acceptance for Yangon Urban and Suburban Intersections

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Abstract. Gap acceptance plays an important role in intersection design and signal warrant. This study investigates gap acceptance of drivers in Yangon, Myanmar. Three T-intersections were selected for study sites; two intersections in the urban area and the other one in Yangon suburb. As Yangon drivers drove on the right-hand side, the key movements that defined the intersection capacity would include left-turn from the major stream (LT-major), right-turn from the minor stream (RT-minor), and left-turn from the minor stream (LT-minor). Raff’s method was applied to determine the gap acceptance for these three conflicting movements. The result showed that the gap acceptance for LT-minor was the longest ranging between 7 to 15 seconds. The shortest gap acceptance belonged to the RT-minor for 4 to 8 seconds. The gap acceptance at urban sites was also shorter than that of suburban in all three movements. The drivers tended to decrease their gap acceptance when the traffic volume increased. However, the relationship between the gap acceptance and traffic flow was not significant.

1. Introduction

Yangon is the largest and the most important commercial city of Myanmar. In 1941, after the British colonized time, the population of Yangon was about half a million. The number steadily increased and reached approximately 1.6 million in 1950. The population growth rate ranges from 22.2% to 22.4% annually [1]. As more rural residents continue to move to urban for various reasons, the urbanization of Yangon has been rapidly increased. Based on the current growth rates, it is expected the population would top 7 million in next 20 years. Figure 1 shows rapidly growth of Yangon population.

![Figure 1. Yangon population growth in ten decades](image-url)
Rapid urbanization and motorization have been observed along with the population growth. The city transport infrastructure has not been efficient to accommodate vehicles. There has not much improvement in city’s infrastructure although the population growth increases significantly. In Yangon to date, there has not been an urban rail transit system. The railway is only the public transportation which provides high quality intercity service. Thus, the Yangon city’s transportation mainly depends on the roadways. The increasing number of road vehicles induces traffic problems and increase accidents. In 2017, WHO reported that over 10,000 road accidents fatalities in Myanmar which accounts for 2.67% of total deaths by all causes [2]. This statistic took Myanmar to 80th rank in the world. The solutions to reduce traffic problems and accident risks are needed by investigating the traffic flow and intersections.

As traffic congestion grows, the drivers become more impatient and aggressive. This became the potential cause of the road accident [3]. It is widely accepted that the gap acceptance is an important characteristic of the drivers’ performance to improve the road safety [4]. This paper will investigate and analyze the gap acceptance for Yangon in both urban and suburban regions. Then, it can provide a better understanding on the gap acceptance, which is based on traffic flow and drivers’ behaviors. Moreover, this paper will verify whether the gap acceptance is influenced by the traffic flow or not. This finding can support the further studies for capacity analysis and intersection designs based on the traffic flow characteristics.

2. Importance of gap acceptance and its previous studies

The gap acceptance has been studied theoretically as well as empirically over the past years with various techniques. The main idea involves determination of a critical gap length. The gap acceptance is based on an assumption that drivers will use or “accept” gaps that are longer than the critical gap and “reject” those that are shorter. Determination of critical gap normally depends upon the conflicting traffic volume and the drivers’ decision. A vehicle will stop and wait to enter intersections when the opportunity of large gap is present. If the driver waits too long for the opportunity and gets frustrated over heavy traffic stream, he or she might accept the short gap length to enter the intersection and risk collision. Thus, gap acceptance is an essential factor to improve road safety. Normally it is also an indicative factor for signal warrant.

It can usually be hypothesized that the gap acceptance can vary with the flow in one place to another. Different flow states may have different gap acceptance. Many techniques have been used to determine gap acceptance for various conditions; some of these are Raff’s method [5], Logit and Probit models [6], Hewitt method [7], Maximum Likelihood Method [8] and Probability Equilibrium Method [9]. These critical gap estimating techniques and require the same information, including the accepted and rejected gaps. The gap is accepted if the vehicle on the minor stream can cross or/and merge into the major stream flow safely. Otherwise, the minor street drivers will reject the gap that they feel not safe enough to enter the intersection.

Many earlier researchers observed gap acceptance studies. Ashton [4] proposed the first assumption that the gap duration significantly influences traffic behavior. Normally, the accepted gaps are believed to be between 3 and 12 seconds [10,11]. Gap acceptance depends on several factors, a number of studies found that the shorter gap was accepted in the traffic with high flow [12,13]. The number of accepted gap was longer [12] and the number of shorter gap was found in front of small vehicles [14]. The drivers accepted riskier gaps around motorcycles than cars [15]. The accepted time gaps became significantly shorter in front of the bicycles [16]. The drivers accepted shorter gaps in straight movement than turning maneuver [17]. The gap acceptance for Australia rural regions in 2013 study was focused on the gap duration of drivers’ turning maneuver and its influence on the gap acceptance behavior [18]. Although the gap acceptance could influence the drivers’ decision and traffic safety, their findings pointed out that the drivers’ types of maneuver could change the gap acceptance. This point can help the development of intersection designs. Similarly, the gap acceptance study for Yangon will support the improvement of Yangon’s intersection designs.
3. Study sites and data collection
The study sites comprise three T-intersections; two of which are located in the urban areas and the other is in the suburban. Both urban intersections consist of two-lane major and two-lane minor roads. The suburban intersection includes four-lane major road and two-lane minor. These sites are in the moderately busy intersections of Yangon, and the traffic can be assumed as the intermediate flow including peak times. The city of Yangon drives on the right side. Thus, the gap acceptance for three turning movements are investigated; left-turn from major (LT-major), right-turn from minor (RT-minor) and left-turn from minor (LT-minor) maneuvers. The schematic study sites are illustrated in figure 2.

Figure 2. Plan of studied intersections (a) urban area (b) suburban area.

The camera was placed at the three study sites and the flow and gaps were retrieved from the video. The eight-hour traffic flow data were recorded in the morning, afternoon and evening peak hours for an average weekday. Traffic flows were counted in vehicles per hour from the recorded video. The arrival times of major stream vehicles at the specific point and the arrivals and departures of minor stream vehicles were measured. However, the actuate gap acceptance data could not be resulted from the site data collection of video recordings. The collected data were needed to be extracted in seconds by a vehicle-counting program to get the gaps which were required for analysis.

4. Analysis using Raff’s method
The major stream traffic arrival pattern is assumed to be random, i.e., not affected by control devices. According to the results, it could be proved that the observed gaps are in general represented Pearson distribution, using a model parameter specific to the location [19]. Then, the gap acceptance is determined by Raff’s method. The critical gap can be defined as the number of accepted gap less than it is equal to the number of rejected gap greater than it. In the analysis, it is noticeable that any particular driver can only accept one gap, whereas she can reject many of them at any one time especially peak hours. It can be found that there are many more rejected than accepted gaps. The cumulative distributions of accepted and rejected gaps are resulted from the observed data and used to plot three pairs of curves for three turning movements: LT-major, RT-minor and LT-minor. Then, the critical gaps can be obtained as the intersections of pairs of curves.

Table 1 shows the range of the critical gap values and it can be clearly seen the different between urban and suburban regions for each movement. In our study sites, the flow for urban area is around 300-800 veh/hr and that of suburban is between 100 and 500 veh/hr. For LT-major and RT-minor movements, the critical gap intervals are not quite different although the values are different for urban and suburban. The drivers choose to enter the intersection in shorter gaps at urban; it means the drivers may be aggressive and impatient because of traffic jam in the downtown areas. At the suburban intersection, the drivers have long acceptable gaps as the flow is not quite high, and they can choose longer gap to merge the intersection. Thus, it can be assumed that the traffic flow has the significant impact for the gap acceptance and the drivers’ maneuver.

The left-turn movement from minor stream is the last priority of traffic stream and it has to be subordinate to all other streams. Thus, the drivers who want to use this maneuver need to wait longer time than others and also they need longer acceptable gaps as their maneuver cross the intersection. The acceptable gap for this movement is ranging from 7 to 11.5 sec for urban and around 9.5-15 sec.
for suburban. Longer gaps are accepted for both regions. It may be suggested that the drivers are patient and can wait to cross the intersection, however, those longer gap acceptance are mainly based on the traffic flow. We can prove that point by comparing the interval values of both areas. The critical gap range for urban area is found shorter than that of suburban area, as the traffic flow for urban is higher than suburban. According to the results, it can conclude that the traffic flow is inversely proportional to the minimum gap acceptance. The higher the flow in traffic stream, the lower gap values the minor street drivers will get to enter the major stream.

Table 1. Critical gap intervals for three movements in urban and suburban regions (seconds).

| Movements | Urban       | Suburban    |
|-----------|-------------|-------------|
| LT-major  | 4.62 to 8.17| 6.67 to 11.33|
| RT-minor  | 4.21 to 6.44| 6.00 to 8.00 |
| LT-minor  | 7.00 to 11.29| 9.71 to 15.00|

The resulting critical gap values are displaced in the scatter plots. Figure 3 shows three trend lines for three turning movements for urban area (a) and suburban area (b) respectively. In both parts (a) and (b), it is visible that the gap acceptance values decreases along with the increasing traffic flow. That shows the gap acceptance can vary with the traffic flow.

While the data show the same trends, the regression slope t-test method is used to validate this finding. Table 2 illustrates the results of linear regression analysis for both urban and suburban areas. However, all slope values are not much different from zero. This provides no evidence that the gap acceptance values vary significantly with the flow of traffic streams. The coefficient of determination; R² values, are around 17 to 23 % except for one urban movement. Although R² values are lower values, it cannot assume that the dependent variable; gap acceptance, has less actuate predictions from the traffic flow as the observation results depend on the human behavior [20]. However, the hypothesis testing with 95% level of confident gives the unexpected results. The p-values for all movements except one urban movement (LT-minor) are greater than the alpha value (0.05). P-value needs to be lower than alpha value to confirm the significant appearance [21]. This result is quite different than others. Although we can see clearly that all trend lines decrease when the traffic flow increases, it cannot be proved that the traffic flow has significant effect to the gap acceptance. It may be suggested that the relationship between the gap acceptance and traffic flow is not apparent. It cannot say, however, there is no relationship between the gap acceptance value and the traffic flow. It can be resulted that the drivers tend to decrease their gap acceptance when the traffic volume increases. Thus, urban area has lower critical gap values than suburban area.
Table 2. Regression slope test and hypothesized results.

| Region   | Movement | a      | b      | R^2  | p-value | alpha |
|----------|----------|--------|--------|-------|---------|-------|
| Urban    | LT-major | -0.0035| 8.4414 | 0.2259| 0.0628  | 0.05  |
|          | RT-minor | -0.0026| 6.9232 | 0.1822| 0.0992  | 0.05  |
|          | LT-minor | -0.0077| 13.63  | 0.4718| 0.0033  | 0.05  |
| Suburban | LT-major | -0.0055| 10.083 | 0.1735| 0.1086  | 0.05  |
|          | RT-minor | -0.0029| 7.5339 | 0.2175| 0.0686  | 0.05  |
|          | LT-minor | -0.0077| 14.689 | 0.2278| 0.0616  | 0.05  |

5. Conclusion

Critical gaps for left-turn from major stream and right-turn from minor stream (regarded as Rank 2 in traffic priority) are quite similar; 4 to 8 seconds in urban and 6 to 11 seconds in suburban areas. Left-turn movement from minor stream (Rank 4, the last priority) has the longest critical gaps. The resulted actuate gap values for urban and suburban areas of Yangon can be seen in Table 1. According to the observation results, drivers at suburban intersection have longer critical gaps than urban ones. Lighter traffic tends to result in longer gaps. The relationship between the volume and gap acceptance is not evident. This gap acceptance study has the limitation for U-turns. In some intersections with limited capacity, if U-turn is to be allowed, the gap acceptance for the U-turn maneuver must also be investigated. Care should be taken as U-turns most probably require very long gap and affect intersection capacity significantly. In the further stages, the investigation of gap acceptance behavior will be applied to signal warrant of intersection designs for Yangon. However, the U-turns condition needs to be considered in the future research for the gap acceptance of Yangon.

6. References

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