# DETERMINATION OF GAP ACCEPTANCE AT PRIORITY INTERSECTIONS

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## ABSTRACT
Vehicles from minor approach at a stop–controlled intersection will wait for an appropriate gap to exist in the conflicting traffic stream before performing the merging or crossing manoeuvres at the intersection. In practice, driver's gap acceptance behaviour is one of the important aspects considered in the design and analysis of stop–controlled intersections. This paper describes the result of a study carried out to determine the drivers' gap acceptance at stop–controlled intersections where the major approach vehicles have priority over the minor road drivers. The data were collected at two stop–controlled intersections in an urban area using a video camera recording technique and gap data was analysed using the Maximum Likelihood method. The result of the study indicates that the gap acceptance for the drivers making the left-turn from minor road into the major was in the range of 6.00 to 10.00 seconds. The gap acceptance for the drivers making a right–turn from minor road into the major was in the range of 10.00 to 15.00 seconds. The result also shows that the gap acceptance values decrease when the volume of the major stream traffic increases.

## 1. INTRODUCTION
The critical gap is described as the lowest time interval on the major approach that allows the minor stream vehicles go into the intersection. Therefore, the driver's critical gap is the lowest gap that would be acceptable. A specific vehicle would reject any gaps smaller than the critical gap and would accept gaps larger than or equal to the critical gap. Critical gap is an important aspect of driver's behaviour which is considered in the design and analysis of priority types of intersections. Transportation Research Board (2000) suggested that driver's critical gap can be calculated based on the observations of the greatest rejected and lowest accepted gap for a given intersection. This paper describes the results of a study carried out to determine driver's critical gap at stop–signed intersections.

## 2. LITERATURE REVIEW
There have been various methods and studies for determination the gap acceptance and critical gap at intersections. Tian et al (1999) asserted that critical gap is a significant parameter for determination of gap acceptance. In this case, the critical gap and gap acceptance cannot be calculated directly from the site study.

One of the earliest techniques for calculating critical gap seems to be that of Raff's model. A study by Retzko (Brilon et al., 1999) reported that the Raff's model has been used in some countries.

In 1971, Miller (1971) published a review for estimation the gap acceptance on the basis of nine methods. He derived a mathematical description for calculation critical gap where the traffic volumes have influence in the values of critical gap estimated.

In 1992, Troutbeck (1992) suggested a microscopic model to estimate gaps. In this model, the individual values of the estimated gaps have been utilized. This model is on the basis of Maximum Likelihood calculation. This model is actually based on the assumption that drivers have homogeneous and consistent behaviour. In a study, Siegloch (Brilon, et al., 1999) established a new model for estimation the critical gap at unsignalized intersection. In This method, gap acceptance and consequently critical gap have been estimated by regression technique.

Brilon et al (1999) have provided quite a comprehensive review of some significant techniques for calculating gap acceptance at priority intersections. A set of quality criteria was also formulated. They suggested that the Hewitt's model (Hewitt, 1983, 1985, 1993) and the Maximum Likelihood Method (Tian, et al., 1999) work better than other models for estimation the gap acceptance.

A study by Hamet (Guo, et al., 2011) reported that the various events have influence in either accepted or rejected manoeuvres including geometry of intersections, drivers' behaviour, traffic flow, and waiting time of drivers. Troutbeck (1992) explained that the critical gap for various drivers followed a specific distribution such as hyper–Erlang distribution (e.g. Brilon (1995)) or a log–normal distribution. However, some researchers presumed that the values of critical gaps are a fix value (Tanyel, et al., 2005; Troutbeck, et al., 1999).

A recent study by Wu (2012) suggested a method of probability equilibrium between the accepted and the rejected gaps at priority intersections. This model is based on the cumulative distributions of the accepted and rejected gaps. The final model from the macroscopic equilibrium is more suitable for calculating critical gaps. This method is said to produce outcomes similar to that from Troutbeck's technique if the identical sample data are used. The Wu's model has actually found wide applications in various countries, such as in Netherlands, Spain, Germany, Canada, and the United States (Wu, 2012).

All of the previous techniques for estimating critical gap and also gap acceptance require the same information, including the accepted and the rejected gaps. This paper concentrates on the determination of gap acceptance at Two Way Stop Controlled (TWSC) intersections. The procedure of gap acceptance estimation based on the maximum likelihood method is provided as expression in Eqn. (1).

$$\binom{n}{A} * P^A * (1-P)^{(n-A)} \quad (1)$$

Where: n = the number of accepted and rejected gap; A = the number of accepted gap; and P = the probability of accepted gap.

## 3. METHODOLOGY

### 3.1 Site Description

In this research, data collection was carried out at two three–arm priority intersections, i.e. at site 1 which is the Titiwangsa3/Titiwangsa4 junction and site 2 which is Kebudayaan/ Kebudayaan3 junction. Site 1 has one lane on each major road approach and site 2 has two lanes on each major road approach. Both junctions are located in an urban area in Johor, Malaysia.

### 3.2 Data Collection and Analysis

Data pertaining to the analysis of gap acceptance and rejection at both intersections was collected using a video recording technique. Data collection was carried out for a range of traffic volumes at each junction to ensure sufficient data is obtained a sound statistical analysis. The vehicle's arrival and departure times on both minor and major approaches were extracted from the video recordings using an event recorder computer program.

The gap acceptance data, i.e. the number of accepted and rejected gaps, and the time periods of accepted gaps for minor road drivers was analysed using the Maximum Likelihood Method which is a discrete and binomial distribution.

## 4. RESULTS AND DISCUSSION

In this study, data was collected at both intersections for the drivers making right–turn and left-turn from minor road into the major road. The total number of the vehicles observed is indicated in Table 1.

Table1. Numbers of accepted, rejected and vehicles observed at both intersections

| Movements | T.V.O | T.A.G | T.R.G |
|---|---|---|---|
| Left Turn | 2012 | 1416 | 596 |
| Right Turn | 1020 | 426 | 594 |

Note:
T.V.O: Total Vehicles Observed; T.A.G: Total Accepted Gaps; T.R.G: Total Rejected Gaps

The accepted and rejected gaps were grouped into intervals of 3 to 4 seconds for the analysis. Table 2 and 3 summarise the numbers of accepted and rejected gaps at site 1 and site 2, respectively.

Table 2. Numbers of accepted and rejected gaps at Titiwangsa3/Titiwangsa4 junction (site 1)

| Range of gaps (sec) | Left | | | Right | | |
|---|---|---|---|---|---|---|
| | A.G (A) | R.G | T.O.G (n) | A.G (A) | R.G | T.O.G (n) |
| 0-3 | 263 | 125 | 388 | 43 | 73 | 116 |
| 3-6 | 236 | 117 | 353 | 78 | 109 | 187 |
| 6-10 | 135 | 51 | 186 | 35 | 61 | 96 |
| 10-15 | 158 | 67 | 225 | 36 | 52 | 88 |

Note:
A.G: Accepted Gaps; R.G: Rejected Gaps; T.O.G: Total Observed Gaps

Table 3. Numbers of accepted and rejected gaps at Kebudayaan/Kebudayaan3 junction (site 2)

| Range of gaps (sec) | Left | | | Right | | |
|---|---|---|---|---|---|---|
| | A.G (A) | R.G | T.O.G (n) | A.G (A) | R.G | T.O.G (n) |
| 0-3 | 224 | 114 | 338 | 93 | 122 | 215 |
| 3-6 | 182 | 65 | 247 | 86 | 105 | 191 |
| 6-10 | 125 | 25 | 150 | 46 | 61 | 107 |
| 10-15 | 93 | 32 | 125 | 9 | 11 | 20 |

Note:
A.G: Accepted Gaps; R.G: Rejected Gaps; T.O.G: Total Observed Gaps

As shown in Table 2 and Table 3, the gap acceptance and rejection data was divided into four groups, i.e. 0–3sec, 3–6sec, 6–10sec, and 10–15sec. The following calculations illustrate the example of the application of the maximum likelihood method to estimate the appropriate gap acceptance for left turn movements at Kebudayaan/ Kebudayaan3 junction.

$N_{(0\text{-}3)}$ =338, $N_{(3\text{-}6)}$=247, $N_{(6\text{-}10)}$=150, and $N_{(10\text{-}15)}$=125

$A_{(0\text{-}3)}$ =224, $A_{(3\text{-}6)}$=182, $A_{(6\text{-}10)}$=125, and $A_{(10\text{-}15)}$=93

$P_{(0\text{-}3)}$ =0.66, $P_{(3\text{-}6)}$=0.74, $P_{(6\text{-}10)}$=0.83, and $P_{(10\text{-}15)}$=0.74

0-3sec➔ $\binom{338}{224} * 0.66^{224} * (1-0.66)^{(338-224)}$=0.05

3-6 sec➔ $\binom{247}{182} * 0.74^{182} * (1-0.74)^{(247-182)}$=0.06

6-10 sec➔ $\binom{150}{125} * 0.83^{125} * (1-0.83)^{(150-125)}$=0.09 OK

10-15sec➔ $\binom{125}{93} * 0.74^{93} * (1-0.74)^{(125-93)}$=0.08

The ranges of minimum gap accepted by the drivers derived using the maximum likelihood method are summarised in Table 4.

Table 4. The level of the gap acceptance for drivers from minor road into the major road

| Movements | Range of minimum gaps (sec) |
|---|---|
| Left Turn | 6 – 10 |
| Right Turn | 10 – 15 |

In general, the left–turning movement drivers tend to accept a gap in the range of 6 – 10 sec as a safe gap to merge into the main stream traffic flow. The right–turning drivers, on the hand, perceive much longer gaps than those on the left turn lane, i.e. in this study the minimum gap accepted is found to be in the range of 10 – 15 sec. The longer gaps required by the right –turning drivers from minor approach into the major is probably due to the fact that they have to look for two safe gaps to merge, i.e. gaps in the near stream traffic and in the far stream traffic.

## 5. CONCLUDING REMARKS

This paper presented the values of gap acceptance at priority intersections based on the maximum likelihood method for the data obtained during morning and afternoon. The findings of the analysis can be summarised as follows:

(a) The values of gap acceptance for left turn movements from minor road were in the range of 6 to 10 second.
(b) For the right turning movements, the values of gap acceptance were about 10 to 15 second.
(c) The results also indicated that the gap acceptance values decreases for both right turns and left turns as the volume of major stream traffic increases.

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