

CRITICAL HEADWAY AT UNSIGNALIZED INTERSECTIONS - LITERATURE REVIEW

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Abstract: The critical headway is one of key traffic flow parameters for determining the capacity and level of service. The adoption of recommended critical headway values leads to inaccurate capacity estimation and poor investment decisions. Therefore, it is very important that the estimated values of this headway be as precise and accurate as possible in order to reflect the real behavior of drivers and real traffic conditions of a certain area or country. This paper provides a synthesis of selected studies in which the critical headway was estimated on the basis of real data collected at unsignalized intersections. The aim of this paper is to summarize the key results and conclusions related to the factors influencing the probability of accepting a headway and the most commonly used methods for its estimation. A detailed search of studies in which critical headways were analyzed revealed that no review paper on the analyzed intersections has been published so far.

Keywords: critical headway, unsignalized intersections, systematic review.

1. Introduction

Intersections where traffic is controlled by traffic signs and general traffic rules are the most common type of intersections. These intersections are known in the world as unsignalized or priority intersections. According to Elefteriadi (2014), an unsignalized intersection is an intersection where at least one of the movements is regulated by a “stop” or “yield” traffic sign. Gartner *et al.* (2001) state that each driver at the minor road of unsignalized intersection must decide on a headway in the major stream which is large enough to safely perform the desired vehicle maneuver.

This process is known as a process of gap acceptance expressed in seconds. Pawar and Patil (2019) state that drivers on minor roads of unsignalized intersections are generally at risk due to their estimation of a safe headway and, as a result of poor judgment, conflicts with the vehicle in the major flow are possible.

According to Tian *et al.* (1999), headways between vehicles are defined in such a way that the passage time of any vehicle that conflicts directly with a subject vehicle can be defined as a begin headway event. Raff (1950) defined a headway as an interval that passes from the arrival of major-stream

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vehicle at the intersection to the arrival of the next major-stream vehicle. According to Kuzović and Bogdanović (2010), the headway, as one of the basic traffic flow parameters, represents the time between the passage of the “front” of two consecutive vehicles, in one direction of one-way roads, i.e. in both directions of two-way roads, through the imaginary cross section of an observed road segment. To define the process of accepting time intervals, another term was introduced, the so-called lag. A lag is actually the first interval faced by the minor-stream driver. The lag represents the time from the moment when the minor-stream vehicle arrives at the stop line until the moment when the major-stream vehicle passes in front of the road where the minor-stream vehicle has stopped (Tian *et al.*, 1999).

One of the traffic flow parameters that most affects the capacity and level of service is the critical headway. According to Brilon *et al.* (1999) and Kuzović and Bogdanović (2010), the critical headway is defined as the minimum required headway in the major stream that allows one vehicle from the minor stream to enter the center of an intersection. Tanackov *et al.* (2018) proved that subjective safety time participates on average with one third of the time in the critical headway. Although there are manuals that recommend values of critical headway that can be used in different conditions, more accurate and precise values can be obtained by observations and field research (Zhou *et al.*, 2017). In this way, it is performed the process of adjusting input parameters according to real traffic conditions at intersections with the values which are measurable, in order to obtain more realistic data of theoretical models (Maslač *et al.*, 2018). Up to now, numerous models for estimating the values of critical

headway have been given in studies. The most significant and most frequently used methods and procedures for its estimation are: Siegloch’s method, Lag method, Logit method, Raff’s method, Ashworth’s method, Harder’s method, Probit procedures, Hewitt’s method, Maximum Likelihood Method and Probability equilibrium method.

The critical headway was called the “critical gap” until 2010, when the name “critical headway” was adopted in order to avoid doubts about different uses of the same term. Namely, the term “gap” usually refers to the time interval between the rear end of the first vehicle and the front end of the second vehicle following the first vehicle, while the “headway” is the time interval between the front ends of two consecutive vehicles (Prassas and Roess, 2020). The critical headway is most often denoted by t_c , but the notation t_g can also be found in the literature.

In this paper, it is performed a comparative analysis of the results obtained in selected studies, in which the factors influencing the gap acceptance between vehicles are considered, and the emphasis of the research is on the critical headway. The analysis includes studies conducted at four types of unsignalized intersections, as follows:

- Intersections with a minor road controlled by the traffic sign “stop”, the so-called TWSC intersections (Two-Way STOP-Controlled Intersections);
- Intersections with all roads controlled by the traffic sign “stop”, the so-called AWSC intersections (All-Way STOP-Controlled Intersections);
- Intersections with a minor road controlled by the traffic sign “yield”, the so-called TWYC intersections (Two-Way Yield-Controlled Intersections);

- Unregulated or uncontrolled intersections with the so-called the right-hand rule.

2. Research Methodology and Preliminaries

For the purposes of this paper, an electronic database of scientific papers was searched by using Google and Google Scholar during the month of September 2020. The following keywords and their combinations were used in the search: critical headway, critical gap, methods for estimating the critical headway, unsignalized intersections, priority intersections, stop-controlled or yield-controlled intersections. By this way of searching, it has been identified a total of 130 papers that are in some way related to the critical headway. However, the selection led to a significant reduction in the number of analyzed publications, so the results and conclusions of 67 publications are presented within this literature review. The selection of publications covered 34 studies in which the values of the critical

headway at unsignalized intersections in different countries in the period from 2000 to 2020 were estimated.

Figure 1 presents the number of publications in the period from 2000 to 2020 in which critical headways were estimated using different methods. It can be noticed that for the years 2001, 2003 and 2006, as well as for the period 2008-2010, no studies have been found where the critical headway was calculated. Since 2014, there has been a noticeable trend of growth in the number of published papers in which the value of the critical headway was estimated, and the largest increase is in 2015. Figure 2 shows the number of publications where the values of the critical headway in the period 2000-2020 were calculated by countries where the studies were conducted. It is evident that by far the largest number of studies were conducted in India, followed by the USA, Malaysia and China. It should be noted that in the paper (Chandra and Mohan, 2018), critical headways were estimated in two countries, i.e. India and the United States.

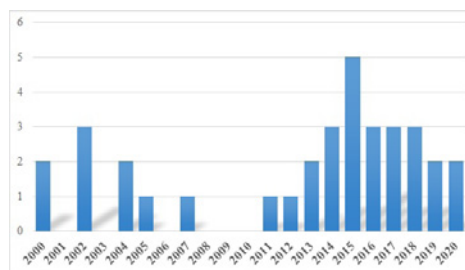


Fig. 1.

Number of Publications with Estimated Values of the Critical Headway by Years

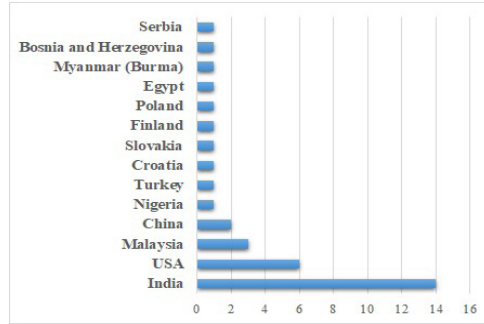


Fig. 2.
Number of Publications with Estimated Values of the Critical Headway by Countries

Based on Figure 3, it can be concluded that the largest number of publications in the period from 2000 to 2020 was published in the *Transportation Research Record*. It is followed by *Transportation Letters*, *IATSS*

Research and Journal of the Indian Roads Congress. Out of a total of 34 journals/conferences/institutions, 24 published per one paper in which the value of the critical headway was determined.

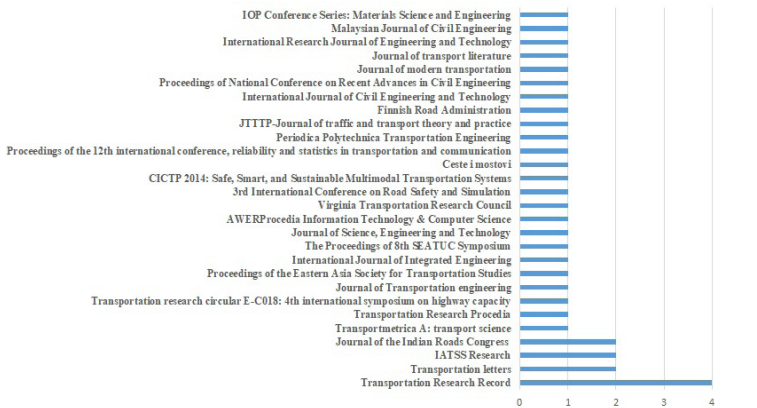


Fig. 3.
Number of Publications with Estimated Values of Critical Headways by Journals/Conferences/Institutions

3. Factors Influencing the Gap Acceptance between Vehicles

In (Devarasetty *et al.*, 2012), it was found that the type of headway offered to the driver affects the gap acceptance. Lord-Attivor and Jha (2013) found that the waiting time

at the stop line is the most common factor influencing the driver's decision whether to accept a headway. In (Pollatschek *et al.*, 2002), it is presented a model according to which drivers from a minor stream at an unsignalized intersection accept a headway in the major stream when the benefit of

entering the major stream outweighs the risk. Sangole *et al.* (2011) developed a gap-acceptance model for two-wheelers when turning right from the major road using a neuro-fuzzy approach. Research on several different types of intersections for different maneuvers, as well as for different types of vehicles, was conducted by the authors in (Sangole and Patil, 2014). In (Zhou *et al.*, 2017), it was found that the number of lanes on the major road, the presence of a left-turn lane, the speed limit and the age of drivers did not show a significant impact. However, in (Akçelik, 2012), it was concluded that parameters related to the acceptance of headways depend on the geometry of intersections, i.e. the number of traffic lanes on the major road. In contrast to Zhou *et al.* (2017), Maurya *et al.* (2016) found that the age of drivers has a significant impact on the gap acceptance.

Yan *et al.* (2007) confirmed the results of previous studies using a driving simulator, i.e. found that the age and gender of drivers in the major traffic stream have a significant impact on the acceptance of headways. However, unlike Maurya *et al.* (2016) where it is noticed that drivers accept smaller headways in case of lower approaching speed, here the authors found that drivers accept smaller headways in case of higher speeds in the major traffic stream. In (Beanland *et al.*, 2013), after a driving simulation, the drivers were interviewed where they were asked what influenced their decision to make a safe turn. Their responses showed that drivers are largely unaware of how they change their own behavior in accordance with traffic direction and the type of maneuvers they undertake. In (McGowen and Stanley, 2012), it was used the Monte Carlo simulation model in order to perform a comparison of the proposed model for estimating the critical

headway with the Maximum Likelihood Method using the Monte Carlo simulation model. Mohan and Chandra (2016) using the VISSIM simulation program showed that the Maximum Likelihood Method, Wu's method, Raff's method and the Acceptance curve method provide consistent results, while Probit, Logit and Ashworth's method vary depending on conflicting flow rates.

4. Investigation of Critical Headway at Different Types of Unsignalized Intersections

Within this section, it is presented authors' observations and conclusions related to the calculation of the critical headway by applying different methods to four types of unsignalized intersections in the period 2000-2020.

4.1. Critical Headway at TWSC Intersections

Mohan and Chandra, (2017) indicate that not all methods have an appropriate approach to the complex behavior of drivers in the heterogeneous traffic conditions prevailing in India and other developing countries. Therefore, a new Occupancy time method based on occupancy time has been proposed. In (Mohan and Chandra, 2018) the authors also showed that the Occupancy time method provides the most realistic values of the critical headway. The results presented in (Chandra and Mohan, 2018) showed that the critical headway calculated for passenger cars in India is 20-31% lower than the value of this interval in the USA. However, in (Ma and Zhao, 2019), it was found that the values obtained in China are significantly higher than those in India. In (Bogdanović *et al.*, 2013), the values of the critical headway determined at non-standard

three-legged intersections are higher by 15% to 110% compared to the values for standard intersections recommended in (HCM, 2010). Non-standard four-legged intersections were analyzed by the authors in (Bogdanović *et al.*, 2017).

Tian *et al.* (2000) also found that with the increase in the number of lanes on the major road or the number of legs at the intersection, the critical headway increases due to difficult maneuvering. These results were confirmed in (Ma and Zhao, 2019) during left-turn and right-turn movements from minor streams, while the reverse was the case for left-turn movements from the major stream. Tian *et al.* (2000) also found that the critical headway increases with increasing an approach grade, as well as with a normal or large turn angle, which was also proven in (Saplioglu and Karasahin, 2013). Cvitanić and Lozić (2002) noticed that the largest rejected headways are by minor-road vehicles in situations when vehicles from the major road perform a left-turn maneuver. Harwood *et al.* (2000) state that if drivers accept a certain critical headway in the major stream when turning and if such turning maneuvers are performed safely, then a sufficient sight distance at the intersection should be provided to allow drivers to recognize the critical headway. In addition, the authors noticed that trucks require longer headways to enter the major stream than passenger cars as found in (Tian *et al.*, 2000) and (Kareem, 2002). This data indicates that it is necessary to provide a longer sight distance at intersections where trucks frequently make turns.

In (Ibrahim and Sanik, 2007), the values of the critical headway were found to be much less for motorcycles than for passenger cars. The values of the critical headway obtained in previous paper are smaller compared

to the values in (Sahraei and Puan, 2014) and (Fajaruddin *et al.*, 2015) in which the research was also conducted in Malaysia. In (Dissanayake *et al.*, 2002), it was found that the critical headway becomes larger as the intersection is closer to the outer ring (peripheral parts of the city). Ma and Zhao (2019) found that the critical headway increases by about 18.74% when the intersection location is moved from the central district to the outer one.

4.2. Critical Headway at AWSC Intersections

Abhigna *et al.* (2020) conducted a survey at two AWSC intersections selected in such a way that there is a clear difference in the proportion of heavy vehicles. The values of the critical headways for vehicles turning right from the minor street estimated using the Raff's method are smaller compared to the values obtained using the Clearing behavior of the vehicles. The authors found that the value of the critical headway increases with the size of the vehicle, as well as with higher major-stream flow intensity.

4.3. Critical Headway at TWYC Intersections

In (Chodur, 2005), it was conducted a survey at 32 intersections with minor streams controlled by the traffic sign "yield", but also by the traffic sign "stop". Unlike (Luttinen, 2004), this paper states that the individual impact of these two traffic signs used on the city road network is statistically insignificant. It was found that the number of traffic lanes on the major road significantly affects the critical headway when turning left from the major road. In addition, the size of a city has a significant impact on the value of the critical headway. On the other

hand, Stanimirović *et al.* (2020) found that the characteristics of drivers significantly affect the value of the critical headway. Specifically, the values of the critical headway of non-resident drivers are higher by about 1 s compared to the values of resident drivers, which directly affects the decrease in capacity at the intersection. The authors also showed that the values of the critical headway deviate from those recommended in the manual (HCM, 2016).

4.4. Critical Headway at Uncontrolled Intersections

The analysis conducted in this paper indicates evident aggressiveness of drivers in developing countries, such as e.g. India. For this reason, TWSC intersections in India, regardless of the presence of traffic signs, are often characterized as uncontrolled or partially controlled intersections. In (Dutta and Ahmed, 2017) it is stated that drivers behave aggressively not because they lose patience due to the unavailability of an acceptable headway but because they do not respect traffic rules.

In (Serag, 2015), it was noticed that the value of the critical headway is higher than the value of the critical lag which was also found in (Dutta and Ahmed, 2016). In addition, in (Serag, 2015), it was found that waiting time, type and size of the vehicle do not significantly affect the probability of accepting a headway. Contrary to the above, in (Maurya *et al.*, 2016) and (Rao *et al.*, 2017), it has been proven that vehicle size is a significant influencing factor. According to Patil and Sangole (2016), the values of critical headways for two-wheelers are much lower compared to the values of critical headways in which all vehicle categories are covered. Also, unlike (Serag, 2015),

Maurya *et al.* (2016) noticed that drivers accepted shorter headways in case of longer waiting times and higher number of rejected headways.

Patil and Pawar (2014) found that the speed of vehicle approaching from the major stream does not significantly affect the acceptance of temporal headways, while the accepted spatial headways depend on it. On the other hand, Maurya *et al.* (2016) found a relationship between temporal headways and approaching speed, more precisely, drivers accepted smaller headways in case of lower approaching speed, and larger headways in case of higher approaching speed. According to San and Siridhar (2019), drivers accepted shorter headways as traffic intensity increased. According to (Serag, 2015), the critical headway/lag decreased as the priority vehicle slowed down or even stopped to let the vehicle from the minor stream pass.

5. Summary Analysis of Results

Figure 4 presents the percentage share of studies in which the values of the critical headway at different types of unsignalized intersections in the period 2000-2020 were estimated. It is obvious that most studies of critical headway were conducted at TWSC intersections. Following TWSC intersections, most studies were conducted at uncontrolled intersections. However, it should be borne in mind that the most countries where critical headways were estimated at uncontrolled intersections are in fact developing countries. In such countries, it is evident very aggressive behavior of drivers who usually do not respect the priority of drivers in the priority flow. Therefore, in developing countries, TWSC intersections are very often considered

uncontrolled or partially controlled intersections. The smallest number of studies has been conducted at AWSC intersections,

and the reason for this may be that this type of intersection is not as prevalent in the world as in the USA.

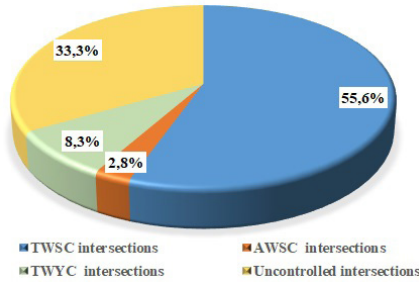


Fig. 4.
Percentage Share of Studies of Critical Headways at Different Types of Unsignalized Intersections

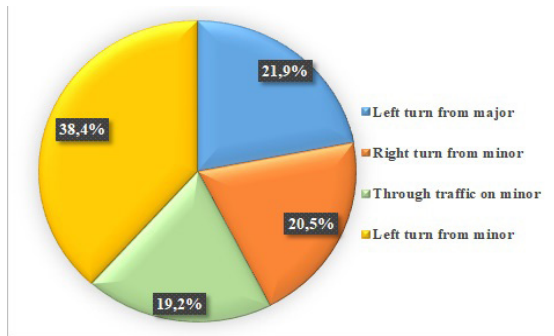


Fig. 5.
Percentage Share of Analyzed Maneuvers when Determining Critical Headways

In studies conducted in the period 2000-2020, the values of critical headways for different maneuvers were estimated. It is important to note that the maneuvers presented in Figure 5 correspond to the right-hand drive rule, i.e. the maneuvers in the analyzed studies in which the left-hand drive rule is in force are adjusted (e.g. right turn in India corresponds to left turn and vice versa). Based on the figure, it can be concluded that the largest number of analyzed maneuvers when determining

critical headways belong to a left turn from a minor road. According to many authors, a left turn from a minor road is the most complicated maneuver for drivers (Rao *et al.*, 2017; Lord-Attivor and Jha, 2012; Tupper *et al.*, 2011; Harwood *et al.*, 2000). In (Ragland *et al.*, 2006) it is presented a video system (Intersection Decision Support system) that warns drivers who intend to make a left turn and provides them with information about conflicting traffic from the opposite direction.

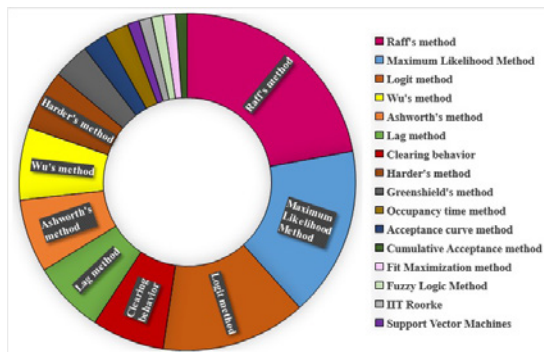


Fig. 6.
Applied Methods in Studies to Estimate Critical Headways

Based on Figure 6, it can be concluded that Raff’s method was used in most studies for estimation of critical headway. This is expected because the Raff’s method is the earliest method for estimating the value of critical headway, and it is still used in many countries due to its simple application. In the second place is the Maximum Likelihood Method, and its benefits of application for precise and accurate results have been reported in numerous studies (Troutbeck, 1992; Brilon *et al.*, 1999; Bunker, 2012; Brilon, 2016; Mohan and Chandra, 2016). According to Wu, (2006) and Wu, (2012),

the main disadvantages of this method are assumed distribution of critical headway and that the method is iterative, and therefore complicated. However, in (Troutbeck, 2014), it is explained in detail how the method is in fact easy to use and that it can be developed to estimate the critical headway in Excel. In the third place in terms of percentage of use is the Logit method, followed by Wu’s method, Ashworth’s method, Lag method, Clearing behavior of the vehicles and Harder’s method. Table 1 presents the methods used in particular studies and countries and shows key conclusions and results.

Table 1
Key Conclusions and Methods used in the Analyzed Studies

Authors	Country	Research Methods	Key Conclusions
Mohan and Chandra, (2017)	India, USA	MLM, Lag, Wu’s, Harder’s, Logit, modified Raff’s and Occupancy time method	It is proposed a new method (Occupancy time method) which is applicable in both homogeneous and heterogeneous traffic conditions.
Mohan and Chandra, (2018)	India	Occupancy time method	t_c increases with an increase in the participation of large vehicles in the conflicting flow.
Ibrahim and Sanik, (2007)	Malaysia	MLM	It is proposed a composite formula for estimating t_c that takes into account a mixed traffic flow composition.
Fajaruddin <i>et al.</i> , (2015)	Malaysia	Raff’s and Logit method	Waiting time, headway size, lane change, speed, and vehicle type in a conflicting flow affect the gap acceptance.

Authors	Country	Research Methods	Key Conclusions
Sahraei and Puan, (2014)	Malaysia	MLM	Values of acceptable headways decrease as the flow of vehicles in the major stream increases.
Kareem, (2002)	Nigeria	n.a.	The value of the headway is lower on weekdays than on weekends, as well as for younger male drivers and drivers who drive smaller vehicles.
Saplioglu and Karasahin, (2013)	Turkey	Fuzzy Logic Method	The flow of vehicles on the major road and the speed of oncoming vehicles are inversely proportional to t_c .
Lakkundi et al., (2004)	Virginia, USA	Raff's method	Based on t_c , it is possible to determine whether it is necessary to introduce an additional lane for left turns.
Chandra and Mohan, (2018)	India and USA	MLM	t_c for passenger cars in India is significantly less than t_c in the USA; t_c for two-wheelers is even smaller than t_c for passenger cars.
Dissanayake et al., (2002)	Florida, USA	Logit model	The daytime/nighttime driving factor affects the t_c values only for older drivers.
Tupper et al., (2011)	Massachusetts and Oregon, USA	Raff's, Cumulative Acceptance and Fit Maximization method	The presence of a queue behind the driver, the driver waiting time and the number of headways rejected had the greatest impact on t_c .
Tian et al., (2000)	USA	MLM	The main influencing factors on t_c are the geometry of the intersection, the type of vehicles, the grade of approach, the type of maneuver and the delays of vehicles.
Harwood et al., (2000)	USA	Raff's and Logit method	t_c is suitable for determining the sight distance.
Liao et al., (2014)	China	Raff's method	t_c depends on an intersection location, working days/holidays and days/ nights.
Ma and Zhao, (2019)	China	MLM and Raff's method	t_c depends on the maneuver, the geometry and location of the intersection.
Cvitanić and Lozić, (2002)	Croatia	MLM	The direction of vehicle movement from the major stream has a significant impact on the gap acceptance.
Gavulová, (2012)	Slovakia	MLM, Raff's and Wu's method	t_c is different for the samples considering drivers who did not reject any headway from the samples in which they are not taken into consideration.
Bogdanović et al., (2013)	Serbia	Cumulative Acceptance model	t_c is significantly higher at non-standard TWSC intersections compared to standard ones.
Abhigna et al., (2020)	India	Raff's method and Clearing behavior of the vehicles	t_c increases with an increase in the dimensions of vehicles and a higher intensity of the major stream.
Stanimirović et al., (2020)	Bosnia and Herzegovina	Mean interval value eliminating extreme values	The t_c values of non-resident drivers are higher by about 1 [s] compared to the resident drivers.
Luttinen, (2004)	Finland	MLM and Raff's method	t_c is probably lower at TWYC intersections compared to TWSC intersections.
Chodur, (2005)	Poland	MLM	There is no significant difference in t_c values at TWYC and TWSC intersections.

Authors	Country	Research Methods	Key Conclusions
Patil and Pawar, (2014)	India	MLM, Raff's, Ashworth's, Logit and Lag method	The approaching speed of the vehicle from the major stream affects the acceptance of spatial headways, but not the acceptance of temporal headways.
Rao <i>et al.</i> , (2017)	India	Raff's, Harder's, Wu's and the method proposed by IIT Roorkee	t_c increases with increasing vehicle dimensions.
Dutta and Ahmed, (2016)	India	Clearing behavior of the vehicles	Critical headway values are greater than critical lag values.
Dutta and Ahmed, (2017)	India	Clearing behavior of the vehicles and Logit method	The length of the headway, the time required to clear the intersection and the aggressiveness of drivers affect the gap acceptance.
Amin and Maurya, (2015)	India	Clearing behavior of the vehicles, Acceptance curve method, Raff's, Greenshield's, Lag, Harder's, Logit, Ashworth's and Wu's method	Clearing behavior of vehicles is the only suitable method for estimating t_c in mixed traffic conditions.
Maurya <i>et al.</i> , (2016)	India	MLM, Clearing behavior of the vehicles, Acceptance curve method, Raff's, Greenshield's, Lag, Harder's, Logit, Ashworth's and Wu's method	Evident aggression of young people and male drivers, as well as motorcyclists without the presence of passengers; accepting smaller headways in case of lower approaching speed, longer waiting time and higher number of rejected headways.
Amin <i>et al.</i> , (2018)	India	Clearing behavior approach, Raff's, Wu's, Logit, Greenshield's, Harder's and Ashworth's method	It has been confirmed that the Clearing behavior approach provides the most reliable values of t_c .
Serag, (2015)	Egypt	Raff's method	The type of offered interval (headway or lag) affects its acceptance.
San and Siridhara, (2019)	Myanmar (Burma)	Raff's method	Headways are shorter in urban than in suburban areas.
Patil and Sangole, (2015)	India	MLM, Raff's, Ashworth's, Lag and Logit method	Maximum Likelihood Method provides the most relevant results.
Patil and Sangole, (2016)	India	MLM, Raff's, Lag, Ashworth's and Logit method	The probability of accepting the offered headway is higher if drivers are young and/or if the conflicting vehicle is a two-wheeler.
Pawar <i>et al.</i> , (2015)	India	Support Vector Machines (SVM) and Logit method	It has been proven that the application of the SVM method enables the prediction of accepted and rejected headways.

Note: MLM=Maximum Likelihood Method, t_c =critical headway, n.a.=not available, IIT Roorkee= Indian Institute of Technology Roorkee.

6. Conclusions and Guidelines for Further Research

In the last few years, the number of studies estimating the values of the critical headway at unsignalized intersections has been increasing significantly. Therefore, the literature review performed in this paper can serve not only to synthesize the results of existing studies, but also to provide an insight into what has been done so far and what may be investigated in the future. The main goal of this paper is to consolidate authors' key results and observations related to critical headways from different and carefully selected relevant sources. The search of publications analyzing critical headways revealed that no review paper on the headway at four different types of unsignalized intersections has been published so far, which is the main contribution of this literature review. Within this paper, roundabouts have not been considered, even though they also belong to unsignalized intersections, due to the fact that there are already literature reviews that have analyzed this type of intersections. In addition, traffic control rules at roundabouts differ significantly from the rules at unsignalized intersections discussed in this paper.

In most studies, it has been noticed that the longer the waiting time and the higher the number of rejected gaps, the higher the probability of accepting a shorter headway (Zhong *et al.*, 2007; Tupper *et al.*, 2011; Maurya *et al.*, 2016). This phenomenon indicates that drivers lose patience while waiting and make decisions to the detriment of their own safety and the safety of other road users. Also, in a significant number of studies, the authors claim that with

increasing flow and speed of oncoming vehicles in the major stream, the value of the critical headway decreases (Tian *et al.*, 2000; Saplioglu and Karasahin, 2013; Sahraei and Puan, 2014). However, although some of the mentioned factors have shown a significant influence in some studies, in other studies it has been found that there is no significant impact on the gap acceptance by the same factors (Patil and Pawar, 2014). Yan *et al.* (2007) state that drivers accept smaller headways in case of higher speed in the major stream as opposed to Maurya *et al.* (2016) who claim the opposite. In the future, it should be performed a survey at a number of locations in different traffic flow conditions in order to determine whether there is a dependence of gap acceptance on certain factors and what is their real impact on headways.

The values of critical headways vary from one country to another, and this is due to cultural differences, then differences in drivers' behavior, their habits and customs. As a result of the variations in the values of critical headways, there are differences in capacity calculation at unsignalized intersections in particular countries. The use of recommended values of critical headways can lead to wrong investment decisions. Therefore, the main focus of this paper was on studies where it was performed the local measurements of headways between vehicles calculating critical headway values which reflected real traffic conditions in a particular area or country. Within this literature review, it has not been identified any paper estimating the critical headway for a U-turn on the major road. This is probably due to the insufficient amount of data collected to estimate the critical headway

since this maneuver at intersections is not as representative as others. San and Siridhara (2019) recognize this unexplored maneuver in their paper as a lack of the research.

Based on the summarized results, it is possible to conclude that the three methods having the greatest application are in the following order: Raff's method, Maximum Likelihood Method and Logit method. However, in some developing countries it has not been possible to apply these methods due to heterogeneous traffic conditions. It is for this reason that methods adapted to such traffic conditions have been developed, such as: Occupancy time method and Clearing behavior of the vehicles.

Luttinen (2004) states that it is very possible that the critical headway will be smaller at TWYC intersections compared to TWSC intersections as opposed to Chodur (2005) who claims that there is no significant difference between the intervals at these two types of intersections. However, the search of the papers revealed that it was conducted a very small number of studies where the critical headway at TWYC intersections was estimated. In the future, the gap acceptance at this type of intersection should be investigated in more detail in order to better understand the difference between the values of critical headways at TWYC and TWSC intersections.

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