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Overtaking Conflict Analysis and Risk Modeling for Undivided Two-Lane Road Section

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Abstract: *With the continuous growth of urbanization and increasing vehicular traffic, the analysis of overtaking manoeuvres has become crucial for ensuring road safety and efficient traffic flow. This study involves comprehensive analysis and modelling of overtaking traffic conflicts on two-lane two-way roads. The study locations include three straight road stretches connecting Chavadimukku-Karyavattom road, Karyavattom- Kazhakoottam road and Karickom- Kottarakkara road, where the overtaking of vehicles found more. The main objective was to investigate and evaluate the potential conflicts arising from overtaking manoeuvres, considering various traffic parameters with the help of a surrogate safety measure (SSM) called the Time to Collision (TTC). TTC value of 1.4 was found to be the threshold value for severity classification. The severity levels divided into 4 levels based on the TTC values, which include severe, moderate, minor and no conflicts. With the help of TTC values, severity models of the conflicts at the selected locations were developed and these conflict models were developed using multinomial logit (ML) and ordered probit(OP) models. Key factors influencing overtaking behaviour, including vehicle speed differentials, overtaking distance, type of vehicle overtaking etc. are systematically manipulated to assess their individual and collective effects on traffic conflicts. From the study the ML model was found more fit for the severity study of overtaking manoeuvres for the selected study location.*

Key Word: *Time to Collision, Over taking conflicts, Severity models Time to Collision, Overtaking conflicts, Severity models.*

I.INTRODUCTION

On a two-lane roadway, overtaking becomes one of the primary sources of traffic conflicts. Studies on the assessment of overtaking safety can yield valuable data for preventing traffic accidents on two-lane highways. It is anticipated that the majority of collisions result from poor overtaking manoeuvres, since many overtakes occur with a small gap or when an opposing vehicle is present. On undivided highways, cars travelling at design speed must regularly be able to pass slower-moving vehicles in order to provide a greater level of service. Drivers must have enough sight distance available to them in order to execute an overtaking manoeuvre safely because it requires occupying road space that is often occupied by opposing traffic. (IRC: 66-1976). It is very difficult to estimate the extent and severity of overtaking concerns due to a lack of comprehensive studies and substantial data restrictions. To assess the likelihood of conflicts on roads, surrogate safety measures can be employed. Traffic conflict-based safety analysis is preferable to crashes data-based analysis. Conflict severity analysis of overtaking manoeuvre aids in estimating the risks associated with the overtaking conflicts. In the study, Time to Collision (TTC) was used as a surrogate safety measure to classify the severity of overtaking conflicts. Different statistical models are used to estimate factors affecting overtaking conflict severity.

II.LITERATURE REVIEW AND SUMMARY

A detailed review of literature was done to find out various studies conducted on conflict determination at various locations specifically on overtaking. Day et al, 2008 examined how cars overtake other vehicles in mixed traffic situations on undivided roads. To collect overtaking data on a two-lane, two-way undivided road, moving car observer and registration plate approaches were employed. The overtaking behaviors of all vehicle categories in mixed traffic scenarios were recorded and modeled statistically. Mohaymany et al, 2011 studied twelve two-lane country roads subjected to a traffic conflict approach in order to look into possible accidents and, consequently, determine the geometric and traffic elements influencing traffic conflicts. Two sets of data were examined separately using Pearson's chi-square test to assess how they related to traffic conflicts. The percentage of time spent following, the proportion of heavy vehicles, the direction of traffic, the mean speed, the speed standard deviation, the kind of section, the width of the road, the longitudinal slope, the holiday or workday, and the illumination condition were considered as the independent factors. Ghods and Saccomanno, 2016 developed a two-lane highway microscopic overtaking gap acceptability model and verified it with video-recoding data. Each driver's estimate of the anticipated Time-to-Collision (TTC) with the closest opposing vehicle at the conclusion of the maneuver determined whether to commence overtaking. Using overtaking video recording data for a two-lane highway, the gap acceptance model is calibrated and validated. Asaithambi and Shravani, 2017 investigated how cars overtake one another in mixed traffic on unrestricted roadways. On a two-lane, two-way undivided road, overtaking data was gathered using the registration plate approach and the moving automobile observer method. The acceleration characteristics, overtaking vehicle speeds, overtaking time, overtaking distances, safe opposing gap needed for overtaking, and other information are among the data that were retrieved and examined. Mahmud et al, 2017 examined in detail the creation and use of proximal surrogate safety indicators. The document offers a summary of the key guiding principles, the most salient characteristics, and any previous critical or threshold levels for each of the major indicators under consideration. Figueira and Larocca, 2020 in their study of overtaking behaviours in controlled traffic conditions involved the analysis of data collected on a two-lane road. This study offered a method for observing passing manoeuvres on two-lane highways in a driving simulator and looked into how the following gap distance, which serves as a driver behaviour indicator, is affected by the passing sight distance, the type of vehicle to be overtaken, and the speed of the impeding vehicle. Mahmud et al, 2022 in the study the nature and severity of probable conflicts during overtaking maneuvers are considered while evaluating safety risk. The study was conducted in a traffic setting with a variety of patterns on a bidirectional, undivided two-lane highway. For the overtaking maneuver, a risk severity model was created. Three alternative discrete outcome frameworks are discussed and their applicability is assessed which include the mixed logit (MXL), ordered probit (OP), and multinomial logit (ML) models. The study discovered that the likelihood of serious conflicts is significantly impacted by the speed difference between overtaking and overtaken vehicles. Torkashvand et al, 2022 tried to establish a TTC threshold as a surrogate safety measure, the study assessed overtaking behaviors and determined how these behaviors affected the TTC. To investigate the risk likelihood of the TTC threshold, a dynamic probabilistic risk strategy based on binomial logistic regression and higher order ordinary differential equations was created. The acquired data showed that, as a result of overtaking behavior, the TTC threshold was 2.4 s. Space headway, time headway, and overtaking speed could increase the probability risk of the TTC threshold by 97, 95, and 93%, respectively, according to the findings of dynamic risk probabilistic models.

Most studies related to overtaking of vehicles carried out in homogenous traffic condition with lane-based traffic using driver simulators. Only few of the researches analyzed overtaking characteristics in heterogenous Indian traffic conditions. Overtaking behaviours of different vehicle categories, different types of overtaking, overtaking speeds etc were studied. The previously examined studies are based on homogeneous lane basis traffic situations with an automobile predominance. Few studies have calculated the likelihood of disputes during overtaking maneuvers in actual traffic situations, which is quite limited in the event of a heterogeneous traffic environment. Additionally, there is a lack of research on the variables, such as probable conflict severity risk during overtaking, that influence overtaking safety risk.

III.DATA COLLECTION AND ANALYSIS

The first step of the study was the selection of a straight two lane-two-way undivided stretch having more number of overtaking. Chavadimukku-Karyavattom road, Karyavattom- Kazhakkoottam and Karickom- Kottarakkara road were chosen as the study locations after the reconnaissance study. Video data of the selected three locations were collected using video camera. Video data was collected for 2 – 2.5 hours from each of the three study locations. The overtaking parameters were then extracted from the collected data. Overtaking time, overtaking and overtaken vehicle speed, relative speed between vehicles, type of overtaken and overtaking vehicles has to extracted from the video data. Using the collected data Time to Collision (TTC) is calculated. To find the time difference, positions etc from the video data Kinovea software was used. Fig.1 shows the user interface of Kinovea software.

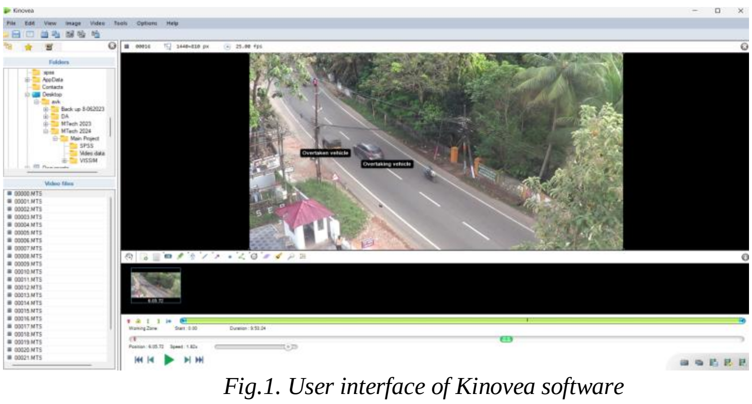

Fig.1. User interface of Kinovea software

3.1 Determination of Time to Collision

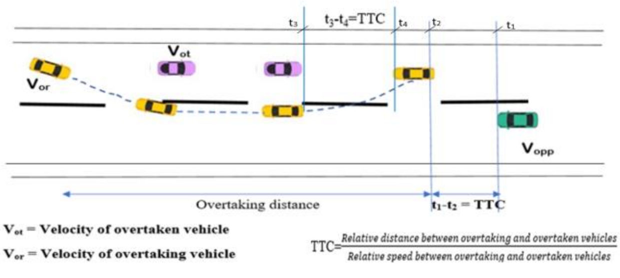

Fig.2. Illustration of TTC calculation

Time to Collision (TTC) is the time required for vehicles to collide each other if they continue to move in the same path (Hayward et al). It can be specified as the time needed to cover the distance between the lead and following vehicle with the relative speed between the lead and following vehicle. Fig. 2 shows the illustration of determining TTC during overtaking.

Critical TTC is defined as the minimum accepted TTC at the conflict point by the following vehicle. A traffic condition with a TTC value less than critical TTC is termed a critical conflict. Cumulative percentage frequency curve of overtaking conflicts with TTC were drawn to determine critical TTC for the overtaking vehicles. Cumulative percentage frequency curve drawn is shown in Fig.3.

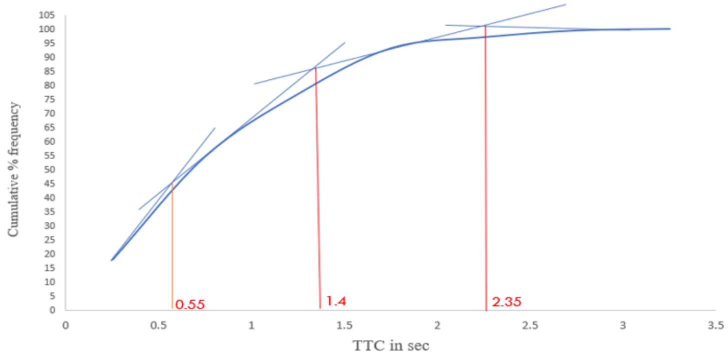

Fig.3. Cumulative percentage frequency curve showing threshold TTC values

Threshold value of the obtained TTC values were calculated from the cumulative frequency distribution. A critical threshold value of 1.4 was found out from the frequency diagram. TTC values obtained less than 1.4 were considered as critical conflicts and above the value as non-critical conflicts. The upper and lower limits were also estimated from the diagram. The obtained threshold values are 0.55, 1.4 and 2.35. So, the limits of severity classification are <0.55, 0.55-1.4, 1.4-2.35 and >2.35. Based on the obtained threshold value the conflicts are categorized to severe, moderate, minor and no conflict categories. The TTC values classified to four groups for severity analysis is shown in the table 1.

Table 1. TTC values for different severity category.

Severity level	TTC range
Severe	<0.55
Moderate	0.55-1.4
Minor	1.4-2.35
No conflicts	>2.35

3.2 Analysis of overtaking conflicts

The conflicts within the three locations were combined to develop the results. A total 589 conflicts were obtained from the data. Graphical representation of the number of conflicts is shown in fig. 4.

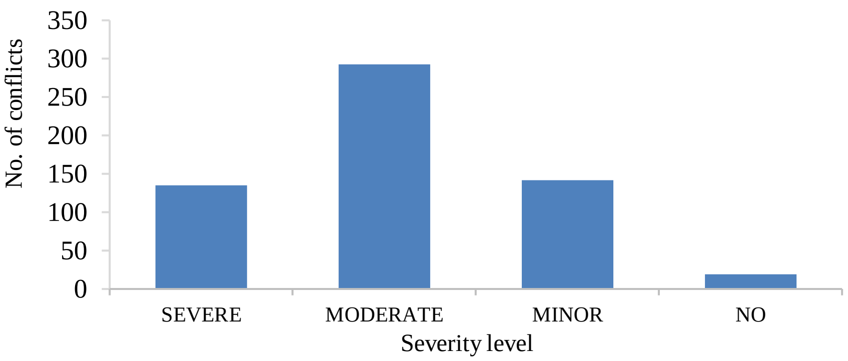

Fig. 4 Number of conflicts corresponding to severity level

From the collected data it is found that moderate level of conflicts was found more during the observed period. 293 conflicts were found to be moderate conflicts, were the TTC values are in between 0.55-1.4. The increase on moderate conflicts can be due to the geometric conditions of the road, and varying speed of the vehicles. Considering the selected location, the number of two-wheelers were found more as the overtaking and overtaken vehicle type. Only few bus overtaking was considered in the study due to the restricted camera view. The type of overtaking vehicles involved in severe conflicts, moderate and minor conflicts are represented in fig. 5, fig.6 and fig. 7 respectively.

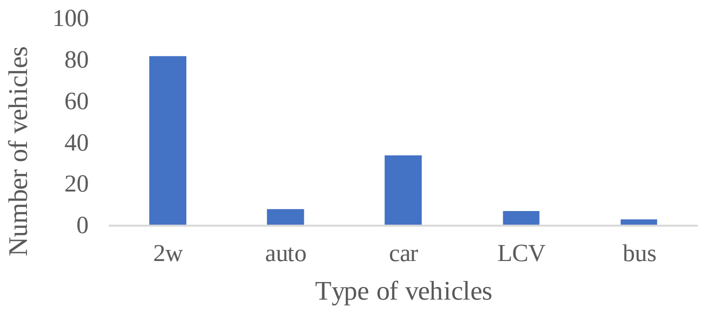

Fig.5 Number of different types of overtaking vehicle in severe conflicts

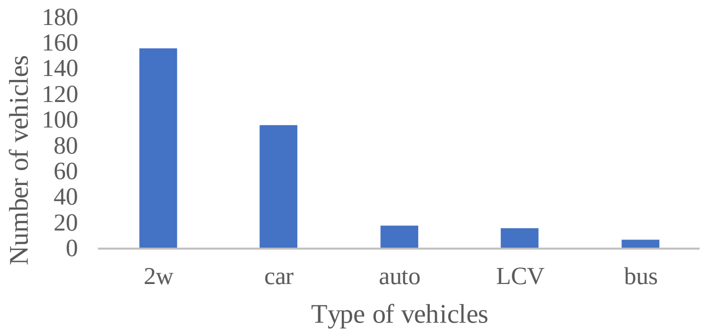

Fig.6 Number of different types of overtaking vehicle in moderate conflicts

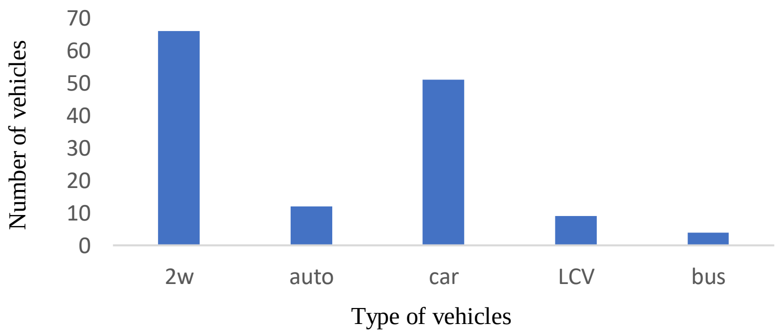

Fig.7 Number of different types of overtaking vehicle in minor conflicts

For all the cases the number of two-wheelers were found high as the overtaking vehicles. 61% of the total overtaking vehicles is two-wheelers for severe conflicts. From the observed data, the 2w-2w overtaking is found to be 60.24% of severe conflicts. 53.24% of total vehicles is two wheelers for moderate conflicts. From the collected data, the 2w-2w overtaking is found to have more moderate number of conflicts. 54.6% of the total moderate conflicts is due to 2w-2w overtaking. 46.47% of total vehicles in overtaking is found to be two-wheelers for minor conflicts. 2w-2w minor conflicts is 42.18% and 2w-car conflicts is found to be 40.62%.

IV.RESULTS AND DISCUSSION

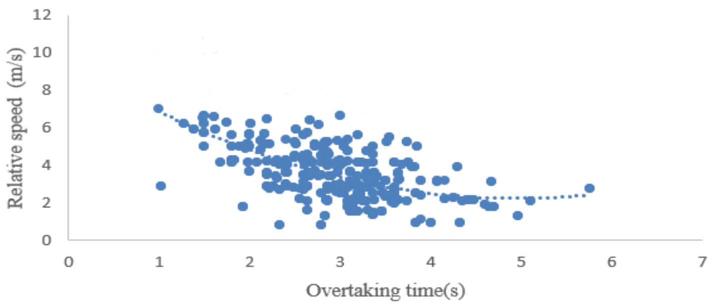

Fig.8. Overtaking time vs Relative speed for total vehicles

Different overtaking parameters such as overtaking time, distance, overtaking and overtaken speed, were extracted from the video data. Different plots are drawn from the collected data marking the relationship between them. Relationship between Overtaking time and Relative speed is shown in fig. 8.

From the collected data, relative speed and overtaking time for all vehicles involved in overtaking found to have a polynomial variation. Relationship between Overtaking time and TTC is shown in fig.9.

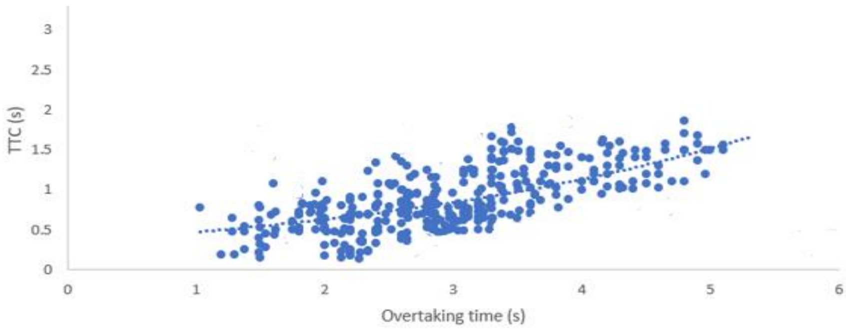

Fig.9. Overtaking time vs TTC for total vehicles

TTC found to be increasing exponentially with increase in overtaking time all type of vehicles. This may also depend on other factors such as the overtaken vehicle speed, overtaking vehicle speed. Relationship between Overtaking time and Overtaking distance is shown in fig. 10.

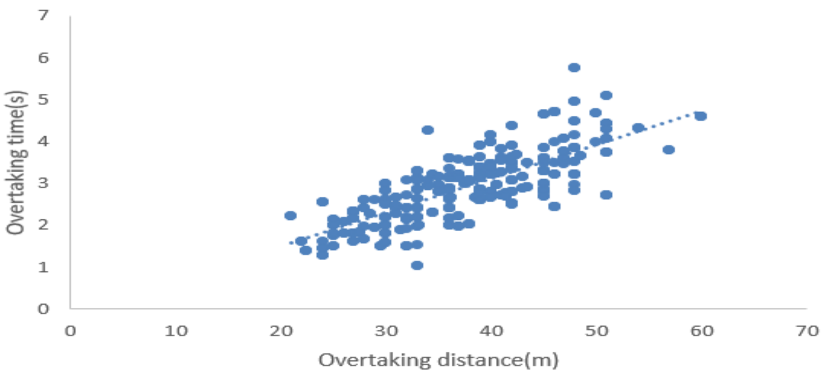

Fig.10. Overtaking time vs overtaking distance for total vehicles

Overtaking time found to be increasing with increase in overtaking distance for all type of vehicles. The trend is linear with every one-unit increase in overtaking distance, overtaking time increases 7.29 %.

4.1 Model Development

The data collected from the study site was used for the model development. Data collected are overtaking time, overtaking distance, overtaking and overtaken vehicle speed, type of overtaking and overtaken vehicle, relative speed and then calculated TTC values. A conflict severity model was developed using Statistical software. The models were developed using multinomial logit model and ordered probit model, as these are used for categorical dependent variables. Severity model was developed with TTC as the dependent variable. Other variables including overtaking time, distance, overtaking and overtaken vehicle speed, type of overtaken and overtaking vehicle and relative speed as independent variables.

Multinomial logit model is a statistical technique used to model relationships between multiple categorical outcome variables and one or more predictor variables. The developed ML model for various severity levels is shown in table 2. It is found that overtaking distance, relative speed, overtaken speed, overtaking and overtaken vehicle type are statistically significant variables as the significance is less than 0.05.

Table 2. Developed ML model

Severity levels	TTC	Coef.	z	P>z
Severe				
	OD	-0.0375	-2.43	0.015
	RS	-0.0678	-3.18	0.001
	ONS	0.0588	1.31	0.051
	OGV			
	car	1.7842	2.73	0.006

	LCV	-2.3590	-2.81	0.005
	2W	2.0320	2.51	0.044
	ONV			
	car	3.9049	2.03	0.048
	auto	-1.5188	-2.48	0.013
	_cons	-0.8528	-0.39	0.045
Moderate				
	OD	-0.0659	-1.75	0.041
	RS	-0.0435	-0.31	0.049
	ONS	0.0593	4.21	0.067
	OGV			
	car	1.2409	2.71	0.045
	LCV	-2.3176	-2.82	0.005
	2W	2.5703	2.81	0.054
	ONV			
	car	3.4080	2.04	0.049
	_cons	-0.4854	-0.23	0.048
Minor	OD	0.0473	1.19	0.042
	RS	0.0716	0.52	0.053
	ONS	-0.0126	-0.28	0.078
	OGV			
	car	-0.8031	-1.24	0.051
	LCV	-2.1434	-2.5	0.012
	2W	0.9923	1.81	0.048
	ONV			
	auto	-1.5285	-2.48	0.013
	_cons	0.8225	0.38	0.051

From the study locations as the overtaking distance increases 1 unit, the probability of conflict to become severe and moderate expected to decrease 3.81% and 6.4% respectively. Similarly, probability of conflict to become minor increases 4.8%. However, this may vary depending upon other factors also. From the collected data as the relative speed increases, the probability of conflict to become severe and moderate expected to decrease 6.5% and 4.3% respectively. For both severe and moderate conflicts as overtaken speed increases, probability of conflict to become severe and moderate expected to increase 6% and 6.1% respectively. Even though the results obtained are statistically significant, it may vary depending on the geometric conditions, road user behaviour etc. The Pseudo R^2 value of the developed model is shown in table 3. McFadden's pseudo R2 ranging from 0.2 to 0.4 indicates a very good model fit. Value greater than 0.1 is good fit. The developed model has a value of 0.151 indicating fairly fit model.

Table 3. Pseudo R^2 table of fit of ML model

Pseudo R-Square	
Cox and Snell	.269
Nagelkerke	.308
McFadden	.151

Ordered probit regression is a statistical method used to model the relationship between one or more independent variables and an ordinal dependent variable. Table 4 shows the Ordered probit model developed.

Table 4. Developed OP model

TTC	Coef.	z	P>z
Overtaking distance	0.01604	2.38	0.017
Rel. speed	0.07706	3.73	0.000
Overtaken vehicle speed	-0.02409	-3.25	0.001
Overtaking vehicle			

type			
car	0.39140	3.74	0.000
auto	0.58913	2.95	0.003
LCV	0.41836	2.14	0.033
bus	0.04501	0.15	0.882
2W	0.25508	1.31	0.046
ONV			
car	-0.16437	-1.29	0.047
auto	0.14981	1.19	0.235
LCV	0.42078	1.63	0.102

Table shows the relation between various variables and TTC values. Here overtaking distance, relative speed, overtaken vehicle speed and type of overtaking vehicle found as statistically significant variables. From the collected data it is found that as overtaking distance increases, TTC increases. For every 1-unit increase in overtaking distance, TTC is expected to increases by 1.6%. It's found that as relative speed increases, TTC increases. For every 1-unit increase in Relative speed, TTC increases by 8%. For every 1-unit increase in Overtaken vehicle speed, TTC found to decrease by 2.4%. The pseudo R^2 value of 0.074 is found low but close to 0.1, indicating that other factors such as behavioural variation also affect the TTC results.

4.1.1 Model Comparison

AIC and BIC values were used for the comparison. If maximum likelihood is used to estimate parameters and the models are non-nested, then the Akaike information criterion criterion (AIC) or the Bayes information criterion (BIC) can be used to perform model comparisons. Lower the value more fit is the model. The BIC is more useful in selecting a correct model while the AIC is more appropriate in finding the best model for predicting future observations. Table 5 shows the comparison between developed ML and OP model.

Table 5. Comparison between developed ML and OP model.

	ML	OP
Pseudo R^2	0.151	0.074
AIC	1175.204	1197.995
BIC	1206.421	1346.157

Here the pseudo R^2 is close to 0.2 for ML model and is very small for OP model. AIC and BIC value being the small is found good model and is small for ML model indicating ML model is more fit for overtaking conflict risk severity model for the collected data.

V.CONCLUSION

The study was conducted to analyze overtaking conflicts using surrogate safety measure TTC. The study is conducted over three straight road stretches of similar geometry. The locations were Chavadimukku-Karyavattom road, Karyavattom-Kazhakkoottam road and Karickom-Kottarakkara road. Different overtaking parameters including overtaking time, distance, overtaking speed, relative speed was collected and the TTC values were calculated and analyzed. From the cumulative percentage distribution curve critical threshold TTC value of 1.4 sec was obtained based on which the conflicts are classified into severe, moderate and minor conflicts. Moderate conflicts with TTC values between 0.55-1.4 were found higher in the selected locations. From the collected data, relative speed and overtaking time have a polynomial variation. This may be due to fluctuation of data. TTC found to be increasing exponentially with increase in overtaking time. For every one-unit increase in overtaking distance, overtaking time increases by 7.29 %. Statistical models were developed for overtaking conflict severity analysis using statistical software. TTC was taken as dependent variable and overtaking parameters as independent variables. From both models the overtaken vehicle speed, overtaking distance, relative speed and type of overtaking vehicle found as significant variables. It is found that TTC value increases with increase in overtaking distance and relative speed. Also, as the overtaken vehicle speed increases, TTC value decreases. However, this result may vary accordingly with other parameters like geometrical conditions and behavioural situations. Comparison of the models shows that ML model is more statistically fit model for conflict severity prediction.

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