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Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Modeling helmet usage behavior of motorized two-wheeler riders in developing countries

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Abstract

Motorcycle crashes make up a large proportion of road casualties in all over the world, particularly in developing countries like India, where motorcycle ownership is high. Wearing helmet decreases the risk and severity of injuries. To increase helmet usage, government has introduced a mandatory helmet usage law for two-wheeler driver and pillion riders in Mumbai, India from April 2016 onwards. Thus, the study objectives are to examine the various factors affecting helmet usage behavior and develop the model for estimating helmet usage behavior of motorcycle rider's in cities. The data were collected in two different time frames, such as before and after helmet mandatory law at randomly selected ten study locations in Mumbai, India. From field survey, 28,209 and 37,245 samples were collected during 2015 and 2016 respectively. This study was performed the statistical analysis of the impact of the state strict law on helmet usage and it was found that helmet usage was increased from 62.81% to 83.53%. Further, Pearson's R, Kendall's tau, Spearman's rho correlation and analysis of variance tests were conducted for identifying the impact of each variable with helmet wearing behavior of motorcyclists. Finally, binary logistic regression model was developed to estimate helmet usage behavior of the motorcycle rider. The model was validated, and their statistical performance results denote that developed model predicts helmet usage behavior more preciously. These study findings and model outcomes can be useful for policy makers to understand about the actual conditions of helmet usage behavior in cities and increase helmet usage rate, and also create policy level decision making on reduction in traffic crashes in India.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: Helmet; Mandatory Law; Binary Logit Model; Correlation Tests

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1. Introduction

Traffic injuries are a major public health problem and a leading cause of death and injury throughout the world, particularly in developing countries. Statistics show that more than 4,80,652 people have died in road crashes and motorcycle users create a high proportion of overall traffic crashes, particularly in developing countries like India, where motorcycle ownership is high. Motorcycle riders are at an increased risk of being involved in a road crashes because they are less visible and moving along with fast moving vehicles such as cars, buses and trucks. Helmet is one of the most important items of personal protective equipment used by motorcycle riders for protection against the hazards connected with driving on roads. While proper use of helmet reduces the risk and severity of injuries by reducing the impact of collision to head. Wearing a helmet decreases the risk and severity of injuries by about 69%; decreases the likelihood of death by around 42%, with the probability depending on the speed of the motorcycle involved.

The law that set and enforce compulsory helmet usage are effective in increasing the rate of helmet wearing behavior while riding two wheelers, which ultimately reduce the injuries or fatality rates. Many countries have succeeded in raising rates of helmet use through adopting laws that make helmet use compulsory, enforcing these laws, and raising public awareness about the laws, as well as the benefits of helmet usage. In Mumbai, one of the major cities in India, total numbers of crashes such as fatal, serious, slight and minor road crashes have risen by 766 cases in 2015 as compared to the previous year. The year 2015 has recorded the most deaths for people travelling on a motorcycle and also the records show that the number of pillion riders who have died has been the highest in this year. In order to reduce motorcycle related fatalities, the helmet act for two wheeler driver and pillion rider was enacted in Mumbai, India from April, 2016. Hence, the purpose of this study is to evaluate the impact of mandatory helmet usage law by motorized two-wheeler users in Mumbai, India for improving the helmet usage rate by applying various remedial measures. This will be useful for taking a policy level decision on helmet usage law.

2. Literature review

The literature reviews have been examined about the impact of strict law on helmet usage while driving the vehicles with respect to non-motorized and motorized vehicle riders. Few studies analyzed about the law of bicyclists helmet wearing law to improve the safety of riders (Piatkowski et al. 2017). The study identified the percentage of change on helmet usage and examined the impact of helmet usage on head injury rates based on various statistical tests (Cameron et al. 1994). Another study examined about the reduction of head injury rate by using the helmet for pedal cyclists and found that helmet usage had significant effect with head injury (Wood and Milne 1988).

Most of the existing studies examined about the impact of strict law on helmet usage for motorized vehicles with respect to various influencing variables. The role of helmets and helmet type with injury were examined and the results show that there was no significant difference in injury with and without helmet survivors and no difference spinal cord injury among full-face and open-face helmet wears (O'Connor 2005). Few research found that lack or improper use of helmets were more likely to result in fatal injuries (Jung et al. 2013). Many studies identified that drivers age, gender, race, formal education level, prior accident experience and type of license held had significant effect with helmet usage behavior (Kulanthayan et al. 2000; Mayrose 2008). Helmet usage was lower at night (Ichikawa et al. 2003), enforcement law increased helmet usage but did not significantly reduce deaths among injured motorcyclists (Ichikawa et al. 2003).

Many existing studies focused on evaluating the rate and effectiveness of helmet use in developing countries. The impact of compulsory helmet legislation on morality rate and types of head and facial injuries were examined for Indian conditions. The authors concluded that mandatory use of helmets, with compulsory helmet law, is an effective measure for reducing soft tissue, head, brain and upper and middle 1/3 facial injuries in motorized two-wheeler accidents (Marya et al. 2017). In Indian studies found that female riders are significantly more inclined to helmet usage and riders educated upto degree and above degree level are found to be more inclined with helmet usage (Hassan et al. 2017). Another studies explored the relation between helmet usage and risky behavior of drivers of motorized two wheeled vehicles in India and the result shows that 69.5% of reported using a helmet for safety, 29.7% as protected from pollution, 1.2% because they met an accident and remaining 2.6% reported other reasons (Dandona et al. 2006).

In Thailand, the study investigated the effect of the helmet act for motorcyclists on increasing helmet use and reducing motorcycle-related deaths and severe injuries. After helmet act, helmet usage increased five-fold while head injuries decreased by 41.4% and deaths by 20.8% (Ichikawa et al. 2003). Another study in Thailand was examined to assess helmet use and associated factors among motorcycle riders. The results indicated that 44.2% of the motorcycle riders and 72.5% of the motorcycle passengers had not been using a helmet (Siviroj et al. 2012). The authors examined the compliance of proper safety helmet use in motorcyclists in Malaysian town. This study found that 54.4% of motorcyclists used helmet properly, 21.4% used improperly, and 24.2% did not wear helmets (Kulanthayan et al. 2000). The authors found that the helmet use law was temporally associated with a 26% decrease in the reported rate of motorcycle crashes in Nebraska compared with other five Midwestern states (Muelleman et al. 1992). In Victoria, Australia, there was an immediate increase in average helmet usage rates from 31% to 75% due to mandatory helmet usage law during 1990 and 1991 (Cameron et al. 1994). In the same city, helmet wearing promotion campaigns conducted which significant increases the wearing helmet rates and reduction in the rate of head injuries (Wood and Milne 1988). In Vietnam, correct helmet usage survey were performed in two cities and both the cites statistically increased helmet use (Bao et al. 2017). Finally existing study suggested that the road safety awareness campaign may have a slight positive effect on reducing non-helmet use among motorcycle riders (Siviroj et al. 2012).

Various methods were used to analyze about the helmet usage behavior, impact of mandatory law on helmet wearing, and reducing severity in head injuries. OR tests (Attewell et al. 2001; Ichikawa et al. 2003; O'Connor 2005), p-value comparisons (Kelly et al. 1991; Marya et al. 2017), chi squared test (Kulanthayan et al. 2000) were used to analyses the helmet usage behavior with respect to various influencing variables and improve the helmet usage behavior which helps to reduce fatalities rate or severity in head injuries. Relative frequency techniques used to analyze about the impact of mandatory law on helmet usages for two wheeler riders (Ichikawa et al. 2003; Mayrose 2008; Muelleman et al. 1992). Trend analysis and negative binomial regressions methods were used to analyze trend data (Bao et al. 2017). ANOVA method was used to analyze about the impact of helmet usage with gender and education level (Hassan et al. 2017). Multinomial logit model was adopted to estimate factor influence motorcyclist injury severities with respect to no helmet usage (Jung et al. 2013). Logistic regression model was developed that related the reduction in head injuries to increased helmet usage (Cameron et al. 1994). The relation between helmet use and risk of death for occupants of two-wheeled motor vehicles were calculated by developing Poisson regression models (Donate-López et al. 2010).

Finally, existing studies have focused on evaluating and analyzing the impact of mandatory helmet usage law and reducing the fatalities rate or severity rate of injuries due to traffic crashes. However, existing studies have seldom considered the impact of driver's gender, age, number of occupants in two wheeler and helmet type with helmet usage behavior. Land use pattern, survey timing and survey days are influencing helmet wearing, it would be important to consider all these parameters in analysis part. Furthermore, there are no studies have been conducted on helmet usage behavior model development by considering in ordered data that fit for Indian conditions. In light of these disappointing states on helmet usage behavior, this study is focused to examine various influencing parameters on helmet usage behavior and develop a framework to estimate helmet usage behavior while driving two-wheelers in India.

3. RESEARCH OBJECTIVES

The objectives of this study are as follows: (a) to examine the influence of various parameters with motorized two-wheeler driver helmet usage behavior before and after the state mandatory law on helmet usage; and (b) to develop a model for estimating the behavior of drivers wearing helmet while riding the two wheeler.

The rest of the paper is organized as follows. The next section introduces the data collection process and data details. Impact of strict state law on helmet usage and factors influencing helmet usage behavior of two wheeler riders are discussed, and model for estimating helmet usage behavior while driving two-wheeler is developed. The application of the proposed model is presented. Finally, some important conclusions, findings and suggestions are summarized.

4. DATA COLLECTION PROCESS

4.1. Study Location

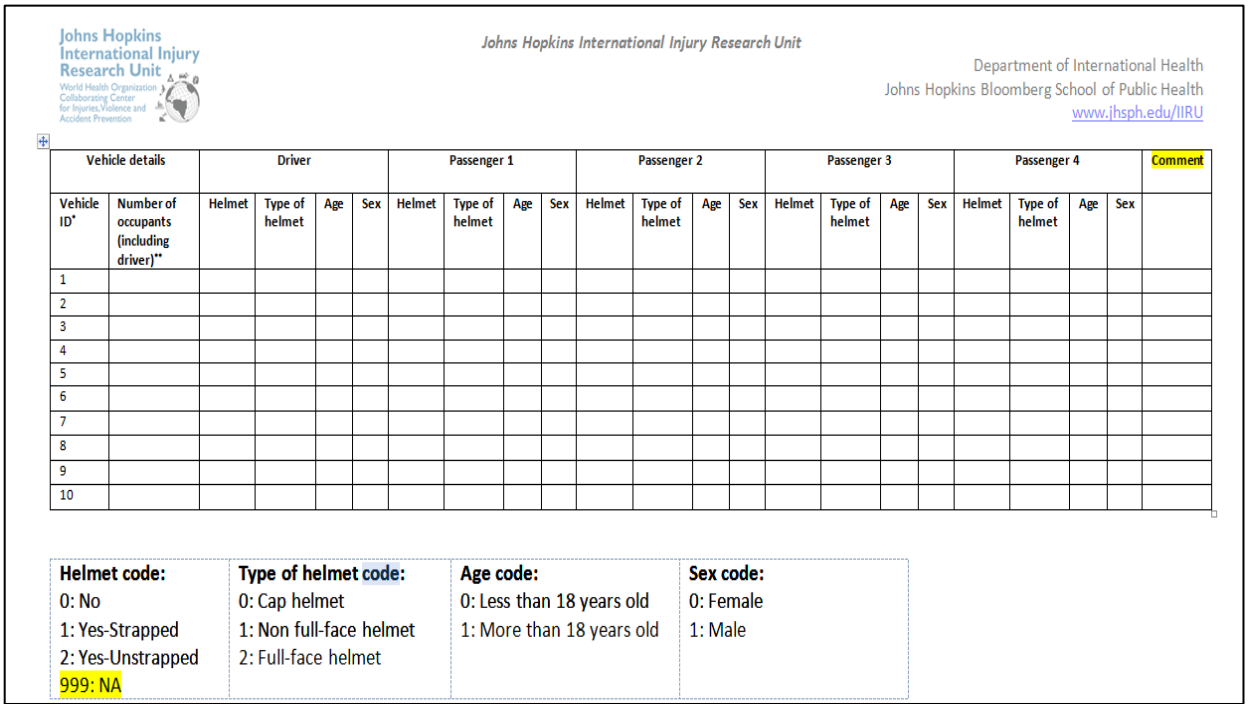
Mumbai is the most populous city in India and the ninth most populous agglomeration in the world, with an estimated population of 20.7 million. As per statistics, 25% of all road deaths were drivers or passengers on two-wheelers in Mumbai. To avoid this fatality rate, the mandatory helmet usage law has been implemented in Mumbai, Maharashtra. It requires all two wheeler drivers and pillion riders to wear a securely fitted helmet. Otherwise a penalty for not wearing a helmet is applied and people caught without a helmet will be sent to a two-hour seminar on traffic rules. The special drive started across Mumbai from 29 April, 2016. In order to measure the progress in helmet usage due to mandatory law, a series of observation surveys were conducted at randomly selected ten locations before (May/June 2015) and after (May/June 2016) the law. The selected locations are located in the central part of the Mumbai suburban area and the locations are finalized near the signalized intersection, which helps to observe the helmet behavior of riders easily during red phases. The details about the selected study locations are presented in Table 1.

Table 1. Details about selected ten study locations

ID	Location	Lane and Road Type	Land use Pattern	Traffic Flow
A	Diamond Garden Junction	4-lane divided arterial road	Residential	Medium
B	Godrej Junction	6-lane divided highway	Industrial	High
C	Hiranandani Garden Junction	6-lane divided arterial road	Mixed	High
D	Oberoi Junction	6-lane divided arterial road	Commercial-Industrial	High
E	CST Junction	6-lane divided arterial road	Commercial	High
F	Kings Circle Junction	4-lane divided arterial road	Residential	Medium
G	Shankar Ganekar Marg Junction	4-lane divided arterial road	Commercial-residential	High
H	S V Junction	4-lane divided arterial	Commercial	Medium
I	Mahatre wadi Junction	4-lane divided arterial road	Commercial-residential	Medium
J	Tilak udyan Junction	6-lane divided arterial road	Mixed	High

4.2. Data Collection

The data collection is part of ongoing research project with Indian Institute of Technology Bombay (IITB) and John Hopkins International Injury Research Unit. Data collection procedure, protocol, and design of survey form were prepared by John Hopkins International Injury Research Unit, Baltimore, USA. The survey was conducted in two different time frames, such as pre-act and post-act of mandatory helmet usage law. A first set of data collection was occurred on one weekday and weekend at each location during May to June 2015. In the second time frame, the same data collection process was followed in two weekdays and one weekend at the same locations during May to June 2016. The survey duration was divided into five equal intervals from 7:30 am to 7:00 pm and each interval was considered as one and a half hours duration. A number of well-trained observers from transportation field were used to conduct the helmet survey. Before starting the data collection process in the field, two day workshop was conducted with all the observers to train them for getting more accurate and reliable data in the field. Two data collectors were allotted at each location and the required data were filled in the survey form by observers. In addition, the two wheeler volume per 15min interval was counted for three times in a day. The survey interval for helmet usage observation are as follows: 7.30 to 9.00am, 10.00 to 11.30am, 12.30 to 2.00pm, 3.00 to 4.30pm, and 5.30 to 6.30pm and the volume count interval are 9.15 to 9.30am, 12.15 to 12.30pm and 5.15 to 5.30pm. The snapshot of observation form is presented in Figure 1.



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Vehicle details		Driver				Passenger 1				Passenger 2				Passenger 3				Passenger 4				Comment
Vehicle ID*	Number of occupants (including driver)**	Helmet	Type of helmet	Age	Sex	Helmet	Type of helmet	Age	Sex	Helmet	Type of helmet	Age	Sex	Helmet	Type of helmet	Age	Sex	Helmet	Type of helmet	Age	Sex	
1																						
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						

Helmet code:	Type of helmet code:	Age code:	Sex code:
0: No	0: Cap helmet	0: Less than 18 years old	0: Female
1: Yes-Strapped	1: Non full-face helmet	1: More than 18 years old	1: Male
2: Yes-Unstrapped	2: Full-face helmet		
999: NA			

Fig. 1. Observational Survey Form on Helmet Usage Behavior of Motorcycle Riders.

4.3. Data Details

Data were only collected for two wheelers traveling in one direction to avoid double counting and ensure quality data collection. The survey form was contained the details of helmet usage behavior and personal characteristics of the driver as well as passengers. In helmet usage behavior, the conditions of helmet (Not wearing – coded as 0, Wearing and Strapped – coded as 1, and Wearing and Unstrapped – coded as 2) and type of helmet (Cap helmet – coded as 0, Non full-face helmet – coded as 1, and Full-face helmet – coded as 2) were noted for each driver and passengers. In personal characteristics, the age (Less than 18 years old – coded as 0 and More than 18 years old – coded as 1) and gender (Female – coded as 0, and Male – coded as 1) for each driver and passengers were collected during the survey. Land use pattern, Survey timing (7.30 to 9.00am, 10.00 to 11.30am, 12.30 to 2.00pm, 3.00 to 4.30pm and 5.30 to 7.00pm), Weather conditions (dry/no rain, light rain/drizzle, rain, snow, fog, hail and other), Visible presence of law enforcement (police, camera, both or none) and Survey days (weekday or weekend) were collected from the field observations. Also, the number of occupants of each two wheeler was noted in survey sheet. A total of 30 observers were used and 50 days survey was conducted at selected locations. Huge samples were collected at selected ten locations. From the field survey, 28,209 and 37,089 samples were collected during 2015 and 2016 respectively. The collected data is used to analyze the impact of mandatory law on helmet usage and model development for estimating helmet usage behavior of two wheeler rider. Detailed information is discussed in the following sections.

5. IMPACT OF THE STATE STRICT LAW ON HELMET USAGES IN MUMBAI, INDIA

The impact of the state strict law on helmet usages was analyzed by performing various statistical tests. Initially, the descriptive statistics values were calculated and the variations were studied at before and after the mandatory helmet usage law and it was found that the rate of helmet usage was increased from 62.81% to 83.53%. Further analysis, this study was performed the Pearson's correlation, Kendall's tau correlation, Spearman's rho correlation,

and analysis of variance (ANOVA) tests for identifying the impact of each variable of driver behavior and personal characteristics with helmet usage. The tests were performed by using both sets of data (before and after law).

The results of the correlation tests and ANOVA test with the data before the mandatory helmet usage law shows that land use pattern, survey day, survey timing, number occupants on two wheeler, types of helmet, driver gender, and age had significant influence with the behavior of helmet usage while driving a two wheeler in urban areas. To understand about the impact of the same variables on helmet usage behavior, same statistical tests were performed with the data which were collected after the Bombay high court laws on helmet usages. From that, this study found that drivers age, gender, helmet type, land use pattern, number of occupants, survey day and survey interval had a significant effect with the helmet usage behavior of two-wheeler rider. Also, the results match with the factors identified in the statistical analysis by using the data collected before the law. The detailed information's about the significant factors are discussed in the next section.

Table 2. Variable correlation test results (before mandatory helmet usage law)

	Correlation test (before mandatory helmet usage law)					
Variables	Pearson's coefficient	Sig	Kendall's tau coefficient	Sig	Spearman's rho coefficient	Sig
Landuse Pattern	-0.130	0.000	-0.108	0.000	-0.115	0.000
Survey Day	-0.040	0.000	-0.040	0.000	-0.040	0.000
Survey Interval	-0.025	0.000	-0.022	0.000	-0.025	0.000
Occupants	-0.071	0.000	-0.069	0.000	-0.070	0.000
Helmet Type	-0.487	0.000	-0.445	0.000	-0.472	0.000
Age	0.030	0.000	0.030	0.000	0.030	0.000
Gender	-0.027	0.000	-0.027	0.000	-0.027	0.000

Table 3. Variable correlation test results (After mandatory helmet usage law)

Variables	Correlation test (After mandatory helmet usage law)					
	Pearson's coefficient	Sig	Kendall's tau coefficient	Sig	Spearman's rho coefficient	Sig
Landuse Pattern	-0.082	0.000	-0.073	0.000	-0.079	0.000
Survey Day	-0.022	0.000	-0.022	0.000	-0.022	0.000
Survey Interval	-0.027	0.000	-0.024	0.000	-0.027	0.000
Occupants	0.001	0.000	-0.003	0.526	-0.003	0.526
Helmet Type	-0.394	0.000	-0.340	0.000	-0.358	0.000
Age	0.010	0.000	0.010	0.057	0.010	0.057
Gender	-0.068	0.000	-0.068	0.000	-0.068	0.000

5.1. Discussions

Helmet usage rates at before and after of mandatory helmet usage law were investigated and seven significant variables were identified in the previous sections. The details about each variable are discussed in this section.

For land use pattern, the sign value of Pearson, Kendall's tau, and Spearman's rho and p value of ANOVA test (Before and After: 0.000) are less than 0.01 implying that the correlation considered is significant at 99% confidence interval at before and after helmet usage law. The selected locations have different kind of land use pattern such as residential, industrial, commercial and mixed land use. The identification of land use pattern is difficult for Indian conditions due to a complex mix of activities. In analyzing the effects of land use patterns, comparisons were made with the results of survey data at selected 10 locations in pre-act and post-act the mandatory helmet wearing law.

The result shows that the rate of helmet usage has increased for all land use pattern except industrial area due to helmet usage law. The impact of law shows that more than 50% rate of non-helmet usage was decreased at sites which were located in commercial and mixed land use pattern. 38% rate of non-helmet usage was decreased in the residential area. But the rate of helmet usage at industrial area was decreased by 5.34%.

With respect to weekday and weekend, the value of Pearson Kendall's tau, and Spearman's rho Sig and ANOVA p (Before and After: 0.000) is less than 0.01 and ANOVA F value (Before: 28.965, After: 26.357) is greater than the F table value. The rate of usage of helmet in weekday is always higher than the rate of usage of helmet in weekend.

The value of Pearson Kendall's tau, and Spearman's rho Sig and ANOVA p (Before and After: 0.000) is less than 0.01 and ANOVA F value (Before: 31.063, After: 16.677) is greater than the F table value for Survey timing. It is indicated that survey timing in a day has significant on helmet usage behavior in India. The comparisons were performed to identify the differences in helmet wearing rates in the survey timing at before and after mandatory law. Helmet use was higher in the morning peak hours (10-11.30am) compared to evening peak hours (5.30-7pm). Due to mandatory law, the rate of non-helmet wear was reduced nearly 50% at all survey interval. Although, the largest rate of non-helmet wear was observed between 7.30-9.00 am in both before and after mandatory law. The reason's found that drivers were not willing to wear a helmet in the morning, the absence of traffic police or assistance in the morning session and drivers were in a rush to reach their workplace which is eventually preferred to drive without a helmet.

Nearly half of the motorcycle riders (34.26%) had a passenger of which 41.62% had not been using a helmet. The rate of non-helmet use was observed for two wheeler riders with and without passengers and the values were 27% and 41% respectively. From the analysis, it was found that two wheelers who were having a passenger were significantly more often using helmet than those who had no passenger. Due to mandatory helmet usage law, nearly 50% of helmet usage is increased when a pillion rider present in the drive. The rate of helmet usage that drivers who have women and child pillion riders is higher than that drivers who have male and adult pillion riders.

Gender is statistically significant at 99% confidence interval for before and after mandatory law. The helmet wearing rate is increased by male and female drivers due to the helmet mandatory usage law. Before law, only 39.6% of female riders used a helmet properly, but helmet usage increased up to 63.8% after the mandatory law on helmet wear. Also, the rate of helmet use among male riders increased from 32.5% to 44.4% after the mandatory helmet wear law. It is observed that females were more likely to have used a helmet properly than male two wheeler riders.

Only 32.8% and 30% of riders under 18 years of age used helmets properly (Wearing-Stripped) during 2015 and 2016 respectively. From the analysis, it was identified that the highest rate of not using helmet among two wheelers was in the age less than 18years old and the rate was increased from 32.6 to 47.5%. Several reasons for low helmet usage rates among riders less than 18years were observed, forgetting to wear a helmet, no helmet available, the rider does not want to wear a helmet, and design of the helmet. Due to mandatory law, the rate of not wearing helmet of rider's age greater than 18years was decreased from 81.1% to 16.4%. Further, the rate of proper helmet usage was improved from 11.6 to 45%. Helmet use was improved considerably, but attention needs to be drawn to increase helmet usage of riders less than 18years. Significant factors which have been identified in this analysis are used to develop helmet usage behavior model for motorcycle drivers in the following section.

6. MODEL FOR ESTIMATING HELMET USAGE BEHAVIOR OF TWO-WHEELER USERS

The purpose of the model is to understand the impact of mandatory helmet usage law with each variable and estimating the helmet usage behavior of motorized two wheeler riders while riding two-wheeler in developing countries. From the statistical analysis, the results identified the seven influencing factors on helmet usage behavior of driver while riding two-wheeler. These seven significant factors are used to develop a model for estimating the helmet usage behavior of drivers. The categories of helmet usage are divided into two levels such as not wearing or wearing without strapped (rated as 0) and wearing with strapped (rated as 1). A binary logit model was proposed since there were only two possible outcomes – wearing or non-wearing helmet. To accommodate the binary logit model, the dependent variable "Helmet Usage Behavior of Driver" was created containing one if helmet was wear and strapped and zero otherwise. The general form for the binary logit model used in this research is shown in Eq. (1) below:

$$P = \frac{e^{\beta}}{1+e^{\beta}}, \beta = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k \quad (1)$$

As β becomes higher in a positive sense, P would approach 1, which shows that the probability of a success (in this case, a driver wearing helmet) increases. Binary logistic regression (BLR) method is adopted in this study for modeling driver's helmet usage behavior while riding two-wheeler since observations are considered as binary, the binary nature is exploited and the flexible regression framework allows in-depth analysis. The statistical software package SPSS was utilized to estimate the maximum likelihood probability function.

Prior to estimating the binary logit model, the associations between all the variables discussed in Section 5, including the response variable, were examined by estimating the correlation among the variables. For comparison of continuous variables the Pearson correlation was calculated. For comparisons of discrete variables the Kendall's tau, Spearman's rho and ANOVA was calculated. At the 0.05 significance level, the response variable "Helmet Usage Behavior of Driver" is associated with all other variables except the occupants (the number occupants). Of the significant associations between variable pairs, Helmet Usage Behavior of Driver and Driver age had positive associations, as would be expected.

The model was established by including all eight variables into the model at the starting of the analysis and eliminating variables one at a time that were found to be insignificant. A variable was observed significant if its coefficient is statistically diverse from zero. This was concluded by measuring the null hypothesis. The model output comprised the related p-value for each measurement. The p-value is a measure of the probability of the hypothesis test being true. The hypothesis measured in this condition is that the coefficient is statistically same as zero, which was considered as a conclusion rule to choose whether the variable should include in the model. A *p*-value of 0.05 was considered to assist as the standards by which a variable would continue in the model. Hence, any variable with a *p*-value less than 0.05 confirm that less than 5% of the data would specify that the coefficient should be zero. Based on this conclusion rule, variables with a *p*-value more than 0.05 were eliminated from the model and variable with a *p*-value less than 0.05 remained. Variables were removed based on the *p*-value. The model was again rerun and the next variable with more than 0.005 *p*-value would be removed. This procedure was repeated till all the variables had a *p*-value less than 0.05.

The mentioned test procedure was performed in SPSS 16.0 at the 99% confidence interval and the results were presented in Table 4. The binary logit model was developed with 65,298 of driver's behavior observation data on helmet usage.

Table 4. Results of binary logistic regression model

Variables	Estimate	SE	Wald	Sig
Constant	-3.850	0.210	336.459	0.000
Landuse Pattern	-0.203	0.008	617.292	0.000
Survey Day	-0.047	0.019	6.025	0.014
Survey Interval	-0.063	0.007	89.356	0.000
Occupants	0.902	0.018	1865.000	0.000
Helmet Type	-0.006	0.000	627.760	0.000
Age	5.408	0.216	230.559	0.000
Gender	-0.861	0.057	77.367	0.000
Mandatory Helmet Usage Law	0.169	0.019	336.459	0.000

Note: SE = Standard Error

Cox and Snell, Nagelkerke and McFadden R-Square, which are widely used to test the logistic model's goodness of fit, is selected to judge the overall model prediction and the values are 0.260, 0.353 and 0.322 respectively. Further, the considered variables in the proposed model are more significant with a p value less than 0.05. Also, the classification table was used to judge the overall model prediction. The classification table results are presented in Table 5.

Table 5. Classification table results

	Predicted				
	Response Variable	Y = 0 (Not Wearing Helmet)	Y = 1 (Wearing Helmet)	Total	% Correct
Observed	Y = 0 (Not Wearing Helmet)	29142	10776	39918	73.00
	Y = 1 (Wearing Helmet)	10703	14677	25380	57.80
	Total	39845	25453	65298	67.10

From Table 5, the percentage of success prediction of developed binary model is 67.10%. From the model results, it was found that the probabilities of drivers using helmet is highly depended on the type of helmet and the frequency of using helmet increases when the drivers use non-full face helmet.

Validation of the BLR model was performed with the another set of data which contains 13,060 of the driver's behavior data on helmet usage. The data were collected in the month of August 2018 from Location A, B and C. The predicted average rating from the BLR model was compared with field-observed average rating. Statistical performance analyses were performed in Minitab 16.0 software, and the values of MAPE, RMSE, and Success prediction rate were found to be 0.0310, 0.7186, and 48.36 respectively. The Success prediction rate of the BLR method was 48.36, which specifies that 51.64% of the variation in the predicted rating about helmet usage behavior has been explained by the explanatory variables and denotes the acceptable accuracy level of proposed model predictions. The results of the statistical performance results denote that the BLR method is a more efficient, suitable method for estimating the binary data, especially to predict helmet usage behavior of driver while driving the two-wheeler. Therefore, it can be inferred that BLR based helmet usage behavior model is valid and can be used to determine the behavior of drivers on helmet usage.

7. APPLICATION OF PROPOSED MODEL

The developed BLR based helmet usage behavior model is applied to the location Oberai junction (ID D) in Mumbai, India, for model application. The same observation survey was conducted on two weekday and one weekend in the month of July, 2017. A total number of 3996 drivers sample was collected from the survey. The required independent variables such as number of occupants, helmet type, driver's gender, age, land use pattern, survey interval, survey day and law were encoded and applied in developed model.

The field observed mean helmet usage behavior of driver is 0.46 which indicated the majority of the driver were not wearing the helmet or wearing helmet without strapped. The predicted helmet usage value matches the observed helmet usage behavior with an error of 21.98%. The results show that there is a need to apply remedial measures that can increase the helmet usage behavior with strapping while riding two-wheeler. This study suggested that awareness program, enforce law and increasing fines can improve the proper helmet usage (wearing helmet with strap) behavior of two-wheeler riders. On the basis of the validation results and application of the model, it can be concluded that the developed BLR based helmet usage model predicts the driver behavior on helmet usage while riding motorized two-wheeler.

8. CONCLUSIONS

Riding a two-wheeler leads the rider at high risk of sustaining injuries and death compared with other type of vehicles. Helmet use was introduced as an inactive safety measure, designed to protect the head during accidents. Wearing a helmet has been made as a compulsory in many countries and succeeded in raising rates of helmet use through adopting laws, enforcing these laws, and raising public awareness about the laws, as well as the benefits of helmet use. Therefore, mandatory law and police enforcement are observed as one of the most effective methods to improve behavioral risk factors for road traffic.

This study analyzed the effect of the helmet law on helmet usage behavior by considering various variables. To acquire more detailed information about helmet usage behavior, the research presented here identified the significant factors and developed the cumulative logistic regression model on driver wearing helmet with strap. Information was obtained from an observational survey of two wheeler riders at 10 intersections in Mumbai, India. A huge sample size

of data (68263 driver's data) were collected from observational survey for analysis and model development purposes. This study finds that mandatory helmet use has shown to increase the likelihood of helmet usage in Mumbai. Overall, 83.53% riders wore a helmet when travelling by two wheelers after the law. The major reasons for using helmet were to ensure their safety and avoid fines from traffic police. The following conclusions are drawn on the basis of Pearson correlation Kendall's tau correlation, Spearman's rho correlation, and analysis of variance (ANOVA) statistics:

1. Land use pattern, survey interval, number of occupants, type of helmet, driver gender, and age highly influence the driver helmet usage behavior.

2. The helmet usage behavior at industrial area was decreased by 5.34%, which indicates that there is a need to introduce immediate remedial measures for improving helmet usage.

3. The rate of non-helmet behavior during 7.30 to 9.00am was higher than other survey intervals due to not willing to wear helmet in morning, absence of traffic police personnel, and drivers were in a rush to reach work place.

4. The rate of wearing helmet behavior those drivers who have women and child pillion riders is higher than those drivers who have male and adult pillion riders.

5. As expected, it is observed that females were more likely to have used a helmet properly than male two wheeler riders.

6. The rate of non-helmet behavior among the age greater than 18years was decreased from 81.1% to 16.4 due to mandatory law.

This study contributed to identify the various influencing factors on helmet usage while riding two wheeler and developed the choice the model to estimate the probability of using the helmet. This study has a few limitations. First, categories of riders/passengers into adult (greater than 18years) and child (less than 18years) may have been subject to error because it is difficult to judge the exact categories through observation study. Second, the data were only collected during days that were not rainy, and thus, the results cannot be generalized for rainy weather conditions. This study provides useful information for future initiatives addressing helmet use in Mumbai, India. These study findings strongly suggest that increased helmet use through strict helmet usage law would decrease the number of motorcyclist injuries in the Mumbai, India. The results of this study will motivate lawmakers to enact helmet law in all cities throughout the nation. Finally, the developed BLR based model can be useful to estimate the conditions of two-wheeler rider with respect to helmet usage and safety in developing countries. The presented information concerning different peaks of non-helmet motorcyclists will be helpful in advising specific countermeasures against such risky behavior. These findings will be useful for taking policy level decisions and the proposed model will be useful for estimating helmet usage behavior of motorized two wheeler riders while driving two-wheelers in developing countries.

Acknowledgement

This project is sponsored by John Hopkins International Injury Research Unit, Baltimore, USA. The authors also thank the interviewers and the voluntary respondents for their assistance with the data collection in the survey.

References

Attewell, R. G., Glase, K., and McFadden, M. (2001). "Bicycle helmet efficacy: A meta-analysis." Accident Analysis and Prevention, 33(3), 345–352.

Bao, J., Bachani, A. M., Viet, C. P., Quang, L. N., Nguyen, N., and Hyder, A. A. (2017). "Trends in motorcycle helmet use in Vietnam: results from a four-year study." Public Health, Elsevier, 144, S39–S44.

Cameron, M. H., Vulcan, A. P., Finch, C. F., and Newstead, S. V. (1994). "Mandatory bicycle helmet use following a decade of helmet promotion in Victoria, Australia-An evaluation." Accident Analysis and Prevention, 26(3), 325–337.

Dandona, R., Kumar, G. A., and Dandona, L. (2006). "Risky behavior of drivers of motorized two wheeled vehicles in India." Journal of Safety Research, 37(2), 149–158.

Donate-López, C., Espigares-Rodríguez, E., Jiménez-Moleón, J. J., Luna-del-Castillo, J. de D., Bueno-Cavanillas, A., and Lardelli-Claret, P. (2010). "The association of age, sex and helmet use with the risk of death for occupants of two-wheeled motor vehicles involved in traffic crashes in Spain." Accident Analysis and Prevention, 42(1), 297–306.

Hassan, T., Vinodkumar, M. N., and Vinod, N. (2017). "Influence of demographics on risky driving behaviour among powered two wheeler riders in Kerala, India." Transportation Research Part F: Traffic Psychology and Behaviour, Elsevier Ltd, 46, 24–33.

Ichikawa, M., Chadbunchachai, W., and Marui, E. (2003). "Effect of the helmet act for motorcyclists in Thailand." Accident Analysis and Prevention, 35(2), 183–189.

Jung, S., Xiao, Q., and Yoon, Y. (2013). "Evaluation of motorcycle safety strategies using the severity of injuries." Accident Analysis and Prevention, Elsevier Ltd, 59, 357–364.

Kelly, P., Sanson, T., Strange, G., and Orsay, E. (1991). "A prospective study of the impact of helmet usage on motorcycle trauma." Annals of Emergency Medicine, 20(8), 852–856.

Kulanthayan, S., Radin Umar, R. S., Ahmad Hariza, H., Mohd Nasir, M. T., and Harwant, S. (2000). "Compliance of proper safety helmet usage in motorcyclists." Medical Journal of Malaysia, 55(2), 40–44.

Marya, J., Dhirawani, R. B., Dube, G., Pathak, S., Dausage, P., and Sethi, J. K. (2017). "Impact of compulsory helmet legislation on mortality rate and types of head and facial injuries in Jabalpur." Journal of Oral and Maxillofacial Surgery, Medicine, and Pathology, Elsevier Ltd., 29(1), 24–28.

Mayrose, J. (2008). "The effects of a mandatory motorcycle helmet law on helmet use and injury patterns among motorcyclist fatalities." Journal of Safety Research, 39(4), 429–432.

Muelleman, R. L., Mlinek, E. J., and Collicott, P. E. (1992). "Motorcycle crash injuries and costs: Effect of a reenacted comprehensive helmet use law." Annals of Emergency Medicine, 21(3), 266–272.

O'Connor, P. J. (2005). "Motorcycle helmets and spinal cord injury: helmet usage and type." Traffic injury prevention, 6(1), 60–6.

Piatkowski, D. P., Marshall, W., and Johnson, A. (2017). "Identifying behavioral norms among bicyclists in mixed-traffic conditions." Transportation Research Part F: Traffic Psychology and Behaviour, 46, 137–148.

Siviroj, P., Peltzer, K., Pengpid, S., and Morarit, S. (2012). "Helmet use and associated factors among thai motorcyclists during Songkran festival." International Journal of Environmental Research and Public Health, 9(9), 3286–3297.

Wood, T., and Milne, P. (1988). "Head injuries to pedal cyclists and the promotion of helmet use in Victoria, Australia." Accident Analysis and Prevention, 20(3), 177–185.